Technical ideas for environmental risk identification and assessment in Nangang petrochemical industry zone in Binhai New Area of Tianjin

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Abstract. At present, industrial development at the regional level has become a new economic growth point in China. As an industrial pillar and high-risk industry for economic development in China, the highly agglomeration form of petrochemical industry will increase the occurrence probability of environmental emergencies and trigger a chain reaction. Regional, industrial or comprehensive environmental risk assessment is still in a preliminary stage although some result foundations for regional environmental risks have been constructed in domestic and foreign. Therefore, this paper discusses the technical ideas for environmental risk identification and assessment in the petrochemical park area, which is based on Nangang petrochemical industry zone in Binhai New Area of Tianjin, meanwhile providing a useful case for related work in similar regions.

1. Introduction
In response to the requirements of upgrading and optimizing the industrial structure and layout in the 12th Five-Year Plan and the 13th Five-Year Plan, industrial development on a regional scale has become a new trend of economic development in China. Petrochemical industry zone is a product of the compliance of modern petrochemical industry with the large-scale and intensive development trend, which the hazardous chemicals are numerous, diverse and intensive. Once an accident occurs, it may cause a series of chain effects and inflict damage on residents, units and the natural environment around the area[1]. Therefore, evaluating regional risk for petrochemical areas is imminent.

In recent years, a large number of scholars in domestic and foreign have studied regional environmental risks and formed systematic evaluation frameworks and methods. Zabeo et al. (2011) evaluated the vulnerability of regional environmental risk receptors by applying multi-objective decision making and spatial analysis techniques[2]. J. A. Acosta et al. (2018) use the pollution index method combining with GIS to identify environmental risk areas affected by heavy metals[3]. Giubilato et al. (2018) proposed a hierarchical method for environmental chemical risk sources based on evidence weights on a regional scale to identify priority management areas[4]. Marya et al. (2018) explored the framework of urban regional environmental risk assessment based on a conceptual model[5]. Zhang X C et al. (2012) constructed a method for regional atmospheric environmental risk source identification and rapid risk assessment[6]. Xie Y B et al. (2013) applied the information diffusion method to comprehensively evaluate existing and planned risk sources in Nansha, Guangzhou and to solve the problem of insufficient evaluation information[7]. Xing Y J et al. (2016) utilized the set-pair analysis to construct the environmental risk field of risk source, and obtained the
environmental risk level distribution of Nanjing chemical industry park[8]. Yu H et al. (2017) used the index method combined with remote sensing technology to analyze the risk level of the Tianjin Port area[9]. Currently, due to the short history of research in domestic and foreign, researches have only been conducted on specific regions, and regional, industry or comprehensive environmental risk identification and assessment system has not been formed. Therefore, this paper takes the Nangang Petrochemical Industry Zone of Tianjin Binhai New Area as the object to explore the technical ideas for environmental risk identification and assessment in the petrochemical park area.

2. The ideas and results of environmental risk identification

Nangang Petrochemical Industry Zone in Binhai New Area of Tianjin is mainly engaged in the development of petrochemical and metallurgical equipment manufacturing that more than 20 high-risk enterprises gathered in the region. The type and quantity of the hazardous chemicals production, storage and transportation in this region are numerous while the hidden danger of environmental risk is higher. In addition, because the region is close to the ocean meanwhile the environmental risk receptor is fragile, the ‘superimposed’ and ‘cumulative’ effects of risks are obvious, and the low level of environmental risk management and control has become a bottleneck for regional development[10-11]. Therefore, this paper constructs the risk identification technology and idea based on the risk source investigation and hidden danger analysis of the whole system in this region.

