ACTION TD1105 EuNetAir

European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability

BOOKLET

WORKING GROUPS MEETING

New Sensing Technologies and Modelling for Air Pollution Monitoring: EuNetAir Air Quality Joint-Exercise Intercomparison

IDAD - Institute of Environment & Development

and University of Aveiro

Aveiro, 13 - 15 October 2014

COST EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

ESSEM Domain

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COST Action TD1105

European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability - EuNetAir

WORKING GROUPS MEETING

New Sensing Technologies and Modelling for Air Pollution Monitoring: EuNetAir Air Quality Joint-Exercise Intercomparison

Aveiro (Portugal), 13 - 15 October 2014

Joint-Exercise Kick-off, 13 October 2014: IDAD - Institute of Environment & Development
WG Meeting, 14-15 October 2014: Environment & Planning Department Auditorium
University of Aveiro, Campus Universitário, 3810-193 Aveiro, Portugal

WG1-WG4 Meeting AGENDA	
13 October 2014 - Monday	*(Participation limited to Joint-Exercise Members only)*
09:00 - 17:00	***REGISTRATION***
09:00 - 12:00	**Group Meeting: *EuNetAir* AQ Joint-Exercise Intercomparison**
12:00 - 13:00	*Lunch*
13:00 - 17:00	**Installation of Sensors in AQ Mobile Lab in Aveiro City Centre**
20:30	*Free Dinner*
14 October 2014 - Tuesday	*(Participation open to WG1-WG4 Members)*
09:00 - 18:00	***REGISTRATION***
09:00 - 09:30	**Session 1: Welcome Address**
09:30 - 11:00	**Session 2: Plenary Session**
11:00 - 11:30	*Coffee Break*
11:30 - 13:00	**Session 3: Oral Presentations**
13:00 - 14:00	*Light Lunch offered by COST Action organization*
14.00 - 15.00	**Session 4: Poster Presentations**
15.00 - 16.30	**Session 5: Oral Presentations**
16:30 - 17:00	*Coffee Break*
17.00 - 18.30	**Session 6: Oral Presentations**
20:30 - 23:00	*Social Dinner*
15 October 2014 - Wednesday	*(Participation open to WG1-WG4 Members)*
09:00 - 13:00	***REGISTRATION***
09:00 - 11:00	**Session 7: Oral Presentations**
11:00 - 11:30	*Coffee-break*
11:30 - 13:00	**Session 8: Oral Presentations**
13:00 - 14:00	*Light Lunch offered by COST Action organization*
14:00 - 16:00	**Session 9: Oral Presentations**
16:00 - 16:30	**Session 10: Discussion and Future Plans of Action**
16:30	***End of the WG1-WG4 Meeting and Farewell***

COST is supported by the EU Framework Programme

European Science Foundation — ESF provides the COST Office through a European Commission contract

Background and goals

About COST Action TD1105 *EuNetAir*

COST Action TD 1105 EuNetAir, a Concerted Action on *New Sensing Technologies for Air-Pollution Control and Environmental Sustainability*, is a running Networking funded in the framework *European Cooperation in the field of Scientific and Technical Research* (COST) during 2012-2016.

The main objective of the Concerted Action is to develop new sensing technologies for Air Quality Control at integrated and multidisciplinary scale by coordinated research on nanomaterials, sensor-systems, air-quality modelling and standardised methods for supporting environmental sustainability with a special focus on Small and Medium Enterprises.

This international Networking, coordinated by ENEA (Italy), includes over 80 big institutions from 28 COST Countries (EU-zone: *Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Latvia, The Former Yugoslav Republic of Macedonia, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom*) and 7 International Partners Countries (extra-Europe: *Australia, Canada, China, Morocco, Russia, Ukraine, USA*) to create a S&T critical mass in the environmental issues.

About the *WG1-WG4 Meeting* at IDAD, Aveiro, Portugal, 13 - 15 October 2014

The WG1-WG4 Meeting (WGM) will be held on 14-15 October 2014 at IDAD - Institute for Environment and Development, University of Aveiro, Aveiro (Portugal) under chairing of Prof. Carlos Borrego (MC Member). The core-issues of the COST Action TD1105 will be surveyed and presented as current results and scientific and technological breakthrough. WG1-WG4 Meeting will discuss on ***New Sensing Technologies and Models for Air-Pollution Monitoring*** in an interdisciplinary approach aiming to provide **intercomparison *sensors-versus-analyzers***, harmonization of the environmental measurements and experimental campaigns, exchange of best practices, quality assurance, quality control, data quality, methods and protocols, development of new sensing technologies, modelling of air pollution, experimental campaigns.

High quality output such as joint-publications of the achieved results of the environmental campaign and discussion of the AQ results to be shared in the Action partnership by future meetings are highly expected. Several teams of the COST Action TD1105 are largely interested and involved by their expression of interest to join on the experimental campaign in Aveiro for Joint-Exercise Intercomparison including the contribution in expertise to the multidisciplinary inter-WGs meeting. At the open ***WGs Meeting*** of the COST Action TD1105 *EuNetAir*, a strong impact on focus of critical environmental issues would be mutual benefit.

More Information

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MC Chair/Proposer of COST Action TD1105 EuNetAir
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Technical Unit for Materials Technologies - Brindisi Research Centre
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WORKING GROUPS MEETING

New Sensing Technologies and Modelling for Air Pollution Monitoring: EuNetAir Air Quality Joint-Exercise Intercomparison

Aveiro (Portugal), 13 - 15 October 2014

Joint-Exercise Kick-off, 13 October 2014: IDAD - Institute of Environment & Development
WG Meeting, 14-15 October 2014: Environment & Planning Department Auditorium
University of Aveiro, Campus Universitário, 3810-193 Aveiro, Portugal



Action Meeting Programme Committee

Michele Penza, ENEA, Brindisi, Italy
Carlos Borrego, IDAD, University of Aveiro, Portugal
Ole Hertel, Aarhus University, Denmark
Kaarle Hameri, University of Helsinki, Finland
Nuria Castell, NILU, Kjeller, Norway
Anita Lloyd Spetz, Linkoping University, Sweden
Andreas Schuetze, Saarland University, Germany
Ingrid Bryntse, SenseAir AB, Sweden
Juan Ramon Morante, IREC, Spain
Marco Alvisi, ENEA, Italy
Corinna Hahn, Eurice GmbH, Saarbrucken, Germany
Juliane Rossbach, Eurice GmbH, Saarbrucken, Germany
Annamaria Demarinis Loiotile, University of Bari, Italy
Ana Margarida Costa, IDAD, Aveiro, Portugal
Miguel Coutinho, IDAD, Aveiro, Portugal
Joao Ginja, IDAD, Aveiro, Portugal

URL: www.cost.eunetair.it

COST Action TD1105 EuNetAir Steering Committee

Michele Penza, ENEA, Brindisi, Italy - *Action Chair*
Anita Lloyd Spetz, Linkoping University, Sweden - *Action Vice-Chair*
Juan Ramon Morante, IREC, Spain
Andreas Schuetze, Saarland University, Germany
Ole Hertel, Aarhus University, Denmark
Ingrid Bryntse, SenseAir AB, Sweden
Jan Theunis, VITO, Belgium
Marco Alvisi, ENEA, Brindisi, Italy
Gianluigi De Gennaro, University of Bari, Italy
Fabio Galatioto, Newscastle University, UK
Ralf Moos, University of Bayreuth, Germany
Mar Viana, CSIC-IDAEA, Barcelona, Spain
Iveta Steinberga, University of Latvia, Riga, Latvia
Corinna Hahn, Eurice GmbH, Saarbrucken, Germany - *Grant Holder*
Julian Gardner, University of Warwick, UK
Rod Jones, University of Cambridge, UK
Giorgio Sberveglieri, University of Brescia, Italy
Eduard Llobet, Universitat Roviri I Virgili, Tarragona, Spain
Thomas Kuhlbusch, IUTA eV, Duisburg, Germany
Albert Romano-Rodriguez, Universitat de Barcelona (UB), Spain
Carlos Borrego, IDAD, University of Aveiro, Portugal
Annamaria Demarinis Loiotile, University of Bari, Italy - *Secretary*

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COST
EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

Monday, 13 October 2014

COST Action TD1105 EuNetAir

Joint-Exercise Kick-off at IDAD - Institute for Environment and Development
University of Aveiro, Campus Universitàrio, 3810-193 Aveiro, Portugal

09:00 - 17:00	**COST Meeting Registration** *Participation limited to Joint-Exercise Members only*
09:00 - 12:00	***Group Meeting: EuNetAir AQ Joint-Exercise Intercomparison*** *Chairperson: Carlos Borrego, Local Chair, IDAD, Aveiro, Portugal*
09:00 - 09:20	**Welcome Address and Intercomparison Features** *Carlos Borrego*, Local Organizing Committee Chair, IDAD, Aveiro, Portugal
09:20 - 09:40	**COST Action TD1105: European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability. Updating** *Michele Penza*, Action Chair, ENEA, Italy
09:40 - 10:30	**Discussion and Inputs from Joint-Exercise Intercomparison Participants**
10:30 - 11:00	**Coffee Break**
11:00 - 12:00	**SHORT PRESENTATIONS (max 5 minutes) on Sensor-System Technical Features of each Team joining to the 1st EuNetAir AQ Joint-Exercise Intercomparison *Sensors-versus-Analyzers*** *Chairpersons: Michele Penza, Action Chair - ENEA, Brindisi, Italy* *Ana Margarida Costa, Local Co-Chair, IDAD, Aveiro, Portugal*
	EuNetAir Partner: Air Quality Mobile Laboratory of IDAD *Joao Ginja,* Local Organizing Committee Member, IDAD, Aveiro, Portugal
	FP7 Project MSP (ICT-2013-10): Multi-Sensor Platform for Smart Building Management and EuNetAir Partner: Sensor Box for Campaign *Anton Köck*, Project Leader, Materials Center Leoben Forschung GmbH (MCL), Leoben, Austria
	MSP-Consortium Partner: Gas Sensors Measurements and Air Sampling for GC-MS *Oliver von Sicard*, Siemens AG, Munich, Germany
	MSP-Consortium and EuNetAir Partner: EveryAware SensorBox (NO_2, O_3, CO, Black Carbon) *Bart Elen and Jan Theunis*, Action WG Member, VITO, Mol, Belgium
	MSP-Consortium and EuNetAir Partner: Low-power Portable NO_2 AQ Sensor-System *Peter Offermans*, Action WG2 Member, IMEC Holst-Centre, Eindhoven, The Netherlands
	EuNetAir Partner: Air-Sensor-Box (NO_2, O_3, CO, SO_2, PM, T, RH) *Domenico Suriano, Mario Prato and Michele Penza*, Action WG Member, ENEA, Brindisi, Italy
	EuNetAir Partner: Sensor-Box (NO_2, PM_{10}, $PM_{2.5}$, $PM_{1.0}$) *Renè Otjes and Ernie Wijers*, Action WG Member, ECN, Petten, The Netherlands
	EuNetAir Partner: Static and Mobile Sensor-Box (NO, NO_2, O_3, CO, CO_2, SO_2) *Nuria Castell and Philipp Schneider*, Action WG Member, NILU, Kjeller, Norway
	MSP-Consortium and EuNetAir Partner: CMOS Sensor-System for Air Quality Monitoring *Foysol Chowdhury*, Action WG Member, CCMOSS Ltd, Cambridge, UK

Joint-Exercise Partner: Relative Humidity Sensor-System for Air Quality Measurements
Nicolas Andrè, Universitè Catholique de Louvain, Louvain, Belgium

EuNetAir Partner: CO_2 Sensor-System for Air Quality Measurements
Joakim Enerud, SenseAir AB, Delsbo, Sweden

EuNetAir Partner: Gas Sensor-System for Air Quality Measurements
Wolfhard Reimringer, 3S GmbH, Saarbrucken, Germany

EuNetAir Partner: Microsensor-Box (NO_2, O_3, p, T, RH) for Air Quality Measurements
Kostas Karatzas, Aristotle University of Thessaloniki, Greece

EuNetAir Partner: SNAQ Sensor Boxes for Air Quality Measurements
Paul Smith, University of Cambridge, Centre for Atmospheric Science, UK

EuNetAir Partner: AQMesh Pod Sensor-Box (NO, NO_2, O_3, CO)
Mar Viana and Mariacruz Minguillon, Action WG Member, CSIC-IDAEA, Barcelona, Spain
Amanda Randle, AQMesh, Warwickshire, UK
- **NOT ATTENDED but their Sensors in Aveiro Intercomparison**

12:00 - 13:00	**Light Lunch offered by COST Action organization**
13:00 - 17:00	***Installation of Sensors in AQ Mobile Lab in Aveiro City Centre*** *Chairperson: Ana Margarida Costa, Local Co-Chair, IDAD, Aveiro, Portugal*
13:00 - 17:00	**All Partners install own sensor-systems and equipment in the AQ Mobile Laboratory parked in the Aveiro city centre**
20:30	**Free Dinner**

Tuesday, 14 October 2014

COST Action TD1105 EuNetAir

organized by IDAD - Institute of Environment and Development

WG Meeting at Environment and Planning Department Auditorium
University of Aveiro, Campus Universitàrio, 3810-193 Aveiro, Portugal

09:00 - 18:00	**COST Meeting Registration** *Participation open to WG1-WG4 Members*
09:00 - 09:30	***Session 1: Welcome Address*** *Chairperson: Carlos Borrego, Local Chair and Action MC Member, IDAD, Aveiro, Portugal*
09:00 - 09:10	*Michele Penza*, COST Action TD1105 Chair, ENEA, Brindisi, Italy
09:10 - 09:20	*Raquel Madureira*, City Councilor for Environment, Aveiro, Portugal
09:20 - 09:30	*Manuel Assuncao*, Rector, University of Aveiro, Portugal
09:30 - 11:00	***Session 2: Plenary Session*** *Chairperson: Michele Penza, Action Chair - ENEA, Brindisi, Italy*
09:30 - 10:00	**COST Action TD1105: European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability. Overview and Plans of COST Action TD1105** *Michele Penza*, Action Chair, ENEA, Brindisi, Italy
10:00 - 10:30	**Human and Environmental Sensing for Hazardous Professions** *Joao Paulo Cunha*, Faculty of Engineering, University of Porto, Portugal
10:30 - 11:00	**Air Quality Monitoring and Modelling: Turning Research into Products and Services** *Carlos Borrego,* Institute of Environment and Development, Aveiro, Portugal
11:00 - 11:30	**Coffee Break**
11:30 - 13:00	***Session 3: Sensor-Systems for Air Quality Monitoring*** *Chairperson: Michele Penza, Action Chair - ENEA, Brindisi, Italy*
11:30 - 12:00	**Nanotech Sensors for Gas Sensing Applications** *Giorgio Sberveglieri*, Action MC Member, University of Brescia, Brescia, Italy
12:00 - 12:30	**FP7 Project MSP (ICT-2013-10): Multi-Sensor Platform for Smart Building Management - Progress and Aspects of Nanowire Integration** *Anton Köck*, Project Leader, Materials Center Leoben Forschung GmbH (MCL), Leoben, Austria
12:30 - 13:00	**Air Quality Sensor Performance: Laboratory and Field Observations** *Nuria Castell*, MC Member, NILU - Norwegian Institute for Air Research, Kjeller, Norway
13:00 - 14:00	**Lunch offered by COST Action organization**

14:00 - 15:00	***Session 4: Posters on Air Quality Monitoring*** *Chairperson: Ana Margarida Costa, Local Co-Chair, IDAD, Aveiro, Portugal*
	Posters (max sizes: 90 cm width x 120 cm height) will be exhibited on Board Panels by Presenters, preferably Early Stage Researchers and Teams from Joint-Exercise including WG Meeting attendees
P01	**A Portable Low-Cost High Density Sensor Network for Air Quality at London Heathrow Airport** *Paul Smith*, University of Cambridge, Centre for Atmospheric Science, UK
P02	**Air-Sensor Box: A Compact Solution for Air Quality Control** *Domenico Suriano,* ENEA, Brindisi, Italy
P03	**A Silicon-On-Insulator (SOI) Platform Functionalized by Atomic Layer Deposition (ALD) for Humidity Sensing** *Nicolas Andrè*, Universitè Catholique de Louvain, Louvain, Belgium
P04	**Gas Sensing Characterization of CMOS Integrated Nanocrystalline SnO_2-Au Thin Films** *Robert Wimmer-Teubenbacher*, Materials Center Leoben Forschung GmbH (MCL), Leoben, Austria
P05	**Outdoor Test Platform for MOX Sensors** *Wolfhard Reimringer*, 3S GmbH, Saarbrucken, Germany
P06	**Indoor Air Quality Assessment in Elderly Care Centers in Porto, Portugal** *Livia Aguiar*, National Institute of Health, Porto, Portugal
P07	**Source Apportionment of Urban $PM_{2.5}$ in Denmark** *J.K. Nøjgaard, A. Massling and T. Ellermann*, Aarhus University, Roskilde, Denmark
P08	**New Particle Formation Events at the Lille Valby Semi-Rural Background Site in Denmark** *F. Wang, M. Ketzel, A. Massling and A. Kristensson,* Aarhus University, Roskilde, Denmark
P09	**Trends of Particle Number and Mass Concentrations in and Around Copenhagen** *A. Massling, T. Ellermann, M. Ketzel and J.K. Nøjgaard,* Aarhus University, Roskilde, Denmark
P10	**Agricultural Airborne N-Pollution, Particle Pollution, Public Health Effects: A GIS based Study** *R.G. Peel, T. Sigsgaard, C.B. Pedersen, S. Gyldenkærne, O. Hertel,* Aarhus University, Denmark
P11	**Assesment of Potential for CoExposure to Allergenic Pollen and Air Pollution in Copenhagen** *P. Viuf Ørby, R. Peel, C.A. Skjøth, V. Schlünssen, J. Bønløkke, T. Ellermann, A. Brændholt, T. Sigsgaard, O. Hertel,* Aarhus University, Roskilde, Denmark

