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Environmental risk zoning and assessment of oil and gas pipelines (case study: ethylene gas-transfer pipeline)

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In order to sustainable development, due to economic development of country, hazards, risk and environmental consequences of oil, gas and petrochemicals transmission by pipeline should be considered. The assessment of the risk in oil, gas transportation, and also petrochemical raw materials through pipelines is one of the issues that needs attention and extensive planning. In spite of the importance of this fact, so far in scientific and operational conventions, no specific instruction and solution has been provided for assessing the risk. For removing some of these shortcomings, the present study has investigated the environmental risk assessment in the first section of ethylene gas pipeline. The method used in this study is indexing system based on weighting by using GIS. According to this method, the assessment and zoning of environmental risk was conducted based on two main indexes: the index sum and the leak impact index. The results were determined on the environmental risk zoning map of ethylene gas transfer pipeline. The ranges of the risk potential were very high, high, medium and low. These areas have been attained in the Geographical information system (GIS) from the overlapping of the information layers of each of the indexes which have been studied two kilometers from the sides of the pipeline. According to the study, 2 percent (7 km) of the total length of the pipeline has a very high risk potential, 31 percent (127 km) has a high risk potential, 42 percent (176 km) with an average risk potential, and 25% (101 km) of the whole route has a low risk potential. In order to reduction of environmental risk, mitigation measures have been presented in three phases of designing, constructing and operating. The proposed programs contain controlling approaches and considering the implementation and maintaining the monitoring programs using managerial decision systems.

Keywords: Environmental risk assessment (ERA), Environmental risk zoning, Indexing system, Index sum, Leak impact index, Geographical information System (GIS).

1. INTRODUCTION

Although pipelines continue to be the safest way to transport fluids over long distances, accidents still threaten the public and environment, exposing the industry to security. Therefore the risk assessment must include a definition of probability of failure and a measure of potential consequences [1]. Environmental risk assessment is a process which aims to analysis the qualitative, as well as quantitative risks. In addition, this process simultaneously attempts to predict the potential risks considering the sensitivity and vulnerability of the surrounded environ [2]. Although, construction of gas lines plays a vital role in well transferring of these substances technically, as well as economically, it could affect significant impacts on the environment due to high vulnerability of the studied process [3].

In order to reach sustainable development aims and decreasing harmful risks, it is necessary to conduct risk management [4].A comprehensive plan of risk management includes: assessing the environmental risk, the ways of controlling risk, applying decision-making systems, implementing the monitoring programs and protecting the system under the study [5]. On the other hand risk management process consists of identification, assessment and mitigation of risk. Indexing method is a well-accepted approach to classification and qualification of the numerous types of environmental risks which has been applied at this research in order to environmental risk assessment and zoning of ethylene gas pipeline [6]. According to the applied method and environmental characteristics of the studied site (topographical properties and natural, as well as manmade consequences), environmental risk assessment and zoning studies for ethylene gas pipeline with 411 kilometers long are determined and its risk management program was presented.

2. RESEARCH APPROACHES

The applied approaches for assessing and presenting the risk management program are mentioned briefly below:

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Assessment methods: for assessing the environmental risk in the study. The indexing system as the study basis has been selected. It should be mentioned that the indexing system is a comprehensive applicable approach on which based on this approach, the risk potentials project is assessed based on the existing indices and criteria.

The case study: in this research, the first section of the gas pipeline of ethylene has been selected as the case study and the results will be generalizable to all the gas transition lines.

The planning process: The planning process was used for having a reasonable and eligible connection between different phases of research and attaining suitable implementation results to reduce the development risks of gas industry in the region. And finally, the project of environmental risk management was provided. At first, the affective and the affected potentials were identified from the risk project was identified, and then, each of components was examined and based on that, a certain risk management program was provided.

3. THE STUDY SCOPE

It is obvious that without having a complete knowledge about the plan under study and its surrounding, one cannot give any idea about the strength or the weakness of the project towards the environmental risk. So, firstly the characteristics of the project ethylene gas pipeline transition were examined. Secondly the environment taking the impact was investigated. Some of the project characteristics and environmental factors which have been investigated in the study have been pointed in section (3-4), the scoring criteria have been investigated briefly. After a complete knowing of the pipeline project of ethylene transition and also the mentioned parameters of the region environment in the study scope, the assessment method of the environmental risk was chosen and it was considered as the base of the study.

