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OCCUPATIONAL RISK ASSESSMENT AT HAZARDOUS INDUSTRIAL FACILITIES

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The present study proposes a semi-quantitative approach to occupational risk assessment at hazardous industrial facilities. The basic idea of the proposed approach is to merge spatial information and job profile features in order to improve occupational risk assessment.

Nowadays high attention is paid to integrated risk assessment which is mainly forced by the tendency to a more efficient safety management system. Occupational Safety (OS) and Accident Hazard (AH) are two major concerns at process industry. These two risks have been traditionally analyzed in a separate way in industrial practice as well as in the legislation. In industrial practice, AH scenarios are very roughly evaluated during OS assessment and vice versa. At present the increasing attention towards integrated safety management systems is forcing plants to manage all risk sources. This integration becomes critical for larger establishments – such as refineries and petrochemical plants – due to the high number of exposed workers and the intrinsic plant complexity [1 – 5].

The goal is to have a unified metric for all potential hazards: occupational injuries and diseases (e.g. due to chemical and physical exposures), and major accidents (e.g. due to losses of hazardous or toxic materials, etc.). Thus, an integrated risk level (*Rj*) characterizing the *j*-th work profile (i.e. for each worker belonging to this job profile) has been proposed in equation 1:

$$R_j = \sum_{k=1}^{K}\left[\left(\left[(R)\right]_{OS}\right)_k + \left(\left[(R)\right]_{AH}\right)_k\right]\cdot t_{j,k}\ , \quad (1)$$

where the $t_{j,k}$ – parameter represents the time spent by the *j*-th worker in the *k*-th unit (expressed as percentage); the R_{OS} and R_{AS} indexes estimate occupational and accidental risk levels respectively in the *k*-th unit.

Then the two risk indexes are described in detail.

For the R_{OS} estimation, an individual OS risk level index, is defined by equation 2 for the *k*-th unit:

$$R_{OS,k} = \sum_{i=1}^{N_k} P_{t,k}\cdot S_{t,k}\cdot M_{t,k}\ , \quad (2)$$

where N_k is the total number of hazards estimated in the *k*-th unit; the $S_{t,k}$ parameter estimates the severity of consequences characterizing the *i*-th hazard in the *k*-th unit; the $P_{t,k}$ parameter represents the event probability and the $M_{t,k}$ parameter represents the mitigation capability estimated for the *i*-th hazard in the *k*-th unit.

For the R_{AH} estimation, a global risk level characterizing the k-unit is defined in equation 3:

$$R_{AH,k} = \sum_{i=1}^{N_h} P_{t,h}\cdot S_{t,h}\cdot A_{t,h}\ , \quad (3)$$

where N_h is the total number of accidental scenarios estimated in safety reports; the $S_{t,h}$ and the $P_{t,h}$ parameters represent respectively the consequence severity and the probability (expressed in event/year) evaluated for the *h*-th accidental scenario. The $A_{t,h}$ parameter is defined as the part (expressed as percentage) of the plant area affected by damage areas, estimated for the *h*-th scenario.

The following hypotheses have been suggested for the model development:

– Estimated risks in each area are independent.
– Hazard sources have a fixed position within the plant layout.
– The worker presence at different plant units is assumed constant during the work shift.

The proposed method has been tested at a plant of propane deasphalting sludge of «Naftan» JSC, where about 50 people work every day. It represents an effective test case as different hazard types are simultaneously present. Information about estimated probability and consequence severity for each *i*-th hazard category outlined for each k-th workplace ($W_1 – W_6$) are reported in Table 1.

Results showed that W_5 and W_4 are the most critical workplaces for the Occupational Safety analysis.

Information about estimated consequence severity and the probability (expressed in year) evaluated for the *h*-th accidental scenario are reported in Table 2.

After calculating separately the two indexes (R_{OS} and R_{AH}), the integrated risk level for each job profile may be derived as defined by equation 1. Thus, these «local» indexes characterizing the specific risk type will be converted in so called «individual» indexes by combining with data about the time spent by each individual job profile at each workplace (detailed calculation is proposed in Table 3).

Thus, high risk level at the unit of propane deasphalting sludge of «Naftan» JSC is due to such occupations, as compressor unit machinist and machinist of processing pump machinist.