15:00 - 16:30	***Session 5: Air Quality Sensor Measurements*** *Chairperson: Giorgio Sberveglieri, Action MC Member, University of Brescia, Italy*
15:00 - 15:30	**Indoor Air Quality Sensing - An Industry Perspective** *Oliver von Sicard*, Siemens AG, Munich, Germany
15:30 - 15:50	**New Sensing Technologies for Air Quality Control: Field Evaluation of Micro-Sensors against Standard Methods** *Joao Ginja,* Institute of Environment and Development, Aveiro, Portugal
15:50 - 16:10	**Development of AirBox (NO_2, PM_{10}, $PM_{2.5}$) and its Application as Network in City of Eindhoven** *Renè Otjes and Ernie Wijers*, Action WG Member, ECN, Petten, The Netherlands
16:10 - 16:30	**Towards Ultra-Low-Power Environmental Air Monitoring with Power HEMTs** *Peter Offermans*, Action WG2 Member, IMEC Holst-Centre, Eindhoven, The Netherlands

16:30 - 17:00	**Coffee Break**

17:00 - 18:30	***Session 6: Air Quality Sensor Applications*** *Chairperson: Anton Kock, Action MC Member, MCL Forschung GmbH, Leoben, Austria*
17:00 - 17:30	**CMOS Sensor-System for Air Quality Monitoring** *Foysol Chowdhury*, Action WG Member, CCMOSS Ltd, Cambridge, UK
17:30 - 17:50	**Towards Real-time Data Fusion of Low-Cost Sensor Observations with Model Output for Mapping Urban-Scale Air Quality** *Philipp Schneider*, Action WG Member, NILU, Kjeller, Norway
17:50 - 18:10	**Air Sensor-Box for Air Quality Control Measurements** *Michele Penza and Domenico Suriano*, Action WG Member, ENEA, Brindisi, Italy
18:10 - 18:30	**Does the Evolution of Sensor Technology and Computational Methods Lead to a Revolution in AQ-Environmental Monitoring and to a New Generation of Quality of Life Information Services?** *Kostas Karatzas*, Aristotle University of Thessaloniki, Greece
20:30 - 23:00	**Social Dinner**

Wednesday, 15 October 2014

COST Action TD1105 EuNetAir

organized by IDAD - Institute of Environment and Development

WG Meeting at Environment and Planning Department Auditorium
University of Aveiro, Campus Universitàrio, 3810-193 Aveiro, Portugal

09:00 - 13:00	**COST Meeting Registration** *Participation open to WG1-WG4 Members*
09:00 - 11:00	***Session 7: Environmental Measurements and Modelling*** *Chairperson: Carlos Borrego, Local Chair and Action MC Member, IDAD, Aveiro, Portugal*
09:00 - 09:30	**Distribution of Pollen and Particulate Matter within the Urban Agglomeration of Berlin** *Hans-Guido Muecke*, WHO Collaborating Centre for Air Quality Management and Air Pollution Control - Federal Environment Agency, Berlin, Germany
09:30 - 10:00	**Air Quality Modelling in Slovenia: Studying Sensitivity of Operational WRF/Chem Forecast** *Rahela Zabkar*, University of Ljubljana, Liubljana, Slovenia
10:00 - 10:20	**Air Quality Measurements and Modelling in Hungary** *Krisztina Labancz*, Hungarian Meteorological Service, Budapest, Hungary
10:20 - 10:40	**Air Quality Modelling in Latvia: Challenges and Failures** *Iveta Steinberga*, University of Latvia, Riga, Latvia
10:40 - 11:00	**Emergency Response and Chemical Weather Forecast Systems in Bulgarian NIMH** *Kiril Slavov*, Bulgarian Academy of Sciences, Sofia, Bulgaria
11:00 - 11:30	**Coffee Break**
11:30 - 13:00	***Session 8: Health Assessment of Human Exposure to Air Pollution*** *Chairperson: Miguel Coutinho, IDAD, Aveiro, Portugal*
11:30 - 12:00	**Assessing Human Exposure to Air Pollution in Health Assessment Studies in Europe** *Ole Hertel*, Action WG3 Chair, Aarhus University, Roskilde, Denmark
12:00 - 12:20	**Health and Indoor Environment in Elderly Care Centers** *Ana Sofia Mendes*, National Institute of Health, Porto, Portugal
12:20 - 12:40	**Indoor and Outdoor Levels and Content of Selected Toxic Species in PM_{10} and $PM_{2.5}$ of Urban Kindergarten Located in Residential-Commercial Area** *Milena Jovasevic-Stojanovic*, Action WG3 Member, Institute Vinca, Belgrade, Serbia
12:40 - 13:00	**Spatial Distribution and Origin of Pollutants in Lichens for Fingerprinting of Air-Pollution** *Cristina Maguas*, University of Lisbon, Lisbon, Portugal
13:00 - 14:00	**Lunch offered by COST Action organization**

14:00 - 16:00 ***Session 9: Market-Oriented and Commercial Sensors for Air-Pollution Control***
Chairperson: Oliver von Sicard, Siemens AG, Munich, Germany

14:00 - 14:20 **Chemical Sondes using Low Cost Sensors: Project Aims and Outlines**
Paul Smith, University of Cambridge, Centre for Atmospheric Science, UK

14:20 - 14:40 **NDIR Sensors: Trends and Applications**
Joakim Enerud, SenseAir SA, Delsbo, Sweden

14:40 - 15:00 **A Versatile Outdoor Platform for MOX Sensor Field Tests**
Wolfhard Reimringer, 3S GmbH, Saarbrucken, Germany

15:00 - 15:20 **A Silicon-On-Insulator (SOI) Platform Functionalized by Atomic Layer Deposition (ALD) for Humidity Sensing**
Nicolas Andrè, Universitè Catholique de Louvain, Louvain, Belgium

15:20 - 15:40 **Volatile Organic Compound Detection by Polymer-Nanostructured Carbon Composite**
G.Sakale, M.Knite, S.Stepina, E.Liepa, S.Sergejeva, Riga Technical University, Latvia

15:40 - 16:00 **Towards Zero-Power Gas Detection Systems Based on Single Nanowires**
Albert Romano-Rodriguez, Universitat de Barcelona, Department of Electronics, Barcelona, Spain

16:00 - 16:30 ***Session 10: Discussion and Future Plans of Action***
Chairperson: Michele Penza, Action Chair - ENEA, Brindisi, Italy

16:00 - 16:10 **Future Plans of COST Action TD1105 *EuNetAir***
Michele Penza, Action Chair, ENEA, Italy

16:10 - 16:20 **Research & Innovation Needs Completion of COST Action TD1105**
Marco Alvisi, Action SIG1 Leader, ENEA, Italy

16:20 - 16:30 **Inputs and Advices from *Action Workshop Advisory Board*:**

- *Carlos Borrego*, IDAD, Institute for Environment and Development, Aveiro, Portugal
- *Anton Kock,* MCL Forschung GmbH, Leoben, Austria
- *Iveta Steinberga*, University of Latvia, Riga, Latvia
- *Hans-Guido Muecke,* WHO CC for Air Quality Management and Air Pollution Control - Federal Environment Agency, Berlin, Germany
- *Oliver von Sicard,* Siemens AG, Munich, Germany

16:30 ***End of the WG1-WG4 Meeting and Farewell***

WELCOME ADDRESS

This is a great honor and my pleasure to chair and welcome to ALL PARTICIPANTS of the **Working Groups Meeting**, joined to **Air Quality Joint-Exercise Intercomparison**, of our COST Action TD1105 *European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability - EuNetAir*.

This COST Meeting - held on 13-15 October 2014 - on ***New Sensing Technologies and Modelling for Air Pollution Monitoring*** is organized by IDAD (Institute for Environment and Development) and University of Aveiro, supported by **Municipality of Aveiro** and hosted at **Auditorium of Environment and Planning Department**, Campus Universitario, with the Local Organizing Support from IDAD, Aveiro, Portugal.

This **WGs Meeting** follows the previous *COST WGs Meeting in Copenhagen* (3-4 October 2013), and it is attended from at least 50 Participants and includes 10 Sessions with 2 Keynote Speakers, 9 Invited Speakers, 19 Oral Speakers and 8 Poster Presenters from at least 17 COST Countries. **Intercomparison** was participated by 15 Teams from 12 COST Countries. An international Advisory Board (*Steering Committee*) composed by 22 Members has served with S&T inputs to define Workshop Programme. *Female participants* are as 30% and *Male participants* are as 70% with a quota of *Early Stage Researchers* as 23%.

The concerted COST Action TD1105 *EuNetAir* - related to R&D issues of the air quality monitoring including environmental technologies, nanomaterials, functional materials, gas sensors, smart systems, air-pollution modelling, measurements, methods, standards and protocols - is very pleased to connect international specialists and excellent scientists to create a networking of Pan-European R&D platform from 28 COST Countries and 7 Non-COST Countries. Most part of COST Countries are represented in this Meeting.

Special thanks to **COST Officers**: Dr. Deniz Karaca, *ESSEM Science Officer* and Dr. Andrea Tortajada, *Administrative Officer*, involved to manage policy & administration in our Action.

On behalf of the Action Management Committee, I would like to thank ALL Workshop **Participants**, **Grant Holder**, **Action Scientific Secretary**, **Local Organizing Committee** by IDAD, **Environment and Planning Department**, and **University of Aveiro**, represented by Rector, finally **Municipality of Aveiro**, represented by *City Councilor for Environment*, in order to give us the opportunity to disseminate the results of the COST Action TD1105 *EuNetAir* towards a wide international targeted audience involved in the Air Quality Control, with special focus on *Joint-Exercise AQ Intercomparison*, as local hot-issue.
With their valuable scientific work and management, kind availability and great enthusiasm will make our Action Meeting very successful !

Enjoy your *EuNetAir* WGs Meeting at *Environment & Planning Department* in Aveiro !

Aveiro, 8 October 2014

Michele Penza, ENEA, Brindisi, Italy
COST Action TD1105 Chair
michele.penza@enea.it

EuNetAir COST Action TD1105 Logo

LIST OF PRESENTERS

Joint-Exercise Kick-off at IDAD - Institute for Environment and Development Group Meeting: EuNetAir AQ Joint-Exercise Intercomparison

Welcome Address and Intercomparison Features
Carlos Borrego, Local Organizing Committee Chair, IDAD, Aveiro, Portugal

COST Action TD1105: European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability. Updating
Michele Penza, Action Chair, ENEA, Italy

Discussion and Inputs from Joint-Exercise Intercomparison Participants

SHORT PRESENTATIONS on Sensor-System Technical Features of each Team joining to the 1st EuNetAir AQ Joint-Exercise Intercomparison Sensors-versus-Analyzers

EuNetAir Partner: Air Quality Mobile Laboratory of IDAD
Joao Ginja, Local Organizing Committee Member, IDAD, Aveiro, Portugal

FP7 Project MSP (ICT-2013-10): Multi-Sensor Platform for Smart Building Management and EuNetAir Partner: Sensor Box for Campaign
Anton Köck, Project Leader, Materials Center Leoben Forschung GmbH (MCL), Leoben, Austria

MSP-Consortium Partner: Gas Sensors Measurements and Air Sampling for GC-MS
Oliver von Sicard, Siemens AG, Munich, Germany

MSP-Consortium and EuNetAir Partner: EveryAware SensorBox (NO_2, O_3, CO, Black Carbon)
Bart Elen and Jan Theunis, Action WG Member, VITO, Mol, Belgium

MSP-Consortium and EuNetAir Partner: Low-power Portable NO_2 AQ Sensor-System
Peter Offermans, Action WG2 Member, IMEC Holst-Centre, Eindhoven, The Netherlands

EuNetAir Partner: Air-Sensor-Box (NO_2, O_3, CO, SO_2, PM, OPC, T, RH)
Domenico Suriano, Mario Prato and Michele Penza, Action WG Member, ENEA, Brindisi, Italy

EuNetAir Partner: Sensor-Box (NO_2, PM_{10}, $PM_{2.5}$, $PM_{1.0}$)
Renè Otjes and Ernie Wijers, Action WG Member, ECN, Petten, The Netherlands

EuNetAir Partner: Static and Mobile Sensor-Box (NO, NO_2, O_3, CO, CO_2, SO_2)
Nuria Castell and Philipp Schneider, Action WG Member, NILU, Kjeller, Norway

MSP-Consortium and EuNetAir Partner: CMOS Sensor-System for Air Quality Monitoring
Foysol Chowdhury, Action WG Member, CCMOSS Ltd, Cambridge, UK

Joint-Exercise Partner: Relative Humidity Sensor-System for Air Quality Measurements
Nicolas Andrè, Universitè Catholique de Louvain, Louvain, Belgium

EuNetAir Partner: CO_2 Sensor-System for Air Quality Measurements

Joakim Enerud, SenseAir AB, Delsbo, Sweden

EuNetAir Partner: Gas Sensor-System for Air Quality Measurements
Wolfhard Reimringer, 3S GmbH, Saarbrucken, Germany

EuNetAir Partner: Microsensor-Box (NO_2, O_3, p, T, RH) for Air Quality Measurements
Kostas Karatzas, Aristotle University of Thessaloniki, Greece

EuNetAir Partner: SNAQ Sensor Boxes for Air Quality Measurements
Paul Smith, University of Cambridge, Centre for Atmospheric Science, UK

EuNetAir Partner: AQMesh Pod Sensor-Box (NO, NO_2, O_3, CO)
Mar Viana and Mariacruz Minguillon, Action WG Member, CSIC-IDAEA, Barcelona, Spain
Amanda Randle, AQMesh, Warwickshire, UK

WG Meeting at Environment and Planning Department Auditorium University of Aveiro, Campus Universitàrio

Session 1: Welcome Address

Michele Penza, COST Action TD1105 Chair, ENEA, Brindisi, Italy

Raquel Madureira, City Councilor for Environment, Aveiro, Portugal

Manuel Assuncao, Rector, University of Aveiro, Portugal

Session 2: Plenary Session

COST Action TD1105: European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability. Overview and Plans of COST Action TD1105
Michele Penza, Action Chair, ENEA, Brindisi, Italy

Human and Environmental Sensing for Hazardous Professions
Joao Paulo Cunha, Faculty of Engineering, University of Porto, Portugal

Air Quality Monitoring and Modelling: Turning Research into Products and Services
Carlos Borrego, Institute of Environment and Development, Aveiro, Portugal

Session 3: Sensor-Systems for Air Quality Monitoring

Nanotech Sensors for Gas Sensing Applications
Giorgio Sberveglieri, Action MC Member, University of Brescia, Brescia, Italy

FP7 Project MSP (ICT-2013-10): Multi-Sensor Platform for Smart Building Management - Progress and Aspects of Nanowire Integration
Anton Köck, Project Leader, Materials Center Leoben Forschung GmbH (MCL), Leoben, Austria

Air Quality Sensor Performance: Laboratory and Field Observations
Nuria Castell, MC Member, NILU - Norwegian Institute for Air Research, Kjeller, Norway

Session 4: Posters on Air Quality Monitoring

P01: **A Portable Low-Cost High Density Sensor Network for Air Quality at London Heathrow Airport**
Paul Smith, University of Cambridge, Centre for Atmospheric Science, UK

P02: **Air-Sensor Box: A Compact Solution for Air Quality Control**
Domenico Suriano, ENEA, Brindisi, Italy

P03: **A Silicon-On-Insulator (SOI) Platform Functionalized by Atomic Layer Deposition (ALD) for Humidity Sensing**
Nicolas Andrè, Universitè Catholique de Louvain, Louvain, Belgium

P04: **Gas Sensing Characterization of CMOS Integrated Nanocrystalline SnO_2-Au Thin Films**
Robert Wimmer-Teubenbacher, Materials Center Leoben Forschung GmbH (MCL), Leoben, Austria

P05: **Outdoor Test Platform for MOX Sensors**
Wolfhard Reimringer, 3S GmbH, Saarbrucken, Germany

P06: **Indoor Air Quality Assessment in Elderly Care Centers in Porto, Portugal**
Livia Aguiar, National Institute of Health, Porto, Portugal

P07**: Source Apportionment of Urban $PM_{2.5}$ in Denmark**
J.K. Nøjgaard, A. Massling and T. Ellermann, Aarhus University, Roskilde, Denmark

P08**: New Particle Formation Events at the Lille Valby Semi-Rural Background Site in Denmark**
F. Wang, M. Ketzel, A. Massling and A. Kristensson, Aarhus University, Roskilde, Denmark

