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SURFACE TENSION, WETTABILITY AND ABSORPTIVITY OF BASIC COMPONENTS OF WETTING AGENTS

Streszczenie

W artykule przedstawiono zdolność zwilżania i podatność na wchłanianie roztworów podstawowych składników środków zwilżających i ich mieszanin przeznaczonych do gaszenia pożarów lasów.
Praca naukowa finansowana ze środków na naukę w latach 2007-2010 jako projekt badawczy rozwojowy numer R00-O0046/03 „Badania nad otrzymaniem ekologicznego, biodegradowalnego środka zwilżającego, zwiększającego skuteczność akcji ratowniczo-gaśniczych i podnoszącego bezpieczeństwo powszechne kraju" przez Ministerstwo Nauki i Szkolnictwa Wyższego.

Summary

This article describes the wetting power and absorbing capacity for the basic components of the wetting agents applied to fight forest fires. Scientific work financially supported from funds reserved for science in 2007-2010, as a research and development project R00-O0046/03: „Badania nad otrzymaniem ekologicznego, biodegradowalnego środka zwilżającego, zwiększającego skuteczność akcji ratowniczo-gaśniczych i podnoszącego bezpieczeństwo powszechne kraju".

Introduction

Forest fires plague Poland every year. They have dramatic environmental consequences, such as deforestation and forest soil degradation, and the prevention and extinction of forest fires consume significant financial resources.

The employment of wetting agents is indispensable for extinguishing peat-bog and forests fires, which by their specificity multiply speed of penetration of the burning material.

Improved efficiency in extinguishing fires of hydrophobic materials may be available when water is replaced with solutions of wetting agents. Wetting agents are mixtures of various components; water, surfactants (surface active agents), solvents, corrosion inhibitors, preservatives, dyes, and others. Surface-active substances are readily soluble in water and lower surface tension value of water solutions. Such a mixture boosts the wetting ability of the solution on the surface of hydrophobic material. When added to water, those compounds improve its fire extinguishing properties, and thus improve efficiency of rescue actions. Increase of efficiency of fire fighting water solution relies on obtaining better surface absorptivity of solid inflammable material as well as on boost of speed of diffusing of fire fighting medium for burning surfaces.

Wetting agents are assigned for extinguishing fire of wood (forest) and peat-bogs, cotton, coal and other smoldering and glowing fires. Surfactants in these types of compounds are selected on the basis of their ability to reduce surface tension value in water solutions and their ability to increase wetting.

In this respect, individual surface-active substances differ significant in efficiency, and suitable selection of substances is the basis of good quality of wetting agents. Research shows that liquids with high surface tension only slightly wet inflammable materials and do not penetrate to depth of slot, roughness of loose and fibrous materials. Interaction of two different types of surfactants in aqueous solution can result in a synergistic enhancement of their interfacial properties, such as surface tension, wetting and foaming.

Certainly these additions change physical properties of water solution and impact the mechanism of extinguishing chemical compounds. Extinguishing solid inflammable materials relies on the extinguishing agent cooling the external layers to lowest temperature from temperature of giving off mobile and inflammable fraction. Increase of efficiency of fire-fighting water wetting agent solution relies on obtainment of better percolate to surface of solid inflammable material, as well as on boost of speed of propagation across burning surfaces. Solution penetrates to depth to which plain water does not have access. Water with surfactants penetrates capillary. It causes boost of capability to conducting heat by wetting agent solution and thus improves fire extinguishing properties and efficiency of rescue actions. Research wettability and absorptivity of anionic and non-ionic mixtures were verified.

Materials

The following commercial surfactants were used in this study:

1. **Sulforokanol L-327 -** fatty alcohol C_{12}-C_{15} ethoxy sodium sulphates, content of active substance ca 28 %, product of PCC ”Rokita” Poland
2. **Alkilolobenzenosulfonian sodu –** sodium alkylbenzenesulfonate, content of active substance 50,5 %, product of PCC ”Rokita” Poland
3. **Glucopon 225DK** - alkylpolyglycoside of alcohol C_8-C_{10}, content of active substance ca 70 %, product of Cognis Polska Sp. z o.o. Poland
4. **Sulfobursztynian N-5 -** sodium salt of monoester of sulfosuccinic acid and ethoxylated nonylphenol, content of active substance ca 30 %, product of ICSO „Chemical Production sp. z o.o” Poland
5. **Rokanol RZ4P11 -** ethoxylated and propoxylated saturated fatty alcohol C_{16}-C_{22}, product of PCC ”Rokita” Poland
6. **Rokanol IT 7 -** oxyethylenated synthetic fatty alcohol C_{13}-C_{15}, product of PCC ”Rokita” Poland
7. **Rokopol D 2002** – polyoxypropylenediol, product of PCC ”Rokita” Poland
8. **Peat –** product of „Hollas” Pasłęk”