4. ENVIRONMENTAL RISK ZONING AND ASSESSMENT

According to the existing definitions, Risk is defined as this uncertainty of outcome, whether positive opportunity or negative threat, of actions and events. The risk has to be assessed in respect of the combination of the likelihood of something happening, and the impact which arises if it does actually happen [7]. When we ask "What is the risk?" we really ask three questions: (i) what can go wrong? (ii) What is the likelihood of that happening? And (iii) what are the consequences? [8].

In the applied method, for assessing the environmental risk of gas pipeline transition, two main indexes are studied including: Index sum and Leak impact index. The main factors above were mixed by examining each subsection of the mentioned indexes and weighing the considered indices and then, the environmental risk was carried out. The process of environmental risk assessment of Ethylene gas pipeline has been illustrated in the flowchart in Fig 1.

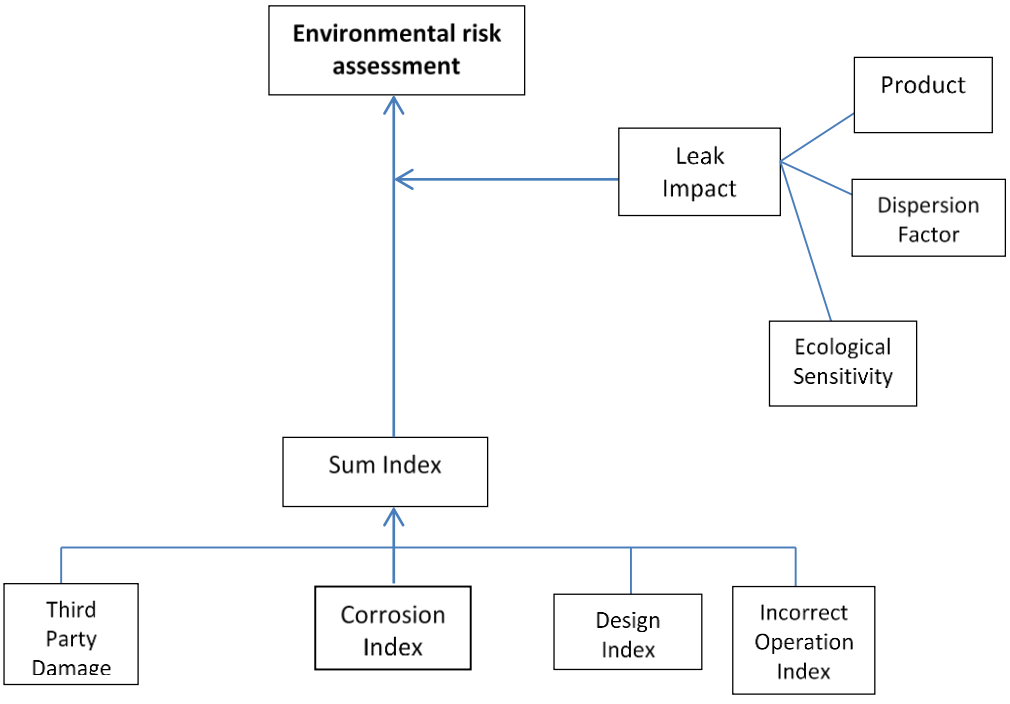

Fig 1. The process of environmental risk assessment and management of the ethylene gas-transfer pipeline

4.1. Index sum

The index sum is the first index of environmental risk assessment and it includes all the factors which are effective in the increase of the likelihood of actualizing incidents or danger in the pipeline route. This group which is probable in the increase of incidence or danger in the route of gas pipeline transition is divided into two main groups: the first group is the risks inherent indices which can be searchable and identifiable in gas transition system. The second group is the external indices which encompasses the components and factors being outside the gas transition system. In the section of index sum, four main factors were examined as explained below [9].

- Third party damage index
- Corrosion index
- Design index
- Incorrect operation index

4.1.1. Third party damage index. Any damage or risk of damage as a result of natural and human factors' function out of gas transition set is known as Third Party Damage [9]. Therefore, in this index, all the mentioned factors which increase the likelihood of risk will be examined. Although the effects of such factor seems low, but the examination of literature reviews across the world suggest that a large part of incidents made in gas transition system was in effect of the Third Party Damage.

4.1.2. Corrosion index. The most important factor in examining the risk potential resulting from corrosion in gas pipeline is the corrosion caused by internal factors (the corrosiveness of the gas inside the pipe) and its environment. Environmental parameters of corrosion including the corrosion resulting from atmospheric agents.