P09**: Trends of Particle Number and Mass Concentrations in and Around Copenhagen**
A. Massling, T. Ellermann, M. Ketzel and J.K. Nøjgaard, Aarhus University, Roskilde, Denmark

P10**: Agricultural Airborne N-Pollution, Particle Pollution, Public Health Effects: A GIS based Study**
R.G. Peel, T. Sigsgaard, C.B. Pedersen, S. Gyldenkærne, O. Hertel, Aarhus University, Denmark

P11**: Assesment of Potential for CoExposure to Allergenic Pollen and Air Pollution in Copenhagen**
P. Viuf Ørby, R. Peel, C.A. Skjøth, V. Schlünssen, J. Bønløkke, T. Ellermann, A. Brændholt, T. Sigsgaard, O. Hertel, Aarhus University, Roskilde, Denmark

Session 5: Air Quality Sensor Measurements

Indoor Air Quality Sensing - An Industry Perspective
Oliver von Sicard, Siemens AG, Munich, Germany

New Sensing Technologies for Air Quality Control: Field Evaluation of Micro-Sensors against Standard Methods
Joao Ginja, Institute of Environment and Development, Aveiro, Portugal

Development of AirBox (NO_2, PM_{10}, $PM_{2.5}$) and its Application as Network in City of Eindhoven
Renè Otjes and Ernie Wijers, Action WG Member, ECN, Petten, The Netherlands

Towards Ultra-Low-Power Environmental Air Monitoring with Power HEMTs
Peter Offermans, Action WG2 Member, IMEC Holst-Centre, Eindhoven, The Netherlands

Session 6: Air Quality Sensor Applications

CMOS Sensor-System for Air Quality Monitoring
Foysol Chowdhury, Action WG Member, CCMOSS Ltd, Cambridge, UK

Towards Real-time Data Fusion of Low-Cost Sensor Observations with Model Output for Mapping Urban-Scale Air Quality
Philipp Schneider, Action WG Member, NILU, Kjeller, Norway

Air Sensor-Box for Air Quality Control Measurements
Michele Penza and Domenico Suriano, Action WG Member, ENEA, Brindisi, Italy

Does the Evolution of Sensor Technology and Computational Methods Lead to a Revolution in AQ-Environmental Monitoring and to a New Generation of Quality of Life Information Services?
Kostas Karatzas, Aristotle University of Thessaloniki, Greece

Session 7: Environmental Measurements and Modelling

Distribution of Pollen and Particulate Matter within the Urban Agglomeration of Berlin
Hans-Guido Muecke, WHO Collaborating Centre for Air Quality Management and Air Pollution Control - Federal Environment Agency, Berlin, Germany

Air Quality Modelling in Slovenia: Studying Sensitivity of Operational WRF/Chem Forecast
Rahela Zabkar, University of Ljubljana, Liubljana, Slovenia

Air Quality Measurements and Modelling in Hungary
Krisztina Labancz, Hungarian Meteorological Service, Budapest, Hungary

Air Quality Modelling in Latvia: Challenges and Failures
Iveta Steinberga, University of Latvia, Riga, Latvia

Emergency Response and Chemical Weather Forecast Systems in Bulgarian NIMH
Kiril Slavov, Bulgarian Academy of Sciences, Sofia, Bulgaria

Session 8: Health Assessment of Human Exposure to Air Pollution

Assessing Human Exposure to Air Pollution in Health Assessment Studies in Europe
Ole Hertel, Action WG3 Chair, Aarhus University, Roskilde, Denmark

Health and Indoor Environment in Elderly Care Centers
Ana Sofia Mendes, National Institute of Health, Porto, Portugal

Indoor and outdoor levels and content of selected toxic species in PM_{10} and $PM_{2.5}$ of urban kindergarten located in residential-commercial area
Milena Jovasevic-Stojanovic, Action WG3 Member, Institute Vinca, Belgrade, Serbia

Spatial Distribution and Origin of Pollutants in Lichens for Fingerprinting of Air-Pollution
Cristina Maguas, University of Lisbon, Lisbon, Portugal

Session 9: Market-Oriented and Commercial Sensors for Air-Pollution Control

Chemical Sondes using Low Cost Sensors: Project Aims and Outlines

Paul Smith, University of Cambridge, Centre for Atmospheric Science, UK

NDIR Sensors: Trends and Applications
Joakim Enerud, SenseAir SA, Delsbo, Sweden

A Versatile Outdoor Platform for MOX Sensor Field Tests
Wolfhard Reimringer, 3S GmbH, Saarbrucken, Germany

A Silicon-On-Insulator (SOI) Platform Functionalized by Atomic Layer Deposition (ALD) for Humidity Sensing
Nicolas Andrè, Universitè Catholique de Louvain, Louvain, Belgium

Volatile Organic Compound Detection by Polymer-Nanostructured Carbon Composite
G.Sakale, M.Knite, S.Stepina, E.Liepa, S.Sergejeva, Riga Technical University, Latvia

Towards Zero-Power Gas Detection Systems Based on Single Nanowires
Albert Romano-Rodriguez, Universitat de Barcelona, Department of Electronics, Barcelona, Spain

Session 10: Discussion and Future Plans of Action

Future Plans of COST Action TD1105 EuNetAir
Michele Penza, Action Chair, ENEA, Italy

Research & Innovation Needs Completion of COST Action TD1105
Marco Alvisi, Action SIG1 Leader, ENEA, Italy

Inputs and Advices from Action Workshop Advisory Board:

- *Carlos Borrego*, IDAD, Institute for Environment and Development, Aveiro, Portugal
- *Anton Kock*, MCL Forschung GmbH, Leoben, Austria
- *Iveta Steinberga*, University of Latvia, Riga, Latvia
- *Hans-Guido Muecke*, WHO CC for Air Quality Management and Air Pollution Control - Federal Environment Agency, Berlin, Germany
- *Oliver von Sicard*, Siemens AG, Munich, Germany

ABSTRACTS OF INVITED TALKS

Invited Talk

COST ACTION TD1105 ON NEW SENSING TECHNOLOGIES FOR AIR-POLLUTION CONTROL AND ENVIRONMENTAL SUSTAINABILITY: OVERVIEW AND PLANS OF ACTION

M. Penza and Consortium *EuNetAir*
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Abstract

This is a short overview of the COST Action TD1105 *EuNetAir - European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability* - funded in the framework *European Cooperation in the field of Scientific and Technical Research* (COST) during the period 2012-2016.

The main objective of the Concerted Action is to develop new sensing technologies for Air Quality Control at integrated and multidisciplinary scale by coordinated research on nanomaterials, sensor-systems, air-quality modelling and standardised methods for supporting environmental sustainability with a special focus on Small and Medium Enterprises.

This international Networking, coordinated by ENEA (Italy), includes over 80 big institutions and over 180 international experts from 28 COST Countries (EU-zone: *Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Latvia, The Former Yugoslav Republic of Macedonia, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom*) and 7 Non-COST Countries (extra-Europe: *Australia, Canada, China, Morocco, Russia, Ukraine, USA*) to create a S&T critical mass in the environmental issues.

This COST Action [1, 2] (see logo in Fig. 1) will focus on a new detection paradigm based on sensing technologies at low cost for Air Quality Control (AQC) and set up an interdisciplinary top-level coordinated network to define innovative approaches in sensor nanomaterials, gas sensors, devices, wireless sensor-systems, distributed computing, methods, models, standards and protocols for environmental sustainability within the European Research Area (ERA).

The state-of-the-art showed that research on innovative sensing technologies for AQC based on advanced chemical sensors and sensor-systems at low-cost, including functional materials and nanotechnologies for eco-sustainability applications, the outdoor/indoor environment control, olfactometry, air-quality modelling, chemical weather forecasting, and related standardisation methods is performed already at the international level, but still needs serious efforts for coordination to boost new sensing paradigms for research and innovation. Only a close multidisciplinary cooperation will ensure cleaner air in Europe and reduced negative effects on human health for future generations in smart cities, efficient management of green buildings at low CO_2 emissions, and sustainable economic development.

Figure 1. COST Office, ESSEM Domain and Action TD1105 EuNetAir Logo.

The aim of the Action is to create a cooperative network to explore new sensing technologies for low-cost air-pollution control through field studies and laboratory experiments to transfer the results into preventive real-time control practices and global sustainability for monitoring climate changes and outdoor/indoor energy efficiency. Establishment of such a European network, involving Non-COST key-experts, will enable EU to develop world capabilities in urban sensor technology based on cost-effective nanomaterials and contribute to form a critical mass of researchers suitable for cooperation in science and technology, including training and education, to coordinate outstanding R&D and promote innovation towards industry, and support policy-makers. Main objectives of Action are listed, but not limited to:

- to establish a top-level Pan-European multidisciplinary R&D platform on new sensing paradigm for AQC contributing to sustainable development, green-economy and social welfare
- to create collaborative research teams in the ERA on the new sensing technologies for AQC in an integrated approach to avoid fragmentation of the research efforts
- to train Early Stage Researchers (ESR) and new young scientists in the field for supporting competitiveness of European industry by qualified human potential
- to promote gender balance and involvement of ESR in AQC
- to disseminate R&D results on AQC towards industry community and policy makers as well as general public and high schools.

The Workplan is organized in four complementary Working Groups (WGs), each devoted to a progressive development of synthesis, characterization, fabrication, integration, prototyping, proof-of-concepts, modeling, measurements, methods, standards, tests and application aspects. The four WGs with the specific objectives are:

- **WG1**: *Sensor materials and nanotechnology*
- **WG2**: *Sensors, devices and sensor-systems for AQC*
- **WG3**: *Environmental measurements and air-pollution modeling*
- **WG4**: *Protocols and standardisation methods*

This Action will focus on the study of sensor nanomaterials and nanotechnologies exhibiting unique properties in terms of chemical and thermal stability, high sensitivity, selectivity. Nanosize effects of functional materials will be explored for integration in the gas sensors at low power-consumption. Furthermore, specific nanostructures with tailored sensing properties will be developed for gas sensors and sensor-systems with advanced functionalities.

Selected high-quality research products and innovative technologies developed by the partnership of COST Action TD1105 are shown in the Figure 2.

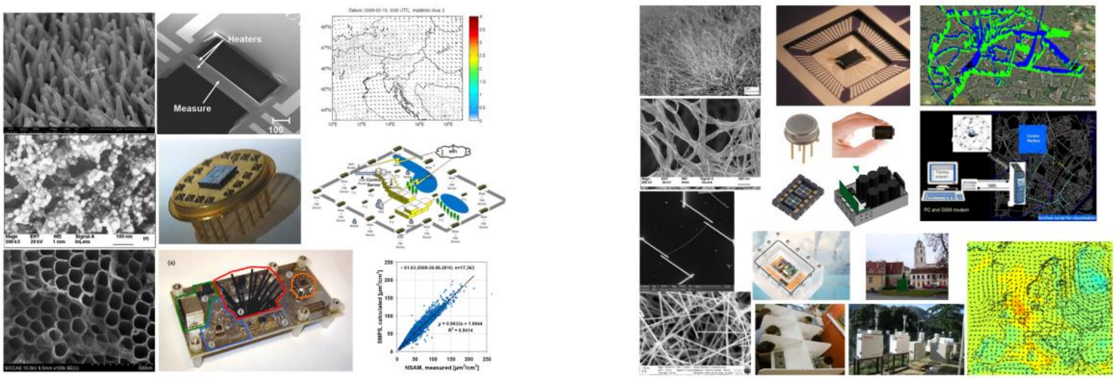

Figure 2. Selected R&D technological products developed by some partners (academia, research institutes, agencies, industry) involved in the COST Action TD1105 *EuNetAir*. Courtesy from *EuNetAir* partnership.

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1. Action Memorandum of Understanding: http://www.cost.eu/domains_actions/essem/Actions/TD1105
2. Action website: http://www.cost.eunetair.it

Invited Talk

HUMAN AND ENVIRONMENTAL SENSING FOR HAZARDOUS PROFESSIONS

João Paulo Cunha
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Abstract

Personalized healthcare and wellness management is increasingly being adopted given the evolution of new technologies that are converging to support this concept of knowing better your genes and your physiological state and trimming your day-to-day activities or your treatments and therapeutics for each person. Apart from the genomics and proteomics contribution to this concept that is getting most of the attention in the scientific media [1], self tracking or quantified-self monitoring based on novel human (and surrounding environment) sensing [2] constitutes another component that can contribute to this objective.

Within this movement, wearable technologies may play a central role. These technologies have been evolving towards its daily usage [3] and are becoming a major player in the personalized health&wellbeing challenge [4]. We have been addressing this challenge for the last 10 years, and provided some contributions in the area [5,6,7].

In this invited talk, we will present the evolution of different wearable human and environmental sensing technologies that enables monitoring of different variables the human is exposed to in different scenarios. We have been particularly interested on hazardous professionals' groups such as firemen, policemen and paramedics first responders. We will also address how we are evolving these technologies to be integrated into the "Future Cities" concept [8] we are implementing in the city of Porto, addressing, for example, the Public Bus drivers professionals.

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AIR QUALITY MONITORING AND MODELLING: TURNING RESEARCH INTO PRODUCTS AND SERVICES

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Introduction

IDAD-Institute of Environment and Development acts as the interface unit for development, consulting and services of University of Aveiro. IDAD is a scientific and technical not-for-profit association, acting at an integrated support level to meet the environmental needs of the business world. IDAD's mission is to provide expertise to companies and public administration to follow the best environmental solutions in the transition towards sustainable development. IDAD envisions acting as a center of excellence in the application of knowledge in the areas of environment and sustainable development.
IDAD was founded in 1993 by the University of Aveiro, involving from the very start a set of Departments that are now the basis of Centre for Environmental and Marine Studies (CESAM). IDAD is an autonomous organization with its own technical staff and by law promotes a strong and special connection between the Institute and the Department of Environment and Planning (DAOUA).
IDAD's main areas of activity include: air pollution, environmental assessment and sustainable development. Along with the consulting area, an accredited Laboratory is available for the development of analysis in several environmental matrices.
During the period between 2009 and 2013 IDAD was involved in more than 400 contracts with public and private entities. A significant fraction of these contracts were focused on environmental sampling and analysis of several environmental matrices such as air, water, noise, soil and wastes.

Air Pollution

IDAD develops projects not only on outdoor air quality monitoring and modelling, but also on air quality inside buildings and noise, and their impact on health.
IDAD's Laboratory capabilities includes sampling equipment for particle matter, gaseous pollutants such as SO_2, NO_x, CO and O_3, metals, PAH and PCDD/PCDF. Part of this equipment is combined in a mobile van. During the last couple of years IDAD has been quite active in the field of olfactometry with specific equipment to perform emission and field sampling of odors.
IDAD uses a complete set of dispersion models depending of the objectives of the study: local, regional, passive and chemical models.
Examples of projects:

- Assessment and simulation of the wildfire impact on air quality of Trofa.
- Air quality monitoring of the Estarreja industrial complex.
- Air quality impact assessment on the new airport of Lisbon.
- Air quality monitoring plant of the waste-to-energy plant of Valorsul in the Lisbon Metropolitan Region.
- Eolic potential forecast.

- Monitoring of the air quality of Portuguese airports.
- Air quality monitoring of the refinery of Porto.
- Modelling of atmospheric emissions from Jacobsen Elektro Thermal Plant in Takoradi, Ghana.
- Air quality modelling of the urban master plan for Katembe, Mozambique.
- Air quality monitoring of the Port of Leixões.
- Design of the Air Quality Monitoring Network of Fortaleza, Brazil.

Environmental Assessment

Environmental Impact Assessment can be defined as the process of identifying, predicting, evaluating and mitigating the biophysical, social, and other relevant effects of development proposals prior to major decisions being taken and commitments made. IDAD conducts EIA studies since 1996 and has experience in all stages of the process and in a wide diversity of sectors.

IDAD was on the front row of Strategic Environmental Assessment studies in Portugal. SEA informs planners, decision makers and affected public on the sustainability of strategic decisions structured under plans and programs. The Institute holds a large expertise on the different stages of the SEA process.

In addition IDAD developed comprehensive monitoring programs. Some monitoring projects performed by IDAD include several environmental matrices (air, water, soil, flora, fauna, public health) and focus in the interactions between these environmental compartments. Some examples of recent projects:

- External environmental monitoring program of the waste-to-energy plants.
- Risk sustainable management of the National Water Plan (climate change component).
- Analysis of biodiversity in the area of the Teksid plant in Aveiro.
- SEA of the coastal management plan for Ovar – Marinha Grande.
- Environmental assessment of the PROCIDADES Program in Aracaju, Brazil.

Sustainable Development

IDAD has a set of instruments and tools that allow the practical application of sustainability into decision-making processes as well as its monitoring and regular follow up.

Within this sector IDAD carries out the following activities:

- Sustainability Reports
- Corporate Sustainability Policy Benchmarking
- Event Sustainability Management
- Participatory processes
- Local Agenda 21
- Public Policies

The motto for the creation of IDAD was to provide an effective response to the environmental consulting needs of the society. After more than 20 years of activity there are no doubts that IDAD has a very important participation in some of the most significant environmental decision making processes in Portugal. It is clear that IDAD managed to fulfill its initial aim of promoting the transfer of knowledge between the University of Aveiro and the society. This objective was attained with the strong collaboration with both the IDAD own personnel and the University staff.

