ASSESSMENT OF ENVIRONMENTAL OIL SPILLS AND ECONOMİC-ENVİRONMENTAL RISKS

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Abstract

The article classifies oil spills in the environment related to accidents in oil production and transportation processes and proposes a new methodological approach for the assessment of environmental and economic risks for various oil spill cases. It was determined that although this risk is low in some cases, it is important to take into account the cases where the consequences are severe because of large-scale oil spills.

Keywords: environment, oil spills, ecological factor, eco-economic risks, probability, accidents.

I. Introduction

The factor that most affects the economic performance of oil and gas production and transportation processes is the release of hydrocarbons into the environment during accidents. Accidents disrupt normal work routines, cause operational difficulties that lead to material losses, cause considerable damage to the environment and create a fire-explosion hazard. In such cases, the damage to the environment, the losses, and the recovery of work regimes are highly dependent on the prompt determination and elimination of accidents [1-3].

Table 1: *Deviation of the frequency of accidents by separate categories*

Categories	Accidents	Approximate frequency of accidents	Characteristics of accident probabilities
1	Practically impossible	< 10^{-6} 1/year or once in morethan 1 million years	Although such cases are not excluded, they almost neverhappened.
2	Rare	$(10^{-6} - 10^{-4})$ 1/year or once in $10^4 - 10^6$ years	These cases have happened only a few times worldwide.
3	Unlikely	$(10^{-4} - 10^{-2})$ 1/year oronce in 100-10000 years	This kind of accident happens, but it is unlikely during the implementation of the project.
4	Likely	$(10^{-2} - 1)$ 1/ year oronce in 100 years	Such an accident is possible when the project is realized .
5	Practically unavoidable	>1/ year or not less than once in a year	On average, it can happen no less than once a year.

Accidents occurring in oil and gas extraction and transportation systems are divided into 5 categories according to the severity of their consequences [4-7]. The deviation of the frequency of accidents by separate categories is shown in table 1, and the characteristics of the results by degrees of severity in different categories are shown in table 2.

Table 2: *Categories of accidents by degrees of severity and characteristics of their consequences*

Categories of accidents by degrees of severity	Characteristics of the consequences of accidents
Imperceptible	No effect on the health and safety of the population. No damage or breakage in the object, no impact on natural resources.
Less valuable	No loss of life or serious damage to people, the object is slightly damaged, no idle state, light and short-term impact on the environment.
Severe	Serious damage to facilities and human life casualties is possible, but there is no fear for the health and life of people among the population, although there are negative, ultimately reversible effects on a number of natural resources.
Critical	Casualties and injury to a large number of people working at the facility, significant damage to the facility, and significant and long-term damage to two or more natural resources.
Catastrophic	The occurrence of an emergency resulting in a large number of human casualties and irreparable damage to a large number of natural resources.

According to the currently available operating experience, oil leaks from pipelines are divided into the following categories according to the size of the leak site and the amount of spilled oil [1,3,4]:

- small leaks: leaks that do not exceed 3-5% of the nominal consumption of the oil pipeline. Such leaks can occur from holes with a diameter of 5-10 mm (average 7.5 mm), which corresponds to the size of holes caused by corrosion in belts. Small leaks are mainly determined by the amount of hydrocarbon vapors in the air. According to operational experience, these leaks can be determined within 7 days;
- medium leaks: leaks that make up to 5-10% of the nominal consumption of the belt, holes varying in size from 10-50 mm are accepted as the places of leakage. Such leaks are usually identified and detected within 1hour by indirect means;
- major leaks: covers leaks of more than 10% of the rated consumption in the belt up to complete collapse. The dimensions of the leakage places are taken as a limit equal to the diameter of the belt from 50 mm. Major oilleaks can be detected within 5 minutes based on the indicators of the devices.
- "hidden" or hard-to-detect leaks: leaks in pipelines of up to 3% of nominal flow or very small leaks. Forthe purpose of evaluating such leaks, the size of the leaks can be taken as 3-5 mm (4 mm on average). Practically, these leaks are considered to be cases of leaks that are not detected by traditional methods or are very difficult to determine, and the time for their detection is conventionally accepted as 30 days [5].

II. Solution

It is also necessary to assess the direct damage caused by oil losses during oil spills. This assessment is also important for proper oil accounting and maintenance in case of accidents. Depending on the amount of oil spilled into the environment the value of oil loss due to an accident $G_{n.i}$ can be determined as follows:

$$G_{n.i} = G_{n.s.q} \cdot gt_s \quad (1)$$

where:

$Q_{n.s.q}$ - sale price or cost of crude oil, AZN./t;

g - the amount of oil spilled into the environment per unit time, t/h;
t_S - the time period for oil leakage into the environment, hours (in calculations, it is considered as the time ofdetection of the leak).

