Elemental Composition and Structure of Commercially Available Personal Radiation Shielding Protective Clothing

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Some samples of commercially available personal radiation shielding clothing (RSPC) are tested at the Nuclear Protection Department of the National Institute for NBC Protection (SUJCHBO v. v. i., Czech Republic). Due to the shielding layer this kind of protective clothing protects not only against radioactive contamination but also against penetrating ionizing radiation. Tested samples of RSPC are presented in the table below. In the first part of the testing the attenuation of X and Gamma radiation penetrating the samples of RSPC was measured. Obtained results were published by Kozlovska et al. (2015 – in press).

The next part of the testing is based on Monte Carlo simulation of the effect of reducing the effective dose for a human wearing RSPC in a radioactive atmosphere. For these simulations it is necessary to know the elemental compositions of RSPC samples. As the producers do not provide complete information about RSPC composition, samples of individual RSPC shielding layers were taken to be analyzed with regard to elemental composition and structure. This poster presents used methods and testing of obtained results. The effective dose simulations using obtained results will be presented in further work.

	DEMRON Radiation Torso Vest 1Ply-4Ply	Df Vest (W-2mm/W-1mm)	BIORUBBER E-400 Vest + Pants	BIORUBBER E-600 Vest	DEMRON Full Body Suit	DEMRON Class 2 Full Body Suit	HKX 1558 Whole Body Anti-Radiation Wear
Picture							
Producer	Radiation Shield Technology (USA)	Alpha Technical Research Co. Ltd. (JPN)	YAMAMOTO Corporation (JPN)	YAMAMOTO Corporation (JPN)	Radiation Shield Technology (USA)	Radiation Shield Technology (USA)	Guangzhou Hekang Biotechnology Co. Ltd. (CHN)
Shielding material	DEMRON[a] 1 ply-4 ply	Tungsten in resin	BIORUBBER[b] E-400	BIORUBBER[b] E-600	DEMRON[a] 1 ply	DEMRON[a] 1 ply	Lead compounds in vinyl

[a] DEMRON is a water and gas tight polymer composite of PE, PVC and inorganic salts of high atomic number elements (excluding lead), it is laminated into textile layers

[b] BIORUBBER consist of heavy metal (primarily lead) alloys dispersed in synthetic material with regular honey-comb structure of cells, created by pure limestone, it is laminated into special anti-adhesive BRS layers

Composition and structure study of RSPC

The collection of gathered RSPC can be divided according to their shielding layers material into four groups (DEMRON, BIORUBBER, Df and HKX). Several samples were taken from each type of shielding material. The samples were then analyzed using the following methods:

- Material composition of shielding layers of individual RSPC was studied using X-ray fluorescence spectrometry (XRF) and elemental chemical analysis.
- Structure study of individual RSPC was performed by scanning electron microscopy (SEM). Using energy-dispersive X-ray spectrometry during SEM analysis of samples RSPC the material information was also collected.
- Obtained results of material composition were corrected using results of measuring X and Gamma radiation attenuation in RSPC published by Kozlovska et al. (2015 – in press)

Material composition of RSPC shielding layers

Using the analysis mentioned above, the elemental composition of each of the shielding materials was found. The content of each detected element was determined and the weight percentage was calculated for the content of each element presented in the sample of RSPC. In general the results of analysis may be summarized as follows: The shielding material DEMRON is composed mainly of bismuth and tungsten. In the shielding material of BIORUBBER, as well as in the shielding material of the HKX 1558 suit, lead content dominates. And finally the shielding material of the Df Vest contains mainly tungsten.

Structure of RSPC

The structure of the samples of RSPC was studied using SEM. The photos from the SEM (Fig. 4) show the material structure for each of the shielding materials. The SEM photos show that the materials differ in homogeneity of the shielding layer. This is probably due to different ways of incorporation of heavy metals into the shielding material. It is worth noting that the surface layer BRS of the material BIORUBBER is compact and closed unlike other materials, which are covered on the surface by textiles. Due to this structure the BIORUBBER material has a smaller surface than other materials, which can significantly reduce the possibility of the surface contamination by the radioactive particles.

