Analysis of accidents at the facilities of main pipeline transport and oil production

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Abstract. The article presents statistical data on industrial accidents that occurred at hazardous production facilities in the oil and gas industry and main pipeline transport in the Russian Federation. The dynamics of changes in accidents has been analyzed and the damaging factors in the occurrence of fatal accidents by hazard classes have been considered. The results of this study can be used to build predictive simulation models for the purposes of technosphere safety management.

1 Introduction

Modern conditions for the development of oil companies that operate hazardous production facilities of trunk pipeline transport require the activation of all possible resources to reduce the number of accidents and their consequences [1]. The implementation of the most dangerous emergencies can lead not only to large economic losses for enterprises and stakeholders, but also to catastrophic consequences with group deaths, which can adversely affect the functioning of the enterprise as a whole. Therefore, in order to develop and implement innovative technological and managerial tools in the field of increasing the level of industrial safety at oil and gas production and transportation facilities, it is necessary to conduct a comprehensive study of accidents, their causes, and consequences.

2 Methods

As part of the study of accidents at oil production facilities and main pipeline transport in the Russian Federation, the following methods were used: statistical analysis, quantitative and qualitative risk assessment, comparative analysis [2]. Based on the statistical data given in the annual reports of the Federal Service for Environmental and Technological Supervision, a comparative analysis of the accident rate for different classes of hazardous production facilities was carried out [3].

3 Results

At the moment, one of the key sectors of the economy of the Russian Federation is oil and gas production. Thus, oil production, taking into account gas condensate, is more than 550

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million tons per year, and natural gas production amounted to 692.33 billion cubic meters of gas in 2020. A high volume of production and transportation requires the use of a complex set of technical devices, which may cause emergencies. Therefore, the state Federal Supervision in the field of industrial safety carries out supervisory activities for hazardous production facilities (HPF) for the prevention and prevention of accidents. As of 2020, it controls the activities of 8687 hazardous production facilities in the field of oil and gas production [4].

Table 1. The number of hazardous production facilities by hazard class and the number of cases of fatal injuries.

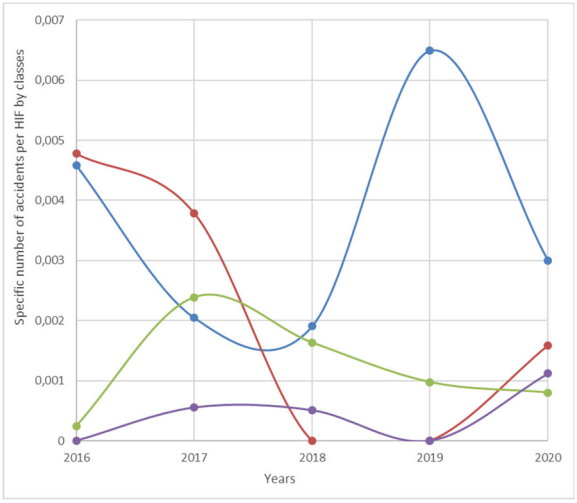
Class	Indicator	2020	2019	2018	2017	2016	2015	2014	2013
Total:	Number of HPFs	8687	7051	7864	7525	7575	7560	7287	0
1		666	462	525	488	436	388	278	-
2		1258	1046	1100	1056	1047	939	891	-
3		4981	4100	4281	4183	4095	4277	4117	-
4		1782	1443	1958	1798	1997	1956	2001	-
Total:	accidents	10	7	9	16	8	17	18	18
	oil production facilities	10	6	9	16	8	16	17	16
	gas production facilities	0	1	0	0	0	1	1	2
Total:	traumatism	8	8	12	7	12	19	9	18
	oil production facilities	8	8	12	7	12	19	9	18
	gas production facilities	0	0	0	0	0	0	0	0
Total:	accidents	10	7	9	16	8	17	18	18
1		2	3	1	1	2	-	-	-
2		2	0	0	4	5	-	-	-
3		4	4	7	10	1	-	-	-
4		2	0	1	1	0	-	-	-

Table 1 presents data on the number of accidents at supervised facilities of Rostekhnadzor in the oil and gas industry for the study period. The Rostekhnadzor report for 2013 does not provide data on hazard classes. The total number of HIFs increased by 19% over seven years, the largest increase occurred in hazard class 1 and amounted to 240%, however, despite this, the smallest number of accidents is observed in class 1, which is explained by more serious requirements in the field of industrial safety and the number of scheduled and unscheduled inspections, as well as increased training of personnel and the work of the labor protection and safety department.

