Final Report

Project Number:	DERI_06 AEROSZOL1
Project Title:	Hardware and software developments for the determination of the health effects of inhaled aerosols
Workpackage Numbers:	1.-4. (Final Report)
Reporting Period:	2007. 01. 01. – 2010. 01. 01.
Partners of the Consortium:	Technoorg-Linda Scientific Technical Developing Ltd. Hungarian Academy of Sciences KFKI Atomic energy Research Institute Envi-Tech Ltd.
Project Leader:	Dezső Szigethy, director of Technoorg-Linda Ltd.

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Short, comprehensive description of the results achieved during project execution

The execution of the project was carried out according to the project schedule. The proposed tasks and subtasks were all completed. During the project good cooperation has formed between the research institutions and the companies involved in research and development activities. This is well conformed by the successful application of the scientific and technical results. The participants of the project held numerous meetings during the execution of the project, which promoted the progress of the research tasks. Most of the results were presented on international conferences and journals. The references of the numerous publications (3 book chapters, 15 articles in international journals with impact factor, 1 paper in Hungarian journal, 9 publications in conference books and 32 conference abstracts) are listed in the end of this report. The utilization of some of the results has already been completed; other results are near to utilisation in the industry. While fundamental and applied research was in the focus of the first two reporting periods of the project, in the third and fourth periods great emphasis has been laid on the exploitation and marketing of the products. This task was leaded by the two companies participating in the project.

Several result were achieved throughout the project that are unique both on national and international level. During project execution a measuring device, which is based on state-of-the-art technologies, has been developed for the investigation of the air flow filed, particle transport and deposition in hollow replicas of the human airway system. The device composed of the glass pipe structure, the realistic hollow resin lung cast and the optical measuring system that measures the flow and deposition features within these replicas means considerable scientific result. The stochastic lung deposition model, which operates in the whole respiratory tract, and the computational fluid dynamics (CFD) model, which describes the regional deposition processes, are mathematical models based on the latest scientific results and are unique within their own category. Utilising these models user friendly software has been elaborated, which can be valuable product on the market. Some units of the applied measuring device, which were developed in the frame of this project, are important product of the national and international market on their own. The most important results reached in the reporting periods are listed below by subtasks:

First reporting period (1 January 2007 – 31 August 2007)

Subtask 1.1.: The professional issues of the project were analysed and planned at the beginning of the project during two consecutive project meetings and several phone calls. At the same meetings the main aspects of the project coordination and partnership were debated. Since Hungarian partners were the first to apply and get funded the plans were elaborated for two scenarios: acceptance or rejection of the national proposals of the Austrian or German partners.

Subtask 1.2.: CT image series were acquired from the nasal, oral, pharyngeal and laryngeal airways. Morphologically realistic three dimensional airways were digitally reconstructed based on these planar slices.

Subtask 1.3.: Several bronchial airway replicas were prepared in order to optimise the process and to identify the most appropriate technique of cast preparation. During this multistage process a large number of setup options and materials were checked and tested.

Subtask 1.4: Numerical discretization of the idealized airway geometries and realistic ones has been realised by the application of appropriate computational meshes. In this way the digital geometries were converted into computational domains for future fluid and particle dynamics simulations.

Subtask 1.5.: CFPD (computational fluid and particle dynamics) computations have been performed in a geometry consisting of trachea and central bronchi up to the fifth airway generation. Results highlighted the inhomogeneous spatial distribution of particle deposition within the central airways. The strongly nonuniform character of particle deposition patterns was stated also by parallel XRF measurements and computations in realistic rat airways.

Subtask 1.8.: Charge and concentration measurement methods applicable in case of human inhalation experiments were selected, set up and developed for particles in the 5 nm – 100 µm size range. Furthermore, processing procedures of experimentally measured data were elaborated.

Second reporting period (1 September 2007 – 31 August 2008)

Subtask 2.2. Further CT image acquisition from the upper airways of another subject (with gender opposite to the one examined in the first reporting period) has been completed. A 3D digital model geometry was also created. The new 3D model geometry has been compared to the ones composed before in order to highlight the intersubject differences.