For more details concerning IDAD please consult the web page http://www.ua.pt/idad/#.

Invited Talk

NANOTECH SENSORS FOR GAS SENSING APPLICATIONS

C Cerqui[1], E Comini[1], A Ponzoni[2], D Zappa[2], G Sberveglieri[1]

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[2]*SENSOR, CNR-INO, via Valotti 9, Brescia, Italy*

Abstract

Increasing concern on health hazard due to pollution or terrorist attacks encouraged a research effort on gas sensing for real-time monitoring of all aspects of indoor and outdoor environments. Industrial requirements for a sensor are high sensitivity, high selectivity and good stability, together with low fabrication costs. Among all possible technological approaches, conductometric gas sensors based on metal oxide semiconductors are the most promising for the development of low cost and reliable sensors.

Metal oxides in forms of nanowires are interesting materials for chemical sensors. Their peculiar morphology assures a high surface to volume ratio necessary to maximize surface related properties like the ones governing chemical sensing transduction principles. Their exceptional crystalline features guarantees stable crystalline and therefore electrical properties over long-term operation, a required quality for an industrial application of any kind of sensor or device in real environments.

Metal oxide quasi-1D nanostructures have been prepared according to the recently proposed evaporation-condensation process with Vapour-Liquid-Solid growth mechanism, consisting of thermally-driven evaporation of bulk metal oxides followed by condensation and by the thermal oxidation method.

Structural characterization has been performed in order to confirm the amount of material deposited on nanowires. Batches of conductometric sensors (chemiresistors) based on nanowires have been fabricated and tested towards different gases to compare their functional properties.

To develop gas sensors featuring different response spectra, useful to gain selectivity through the exploitation of an electronic nose system, we followed two routes: i) the preparation of chemiresistors layers based on different oxides, namely SnO_2, ZnO, CuO; ii) the functionalization of nanowires with catalytic nanoparticles such as Au, Ag, CuO.

To investigate the morphology of metal oxide nanostructures and the effectiveness of the functionalization process, a field-emission scanning electron microscope SEM LEO 1525 equipped with EDX detector was used (Figure 1 (a) - (d)).

The different effect of the working temperature on the response to NO_2 and ethanol are shown in figure 2 (a) - (b) for ZnO and SnO_2 based gas sensors.

As far as selectivity is concerned, different sensing mechanism would introduce a major benefit. In this frame, novel gas-sensor architectures, based on surface ionization mechanism and planar layout have also been investigated. The sensing mechanism, the different layout structures, namely the traditional vertical and the planar ones, will be discussed, showing preliminary results obtained in our lab.

Invited Talk

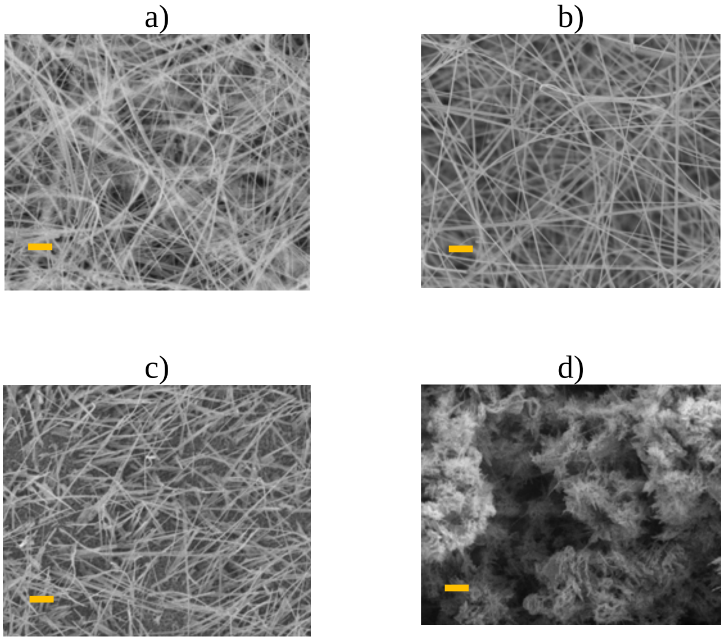

Figure 1. SEM images of the different morphologies obtained for zinc (a), tin (b) oxides prepared by thermal evaporation and copper (c) and zinc (d) oxides prepared by thermal oxidation (The bar is 1 micron). Sensor temperature effects on the ZnO and SnO_2 based gas sensors to ethanol (e) and NO_2 (f).

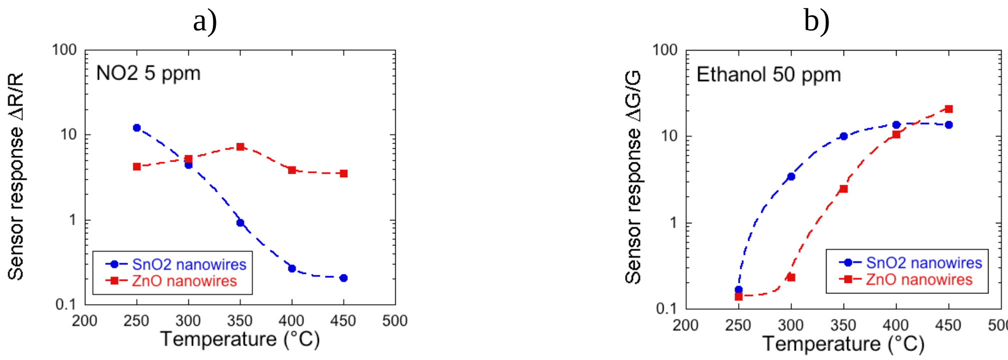

Figure 2. Sensor temperature effects on the ZnO and SnO_2 based gas sensors to ethanol (a) and NO_2 (b).

ACKNOWLEDGEMENT

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Invited Talk

MULTI-SENSOR PLATFORM FOR SMART BUILDING MANAGEMENT - PROGRESS AND ASPECTS OF NANOWIRE INTEGRATION

Anton Köck[1], J. Krainer[1], E. Lackner[1], S. Steinhauer[1], R. Wimmer-Teubenbacher[1]
E. Brunet[2], G. C. Mutinati[2], J. Siegert[3], K. Rohracher[3], F. Schrank[3], M. Schrems[3]
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Abstract
Gas sensors are of high importance for many applications ranging from indoor air quality monitoring and personal safety systems for CO detection in household heating systems to outdoor environmental monitoring. All these applications require reliable, compact and efficient gas sensor systems which are capable for multi-gas sensing. However, up to now, there are no gas sensor devices on the market which are capable for multi-gas sensing and which could fulfil the requirements for smart gas sensor applications in consumer electronics.

A most powerful strategy to improve gas sensor performance is the implementation of nanostructured materials, such as nanowires, graphene, carbon nanotubes or nanoparticles, which have a high surface to volume ratio and thus a strong interaction between the surrounding gas and the material. A gas sensor array implemented with CMOS technology might be the approach of choice to solve multi-parameter sensing requirements for daily life applications as well as cost issues. Two major obstacles have to be overcome for the realization of smart sensor systems for daily life applications:

- Employment of nanocomponents as sensing elements to improve and optimize gas sensor performance,
- Heterogeneous integration of the nanocomponents with CMOS devices to ensure low cost fabrication.

The MSP project “Multi-Sensor Platform for Smart Building management” is focused on the development of essential components and sensors that are required for the realization of miniaturized smart systems capable for indoor and outdoor environmental monitoring:

- Gas sensors for detection of potentially harmful or toxic gases
- Sensors for particulate matter and ultrafine particles
- Development of IR sensors for presence and fire detection
- Development of optimized IR detectors based on SOI thermopiles
- Development of highly efficient photovoltaics and piezoelectrics for energy harvesting
- Development of light sensor and UV-A/B sensors.

The concept of the MSP-project is based on rigorous employment of Through-Silicon-Via (TSV) technology to enable flexible 3D-integration of components and sensors on CMOS electronic platform chips in order to develop highly innovative miniaturized smart systems

with significantly advanced functionalities. The MSP concept shall enable the early take up of Key Enabling Technologies for highly innovative product development.

Concerning the development of gas sensos the MSP project is focused on novel devices based on nanowires, nanoparticles, graphene, carbon nanotubes and AlGaN/GaN on MEMS technology fabricated micro-hotplates for detection of potentially harmful or toxic gases (CO, CO_2, VOCs, NO_2, O_3). A most important aspect within the MSP-project is thus the implementation of nanocomponents on CMOS devices.

In this paper we discuss integration aspects of metal oxide nanowires for gas sensing applications. We present the gas sensing performance results of SnO_2, CuO, [1-3] and ZnO nanowire gas sensor devices, where single and multi-nanowire device configurations have been employed in order to optimize the sensor design (Fig. 1 and Fig. 2). Nanowires are basically well suited for gas sensing detection, because they have the advantage of improved stability due to high crystallinity. This leads to enhanced sensitivity and improved performance, which is validated by the detection of small concentrations of the toxic gases CO (10 ppm) and H_2S (10 ppb). However, nanowiress are also raising lot of technological problems concerning integration issues such as required transfer processes or ohmic metal contacts. We will present TEM studies on SnO_2-NW sensors, discuss reliability aspects of NW gas sensors and present statistical measurement results achieved from numerous SnO_2 single nanowire devices.

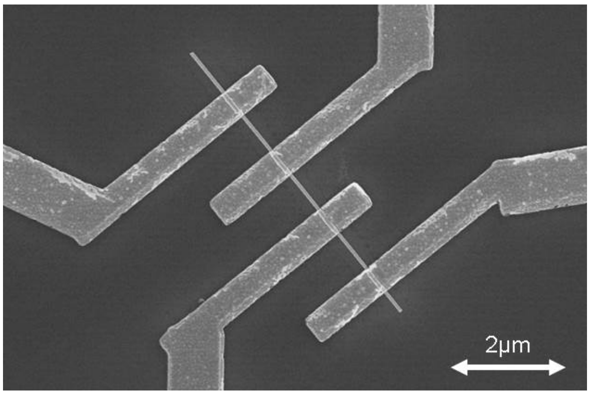

Fig.1: CuO single nanowire gas sensor device.

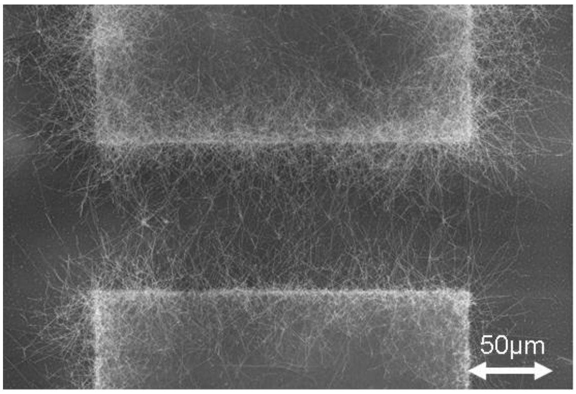

Fig.2: SnO2 multi nanowire gas sensor device.

This work was done within the project "MSP - Multi Sensor Platform for Smart Building Management" (FP7-ICT-2013-10 Collaborative Project, No. 611887).

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Invited Talk

AIR QUALITY SENSOR PERFORMANCE: LABORATORY AND FIELD OBSERVATIONS

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Abstract

Monitoring air quality is essential for understanding how pollutants are distributed in the atmosphere and how they affect human health and the environment as a whole. However, air quality data at street level is currently scarce or non-existent. In Oslo there are only eleven stations distributed between background and traffic stations.

The appearance of new low-cost sensors provides an opportunity to monitor air quality at higher spatial resolutions. Low-cost sensors are smaller, portable and easy to use. However there are challenges in the use of sensor data, mainly related to data quality, comparability and derivation of information from the data sets (Castell et al., 2013).

This work presents an evaluation of the performance of low cost sensor platforms under controlled conditions in a laboratory and under real-world conditions.

The sensor platforms consist of multiple individual electrochemical sensors monitoring the gas pollutants NO_2, NO, O_3, CO and meteorological sensors monitoring temperature, atmospheric pressure and relative humidity. We present the results obtained for static sensor platforms in the laboratory and co-located with air quality reference monitoring station in Oslo.

Figure 1 shows the results obtained in a laboratory for the NO and NO_2 sensors. The temperature and relative humidity are constant, with values of 34% and 23°C, respectively. Both sensors present a good linearity, with correlation coefficients of 0.9 for the NO sensor and 0.7 for the NO_2 sensor.

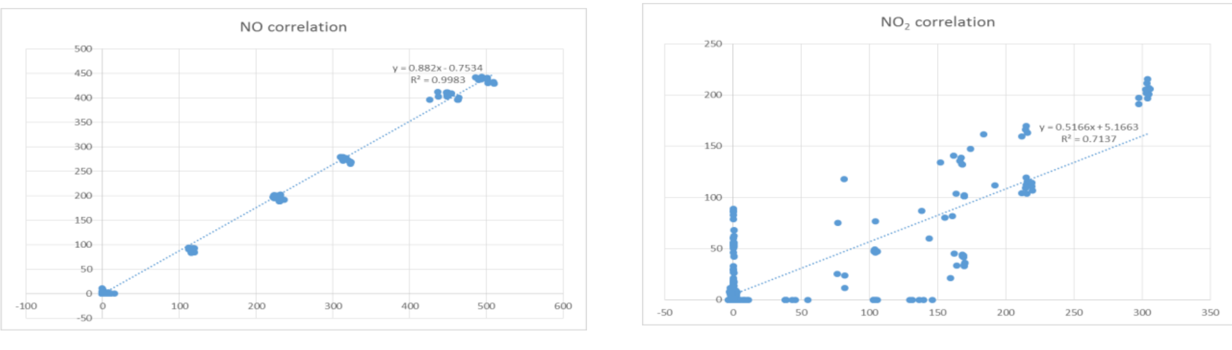

Figure 1. Correlation between the low-cost sensor and the reference equipment for NO and NO_2 in laboratory conditions with constant temperature and relative humidity. The values are in ppb.

Figure 2 shows that the field results have lower correlations than those obtained in the laboratory, especially for NO_2, which is mainly due to the influence of temperature and humidity in the sensor response and the cross-interferences with other pollutants (Aleixandre & Gerboles, 2012). The Pearson correlation of the field comparison was found to be R = 0.83 for NO and R = 0.57 for NO_2. The low cost sensor platform was in the field from the period

between 13 February 2014 through 2 June 2014. The data shown are hourly averaged observations.

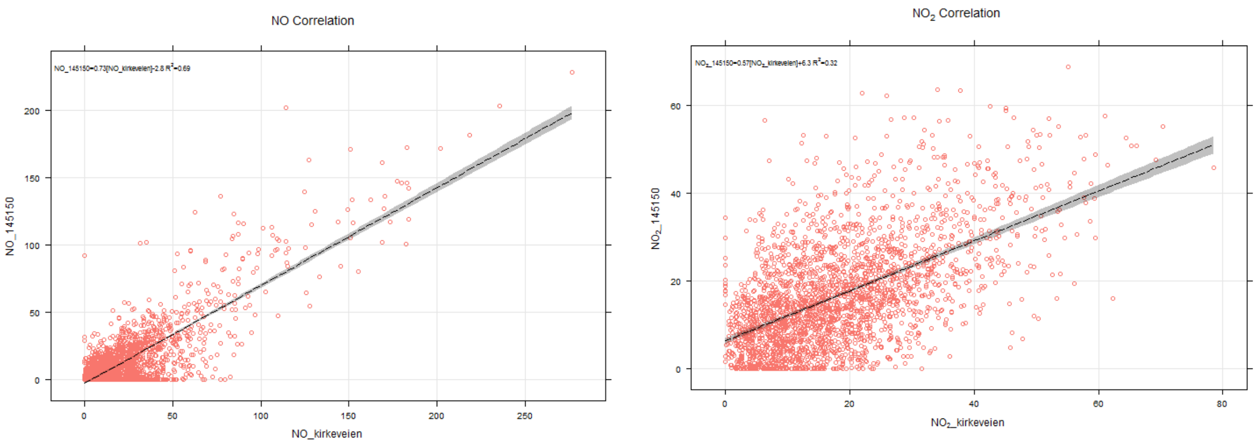

Figure 2. Correlation between the low-cost sensors and the reference equipment for NO and NO_2 in the field during the period from 13 February through 2 June 2014. The values are in ppb.

The presented results are part of the ongoing work of the European projects CITI-SENSE and Citi-Sense-MOB. The next step will be to evaluate the long-term stability of sensors in field, as well as to assess the performance of other sensor platforms and pollutants in laboratory and in field.

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Invited Talk

INDOOR AIR QUALITY SENSING - AN INDUSTRY PERSPECTIVE

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Abstract

For the industries involved in providing building infrastructure and building management systems (especially HVAC) the use of gas sensors becomes increasingly important. This presentation will give a short insight into the requirements and the reasoning of the industry for them.

As the building industry is rather conservative in the use of new technologies, the use of gas sensors is driven mainly by regulations.
Currently there are extensive activities to establish regulations regarding fire gas detection (e.g. Underwriters Laboratories UL217, UL268 or European Committee for Standardization EN54-26, EN54-30, EN54-31). Additionally in the US new regulations demand CO warning systems in all bedrooms (domestic and hotels).
The certification process for fire gas detectors is rather difficult for most sensors as 100%-functionality is mandatory under all conditions. Currently only electrochemical cells are in use for CO-warning and as multicriteria-detectors for early fire detection.