4.1.3. Design index. The relationship between the principles of the transmission line design with the real conditions in operation will be examined in the form of design criteria. Several factors are involved in the design parameter, which include the pipe tension, the relative tolerability of the whole transition system, the movement of earth and the surge pressure [9].

4.1.4. Incorrect operation index. Human being as the main system user plays a considerable role in directing, functioning and controlling the existing components in the procedures, and there will be likelihood of appearing error in each of the sections especially in the operation phase. Therefore, identification and prediction of the potential risk of these branches of the risk are very difficult and is essential at the same time.

4.2. Leak impact index

The second main theme of the environmental risk assessment is the Leak impact index. All factors that are effective in the intensity or weakness of environmental risks are discussed in this section. The components examined in this section are divided into three main parts and seven subsections namely (1) the hazard of product (including sub-components: the acute risks and chronic risks), 2. Dispersion factor (including sub-components: leakage and population density) and (3) ecological sensitivity index (including sub-components: the important and main rivers, protected areas, and special habitats) [4]. In this axis, the intensity of the effects resulting from any of the potential risks were analyzed which can represent the real risks arising from the project considered by studying both the possibility of risk and severity of its effects.

4.3. Scoring criteria for environmental risk assessment

Each of the potential risks of pipeline has been scored in the previous section and then, they were combined together. In order to have a better analysis, at first, the factors affecting risk in each category were summed, and then, the privileges of each class in studied major groups were summarized. The total score of each of the parts used in the environmental risk assessment of ethylene gas pipeline is provided in the Table in Fig 2.

4.4. Environmental risk analysis and results

According to the methodology, total detected risks were tabulated in two classes: sum Index and Leak Impact Index. Total factors which play a crucial role in accident occurrence throughout the pipe line are included in Sum index group. Four sub-indices are branched from sum index, including Third Party Damage Potential, Corrosion Index, Design Index, Incorrect Operation Index. On the other hand, Leak

Impact Index covers all the factors which are effective in increase or decrease of the environmental risks such as Product Hazard, Dispersion Factor and Ecological Sensitivity as receptors. Then, overlapping of information layers and consequently risk classification has been done. By combination of sub-indices of sum index with Leak Impact Index besides considering score of each factor the total plan of sum index, as well as Leak Impact Index is provided which represents the accident potential and impact severity, respectively. It is noteworthy that the result of this combination is

multiplication of the final scores in the pipe line course in each of the mentioned indexes indicates different intervals along the path with the range of environmental risk effects. As shown in risk classification table, low score represents high risk level and there has been detected a contrary relation between score and risk level.

In the following Ultimate map of pipe line risk was drawn based on the combination of sum risks index along with Leak Impact Index maps using overlay functions by geographical information system (GIS). Different environmental risks widths (zones) of the gas ethylene transition in the course of the path (411 kilometers) were determined such as (1 kilometer in the whole path and 2 kilometers in residential areas and 5 kilometers in the protected areas) [10] and the final maps of the total risks index and impact index were put together and their results as the final zoning of the environmental risk has been provided in the map.

Results of this study shown that 2 percent (7 km) of the total length of the pipeline has a very high risk potential, 31 percent (127 km) has a high risk potential, 42 percent (176 km) with an average risk potential, 25% (101 km) of the whole route has a low risk potential. It is to be noted that the high risk level detected due to the ecological sensitivity in route of the pipeline included passing through the Helleh protected area, also intersecting with important rivers such as Helleh and Mond river. Other ecological sensitivity, including existence of population centers in route of the The overlaying maps and final environmental risk zoning map of the ethylene gas pipeline has been shown in the Fig 3.

