



Sokolenko N.,
Ruban E.,
Ostrovka V.,
Moroz O.,
Popov Ye.,
Sedych H.

STUDY OF THE TOXICOLOGICAL CHARACTERISTICS OF WATER-SOLUBLE SURFACE-ACTIVE SUBSTANCES OBTAINED BASED ON PHENOL, FORMALDEHYDE AND SODIUM SULPHITE

Об'єктом дослідження є продукти реакції конденсації фенолу, формальдегіду та сульфїту натрію у водному середовищі, з метою отримання водорозчинних нетоксичних продуктів на його основі, що можна запропонувати для використання в якості поверхнево-активних речовин. В ході дослідження вивчали вплив умов проведення реакції (співвідношення компонентів, температури і часу процесу) на якість отриманих продуктів та їх токсикологічні характеристики. Підібрано оптимальне співвідношення вихідних реагентів фенол : формальдегід : сульфїт натрію : вода, яке дозволяє отримати продукт з поверхнево-активними властивостями та у складі якого не містяться речовини, що можуть бути шкідливими для здоров'я. Було рекомендовано час процесу конденсації в межах 1 години, підібрана оптимальна температура реакції 130 °С. Якісні характеристики отриманого продукту дозволяють рекомендувати застосування його в якості аніоноактивної поверхнево-активної речовини. Для цього було вивчено симптомологічні та токсикологічні властивості новорозробленої поверхнево-активної речовини – продукту конденсації фенолу, формальдегіду та сульфїту натрію у водному середовищі. На основі проведених досліджень встановлено, що при введенні в шлунок піддослідних білих щурів-самок таких поверхнево-активних речовин спостерігається слабка подразнювальна їх дія на слизові оболонки та шкіру. За критерієм смертності, при одноразовому пероральному введенні (ЛД₅₀), шкідливої дії речовини на щурів не відмічено. За результатами досліджень, продукт можна віднести до IV класу небезпеки (малобезпечні речовини) згідно з ГОСТ 12.1.007.

Згідно з токсикологічними висновками, отриманий продукт можна рекомендувати для використання як текстильно-допоміжну речовину, у технологічних операціях відбілювання, фарбування і друкування тканин, що стикаються зі шкірою людини. А також як добавки до бетонних сумішей, що використовуються у будівельній промисловості та інших галузях промисловості.

Ключові слова: продукт конденсації фенолу, формальдегіду та сульфїту натрію, поверхнево-активні речовини, токсикологія, летальна доза.

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1. Introduction

Household human needs, industry and agriculture are closely related to the use of synthetic surface-active substances (surfactants). Surfactants are used as sanitation preparations, detergents, and others. In the textile industry, as an auxiliary substance in the production of optical brighteners, rectifiers for dyeing fabrics are used. In the paint industry in the production of organic dyes and as latex stabilizers, surfactants are also used as a component of plasticizing additives in the construction industry [1–3].

The most widely used are surfactant anionic class. Such products are mainly obtained on the basis of naphthalene: NF Dispersant (product obtained by sulfonation of naphthalene with sulfuric acid followed by condensation with formaldehyde), BNF dilator (condensation product of 2-naphtholsulfonic acid with formaldehyde, manufactured in Ukraine), VANISPERSE A (sodium lignosulfonate, manufactured in Norway). Due to the shortage of raw

materials – naphthalene and its derivatives and lignin, in Ukraine the production of these products has significantly decreased. There was a need to develop surfactant technology, the properties are not inferior to existing ones, the basis of which would be available raw materials.

Therefore, *the object of research* is products obtained during the condensation reaction of phenol, formaldehyde and sodium sulfite in an aqueous medium, which were proposed for use as water-soluble non-toxic surface-active substances (surfactants). And *the aim of research* is studying the symptomatological and toxicological properties of the product obtained on the basis of phenol, formaldehyde, sodium sulfite and it is proposed to use it as surfactant.

2. Methods of research

It has been proposed to obtain surfactant using phenol, formaldehyde and sodium sulfite. This raw material is widely available, and chemical reactions during their

interaction proceed easily and with a high yield of the finished product.

From the literature there are known methods for producing surfactants based on phenol and its derivatives. So, in [4], a method for producing a dispersant by condensing phenol with formaldehyde and sodium sulfite at a temperature of 125–200 °C under pressure for six hours in the presence of alkaline agents, including caustic soda, is described. Surfactant can also be obtained from phenol derivatives. The condensation process of metacresol or a technical mixture of cresols with formaldehyde was carried out at a temperature of 90–95 °C for six hours. Then kept at a temperature of 115–125 °C for two hours. The resulting product reacted with 2-naphthol-6-sulfonic acid in the presence of sodium hydroxide under pressure at a temperature of 112–115 °C for five hours [5].

