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Obtaining New Suspensions Based on Bentonite and Evaluating their Fire-Fighting Effectiveness

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ABSTRACT: The article presents the results of research on the production of bentonite and these clay-based suspensions and their effect on the flammability of wood samples. The research was conducted in three phases. By studying the relationship between the rheology and thermal properties of liquid suspensions invented in the first stage, their viscosity relative to ordinary water in relation to temperature was studied. By immersing the samples in liquid suspensions invented in the second stage, it was studied how resistant these samples were to the effects of fire compared to ordinary water. In the third stage, the effectiveness of the liquid-containing suspensions invented against ordinary water was tested using a newly developed laboratory device.

The scientific results of the research are prepared in the form of comparative tables and graphs. The procedure for each study, the devices used, and the composition of the substances used to prepare the suspensions were developed. The study concluded that the advantages of bentonite-containing suspensions are that they are a very effective fire extinguishing agent for use in firefighting practice.

KEYWORDS: bentonite, component, moisture, alkaline soil bentonites, clay, gel, mineral raw materials, viscosity, sulfanol, sodium bicarbonate, suspension, agglomeration, rheometer, ceramic pipe, dispersion, dispersant, mixture, working fluid, wood sample, combustible material, temperature, high concentration suspension, combustion time, ignition, heat flux, fire extinguishing agent.

I.INTRODUCTION

During the study of fire extinguishing agents [1-4], it became clear from the data presented in the literature that the basis of the composition of fire extinguishing agents are mineral raw materials. These mineral raw materials mainly include carbonates, phosphates, oxides common in nature, and a wide variety of chemical compounds in their various forms.

Based on the results of studies of fire extinguishing mechanisms by leading scientists [1-3], it is possible to draw the right conclusion about what chemical compounds can be used in the development of fire extinguishing compositions.

When comparing and analyzing powder fire extinguishing compositions [1-4], data on clay compositions [5-8] and data obtained from our own research [9], it was found that there are many similarities in the composition and properties of these substances.

An analysis of the scientific literature published in recent years has shown that the use of mineral raw materials is more effective in the development of liquid and powder fire extinguishing compositions [10-15].

The most commonly used fire extinguishers in firefighting practice today are liquid-containing fire extinguishers. Liquid fire extinguishing agents are substances or mixtures thereof which, in the conditions of use, are mainly in a liquid state.

Today in the world there is a large-scale scientific and practical research aimed at creating technologies for the production of liquid fire extinguishers and their scientific basis. In this regard, it is an environmentally safe liquid for the human body, including the ability to extinguish fires in large areas relative to water with a small amount of fire extinguishing agent, the ability to encircle fire in a short time, quickly stop flammable on the surface, quickly extinguish flammability of substances and materials The creation of fire extinguishers in the state is one of the important tasks.

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In a number of foreign countries, including the United States, Japan, Germany, France, Italy, Russia, China, the United Kingdom, and a number of other developed countries, special attention has been paid to the improvement of liquid fire extinguishers. In the production of such fire extinguishers are much more effective than ordinary water, do not require complex techniques to apply, have the ability to prevent re-combustion after coating the surface of combustible material, and environmentally friendly bentonites are also important.

It is well known that when the viscosity of fire extinguishing agents has a certain high value, this leads to a high fire-fighting property and efficiency of the substance. This is due to the fact that the content falling on the surface of the combustible material covers this surface more and causes the content to stick more on this surface, which in turn prevents re-ignition. Because we know from research that the faster and better the coating of the burning surface, and thus the complete closure of the surface, the faster the combustion process stops. This, in turn, allows you to effectively extinguish a fire in a short time, with minimal losses. To achieve such an effect, the fire-fighting composition created must be prepared on the basis of mineral raw materials and also be convenient and inexpensive to use.

Based on the above analyzes and the results of our initial research, in our next phase of research, we selected the concrete raw material and the compound based on it as the local raw material in the development of liquid fire extinguishers.

Today, bentonite is a very demanding material, it is increasingly used in construction, pharmaceuticals, food and other major industries. One of its useful features is reflected in the fact that it significantly increases the service life of buildings and structures for various purposes.

The main advantage of bentonite is that it has a good ability to absorb moisture. When bentonite is immersed in water, the grains of this material multiply by about sixteen times and become a dense gel state. This condition prevents the movement of moisture later. The water-absorbing and water-absorbing properties of bentonite perfectly protect buildings from high humidity.