In contrast to the above mentioned standards there are almost no guidelines for IAQ. There are recommendations (e.g. by ASHRAE or several national or international organizations) but the Pettenkofer-Limit as a concentration of CO_2 (> 1000ppm) above which physiological effects are detectable still guides most IAQ applications. This so called comfort application (temperature, relative humidity and CO_2) gains importance when it comes to lowering energy consumption of buildings by using demand controlled ventilation. The main reason for using CO_2 as the marker gas is that it can be measured quite accurately (+/- 50ppm) using optical infrared absorption measurements (NDIR). The drawbacks of this technology are the high price, sensor size and energy consumption of the sensing element.

Measuring VOCs is usually done using SnO_2-based metal-oxide sensors. As those sensors are highly non-specific, they are currently not used to control building ventilation (at least not by Siemens).
One of the main problems with using VOC-sensors is that some of the relevant toxic gases as described in regulations (e.g. formaldehyde) occur in very small concentrations only (ppb) which are very hard to detect by SnO_2-sensors in a real life environment. Also many sources of VOCs like carpets, fresh paint or mould provide a more or less constant background of VOCs which makes measuring specific concentrations difficult by using metal oxides.

As long as there is still a lack in specific VOC-sensors most building technology industries will stick to CO_2 as the "guiding gas".

Oral Presentation

NEW SENSING TECHNOLOGIES FOR AIR QUALITY CONTROL: FIELD EVALUATION OF MICRO-SENSORS AGAINST STANDARD METHODS

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The current air quality monitoring strategy is manly based on measurements from fixed monitoring stations, not always reflecting the exposure and effects on humans. Advanced air pollution control systems based on low-cost sensing technologies opened a new vision for air quality control and exposure assessment. Their performances allow for a new strategy, resulting in fast responses, low operating costs and high efficiencies that cannot be achieved with conventional approaches. Nevertheless, much research remains to be done to integrate these new technologies, particularly on the quality check of the sensors performance against conventional methods in field exercises [1, 2].

This work presents a performance evaluation of ozone micro-sensors against standard method during field campaigns performed from November 2013 to January 2014. The application of new sensors side by side with standardised equipment in field studies allows assessing the reliability and uncertainty of these low-cost sensors, especially regarding an accurate detection of pollutant concentration peaks.

The measurement campaigns were conducted in two major Portuguese airports, Lisbon and Oporto, in 6 monitoring sites, from October 2013 to January 2014. The micro-sensors were installed in a shelter at the top of roof of IDAD's mobile laboratory. IDAD's Laboratory measured several atmospheric and meteorological parameters: NO, NO_x, NO_2, CO, O_3, SO_2, BTEX, temperature, relative humidity, radiation, precipitation, wind velocity and wind direction. The comparison exercise was performed with the reference equipment for O_3 (ultraviolet photometry). For MEMS (Micro Electro Mechanical Systems) sensors, gas detection is based on the physical principle involving the modulation of conductance within a layer of semiconductor material. The impedance characteristics of the semiconductor are altered through reactions with oxidizing gases present in the air. The pollutant concentration is calculated as the measured resistance (R_S) adjusted by the calibration and temperature compensation parameters.

A statistical analysis of field results was conducted allowing a performance evaluation of these low-cost sensors. The results were treated for each measurement following bibliographic references and information from the manufacturer, namely temperature correction and methodology for calculation of the function for each sensor [3, 4, 5]. Figure 1 presents an example of correlations between the data from micro-sensors and ozone reference analyser. For ozone was possible to identify measurements with a strong correlation between micro-sensor and UV analyser. Preliminary correlations with R^2 between 0,68 and 0,88 were achieved for a significant number of measurements.

Oral Presentation

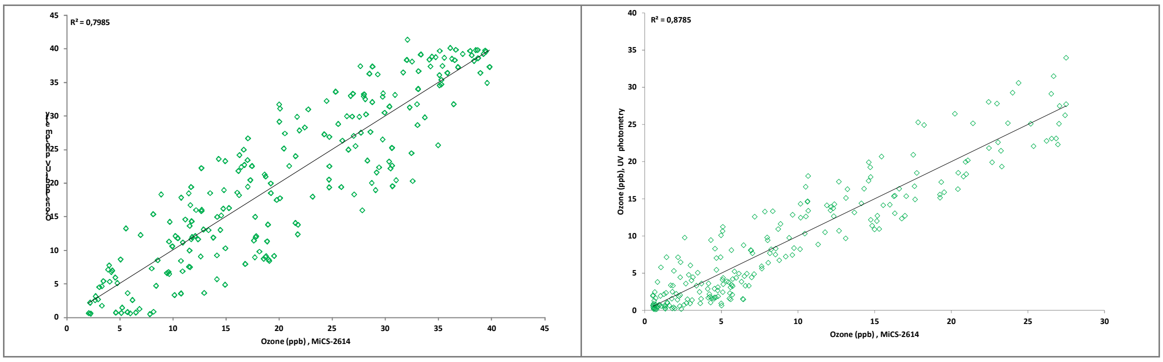

Figure 1. Example of correlation between micro-sensor and UV analyser.

The present work showed promising results for O_3 micro-sensors. Examples of reference measurements and calculated concentration from micro-sensor signal are presented in Figure 2. Several of the measurements presented strong correlations and equivalence between daily concentration profiles.

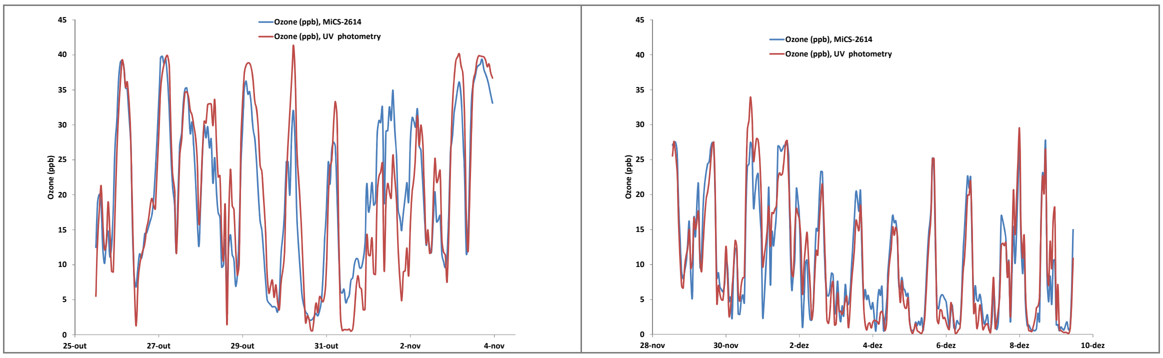

Figure 2. Example of correspondence between reference measurements and micro-sensor results for O_3.

The utilisation of micro-sensors is still not mentioned for regulatory purposes in European legislation, nevertheless their use can be particularly valuable to have highly spatially and temporally resolved air quality data and to improve exposure assessment. Although there is a significance research and development of low cost sensors for pollutant monitoring, data treatment of sensors signals from field campaigns remains limited and challenging. The preliminary evaluation performed confirms that O_3 micro-sensors could be a promising technique for air quality monitoring. Their performances can lead to new strategies for air quality control, rapid mapping of air pollution over small areas, validation of atmospheric dispersion models or evaluation of population exposure.

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Oral Presentation

DEVELOPMENT OF AIRBOX (NO_2, PM10, PM2.5) AND ITS APPLICATION AS NETWORK IN CITY OF EINDHOVEN

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Figure 1. Airbox

Abstract

During recent years ECN developed high quality sensors for pollutants in ambient air. Currently developed sensors for PM2.5, PM10 and NO_2 are applied for third parties. Field of application are urban air quality and emission monitoring from transit storage and handling of dry bulk like ore and coal. Low cost high quality sensors are of importance to operate high density networks which are desired both for urban areas and around transit areas but are not available.

The sensors are placed in a weatherproof enclosure, the AirBox. The AirBox communicates by GPRS every 10 minutes with a server to upload the data and to accept new firmware if requested. Meanwhile data is kept safe locally on a SD card. The sensor set up is modular. The box is battery operated and usually mounted on a streetlight for charging at night time.

The first urban air quality network was installed in October 2013 in Eindhoven, The Netherlands. The network represents 35 locations at relevant places like hospitals, traffic hotspots, construction sites, railways and back ground stations. The project is funded and operated by members of the Aireas community [1], a joint venture of local authorities, active citizens, technological institutes and universities. A driver was to create a network platform that could form the basis for various types of new initiatives, scientifically, commercially and to enhance sustainability. These activities are currently taking off. City hotspots become visible at low wind speed conditions. Figure 2 was made in cooperation with TU Twente.

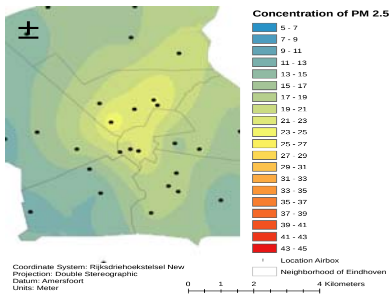

Figure 2. PM2.5 distribution

The sensors are commercially available low cost detectors that have been enhanced. We improved sensors by using the knowledge acquired by 30 years of experience with development of highly sophisticated instrumentation like MARGA [2]. The PM sensor is a simple optical sensor smartly interfaced, revealing also the size distribution and operational information. The UFP fraction can still not be detected. NO_2 is detected by means of an electrochemical sensor. This sensor type is however highly sensitive for variation in relative humidity and other gases. We applied a method to deal with these issues in situ (patent pending).

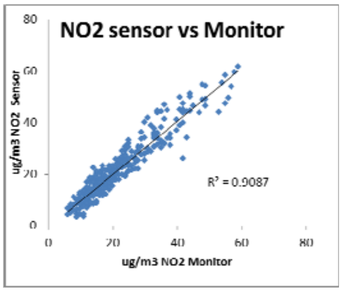

Figure 3. NO_2 sensor performance

In the field the sensors are calibrated against reference methods. Precision and variation of accuracy were characterised at rural and urban locations. Figure 3 for NO_2 is a comparison with a chemiluminescence monitor. Hourly averages are shown for a period of 2 weeks.

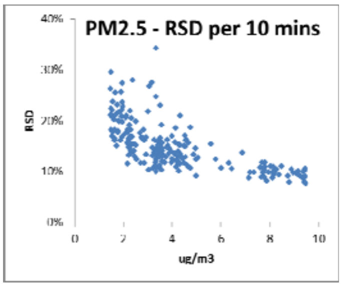

Figure 4. Precision PM sensor

During an October storm in 2013 the precision of the installed PM sensors (25 at that time) in Eindhoven was assessed by means of the relative standard deviation. Above 5 ug/m^3 the RSD converge to 10%. Taking into account residual local effects the RSD is at least better than the results shown. For hourly averaged values the RSD converge at 8%.
Currently equivalence testing with reference methods are performed by GGD Amsterdam for PM and NO_2. According to the directives tests will be executed at 4 different locations and seasons.

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Oral Presentation

TOWARDS ULTRA-LOW-POWER ENVIRONMENTAL AIR MONITORING WITH POWER HEMTS

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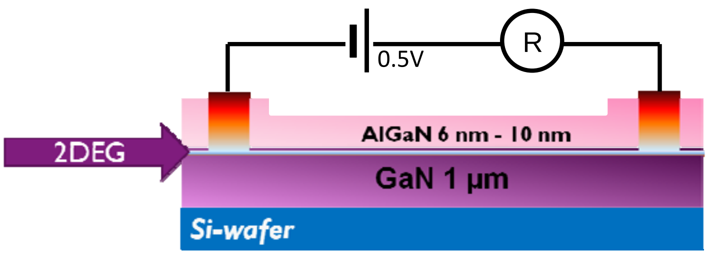
Abstract

There is a high demand for environmental monitoring devices, which combine sensitivity and selectivity with compactness, portability and low cost. We develop sensors meeting these criteria based on AlGaN/GaN hetero junctions (Fig 1a). Recent developments in the growth of epitaxial III-nitride layers on Si(111) substrates allow for the large scale production of devices with a highly mobile two dimensional electron gas (2DEG) formed at the interface between GaN and AlGaN. The sensitivity of these open gate devices can be tuned to the low-ppb range by precise recessing of the AlGaN sensitive area [1]. This allows, for example, the detection of NO_2 at the low-ppb level. NO_2 is a major air pollutant that is subject to environmental regulation. For use in autonomous air quality monitoring networks, it is essential that power consumption is minimized. We have investigated the feasibility of operating GaN based sensors at room temperature and find that a slope-based detection scheme in combination with periodic heating-induced gas desorption allows near-continuous air quality monitoring with low power consumption. A drawback of room-temperature operation, however, is the large influence of humidity on the sensor response [2]. We find that under continuous heating (200–300°C) the (cross-)sensitivity to humidity is strongly diminished, while response and recovery times are improved by at least an order of magnitude. In order to minimize the power consumption for heating, and enable autonomous, battery powered operation, conductive heat losses to the sensor package (Fig 1b) need to be drastically reduced. We show the development of ultra-low-power GaN membrane-based environmental micro sensors starting from high power HEMTs grown on 8” GaN-on-Si wafers.



(a)

(b)

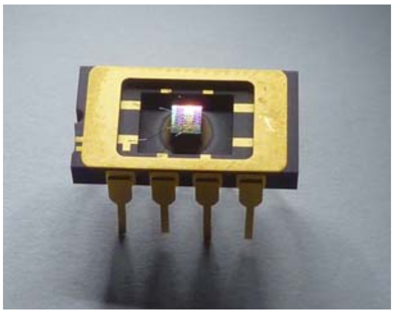


Figure 1. Schematic view of the structure (a), photograph of the wire bonded device (b).

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Invited Talk

CMOS SENSOR SYSTEM FOR AIR QUALITY MONITORING

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Abstract
It is evident that with a rapidly growing demand for integrated sensors being employed in wearable devices and smartphones as well as other portable equipment, the need for low cost, low power, miniature sensors with multi-sensing features and a unified system architecture is becoming paramount [1]. Integrated physical sensors, such as MEMS accelerometers, gyroscopes, microphones, are well-established in the smartphone market where they are typically interfaced via a sensor hub; with most common method of data transfer achieved using I^2C communication protocol. The majority of these MEMS physical sensors are based upon standard silicon (CMOS) process and thus they are either manufactured as a single chip solution [2] or co-packaged with the sensor chip and ASIC die bonded in the same package [9]. Similarly, any new sensors that need to be included in a wearable application must also support this interfacing requirement so that they can be readily integrated within a system where space on PCB is very limited and the overall physical dimension is highly restricted. In this presentation we have identified one of the key areas where new sensors are likely to make a significant impact; namely, health and well-being - and this includes air quality monitoring, for detecting hazardous environmental gases such as CO, NO_X, CO_2, O_3, NH_3, and VOC. Current chemical sensors are typically based on bulky electrochemical, metal-oxide or infrared technologies and thus they are not suitable for high volume portable applications [4]. However, over the last decade, researchers found ways to produce an integrated MEMS micro-heater on a silicon platform, where it has been possible to manufacture these gas sensors on a 1mm × 1mm die, using metal-oxide (MOX) sensing materials such as SnO_2, WO_3, structured as nano-materials. Given that there is limited space available on the PCB in a smartphone or wearable devices, it is not desirable or practical to incorporate all these sensors as individual components. One of the most promising ways to overcome this problem is to exploit multi-sensing capabilities of the MOX sensing material where it is found that thermal modulation [3] or pulsed measurement techniques can be used for sensing different gases using a single device. An example of a multi-gas sensing chip, schematic, daughter board and main board is shown in Fig. 1 to 4, respectively. As with all MOX gas sensors, compared to bulky electrochemical gas sensors, they do suffer from selectivity and sensitivity to target gases. Thus it is generally accepted that for portable applications, at present performance trade-off over cost is made where these sensors are initially being deployed as air quality level indicator instead of showing absolute value of gas concentration figure. However, by miniaturising the device, it is possible to integrate four or more sensors on a single die of less than 2 mm × 2 mm using a standard CMOS process with DRIE, MEMS platform with tungsten metallisation for developing air quality monitoring system for high stability micro-heater and sensing electrodes [5]. Redundancy and preparatory algorithmic solutions can be used to enhance the performance of the sensor in terms of selectivity [7,8]. Given that we are using a CMOS process, as a part of our on-going R&D activities, some examples of fully integrated sensor with on-chip signal conditioning circuit together with system developed with co-chip ASIC solution for sub-ppm level NO_2 sensing will also be presented [6].