Subtask 2.3.: By solving the problems encountered in the previous reporting period regarding the preparation of airway casts (bubbles, wholes etc.) new replicas of near the whole bronchial tree have been prepared.

Subtask 2.4.: Numerical meshes were applied to the geometries reconstructed in the frame of subtask 2.3. A special size function technique has been applied to adequately mesh the highly complex geometries. The resulting mesh was unstructured and inhomogeneous.

Subtask 2.5: The working group of the Hungarian Academy of Sciences KFKI Atomic Energy Research Institute has been performed air and particle transport simulations in idealised and realistic geometries. The geometry reconstructed based on CT images has been scaled so that its tracheal inlet had the same diameter like the idealised one. In this way it became possible to compare the results obtained on idealized geometries on those provided by realistic airways.

Subtask 2.6.: Two complex central airway models were constructed from straight glass tubes. The models were connected to the aerosol generator and breathing simulator devices developed in the frame of subtask 2.8. Air velocity values have been determined in some special locations inside the glass models.

Subtask 2.7.: Results of the aerosol inhalation experiments performed by EUREKA partners (Inamed GmbH, GSF) have been processed and compared to the computational results of the Déri project (Hungarian Project).

Subtask 2.8.: Aerosol generator and measurement devices have been further developed. Aerosols were generated in the 5 nm – 100 µm size range. Airflow velocity profiles have been measured in regions of interest of the airway models.

Third reporting period (1 September 2008 – 31 August 2009)

Subtask 3.5.: In the frame of this task, computational fluid dynamics based calculations were carried out on the transport and deposition of inhaled particles in the regions of the respiratory system most preferred by the malignant mutations that is the large bronchi of the central airway system for inhalation conditions and particle parameters that were considered to be the most important. Further, numerical algorithms were developed and applied for the quantification of local distribution of particle deposition patterns.

Subtask 3.6.: A novel technique has been elaborated for the fabrication of realistic hollow airway replicas. Laser based measurement were completed for particle transport velocities in the constructed hollow casts applying a Doppler method. Based on the results of the measurements velocity profiles were reconstructed in different locations of the pipe system.

Subtask 3.7.: The results of the *in vivo* experiments carried out by the Germen partners of the international EUREKA project were compared with the results of the simulations completed by the Hungarian participants of the Déri Miksa project. In the case of both measuring techniques, the comparisons were made for healthy, COPD (chonic obstructive pulmonary disease) as well as asthmatic airways. In all the cases, the results showed good agreement.

Subtask 3.8.: The Testovent probe applied in the previous reporting period for the determination of the aerosol parameters was replaced by a Laser Doppler instrument since this needs not to be placed in the flow space and, thus, the flow is not perturbed. Particle velocities, size distributions and particle concentrations were determined by the help of this device. The results were compared to those obtained by the numerical models elaborated for this purpose. The results were again in good accordance with each other.

Subtask 3.9.: The measuring device developed in the previous reporting period was completed with five new units. The instrument was utilised to measure the flow patterns characteristic in our glass and resin replicas. By doing so, the testing of the device was also performed.

Subtask 3.10.: In the frame of this task the validation of the lung models developed and utilised during this project were carried out. Furthermore, CFD calculations were completed in the integrated geometry containing the nose, pharynx, larynx, trachea and central airway system. The results of the numerical model were compared with the results of both *in vitro* and *in vivo* measurements. These comparisons were performed by the calculations of flow profiles and deposition patterns. The values obtained by different methods usually were in good agreement with each other. The deviations were within reasonable limits.

Subtask 3.11.: The specifications and information of the potential consumers were started. The Aerosol Department of the University of Vienna, the GRIMM Aerosoltechnik GmbH+Co.KG Ainring, the Joint Research Centre, the Institute for Environment (Ispra, Italy), the American TSI Co and the University of Veszprém collaborated in performing this task. The products were also introduced in the ÖKOTECH exhibitions. The designs of the fliers were also finished.

Forth reporting period (1 September 2009 – 31 December 2009)

Subtask 4.8.: The device jointly constructed was further developed and some new measurements were completed. The Doppler velocity measuring device was developed in two ways in this period: a) the Nd:YAG laser was replaced by a He-Ne laser and b) we succeeded in making some areas of the resin replica transparent enough.

