DE GRUYTER OPEN
International Conference KNOWLEDGE-BASED ORGANIZATION
Vol. XXIV No 3 2018

SPECIFICATION OF DESTRUCTIVE INFLUENCES OF SELECTED DECONTAMINATION MIXTURES ON MATERIALS USED FOR CONSTRUCTION OF CHEMICAL SPECIALISTS´ GARMENTS DESIGNATED FOR ISOLATIVE PROTECTION OF THE BODY SURFACE

Zdeněk MELICHAŘÍK*, Pavel OTŘÍSAL**

*** Faculty of the Physical Culture of the Palacký University in Olomouc, Olomouc, Czech Republic,**
**** NBC Defence Institute of the University of Defence in Brno, Vyškov, Czech Republic, zmeldy@seznam.cz, Pavel.Otrisal@unob.cz**

Abstract: *A paper deals with the influence of selective decontamination mixtures established in the Czech Armed Forces on an isolative protective foil used to the construction of anti-gas protective garment marked as OPCH-05. Presented information are a part of thematically focused works aimed to study of influences of all established decontamination mixtures on the Czech Armed Forces Chemical Corps´ garments of anti-gas protection. The quality of provided the Czech Armed Forces Chemical Corps´ specialists isolative protection is limited with the existence of several aspects which significantly determine with their materials equipment. For providing isolative protection of the body surface are used such as protective garments which are the hermetic type and they are constructively solved with the employment of the butyl-rubber polymeric mixture. The effective protection of the body surface must be guaranteed even within the presumption of a repeated contact with decontamination mixtures.*

Keywords: decontamination mixtures, breakthrough time, MIKROTEST, decontamination, anti-gas protective garment OPCH-05

1. Introduction

An aim and a sense of fulfillment of tasks of decontamination performed by the Czech Armed Forces (CAF) Chemical Corps´ (CCs) specialists is to remove consequences of weapons of mass destruction (WMDs) and toxic industrial materials (TIMs) on forces as a result of the activities not only a military but also non-military character. Very important task of the CAF CCs specialists is producing conditions to the CAF for fulfillment of tasks in areas contaminated with chemical warfare agents, radioactive agents and biological warfare agents. In connection with the possibility of an effective reaction on crisis situations which originate in the consequence of studious or organized WMDs employment eventually organized or accidental releases of TIMs it is necessary to claim that it is not possible to expect the state when comes to the complete elimination of negative influences of toxic chemical or radioactive compounds on forces and, moreover, civilian population.

The CAF CCs specialists use procedures and principles of decontamination during fulfillment of tasks connected with the consequent management after WMDs employment and within formation of conditions for forces. From the general view the decontamination is a procedure

DOI: 10.1515/kbo-2018-0149
© 2015. This work is licensed under the Creative Commons Attribution-NonCommercial-NoDerivatives 3.0 License.

during that comes to elimination of chemical warfare agents, toxic industrial chemicals, biological compounds and removing radioactive agents from a surface of a body, armament, vehicles, and other materials. From an operational point of view the decontamination is divided on immediate one which is performed by soldiers just in time after contamination, partial one which is done only on the parts which serve for fulfillment of tasks and, furthermore, thorough one which is performed with the CAF CCs in the cooperation with other units. Its task is to reduce people, armament, other materials, areas contamination on hygienically acceptable norms and enable partial or complete withdrawal of individual protective equipment and to continue in a combat action with minimal time delay. Based on knowledge of operational tasks fulfilled in all types of military operations it is possible to suppose that the probability of a contact of decontamination mixtures with an anti-gas garment of OPCH-05 which is established in the CAF is real within the decontamination. The direct contact of some decontamination mixtures with above mentioned anti-gas garment can lead to decrease of its protective properties and thus to subsequent exposure of the CAF CCs specialist due to toxic compounds effects [1].