Invited Talk

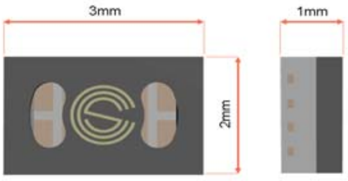

Fig 1: Basic MEMS CMOS multi-gas sensor chip

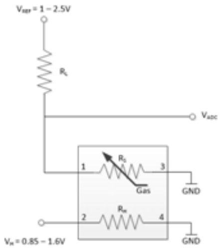

Fig 2: Mutli-gas sensor schematic

Fig 3: Daughter board with multi-gas sensor

Fig 4: Main board

Since one of the important gases that needs to be monitored for air quality is CO_2, and due to the fact that most reliable detection method is by NDIR method, we will also present an example of a system implementation using our MEMS, CMOS IR emitter and detector solution. Gas monitoring systems of this type require primarily four main components: (i) IR emitter and detector with filter; (ii) Optical path; (iii) Electronic control circuit and system interface; and (iv) Firmware/software. The basic building blocks for each of these components will be described together with initial high concentration measured response to CO_2 will be presented to show that CMOS sensor system is also applicable for mid-infrared optical method of air quality monitoring that can potentially be miniaturised for portable electronic consumer devices.

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Oral Presentation

TOWARDS REAL-TIME DATA FUSION OF LOW-COST SENSOR OBSERVATIONS WITH MODEL OUTPUT FOR MAPPING URBAN-SCALE AIR QUALITY

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Abstract

Urban-scale air quality maps are useful for a wide variety of applications. One of the many promising new aspects of low-cost microsensors for measuring air quality is that they have the potential to improve urban-scale air quality mapping as they allow for the deployment of a much larger number of nodes throughout the city area than would be possible with costly reference stations. Even though the accuracy of the low-cost microsensors does not reach the same level as reference stations, a higher spatial density of observations should be able to capture a lot more of the fine-scale spatial variability in pollutants, even if only indicative measurements are available.

Existing methodologies for mapping urban scale air pollution include land-use regression techniques and dispersion modelling. Here we present the methodology and some initial results of an automated data fusion technique for real-time mapping of urban air quality. Data fusion as a subset of data assimilation (Lahoz and Schneider, 2014) aims at optimally combining two datasets or more datasets into a new product which is more useful than the separate datasets on their own.

The data fusion approach described here uses the output from a local air dispersion model as basemaps and subsequently fuses them using geostatistical techniques with real-time observations from a low-cost sensor network deployed throughout a city. In order to generate static maps, which are essentially used as a proxy to guide the interpolation of the observations, we use the EPISODE air pollution dispersion model (Slørdal, Walker and Solberg, 2003). This is a combined 3D Eulerian/Lagrangian air pollution dispersion model for urban and local-to-regional scale applications. The model includes schemes for advection, turbulence, deposition, and chemistry. EPISODE is generally run at a spatial resolution of 1 km. The resulting concentrations fields are subsequently post-processed and downscaled to a spatial resolution of 100 m using a high-density network of receptor points. This is also the spatial resolution of the basemaps used for the data fusion.

The underlying methodology for the data fusion approach is based on residual kriging and includes a fully automated system for establishing a relationship between the downscaled model output and the observations, estimating the spatial autocorrelation function from the observations, performing kriging of residuals, and producing the final map as a combination of a regressed map and kriged residuals. Figure 1 gives an example showing the result from fusing the annual average concentration of NO_2 as computed by the EPISODE model with a synthetic dataset of observations at 50 stations located throughout Oslo. First results indicate that the system is very well capable of adequately adjusting the static basemaps with new information from the observations. The impact of the stations is limited to the station's spatial sphere of influence as specified by the theoretical semivariogram. Outside of the area where

the observations were taken the basemap remains largely unmodified. Evaluation of the methodology is being carried out using the leave-one-out cross validation technique.

The system further includes an automated component for filling short data gaps at individual nodes on the order of several hours using fully automated time series analysis based on autoregressive integrated moving average (ARIMA) modelling.

The results presented here are part of the ongoing FP7-funded project CITI-SENSE.

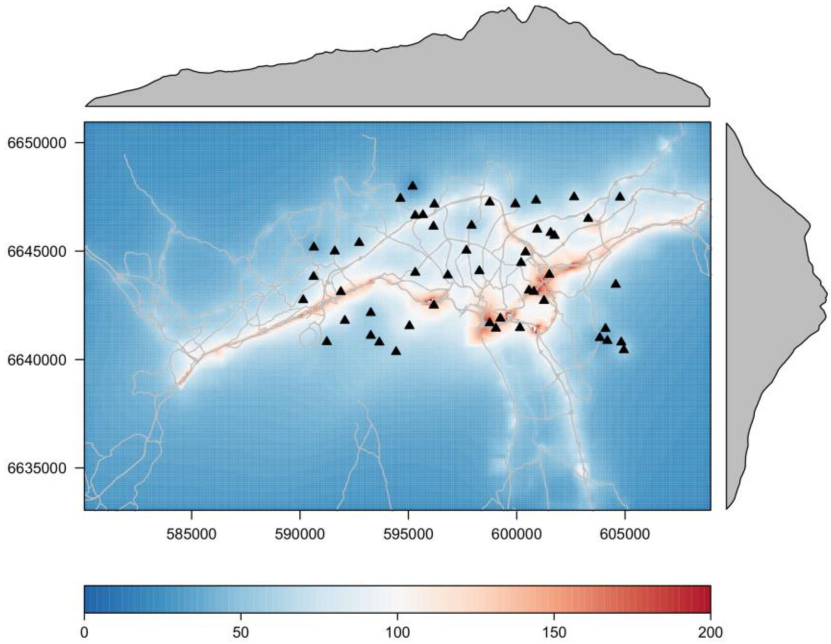

Figure 1. Example of an urban scale NO_2 concentration map (units in $\mu g/m^3$) for Oslo generated by fusing annual average concentration map derived from the EPISODE air pollution dispersion model with hourly observations from 50 locations throughout Oslo (black triangles). The grey lines represent the network of major roads.

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Oral Presentation

AIR-SENSOR BOX FOR AIR QUALITY CONTROL MEASUREMENTS

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Abstract

Environmental monitoring is strongly required to protect the public health and save the environment from toxic contaminants and pathogens that can be released into air. Air-pollutants include carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), that originate from various sources such as vehicle emissions, power plants, refineries, industrial and laboratory processes. However, current monitoring methods are costly and time-consuming, also limitations in sampling and analytical techniques exist. Clearly, a need exists for accurate, inexpensive long-term monitoring of environmental contaminants using low-cost solid-state gas sensors that are able to operate on-site and real-time. Calibrated cost-effective gas sensors are a very interesting solution for networked systems suitable to monitor air-pollutants in urban streets and real scenario of smart cities with high spatial and time resolution. In ENEA, at Brindisi Research Center, a handheld gas sensor system called *AIR-SENSOR BOX* based on solid state gas sensors was designed and implemented [1-4]. This system is the last result of our researches in the area of tiny and portable system for air quality control based on cost-effective solid state gas-sensors. The main goal of the system designed and built in our laboratory is the development of a portable equipment in order to detect some air-pollutant gases such as CO, SO_2, NO_2, O_3 and PM in the urban areas at outdoor level.

In order to give our equipment a high flexibility grade, we have designed it in a modular style: it is composed by the main board, one or more sensors boards, an USB port hub and the power module. Main board is a *Raspberry PI* module which is in charge to interface the end-user with the sensor boards, providing the necessary services which implement all the equipment functionalities. Sensor boards communicate with main module via USB ports hub following the master-slave scheme. The end user interface is given by a web browser page by which operators can get machine full remote control. This is possible by connecting any PC with the web server running on the Raspberry board via Wi-Fi or LAN or GPRS-UMTS connection. AIR-SENSOR BOX can operate with several sensor boards at the same time by means of the USB hub and, therefore, it can run a great variety of sensors. In this occasion, we are using electrochemical sensors by *Alphasense*, an Optical Particle Counter (OPC) by *Shinyei*, a humidity sensor by *Honeywell*, and a temperature sensor by *Microchip*.

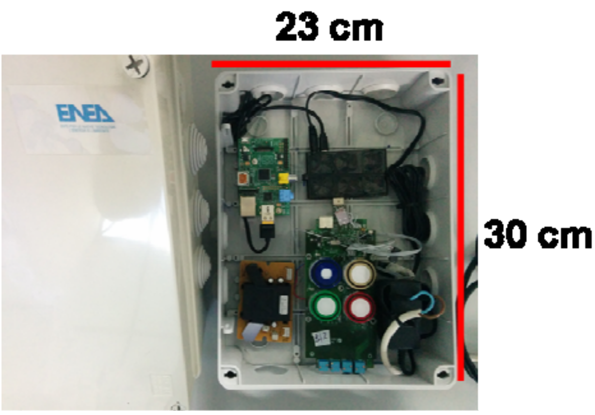

Figure 1. Air-Sensor Box system by ENEA, Brindisi.

Several tests in collaboration with ARPA-Puglia, (public agency for pullution monitoring and control) and the Joint Research Center (JRC), Institute for Environment and Sustainability (IES) in Ispra (Italy) were performed. In these tests, we compared our sensor response with the data given by traditional chemical analyzers placed in the fixed stations provided by ARPA-Puglia and JRC in terms of mean and maximum error between the data given by our sensor-device and the data given by reference equipment in the time domain. They gave us encouraging results for CO detection in terms of mean error and maximum error with respect to the reference equipments (see Figure 2), but we found that interfering gases effects are still an open problem (Figure 3) for NO_2 detection with O_3 as an interfering gas.

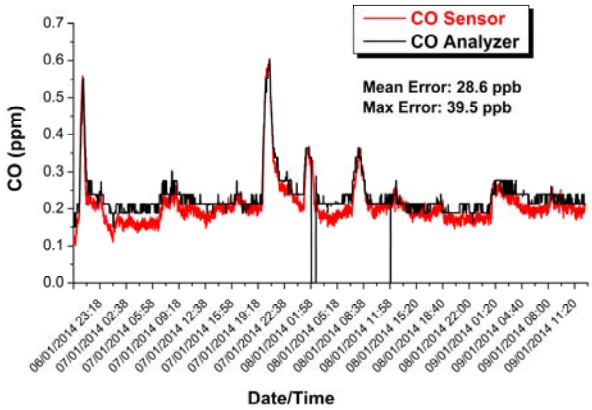

Figure 2. Electrochemical CO sensor response in real scenario.

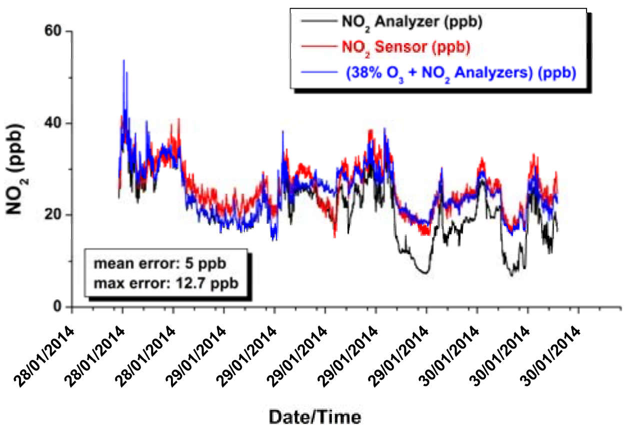

Figure 3. Electrochemical NO_2 sensor response in real scenario.

We are planning more systematic tests in order to better investigate interfering gases effects, sensor stability and lifetime in real scenario, and moreover, the proper maintainance procedures (e.g. sensor re-calibration rates).

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Oral Presentation

DOES THE EVOLUTION OF SENSOR TECHNOLOGY AND COMPUTATIONAL METHODS LEAD TO A REVOLUTION IN AQ-ENVIRONMENTAL MONITORING AND TO A NEW GENERATION OF QUALITY OF LIFE INFORMATION SERVICES?

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Abstract

Developments in the area of sensor technologies have resulted in low cost, small size, low energy consumption sensors for air quality monitoring. In addition, the broad development of the smart phone market has led in the availability of a variety of sensors embedded to the devices, which can provide sensor-based information for a variety of environmental parameters: air temperature and relative humidity readings are becoming more and more available, accompanied by atmospheric pressure. In addition, geolocation information is being produced via embedded GPS sensors, while accelerometers allow for the estimation of mobility patterns. These developments lead to the production of vast amounts of data that come from data sources with varying credibility and accuracy.

Production of information related to the quality of the environment and to it's impact on quality of life is also extended to sources like social media [1], while initiatives on participatory environmental sensing (or VGI recording) also contribute to the generation of an excessive amount of data related to the quality of the atmospheric environment [2].

This plethora of data very well suits the concept of Big Data. Thus, the emphasis in scientific development is put not only on the collection of air quality data (and thus the development of the sensor technologies), but also on the ability to manage, analyze, summarize, visualize, and discover knowledge from the collected environmental data in a timely manner and in a scalable fashion.

For doing so, a "data-centric" approach is required allowing for data analysis, knowledge extraction, atmospheric quality simulation and forecasting. Moreover, as more and more data accumulate on Quality of Life (QoL) issues affected by environmental parameters, it is important to be able to also analyse such data and to make use of all available information in order to design and develop new types of information services for QoL support. This need is much more pronounced when the atmospheric environment has direct impacts to health status and causes health problems, like in the case of asthmatic people and air quality, or the case of hay fever sufferers and aeroallergents. In the latter case, a personalised approach is emerging for QoL information services, where the interested person is informed not only on the expected quality of the atmospheric environment, but on the impacts foreseen for his personal health status and related symptoms [3].

The aforementioned requirement for personalised information service provision is also driven by new developments in the area of environmental monitoring systems, where there is a trend towards proactive, instead of reactive systems. Proactive systems take the initiative of

communication with the end users about topics that the end-user is not aware of, but which the system believes is of importance for them [4].

These developments in sensor technologies, in data-oriented computational methods and in ICT may revolutionize environmental monitoring and thus lead to a new generation of information services, with strong QoL orientation.

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Invited Talk

PARALLEL MEASUREMENTS OF PARTICULATE MATTER AND POLLEN IN BERLIN

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Abstract
Pollen allergy currently affects nearly a fifth of the German and European population. Recent reports indicated links between global climate change and altered local pollen productions. In rural areas the formation of primary bioaerosols (pollen) is prevalent, while the situation in urban agglomerations is less investigated so far. Pollen measurements are not part of continuous ambient air measurements provided by the responsible air quality monitoring networks in Germany. Some model calculations derived that a contribution of aeroallergens may comprise 5% to PM_{10} mass in ambient air in periods when vegetation is partly active (Winiwater et al., 2009). Because information on pollen at the city level is missing, there is a need to improve the understanding on small scale distribution and variation of pollen and their contribution to fine particulate matter in a city, as well as to ameliorate assessments of exposure and health impacts of aeroallergens in an urban population.

Thus, a comparative pilot study was conducted by the Federal Environment Agency (Umweltbundesamt/UBA) in co-operation with the Foundation German Pollen Information Service (Stiftung Deutscher Polleninformationsdienst/PID) to investigate the spatial distribution and burden of fine particulate matter (PM_{10}) and various pollen species (during the grass pollen season) in ambient air in the city of Berlin.

PM_{10} and pollen measurements took place as 24h daily samplings carried out in parallel during a period of six weeks between 12 May and 23 June 2011 at three monitoring sites in the city of Berlin. They are characterized as inner-city park (*Tiergarten*), suburban (*Adlershof*) and traffic-related hot spot located nearby residences (*Stadtautobahn/Westend*). All three sites are influenced by different vegetation conditions. PM_{10} was daily sampled by UBA with three low-volume samplers (Kleinfiltergerät LVS3.1 Derenda; flow rate of 2.3 m^3/h). Particles were collected on glass fiber filters (Pallflex, Tissuquartz 2500QAT-UP, 47 mm) and gravimetrically determined at UBA laboratory. Pollen were sampled by PID with three Burkard pollen traps. The concentration was optically determined at Charité laboratory according the national guidelines for pollen analytic. The samples were analyzed by an experienced co-worker and stored for further analyses.

Table 1 show PM_{10} concentrations measured during the six week period at the respective three monitoring sites in the city of Berlin, with highest concentration at station *Stadtautobahn/Westend* (approximately 155,000 vehicles per 24h passing this section of the inner city motor highway *BAB 100*), medium at *Tiergarten* (around 34,000 vehicles per 24h), and lowest at *Adlershof* (around 4,500 vehicles per 24h).

Table 2 show the results of daily grass pollen counts with - again and surprisingly - highest concentration at station *Stadtautobahn/Westend*, medium in the suburban area *Adlershof*, and unexpected lowest at *Tiergarten*.

Table 1. PM_{10} concentrations [µg/m³] measured in Berlin in May/June 2011.

Stations (type)	Mean	Max.	Std.dev.
Adlershof (suburban)	15.2	29.5	5.2
Tiergarten (city, park)	18.9	34.4	6.6
Stadtautobahn/Westend (traffic)	22.6	35.5	7.5

Table 2. Concentrations of grass pollen and total pollen counts [pollen counts/m³ air per 24h] measured in in Berlin in May/June 2011 (43 daily samplings per station).

Stations (type)	Mean	Max.	Std.dev.
Tiergarten (city, park) - grass - total pollen	7.9 62.1	33 136	7.9 34.3
Adlershof (suburban) - grass - total pollen	11.8 55.8	65 185	15.6 41.6
Stadtautobahn/Westend - grass (traffic) - total pollen	17.2 72.3	83 163	18.2 36.9

Parametric (Pearson) correlation coefficients have been calculated to assess the relationship of concentration distribution within this measurement period between the three monitoring sites, for both PM_{10} and grass pollen. Table 3 shows highly significant correlations (** $p < 0.01$) between the measurements at the three monitoring sites, found for both parameters.