Subtask 4.9.: The results of the aerosol measurements were collected, summarized and analysed. The completed measurements yielded a series of new results since, to the best of our knowledge, up to the present similar measurements were never performed on complex airway replicas made of glass or resin. A part of these results have been published and presented in international conferences. The attained results are in line with the results of the models.

Subtask 4.10.: The lung models were jointly tested and checked again. Lung diseases were simulated with the help of the whole respiratory system deposition models and additional calculations were performed with the help of the CFD based models. The elaborated whole respiratory tract aerosol deposition model and software is ready for the market.

Subtask 4.11.: Measures were taken to find new partners to expand the possibilities of marketing. We have contacted several companies and new project proposals were submitted to some of these companies. The dissemination of the products was continued. Several possibilities were developed for the potential further improvements of the products.

Subtask 4.12.: The final reports and overall documentations were prepared.

Subtask 4.13.: The closure of the project is started. The final documentation is prepared.

Further exploitation possibilities of the results achieved during project execution

The exploitation possibilities of the products of this project are most obvious in the area of companies involved in the production of aerosol medicine. Applying the numerical whole respiratory tract deposition model, the delivery method and particle size of different aerosol drugs can be investigated and optimised in a unique way in the case of various health conditions of the patient (healthy, asthmatic, COPD, emphysema etc) both for adults and infants of different age. To the best of our knowledge, besides the one developed in this project, whole human respiratory tract aerosol deposition model which is able to characterise both healthy subject and diseased patients is not available in the academic circles or the in the international market. The state-of-the-art aerosol measuring device developed in this project can easily be made suitable for numerous other tasks, since the elaborated device can be very useful for all the companies or institutions involved in the measurement of aerosol transport and deposition. As maintained in the previous report, the elaborated measuring technique may be very useful for the investigation of other airway replicas. Beyond these, the instrument is suitable to measure several parameters and the deposition distribution of particles moving through any kind of transparent geometries. The airway replicas made of glass and resin and similarly the computational airway models constructed in this project can also make for educational and illustrative purposes. Thus, the above mentioned range of end users can be widened by educational institutions, as well. The developed aerosol measuring device is a multi component instrument that is easy to develop in several directions. Therefore, the different units of the system can be widely utilised. For instance the device without the Doppler velocity measuring instrument and the airway models can be applied for the measurement of the size distribution, concentration, charge and some other parameters of aerosols in the particle size range of 5 nm – 100 µm, that practically covers the whole reparable range. Similarly, the computational three-dimensional airway models developed in the project in suitable form can be utilised by several computer aided design (CAD) software available on the market. According to the above mentioned the elaborated products may be useful for several companies involved in tasks that differ from those described in the project e.g. companies that fabricate or utilise glass-wool or rock-wool for insulations, since, following a minor additional development, the techniques developed here can be utilised to assess the deposition of the aerosols originating form these materials in the respiratory system of the employees working with these materials. By the help of his method, suitable protection can be devised for these workers

Publications connected to the Déri Miksa project from 1 January 2007 to 31 December 2010

Book chapters:

1. Szymanski W.W., Golczewski A., Nagy A., Gál P., Czitrovszky A. (2007) An innovative approach to Optical Measurement of Atmospheric Aerosols – Determination of the size and complex refractive index of single aerosol particles, in Advanced Environmental Monitoring, ed. Y.J. Kim, U. Platt, Springer, pp. 167-187, 2007.

2. Balásházy I., Farkas Á., Szőke I., Konyicska-Egresi J., Karlinger K., Kerényi T., Nagy J. (2008) A radonterhelés sejtszintű modellezése. Könyv: Környezet és Egészség. Tanulmányok egyes környezeti, fizikai és kémiai tényezők hatásairól. Szerkesztő: Köteles Gy. és Tompa A., Possum Kiadó, Budapest, ISBN 978-963-87453-3-4.