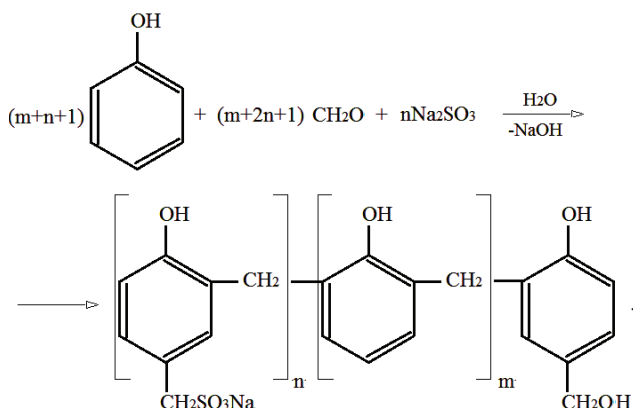
It is also proposed the synthesis of such compounds by condensation of phenols with formaldehyde and further sulfonation of the obtained phenolaldehyde resin (novolak) with sulfuric acid, taken in a small amount. Sulfonation of the novolak type resin was carried out at a temperature of 110–120 °C with concentrated sulfuric acid for 4–8 hours [6]. The disadvantage of this method is that the reaction product is a rather complex mixture of monomers, dimers, trimers and free phenol. The method described [7], consists in the condensation of phenol and its derivatives with formaldehyde and sodium sulfite with a ratio of 1:(1.1–1.4):(0.3–1.6) and a condensation time of 2–15 hours in temperature range 90–120 °C.

In laboratory conditions, surfactants based on phenol, formaldehyde, and sodium sulfite in an aqueous medium are obtained [8].

The influence of temperature, the ratio of the starting components and the exposure time on the yield of the finished product is investigated.

The initial components are loaded into the apparatus in the ratio water: sodium sulfite (in terms of anhydrous): formaldehyde (in the form of a 37 % solution): molten phenol in the ratios 17–19:0.1–1.0:1.2–1.47:1. The mixture was heated to a temperature of 120–150 °C and kept at this temperature from 0.5 to 1 hours. The pH of the reaction mass is 9. During the process, every 10 minutes a sample was taken for analysis: the content of free phenol was determined.

General reaction equation:



Thus, it is found that the ratio of reagents affects the quality of the final product. The lack of formaldehyde or sodium sulfite led to the polymerization of the reaction mass and to obtain a solid resin. The optimal ratio

of phenol: formaldehyde: sodium sulfite: water, which is 1:(1.25–1.47):0.4:(16–20), is selected.

It is found that for the selected ratio of components and the time of the condensation, the optimal reaction temperature is 130 °C.

A small amount of phenol is present in the obtained liquid products; it did not enter the condensation reaction in an amount of up to 5–10 %. The sulfate content is up to 0.6 %. Free formaldehyde is not found. The drying product of such a substance is a brown powder with a basic substance content of 96–98 %. This product is soluble in water, alcohol and alkalis. The qualitative characteristics of the resulting product allow to recommend its use as anionic surfactant. For example, when dispersing dyes, in concrete compositions for construction, in the textile industry when dyeing and bleaching fabrics, as an expander in the manufacture of batteries, etc.

According to the research results, a technology has been developed for producing surfactants that are highly environmentally friendly and economically viable, and can be proposed to expand the scope of surfactant and is an alternative substitute for substances that are already used.

Symptomatological and toxicological properties of the obtained surfactant are not described in the literature, as it has not been previously used in production. Therefore, the question arose to study its general toxicological effect on the skin and internal organs of a person.

The toxicological properties of individual products used in the technological process of surfactant synthesis, namely phenol, formaldehyde (formalin) and sodium sulfite, were previously studied. Then a toxicological study of the properties of the target product (in the form of its 40 % aqueous solution) is performed on white rats-females.

The study of the toxicological properties of the condensation product of phenol, formalin and sodium sulfite is carried out in accordance with the requirements specified in [9, 10], as well as using other proprietary developments.

The studies were carried out on 48 laboratory Wistar rats, in compliance with the Regulation on the Protection of Vertebrate Animals Used for Scientific Purposes (Strasbourg, 2010), the Regulation of the Council of Europe Bioethics Convention (1997), the Helsinki Declaration of the World Medical Association (1996), general ethical principles of scientific research adopted by the First National Congress of Ukraine on Bioethics (Kyiv, 2001), Law of Ukraine No. 3447-IV «On the Protection of Animals from Cruelty» (2006).