2.1 The idea of risk source identification

The purpose of risk source identification is to identify and screen out risk substances, equipment and management nodes that need to be assessed and managed, and to analyze the occurrence probability of potential risk accidents. Current research usually judges the hazard source risk level only by the substance type and quantity or the process inherent safety, and the evaluation method is simple while the result of risk source identification is deviated greatly. Under the guidance of safety system engineering theory and accident cause theory, this paper proposes the basic procedure of risk source identification, including risk substance identification, risk equipment identification, identification risk source management node, risk source control management mechanism and possible risk accident scenario identification (Figure 1). Firstly, identify risk substances and equipment, meanwhile analyzing possible sources of risk. Then conduct bow analysis on the basis, which is to utilize the combination of fault tree and accident tree to analyze the antecedents and consequences of the accident, build possible accident scenarios, and identify the nodes that form the accident occurrence and evolution, which are the key nodes of risk source control management.
2.2 The analysis result of risk source identification

According to the data analysis and on-site investigation, and combining with the risk source identification ideas designed in this paper, it is identified that the main environmental risk source in the Nangang Petrochemical Industry Zone of Tianjin Binhai New Area is divided into enterprise risk source, risk source of hazardous chemical transportation pipeline network, and risk source of hazardous chemical transportation road. The risk source identification results are as follows: 1) Contrasting the "Business Risk Assessment Method for Environmental Emergencies"(HJ941-2018), there are 10 major risk enterprises, 11 larger risk enterprises and 8 general risk enterprises in Nangang Petrochemical Industry Zone. 2) The area involves about 11 pipelines for hazardous chemical transportation such as crude oil and natural gas. The pipeline network traverses several trunk roads and rivers. 3) About 15 major roads are involved for the transportation of regional hazardous chemicals.

Environmental risk receptors: the atmospheric environmental risk receptors in the region include residential quarters, hospitals and schools, and the population which is involved is about 156,200; water environmental risk receptors in the region include 3 rivers and 2 farms.

Environmental emergency materials: more than 20 risk enterprises in the region have set up corresponding environmental emergency materials.

According to the risk identification results, table 1 lists the key attention risk sources in this region, identifies the types of typical emergencies that may occur, and analyzes the impact ways and means of risk accidents.
Table 1. The scenario analysis of typical environmental emergencies

| Risk source       | Types and scenarios of risk accident                                                                                                                                                                                                 | Impact ways of risk accident                                                                                     | Main influence approach                        |
|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------|-----------------------------------------------|
| Production        | The region focuses on the construction of large-scale petrochemical projects in petrochemical industry, marine chemical industry, one-carbon chemical industry and energy comprehensive utilization. Because the production and operation process contains a large number of toxic and explosive substances, it may cause the leakage of substances such as benzene, hydrogen sulfide, ammonia, ethylene and acrylonitrile. | The poison leakage may affect/damage the ecological environment around the area through atmosphere and water diffusion. | By human inhalation and ingestion              |
| equipment         |                                                                                                                                                                                                                                | Fire and explosion transfer dangerous substances to the atmosphere through heat radiation, smoke, shock waves, projectiles, and affecting/damaging nearby ecological areas. | By buildings and facilities damage and human inhalation                                                      |
| storage system    | The regional ports are equipped with storage tanks for petroleum, refined oil, ethylene, dichloroethane, ethylene oxide, propylene oxide, solvent oil, styrene, benzene, and the storage volume is large. The storage of a large amount of oil may cause fires/explosions, and even fires often lead to a chain reaction malignant accident between storage tanks. |                                                                                                                                                      |                                               |
| Transportation    | With the increase of regional storage, the amount of transportation replenishment also increase accordingly. Ship oil spill and chemical spill accident may increase when transported by sea or road. Crude oil and natural gas transmission pipelines may also occur leakage accidents. | Leaked poisons affect the surrounding ecological environment through water and soil.                          | By human ingestion                             |
| system            |                                                                                                                                                                                                                                |                                                                                                                                                      |                                               |
| Utility project   | The region will form a large petrochemical project group. Due to the large scale of production and operation, the dysfunctional operation of infrastructure such as water treatment and air pollution control may release a large amount of pollutants in an instant, thus affecting the ecological environment and human health of the region. | Leaked poisons affect the surrounding ecological environment through water and soil.                          | By human inhalation and ingestion              |

