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Fast-Hardening Foam: Fire and Explosion Prevention at Facilities with Hazardous Chemicals

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Abstract

Analysis of the terroristic attacks in Siria, Afghanistan and other countries has shown high probability of the hazardous chemicals application by the terroristic groups. In the article the most catastrophic accidents which were connected with hazardous chemicals are described.

That is why research and developments in the sphere of protection from hazardous chemicals are still actual.

This article is dedicated to the new screening method of the spilled hazardous chemicals surface on the example of protection of the factories with these substances. Methodology, experimental apparatus, protective fast-hardening foam features, names of hazardous chemicals are shown.

Test were made for such chemicals as: acetic acid, acetone, ammonia, bromine, chlorbenzene, chloroform, hydrogen bromide, hydrogen chloride, hexane, hydrazine, diesel fuel, dichlorethane, kerosene, toluene, phenol, hydrogen fluoride. Fantastic results were achieved in terms of isolating capability of the fast-hardening foam against evaporations of the pointed substances.

1. Introduction

Industrial and technological progress today is occurring faster and faster. The reasons are growth of the industrial production volumes, complication of the technological processes, development and implantation of the high-tech and so on. All of that allow people around the world consume new benefits, use resources more effectively and raise their living standards eventually.

At the same time this trend has another side. There is industrial safety which does not keep up with industrial progress. And eventually safety of important and dangerous assets does not fit to requirements which are being created by technological progress speed. Evidently this situation may lead to the catastrophic consequences. And it happens indeed. For example:

2. Some Accidents with Hazardous Chemicals Influence

21st of September 2001, Toulouse, France. Explosion of 300 tones of ammonium nitrate (NH_4NO_3) at the chemical factory AZF. 30 people were dead, 3000 people were injured, several thousand living houses and buildings were destroyed including 80 schools, 2 universities, 185 kindergartens. 40000 people became homeless; more than 130 enterprises were closed. Total losses cost is 3 billions Euros.

22nd of April 2010, Gulf of Mexico near the coast of Louisiana. Explosion and 36-hours fire killed 11 people and flooded controlled drilling platform Deepwater Horizon. Oil leakage was stopped only on 4th of August. 5 million barrels of the raw oil were spilled to the Gulf of Mexico. Ecological losses are irreplaceable *(figure 1).*

Figure 1. Flooding of the drilling platform in the Gulf of Mexico in result of explosion

4th of October 2010. Explosion at the aluminum production factory (west Hungary) has destroyed tank with toxic waste which is called "red sludge". About 1.1 million m^3 flooded Kolontar and Dechever towns westward from Budapest. In the result of accident 10 people were dead and 150 people were injured *(figure 2).*

Figure 2. Red sludge leakage in Kolontar and Dechever towns (Hungary)

1st of September 2011, Chelyabinsk, Russia. Due to the fire in the freight car at the railway station tanks with high toxic substance bromine have been unsealed. In the result about 237 people asked a help, about 5 people were hospitalized.

12th of August 2015. Due to several strong explosions in Tianjin (China) hazardous chemicals concentration in the air exceeded the norm 27 times! About 114 people were dead, about 70 people disappeared, about 700 people were injured. Several hundred tones of the sodium cyanide were detected at the accident place *(figure 3).*

These catastrophes do not make the full list of accidents at all. They not only kill a lot of people but inflict irreparable damage to the Earth ecosystem as well which practically impossible to estimate.

Most victims at these accidents are caused by storage, production, transportation, usage of hazardous chemicals which break out and kill people and environment.

Figure 3. Consequences of explosion in Tianjin (China)

3. Investigations of RPA “SOPOT”

In 2015-2016 RPA “SOPOT” (St. Petersburg, Russia) has developed Fast-Hardening Foam (FHF) for fire and explosion prevention based on the structured silica particles (SiO_2). It is fire-extinguishing foam in which polymerization process is occurring during its generation and delivery to the fire object. This fact is caused by sol-gel transition which is well-known process in the colloidal chemistry. Thereby this foam becomes solid. At the same time it acquires absolutely new properties for any fire-fighting foams such as high adhesion, mechanical durability, thermal stability, heat and fire resistance and others. Besides FHF is fast degradable according to the GOST 32509-2013 what means that it is completely clean, biodegradable and environment friendly product. For delivery of FHF at the long distances there have been developed or modernized technical means with capacity from 1 to 100 Liters per second (L/s).

In 2017 laboratory of fire and explosion prevention (RPA “SOPOT”) has made extensive investigations of isolating capability of FHF on the evaporative hazardous chemicals.

4. Experimental Section

Glasses were filled with hazardous chemical. Then its surface was covered with FHF. Then plastic container was inserted inside the top of the foam. Silicone tube was inserted in the hole of the plastic container from the side. This tube passed through the indicator tube and was connected with aspirator *(figure 4).*

With using of aspirator air above the foam layer was deflated through the silicone tube in the one-time intervals (1 hour) mode. Air volume and deflation time were determined according to the manuals for each indicator tube. When air passed through the indicator tube it was stained to another color *(figure 5)*. Concentration of the hazardous chemicals vapors in the air above the foam layer was determined with indicator tubes.