3. Balásházy I., Kudela G., Zichler Sz., Dobos E., Horváth A., Szőke R., Horváth I. (2008) Inhalált aeroszolok légzőrendszeri kiülepedése. Könyv: Környezet és Egészség. Tanulmányok egyes környezeti, fizikai és kémiai tényezők hatásairól. Szerkesztő: Köteles Gy. és Tompa A., Possum Kiadó, Budapest, ISBN 978-963-87453-3-4.

Papers in international journals with impact factors:

1. Balásházy I., Alföldy B., Molnár A.J., Hofmann W., Szőke I., Kis E. (2007) Aerosol drug delivery optimization by computational methods for the characterization of total and regional deposition of therapeutic aerosols in the respiratory system. Current Computer-Aided Drug Design 3, 1, 13-32.

2. Farkas Á., Balásházy I. (2007) Simulation of the effect of local obstructions and blockage on airflow and aerosol deposition in central human airways. Journal of Aerosol Science 38, 865-884.

3. Lopez M.A., Etherington G., Castellani C.M., Franck D., Hurtgen C., Marsh J., Nosske D., Dörfel H., Andrasi A., Bailey M., Balashazy I., Battisti P., Bérard P., Berkowski V., Birchall A., Blanchardon E., Bonchuk Y., Boschung M., Carlan de L., Cantone M.C., Challeton-de Vathaire C., Cruz-Suarez R, Davis K., Dorrian D., Giussani A., Le Guen B., Hodgson A., Jourdain J.R., Koukouliou V., Luciani A., Malatova I., Molokanov A., Moraleda M., Muikku M., Oeh U., Puncher M., Rahola T., Ratia H., and Stradling N. (2007) Coordination of Research on Internal Dosimetry in Europe: the CONRAD Project. Radiation Protection Dosimetry 127, 1-4, 311-316.

4. Szőke I., Balásházy I., Farkas Á. and Hofmann W. (2007) The effect of inhomogeneous activity distributions and airway geometry on cellular doses in radon lung dosimetry. Radiation Protection Dosimetry 127, 1-4, 68-72.

5. Szőke R., Alföldy B., Balásházy I., Hofmann W. and Sziklai-László I. (2007) Size Distribution, Pulmonary Deposition and Chemical Composition of Hungarian Biosoluble Glass Fibers. Inhalation Toxicology 19, 4, 325-332.

6. Balásházy I., Hofmann W., Farkas Á. and Madas B.G. (2008) Three-dimesional model for aerosol transport and deposition in expanding and contracting alveoli. Inhalation Toxicology 20, 611-621.

7. Farkas Á. and Balásházy I. (2008) Quantification of particle deposition in asymmetrical tracheobronchial model geometry. Computers in Biology and Medicine 38, 508-518.

8. Lopez M.A., Etherington G., Castellani C.M., Franck D., Hurtgen C., Marsh J., Nosske, Breustedt B., Blanchardon E., Andrasi A., Bailey M.R., Balashazy I., Battisti P., Bérard P., Birchall A., Broggio D., Challeton-de Vathaire C., Cruz-Suarez R., Doerfel H., Giussani A., Hodgson A., Koukouliou V., Kramer G.H., Le Guen B., Luciani A., Malatova I., Molokanov A., Moraleda M., Muikku M., Oeh U., Puncher M., Rahola T., Stradling N. and Vrba T. (2008) Internal Dosimetry: Towards harmonisation and coordination of research. Radiation Protection Dosimetry 131, 1, 28-33.

9. Szőke I., Farkas Á., Balásházy I. and Hofmann W. (2008) Modelling of cell deaths and cell transformations of inhaled radon in homes and mines based on a biophysical and microdosimetric model. International Journal of Radiation Biology 84, 2, 127-138.

10. Balásházy I., Horváth A., Sárkány Z., Farkas Á., Hofmann W. (2009) Simulation and minimisation of airway deposition of airborne bacteria. Inhalation Toxicology DOI:10.1080/08958370902736646.

11. Balásházy I., Farkas Á., Madas B.G., Hofmann W. (2009) Non-linear relationship of cell hit and transformation probabilities in low dose of inhaled radon progenies. Journal of Radiological Protection 29, 147-162.

12. Kerekes A., Nagy A., Czitrovszky A. (2009) Experimental flow and deposition studies with hollow bronchial airway models, Journal of Aerosol Medicine and Pulmonary Drug Delivery 22, 2, 175-176.