Using the classification of oil spills by categories, it is possible to estimate the economic damage caused by oil losses. In the calculations, the selling price of 1 ton of oil included in expression (1) is accepted as $G_{n.s.q}$ (200 AZN on average). Based on the deviation of oil losses by leakage categories, the damages caused by oil losses that occurred in different pipelines, i.e. at different prices of the nominal consumption of oil, until the leaks were detected, were calculated. It has been established that if leakage cases are detected late, rather than withinthe nominal time, then the material damage will increase as much. If "hidden" leaks during operation remain undetected for 1 month, then the damage caused by oil losses for pipelines with nominal consumption values of10, 50, 100, 200, 500, 1000, 5000 t/h can be valued at 5.4; 27; 108; 270; 540; 2700 thousand AZN, respectively. Since the oil pipeline system is considered a potential source of danger during operation, the assessment of the risks of oil spills from possible accidents is of great ecological and economic importance. The level of risk largely depends on the magnitude of expected losses and the probability of occurrence. As environmental damage and oillosses increase by the amount of oil spills increases, the possibility of losses and damage that may occur also increases. In this case, the level of risk depends more on the magnitude of expected losses and their probability of occurrence. Therefore, the risk assessment procedure requires the knowledge of two quantities, first. These quantities are the cost of damage in the event of an accident and the probability of this event occurring. The integral risk for a number of events is defined as the sum of the risks of these events. In this case, the probability of the last event is defined as the multiplication of the probabilities of all events. Eco-economic risks can be calculated according to the classification of oil spills from pipelines based on the existing operating experience of oilpipelines. Assume that the oil spill accident is (g, m^3/hour). Then the rate of oil spill will be g/G (G – consumption of oil in the pipeline in the event of an accident, m^3/hour). Taking into account the information given above andthe elements of probability theory, it is possible to write [8] for the determination of the eco-economic risk (R)related to oil spills:

$$R = R1i \cdot R2i \cdot Z \tag{2}$$

where:
R_{1i} - the risk of accidental oil spills with environmental consequences;
R_{2i} – the risk that causes the facility to be out of order or out of normal operation;
Z - the maximum economic damage caused by an oil spill.

According to the statistical analysis and logical conclusion, it can be accepted that there are various monotonically decreasing dependencies between the probability (risk) of $R1i$ and the degree of oil spillage. In this case, the probability of R2i, which is determined by a special group of experts, will be expressed by monotonically increasing dependencies according to the degree of oil spill (Fig. 1).

Taking into account the variation of R1i and R2i probabilities, depending on the degree of oil spill (g/G), the environmental-economic risks (R) for different scenarios were calculated as follows:

$$R_1 = R_{11}\ R_{21};\ R_2 = R_{11}\ R_{22};\ R_3 = R_{11}\ R_{23};\ R_4 = R_{12}\ R_{21};$$
$$R_5 = R_{12}\ R_{22}; R_6 = R_{12}\ R_{23};\ R_7 = R_{13}\ R_{21};\ R_8 = R_{13}\ R_{22};\ R_9 = R_{13}\ R_{23}.$$

The variations of the calculated values of these risks for different deviation scenarios is shown in figure 2.