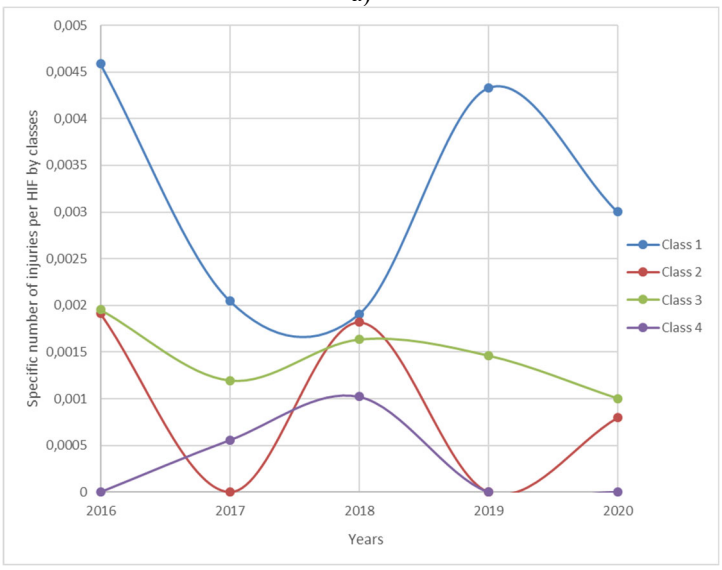
At class 2 facilities, there was an increase in hazardous production facilities by 41%, and in 2018 and 2019, not a single accident was recorded. Class 3 accounts for the largest number of accidents in total, so in 2017 it accounted for 63% of the total number of accidents, and in 2018 the share of accidents in the total number of hazardous facilities increased to 66%, but in 2019 and 2020 the share of accidents decreased by 33% and 66% respectively. However,

attention should be paid to the share of the 3rd class. Figure 1a) shows the ratio of the number of accidents and the number of HIFs by hazard class.

Over the past four years, there has been a tendency to reduce the number of accidents in hazard classes 1 and 3, in turn, the largest value was registered in 2017, and in 4 class in 2016 no accidents were recorded, but in 2019 and 2020 there were two accidents per year in 1 and 2 classes. There were 4 accidents in the 3rd grade, which corresponds to the indicators of 2019. In general, with the exception of outlier data for 2020, there is a clear downward trend in both accidents and industrial injuries.



a)



b)

Fig. 1. Distribution by years: a) the ratio of the number of accidents to the number of hazardous production facilities by hazard classes, b) the ratio of the number of fatal injuries to the number of hazardous production facilities by hazard classes.

Figure 1 illustrates that most of the accidents were recorded in the field of oil production. This phenomenon is associated with the specifics of mining, which includes work with

flammable liquids, heavy equipment, in conditions of hard physical labor and often in adverse weather conditions. The number of accidents cannot be considered in isolation from the number of fatal injuries, Figure 1 b) shows the dynamics of changes in the number of fatal injuries by hazard class.

Analyzing the indicators of fatal injuries, it should be noted that there is a tendency to increase at facilities of hazard classes 1 and 2, which indicates the ineffectiveness of measures taken by jointly controlling and operating organizations in order to ensure a high level of industrial safety, and the human factor is also cited as a frequent cause of accidents.

In grade 4, there is a decrease in the number of fatal injuries, which is also explained by an increase in the level of industrial safety. In grades 2 and 3, cyclical fluctuations occur, which may be due to the influence of unaccounted factors and errors in the analysis caused by a short time interval.

To develop mechanisms to reduce the number of accidents and fatal injuries at oil and gas production facilities, it is necessary to analyze the distribution of fatal accidents at oil and gas production facilities by traumatic factors and the distribution by types of accidents, which are presented in Table 2.

Table 2. Distribution by types of accidents and damaging factors in the event of an accident with a fatal outcome (http://www.gosnadzor.ru/).

		2020	2019	2018	2017	2016	2015	2014	2013
Total:	By type of accident	10	7	9	16	8	17	18	18
	Open fountains and blowouts	2	2	3	9	2	5	6	4
	Explosions and fires at facilities	6	2	1	3	2	5	2	2
	Fall of drilling (operational) rigs, destruction of their parts	0	0	1	0	1	1	1	2
	Other (destruction of technical devices, oil spills)	2	3	4	4	3	6	9	10
Total:	fatal accidents due to traumatic factors	8	8	12	7	12	19	9	18
	thermal effect	3	2	3	2	2	4	2	1
	Falling from height	0	0	0	1	2	2	0	3
	Toxic Substances	2	1	2	0	0	2	0	0
	lack of oxygen	1	2	1	0	0	0	0	0
	blast wave	0	0	1	0	1	1	1	1
	Destroyed technical devices	2	1	5	4	1	3	2	3
	Other	0	2	0	0	6	7	4	10

