Study of the impact of fire-extinguishing foaming agents on agricultural crops

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Abstract. In order to study the qualitative and quantitative effects on living organisms, the toxic effect of foaming agents was assessed. As an object, the use of seeds of sowing oats (Avena sativa) is proposed. It has been established that the development and growth of the root system of the bioindicator directly depends on the degree of soil toxicity. The greatest negative impact on the test object was produced by a nonionic foaming agent at a concentration of 10 mg/l.

1. Introduction
The issue of environmental safety and purity of consumed products has always been relevant in any region. It is known that many agricultural crops are indicators of pollution and react to the introduction of a pollutant into the soil [1-5]. Combustible materials are extremely diverse in their composition and can seriously affect the environment. Foaming agents used in fire extinguishing can transform the natural soil cover.

There is a direct dependence on the type and scale of the fire, and the pollution of the environment with fire extinguishing foams. The water used for extinguishing may contain pyrolysis products of combustible materials and flame retardants. Other additives contained in combustible materials can enter the water [6-7]. The fire-extinguishing foam, after destruction, can enter the water stream through drains, drainage collectors into groundwater, soil and water bodies, which can pollute the environment and lead to the death of the crop. Accumulating in living organisms, pollutants lead to contamination of subsequent links in the food chain, causing diseases in humans and animals [3; 8].

In connection with the above, the topic related to the study of the toxic effect of the foaming agent on the test objects seems to be very relevant [9-10]. An effective approach for determining the degree of toxicity is the use of bio testing methods, which allow an integral assessment of the ecological state of an object.

Foaming agents are made on the basis of synthetic surfactants or substances of natural origin. These are concentrated aqueous solutions. The composition of foaming agents includes additives (antifreezes, mineral salts) that give them the desired parameters - they lower the freezing point, affect the surface tension coefficient and increase the viscosity. Foaming agents are classified according to their ecological properties: biologically "soft" or biodegradable, and "hard". According to the degree of influence on the human body, synthetic hydrocarbon general-purpose foaming agents belong to the 4th hazard class (low-hazard); intended use - to the 4th or 3rd (moderately dangerous) class.
It can be difficult and financially expensive to determine the quantitative chemical composition of the foam, in such cases bio testing methods can be used to study the total effect of substances on a living organism [2; 4].

The aim of this work is to study the effect of foaming agents on test objects: watercress (Lepidium sativum) and seed oats (Avena sativa).

2. Materials and methods
In order to assess the toxic effect of foaming agents on living organisms, we took foaming agents of different brands and evaluated the effect on test objects. To assess the degree of soil contamination, monocotyledonous and dicotyledonous indicator plants were used: watercress (Lepidium sativum) and common oats (Avena sativa) [1, 5]. The seeds were used from one batch and one year of packaging. We followed the morphological changes in quality indicators under the influence of pollution, such as germination energy, seed germination, main root length, total biomass.

Before sowing, the seeds were selected by weight, heavy and light were discarded in order to neutralize the effect of seed quality on the course of the experiment. The soil was sieved through a sieve to remove large fragments, and vessels 15 cm high were filled with soil. Wells 10 mm deep were prepared, one seed was placed in each well, and the soil was carefully leveled. A 16-hour daylight was maintained with a temperature of 23 ± 3 °C, illumination of 15 thousand lux. The exposure lasted 22 days.

The experiments were carried out in triplicate. Linear measurements of the aboveground part were measured with a ruler with an accuracy of 1 mm. Weight - on scales with an accuracy of 0.01 g.

Seed germination (B,%) was calculated using the formula:

\[
B = \frac{a}{b} \times 100\%
\]

Where \(a\) - is the number of germinated seeds; \(b\) - is the total number of seeds taken for germination.

The average value of the length of the roots (Lcp, cm) for the control and experimental samples was determined by the formula:

\[
Lcp = \frac{Li}{n}
\]

Where \(n\) - is the total number of seeds taken in the experiment (\(n = 50\)).

The inhibition effect (ET,%) was determined by the formula:

\[
ET = \frac{Lk - Lop}{Lk} \times 100\%
\]

Where \(Lk\) - the average length of the roots in the control (cm); \(Lop\) - average root length in the experiment (cm).

Statistical processing of the results was carried out in Microsoft Excel and Statistica-9 programs.

3. Results
To register acute toxicity, 6 types of samples were used.

Three types of control:

- Site No 1.1 with clean soil without pyrogenic effects;
- Site No 1.2 with clean soil, with pyrogenic effect;
- Site No 1.3 with addition of heavy metal CdCl₂ (10 MPC) to the soil.

Three types of prototypes that were treated with soft and hard foaming agents:
At section No 2.1, LVG extinguishing of flammable liquids bottling was carried out using the solution "PO-NSV";
At section No 2.2, LVG extinguishing of flammable liquids bottling is carried out with the help of "Aquafom" solution;
At section No 2.3, LVG bottling is extinguished with the help of non-ionic "Sulfonol NP-3", at a concentration of 10 mg/l.

All sites were exposed to fire. The required amount of extinguishing agent was determined based on the area of the fire (1 m²). The time for the substance consumption is the same for all samples.