3. Regional environmental risk assessment

3.1 Risk assessment method

The three risk assessment methods recommended in the “Recommendation Methods for Risk Assessment of Environmental Emergencies in Administrative Regions” issued by the former Ministry of Environmental Protection are mature in the risk assessment of regional environmental emergencies and they have good generalization performance. Among them, the index method builds three types of risk indicators and conducts index quantification and comprehensive evaluation by analytic hierarchy process, which is based on the theory of environmental risk system and the factors such as ‘Environmental risk source strength S, Environmental risk receptor vulnerability V, Environmental emergency risk prevention and management capacity M’. The assessment method mainly carries on the macroscopic and overall grasp to the regional environmental risks, and obtains the overall level of risk. Due to the small area of the research object, the large number of trans-boundary rivers, and the atmospheric and water environmental risks which are greatly affected by the trans-boundary, this paper based on the survey results uses the index method to carry out the quantitative assessment of the corresponding risk index, determines the regional environmental risk level, and conducts the environmental risk assessment sub-area classification in the research area according to the sensitive target type, which the sub-area includes atmospheric environmental emergency event risk assessment sub-area, water environmental emergency event risk assessment sub-area, and comprehensive environmental risk assessment area.
3.2 Risk assessment result

On the basis of the environmental risk identification and data preparation, and according to the evaluation indicators in the schedule 1 of ‘Recommendation Method for Risk Assessment of Environmental Emergencies in Administrative Regions’, calculated each indicator value and add it up, to get environmental risk source strength (S) index, environmental risk receptor vulnerability (V) index, and environmental emergency risk prevention and management capacity (M) index. After that, calculate the environmental risk (R) index based on their weights. According to the numerical interval of the environmental risk index, the environmental risk of the region is divided into four levels: high, relatively high, medium and low. Therefore, table 2 lists the water environmental risk index ($R_w$), the atmospheric environmental risk index ($R_a$) and the integrated environmental risk index ($R_i$) calculated according to the following formula.

$$R_w = \frac{3}{3}S_w \cdot V_w \cdot M_w$$

$$R_a = \frac{3}{3}S_a \cdot V_a \cdot M_a$$

$$R_i = \frac{3}{3}S_i \cdot V_i \cdot M_i$$

Table 2. The risk index of the research area

| Category  | S  | V  | M  | R   | Classification principles |
|-----------|----|----|----|-----|--------------------------|
| Water     | 42 | 35 | 57 | 43.76 | [40,50) RH |
| Atmosphere| 46 | 66 | 66 | 58.52 | [30,40) M  |
| Integrated| 40 | 39 | 58 | 44.89 | <30 L       |

According to this table, the result of the Nangang Petrochemical Industry Zone in Tianjin Binhai New Area which is evaluated by using the index method of ‘Recommended Method for Risk Assessment of Environmental Emergencies in Administrative Regions’ is that the water environmental risk index and the integrated risk index are relatively high risks while the atmospheric risk index is high risk.

4. Results and discussion

1) The agglomeration of petrochemical industry has promoted the economic development in China, however it also increased the occurrence probability of regional environmental risk events. According to the research on regional environmental risks in domestic and foreign in recent years, systematic research results on regional, industrial and comprehensive environmental risk identification and classification techniques have not yet been formed. Therefore this paper which is based on Nangang Petrochemical Zone of Binhai New Area discusses the technical ideas of regional environmental risk identification and assessment in petrochemical industry.

2) According to the characteristics of the study area, the basic procedure for environmental risk identification is proposed. After that, based on the ‘Business Risk Assessment Method for Environmental Emergencies’ (HJ941-2018), the risk sources, risk receptors and material reserves of the study area are identified, and then the typical emergency environmental events that may occur in the area are analyzed. Finally, based on the index method in ‘Recommended Method for Risk Assessment of Environmental Emergencies in Administrative Regions’, it is determined that in the research area, the regional water environmental risk and regional integrated environmental risk are relatively high risks while the atmospheric risk is high risk.

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