Description of research

The purpose of tests and search for new agents was to develop and implement the best and most effective fire-fighting capabilities. Studies were conducted to determine the influence of the concentration and composition of aqueous solutions of the mixtures of surfactants on the wettability of peat and its absorptivity. The correlation between the adsorption of the surfactants solution at peat and the wetting time was also investigated.

The investigations covered physical-chemical properties of individual surface-active compounds and their mixtures in aqueous solutions, then often showing synergistic effects. The commercial formulations used in this work belong to two surfactants types: non-ionic and anionic. After determining properties of the individual compounds were analyzed binary systems: non-ionic-anionic surfactants and mixture with tree compounds (two non-ionic and one anionic). Mixtures were prepared from surfactants which revealed the best features. The surface tension of the water was always monitored before solution preparation.

After determining the surface tension, wettability and absorptivity, solutions of the individual surfactants were analyzed for the influence of using solutions of mixtures of

surfactants. In most practical applications, mixtures of surfactants, rather than individual surfactants, are used intentionally, or unavoidably in the case of some commercial surfactants. The behavior of the mixture is often different from that of a single surfactant, and in some cases synergetic effects are observed.

One method of decreasing the environmental impact of surfactants is to use mixtures of known surfactants whose interfacial properties exhibit synergism. Consequently, lower quantities of surfactants are needed to achieve the same effect or performance for the mixture with synergism than without synergism.

1. Surface tension measurements

These measurements were made at 20 °C with tensiometer K9 ET (Krüss, Germany) under atmospheric pressure by Du-Noüy ring method. The platinum ring was thoroughly cleaned, and flame dried before each measurement. The measurements were done in such a way that the vertically hung ring was dipped into the liquid to measure its surface tension. It was then pulled out. The maximum force needed to pull the ring through the interface was then expressed as the surface tension. Measurements of the surface tension of pure water and acetone at 20 °C were performed to calibrate the tensiometer and to check the cleanliness of the glassware. In all cases, more than ten measurements were carried out, and the standard deviation did not exceed ± 0.2 mN/m. The temperature was controlled within ±0.1 °C.
Aqueous solutions of various surfactants and their mixtures with the weight ratios equal to 3:1 and 1:1 were prepared in concentration 0.5%. The solutions for measurement were freshly prepared before each evaluation. The surface tension was measured for these solutions of individually surfactants and as mixtures.

2. Wetting time

One of the measures of the properties of surfactants water solutions is time of peat evaluations. Peat was subjected drying to obtain moisture content ~ 10%, moistness below which underbrush is very flammable and is determine alarm condition for fires of forest. Dried peat was put in metal bush which was constituted simultaneously element of appliance compression, next was subjected press to definite volume. In such a prepared material it was put definite volume research wetting agent. Measurement time was conducted from the moment opened valve burette till the drop wetting agent was tearing from wire cloth. On account of occurrence large measuring error to research was employed peat of granulation

<0,5 mm. The standard deviation of wetting time did not exceed ± 1s. These measurements were made at 20 °C. The temperature was controlled within ±0.1 °C.

3. Absorbing capacity

10 g peat was concluded ~ 8 ÷ 10 % water press in a pneumatic press under pressure $7{,}6 \times 10^5$ Pa. Received elements on measurements h = 20 mm and Ø = 30 mm were put in baskets, which were made from copper mesh.