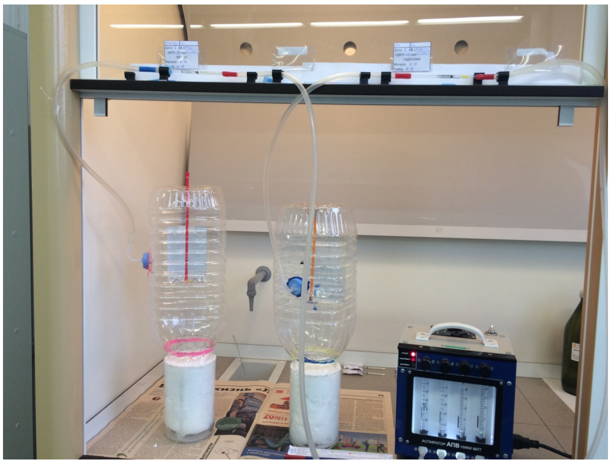

Figure 4. Measuring of the hazardous chemicals vapor concentration in the air above the foam layer

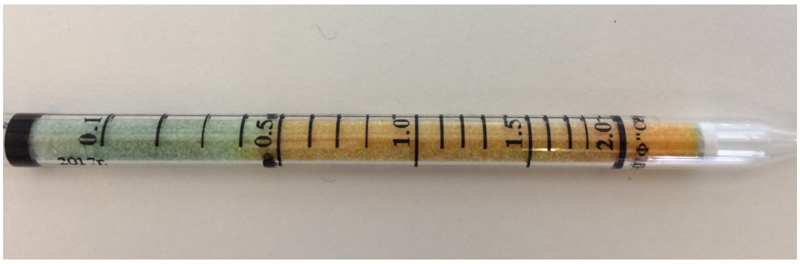

Figure 5. Indicator tube

Thereby isolating capability of the foam was determined. The lower hazardous chemicals vapors concentration in the air the higher isolating capability of the foam. Measured vapor concentration was compared with maximum permissible concentration (MPC) for the work zone on the one time mode.

After all measurements penetration coefficient was calculated according to the GOST R 12.4.262.2011 which shows weight of the substance which penetrates through the 1m^2 of protective foam layer for 1 second.

Results of investigations are presented in the Table 1:

Table 1. Results of investigations

Substance	Chemical formula	Time period of the vapor concentration below MPC	Penetration coefficient (averaged), mg/m^{2}s
Acetic acid	CH_3COOH	>6 hours	0
Acetone	C_3H_6O	>2 hours	58,7
Ammonia	NH_3	>6 hours	0,9
Bromine	Br_2	>6 hours	0
Chlorbenzene	C_6H_5Cl	>6 hours	0
Chloroform	$CHCl_3$	>4 hours	2,7
Dichlorethane	$ClCH_2$-CH_2Cl	>6 hours	0
Diesel fuel	-	>6 hours	22,4
Hexane	C_6H_{14}	>6 hours	80,2
Hydrazine	N_2H_4	>6 hours	0
Hydrogen bromide	HBr	>6 hours	0
Hydrogen chloride	HCl	>6 hours	0
Hydrogen fluoride	HF	>6 hours	0
Kerosene	-	>6 hours	10,3
Toluene	C_6H_5-CH_3	>6 hours	9,8
Phenol	C_6H_6O	>6 hours	0
Petrol	-	>6 hours	8,7

The same trials were made for several chemicals in the mode of their heating till 40°C. Results were practically the same or even better than results of trials in the normal conditions mode.

Figure 6. Measuring of the bromine vapor concentration in the air above the foam layer (temperature of bromine is 40°C)

Results of investigations are presented in the table 2:

Table 2. Results of investigations (temperature of chemicals is 40°C)

Substance	**Chemical formula**	**Time period of the vapor concentration below MPC**	**Penetration coefficient (averaged), mg/m^{2}s**
Ammonia	NH_3	>6 hours	0
Bromine	Br_2	>6 hours	0
Hydrogen bromide	HBr	>6 hours	0
Hydrazine	N_2H_4	>6 hours	0
Toluene	C_6H_5-CH_3	>6 hours	0,6
Acetic acid	CH_3COOH	>6 hours	0
Hydrogen fluoride	HF	>6 hours	0
Hydrogen chloride	HCl	>6 hours	0
Chloroform	$CHCl_3$	>4 hours	7,3

5. Conclusion

1) Analysis of investigations results has shown that Fast-Hardening Foam based on structured silica particles is able to contain hazardous chemicals evaporation below MPC during the time period from 1 hour till more than 24 hours.

2) This time period is **more than 6 hours** for: ammonia, bromine, hydrogen bromide, hexane, hydrazine, diesel fuel, dichlorethane, kerosene, toluene, acetic acid, phenol, hydrogen fluoride, chlorbenzene, hydrogen chloride; **more than 4 hours** for: chloroform**; more than 3 hours** for: acetone.

3) During the heating of the hazardous chemicals till 40°C and maintaining of this temperature during the whole experiment time period of hazardous chemicals evaporation below MPC is **more than 6 hours** for: ammonia, bromine, hydrogen bromide, hydrazine, toluene, acetic acid, hydrogen fluoride, hydrogen chloride; **more than 1 hour** for: chloroform.

4) These investigations have proved that the covering of the hazardous chemicals with Fast-Hardening Foam based on structures silica particles allows to reduce sharply risk of the poisoning with hazardous chemicals vapors. Application of this technology allows to improve safety of rescue operations made by Emercom, Ministry of defense or special departments of industrial enterprises.

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