To date, research on the application of bentonite clay in firefighting practice has not been conducted not only in the Republic of Uzbekistan, but also in other countries around the world. To this end, a number of experiments, research studies and scientifically based results on the application of bentonite clays in firefighting practice have been conducted.

Bentonite, $NaHCO_3$, sulfanol were selected for the study and 3 different suspensions were prepared (Table 1 shows the percentage of additives added to the prepared suspension).

Table 1

The composition of the suspensions obtained for the research work

Suspension number	The composition of the suspension			
	bentonite, %	$NaHCO_3$, %	sulfanol, %	water, %
1	5	1	0,1	93,9
2	5	1	0,3	93,7
3	5	1	0,5	93,5

The research was carried out in the following order: for the preparation of suspensions, first of all, the contents were weighed on an electronic scale and 3 containers with a volume of 100 g were prepared, these containers were filled with suspensions of 3 different compositions and numbered. The suspension in each container was dispersed for 30 min using an Ultrasonic Desintegrator type UD-11 automatic (destrigator) device.

It is known that a mixture of bentonite, sodium bicarbonate, and sulfanol undergoes an agglomeration process in water, the mixture is dispersed to break down the agglomerates in the water, and the suspension is made ready.

A Rheometer RS-600 device was selected to measure the viscosity of the dispersed suspensions. To do this, first use a rheometer

In order to verify the correct operation of the RS-600, the viscosity of the water was determined and compared with the data given in the literature [16-18]. After the data obtained were consistent with the data presented in the literature, research work began.

The research was conducted in 3 stages.

In the first stage, by studying the relationship between the rheology and thermal properties of liquid suspensions invented, their viscosity relative to ordinary water in relation to temperature was studied.

In the second stage, by soaking the samples in liquid suspensions, it was studied how resistant these samples were to the effects of fire compared to ordinary water.

In the third stage, the effectiveness of the liquid suspensions invented over ordinary water was tested using a newly developed laboratory device.

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We will now take a step-by-step look at the test experiments performed.

In the first stage, 3 different suspensions consisting of bentonite, NaHCO3, sulfanol and water were initially prepared (the composition of the suspensions is given in Table 1) and placed in 3 containers.

Table 1.

Experiment number	The composition of the prepared suspension				water, %
	Bentonite, %	$NaHCO_3$, %	Sulfanol, %	water, %	
1	2	1	0,1	96,9	100
2	2	1	0,3	96,7	100
3	2	1	0,5	96,5	100

To measure the dynamic viscosity and rheology of the prepared suspensions, a Reometer RS-600 device, a thermostat, a compressor and a computer set were made ready for the experiment.

Using this device, the dynamic viscosity and rheology of each of the 1, 2, and 3 suspensions of plain water were first studied 3 times separately at 23°C (room temperature), 300°C, 400°C, and 50°C.

The experiment was conducted in the following sequence:

1. The viscosity of the water is checked in order to check that the rheometer RS-600 is working properly. To check the viscosity of the water, we use a DG41 cylinder (vessel) (in general, this vessel in all 5 studies). DG41 is used to measure the viscosity of liquids with low viscosity.

2. Simple water and suspensions required for the experiment are selected. For this purpose, water - m^1 and suspensions consisting of bentonite clay of various compositions, $NaHCO^3$ and sulfanol - m^2, and the amount of suspensions to be placed in the vessel of the rheometer device is determined using the following formula:

$$X_m = \frac{m_2}{m_1 + m_2}, \%$$

$$m = \rho \cdot \upsilon = 10^3 \cdot 6{,}1 \cdot 10^{-6}\ м^3 = 6{,}1\ гр,$$

where: υ is the liquid measurement capacity of the DG41 cylinder, 6.1 gr.

3. The pre-prepared suspension is filled into the DG41 cylinder (container) and the DG41 cylinder (container) is placed inside the device.

4. Given that the measurement of the viscosity of the suspensions is performed using the RheO Min Job Manager program, in this program the speed interval is set from 0 s-1 to 3500 s-1, and the measurement time is set to 600 seconds (10 minutes).

5. It is determined that the viscosity depends on the shear rate, it is this indicator that indicates at what points the viscosity of the mixture is high or low.

