DE GRUYTER OPEN

RTU

Material Science and Applied Chemistry doi: 10.1515/msac-2015-0015

2015/32

Physicochemical Pretreatment of Contaminated Microfibre Cloths after Their Use in Waterless Car Wash

Silvija Strikauska[1], Andrejs Berzins[2], Lauris Arbidans[3], Agnese Kukela[4], Olga Muter[5], Maris Klavins[6],
[1–6]University of Latvia

***Abstract* — Contaminated microfibre cloths (80 % polyester and 20 % polyamide) which were previously used in waterless car cleaning process were treated in ultrasonic bath. Efficiency of water, ethanol, 2-propanol and ethylene glycol as liquid phase for ultrasonic treatment was compared. Chemical oxygen demand (COD), concentration of surfactants and total nitrogen in the extract were tested after 0 min, 10 min, 30 min and 60 min ultrasonic (US) exposure (42 kHz). In all cases the COD values gradually increased in a time dependent manner from 6 % to 35 % with ethanol, from 17 % to 37 % with ethyleneglycol and from 17 % to 33 % with 2-propanol at 10 to 60 min US mode, respectively.**

***Keywords* — Chemical oxygen demand (COD), microfiber cloth, surfactants, waterless car cleaning.**

I. Introduction

Waterless car wash is a spray-on cleaning method that safely removes dirt from car surfaces and leaves the car clean. Cleaners used in waterless wash consist of surfactants, waxes and other compounds and are non-toxic, biodegradable and phosphate free [1]. The main benefit of this method is ecological: it saves water and eliminates toxic runoff. The spray-on method conserves up to 380 L of water per wash [2]. Waterless wash is commonly mistaken to mean that water is completely eliminated from the cleaning process. This process uses microfibre cloths with split weave that forms liquid-trapping compartments. Besides, the microfibre contains polyester which absorbs liquid and polyamide which holds it in the fabric [3]. Microfibre cloths have static cleaning properties that allow them to attract dirt and dust [3], [4]. Car care products and dirty residue are accumulated in the split weave and are hard to remove.

After the car wash process these cloths have to be washed to enable their reuse. However, many factors influence the quality of reused cloths and optimal conditions for their washing have to be elaborated. In particular, if inappropriate detergent is used, microfibre will lose its magnetic attraction features. Waxes and polymer sealants are not water soluble; they dry and adhere to the fibres. Cold water will preserve them in solid state and will not wash them off. Hot water, however, will soften them and loosen them from the threads — thus allowing the detergent to lift the contaminants from the fabric [5], [6]. Due to physicochemical properties of the detergent [7]–[10] it is necessary to examine the amount of pollutants entering the wastewater system together with laundry effluents. Once in environment, surfactants may have a harmful effect on organisms living there, mainly due to their toxicity and the enhanced solubility of other toxic organic compounds [11]–[14]. Because surfactants have strong adsorbing properties and toxicity level, they affect biological activity of microorganisms; this leads to decrease of efficiency of wastewater treatment [15]. There are a lot of different methods used for cleaning wastewater from surfactants to avoid these problems [16], [17].

Physical or/and chemical pretreatment of the dirty cloths in a small volume of liquid could potentially reduce the amount of wastewater with high concentration of surfactants and other toxic compounds. Ultrasound is known to be a very effective and non-polluting method of activation in different industrial processes such as cleaning, homogenisation, emulsification, sieving, filtration, crystallisation, extraction, degassing and stripping [18], [22]. Ultrasonic sound waves radiate into solution in the form of a vertical wave. The micro-agitation occurring in the vicinity of the cavitation bubble effectively wets out the surface and helps to displace particulate contaminants or grease [19].

Ultrasonic treatment of textile materials in aqueous or other solutions is used to remove natural fats, waxes, proteins and other constituents, also dirt, oil and other impurities, and bleaching, dyeing, finishing and washing [20]. The effects of ultrasonic agitation in laundering onproperties of wool fabrics were reported by Hurren *et al.* [19]. Ultrasonic agitation caused less fibre migration than hand washing, rate of thickness increase and felting was reduced [19]. Operation of US in pulse mode could be useful in order to reduce consumption of electrical energy [21].