The toxic properties of the condensation product were studied in laboratory white rats females with a single introduction of surfactant into the stomach, by applying to the skin and mucous membranes of the eyes. The content of female rats met the requirements set forth in [11, 12]. The experiments used white female rats that were apparently healthy and from the same batch. Minimum statistical group is consisting of 6–10 animals. The death and survival of animals were taken into account within 14 days. Female rats were assessed using adequate tests. When introduced into the stomach and applied to the skin, the following are determined:

- clinical picture of poisoning;
- body weight, mass of internal organs;
- mortality of laboratory animals from the administered dose;
- condition of the skin and mucous membranes of the eyes of rats after applying fine powder of the test product.

3. Research results and discussion

When a suspension of surfactant powder at a dose of 10 g/kg body weight was introduced once into the stomach of female rats, 5 animals died, and at a dose of 7 g/kg, one out of 6 animals died in the experiment (Table 1). Animals died on the first day. The LD₅₀ value was 8.34±0.665 g/kg body weight, LD₁₆ and LD₈₄ were 6.96 g/kg and 10.06 g/kg body weight, respectively. The slope angle function of the direct «dose – death time» angle ∠S was equal to 1.6437 (Table 2), the slope angle function of the direct «dose-effect» angle ∠S was 1.2027, the lethal dose variability coefficient was 1.477, and the coefficient hazard amounted to 0.0009938 (Table 3).

During the autopsy of animals that survived and were slaughtered after the observation period and microbiological examination of the internal organs, it was determined that the masses of the organs of the research group did not differ from the control in coefficients (Table 4).

Table 4

Mass ratios ($X+S_x$) of the internal organs of female rats with a single oral administration of the product

Experimental conditions	The number of rats in the group, pcs	Lungs	Liver	Kidneys	Spleen	Adrenal glands	Heart
Control	6	7.29±0.9	37.8±1.4	6.69±0.2	3.89±0.40	0.176±0.05	2.51±0.10
Experimental	5	7.52±0.7	37.6±2.4	7.24±0.7	4.86±1.16	0.185±0.09	2.61±0.15

Note: control initial rat weight is 232±5.3 g control final rat weight is 236±4.3 g research rat initial weight is 256±7.7 g research rat final weight is 251±8.0 g

Mortality of laboratory animals (female rats) at a single intragastric administration of the product

The number of female rats in the group, pcs	Dose, g/kg	The number of dead rats by the hour, pcs									Observed effect	
		4	6	9	12	16	18	20	22	24	Dead, pcs	Mortality, %
6	10	–	–	2	2	–	1	–	–	–	5	83.3
6	7	–	–	–	–	1	–	–	–	–	1	16.6
6	5	–	–	–	–	–	–	–	–	–	0	0

Table 1

The local irritating effect of the product was studied in rats by a single application of the aqueous paste of the product on a clipped skin area (4×4 cm) with an exposure of 4 hours. Animals were pre-examined before the start of the experiment (output background), 1 and 16 hours after application. The skin condition of rats was evaluated by the thickness of the leather fold and visually, as well as by skin temperature. During the experiments, changes in these indicators were not detected. Assessment of the irritating effect of the product studied on the mucous membrane of the eyes was carried out when the substance was introduced in the native form into the conjunctival sac of the right eye of rats. The mucous membrane of the intact eye served as a control. After introducing the substance into the experimental eye, after 5 minutes a narrowing of the slit was observed, the animals rubbed their eyes with a paw. After 40 minutes, irritation of the surrounding tissues in the form of hyperemia, narrowing of the eye gap, swelling and lacrimation was observed. After 24 hours, some signs of inflammation disappeared, but there was swelling and narrowing of the slit to the eye. On the third day, the signs of inflammation completely disappeared, the mucous membrane of the experimental eye did not deviate from the control.

The average effective death time of female rats with a single intragastric dose of 10 g/kg of product

Injected dose, g/kg	Average effective rat death time			Tilt angle function ∠S
	ET ₁₆	ET ₅₀ ±S _x	ET ₈₄	
10	6.46	10.6±1.83	17.4	1.6437

Table 2

Parameters of toxicometry with a single intragastric administration of the product

Injected dose, g/kg at			Hazard class	Tilt angle function γ	Fatal dose variability coefficient	Hazard ratio
LD ₁₆	LD ₅₀ ±m	LD ₈₄				
6.46	8.22±0.76	10.46	IV	1.2727	1.619	0.0009938

Table 3

The average effective death time of ET₅₀ rats was 10.6±1.83 hours. The ET₁₆ and ET₈₄ values were 6.4 and 17.4 hours, respectively (from a dose of 10 g/kg body weight). The picture of acute poisoning was characterized by lethargy, a weak reaction to external stimuli, and negligence. 2 hours after administration of the substance, diarrhea was observed in animals. The death of animals was noted during the first day. On the second day after the administration of the drug, scruffy, ruffled coat, bunching of animals, diarrhea, poor eating of food were noted. On the 4th and 7th day the signs of intoxication disappear. By the end of the experiment, the animals did not differ from the state of the control group of rats during the entire observation period (14 days).