6. The compressor is started, the manometer is determined to be 2 bar and above.

7. RheO Min Job Manager software is launched via PC.

8. The blue button of the thermostat was pressed and it started.

9. The thermometer, which shows the temperature of the water in the thermostat, is examined, and the temperature of the water set for the experiment is determined (e.g., 23, 30, 40, or 50^0S);

10. The cylinder DG41 is filled with water, rinsed 2-3 times, dried using a compressor and filled with the mixture prescribed for the experiment;

11. The rheometer RS-600 is fitted with a seal, into which a cylinder is inserted and firmly fastened with a fastener;

12. Fill the cylinder with 6.1 g of pre-prepared suspension, the top of the cylinder is attached to the device.

13. RheO Min Job Manager software is checked for proper operation. To do this, a new working window opens, the device before Devises, then the sensor is selected and the experiment begins;

14. At the end of the experiment, the thermostat is turned off, the thermometer is taken away from the thermostat, the results obtained are sent to the program RheO Min Job Manager. The received data is taken to Microsoft Office Excel and Origin Pro 8 programs, and the research is formalized using these programs.

At the end of the experiment, the average values of each suspension were obtained at 23 0S (room temperature), 300S, 400S and 50^0S.

It was included in Table 2 and a comparative graph (Figure 1) was prepared based on it.

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Table 2. Depending on the temperature of the suspensions viscosity to water

t / r	Temperature, ^{0}C	Viscosity of the mixture			Viscosity of water
		1- suspension	2- suspension	3- suspension	
1.	25	14,0681	15,77701	15,53535	3,4523
2.	30	14,4463	17,0729	16,7446	3,283258
3.	40	14,95925	17,0535	16,75436	2,99185
4.	50	18,85581	19,6875	20,22697	2,69693

Analyzing the results obtained, the viscosity of suspension 1 is 4,075 times at 25^{0}S and 30^{0}S at 30^{0}S, respectively.

4.4 times, 5.0 times at 400S and 6.25 times at 50^{0}S, the viscosity of the 2nd suspension is 4.75 times at 25^{0}S, 5.2 times at 30^{0}S, 5.7 times at 400S and 7.3 times at 50^{0}S. and the viscosity of the 3rd suspension was 4.5 times higher at 25^{0}S, 5.1 times higher at 30^{0}S, 5.6 times higher at 40^{0}S, and 7.5 times higher at 50^{0}S.

