Supporting Information

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Silica Foams for Fire Prevention and Firefighting

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Electronic Supplementary Information

Testing biodegradability

The technology described below is universal and always carried out to analyze the biodegradability properties of synthetic extinguishing agents.

Determination of biodegradability for foaming agents was performed using (at least) two model aeration tanks (control and test) functioning continuously under normal operating conditions of biological treatment facilities.

Both of the aeration tanks are filled with surfactant-unadapted activated sludge; the control aeration tank is continuously fed with synthetic wastewater with uniform composition, and the test one (after the completion of the preparatory period) with synthetic wastewater with the addition of the test surfactant (or a composition), whose concentration at the inlet of the aeration tank is kept constant for the whole period of experiment. During the experiment indicators for the control and experimental aeration tanks are compared.

Biodegradability of foaming agents was evaluated by the following parameters: time of the induction period (T_{ind}, days) at the maximum inactive mass concentration of the surfactant (MIC, mg/L) in the synthetic wastewater; degree (%) of the total X^{28}_{tot} (by chemical oxygen demand, COD) biodegradation by unadapted sludge within 28 days. Table S1 shows the biodegradability indices for fire-extinguishing foaming agents based on hydrocarbon surfactants and with additives of perfluorinated surfactants used for extinguishing solid combustibles.

Table S1.

Biodegradability and phytotoxicity indicators for foaming agents

Based on synthetic hydrocarbon surfactants		Based on synthetic hydrocarbon surfactants with additives of perfluorinated surfactants	
Composition (mass fraction of perfluorosurfactants, %)			
large-scale fast-hardening sol-gel foam	DDS	Sodium alkyl sulfates; **sodium perfluorohexylethyl sulfonamidobetaines – 0.3–0.5;** useful additives; water – up to 100	TEA alkyl sulfates; **fluoroprotein concentrate 3-5;** protein hydrolysate; useful additives; water – up to 100
T_{ind} (induction period), days			
3 ± 1	7±1	11±1 (hydrocarbon component); > 60 (perfluorosurfactants)	11± (hydrocarbon component); > 60 (perfluorosurfactants)
MIC_a, maximum inactive concentration (for sludge), mg/L			
500 (claimed)	50 (claimed)	75 (claimed); **≈ 0.3 (for perfluorosurfactants)**	15 (claimed); **≈ 0.5–0.8 (for perfluorosurfactants)**
X^{28}_{tot}, total biodegradation by unadapted sludge within 28 days, %			
95 ± 3	90 ± 2	93 ± 2 (hydrocarbon component); **perfluorosurfactants *are non-biodegradable***	93 ± 2 (hydrocarbon component); **perfluorosurfactants *are non-biodegradable***

Testing extinguishing efficiency

Extinguishing efficiency for foamed silica gel in comparison with that for water and air foam was tested according to the procedure described below.

Tests were conducted in the open air at a temperature matching the fire extinguisher operating range, and at a wind speed of no more than 5 m/s, in the absence of precipitation. The model fire seat was a pile of wood in the shape of a cube. The pile was placed on a solid support in such a way that the distance from the bottom of the pile to the support surface was 400 mm. Bars of softwood with a section of 40 mm, length of 500 mm, and timber humidity of 15% were used as a combustible material. Parameters of the model fire seat are shown in Table S2.

Table S2.

Parameters of the model fire seat

Designation for the model fire seat	Number of wooden bars in the pile	Bar dimensions, mm	Number of bars in a layer	Number of layers	Free surface area for the model seat, m^2
1A	72	40x40x500	6	12	4.7

The model fire seat pile was arranged in such a way that the bars of each successive layer were perpendicular to the bars of the underlying layer. Thus, channels of rectangular cross section with a size of 40x40x500 mm were formed throughout the volume.
Parameters of the metal tray for flammable liquid that was placed under the pile correspond to the data of Table S3.

Table S3.

Parameters of the tray for kindling the model fire seat

Designation for the model fire seat	Tray dimensions LxBxH, mm	Water volume, dm^3	Gasoline volume, dm^3
1A	400x400x100	5.0	1.1

The tray was filled with water, forming a level surface. Summer-blend gasoline was poured onto the layer of water. The tray was placed under the pile so that the centers of the tray and pile coincided.

Gasoline in the tray was set on fire. After 8 minutes since the start of combustion, when the pile was engulfed in flames from all sides, extinguishing the model fire seat was initiated.

During the extinguishing, the fire seat was rotated at a rate of 2 rpm, which allowed to successively deliver the extinguishing agent on each side of the seat.

The extinguishing agent was delivered through a low-expansion nozzle with a rate of 1 L/s at a pressure of 0.5 MPa. The distance from the nozzle to the fire seat was 4 m.

Completion of extinguishing the fire seat was followed by about 30 minutes of waiting, and after that the fire seat was re-exposed to the flame. Then, the time of continuous flame exposure was recorded, followed by reigniting the fire seat.