Peat was completely weighed and sunk into research solution. Basket with samples peat were weighed for 4 hours, successive measurements were carried out every 0,5 h. In order to do take these measurements, peat baskets were removed from the solution, and drained of excess of solution, lightly dried, and weighed. After that baskets were sunk in research solution again. The absorbing capacity was defined by:

$$N = \frac{m_n - m_0}{m_0} \cdot 100\% \qquad (1)$$

where:

N – absorbing capacity [%]

m_n – mass of peat after removing from solution [g]

m_0 – mass of dry peat [g]

The standard deviation for each set of values was less than ± 2%. These measurements were made at 20 °C. The temperature was controlled within ±0.1 °C.

Results

1. Surface tension measurements

The surface tension was measured for surfactant solutions in concentration 0,5% (Fig. 1-2).

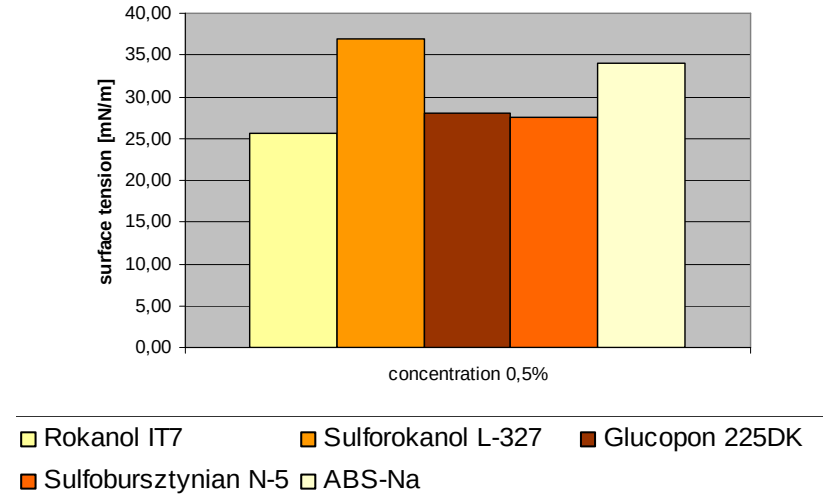

Fig. 1 Surface tension of individual surfactants in concentration 0,5%

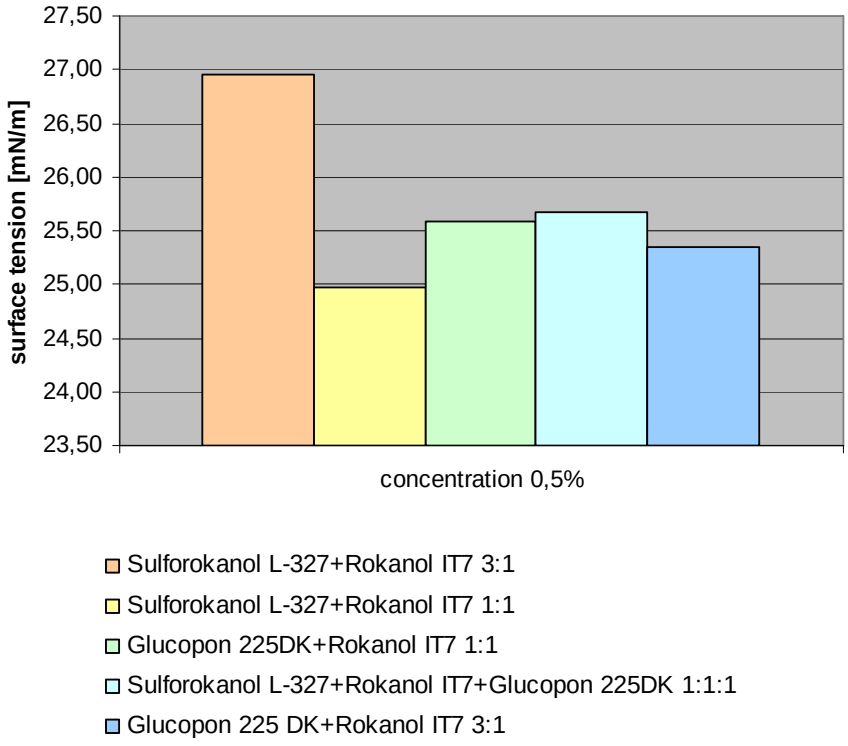

Fig. 2 Surface tension of mixtures of surfactants in concentration 0,5%

Aqueous solutions of surfactants exhibit good value of surface tension. It is also well known that this kind of surfactant is widely used in liquid wetting and extinguishing agents. Ability to reducing surface tension of water solution, high wetting and absorptivity power are an important aspect of products which are widely used in forest fire fighting and processing of various products. The lower value of surface tension was indicated for solutions Rokanol IT-7 - 25,68 mN/m and mixture Rokanol IT-7 and Sulforokanol L-327 (1:1) – 24,97 mN/m in concentration 0,5%.