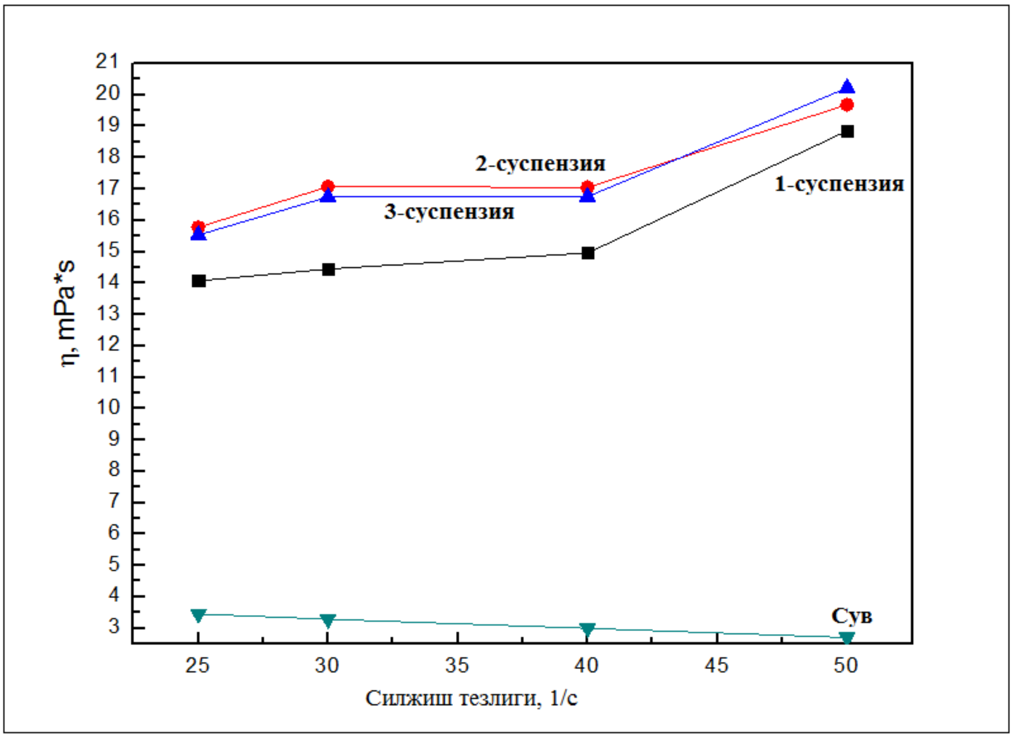

Figure 1. Temperature-dependent viscosity of suspensions of bentonite, sodium bicarbonate, sulfanol in relation to water

If we theoretically study the experiment, the higher the amount of sulfanol in the suspension, the greater the viscosity of the resulting mixture. Through the above experiments, studies were conducted to obtain bentonite suspensions and to study their stability and viscosity at different temperatures, to evaluate their spraying and coating properties on different surfaces, and on this basis to stop the combustion of substances and materials.

In the first stage, the experiments were carried out using the device "Ceramic pipe" specified in the document GOST 12.1.044-89. Standard samples of wood (pine) with dimensions of 150x60x30 mm were used. 4 standard containers of the same size were obtained. The first container was filled with plain water, the rest with 1st, 2nd and 3rd suspensions, 3 wood samples were prepared for each experiment and the experiment was started.

The experiment was conducted in the following sequence:

1. The first, then the second, and third samples of wood were soaked in a container of water for 10 minutes.
2. The temperature in the ceramic tube was maintained at 200 0S for 10 min.

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3. First the first, then the second and third samples were placed inside the ceramic tube, respectively.

4. The samples were alternately tested in a ceramic tube and their burning times were recorded. The tests were continued from temperature change to their ignition, the time values formed were determined and entered in Table 3, on the basis of which a comparative graph (Figure 2) was prepared.

Table 3. Changes in the suspension of bentonite, sodium bicarbonate, sulfanol and water depending on time and temperature

water		**1- suspension**				**2- suspension**				**3- suspension**			
time, seconds	**temperature, ^0C**	**time, seconds**	**temperature, ^0C**	**time, seconds**	**temperature, ^0C**	**time, seconds**	**temperature, ^0C**	**time, seconds**	**temperature, ^0C**	**time, seconds**	**temperature, ^0C**	**time, seconds**	**temperature, ^0C**
1	126	1	146	98	252	1	150	132	340	1	116	255	261
6	137	9	157	107	276	8	152	139	345	9	119	270	265
9	161	14	163	112	301	11	151	144	369	14	125	286	276
14	193	18	171	119	331	23	153	153	376	19	129	293	284
20	233	24	174	124	349	27	157	167	385	21	132	305	296
26	304	28	179	130	369	32	164	178	390	27	134	310	301
32	385	39	186	146	383	46	176	189	401	34	136	325	308
37	454	43	192	152	421	51	189	195	413	45	137	332	314
44	490	49	195	167	436	61	203	204	425	58	138	348	325
49	512	55	201	184	455	68	223	213	428	72	139	359	332
55	571	64	204	191	483	74	247	219	439	79	140	365	343
61	**683**	71	209	195	491	79	271	221	440	88	141	374	360
		89	221	201	494	85	302	235	451	96	144	387	369
		95	243	207	498	92	328	147	467	104	146	399	374
				213	**503**	99	354	261	474	109	149	414	392
						103	381	274	482	116	155	425	411
						118	402	287	497	131	163	431	424
						124	411	**301**	**506**	147	174	444	426
										153	185	452	431
										169	193	467	443
										174	202	473	455
										181	214	479	462
										196	221	486	478
										204	224	491	480
										218	235	496	482
										224	244	503	484
										238	258	509	485
										246	269	514	487
										182	272	518	491
										187	281	527	495
										195	292	532	497
										200	306	548	499
												556	**501**