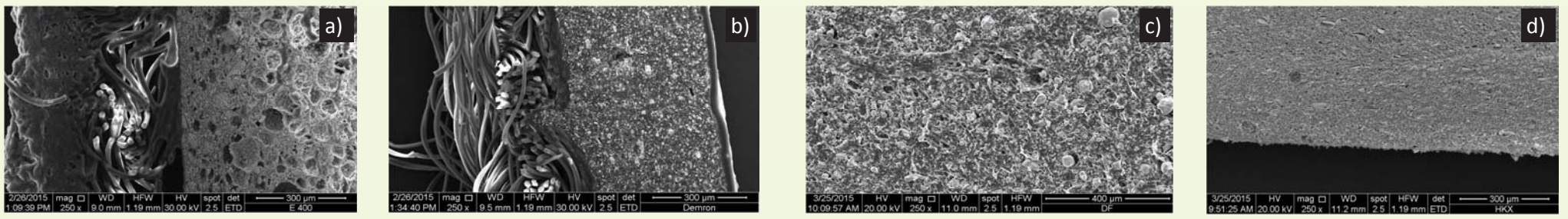

Fig. 1: SEM photos of RSPC samples – a) BIORUBBER RSM E-400 (shielding and cover layer), b) DEMRON Radiation Torso Vest (shielding and cover layer), c) Df-vest (W-2 mm) (shielding layer), d) HKX 1558 Whole Body Anti-Radiation Wear (shielding layer)

Testing obtained information about RSPC

The advantages of a compact closed surface of the BIORUBBER material were confirmed by experiments in the Radon-Aerosol Chamber (RAC). During these experiments, the deposition of radioactive aerosols onto the samples of RSPC samples, placed in the radioactive atmosphere in the RAC, was monitored. As is shown in fig. 2, the contamination of the BIORUBBER samples was much lower than for other RSPC samples.

Obtained results of elemental composition of RSPC samples were used for simulation of the X and gamma radiation attenuation in the RSPC samples. The spectra of photon radiation were simulated using MCNPX 2.6.0 and consequently they were compared with the spectra measured by INSPECTOR 1000 with a scintillation $LaBr_3$ probe IPROL-1. As is evident from the comparison of the simulated and measured spectra of gamma radiation from the ^{133}Ba (Fig. 3), penetrating the sample of Df-Vest (2 mm) and BIORUBBER E-400 Vest, the simulated spectra are in good agreement with measured ones. (The geometry of measurement is well described in Kozlovska et al. (2015 – in press)). This agreement between measured and simulated spectra is also confirmed by the same attenuation values obtained from measured and simulated spectra.

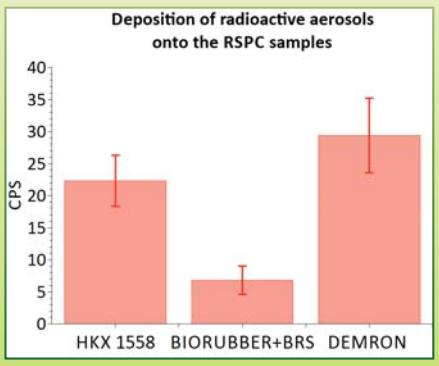

Fig. 2: Comparing the detected response from samples of RSPC after radioactive aerosols deposition in RAC

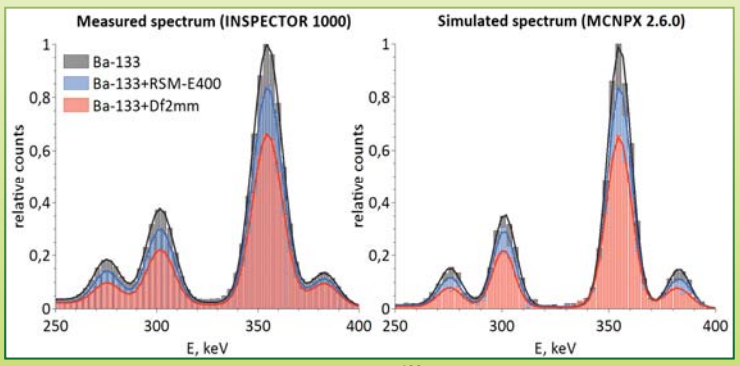

Fig. 3: Comparing the Gamma spectra from ^{133}Ba penetrating samples of BIORUBBER E-400 and Df-vest (W-2mm) with unshielded spectrum

Conclusion

Using several analyses, the elemental composition and structure of commercially available radiation shielding protection clothing (RSPC) were found to be the necessary condition for their simulating. Outstanding agreement between measured and simulated properties of individual RSPC was subsequently achieved. The results will be discussed in more detail in an upcoming publication. The obtained information will be used for simulation of a decrease in the effective dose for a human wearing a sample of RSPC in a radioactive atmosphere. These simulations and their results will be presented in further work.

Acknowledgment

This project has been funded by the Ministry of the Interior of the Czech Republic (project No. VG 20132015105 – "Prevention, Preparedness and Mitigation of Severe Accidents at Czech Nuclear Power Plants in Connection with New Findings of Stress Tests after the Fukushima Accident").

Reference: Kozlovska M., Cerny R. and Otahal P.: Attenuation of X and Gamma Rays in Personal Radiation Shielding Protective Clothing. Health Physics Journal – in press