13. Szőke I., Farkas Á., Balásházy I., Hofmann W. (2009) Stochastic aspects of primary cellular consequences of radon inhalation. Radiation Research 171, 1, 96-106.

14. Czitrovszky A. (2010) Application of optical methods for micron- and sub-micron particle measurements, book chapter in: Aerosols – Science and Technology, J. Wiley, (In print).

15. Horváth A., Balásházy I., Farkas Á., Sárkány Z., Dobos E. and Czitrovszky A. (2010) Airway deposition of intact and fragmented pollens Aerobioogy. (Submitted).

Papers in national journals:

1. Farkas Á. (2009) Radon származékok légúti transzportjának, kiülepedésének és egészségre gyakorolt hatásának számítógépes modellezése. Nukleon 2, 1, 25, 1-10.

Papers in conference books:

1. Balásházy I., Szőke I., Farkas Á., Tatár L.G. and Madas B.G. (2007) Radon and the LNT hypothesis. 4th Hungarian Radon Forum, Veszprém, Hungary, 5 April 2007. Book of Proceedings 39-46, Pannon University Publisher, Veszprém, Hungary, (In Hungarian).

2. Farkas Á., Balásházy I., Szőke I. (2007) Numerical modelling of cellular radiation burden of inhaled radon progenies. IRPA Regional Congress for Central and Eastern Europe, 2007, Brasov, Romania. Book of Abstracts: 60, ISBN 10973-87778-3-6. Proceedings: T1 O-3, p.1-7/CD.

3. Farkas Á., Balásházy I., Szőke I. (2007) Környezeti radioaktív aeroszolok légzőrendszeri kiülepedésnek és biológiai hatásának vizsgálata numerikus módszerekkel. III. Kárpát-medencei Környezettudományi Konferencia, Book of Proceedings 85-89. Editors: Máthé Csongor, Mócsy Ildikó, Urák István és Zsigmond Andrea. Ábel Kiadó: Kolozsvár, 2007. ISSN 1842-9815.

4. Farkas Á. and Balásházy I. (2007) Quantification of radon burden in diseased lungs. 4th Hungarian Radon Forum, Veszprém, Hungary, 5 April 2007. Book of Proceedings 19-24, Pannon University Publisher, Veszprém, Hungary, (In Hungarian).

5. Kudela G. and Balásházy I. (2007) Modelling of clearance of deposited radon progenies from the lung. 4th Hungarian Radon Forum, Veszprém, Hungary, 5 April 2007. Book of Proceedings 25-30, Pannon University Publisher, Veszprém, Hungary, (In Hungarian).

6. Madas B.G., Tatár L.G., Balásházy I., Szőke I. and Farkas Á. (2007) Numerical description of the cellular structure of human bronchial epithelium for the analysis of health effects of inhaled radon progenies. 4th Hungarian Radon Forum, Veszprém, Hungary, 5 April 2007. Book of Proceedings 31-37, Pannon University Publisher, Veszprém, Hungary, (In Hungarian).

7. Farkas Á., Balásházy I., Madas B.G., Szőke I. (2009) Radoninhalációhoz kapcsolódó mikrodozimetriai paraméterek és biológiai végpontok térkorrelációi. V. Magyar Radon Fórum Környezetvédelmi Konferencia, Veszprém, 2009. május 18., Cikkgyűjtemény, Pannon Egyetemi Kiadó, Veszprém, Magyarország.

8. Kudela G., Balásházy I., Madas B.G. (2009) Centrális légúti radondepozíció és tisztulás. V. Magyar Radon Fórum Környezetvédelmi Konferencia, Veszprém, 2009. május 18., Cikkgyűjtemény, Pannon Egyetemi Kiadó, Veszprém, Magyarország.

Conference abstracts:

1. Balásházy I., Szőke I., Farkas Á., Filep A., Zichler Sz., Madas B.G. (2007) Risk of radon progenies and the LNT hypothesis. 6th LOWRAD International Conference on Low Dose Radiation Effects on Human Health and Environment. October 18-20, 2007, Budapest, Hungary. Book of Abstracts 29.