Recently waterless car wash technologies have been applied worldwide. One of the important aspects in these technologies is the cost-efficient and environmentaly-friendly reuse of microfibre cloths. Ultrasonic pretreatment of immersed dirty cloths could serve as a preliminary step for microfibre wash.

The aim of this study was to evaluate the effectiveness of physicochemical pretreatment of dirty microfibre cloths, comparing aqueous and organic solutions and also different periods of ultrasonic pretreatment.

II. Materials and Methods

A. Pretreatment of Cloths

The composition of the used surfactant was complex — it consisted of three components. Firstly, component A — a silicone blend comprising of: a) high viscosity till standard viscosity silicone fluid and wax consisting of about 35 % to about 65 % of polydimethxylsiloxane which had viscosity of from about 200 cSt to about 100 000 cSt at 25 °C, b) silicone wax or wax of natural origin from about 0.5 % to about 5 % by weight. Secondly, component B — a mixture of surfactants containing non-ionogenic and anionic functional groups. Component B consisted of: a) an amine oxide (N-oxide) being disubstituted at the nitrogen atom, b) polyoxyethylene fatty alcohol ethers (alkylene oxide adducts of higher alcohols), c) alkylderivatives of benzylammonium. Thirdly, component C — an organic solvent miscible with water from about 3 % to about 10 % by weight and water from about 0 to about 5 % by weight.

Microfibre cloths (30 × 30 cm, 80 % polyester and 20 % polyamide) were sampled after use in a professional waterless car cleaning process. Four pretreatment solutions (water, ethanol, 2-propanol, ethylene glycol) and four ultrasound modes (0 min, 10 min, 30 min and 60 min) were used for pretreatment of microfibre cloth at 20 °C. Some characteristics of solvents used for pretreatment are shown in Table I.

The dirty cloths were immersed in 200 mL of pretreatment solvents and drenched for 10 min. Then 500 mL of distilled water was added and samples were subjected to ultrasound. Then samples were filtered through filter paper and the main indicators of wastewater were determined.

B. Analytical Methods

Chemical oxygen demand was detected by dichromate method [27], surfactants were determined by solvent extraction method [28] and total nitrogen was detected by Kjeldahl method [29], pH was measured using pH meter *pH 231* (*Hanna Instruments*) [30]. Optical density of pretreatment solutions was determined using spectrophotometer *Expert Plus* (*Asys Hitech GmbH*) at 450 nm. Pretreatment of immersed cloths with ultrasound was performed using *Cole-Parmer SS* ultrasonic cleaner with power output of 42 kHz ± 6 %.

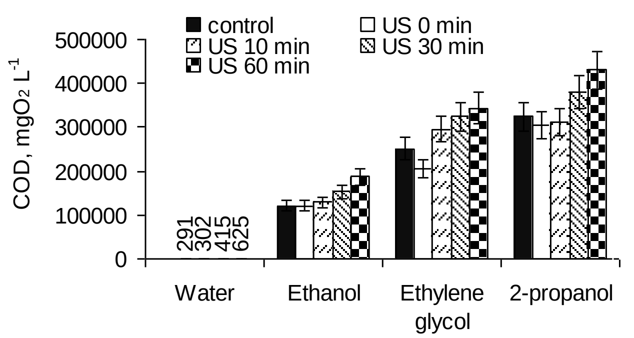
TABLE I

CHARACTERISTICS OF THE USED PRETREATMENT SOLVENTS, LC50 − LETHAL CONCENTRATION 50 %

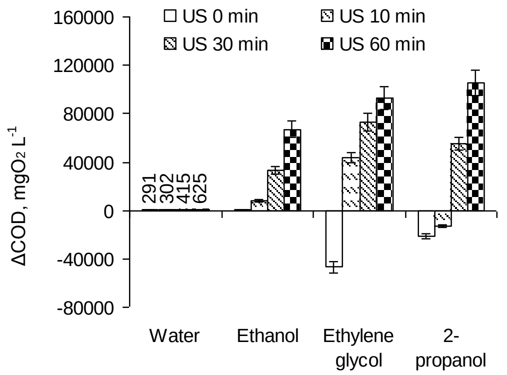
Solvents	Solubility in water	Biodegradability	Toxicity (fresh-water fish)	COD, $g \cdot g^{-1}$
Ethanol [23]	Miscible	Degradable in waste water treatment plants	LC50 = 14200 $mg \cdot L^{-1}$ 96 h	2.09
2- propanol [24]	Miscible	Bio-degradable	11130 $mg \cdot L^{-1}$ LC50 96 h	2.40
Ethylene glycol [25], [26]	Completely	Bio-degradable	16000 $mg \cdot L^{-1}$ LC50 96 h	1.29

III. RESULTS AND DISCUSSION

Efficiency of ultrasonic pre-treatment of microfibre cloth was performed in differing solvents and was evaluated by chemical changes in liquid phase. COD levels determined in the samples after pretreatment of cloths are shown in Fig. 1 A.