2. Wetting time

The wettability as a function of mass concentration *c* [m/m] of the aqueous solutions for individual surfactants and their mixtures was measured and compared (Fig. 3-6).

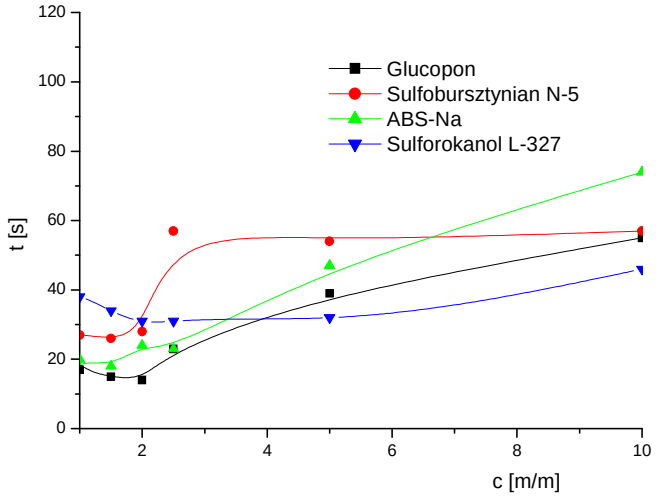

Fig. 3 Effect of concentration of anionic compounds on wettability

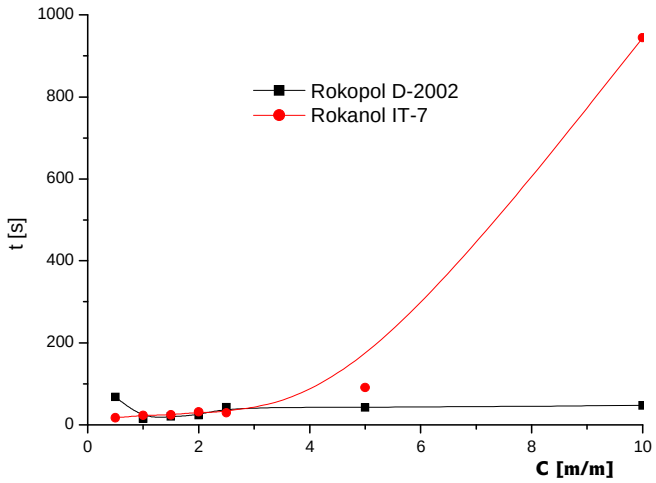

Fig. 4 Effect of concentration of non-ionic compounds on wettability

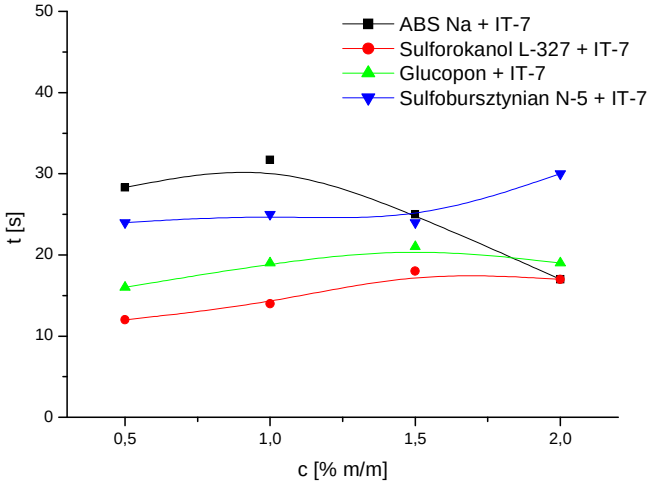

Fig. 5 Effect of concentration for mixtures of anionic compounds + Rokanol IT-7 (3:1) on wettability