Table 3. Pearson correlations coefficient for PM_{10} and grass pollen; (** $p < 0.01$).

r	PM_{10}	grass pollen
Adlershof – Tiergarten	0.87**	0.84**
Tiergarten – Stadtautobahn/Westend	0.81**	0.82**
Adlershof – Stadtautobahn/Westend	0.77**	0.81**

The first results of the parallel measurement campaign in 2011 show the highest burden for urban public health at the traffic hot-spot, both for PM_{10} and grass pollen. Furthermore, for both good correlations were found between the sites. Sound correlations have been determined between concentrations and daily maximum temperature. On several days grass pollen concentration in densely populated parts of the city reached health relevant threshold values that are required to initiate allergenic symptoms. All measurements took place during the peak season of grass pollen emissions in the Eastern part of Germany, to which Berlin belongs.

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Invited Talk

AIR QUALITY MODELLING IN SLOVENIA: STUDYING SENSITIVITY OF WRF/CHEM FORECAST

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Abstract
An integrated high resolution modelling system based on an on-line coupled WRF/Chem model that allows two-way interactions between physical and chemical processes in one unified model has been applied for experimental numerical weather prediction and air quality (AQ) forecast in Slovenia. In the study an evaluation of the AQ forecasting system has been performed for summer 2013. In the case of ozone (O_3) daily maxima 1-day and 2-day model predictions have been compared to the operational statistical O_3 forecast and persistence. In addition, we evaluate the sensitivity of 1-day and 2-day WRF/Chem AQ forecast to (I) model horizontal resolution, (II) inclusion of aerosol direct effects on radiation processes and (III) to the high resolution emission database developed at Slovenian Environment Agency for the purpose of AQ forecasting in Slovenia.

Model Configuration
WRF/Chem model version 3.4.1 has been configured with two nested domains (Fig.1). To produce the 48-h forecast, model is run every day, starting at 00 UTC, with meteorological initial and lateral boundary conditions taken from the Global Forecast System (GFS). For chemical BCs forecasts from global MOZART-4/ GEOS-5 [1] system are used. Current model implementation includes a modified RADM2 gas phase chemistry solver as described in [2], which avoids under-representation of nocturnal O_3 titration in areas with high NO emissions. Among feedbacks only aerosol direct effects on radiation are taken into account.

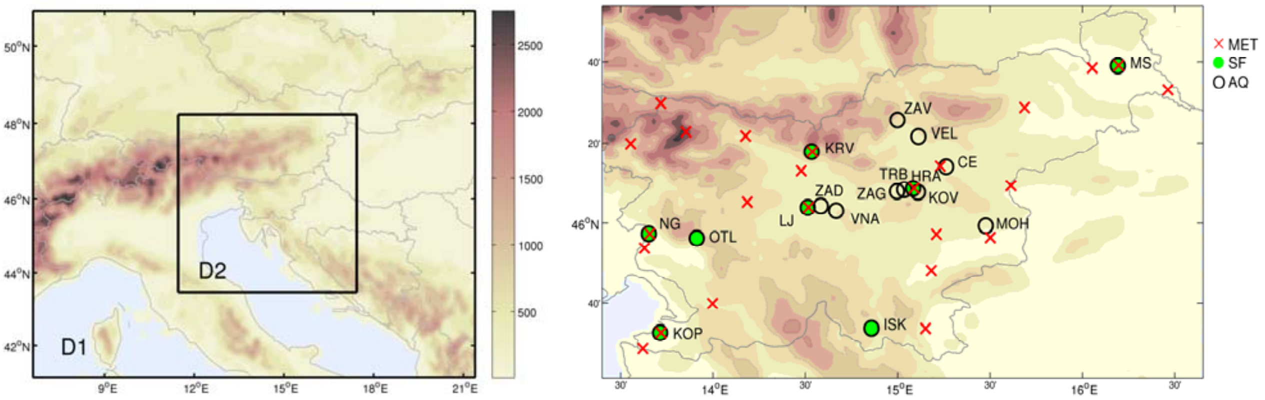

Figure 1. Left) WRF/Chem modelling domains with resolution 11.1 km and 3.7 km. Orography (in meters) is shown in 11.1 km resolution. Right) Locations of monitoring stations used in evaluation of air quality variables (AQ stations; shown are also station abbreviations) and meteorological variables (MET stations). Green dots indicate measuring sites with available statistical forecast for ozone daily maximum (SF).

Biogenic emissions are estimated using MEGAN [3] online model calculations. Detailed anthropogenic inventory for Slovenia has been constructed for year 2009. For areas outside Slovenia anthropogenic emissions for the year 2009 based on the TNO-MACC-II [4] are being used. Daily updates of the WRF/Chem based experimental AQ forecast are provided at http://meteo.fmf.uni-lj.si/onesnazenje.

Results

1-day and 2-day WRF/Chem PM_{10} forecasts show a very low bias. Exceptions during the summer 2013 were two events with significantly over-predicted PM_{10} levels due to prefrontal advection of polluted air masses from neighboring regions. Evaluations of predicted 1-hour and 8-hour daily O_3 maxima show that depending on monitoring site and the evaluation measure applied WRF/Chem O_3 daily maximum forecast can even outperform the statistical model (Fig. 2). But there are also stations which experience high over- or under-prediction of O_3 daily maximum levels.

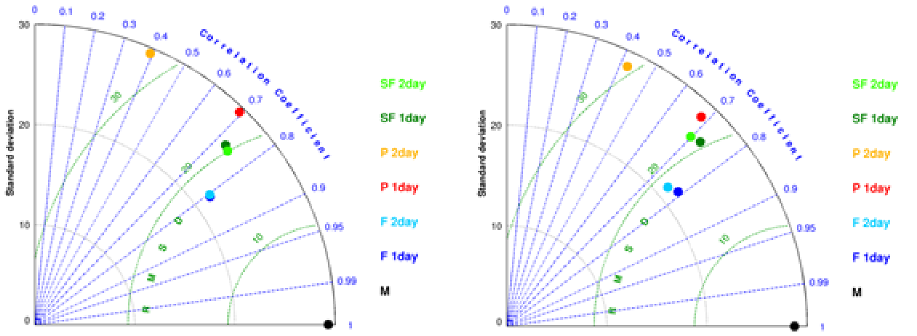

Figure 2. Taylor diagrams comparing 1-day and 2-day O_3 daily maximum statistical forecast (SF), persistence (P) and WRF/Chem forecast (F) for: Left) Mediterranean urban stations (NG, KOP), and Right) rural stations (MS, ISK, KRV, OTL). The 3 month time period (summer 2013) is taken into account.

There are several issues regarding the inclusion of chemistry into numerical weather prediction model, and many model uncertainties can potentially reduce the accuracy of model predictions. To address the added value of an online treatment of aerosol direct effects, we evaluate the impact of the coupled approach on model results and compare it with the impact of increased horizontal grid spacing and detailed anthropogenic emission database used for Slovenia. An example of results is shown in Fig. 3.

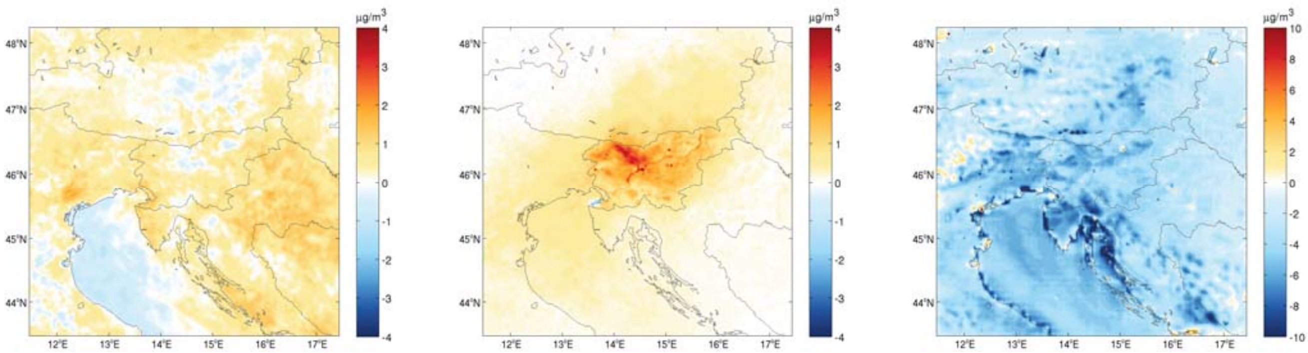

Figure 3. Impact of Left) aerosol direct effects, Middle) detailed anthropogenic emissions for Slovenia, Right) model resolution on 1-day predictions of O_3 daily maxima, averaged over a 2-month period (July-August 2013).

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Oral Presentation

AIR QUALITY MODELLING IN LATVIA:

CHALLENGES AND FAILURES

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Introduction

The aim of the air quality modelling introduction instead of monitoring is clear and could be attracted to several points: (1) due to stricter financial resources modelling is much cheaper than monitoring; (2) models could and should be used for spatial assessment of various pollutants; (3) models are often effectively used for planning purposes. Since the air quality modelling becomes very popular and useful some crucial points should be taken account in order to avoid mistakes and unsatisfied results. This report covers some lessons what have been learned during implementation of air quality modelling as a tool for planning and management purposes.

Models and Parametrization

In Latvia air quality modelling for planning and development purposes according to EU directive requirements has been carried out since 1998. From mathematical point of view Gaussian dispersion models (offered by various companies such as OPSIS or USA EPA) have been used, but for parameterization of atmosphere algorithms from Monin-Obukhov were used. There are also some cases of simpler parameterization used (such as Paskvel-Gifford) for risk assessment in civil engineering in case of chemicals emergency discharge.

Emission Sources

Modelling has been done for particular territory - Riga (capital city of Latvia with densest set of stationary pollution sources, heavy traffic flow and traffic jams, specific architecture with street canyon systems and 50% of population of Latvia). Identification of sources and localization in model has been carried out manually because official reports from operators contain various mistakes, common of them:

(1) inaccurate geographical coordinates;
(2) loss of physical description of sources (no any height of source, unbelievable high discharge rate, etc.);
(3) emissions of pollutants are calculated in order to pay less taxes contrary to real situation assessment (misapplication of methodology);
(4) daily and monthly variability of source working hours were improperly estimated;
(5) traffic flow quantitative and structural assessment was done based on 1 hour counting during traffic jam.

Totally 696 air pollution sources for particulate matter were estimated, 454 of them were point sources, 115 area sources and 127 line (traffic) sources.

Results

Map of summary modelling results for particulate matter (PM_{10}) is given in Figure 1. Map represents summary dispersion results from stationary and mobile sources and natural annual average background concentration (21,3 ug/m^3) should be added to get real situation estimation.

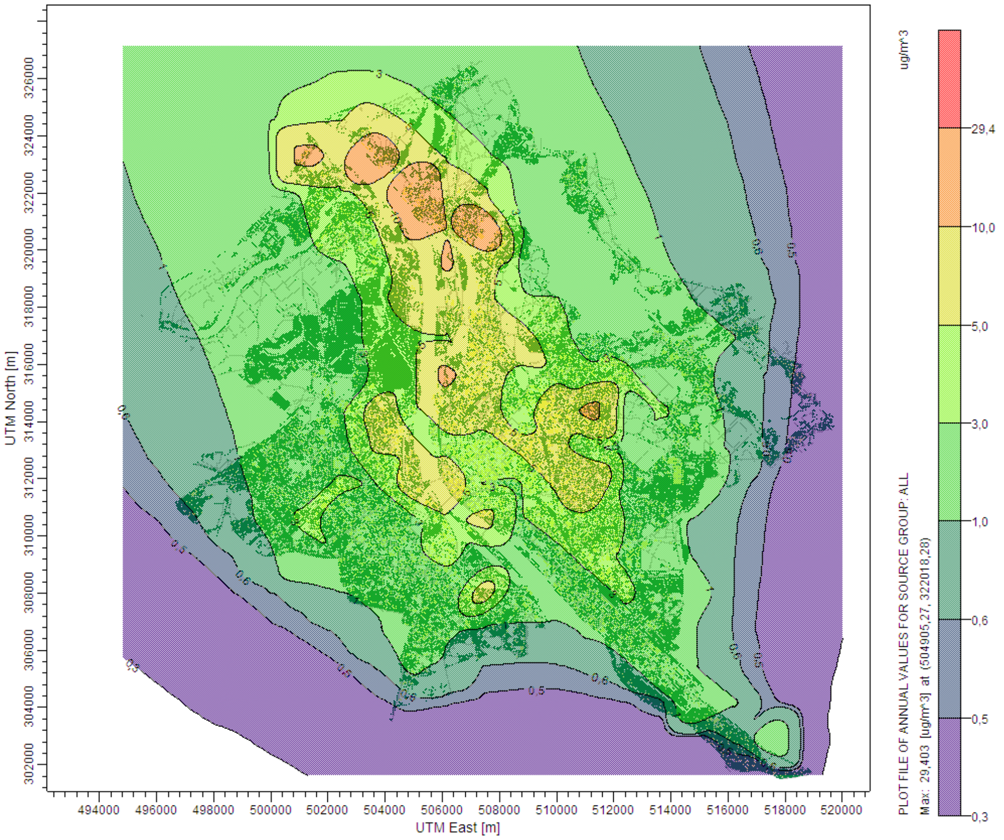

Figure 1. Modelling results of PM_{10} in Riga.

Conclusions

Some lessons have been learned during air pollution modelling tool enforcement:

(1) air quality measurements (even if this is long term monitoring) not always are easily understand because of various parameters affecting them - filter material, pump power, displacement of monitoring station, condition of air-condition system, method of quality assessment and quality control algorithm;
(2) official database of pollution sources are useless;
(3) some of chemical substances are named with different synonyms;
(4) atmosphere parameterization algorithms could affect dispersion result substantially.

Oral Presentation

EMERGENCY RESPONSE AND CHEMICAL WEATHER FORECAST SYSTEMS IN NIMH

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Abstract

Emergency Response System

A PC-oriented Bulgarian Emergency Response System (BERS) in case of nuclear accident is developed and works in the National Institute of Meteorology and Hydrology (NIMH). It's creation and development was highly stimulated by the European Tracer Experiment project. ETEX activities were tracer experiments, proceeded by extensive atmospheric background measurement, real time and off-line long-range dispersion modeling and model evaluation. NIMH took part in all activities of ETEX with the puff model LED [1], results described in [2]. NIMH took part also in the second phase of ETEX (ETEX-II) and in the following model inter-comparison project RTMOD. ETEX-II was an exercise for model results comparison using the ETEX first release database and common meteorological information provided by ECMWF. Two dispersion models were used in ETEX-II: the model LED and the Eulerian dispersion model EMAP [3]. Their runs was ranking ninth (EMAP) and fourteenth (LED) among 34 models [4]. The main results connected with ETEX-II are given in [5].

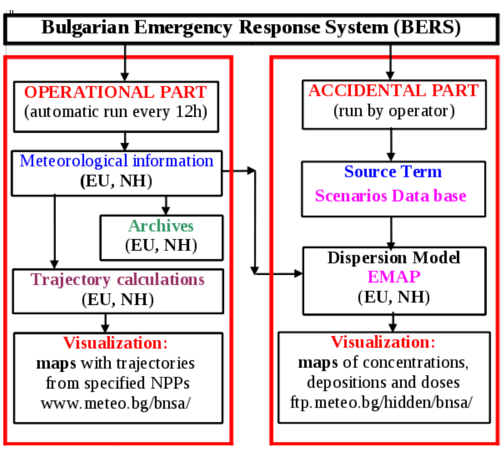

Figure 1. BERS data flow

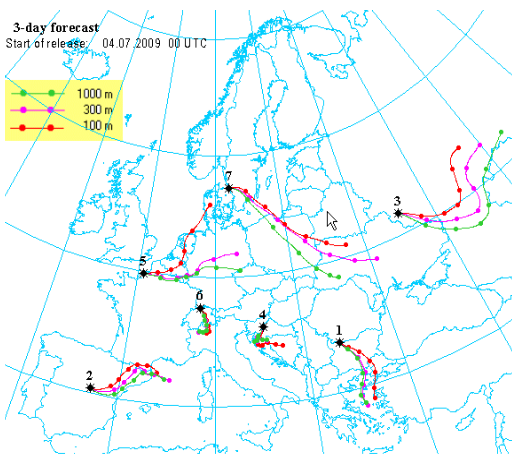

Figure 2. BERS web
(http://info.meteo.bg/ews/index-en.html)

Chemical Weather System

The Air Quality is a key element for the well-being and quality of life of European citizens. According to the World Health Organization, air pollution severely affects the health of European citizens. Both the current level of air pollution studies and social needs in the country, are in a stage mature enough for creating Bulgarian Chemical Weather Forecasting and Information System (CW). For the purpose, a project was started, aiming at designing and setting up such a system able to provide timely, informative and reliable forecast products, tailored to the needs of various users. The system is foreseen to provide in real time forecast of the spatial/temporal air quality behavior for the country and (with higher resolution) for selected sub-regions and cities on the base of the national numerical weather forecast and national emission inventory. The system is realized on 5 nested regions with increasing resolution – from 81 km for Europe to 1 km for Sofia city area. It is based on the WRF-CMAQ models. WRF is driven by NCEP GFS data. The emission input exploits the EMEP/TNO emission inventory for the first two domains (Europe and Balkan peninsula). The three inner domains (Bulgaria, Sofia region and Sofia city) make use of local emission data. The biogenic emissions are calculated by SMOKE model on the base of USGS landuse. The system is run every day at 00Z and produces 3-day forecast for 4 key pollutants: NO2, SO2, PM10 and Ozone. Fool description of the system can be found at its web-site.