2. Kudela G., Balásházy I. (2007) Bronchial radiation burden of the up clearing deeply deposited radon progenies. 6th LOWRAD International Conference on Low Dose Radiation Effects on Human Health and Environment. October 18-20, 2007, Budapest, Hungary. Book of Abstracts 74.

3. Nagy A., Czitrovszky A., Szymanski W.W, Gál P. (2007) Calibration and evaluation of a multi-angle scattering aerosol spectrometer, International Congress on Optical Particle Characterization, pp. 79-80, July 9-13, 2007-11-26, Graz, Austria, 2007.

4. Ocskay R., Salma I., Aalto P., Kulmala M., Gelencsér A., Kiss Gy., Balásházy I. (2007) Number size distribution of atmospheric aerosol particles at urban and rural sites in Hungary with health implications. European Aerosol Conference 2007, Salzburg, Austria, Abstract T08A010.

5. Salma I., Balásházy I. (2007) Characteristic features of urban aerosols and health risk of the anthropogenic components. Meteorological Scientific Days 2007 conference, Budapest, Hungary, 22-23 November 2007. Book of Abstract, 5-8.

6. Szőke I., Farkas Á., Balásházy I., Hofmann W. (2007) Health effects of inhaled radon progenies in homes and mines. European Aerosol Conference 2007, Salzburg, Austria, Abstract T08A020.

7. Szőke R., Sziklai-László I., Balásházy I., Kudela G., Hofmann W. (2007) Pulmonary deposition and chemical composition of biosoluble vitreous fibers. European Aerosol Conference 2007, Salzburg, Austria, Abstract T08A021.

8. Balásházy I., Farkas Á., Szőke I., Hofmann W., Madas B.G. (2008) Development of a complex mechanistic radon induced lung cancer risk model. Lowrad 2008 Conference, 7th International Meeting on the Effects of Low Doses of Radiation in Biological Systems: New Perspectives on Human Exposure. Lisbon, Portugal, 27-29 November 2008. Book of Abstracts 55.

9. Farkas Á., Balásházy I. és Szőke I. (2008) Légúti levegőáramok és részecsketranszport modellezése FLUENT CFD kóddal. ANSYS Konferencia és Partneri Találkozó, Budapest, 2008. október 10.

10. Balásházy I., Farkas Á., Szőke I., Kudela G., Madas B.G. (2009) Inhalált radon leányelemek légúti depozíciója tisztulása és biológiai hatása. IX. Magyar Aeroszol Konferencia, Balatonfüred, 2009. április 27-28. Absztraktgyűjtemény 68-69.

11. Balásházy I., Kudela G. (2009) Radiation burden of the up clearing deeply deposited radon progenies in the central airways. European Aerosol Conference, EAC 2009, Karlsruhe, Germany, 6-11 September 2009, Abstract CD: T122A01

12. Balásházy I., Farkas Á., Szőke I. (2009) Airway deposition and health effects of inhaled radon progenies. European Aerosol Conference, EAC 2009, Karlsruhe, Germany, 6-11 September 2009, Abstract CD: T122A02.

13. Czitrovszky A., Nagy A., Kerekes A. (2009) Air flow and particle deposition experiments with hollow bronchial airway models, Accepted presentation for the European Aerosol Conference, September 6-11, 2009, Karlsruhe, Germany.

14. Czitrovszky A. (2009) "Development of Laser-Based Metrology Methods for Extreme Light Infrastructure Project" 17th International Conference on Advanced Laser Technologies, Sept. 26 - Oct. 1. Antalya, Turkey, Book of Abstracts, p. 205, 2009.

15. Dannhauser D., Nagy A., Czitrovszky A., Szymanski W.W., (2009) Measurement of size and optical properties of aerosol particles with dual-wavelength optical particle spectrometer (DWOPS), 6 pages extended abstract for the Asian Aerosol Conference AAC09, Bangkok, Thailand, Nov. 24-27, 2009.

16. Farkas Á., Balásházy I., Szőke I., Madas B.G. (2009) Computer modelling of transport and deposition of detrimental and therapeutic aerosols in three-dimensional realistic airways. European Aerosol Conference, EAC 2009, Karlsruhe, Germany, 6-11 September 2009, Abstract CD: T101A05.