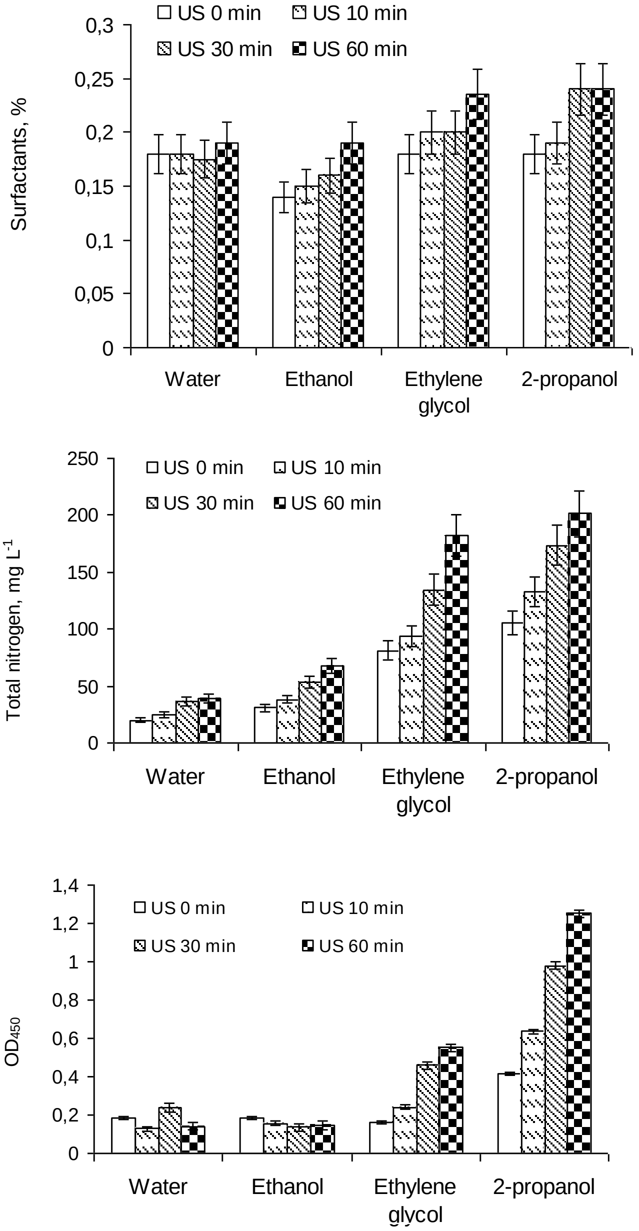


A



B

Fig. 1. Chemical oxygen demand in pretreatment liquids after exposure of dirty microfibre cloths to ultrasound: A — results of COD measurements, including control (background COD of organic liquids used for treatment), B — difference between background COD of organic liquids and COD of liquids after ultrasonic treatment of cloths.



A

B

C

Fig. 2. Concentration of surfactants (A) and total nitrogen (B) in pre-treatment liquids and their turbidity (C) after exposure of dirty microfibre cloths to ultrasound.

COD content was particularly high in ethanol, ethylene glycol and 2-propanol solutions because of the high initial COD values of these solvents — 120 715 mg $O_2 \cdot L^{-1}$, 251 430 mg $O_2 \cdot L^{-1}$ and 325 000 mg $O_2 \cdot L^{-1}$, respectively. In all cases COD values gradually increased in a time-dependent manner as a result of pretreatment by approximately from 6 % at 10 min US mode to 35 % at 60 min US mode with ethanol, from 17 % at 10 min US mode to 37 % at 60 min with ethylene glycol and from 17 % at 30 min US mode to 33 % at 60 min US mode in 2-propanol.

