ISSN 1070-3632, Russian Journal of General Chemistry, 2013, Vol. 83, No. 13, pp. 2614–2617. © Pleiades Publishing, Ltd., 2013.
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Phytotoxicity of a Surfactant-Containing Product towards Macrophytes

S. A. Ostroumov and E. A. Solomonova

Lomonosov Moscow State University, Moscow, 119991 Russia
e-mail: Ar55@yandex.ru

Received May 11, 2012

Abstract—Extending the studies of surfactant-containing products, we have investigated the effect of the Liquid Crystal Concentrate detergent on aquatic macrophytes *Elodea canadensis* within laboratory microcosms. It has been shown that the detergent produced some negative influence on the macrophytes at 50–150 μL/mL (5–15 vol %).

Keywords: Detergent, phytotoxicity, macrophyte, Liquid Crystal Concentrate, *Elodea canadensis.*

DOI: 10.1134/S1070363213130057

In the previous studies of surfactants and their mixtures we demonstrated various toxicity forms of that compounds towards Embryophytes [1–6, 10, 13, 15–19], algae [7–9], and cyanobacteria [20]. The use of synthetic surfactants as constituents of various detergents (and, therefore, the aqueous objects pollution) reached as high as 6 g per person per day (anionic surfactants), 4 g per person per day (nonionic surfactants), and more than 1 g per person per day (cationic surfactants) [2]. Thus, the studies of effects of surfactants and their mixtures on the living organisms, including macrophytes, are essential. In particular, the effects caused by the concentrated surfactant mixtures (used in the detergents production) on the aquatic Embryophytes have not been studied so far; this work was designed in order to fill in the gap.

Here, we report the studies of the effects caused by the concentrated mixture of anionic and nonionic surfactants, Liquid Crystal Concentrate (LCC) produced by Stephenson Group Ltd. (England). LCC is applied as a major component in the manufacturing of cosmetic detergents (shampoo, liquid soap, and foam for bath), it is available in Russian Federation and is widely used. However, the potential toxicity of LCC to aquatic macrophytes has not been tested.

In the previous studies, the toxicity of anionic surfactants towards macrophytes was revealed [1, 2, 3]. LCC contains the anionic surfactant, sodium lauryl sulfate, hence, its potential toxicity needs to be tested. We tested LCC phytotoxicity towards *Elodea canadensis* macrophyte, a widely spread aquatic species.

The experimental results are presented in Table 1. These data demonstrated that the tested sample of the chemical product was phytotoxic.

Table 1. The microcosms parameters, including the biomass of *Elodea canadensis* macrophytes

LCC concentration (μL mL^{-1}) in the aqueous media	Microcosm no.	Biomass (wet weight), g
reference	1	10.82
	2	7.30
	3	7.51
20.00	4	6.94
	5	6.95
	6	6.00
50.00	7	10.10
	8	6.94
	9	5.89
100.00	10	10.8
	11	5.78
	12	5.87
150.00	13	10.40
	14	8.32
	15	7.46

After 7 days of incubation, the turgor decrease was observed at LCC concentrations of 50.00, 100.00, and 150.00 μL mL^{-1}, whereas some fading of leaves was noticeable at LCC concentrations of 100.00 and 150.00 μL mL^{-1}. Partial depigmentation of shoots was observed.

The phytomass of the plants filled the microcosm volume. In the control microcosms, the phytomass distribution was even along the microcosm volume, and the whole water column was filled (only as low as 0–2% of the total volume was free of the plants). In the presence of LCC, the location of the phytomass was close to the microcosm bottom, and the upper part of the water column was free of plants.

In particular, at LCC concentration of 150.00 μL mL^{-1} the upper plant-free layer of water occupied about 25–30% of the total system volume. After 21 days, at the same LCC concentration the plant-free volume in the upper part of the microcosm occupied 35–40% of the total volume, and the macrophytes death was observed.

It is noteworthy that, the observed negative effects were noticeable at the lower LCC concentrations as well, started from 50 μL mL^{-1}, the lowest concentration tested. The results obtained add to the knowledge on the negative effects of other surfactants [6, 15, 19] and chemical mixture products which contain surfactants [4, 5, 10] on aquatic organisms.

The results obtained in this work are in agreement with the previously reported studies. In particular, Table 2 shows a summary of some studies of surfactants and their mixtures effects on different organisms.