The breakthrough time (BT) is one from the most important factors for the assessment of the quality and determination of the resistivity of constructive barrier materials used for providing isolative protection of the body surface. For the purposes of evaluation of effects of decontamination mixtures on isolative protective foil this time can be defined as the period of time [min] which expressed the time of a protective effect of an isolative foil from the moment of the first contact of test chemical (sulfur mustard) with tested constructive material till the moment of apparition of this chemical on a wrong side of tested material in a required amount (concentration) which correspond to given sensitivity of a reaction of used chemical method [2].

Testing of protective suits is performed in the CAF in a stage of their development thus at the time before their establishment into the armament. Testing for CWAs uses a two-stage chemical reaction between the sulfur mustard and indication treatment agents. Hygroscopic cellulose paper colored by the Kongo red color (pH-indicator) is used as a sulfur mustard indicator. The paper is activated after its exsiccation with CNITI-8 chloramide [*N*-chlor-*N*-(2-tolyl)benzamide]. An indication principle lies on CNITI-8 chloramide reaction with sulfur mustard. During this reaction comes to release of hydrogen chloride which changes an alkali form of the acid basic indicator to acid one. It is done with a change of the Kongo red color which alternates from red color into the blue one by the way of the azo-hydrazone tautomery [3]. Indication paper is in a direct contact with a tested constructive isolated folio. The blue-change reveals in a place of CWA permeation. A moment of a threshold amount of CWA (0,005 $mg.cm^{-2}$) permeation is signalized with the first visible blue spot which has an average of 1 mm. Testing is very simple and there in quite no need to use complicated devices. Because the testing is done with real CWA reached results are representative and inform about real tested materials protective properties in face of CWA. During this measurement is necessary to catch the first moment of tested chemical compound permeation on an under-side of tested material.

2. Decontamination mixtures established in the CAF

Fulfillment of specific measurements of chemical, biological, radiological and nuclear (CBRN) defence and chemical support by the CAF CCs specialists among them belong even the thorough decontamination is performed with the employment of established decontamination

mixtures whose survey is summarized in the table 1.

Table 1 The survey of established decontamination mixtures in the CAF designated for decontamination of military vehicles, terrain and objects

Mixture	Composition	Time of Application [min]	Consumption [$dm^3.m^{-2}$]
Hypochlorite decontamination mixture	2 % $Ca(ClO)_2$, 0,5 % detergent ALFA, 1 % oil, rest water	15 – 30	2,5 – 3,0 warmed 1,5
Decontamination mixture No 1	10% mixture of dichloroamine in dichloroethane	10 – 15	0,5 – 0,6
Decontamination mixture OR - 3	30 % cyclohexylamine, 40 % monoethanolamine, 30 % ethanole, on each liter 98 g KOH	15	0,1 – 0,25
Decontamination mixture OR - 3M	40 % diethylentriamine, 30 % natrium ethanolate, 25 % dimethylsulfoxide, 5 % xylene	15	0,1 – 0,25
Decontamination mixture ODS-4	3 % detergent LINKA 1, 2 % NaOH, rest water	5	0,5
	0,15 % detergent LINKA 1, 0,1 % NaOH, rest water	immediately	2,5
Emulsion decontamination mixture	85 volume parts of 10% water suspension of $Ca(OCl)_2$, and 15 volume parts of emulsion oil EO 04	30	0,6 – 1,0
Peroxide decontamination mixture	30 volume parts of 30% hydrogen peroxide and 70 volume parts of organic component of peroxide mixture	30	0,5

For study of destructive effects on the isolative protective foil used for construction of anti-gal garment of OPCH-5 decontamination mixtures have been used as follows:

- hypochlorite decontamination mixture with ingredient of oil and without oil;
- decontamination mixture No 1;
- decontamination mixture ODS-4.

Study of effects of above mentioned decontamination mixtures comes out from long-term authors´ experiences whose confirmation has been verified with the performance of targeted experimental works. The choice of three decontamination mixtures respects typical representatives of spectrum established decontamination mixtures. It means that among them are mixtures designated only for degassing and also deactivation.