An exception was immersion of dirty cloths in ethylene glycol and 2-propanol without ultrasonic treatment. In this case the COD level in solvent was decreased, probably due to sorption of organic molecules on microfibre cloth (Fig. 1 B). This suggests that a part of car care products (cleaning detergent with COD 240 000 mg $O_2 \cdot L^{-1}$) still remain in the split weave of the cloth; therefore, further microfiber cloth cleaning is required. In chemical-free cleaning, namely, with water as pretreatment solution, the determined COD level after 60 min exposure to ultrasound was found to be 625 mg $O_2 \cdot L^{-1}$ (Fig. 1).

As shown in Fig. 2 A, surfactants were detected in all tested immersion solutions after US treatment and their amount gradually increased in a time dependent manner in the sets using ethanol, ethylene glycol and 2-propanol. The maximum concentration of surfactants was found in 2- propanol solution at 60 min US mode, i.e., 0.24 %. No effect of US treatment on removal efficiency of surfactant in water at neutral pH (7) and 20 °C temperature was observed. Testing results (COD values in particular) showed that a part of car care product (cleaning detergent surfactant concentration 11 % was analysed according to method 28) still remains in the split weave of the cloth.

The removal efficiency N_{total} from cloth after pre-treatment is presented in Fig. 2 B. As the result of washing of cloths at 60 min US mode, 200 $mg \cdot L^{-1}$ in 2-propanol solution and 182 $mg \cdot L^{-1}$ in ethylene glycol was obtained. Washing of cloth in water without US at 20 °C by hand gave only a minor value of 40 $mg \cdot L^{-1}$. In all pretreatment cases the N_{total} concentration increased concurrently with increase of US exposure time.

The liquid phase after pretreatment of cloths was muddy due to solid particles and oil drops dispersed in it. Liquid turbidity was shown to be dependent on the treatment mode. In particular, OD_{450} of liquids indicated, that the use of 2-propanol and ethylene glycol was more efficient compared to ethanol and water (Fig. 2 C). Ultrasound treatment stimulated detachment of dirt from cloth in sets with ethylene glycol and 2-propanol in a time dependent manner (Fig. 2 C).

Cleaning effects of ultrasound were explained by two different mechanisms: small-amplitude acoustic bubble oscillations and micro-jets (resulting from the collapse of acoustic bubbles in the boundary layer between fabric and bulk fluid) that gave rise to convective mass transfer in the intra-yarn pores [31].

Warmoeskerken *et al.* operating in 33 kHz ultrasonic transducer frequency use cotton test swatches that contained dried-on sodium chloride as a tracer. It is found that using ultrasonic bath the rinsing of salt from textiles can be speeded up by a factor of 6 [32].

IV. Conclusion

1. Comparison of four liquid phases used in US treatment of dirty cloths as a preliminary step for their cleanup and further reuse showed that ethylene glycol and 2-propanol were more efficient compared to water and ethanol.
2. Maximal values of COD, N_{total} and surfactants were determined in the sample after 60 min US treatment with 2-propanol solution — 430 000 mg $O_2 \cdot L^{-1}$, 200 $mg \cdot L^{-1}$ and 0.24 %, respectively.
3. COD content in pretreatment solutions after washing was particularly high in ethanol, ethylene glycol and 2-propanol

samples because of the high initial COD values in these solutions.

4. A part of car care products still remained in the split weave of the cloth after pretreatment. Therefore, further microfibre cloth cleaning was required.
5. If solvents are used, before wastewater is drained to wastewater treatment plants, the effluents should be processed by mechanical, biological or chemical methods.
6. For chemical free cleaning only water could be used; in this case COD in wastewater after pretreatment was 625 mg $O_2 \cdot L^{-1}$, *N* 40 mg$\cdot L^{-1}$.

ACKNOWLEDGEMENT

The study was financially supported by ERAF project 2 DP/2.1.1.1.0/14/APIA/VIAA/016 "Development of environmentally friendly surface cleaning compositions with emphasis on their potential applications"**.**

SIA Shine Expert provided the technical support for experiments.