Table 1 – Data required for R_{OS} estimation

i-th hazard category	Parameters R_{OS}	k-th workplace					
		Outdoor equipment area	compressor	hot pumping	propane pumping	in furnaces	control room
		W_1	W_2	W_3	W_4	W_5	W_6
Injuries by fall	$P_{t,k}$	0,0522	0,0522	0,0522	0,0522	0,0522	0,0522
	$S_{t,k}$	10	10	10	10	10	10
	$M_{t,k}$	0,1	0,1	0,1	0,1	0,1	0,1
	R_{OS}	0,0522	0,0522	0,0522	0,0522	0,0522	0,0522
Injuries by contact with moving, rotating parts	$P_{t,k}$	0,0169	0,0169	0,0169	0,0169	0,0169	-
	$S_{t,k}$	10	10	10	10	10	-
	$M_{t,k}$	0,1	0,1	0,1	0,1	0,1	-
	R_{OT}	0,0169	0,0169	0,0169	0,0169	0,0169	-
Hearing loss	$P_{t,k}$	0,071	0,091	0,103	0,116	0,199	0,0005
	$S_{t,k}$	3	3	3	3	3	3
	$M_{t,k}$	0,5	0,5	0,5	0,5	0,5	0,5
	R_{OS}	0,1065	0,1365	0,1545	0,174	0,2985	0,0007
Electrical shock	$P_{t,k}$	0,0002	0,0002	0,0002	0,0002	0,0002	0,0002
	$S_{t,k}$	10	10	10	10	10	10
	$M_{t,k}$	0,1	0,1	0,1	0,1	0,1	0,1
	R_{OS}	0,0002	0,0002	0,0002	0,0002	0,0002	0,0002
Thermal burns	$P_{t,k}$	0,0196	0,0196	0,0196	0,0196	0,0196	-
	$S_{t,k}$	3	3	3	3	3	-
	$M_{t,k}$	0,1	0,1	0,1	0,1	0,1	-
	R_{OS}	0,00588	0,00588	0,00588	0,00588	0,00588	-
Chemical burns and freeze burns	$P_{t,k}$	0,0082	0,0082	0,0082	0,0082	0,0082	-
	$S_{t,k}$	3	3	3	3	3	-
	$M_{t,k}$	0,1	0,1	0,1	0,1	0,1	-
	R_{OS}	0,00246	0,00246	0,00246	0,00246	0,00246	
Exposure to harmful substances	$P_{t,k}$	0,0101	0,0195	0,0096	0,0215	0,0219	-
	$S_{t,k}$	10	10	10	10	10	-
	$M_{t,k}$	0,1	0,1	0,1	0,1	0,1	-
	R_{OS}	0,0101	0,0195	0,0096	0,0215	0,0219	-
Total estimated R_{OS}		0,19424	0,23364	0,24174	0,27314	0,39804	0,05313

Table 2 – Data required for the R_{AH} estimation

Accidental scenario	Probability, Pt,h	Consequence severity, St,h	Damage area, м2	RAH
Explosion	2,7·105	100	82448	2,99·10-3
Fireball		100	32206	1,17·10-3
Pool fire		10	1600	5,81·10-6

Table 3 – Estimated total integrated risk level (Rj) values for each j-th job profile

j-th job profile (occupation)	$t_{j,k}$ on k-th workplace						Parameters		
	W_1	W_2	W_3	W_4	W_5	W_6	R_{OS}	R_{AH}	R_j
Unit supervisor	0,15	0,25	0,045	0,045	0,1	0,34	0,1686	0,0035	0,1721
Unit mechanic	0,14	0,02	0,125	0,04	-	0,50	0,0996	0,0029	0,1025
technological unit operator	0,07	0,1	0,13	0,13	-	0,47	0,1289	0,0032	0,1321
Compressor unit machinist	-	0,63	-	-	-	0,27	0,1615	0,0034	0,1649
Processing pump machinist	-	-	0,19	0,46	-	0,25	0,1849	0,0035	0,1884

A semi-quantitative method for integrating Occupational Safety and Accident Hazard risk has been developed and tested at the plant of propane deasphalting sludge of «Naftan» JSC. The model can be applied at processing plants characterized by different units featuring different risk types.

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TECHNOLOGY OF RECEIVING ELEMENTAL SULFUR FROM HYDROGEN SULPHIDE ACID GASES AT OJSC «NAFTAN»: ENVIRONMENTAL ASPECTS AND FEATURES OF THE TECHNOLOGY

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Sulfur-bearing compounds are very detrimental to the environment and to industrial process equipment. They are formed during the purification of hydrocarbon gases from acidic components and usually convert into sulfuric acid or elemental sulfur. Currently industrial production of sulfur is mainly performed by using the Claus process. Utilization of sulfur, obtained during the process of oil refining, is a problem of great environmental significance.

Currently OJSC «Naftan» is at the stage of «reconstruction and modernization program of OJSC «Naftan» for 2010 – 2015», which is based on the latest achievements in the field of oil refining and takes into account the rapidly changing market demands in order to improve efficiency of enterprise performance. Project of delayed coking unit construction is underway, the purpose of which is to increase the depth of oil refining up to 92 – 94 % and the output of additional volumes of light petroleum products.

Due to implementation of technology of environmentally clean diesel fuel production, with sulfur content of 10 ppm (0.001 wt.%) at the hydrotreating units L-24/7 and LCH-24/7 with «Merox» unit, and also due to the introduction of value-added oil refining process (construction a delayed coking unit) the amount of generated hydrogen sulfide increases and it should be utilized.

With an increase of oil refining (up to 12 million tons) and implementation of all the tasks specified by «Development Programme», the production of hydrogen sulfide will become approximately 8800 nm^3/h by 2015[1].

Today hydrogen sulfide, produced at facilities of OJSC «Naftan», is utilized at:

– «unit of sulfuric acid production» I and II stages;

– «unit of sulfuric acid regeneration».

The total designed capacity of the plant is 4800 nm^3/h.

Existing units of hydrogen sulfide utilization work practically with full designed load. Their capacity currently can't be increased above the designed.

In this respect, problem of sulfur-containing gases utilization at the enterprise has become crucial.

Novopolotsk industrial complex has a significant impact on the environment of the city, primarily due to the emission of pollutants into the air and discharges into surface water and groundwater. Powerful industrial development of Novopolotsk not only increases the anthropogenic load on the environment, but also has a negative impact on the living conditions of the population. Table 1 presents data of pollutants emissions into the air in Novopolotsk over the past 13 years [2].

Table 1 – Dynamics of pollutants emissions into the atmosphere in Novopolotsk, thous. tons/year

	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013
From stationary sources	51,5	54,2	64,0	80,0	58,6	63,9	50,3	51,2	67,8	53,5
Per capita, kg	481	519	599	750	548	614	480	485	636	498