3. Evaluation of effects of selected decontamination mixtures on isolative protective foil

3.1 Hypochlorite decontamination mixture

With the comparison of BT outspread to the value of BT of the clean sample which has been 400 min and BT after repeated decontamination of the tested material with hypochlorite decontamination mixture it is possible to claim that it came to increasing of the value of 4889 min. It expresses the growth 89 min. The growth of BT is probably caused with closing polymeric structure of the butyl-rubber from the reason of permeation of decontamination mixture into inner structure of the sample of the tested material and subsequently with presence of the crystalline phase of $Ca(OCl)_2$ not only on its surface but also in

the research isolative material. Creation of a crystalline zone probably causes as retention volumes for sorption processes of the test chemical which significantly slows down diffusion processes. It is a likelihood that based on creation of these retention zones the barrier material becomes les permeable. Based on linear regression analysis (the rate of the red curve and values of BT – figure 1) it is possible to claim that dispersed crystalline phase shows higher resistance (higher values of BT) in relation to permeation of the test chemical [4].

3.2 Hypochlorite decontamination mixture with oil ingredient

The significant impact on BT values changing was recorded with using hypochlorite decontamination mixture with oil ingredient. Within comparison of BT of the clear sample and the value of BT after the tenth decontamination cycle significant decrease of BT from 400 min on 332 min has been recorded. It can be assumed that the decline of BT was caused by the presence of oil which, thanks to its non-polar character, readily permeates into the inner structure of the sample of tested material. Based on the very high boiling point of diesel fuel, which is given in the literature about 180° C, it is possible to believe that the oil constantly affects the sample of material from the reason that the structure of the sample diffuses into the surrounding environment only in a minimal amount. Furthermore, it is also possible to believe that the reduction of BT can be caused by the presence of a solid crystalline phase of calcium hypochlorite, which caused cracks in the internal structure of the butyl-rubber linear chains. These one have lost their elasticity and consequently the ability to achieve the most energy-efficient state with the influence the local increase in the volume of crystalline phases. It is also possible to assume that the destructive effects caused by tearing internal linear structure of the polymer material more efficient space for repeated and intense permeation of organic components hypochlorite decontamination mixture (oil) has been created. It leads to the multiplication of above mentioned effect. Based on the achieved results it is possible to assume that the effect of the hypochlorite decontamination mixture with oil on reduction of the protective properties of the tested isolative foil increased almost linearly thanks to repeated decontamination cycles, which was probably caused by the emergence of significant number of damaged areas with swelling. The test chemical could penetrate into the internal structure of samples after damaged caused by swelling [4].

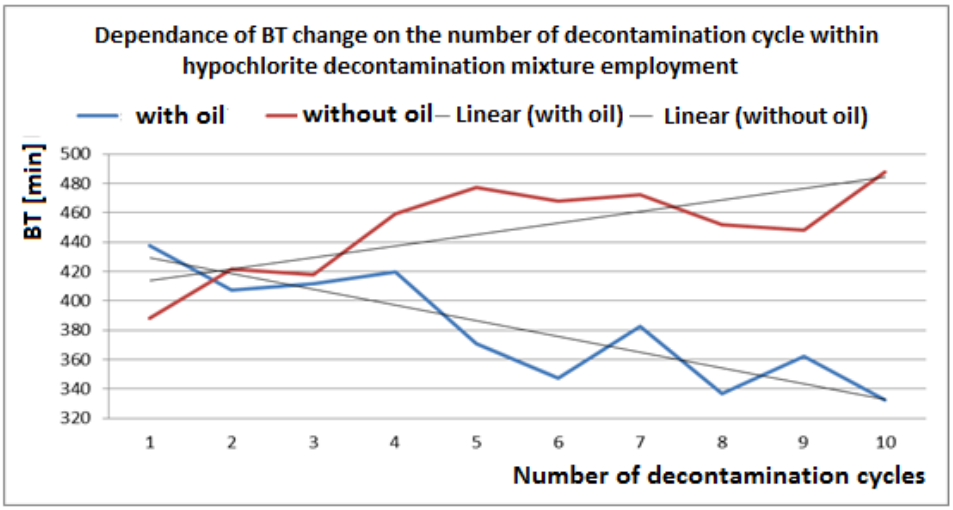

Figure 1: The rate of dependence of BT change of tested material of isolative protective foil OPCH-05 after repeated decontamination with hypochlorite decontamination mixture with oil ingredient and without it