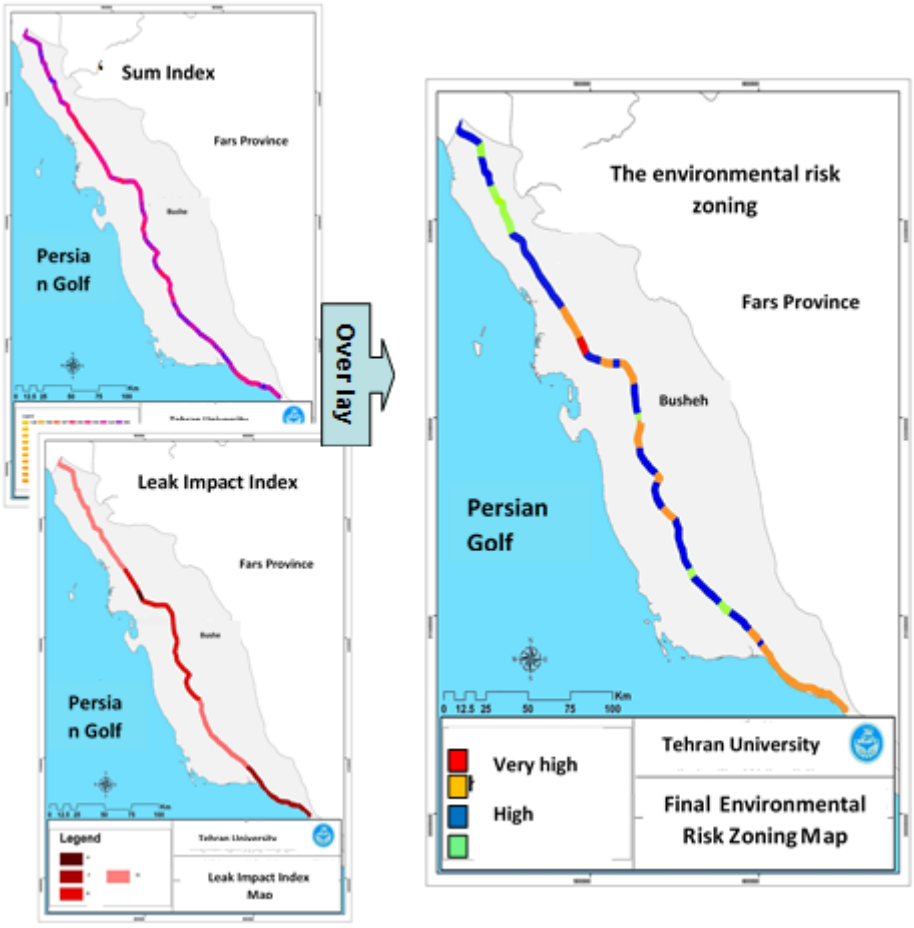

Fig 2. Final environmental risk zoning map of the ethylene gas pipeline.

Table 1. The distribution of the maximum score of environmental risk assessment indexes of ethylene gas pipeline[9].

ltota	scores		Index			class		Group
100	24		The minimum height of cover			Third Party Damage Index		Sum Index
	25	8	3	Population centers	Level of regional activity			
			3	Lines of communication				
			2	ongoing projects				
		9	3	Pipeline	Sensitive activities and risk			
			3	Oil pipeline				
			3	High-voltage power line				
		4	2	Agriculture, forestry and garden				
			2	water pipeline				
		4	Natural potentials					
	6		Pipleline privacy					
	11		Facilities along the way					
	17		Frequency of patrolling and inspection					
	17		Public education campaign					
100	20	10	Product corrosivity			Internal corrosivity	Corrosion index	
		10	Tube internal protection					
	80	25	Cathodic protection			Pipe corrosivity		
		26	Casing					
		20	Soil corrosivity					
100	25		Pipe safety factor			Design index		
	25		The safety factor of transmission system					
	20		Surge pressure					
	30		Soil displacement					
100	35	5	Product hazard identification		Design phase	Incorrect Operation Index		
		15	The maximum tolerable pressure					
		12	The immune system					
		3	Control					
	20	16	Quality Inspection		Building phase			
		3	Check the connection					
		3	Using proper coverage					
		3	pipe insulation Investigation					
	40	4	Implementation of safety programs		Operational phase			
		6	SCADA systems					
		10	Equipments for mechanical errors					
		12	Training programs					
		8	Repairing & maintenance program					
400						Total		
22		4	Flammability		Acute			

	1	4	Activity level		Hazard of Product	Leak Impact Index
	2	4	Toxicity			
	10		chronic			
6	6		Gas leak		Dispersion Factor	
	4		Population density		Ecological Sensitivity (as receptor)	
12	4		Important and main rivers			
	4		Protected Areas			
	4		Special Habitats			
40	Total					

5. CONCLUSION

In the project ethylene gas pipeline transition,at first, the ranges with very high, high, average and low risk potentials were identified by environmental risk assessment as one of the components of risk management program. According to the results, it is highly logical that the patches where are more confronted with threats and damages need more control measures.Some of the control measures include concrete casing in crosssing places, installation of marker in the route of pipeline, using one call telephone system, auditing and patrolling, preparing crisis management program. These measures can be taken during construction and operation phases.

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