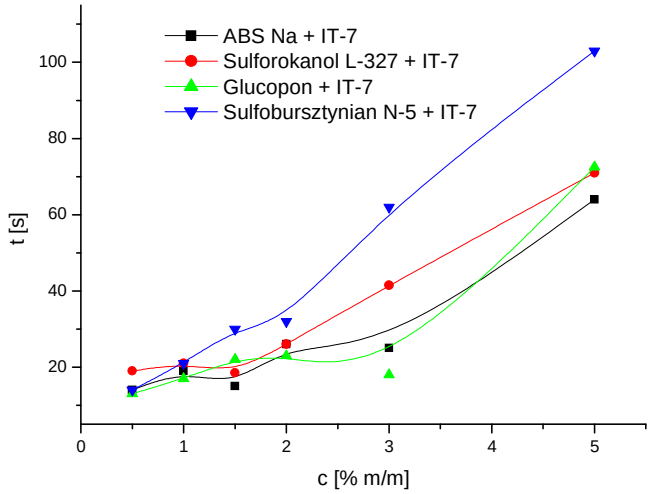

Fig. 6 Effect of concentration for mixtures of anionic compounds + Rokanol IT-7 (1:1) on wettability

The shape of the curve on figure 3 and figure 4 indicate that increase aqueous solution concentration over 2% increase time of peat wetting. The wetting behavior of the prepared surfactants solutions depends on chemical structure of compounds, their properties and concentrations. Synergism of ability for wetting was compared to individual surface-active compounds. The higher wettability was obtained for Sulforokanol L-327 - Rokanol IT-7 (3:1) and Glucopon 225DK- Rokanol IT-7 (1:1) system in 0,5% concentration.

3. Absorbing capacity

The absorbing capacity *N* [%] of peat for aqueous solutions of individual surfactants was measured and compared to that obtained for mixtures (Fig. 7-10).

