Pulmonary deposition and chemical composition of biosoluble vitreous fibers

R. Szőke¹, I. Sziklai-László¹, I. Balásházy¹, G. Kudela², W. Hofmann³

¹KFKI Atomic Energy Research Institute, P.O. Box 49, H-1525 Budapest, Hungary
³Division of Physics and Biophysics, University of Salzburg, Hellbrunner Str. 34, 5020 Salzburg, Austria

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INTRODUCTION
How inhaled fibers may cause cell damage related to tumor formation is presently not exactly known, although there are several hypotheses about it. In vivo studies have provided evidences that the most important parameters to determine the carcinogenicity and the toxicity of fibers are the dimensions, the local doses and the particles’ chemical compositions. Fiber length and alveolar geometry appear to be important limiting factors for the submersion of vitreous fibers into the lungs’ surface lining layer. Fiber dimensions are considered to be important because the macrophages that normally remove particles from the lungs cannot engulf fibers much longer than the macrophage diameter. The chemical composition of fibrous materials plays an important role in fiber-induced toxicity, while fiber biodurability directly correlates with pathogenic potential as it was observed in rodents (Jäckel et al., 2005). The main objectives of this study were to determine the deposition pattern of inhaled fibers in the human respiratory system and the concentration of macro- and microcomponents.

METHODS
Fiber depositions in the human respiratory system of a Caucasian-type healthy adult male and 10 years-old child under different physical exertions were computed by the updated version of the stochastic lung deposition model of Koblinger and Hofmann (1990). The computations by the stochastic lung deposition model were performed on the polydisperse system. The extrathoracic model applies the empirical formula of Stahlhofen. Chemical composition was studied by panoramic instrumental and epithermal neutron activation analysis (INAA, ENAA). The accuracy of the analyses was tested by co-analyses of “NIST 613 Trace Elements in Glass” standard reference material.

RESULTS
The highest deposition values were obtained for the extrathoracic region, more than 80%, and only a small fraction of the inhaled fibers reached the tracheobronchial tree and the acinar region, less than 12.4%. Interception contributes significantly to fiber deposition, particularly in the pulmonary part (Szőke et al., 2007). The number and the mass fraction of the inhaled vitreous fibers deposited in different regions of the human lung at resting activity and light physical exercise breathing conditions are presented in Table 1.

Table 1. Number and mass fraction of inhaled biosoluble vitreous fibers deposited in different pulmonary regions.

<table>
<thead>
<tr>
<th>Physical exertion</th>
<th>Interception</th>
<th>Bronchial region</th>
<th>Acinar region</th>
<th>ET</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number distribution %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>resting active</td>
<td>3.38</td>
<td>4.06</td>
<td>4.93</td>
<td>81</td>
</tr>
<tr>
<td>mass distribution %</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>resting active</td>
<td>0.73</td>
<td>2.36</td>
<td>1.63</td>
<td>94</td>
</tr>
<tr>
<td>active</td>
<td>0.01</td>
<td>0.47</td>
<td>0.31</td>
<td>99</td>
</tr>
</tbody>
</table>

Note: resting= resting activity; active= light physical exercise. ET= extrathoracic region.

The deposition fractions are strongly influenced by the level of physical exertion. Deposition in the lungs decreased with rising flow rate. The high percentage of extrathoracic deposition originates from the nose breathing conditions.

The biosoluble glass wool is characterized by a low amount of alumina (~1 wt% Al2O3) and a high amount of boron trioxide (~12 wt% B2O3). CaO, MgO, Na2O, B2O3, and BaO increase the dissolution coefficient, meaning that increasing amounts of this oxide decreases the dissolution rate in borosilicate glass composition. No significant differences between the analyzed glass wool samples were found for Ag, Cs, and Sb; however, the Co (0.29 ± 0.02 µg/g) and Zn (20.56 ± 1.13 µg/g) concentrations were highest in one sample. The concentration of As varied between 2.33-30.17 ppm. Although the chemical composition of fibers is purportedly not responsible for the carcinogenic effect, it can play a potential role in the induction of related health effects due to their toxic components.

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References