Importantly, the extension of the examples of the macrophytes state testing is relevant to evaluation of toxicity of other chemicals, other than surfactants. Quantitative assessment of the biological effects produced by chemicals is important to fundamental studies as well as applied research, including environmental science, agricultural science, biotechnology, and hydrobiology [11, 12, 18, 21].

EXPERIMENTAL

The experiments were conducted as described elsewhere [1, 5, 6]. In particular, the *E. canadensis* macrophytes were placed to the microcosm (water volume of 1 L), three plants to each, the total biomass being of 7.9±3.6 g (wet weight). The weight of plant biomass is presented in Table 1. The experiments were performed under the conditions of natural photoperiodicity, in three replicates, at water temperature of 11.5±2.5°C. The concentration of LCC after its addition to the aquatic medium of the microcosms was 50.00, 100.00, or 150.00 μL mL^{-1}. The LCC composition was as follows: water (25–50%), sodium laurylsulfate (25–50%), propylene glycol (1–5%), sodium chloride (1–5%), cocamine oxide (1–5%), cocamidopropyl betaine (1–5%), citric acid (0.1–1.0%), tetrasodium salt of ethylenediaminetetraacetic acid (0.1–1.0%), polyquaternium-7 (0.1–1.0%), magnesium nitrate (<0.1%), magnesium chloride (<0.1%), methylisothiazolinone (<0.1%), and methylchloroisothiazolinone (<0.1%) (9 ppm of active isothiazolinone in total).

Table 2. The state of *E. canadensis* macrophytes after treatment with LCC. The range of LCC concentration is given as sodium laurylsulfate concentration according to LCC specification

LCC concentration (μL mL^{-1}) in the aqueous media	Sodium laurylsulfate concentration range (μg mL^{-1}) in the aqueous media	*E. Canadensis* macrophytes state	
		after 7 days	after 21 days
0.00 (reference)	0.00	Normal turgor, normal leaves	Normal turgor, normal leaves
50.00	12.50–25.00	Turgor decrease	Turgor decrease
100.00	25.00–50.00	Turgor decrease, partial depigmentation of leaves	Death of >50% of macrophytes
150.00	37.50–75.00	Turgor decrease, partial depigmentation of leaves	Death of 100% of macrophytes

Table 3. Negative effects of surfactants and their mixtures on the organisms (examples)

Compound(s)	Organisms	Reference
Concentrate of surfactants mixture (LCC)	*E. canadensis*	This work
Anionic surfactant sodium dodecylsulfate, nonionic surfactant Triton X-100, cationic surfactant tetradecyltrimethylammonium bromide; various mixtures of surfactants	Several Embryophytes (*Sinapis alba, Oryza sativa, Fagopyrum esculentum, Triticum aestivum, Lepidium sativum, Camelina sativa*), and *Pistia stratiotes* water lettuce	[1, 2]
Synthetic detergent "Aist-Universal"	*Fontinalis antipyretica*	[4]
Liquid detergent "Amway Dish Drops"	*Elodea canadensis*	
Sodium dodecylsulfate	*Najas guadelupensis*	[6]
Sodium dodecylsulfate	*Potamogeton crispus*	[3, 20]
Cationic surfactant	*Fagopyrum esculentum*	[18]
Anionic surfactant sulfonol	*Lepidium sativum,* and *Fagopyrum esculentum*	[16]
Various surfactants	*Fagopyrum esculentum. Brassica alba,* and *Triticum aestivum*	[15]
Surfactant-containing mixture (liquid detergent) "Vilva"	*Fagopyrum esculentum* and *Oryza sativa*	[14]
Polymeric surfactant, sodium salt of hexane–maleic aldehyde copolymer (M about 20 kDa)	*Fagopyrum esculentum*	[17]
Triton X-100	Cyanobacteria	[21]
Triton X-100	*Thalassiosira pseudonana*	[8]
Sodium dodecylsulfate. Detergents "Kristall," "Tix"	*Alga Plagioselmis prolonga (Cryptophyta)*	[7]
Sodium dodecylsulfate	*Dunaliella salina (Chlorophyta)*	[9]
Surfactant mixtures	*Lens* sp. and *Vigna* sp.	Unpublished data

LCC was a colorless transparent or slightly opaque viscous liquid, pH (non-diluted) of 6–7, the highest viscosity of 6 Pa s at 25°C.

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