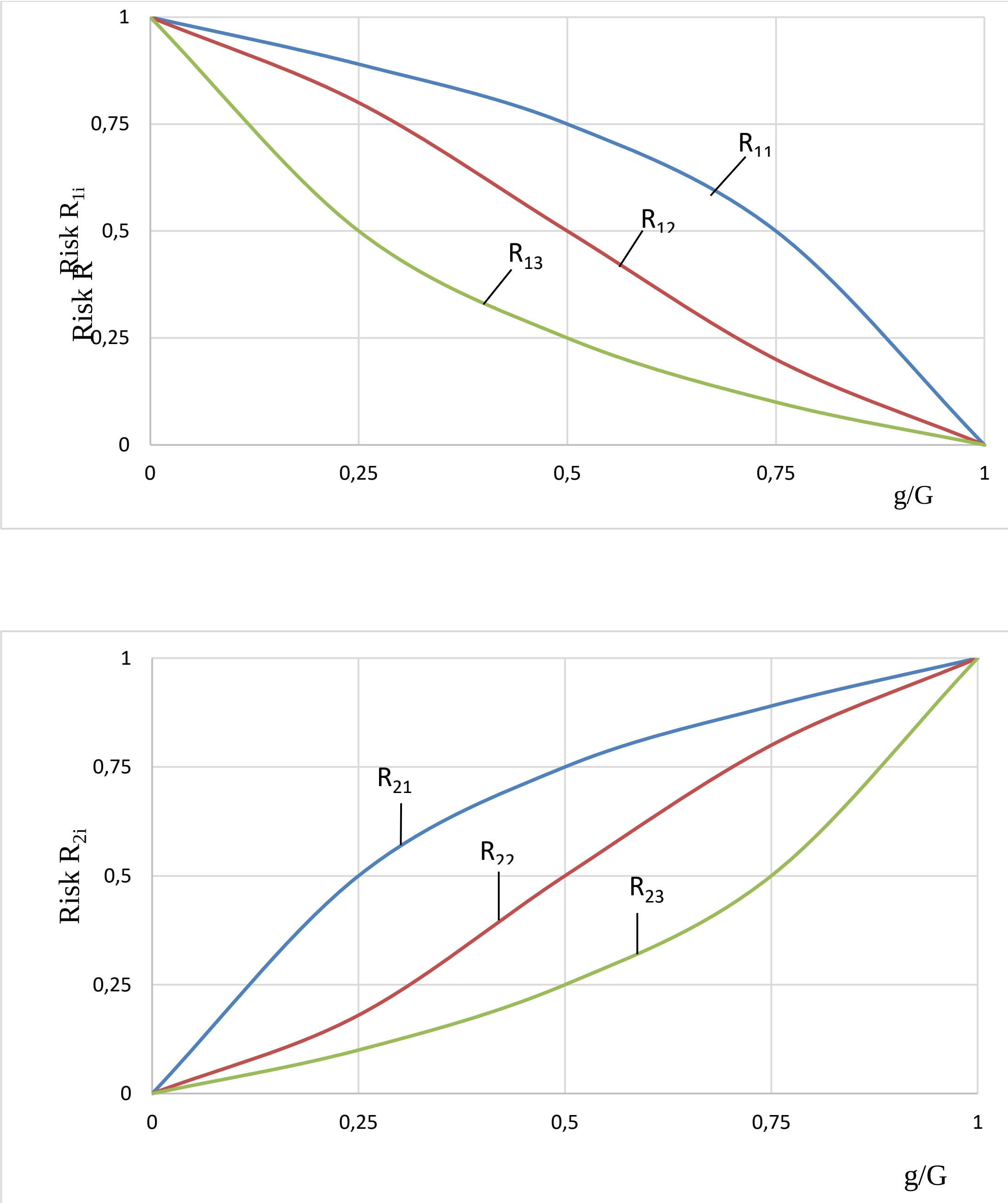

Fig.1: *Dependence of risks R_{1i} and R_{2i} on oil spills*

As given in Figure 2, the maximum risk for the considered options is 0.56, corresponding to option R1. This corresponds to the case of g/G = 50 % of oil spill risk. It means that Rmax= 0.56·Z. In addition to the mentioned, other considered options should also be explored and should not be overlooked. For example, although the maximum risk for the R3 option is low (about 0.25), the result can be alarming because it concerns large-scaleoil spills (about 75%).

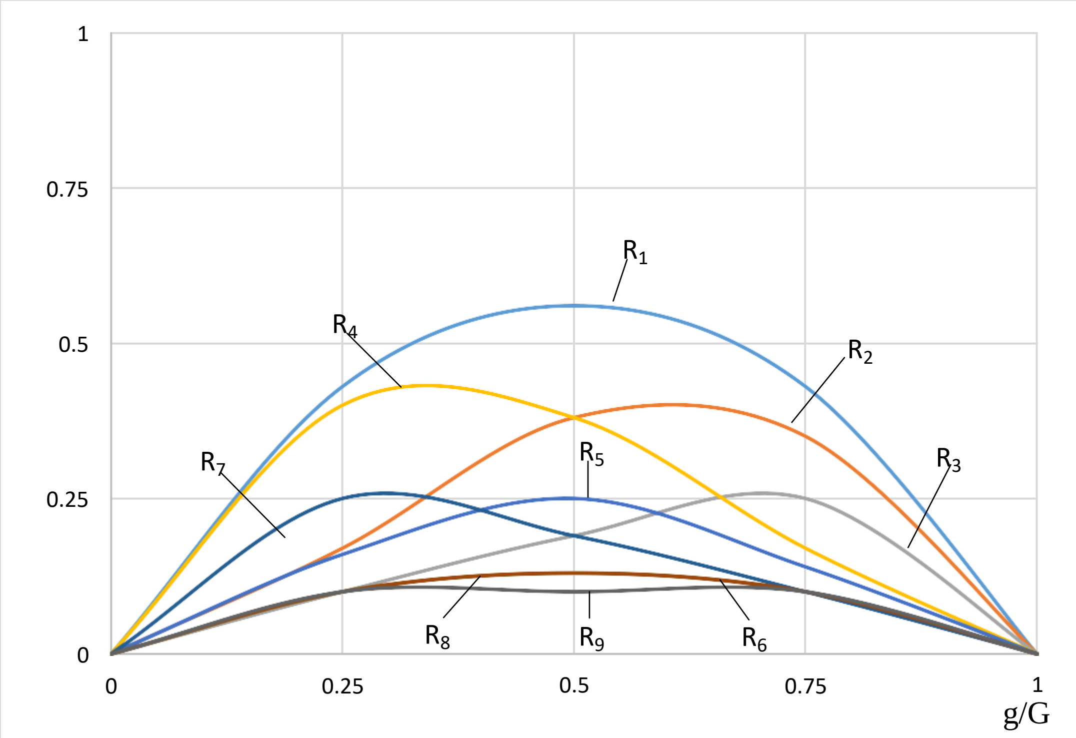

Fig. 2: *Dependence of ecological-economic risk on oil spills*

III. Conclusion

The classification of accidental oil spills that occurred during the extraction and transportation of oil was given, and the material and economic damage was assessed separately, including "hidden" leakage cases.

Taking into account that accidental oil spills result in sufficient environmental and socio-economic effects, a methodical approach was proposed for the evaluation of the environmental and economic risk factor. It was determined that even though the risks are low, large oil spills should be considered very dangerous.

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