3.3 Decontamination mixture No 1

Completely different influences which have been discussed within hypochlorite decontamination mixture occurred during the study of protective properties of the isolative protective folio in relation to decontamination mixture No 1, whose composition is given in the table 1. From the theory of inorganic and polymer chemistry dealing with the general influence of chlorinated non-polar solvents based on halogenated linear unsaturated hydrocarbons with a short hydrocarbon chain on linear elastomers of the unsaturated polyolefin type, resulting in high capacity of halocarbons to penetrate with diffusion processes into the structure of sparsely crosslinked linear and branched amorphous polymers. With the number of decontamination cycles the destructive effects have increased and caused irreversible changes in the structure of the samples of the tested polymeric material. The multiple and relatively prolonged contact of decontamination mixture with tested material in the course of execution of decontamination cycles has been accompanied by swelling and subsequent perforation and total destruction of the tested sample of the material (Figures 2 and 3). In this case, the barrier material does not fulfill any from their protective functions. Due to the total destruction of the tested isolative protective foil, has been abandoned from the performance of BT measurement with MIKROTEST method [5].

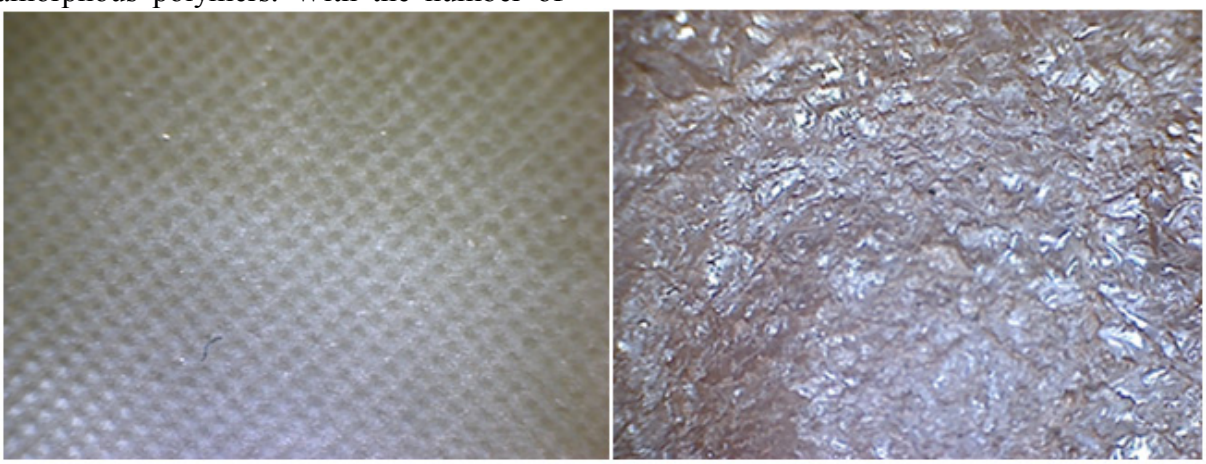

Figure 2: The sample of isolative foil clear (left) and after performance of the fifth decontamination cycle (right)