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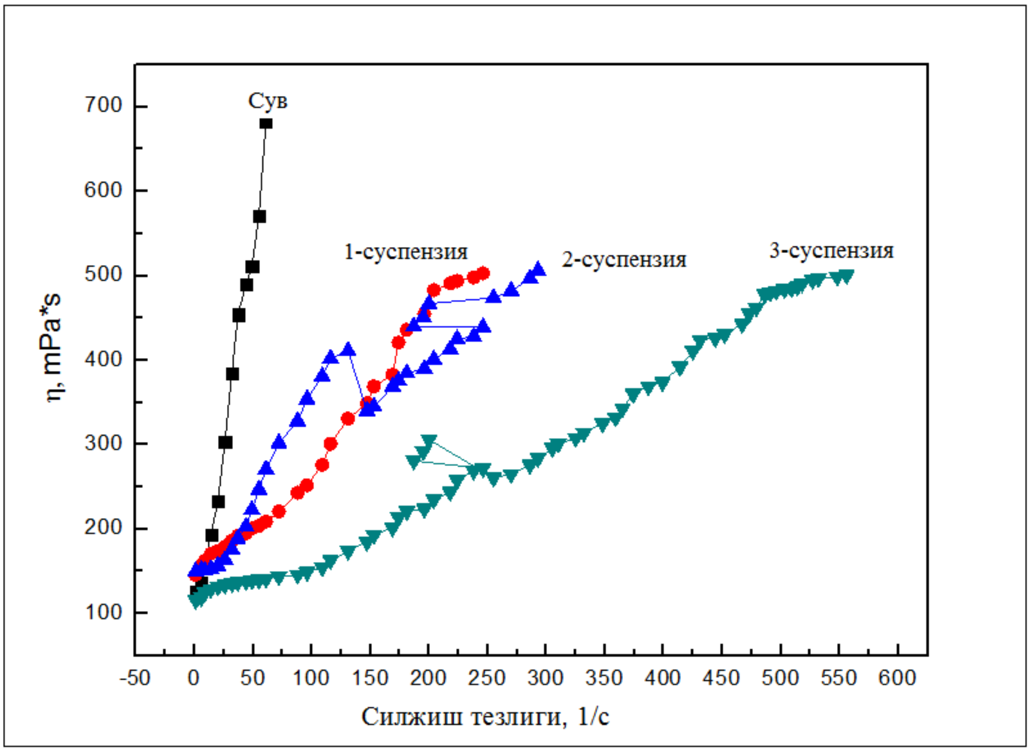

Figure 2. Combustion time of wood samples impregnated with a suspension of bentonite, sodium bicarbonate, sulfanol and water

In the graph shown in this figure, the first water sample immersed in water started complete combustion at 61 seconds, the 1st suspended wood sample at 213 seconds, the 2nd suspended wood sample at 301 seconds, and the 3rd suspended wood sample at 556 seconds.

Hence, the resistance of these bentonite-containing suspensions to the action of ordinary water can be seen from the graph in Figure 2.

In the third phase, the experiments were performed 3 times with water and each suspension, using a newly developed laboratory device (Fig. 3).

The experiment was conducted in the following sequence:

1. Using standard samples of wood (pine) with dimensions of 450x60x30 mm, a firebox (separately for each experiment) consisting of 35 wood samples was prepared.
2. 10 liters of water were poured into a container that is part of a laboratory device.
3. A fire pit was created by burning wood samples. The free burning time of the fire was 10 minutes. The fire began to develop rapidly.
4. The laboratory device was activated and the fire was extinguished using water.
5. The fire in the fire pit was completely extinguished.

Experiments with the first, second, and third suspensions were performed in the same sequence as well as 3 times.

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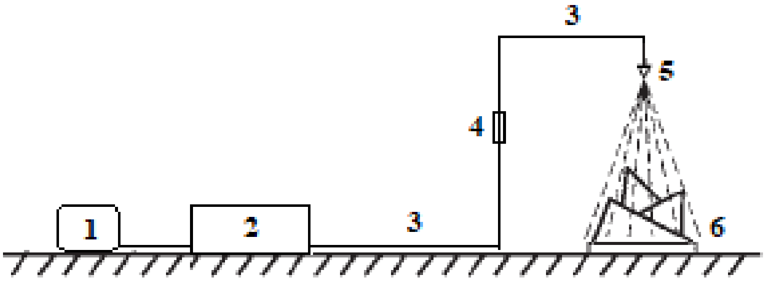

Figure 3. Schematic of the laboratory device: 1 - capacity; 2 - pump; 3 - pipe; 4 - water meter; 5 - sprayer; 6 - Fireplace

Upon completion of the experiment, the mean values of the 3 experiments performed with each suspension and water were entered in Table 4 and a comparative graph (Figure 4) was prepared based on it.

