Accident analysis at oil refining and gas consumption facilities

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Abstract. Today one of the priority goals of any organization operating hazardous production facilities is to increase the level of industrial safety at all stages of the enterprise's life cycle. To select methods and tools, namely various technical and organizational measures aimed at increasing the level of industrial safety it is necessary to conduct an in-depth analysis of emergency situations, their consequences, and also consider the causes of their occurrence. This analysis will make it possible to predict the state of an industrial facility, and its compliance with the declared level of industrial safety.

1 Introduction

In the process of developing a methodology in the field of sustainable development, the main attention is paid to the transition of enterprises to cyclic waste recycling, reduction of emissions into the atmosphere, socially oriented business conduct, however, issues related to the management of industrial risks arising during the operation of oil refining hazardous production facilities of enterprises remain little studied [1]. The occurrence and implementation of major emergencies can lead not only to damage and destruction of equipment, buildings, structures and indirect losses, but also to critical consequences: causing harm to life and health of personnel and the population, as well as emissions of pollutants into the atmosphere and water sources [2-6]. Thus it is relevant to analyze accidents and assess their consequences for the development of mechanisms to reduce the likelihood of major accidents and the possible maximum damage from them [7].

2 Methods

To analyze the accident rate at oil refining and gas consumption facilities in the Russian Federation, statistical methods of analysis were used, and a qualitative and quantitative assessment of the consequences of the implementation of emergency situations was carried out. A comparative analysis was used to determine the dynamics of accidents and deaths with the distribution by hazard classes of production facilities over the study period.

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3 Results

Oil refining is one of the main industries of the Russian Federation. Thus, over the past years, the amount of production of light oil products, such as gasoline, diesel fuel, has been growing, and the amount of fuel oil has been declining, which indicates an increase in the yield of light oil products. The growth in production volumes requires modernization, reconstruction, and an increase in capacity, which causes innovative industrial risks [8]. Therefore, the owners of hazardous production facilities, together with the state Federal Supervision in the field of industrial safety, must develop and implement modern technical and organizational mechanisms to reduce the likelihood of accidents and monitor compliance with industrial safety requirements.

3.1 Objects of petrochemistry, oil and gas processing, oil and product supply

As of 2020, federal state supervision in the field of industrial safety was carried out in relation to 4114 hazardous production facilities of petrochemical, oil and gas processing industries and oil product supply facilities (http://www.gosnadzor.ru/).

Table 1 presents data on the number of accidents and fatal injuries at supervised facilities of the petrochemical, oil and gas processing industry and oil product supply facilities [9], taking into account the distribution of the facilities under consideration by hazard classes. For 2014-2015, information on fatal injuries and accidents is not provided, since Rostechnadzor did not publish these statistics in its annual reports on the results of its activities.

Table 1. The number of hazardous production facilities (HPF) by hazard class and the number of cases of fatal injuries at petrochemical, oil and gas processing, oil product supply facilities.

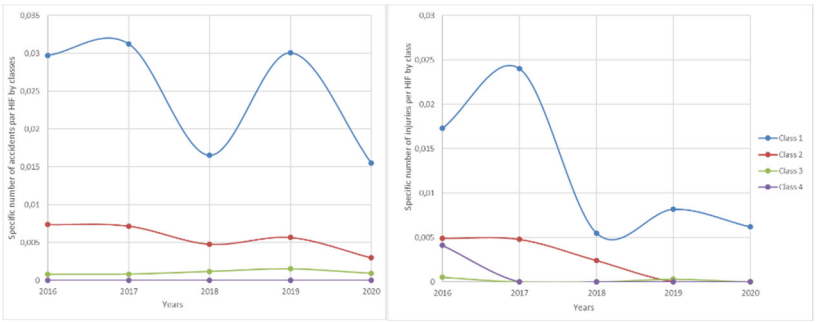
Class	Type of HPF	2020	2019	2018	2017	2016	2015	2014
Total:	The number of HPFs	4114	4147	4389	4721	4790	4907	5331
1		323	366	363	416	404	389	406
2		334	353	418	418	407	418	312
3		3264	3242	3393	3672	3736	3887	4388
4		193	186	215	215	243	213	225
Total:	Accidents	9	18	12	19	18	19	16
1		5	11	6	13	12	-	-
2		1	2	2	3	3	-	-
3		3	5	4	3	3	-	-
4		0	0	0	0	0	-	-
Total:	Fatal injury	2	4	3	12	12	7	11
1		2	3	2	10	7	-	-
2		0	0	1	2	2	-	-
3		0	1	0	0	2	-	-
4		0	0	0	0	1	-	-

The total number of HPFs for the study period decreased by 29%, the largest reduction is observed in class 3 (-34%), in class 1 the number of supervised objects decreased by 25%, and the number of objects in class 2 slightly increased. However, it should be noted that the

total share of this class for the study period is 12%, while the largest number of HPFs is presented in grade 3 and the average number for 7 years is 3654 or 26% of the average number of HPFs for 7 years.