REFERENCES

1. Waterless Car Wash/Eco Touch Preminim Car Care. [online]. [viewed 10.042015]. Available from: www.ecotouch.net/waterless-car wash-rtu-24-oz/
2. Waterless Car Wash-Eco Touch [online]. [viewed 10.04.2015]. Available from: www.ecotouch.ru/shop/product/waterless-car-wash/
3. Microfibre audumu apraksts-Tupperware [online]. [viewed 02.04.2015] Available from: www.twjurmala.lv/f/...microfibre audumi.doc
4. Noderīgi padomi [online]. Norwex Baltic [Viewed 02.042015.] Available from: www.lupatinas.lv/lv/padomi/mazgasana.html
5. Eco Touch (WCW24) Waterless Car Wash-24.oz:automotive. [online]. [viewed 04.04.2015.] Available from: www.amazon.com/Eco-touch-WCW24-Waterless-Wash/dp/B001NQF3QQ
6. Microfiber products [online]. Autogeek [viewed 04.04.2015.] Available from: www.autogeek.net/mictow.html
7. US Patent. *Degreasing substrate with aerosol comprising benzyl alcohol, ethylene glycol (or propylene glycol) monophenyl ether, alkanolamine, corrosion inhibitor, water and propellant*. Vitomir, S. Int. Cl.: C11D 3/20. 19.3.2002, Pat. No US 6,358,907 B1.
8. **Beitāne, L., Ese, I., Koršuvova, T.,** et al. Estimation of chemical compounds in detergents and cosmetics used for daily needs. In: *Int. Conf. "Eco-Balt 2008"*, Latvia, Riga, 15−16. May,Riga: Integro Plus, p. 56.
9. **Stikans, I., Kalnina, D., Busmane, L**. Peristant Organic Pollutants and Lesser Known Problems in the environment, *Material Science and Applied Chemistry*. no. 22, 2010, pp. 78−82.
10. **Holt, M.S., Mitchell, G.C., Watkinson, R.J**. The environmental chemistry, fate and effects of nonionic surfactants. In: *The handbook of environmental chemistry*. vol. 3. Part F. Berlin: Springer, 1992, pp. 89−144. http://dx.doi.org/10.1007/978-3-540-47108-0_2
11. **Juchelka, C., Snell, T.** Rapid toxicity assessment using ingestion rate of cla — docerans and ciliates. *Arch. Environ. Contam. and Toxicol*, 1995, vol. 28, no. 4. pp. 508−512. http://dx.doi.org/10.1007/BF00211634
12. **Ostroumov, S.A**. Inhibitory analysis of top-down control: new keys to studying eutrophication, algal blooms, and water self-purification. *Hydrobiologia*. 2002. vol. 469, pp. 117−129. http://dx.doi.org/10.1023/A:1015559123646
13. **Ostroumov, S.A**. *Biological Effects of Surfactants.* CRC Press. Taylor & Francis. Boca Raton, London, New York. 2006, 279 p.
14. **Stephenson, R.E., Gutierrez, D., Peters, C.,** et al. Elucidation of bacteria found in car interiors and strategies to reduce the presence of potential pathogens. *Biofouling*, 2014, vol. 30, no. 3, pp. 337–346. http://dx.doi.org/10.1080/08927014.2013.873418
15. **Liwarska-Bizukojć, E., Bizukojć, M**. Digital image analysis to estimate the influence of sodium dodecyl sulphate on activated sludge flocs. *Proc. Biochem.*, 2005, vol. 40, pp. 2067−2072. http://dx.doi.org/10.1016/j.procbio.2004.07.020
16. **Aboulhassan, M.A., Souabi, S., Yaacoubi, A.,** et al. Removal of surfactant from industrial wastewaters by coagulation flocculation process. *Int. J. Environ. Sci. Tech*., 2006, vol. 3, no. 4, pp. 327−332. http://dx.doi.org/10.1007/BF03325941