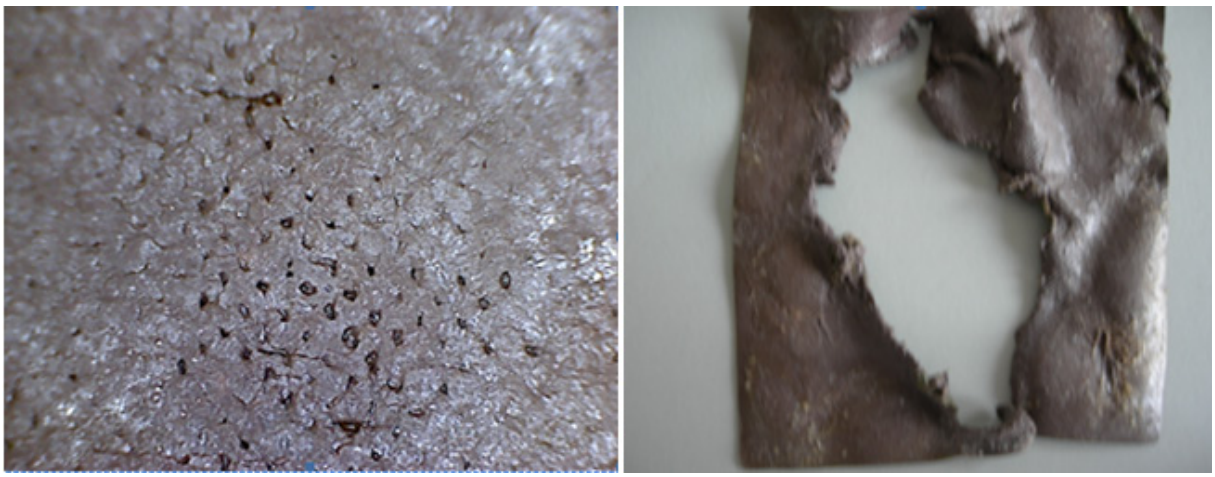

Figure 3: The sample of isolative foil after performance of the eighth decontamination cycle (left) and after performance of the tenth decontamination cycle (right)

3.4 Decontamination mixture ODS-4

As the last in the group of carried out experimental works the influence of decontamination mixture ODS-4 has been studied. The graph in figure 4 shows that this decontamination mixture has quite negligible influence on the protective properties of the tested isolative foil. The value of BT of the pure sample has been (as in previous cases) approximately 400 minutes. This time has been declared by the manufacturer for all sets of measurements performed even with the employment of the MIKROTEST method. The value of BT after performance of the 1st to the 10th decontamination cycle ranged from 400 to 460 minutes. On the basis of linear regression analysis of the measured values of BT (red marking curves in the graph) can be observed a slight increase in relation to the number of decontamination cycles. Based on the above mentioned findings, it is possible to conclude that the protective properties of the tested isolative protective foil do not significantly reduce and change due to effect of decontamination mixtures ODS-4.

4. Evaluation of experimental part

Based on the evaluation of the measurement results in the form of a study conducted after performed decontamination cycles within each set of samples of tested isolative protective foil can be stated that BT changes after the fifth decontamination cycle are evident concerning substantial differences of influence of decontamination mixtures on change of the protective properties of the tested isolative foil expect decontamination mixture ODS-4. While we compare values of BT within samples of hypochlorite decontamination mixture with oil ingredient and without oil it can be summarized that after the fifth and eight decontamination cycle the difference of measured values is more than 100 minutes (figure 5). After conducting the tenth decontamination cycle the difference is more than 160 minutes. In case of decontamination mixture No 1 it was not possible to perform measurement of BT with the help of MIKROTEST method because of total destruction of samples of tested material. The influence of decontamination mixture ODS-4 on relevant changes of protective properties of tested isolative protective foil is quite negligible.