Emergency poisoning assistance. Acute poisoning of surfactant under industrial conditions is unlikely, chronic in the form of irritation of the mucous membranes of the eyes and respiratory organs can occur. In the production of surfactant, the danger to humans is represented by the initial products: phenol and formaldehyde, requires the use of necessary protective equipment. Signs of the influence of surfactants on the human body can be irritation of the mucous membranes of the eyes and respiratory organs. Signs of the influence of the starting synthesis products (phenol, formaldehyde) are mucosal irritation, general weakness, dizziness, headache, sweating, fear, hyperemia of the face, nosebleeds, cramps, shaky gait.

The main preventive measures in the production and use of this condensation product should be aimed at sealing the equipment, localizing places of dust formation. The working room must be equipped with in-exchange supply and exhaust ventilation in accordance with SNiP 2.09.04-85 «Heating, ventilation and air conditioning» and local ventilation in accordance with GOST 12.4.021, ensuring the air condition of the working area in accordance with GOST 12.1.005-88. In accordance with the current DSTU, drinking water must be supplied to the working premises.

Maintenance personnel should be provided with personal protective equipment:

- overalls according to GOST 12.4.103;
- gloves according to GOST 20010;
- gas mask FGP-130KD according to GOST 12.4.121;
- aerosol respirator of the Petal type according to GOST 12.4.028;
- goggles according to GOST 12.4.013.

Cleaning of workplaces should be carried out every month by wet or pneumatic (vacuum cleaner) method, in accordance with SNiP 2.92.76. It is forbidden to eat food in workrooms, to enter overalls in work clothing. If product dust gets on the skin or eyes, rinse with plenty of water. If there are signs of intoxication, the victim should be removed from the contaminated area, rinsed with a nasopharynx with water, provided with bed rest, fresh air, and intensive drinking water consumption per day. For any poisoning, hospitalization and medical attention are necessary. If to receive minor injuries, treat the latter with alcohol, apply an aseptic dressing. Monitoring of the air condition of the working area should be carried out in accordance with the requirements of GOST 12.1.005-88 on phenol and formalin at least once a month.

4. Conclusions

The symptomatic and toxicological properties of the newly developed surfactant, a product of the condensation of phenol, formaldehyde and sodium sulfite, were studied. Based on the studies, it is found that with the introduction into the stomach of experimental white female rats of such surfactant, their weak irritating effect on the mucous membranes and skin is observed. According to the mortality criterion, with a single oral administration (LD₅₀), the harmful effects of the substance are not noted. The product belongs to the IV class of danger (low material safety) according to GOST 12.1.007.

According to the data obtained during toxicological studies, the resulting product can be recommended for use in the manufacture of products in contact with human skin. For example, textile auxiliary substances, additives for technological operations of dyeing and printing of fabrics, and also as additives to concrete mixtures used in the construction industry and other industries.

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Sokolenko Nadiya, Department of Ecology and Polymer Technology, Institute of Chemical Technologies of the Volodymyr Dahl East Ukrainian National, University, Lugansk region, Ukraine, e-mail: sokolenkonadiya@gmail.com, ORCID: <http://orcid.org/0000-0002-1319-2625>

Ruban Elina, PhD, Associate Professor, Department of Ecology and Polymer Technology, Institute of Chemical Technologies of the Volodymyr Dahl East Ukrainian National, University, Rubizhne, Lugansk region, Ukraine, e-mail: ruban.elin@gmail.com

Ostrooka Victor, Senior Lecturer, Department of Ecology and Polymer Technology, Institute of Chemical Technologies of the Volodymyr Dahl East Ukrainian National, University, Rubizhne, Lugansk region, Ukraine, e-mail: ecology@iht.lg.ua, ORCID: <http://orcid.org/0000-0001-6946-7475>

Oleksiy Moroz, Senior Lecturer, Department of Ecology and Polymer Technology, Institute of Chemical Technologies of the Volodymyr Dahl East Ukrainian National, University, Rubizhne, Lugansk region, Ukraine, e-mail: moroz.valeri@ukr.net, ORCID: <http://orcid.org/0000-0003-1700-9039>

Popov Yevgeniy, Doctor of Technical Sciences, Professor, Department of Ecology and Polymer Technology, Institute of Chemical Technologies of the Volodymyr Dahl East Ukrainian National, University, Rubizhne, Lugansk region, Ukraine, e-mail: popov@iht.lg.ua, ORCID: <http://orcid.org/0000-0001-7941-5134>

Sedyh Anna, PhD, Associate Professor, Head of Department, Department of Medical Chemistry, Luhansk State Medical University, Rubizhne, Lugansk region, Ukraine, e-mail: annamik080678@gmail.com, ORCID: <http://orcid.org/0000-0003-4034-7095>