The distribution by types of accidents for 2020 shows that 60% of accidents occur as a result of the destruction of technical devices and spills of oily liquids, and the subsequent explosion or fire of the strait, or an instantaneous explosion and fire of the strait without the formation of a strait mirror. If we analyse the results for 8 years, it turns out that in the first place there will be the destruction of technical devices, spills of oily liquids, in the second place - 31.02% of the implementation of accidents is associated with open flowing and the release of hazardous substances, 24.38% is associated with explosions and fires as a result of

technical and organizational errors, the most rare cause of accidents 5.7% of accidents are associated with the fall of drilling (operational) rigs and the destruction of their parts.

An analysis of the distribution of fatal accidents at oil and gas production facilities by traumatic factors shows that the most common causes are thermal effects (22.7%), destruction of technical devices (24.9%). Significantly less damaging factors are lack of oxygen (5.7%), toxic effects (8.09%), blast wave (4.82%). However, in order to understand the causes of the impact of these damaging factors, it is necessary to analyze the statistical section "Lessons learned from accidents" presented on the official website of Rostechnadzor.

3.1 Main pipeline transport and underground gas storage facilities

Table 3. Number of accidents and fatal injuries by hazard class at trunk pipeline transport and underground gas storage facilities.

		2020	2019	2018	2017	2016	2015	2014
Total:	Number of HPFs	4731	4364	4273	4310	4522	4479	4301
1		903	683	643	694	742	688	663
2		3215	3240	3178	3208	3352	3056	2996
3		345	288	365	358	422	633	561
4		268	153	87	50	6	102	81
Total:	accidents by industry	11	7	12	6	11	13	8
	Gas pipelines	8	4	10	5	9	10	8
	Oil pipelines	3	2	2	1	1	1	0
	Oil product pipelines	0	1	0	0	1	1	0
	Ammonia pipelines	0	0	0	0	0	1	0
	Underground gas storage facilities (UGS)	0	0	0	0	0	0	0
Total:	fatal injuries by industry	3	7	0	2	0	2	2
	Gas pipelines	2	0	0	0	0	1	1
	Oil pipelines	1	5	0	2	0	1	0
	Oil product pipelines	0	2	0	0	0	0	0
	Ammonia pipelines	0	0	0	0	0	0	0
	Underground gas storage facilities (UGS)	0	0	0	0	0	0	1

The average number of hazardous production facilities for the study period increased in class 2 and is 71.86% of the total, in second place are objects of hazard class 1, more than 16.15%, followed by hazard class 3 and 9.61%, respectively, and class 4 is slightly more than

2.38%. The widest range of values is observed in class 4, so if in 2019 683 objects in class 1 had a license to operate, then in 2020 there are already 903 objects, a change in the number of hazardous production facilities could be due to changes in the criteria for the relationship of a hazardous object to a particular hazard class, as well as the merger of HIFs into larger conglomerates, and certainly the development of pipeline infrastructure.

It should be noted that accidents occur much more often on gas pipelines than on oil pipelines, although the situation is absolutely opposite in the production of gas and oil, which is associated with specific requirements for the organization and implementation of the transportation of these substances. In addition, it should be noted that the length of oil pipelines is more than three times less than gas pipelines, 54.941 thousand kilometers and 182.345 thousand kilometers, respectively, which certainly affects the frequency of emergency situations. Also in oil pipelines, a higher pressure is maintained compared to a gas pipeline.

A decrease in the accident rate in relation to the number of HIFs by class was recorded (Fig. 2) only for class 3, the most frequent accidents occur in hazard class 1, the least number of accidents occur at facilities of hazard classes 2 and 4, however, it should be noted that in 2020 the frequency of accidents slightly increased compared to 2019 (63%).