The measurements were carried out in the absence of soil on the root system. For this, the test objects were washed and dried on filter paper.

Table 1 shows the results obtained. The results are presented in the table.

| Plot No. | Germination energy,% | Germination,% | Main root length, cm | Biomass, g |
|----------|----------------------|--------------|----------------------|-----------|
| 1.1      | 100/100              | 100/100      | 9.93/7.7             | 0.85/0.10 |
| 1.2      | 97/100               | 99/100       | 9.01/7.1             | 0.85/0.10 |
| 1.3      | 51/73                | 59/89        | 2.22/2.02            | 0.26/0.04 |
| 2.1      | 92/99                | 97/100       | 8.69/4.0             | 0.75/0.11 |
| 2.2      | 91/97                | 96/99        | 8.65/4.03            | 0.70/0.09 |
| 2.3      | 29/53                | 42/73        | 4.93/3.4             | 0.31/0.06 |

It should be noted that although "Sulfonol NP-3" is tough, it is used in practice to extinguish fires. The biodegradability of harsh types of foaming agents is worse than that of PO-NSV and Aquafom, according to the information provided on the product label, the degree of biochemical degradation is 60-70%.

According to the research results, common oats were found to be more sensitive to contaminants than watercress, which is noted as a hardy species. Subsequently, the study was continued only on seed oats.

For soil samples treated with heavy metal, a high germination energy is characteristic, however, further negatively affecting growth and development.

Phytotoxicity is one of the most informative parameters for assessing the techno genic load on natural environments. The method makes it possible to identify the toxic effect of pollutants or a stimulating effect that activates the development of test cultures.

The phytotoxic effect was considered proven if the phytoeffect was 20% or more (table 2).

| Plot No. | Phytoeffect (%) | Test reaction   |
|----------|-----------------|-----------------|
| 1.1      | 0               | Norm            |
| 1.2      | 9.3             | Norm            |
| 1.3      | 50.3            | Braking effect  |
| 2.1      | 12              | Norm            |
| 2.2      | 12.8            | Norm            |
| 2.3      | 77.6            | Braking effect  |

4. Discussion
The presence of certain types of foaming agents can lead to the suppression of living organisms. Most likely, it is associated with a violation of permeability, a decrease in the supply of necessary substances and oxygen to the seeds of the plant [11].
Paying attention to the composition of the blowing agent can minimize the environmental impact.

5. Conclusion
Based on the foregoing:

- Sowing oats were found to be the most sensitive to pollution;
- The development and growth of the root system of test plants directly depends on the degree of soil toxicity;
- The least harm to the test objects was provided by extinguishing flammable liquids with mild foaming agents. Nonionic foaming agents have a detrimental effect on test objects at concentrations of 10 mg/l, and cause an "inhibitory effect";
- In order to protect the environment, if there is a choice of foaming agent, it is preferable to use rapidly decomposing ones, since they practically do not slow down the processes of self-cleaning of the environment.

References
[1] Balmer D, Flors V, Glauser G and Mauch-Mani B 2013 Metabolomics of cereals under biotic stress: Current knowledge and techniques. *Frontiers in Plant Science* 4 1-12
[2] Butani J V 1994 Cytological effects of pesticides on onion (Allium cepa L.) root tip. *Gujarat. Agr* 20 60
[3] Matthieu N, Bravin A M, Michaud, Bourane L and Philippe H 2010 RHIZOtest: A plant-based biotest to account for rhizosphere processes when assessing copper bioavailability. *Environmental Pollution* 158 3330-7
[4] Melnikova T, Polyakova L and Kozmin G 2008 Application of different biotests to assess biological activity of organochlorine pesticides and their radiation metabolites. *Toxicology Letters* 180 170
[5] Kotelnikovaa A, Fastovetsa I, Rogovaa O, Dmitry S and Volkovab 2020 La, Ce and Nd in the soil-plant system in a vegetation experiment with barley (Hordeum vulgare L.). *Ecotoxicology and Environmental Safety* 206 111193
[6] Christopher J D, Christopher D O, Matthew J R, Dave E C and Matthew P T 2019 Spatial and temporal assessment of responder exposure to snag hazards in post-fire environments. *Forest Ecology and Management* 441 202-14
[7] Paulo P, Juan F M-M and Marcos F 2019 Chapter Four - Environments affected by fire. *Advances in Chemical Pollution, Environmental Management and Protection* 4 119-55
[8] Miriam M R and Paulo P 2020 Editorial: Fire in the environment. *Journal of Environmental Management* 253 109703
[9] Weningera T, Filipovich V, Mesicb M, Clothierec B and Filipovich L 2019 Estimating the extent of fire induced soil water repellency in Mediterranean environment. *Geoderma* 338 187-96
[10] Pereiraa P, Reinb G and Martinc D 2016 Past and Present Post-Fire Environments. *Science of The Total Environment* 573 1275-7
[11] Kiss S, Pasca D and Dragan-Bularda M 1998 Chapter 5 - Studies of the Soil Enzymological Effects of Industrial Emissions Originating from a Point Source (An Industrial Plant). *Developments in Soil Science* 26 69-115