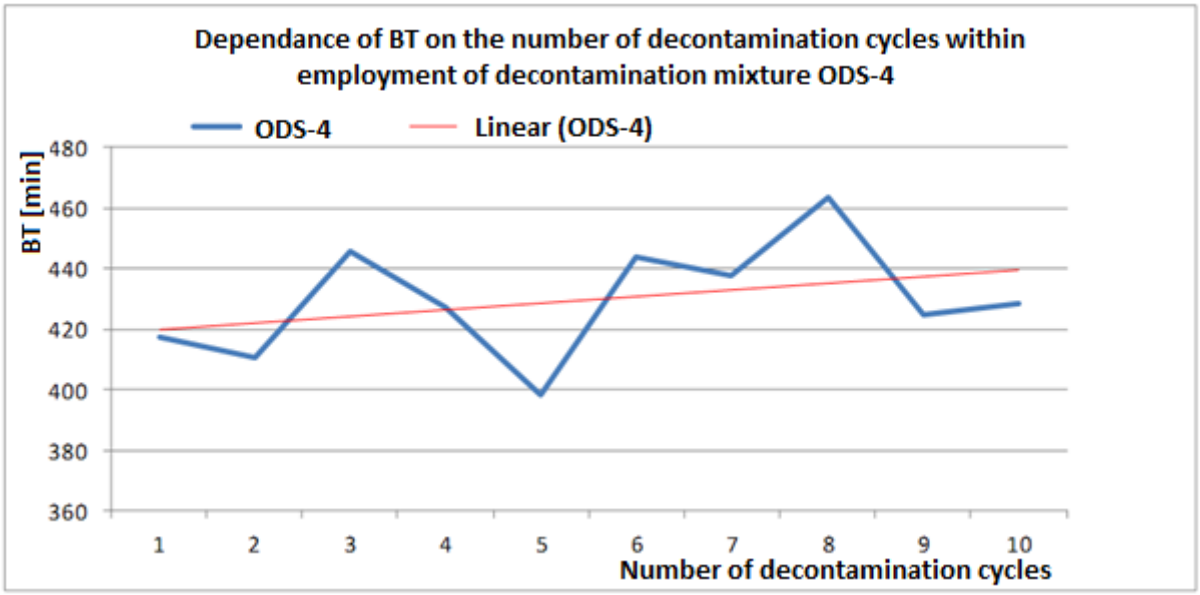

Figure 4: The rate of dependence of BT chase of the tested material of the isolative protective foil OPCH-05 after repeated decontamination with the help of decontamination mixture ODS-4