The analysis shows that over the past 5 years, the largest number of accidents occurred at facilities of the 1st hazard class, which is characterized as extremely highly hazardous production facilities. The total percentage of accidents at facilities of this class in the total number of HPFs changes from 66% in 2016 to 50% in 2018 and increases again in 2019-2020 to 63 and 80% of the total number of accidents.

A decrease in fatal injuries over the study period was recorded in all four hazard classes, however, the share of fatal injuries in hazard class 1 occupies the largest share, so in 2016 it was 58%, in 2017 - 83%, in 2018 - 66%, and in 2019 year - 33%, and in 2020, all cases of fatal injuries occurred at facilities of the 1st hazard class.



a) b)

Fig. 1. The ratio of the number of accidents (a) and cases of fatal injuries (b) to the number of HPFs by class in the petrochemical, oil and gas processing industry and at oil product supply facilities.

Figure 1 shows the decrease in the number of accidents for all four hazard classes, the largest decrease is observed in the 1st class, so in 2016 12 accidents were recorded, in 2017 there were 13 accidents, and in 2018 due to the joint actions of Rostekhnadzor and organizations of the 1st hazard class in the region industrial policy, the number of accidents decreased by 54% compared to the previous year, however, a slight increase to 11 accidents in 2019 and a subsequent decrease in the number to 5 accidents in 2020 should be noted.

The data of Figures 1 (a, b) show that over the entire study period, the largest number of accidents and cases of fatal injuries were recorded at facilities of the 1st hazard class. The decrease in cases of fatal injuries in 2018 by 83% compared to the previous period is most likely due to complex technical and organizational measures aimed at ensuring safety during the World Cup in Russia, during which the supervisory authorities represented by Rostechnadzor, in addition to inspections, carried out exercises aimed at preventing, localizing and eliminating emergencies at extremely hazardous production facilities.

For a deeper analysis of the accident rate, it is necessary to determine which accidents by type and industry most often occur in the petrochemical, oil and gas processing industries and at oil product supply facilities [10].

Table 2. Distribution of accidents (by types and industries) and fatal accidents in the petrochemical, oil and gas processing industries and at oil product supply facilities.

	2020	2019	2018	2017	2016	2015	2014	2013
Total: acc. to the type of accident	9	18	12	19	18	19	19	14

Explosure	5	11	2	6	8	6	5	3
Fire	1	2	9	9	3	11	8	6
Release of hazardous substances	3	5	1	4	7	2	6	5
Total: accidents in branches	9	18	12	19	18	19	19	14
Oil and gas processing industries	0	9	4	14	12	7	13	8
Petrochemical production	4	5	4	2	3	7	2	1
Oil product supply facilities	5	4	4	2	3	5	4	5
The object is not registered in the state register	0	0	0	1	0	0	0	0
Total: fatal injuries by industry	0	4	3	12	12	7	11	4
Oil and gas processing industries	-	1	1	8	8	3	9	3
Petrochemical production	-	2	2	2	2	2	0	1
Oil product supply facilities	-	1	0	2	2	2	2	0

During the study period, 128 accidents were recorded at oil and gas processing and petrochemical industries, at oil product supply facilities. It should be noted that in 2017, the annual report of Rostekhnadzor took into account accidents at a hazardous production facility that did not have a license to operate, which explains the increase in occupational injuries over the specified period. Thus, the largest number of accidents (more than 48.26%) was registered at oil and gas processing facilities, the second place in terms of the frequency of accidents is occupied by oil products supply facilities (more than 27.67%), followed by petrochemical production (23.41%).

The most common type of accident for the study period is a fire, so for six years there were 60 accidents at hazardous production facilities, which is 46.35% of the total for 8 years, explosions occurred less often - 36 cases (27.75%), and the share accidents that led to involuntary releases of hazardous substances without fire and explosion accounted for 25.9% of the total.

The largest number of cases of fatal injuries was recorded at oil and gas processing facilities (48.92% of the total number over 8 years), 11 people or 25.45% died at petrochemical production facilities, 9 such cases were recorded at oil product supply facilities (13.14% of the total number over 8 years).

3.2 Gas distribution and gas consumption facilities

The largest number of HPFs of gas distribution and gas consumption belongs to the 3rd hazard class and makes up more than 94% of the total, in addition, the objects of the

considered hazard class in absolute terms account for the largest number of accidents per year. However, if we consider the accident rate as a specific value, then the objects of the 2nd hazard class are the most emergency (for example, in 2018, one accident occurred at 2768 hazardous production facilities, in 2017 at 1408 hazardous facilities, and in 2016 at 2704 HIFs of the 2nd class danger).

Table 3. Gas distribution and gas consumption facilities by hazard classes.