17. **Paphane, B.D., Ramirez, L.L.Z.** Chemical Pre-Treatment of Anionic Surfactants Contaminated Waste Water at Enaspol A. S. using H2O2/UV Light Waste Water Pre-Treatment Method. *J Environ Anal Toxicol*, 2013, vol. 3, p. 181. http://dx.doi.org/10.4172/2161-0525.1000181
18. **Sivakumar, V., Rao, P.G**. Application of power ultrasound in leather processing: an ecofriendly Approach. *Journal of Cleaner Production*, 2001, vol. 9, pp. 25–33. http://dx.doi.org/10.1016/S0959-6526(00)00028-7
19. **Hurren, C., Cookson, P., Wang, X**. The effects of ultrasonic agitation in laundering on the properties of wool fabrics. *Ultrasonics Sonochemistry*, 2008, vol. 15, pp. 1069–1074. http://dx.doi.org/10.1016/j.ultsonch.2008.04.002
20. **Canoğlu, S., Gültekin, B.C., Yükseloğu, S.M.** Effect of ultrasonic energy in washing of medical surgery gowns. *Ultrasonics*, 2004, vol. 42, pp. 113−119. http://dx.doi.org/10.1016/j.ultras.2004.02.012
21. **Sivakumar V., Swaminathan G., Rao P.G., Muralidharan C.,** et al,. Use of ultrasound in leather processing Industry: Effect of sonication on substrate and substances – New insights. *Ultrasonics Sonochemistry*, 2010, vol. 17, pp. 1054–1059. http://dx.doi.org/10.1016/j.ultsonch.2009.10.012
22. **Sivakumar, V., Chandrasekaran, F., Swaminathan, G., Rao, P.G.** Towards cleaner degreasing method in industries: ultrasound-assisted aqueous degreasing process in leather making. *Journal of Cleaner Production*, 2009, vol. 17, pp. 101–104. http://dx.doi.org/10.1016/j.jclepro.2008.02.012
23. SAFETY DATA SHEET [online]. 20.01.2014. Fisher chemical [viewed 17.04.2015.]. Available from: https://extranet.fisher.co.uk/chemicalProductData_uk/wercs?itemCode=10040602&lang=EN
24. SAFETY DATA SHEET [online]. 18.11.2013. Fisher chemical [viewed 17.04.2015.]. Available from: https://extranet.fisher.co.uk/chemicalProductData_uk/wercs?itemCode=10173240&lang=EN
25. SAFETY DATA SHEET [online]. 1.04.2015. Fisher chemical [viewed 17.04.2015.]. Available from: https://extranet.fisher.co.uk/chemicalProductData_uk/wercs?itemCode=10695572&lang=EN
26. MATERIAL SAFETY DATA SHEET [online]. 19.07.2004. Brenntag Canada Inc. [viewed 17.04.2015.]. Available from: http://www.midwestenergy.ca/images/ethylene_glycol_all.pdf
27. *Water quality- Determination of the chemical oxygen demand*. LVS ISO 6060: 1989
28. Sredstva mojushhie sinteticheskie Metod opredelenija massovoj doli poverhnostno- aktivnyh vesshhesti, GOST 22567.6-87 (in russian).
29. *Water quality − Determination of Kjeldahl nitrogen − Method after mineralization with selenium*, LVS EN ISO 25663: 2000
30. *Water quality − Determination of pH* LVS ISO 10523: 2009.
31. **Moholkar, V.S., Nierstrasz, V.A., Warmoeskerken, M.M.C.G.** Intensification of mass transfer in wet textile processes by power ultrasound. *AUTEX Research Journal*, 2003, vol. 3, no. 3, pp. 129−138.
32. **Warmoeskerken, M.M.C.G., Vlist, P. van der, Moholkar, V.S., Nierstrasz, V.A.** Laundry process intensification by ultrasound. *Colloids and surfaces A: Physicochem. Eng. Aspects*, 2002, vol. 210, pp. 277−285. http://dx.doi.org/10.1016/S0927-7757(02)00372-2