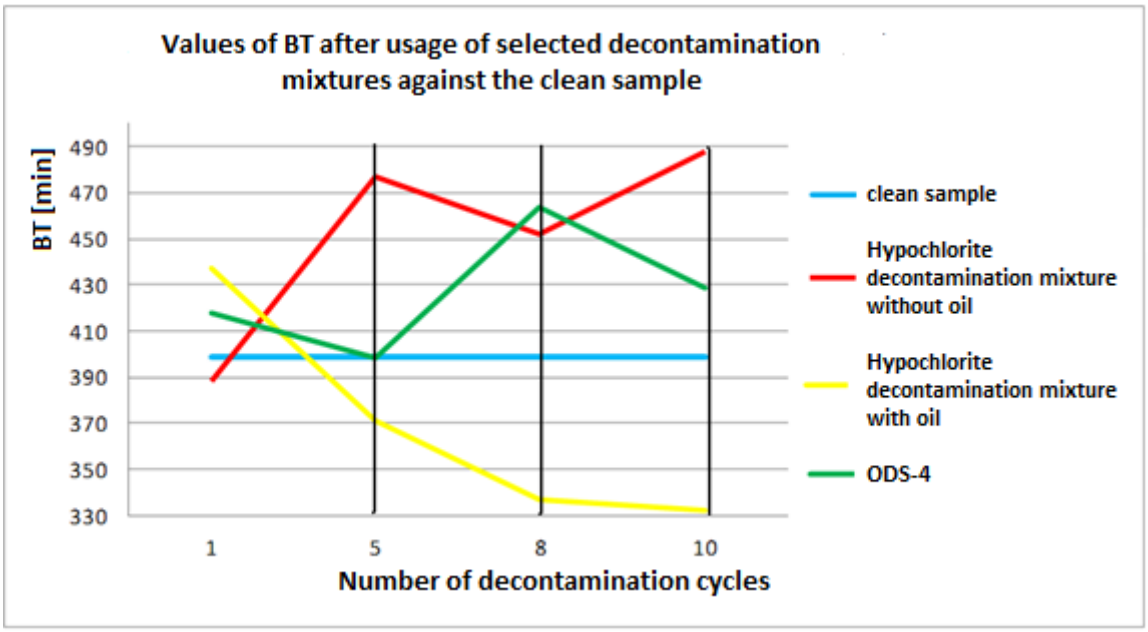

Figure 5: Comparison of changing BT values of tested material after performing the first, fifth, eight, and tenth decontamination cycle with the help of selected decontamination mixtures with the clean sample of the protective foil of OPCH-05

5. Conclusions

Providing high and permanent level protection of the CAF CCs´ specialists against the affection of toxic compounds is one from basic assumption of qualitative fulfillment of decontamination tasks performed by specialists of the CCs. Results introduced in this paper have confirmed that come to different changes of protective properties of tested isolative protective foil not only concerning their mechanical ones but also in relation to change of BT in consequence of the effect of selected decontamination mixtures. With regard to the amount and different chemical composition of simple decontamination mixtures used in the CAF the necessity of study their effects on barrier materials established in army anti-gas protection seems to be absolutely well-founded.

References

[1] OTŘÍSAL, Pavel; MELICHAŘÍK, Zdeněk. Some aspects of the current state of solution of problems of the Czech Armd Forces specialists´ protection against effects of selected decontamination mixtures. (in Czech). In *Zborník vedeckých prác VI. medzinárodnej vedeckej konferencie „Bezpečnostné fórum 2013“ – II. Svazek.* Editoři J. Ušiak, J. Lasicová, D. Kollár. Bánská Bystrica : Fakulta politických vied a medzinárodných vzťahov, Univerzita Mateja Bela v Bánské Bystrici, 6.-7.2.2013, s. 584-591. ISBN 978-80-557-0497-5.

[2] OTŘÍSAL, Pavel; FLORUS, Stanislav; OBŠEL, Vladimír. Breakthrough Time of the Fabric coated with Butyl-rubber Polymer Mixture and its Relationship to the Chemical Structure of selected Toxic Industrial Chemicals. In *Proceedings from 31st International Symposium "Industrial Toxicology 2011".* Editor J. Babjaková. Bratislava : Slovenská spoločnosť priemyselnej chémie, 15.-17.6.2011, s. 24-35. ISBN 978-80-88973-72-0.

[3] MELICHAŘÍK, Zdeněk. Selected Chemical Methods designated for Determination of Chemical Resistance of Isolative Protective Materials against the Affection of Decontamination Mixtures. *Periodica Academica*. 2014, roč. IX, č. 1, s. 58-65. ISSN 1802-2626.]

[4] MELICHAŘÍK, Zdeněk; OTŘÍSAL, Pavel; FLORUS, Stanislav. The influence of hypochlorite decontamination mixture on the change of the chemical resistance of the garments for isolative protection of the chemical specialists´ isolative protection. In Zborník príspevkov 35. medzinárodného vedeckého sympózia „Priemyselná toxikológia 2015. Editoři M. Smolinská, M. Melník. [USB-DISK]. Bratislava : Slovenská technická univerzita v Bratislave, 17.-19.6.2015, s. 189-196. ISBN 978-80-227-4377-8.

[5] MELICHAŘÍK, Zdeněk. Selected aspects of resistivity of barrier materials designated to providing isolative protection of the body surface of chemical specialists. (in Czech). In *Zborník príspevkov 34. medzinárodného vedeckého sympózia „Priemyselná toxikológia 2014.* Editoři M. Smolinská, M. Melník. [USB-DISK]. Bratislava : Slovenská technická univerzita v Bratislave, 18.-20.6.2014, s. 249-257. ISBN 978-80-227-4181-1.