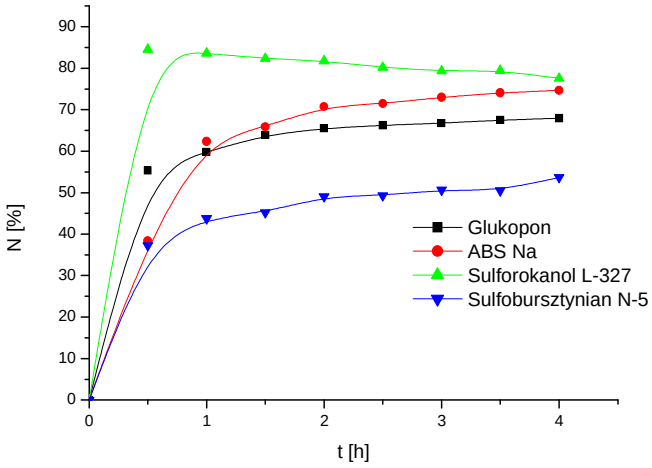

Fig. 7 Absorbing capacity in peat for 1% solutions of anionic compounds

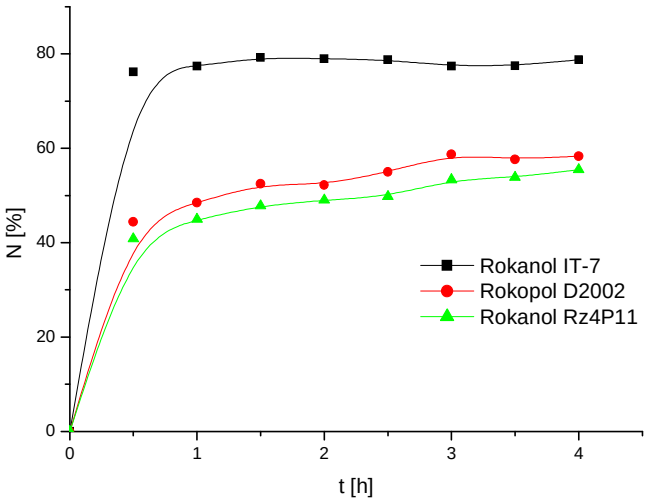

Fig. 8 Absorbing capacity in peat for 1% solutions of non-ionic compounds

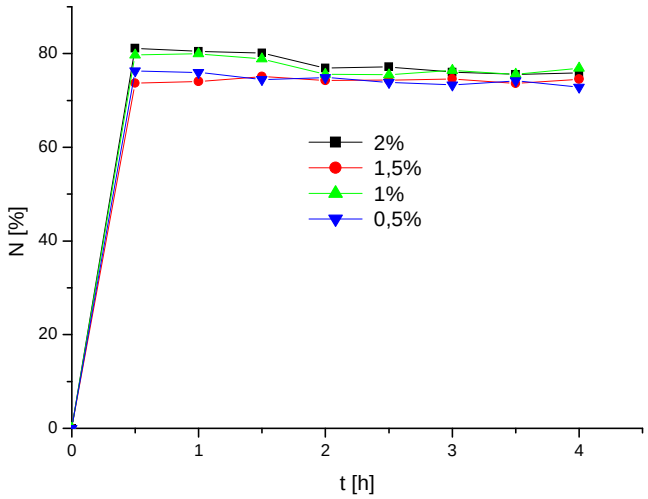

Fig. 9 Absorbing capacity in peat for Sulforokanol L-327 + Rokanol IT-7 (3:1) system

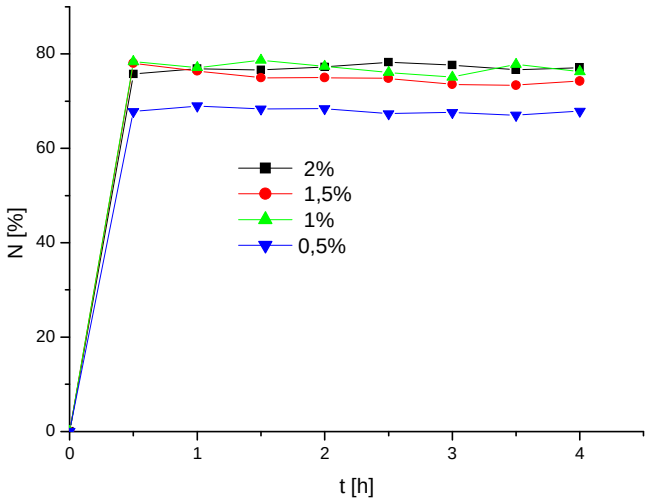

Fig. 10 Absorbing capacity in peat for Glucopon 225DK + Rokanol IT-7 (1:1) system

Figures 7-10 show the absorbing capacity versus time. For anionic and non-ionic compounds absorbing capacity depends on time; for their mixtures absorbing capacity is statistically constant in time from 0,5 to 4 hours. Best absorptivity of surfactant solutions on peat were find for individual surfactants: Sulforokanol L-327, Rokanol IT-7 and mixtures of analyzed surfactants in concentration 2%: Sulforokanol L-327 - Rokanol IT-7 (3:1) and Glucopon 225DK - Rokanol IT-7 (1:1).

Conclusions

1. The addition of the surface-active agent to water decreases surface tension value of solution and enables it to wet a hydrophobic soil. On the basis of results of researched mixtures, the lowest values of surface tension have mixtures: Sulforokanol L-327/Rokanol IT-7 1:1 and Glucopon 225DK/ Rokanol IT-7 3:1.
2. The solution absorptivity is a function of type of surfactant, concentration and time of sorption. From researched anionic surfactants, the best absorptivity values in peat distinguish Sulforokanol L-327 and Glucopon 225DK while among non-ionic surfactants Rokanol IT-7. On the basis of results of research two components mixtures, indicate compound Sulforokanol L-327 and Rokanol IT-7 with the highest absorptivity in peat. Also mixture Rokanol IT-7 and Glucopon 225DK has achieved high absorptivity value.
3. From the researched two components mixtures anionic/non-ionic type it would seem that the most advantageous properties indicates mixtures: Sulforokanol L-327/Rokanol IT-7 and Glucopon 225DK/Rokanol IT-7.
4. Increase concentration of surfactants solution over 2% has an adverse influence impact on wettability. Explanation for this phenomenon requires additional research.
5. As has been indicated, for all analyzed two component systems, synergism of ability for wetting and decreasing surface tension appeared compared to individual surface-active compounds.
6. The concentration of basic components of the wetting agents is probably the most important parameter as it has a direct influence on surface tension, wettability and absorptivity in the finished composition solution. The active matter concentration also, of course, determines the biodegradation index and cost of the finished formulations.

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