Table 4. Water and fire of 1st, 2nd and 3rd suspensions lifting efficiency

T/r	Free burning time of sample, minutes	Spent to put out the fire			
		amount of water, l	1 amount of suspension, l	2 The amount of suspension, l	3 The amount of suspension, l
1.	10	7,65	6,48	6,18	5,44
2.	10	7,39	6,31	5,94	5,81
3.	10	7,71	6,72	6,02	5,23
Average	**10**	**7,58**	**6,5**	**6,04**	**5,49**

According to the analysis of the obtained results, it was found that the amount of suspension 1 is less than the amount of water used to extinguish the fire, the amount of suspension 2 is less than the amount of suspension 2, and the amount of suspension 3 is less than%.

If we theoretically study the experiment, the higher the amount of sulfanol in the suspension, the lower the viscosity of the resulting mixture, its fire-fighting efficiency, and the amount of suspension used to extinguish the fire.

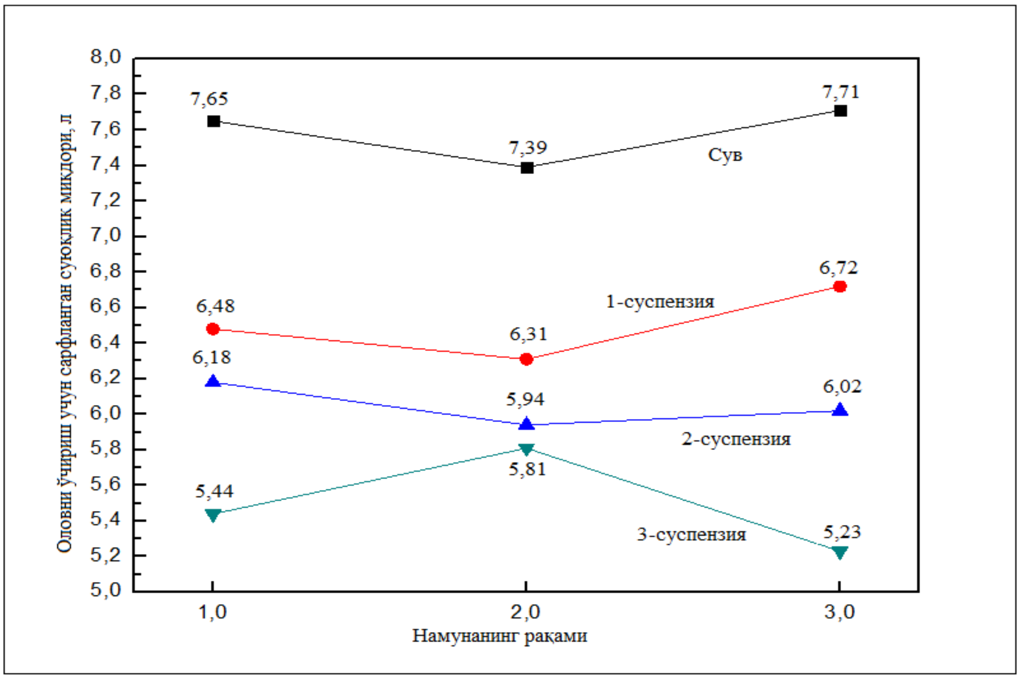

Figure 4. Water and fire of 1st, 2nd and 3rd suspensions lifting efficiency

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In summary, the resulting bentonite suspensions have the following advantages:

- originality and versatility of the composition (can be used in the form of a dry and highly concentrated suspension);
- more effective than ordinary water;
- no special requirements or complex techniques are required for application;
- availability of sufficient quantities of raw materials and the absence of complex techniques for its preparation;
- has the property of preventing the occurrence of re-combustion after coating the surface of the combustible material;
- is environmentally friendly and harmless both in the process of preparation and application, as this substance does not contain harmful substances that emit gases that are toxic to human health when decomposed under the influence of high temperatures;
- The use of firefighting in water-scarce and waterless areas of the country is very effective.

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