17. Farkas Á., Balásházy I., Madas B.G., Szőke I., Kudela G. (2009) Microdosimetric model applied to lung tissue with potential applicability to BNCT of the liver. Young Researchers BNCT Meeting in Mainz 2009, 29 September - 02 October 2009. Book of Abstracts 92.

18. Horváth A., Balásházy I., Sárkány Z., Farkas Á., Hofmann W. (2009) Optimization of airway deposition of inhaled bacteria. European Aerosol Conference, EAC 2009, Karlsruhe, Germany, 6-11 September 2009, Abstract CD: T106A02.

19. Horváth A., Balásházy I., Farkas Á., Sárkány Z., Dobos E., Werner H., Czitrovszky A. (2009) Intakt és töredezett pollenrészecskék légzőrendszeri kiülepedés-eloszlásának vizsgálata a sztochasztikus tüdőmodell segítségével. IX. Magyar Aeroszol Konferencia, Balatonfüred, 2009. április 27-28. Absztraktgyűjtemény 62-63.

20. Kerekes A., Nagy A., Czitrovszky A. (2009) Air flow and particle deposition experiments with a bronchial glass lung modell, National Aerosol Conference Balatonfüred, 27-28 April, pp. 60-61, 2009.

21. Kerekes A., Nagy A., Czitrovszky A. (2009) Experimental flow and deposition studies with hollow bronchial airway models. Journal of Aerosol Medicine and Pulmonary Drug Delivery 22(2), pp.175-176, 2009.

22. Kerényi T., Balásházy I. (2009) Ásványi porok tüdőkárosító hatását befolyásoló tényezők. IX. Magyar Aeroszol Konferencia, Balatonfüred, 2009. április 27-28. Absztrakt-gyűjtemény 64-65.

23. Kudela G., Balásházy I., Madas B.G. (2009)_Radiation burden of the up clearing deeply deposited radon progenies in the central airways. Annual Congress of the European Respiratory Society, Vienna, Austria, European Respiratory Journal 34, 477s.

24. Kudela G., Balásházy I., Dobos E. (2009) Aeroszolok légúti depozíciójának numerikus modellezése beteg légzőrendszerben. IX. Magyar Aeroszol Konferencia, Balatonfüred, 2009. április 27-28. Absztraktgyűjtemény 34-35.

25. Madas B.G., Balásházy I., Farkas Á., Szőke I. (2009) Numerical lung epithelium model for radio-induced carcinogenesis studies. 7th Lung Science Conference, Estoril, Portugal, 27-29 March 2009, Book Abstracts 115.

26. Nagy A., Czitrovszky A., Kerekes A., Szymanski W.W. (2009) A Multi-Angle Laser Light Scattering Aerosol Spectrometer, ALT2009 book of abstracts, p. 107., 17th International Conference on Advanced Laser Technologies, Sept. 26 - Oct. 1. Antalya, Turkey 2009.

27. Nagy A., Czitrovszky A., Kerekes A. (2009) Optical measurement method for the measurement of air pollution, National Aerosol Conference Balatonfüred, 27-28 April, pp. 40-41, 2009.

28. Oszetzky D., Nagy A., Kerekes A., Czitrovszky A. (2009) Vertical concentration distribution measurement of atmospheric aerosols by laser light scattering, ALT2009 book of abstracts, p. 129., 17th International Conference on Advanced Laser Technologies, Sept. 26 - Oct. 1. Antalya, Turkey 2009.

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30. Sárkány Z., Balásházy I., Horváth A., Farkas Á., Dobos E., Czitrovszky A., Hofmann W., Kudela G., Magyar P. (2009) Deposition of pollens in the human respiratory system. European Aerosol Conference, EAC 2009, Karlsruhe, Germany, 6-11 September 2009, Abstract CD: T036A01.

31. Szymanski W.W., Nagy A., Czitrovszky A. (2009) Utilization of elastic scattering of light for characterisation of single, aerosol microparticles, Joint Annual Meeting ÖPG-SPS-ÖGA2 (Austrian Physical Society), Innsbruck 2009.

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