	2020	2019	2018	2017	2016	2015	2014
The number of HPFs	64228	64021	61113	60697	59505	60428	63458
1 class	5	7	3	3	4	4	4
2 class	1052	1046	1017	1118	1129	1114	1306
3 class	59385	58812	58131	57744	56793	57783	60726
4 class	3786	4156	1962	1832	1579	1527	1422

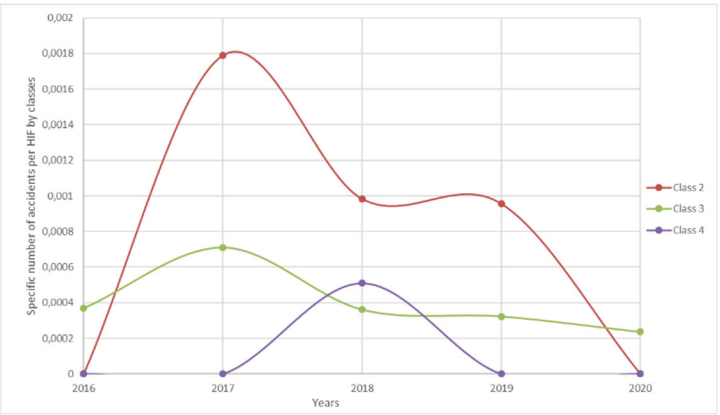


Fig. 2. The ratio of the number of accidents to the number of HIFs by class.

The ratio of the number of accidents by class shows multidirectional dynamics (Fig. 2), which requires additional research to build a trend for changing the safety level and develop an industrial risk management model for gas distribution and gas consumption facilities [11].

Table 4. Distribution of fatal accidents by traumatic factors and accidents at hazardous production facilities by types.

	2020	2019	2018	2017	2016	2015	2014	2013
Total: by types of accidents	14	20	23	43	21	33	21	40
Mechanical damage to underground gas pipelines	5	8	8	23	14	9	9	20
Mechanical damage to gas pipelines by vehicles	2	4	3	4	0	1	0	6
Damage due to natural phenomena	1	2	0	3	2	4	0	1
Corrosion damage to external gas pipelines	1	0	4	2	1	3	2	0

Breaks in welded joints	1	0	1	0	0	1	0	3
Gas leakage, failure of equipment in gas control points (GRP) and cabinet control points (SHRP) of gas consuming equipment	0	1	0	4	0	7	2	4
Explosions during the ignition of gas-using installations and malfunction of the boiler equipment	2	0	3	2	2	2	3	3
Malfunction of liquefied petroleum gas (LPG) equipment	2	2	2	2	2	3	3	1
Other reasons	0	3	2	3	0	3	2	2
Total: fatal accidents	3	0	1	2	3	4	6	2
Poisoning by products of incomplete combustion of gas	3	0	1	1	0	1	3	2
Explosion of gas-air mixture	0	0	0	1	0	1	2	0
thermal effect	0	0	0	0	0	1	1	0
Other	0	0	0	0	3	1	0	0

Based on statistical data, it was found that the most common causes of emergency situations are mechanical damage to underground gas pipelines (43.85%), which is associated with a violation of work in the protected zones of gas pipelines. The remaining reasons are evenly distributed:

1. Mechanical damage to gas pipelines by vehicles (9.33%);
2. Damage due to natural phenomena (6.03%);
3. Corrosion damage to external gas pipelines (6.57);
4. Breaks in welded joints (2.75%);
5. Gas leakage, failure of equipment in gas control points (GRP) and cabinet control points (SHRP) of gas consuming equipment (6.88%);
6. Explosions during the ignition of gas-using installations and malfunction of the boiler equipment (8.67%);
7. Malfunction of equipment, liquefied hydrocarbon gas (LHG) (9.13%);
8. Other reasons (6.79%).

Most often, the damaging factor in the implementation of emergency situations at gas distribution and gas consumption facilities is toxic damage, followed by an explosion and thermal effects during the combustion of the torch (http://www.gosnadzor.ru).

4 Discussion

Based on statistical data on the number of accidents at oil refining and gas consumption facilities, which were obtained from state reports on the activities of the Federal Service for Environmental, Technological, Nuclear Supervision, simulation models for predicting

emergency situations can be developed [12]. However, it should be noted that in order to improve the adequacy of the models, it is necessary to consider in more depth the causes of accidents, the consequences and measures to improve the industrial safety management system. Therefore, in further studies it is proposed to make a factorial analysis of the technical and organizational causes of accidents from the acts of investigation of emergency situations at hazardous production facilities.

5 Conclusions

On the basis of the study, it can be concluded that in order to increase the level of industrial safety and reduce the number of accidents at hazardous industrial facilities of oil and gas processing, main pipeline transport, coordinated work should be carried out between the owners of industrial enterprises and supervisory authorities from the states. So, owners operating hazardous production facilities must comply with all requirements in the field of ensuring industrial safety. Develop and implement modern equipment and technologies that reduce the likelihood of accidents, as well as reduce possible consequences and increase the speed of localization of possible emergencies.

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