Silvija Strikauska, *Dr. biol.*, senior researcher. Fields of research — agrobiotehnology, biotehnology.
Faculty of Geography and Earth Sciences, University of Latvia.
Address: Alberta Str. 10, Riga, LV-1010
E-mail: silvija.strikauska@llu.lv

Andrejs Bērziņš, *Mg. ing.*, researcher. Fields of research — design of bioreactors, studies of biotechnological processes in submerged and solid state processes.
Institute of Microbiology and Biotechnology, University of Latvia.
Address: Kronvalda blvd. 4, Riga LV-1010, Latvia
E-mail: andrejs54@inbox.lv

Lauris Arbidans, AP, laboratory technician. Faculty of Geography and Earth Sciences, University of Latvia.
Address: Alberta Str. 10, Riga, LV-1010
E-mail: lauris.arbidans@yahoo.com

Agnese Kukela, *Dr. geol.*, researcher at the Department of Applied Geology, Faculty of Geography and Earth Sciences, University of Latvia. Author of several scientific publications in the field of weathering studies of stone materials and assessment of preservation state of stone monuments with cultural heritage. Assistant lecturer for the course Geoarchagology.
Address: 10 Alberta Str., LV 1010, Riga, Latvia
E-mail: agnese.kukela@lu.lv

Olga Muter, *Dr. biol.*, senior researcher at the Institute of Microbiology & Biotechnology, University of Latvia. Muter obtained her scientific degree in microbiology at the University of Latvia in 2002. Fields of research: soil microbiology, environmental biotechnologies.
Address: 4 Kronvalda blvd., Riga LV-1010, Latvia.
E-mail: olga.mutere@lu.lv

Maris Klavins: *Dr. habil. chem.*, Professor at the University of Latvia, Faculty of Geography and Earth Sciences, Department of Enviromental Sciences. Kļaviņš obtained his scientific degree in chemistry of biologically active compounds at Moscow State University in 1986 and his habilitated degree at University of Latvia in 1994.
Address: University of Latvia, Raiņa blvd. 19, Riga, Latvia
E-mail: maris.klavins@lu.lv

Silvija Strikauska, Andrejs Bērziņš, Lauris Arbidans, Agnese Kukela, Olga Muter, Māris Kļaviņš. Ar virsmas aktīvām vielām piesārņotu bezūdens automašīnu tīrīšanas mikrošķiedru audumu fizikāli-ķīmiskā priekšapstrāde.
Bezūdens automašīnu mazgāšana pamatojas uz virsmas apstrādi ar mazgājamo līdzekli, kas satur virsmas aktīvās vielas, vaskus un citus savienojumus, kas ir biodegradējami un nav toksiski. Šī līdzekļa noslaucīšanai no automašīnu virsmas, neizmantojot ūdeni, pielieto mikrošķiedras audumu (80 % poliesters un 20 % poliamīds). Lai atkārtoti izmantotu šo audumu, pētīja tā mazgāšanas priekšapstrādes efektivitāti dažādos šķīdinātājos (ūdens, etanols, etilēnglikols un 2-propanols) pie dažādiem ultraskaņas režīmiem (42 kHz, ekspozīcijas laiks 0 min, 10 min, 30 min un 60 min). Izvērtēja dažādu šķīdinātāju efektivitāti audumu attīrīšanā no netīrumiem, tīrīšanas līdzekļa virsmas aktīvām vielām un vaskiem. Analizējamā šķīdumā noteica ķīmiskā skābekļa patēriņu (ĶSP), virsmas aktīvo vielu daudzumu, kopējā slāpekļa daudzumu (N_{kop}) un šķīduma duļķainību. Priekšapstrādes procesos visos gadījumos ĶSP palielinājās, palielinoties ultraskaņas ekspozīcijas laikam no 10 min līdz 60 min: etanola gadījumā no 6 % līdz 35 %, etilēnglikola gadījumā no 17 % līdz 37 % un 2-propanola gadījumā no 17 % līdz 32 %. Mikrošķiedras audumu priekšapstrāde, nepielietojot ultraskaņu, nepalielināja analizējamo šķīdumu ĶSP. N_{kop} un virsmas aktīvo vielu koncentrācija mikrošķiedras audumu priekšapstrādes šķīdumos (izņemot ūdeni) palielinājās, attiecīgi palielinot ultraskaņas ekspozīcijas laiku no 0 min līdz 60 min. Ultraskaņas ekspozīcijas laiks praktiski neietekmēja virsmas aktīvo vielu koncentrāciju ūdens šķīdumā un sasniedza 0,18 %. Visefektīvākais no testējamajiem priekšapstrādes variantiem bija ultraskaņas ekspozīcijas laiks 60 min 2-propanola šķīdumā. N_{kop} un virsmas aktīvo vielu koncentrācija analizējamā paraugā attiecīgi sasniedza 200 $mg \cdot L^{-1}$ un 0.24 %. Optimālo priekšapstrādes variantu noteikšanai, kā arī iegūto šķīdumu ar augstu ĶSP tālākai izmantošanai ir nepieciešami tālāki pētījumi.