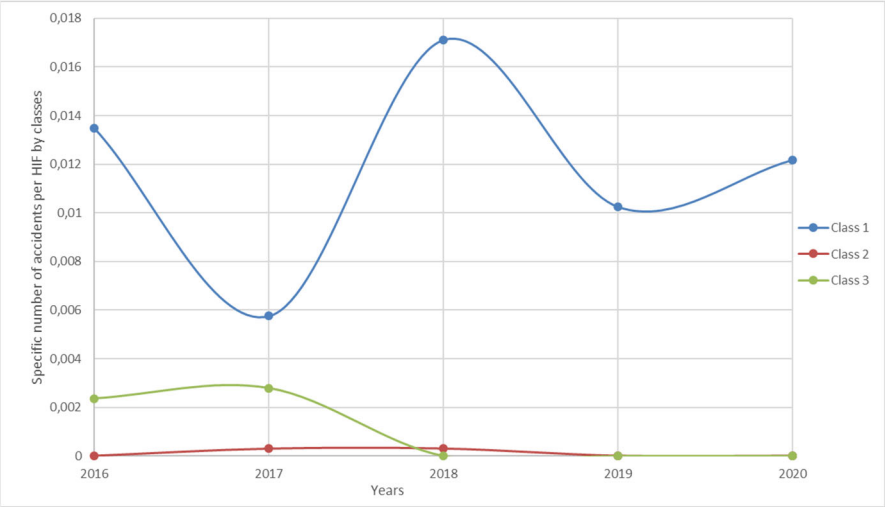


Fig. 2. The ratio of the number of accidents to the number of HIFs by hazard class at the facilities of trunk pipeline transport and underground gas storage.

The most frequent accidents occur on gas pipelines, so on average 9.4 accidents occur every year, more than 80% of all accidents on main pipelines. On average, a little more than one accident per year occurs on oil pipelines. There were only three accidents at oil product pipelines in seven years, and one accident at ammonia pipelines. It should be noted that in 2020, one accident occurs on main gas pipelines per 18.2345 thousand km, on main oil pipelines - 29.9705 thousand km.

Table 4. Distribution of causes of accidents at hazardous production facilities and fatal injuries.

		2020	2019	2018	2017	2016	2015	2014	2013
Total:	Types of accidents	11	7	12	6	11	13	8	12
	Damage during work in the protected area	1	0	1	0	1	2	1	4

	Equipment failure and wear	6	5	10	5	0	0	0	0
	Personnel mistakes	1	2	0	1	0	1	1	0
	Construction /manufacturing defect	3	0	0	0	4	0	0	6
	Pipe metal corrosion	0	0	0	0	6	9	6	2
	Natural emergency	0	0	1	0	0	1	0	0
Total:	Fatal injury by traumatic factors	3	7	0	2	0	2	2	0
	thermal effect	0	2	0	1	0	0	0	0
	Destroyed technical devices	1	5	0	1	0	1	1	0
	blast wave	0	0	0	0	0	0	1	0
	Other	2	0	0	0	0	1	0	0

An analysis of the distribution of accidents presented in Table 4 shows that the most common cause of an accident is equipment failure and wear (36.58%), which indicates a low rate of modernization of production facilities. At the same time, attention should be paid to the low level of incoming control by organizations over the quality of pipelines produced (14.2%).

Pipe metal corrosion is in second place (26.93%), in this regard, it is necessary to direct the attention of supervisory authorities and owners of hazardous production facilities to more thorough non-destructive testing and to prevent the use of main pipelines with an exhausted resource [5].

The next reason is the work in the buffer zone (10.97%). A rare cause of an accident is human error (9.32%), natural emergencies (2%).

The causes of fatal injuries, as the study shows, are the destruction of technical devices (5 cases in 2019), thermal effects, explosions and other factors in one or two cases.

4 Discussion

Thus, the analysis of statistical data on the number of accidents, fatal injuries at oil and gas production facilities and main pipeline transport will make it possible to develop forecasts of emergency situations based on simulation modeling [6, 7]. However, to build an adequate model, it is necessary to use additional information that will allow taking into account the factors and causes of accidents. Therefore, for further research, it is proposed to analyze not only statistical data, but also reports on the investigation of accidents that have occurred, which reflect the technical and organizational causes of accidents, measures to prevent accidents and their consequences. This will make it possible to identify the main groups of reasons on the basis of which it becomes possible to develop and implement technical and organizational changes, both in the technological process and in monitoring compliance with industrial safety requirements [8,9].

5 Conclusion

As a result of the study, it can be concluded that for hazardous production facilities of the 1st hazard class, the smallest number of accidents is observed, however, they are accompanied by the most significant destruction and costs compared to other classes, which is explained by the participation of a larger amount of hazardous substance and more complex technological equipment in an emergency. The largest number of accidents occur at hazardous production facilities of the 3rd hazard class, but they are not accompanied by such large-scale consequences, which is also explained by the characteristics of the hazard class.

When determining the dependence of the number of emergency situations for the studied time interval at the facilities of the main pipeline transport of the oil and gas industry, in contrast to the study of similar facilities for oil and gas processing, a general trend was not identified, the data obtained do not have a clearly defined upward or downward trend and are in the range of average values. This can be explained by the difficulty in implementing control over the occurrence and development of accidents due to the significant territorial dispersal of objects and the climatic features of their location.

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