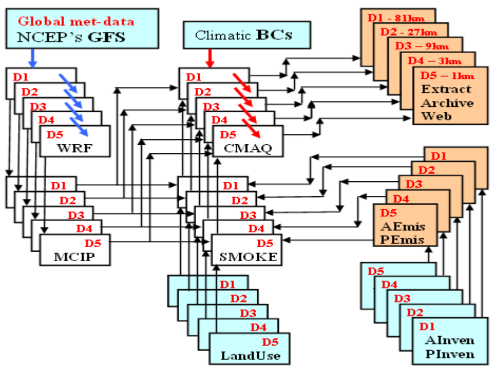

Figure 3. CW data flow

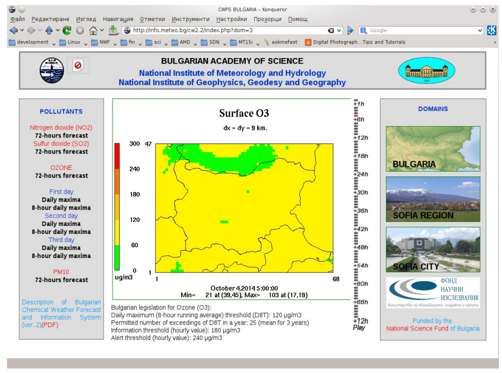

Figure 4. CW web
http://www.meteo.bg/en/cw

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Invited Talk

ASSESSING HUMAN AIR POLLUTION EXPOSURE IN HEALTH ASSESSMENT STUDIES IN EUROPE

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Abstract
It is well documented that air pollution has a negative impact on human health, and that these negative health effects are related to both short-term and long-term exposure [10, 12] - these are usually termed acute and chronic effects. In 2013, WHO estimated that outdoor air pollution results in 3.7 million annual premature deaths worldwide [16]. The International Agency for Research on Cancer (IARC) has likewise in 2013 classified outdoor air pollution in general as a cancer-causing agent (a so-called carcinogen).Urban areas are where the population is most at risk due to generally elevated pollutant levels [9]. According to the European Environment Agency (EEA), between 16% and 30% of the European urban population are currently exposed to annual mean $PM_{2.5}$ (mass of particles with a diameter < 2.5 µm) levels beyond the limit value in the EU Air Quality Directive [7]. Similarly the EEA reports respectively 15% to 17% and 6% to 12% of the European urban population to be exposed to ozone and nitrogen dioxide values above the EU limit values. Furthermore, studies based on register data, exposure assessments and advanced statistical analyses have shown that negative health effects are found also at levels below the guideline limit values.

In most health effects studies related to air pollution, measurements from urban background stations have been applied as air pollution exposure proxies for the urban population. Measurements of urban background pollutant levels have thus been the basis for exposure assessments in European studies such as the APHEA study [4, 15] in which short term health effects were investigated in six European cities. This methodology was also used in the famous American 6-city study [6] that initiated the strong focus on health effects related to long-term exposure to air pollution over the past two decades. Danish studies have demonstrated that address based exposure assessment of traffic air pollution using GIS may provide stronger associations between air pollutants and health effects than have been found when exposure has been assessed from urban background monitoring. In these Danish studies, relations have been found for end points like COPD [3], stroke [1], and diabetes [2].

Allergenic pollen is not classified as a pollutant, and this may be the reason why exposure studies to pollen have received less attention compared with traditional air pollution exposure. This is despite that in many European countries, 20-25% of the population suffer from hay fever. In Europe, the monitoring of pollen is organized within the voluntary programme the European Aeroallergen Network (EAN) that during the time period 2000-2009 included 521 pollen monitoring stations [14]. Chemical air pollutants have the potential to affect allergic subjects directly by stressing the respiratory system [5] but also indirectly e.g. by affecting the allergenic potency of the pollen through protein nitration by the polluted air [8]. The pollen loads are assessed through traditional pollen counts, but measurements of allergens seems as a strong alternative to bring aeroallergen research and monitoring to the same standard as air pollution monitoring. Such studies are e.g. ongoing in Denmark [12].

In air pollution research, meta-analyses point at carbon black and elemental carbon as stronger indicators of health effects in the population [10]. These compounds should therefore

receive much attention in the future revision of the European Air Quality Directives. Pollutants can act as an adjuvant to pollen, increasing the intensity of the allergic reaction in exposed people. It would thus be natural to think in pollen in future air quality monitoring programmes as a part of the air quality monitoring activity.

In recent years, a number of new lightweight online personal exposure monitors that send output to a mobile phone via a Bluetooth connection have become available [11]. This technology is still fairly new, and the devices are in many cases not yet fully validated, but results seem promising and these instruments present many new possibilities in exposure assessment studies. Further developing, testing and exploring the possibilities in application of these devices in the major aim of the COST Action TD1105.

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Oral Presentation

HEALTH AND INDOOR ENVIRONMENT IN ELDERLY CARE CENTERS

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INTRODUCTION

Aged population is growing in most affluent societies of the western world [1], increasing in absolute and relative terms. This is projected to have a major impact on the delivery of health care, particularly acute and emergency services [2]. The older people require significantly more emergency care resources compared to younger adults [2] due to a decline in immune defences and respiratory function, resulting in a higher predisposition to respiratory infections [3]. Such conditions are highly prevalent, multifactorial, and associated with multiple comorbidities and poor outcomes, such as increased disability and decreased quality of life [4].

OBJECTIVES

This article focus on respiratory symptoms of older people living in elderly care centers (ECC). The present results have been produced by measuring and characterizing indoor air quality, thermal comfort and respiratory health in 21 ECC in Porto, Portugal, with a sampling universe of 685 residents. The aim of this study was to evaluate 1) the influence of indoor environmental parameters on older people respiratory health symptoms; 2) the reliability of self-perceived symptoms questionnaires when applied to indoor environmental variables, and 3) develop innovative strategies which, with relatively simple measures, could provide health benefits to ECC residents.

MATERIALS AND METHODS

All ECC located within the Porto urban area and included in the *'Portuguese Social Charter'* were invited to participate in our study. Out of a total of 58 ECC, 36% (n = 21) accepted to participate in the two stages of this study: (1) Environmental data collected for each ECC in two seasons (i.e. summer and winter) starting from November 2011 till August 2013; (2) A respiratory health questionnaire performed from September 2012 to April 2013, along the winter season environmental sampling campaign correspondent to each ECC. The Portuguese version [5] of BOLD (Burden of Obstructive Lung Disease) [6, 7] was administered by a trained interviewer to the older people who gave their informed consent and were able to participate (n= 143). All the participants should had ≥ 65 years old, live in the ECC for more than 2 weeks and possess cognitive and interpretative skills in order to receive the questionnaire.

RESULTS

Our sample was characterized mainly by women (85%), with most people in the age group above 85 years old (48%). Participants presented a reasonable rate of dementia (40%) and they were mostly (61%) physically impaired. Cough (23%) and sputum (12%) were the major respiratory symptoms, and allergic rhinitis (18%) the main self-reported illness. Heart troubles were reported by 37% of the residents. Overall $PM_{2.5}$ median concentration was above reference levels both in winter and summer season. Also, peak values of PM_{10}, total volatile organic compounds, CO_2, bacteria and fungi exceeded the reference levels, compromising indoor air comfort and worsening the already existent respiratory chronic diseases. The winter predicted mean vote (PMV) index was below references, between the 'slightly cool' (-1) and 'cool' (-2) points in the thermal sensation scale, which may potentiate respiratory tract infections. Predicted percentage dissatisfied and PMV indices also showed significant differences by room and by season ($p < 0.01$). Older people exposed to PM_{10} above and temperature below the reference levels presented a higher odds of allergic rhinitis (OR = 2.9, 95% CI: 1.1 – 7.2) and (OR = 0.8, 95%:0.6 – 1.0) respectively.

CONCLUSIONS

Indoor environment have a potential influence in chronic respiratory symptoms on older people living in ECC due to their health susceptibility and decline in immune defences and respiratory function. Self-perceived symptoms questionnaires have some limitations when applied to older people with physical and cognitive impairments. These results need to be confirmed in future studies. Adequate measures, such as, local exhaust ventilation systems near cooking and gas burning devices, as well as, daily slightly moist cleaning of the rooms surfaces would reduce particle accumulation and re-suspension. Low indoor temperatures and discomfort, especially on winter season, could be prevented by simple measures such as insulating ceilings, walls and windows, maintaining natural and passive ventilation.

ACKNOWLEDGMENTS

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Oral Presentation

INDOOR AND OUTDOOR LEVELS AND CONTENT OF SELECTED TOXIC SPECIES IN PM_{10} AND $PM_{2.5}$ OF URBAN KINDERGARTEN LOCATED IN RESIDENTIAL-COMMERCIAL AREA

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Background and aim

First kindergartens and later schools are the microenvironments where adolescents spend significant period of time. Indoor particulate matter (PM) represent mixture of both, infiltrated and indoor-generated PM. Outdoor PM originate mainly from soil, traffic combustion and resuspension, industrial sources, temporally-variable emission sources such there are construction works, district heating plants, parking lots. Although the kindergarten ambient is usually lacks typical home indoor PM sources such there are smoking and cooking, in many studies there are notified comparatively high concentrations of PM in classrooms. Beside infiltrated outdoor PM through the building envelope, level and content of indoor PM are under influence of air exchange rate, surface cleaning practice, number, age and physical activity of children in relation to room area and volume.

Studies about levels of heavy metals and/or PAHs of indoor PM fractions in schools and kindergartens in European countries is concerned in limited number of studies [1-3]. To date, there are no simultaneous studies of the PAHs and elemental compositions of PM in indoor air in any kindergarten/school even other microenvironment in Serbia. The aim of this study was to provide simultaneous information on the mass, organic and inorganic composition of indoor PM fractions of kindergarten located in a densely populated commercial-residential area with high traffic density in city centre of Belgrade. Pollutants like PAHs and trace elements have the potential to cause adverse health effects as some of them are toxic, mutagenic or carcinogenic, etc. For the purpose of better understanding ratio of risk from exposure in indoor and outdoor ambient specific for traffic urban environment in Serbia there were quantified 16 EPA and EU priority PAHs (Nap, Any, Fle , Phe, Ant, Fla ,Pyr, Baa, Chr, Bbf, Bkf, BaP, Inp, Daa, Bpe) and 16 metals and metalloids (Al, Ba, Fe, Ti, Zn, As, Cd, Co, Cr, Cu, Mn, Ni, Pb, Sb, Se, V).

Materials and methods

The kindergarten is located next to the busy street. PM_{10} and $PM_{2.5}$ were collected with LVS (Sven/Leckel LVS3) using quartz filters in the indoor air of room of the kindergarten and simultaneously in outdoor air in front of the windows on a balcony. Campaign was carried out in early spring covering heating and nonteaching season, for a time period of 40 consecutive week days. PMs were collected on daily bases, 24h, while kindergarten was occupied form 6 a.m. to 6 p.m. In the vicinity of the kindergarten there are no known industrial sources of emissions. Microbalance, Precisa XR 125 SM, was used for PM mass quantification. The elemental analysis was performed on ICP-OES (Varian, Vista Pro) and ICP-MS (Octopole Reaction System, Agilent 7500ce), while PAHs were analyzed with GCMS (Agilent 6890N with Mass Selective Detector).

Results

The indoor concentrations were significant for both size fractions, average daily value (24 h) were 40.61 and 32.35 $\mu g/m^3$ for PM_{10} and $PM_{2.5}$, respectively. Mean daily value of PM_{10} and

$PM_{2.5}$ indoor concentrations were varied in range 19.93 - 76.20 and 19.02 - 63.23 μg/m^3, respectively. This study sampling procedure included both time periods, when children were and were not in classroom, while main daily indoor PM concentrations might be underestimating the children exposure to particles. In all studies including study of *Tran et al*. [2], where PM measurements were carried out only during children occupancy, concentrations were about twice as high as 24h average classroom concentrations. In anyway PM concentration for both fractions were higher in indoor during more than 30% days than in outdoor environment of the kindergarten. Al, Zn and Fe represent 90% measured elements in both fractions. Metals had higher average concentration in both fractions in outdoor environment in comparsion with indoor microenvironment. Observed average mean daily concentrations, in indoor and outdoor environment, for Pb, As, Cd and Ni in PM_{10} were below EU annual limit values. It was notified ratio of I/O of analysed elements in PM_{10}: for Al > 1 (1.21), between 0.6 and 0.9 for next element 0,60 < Fe < Sb < Mn < Pb < Ti < Se < V < As < Ni < Co < 0.90 and between 0.95 - 1.05 for Ba, Cd, Cr, Cu and Zn. Average indoor daily values ΣPAHs were 6.79 and 4.04 ng/m^3 in PM_{10} and $PM_{2.5}$, respectively. During campaign, sum of 16 priority PAHs, ΣPAHs, in PM_{10} were higher indoor than outdoor in 23%, while they were identified higher ΣPAHs in 5% of $PM_{2.5}$ samples. Characteristic of this sampling site in indoor and outdoor ambient is that content of PAH in Nap, Ane, Any, Fle and DdA were between 0,4 to 1 magnitude lower in $PM_{2.5}$ than in PM_{10}. Mean values of assigned PAHs in PM_{10} were higher in indoor environment for all PAHs with 2 and 3 rings (Nap, Ane, Any, Fle, Flu) and Daa, that is one of PAH with 5 rings. For other 10 of 16 selected PAHs in PM_{10} mean values are higher outdoor than indoor environment, while in $PM_{2.5}$ all PAHs were higher outdoor. BaP as most representative PAH were content almost all in fine particulate fraction, with concentration of about 0,5 ng/m^3. Average particle bounded PAHs express as ΣBaPE [4] exceeded 1 ng/m^3 for PAHs in PM_{10}, while they were lower than 1 ng/m^3 for PAHs in $PM_{2.5}$.

Conclusions

Data from this study prove that PM_{10} as well as fine PM concentration exceed limit and target values set in current WHO guideline and EU regulative. Average daily mean PM mass as well as ΣPAHs were higher outdoor than indoor in both PM_{10} and $PM_{2.5}$. According to the EU regulative, annual limit value for PAHs in PM_{10} expressed by BaP is 1 ng/m^3. During 40 days of sampling campaign PAHs expressed by ΣBaPE [4] exceeded 1 ng/m^3 in PM_{10} in both, indoor and outdoor kindergarten ambient. Findings above proved that beside sources from outdoor, such as vehicular emission and combustion sources, in indoor ambient of the kindergarten happened generation or/and resuspansion PM from indoor surfaces that may contribute to higher exposure to selected spices.

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Oral Presentation

SPATIAL DISTRIBUTION AND ORIGIN OF POLLUTANTS IN LICHENS FOR FINGERPRINTING OF AIR-POLLUTION

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Abstract

Despite reductions in atmospheric pollutants concentrations, the monitoring of this pollutant is still of great concern. Lichens, which are the result of a symbiosis between algae and fungi and have been used as ecological indicators of environmental changes. Both lichen functional diversity (e.g. *Pinho et al.*, 2008) and accumulation of pollutants (e.g. *Augusto et al.*, 2010) has been used as indicators of industrial pollution and the same approaches have been used as indicators of nitrogen (*Pinho et al.*, 2011, 2014).

Indeed, lichens have been used as bioindicators of the impacts of different pollution sources for over 40 years bringing new insights about the impact of organic and inorganic pollutants, integrating different temporal and spatial scales. However, an unexplored potential as source-tracers remains. In fact, few attempts have been made to try to distinguish and spatially model different sources of both organic and inorganic pollutants using lichens.

Within the organic pollutants, polycyclic aromatic hydrocarbons (PAH) are toxic compounds that have been classified by the International Agency for Research on Cancer as probable or possible human carcinogens. Human exposure to PAH is usually assessed by considering data from a single air monitoring station as being representative of a large region; however, air pollution levels change on small spatial scales and thus also affect environmental exposure.

The use of lichens as environmental biomonitors is a useful tool to assess the levels of PAH with high spatial resolution (e.g. *Augusto et al.*, 2012). Currently, stable isotope analysis is a powerful tool in environmental studies to trace, record, source, and integrate ecological parameters of interest.

Moreover, the impacts and variations that result in changes to modern environments are also seen as changes to the H, C, N, O and S isotope ratios of atmospheric gases, soil organic matter and its diverse chemical substrates, as well as water sources in the hydrosphere and the atmosphere (*Dawson et al.*, 2007; *Máguas et al.*, 2011). Thus, the H, C, N, O, S, and Sr isotopes are the elements that vary the most on Earth, constitute the bulk of all living matter, and are used most effectively to track changes in the Earth's biogeochemical cycles.

Accordingly, in this study we will assess: (1) human exposure to PAH in a petrochemical region in Portugal, integrating data from environmental biomonitors (lichens), air, and soil in a regional area, (2) N and S isotopic values in an industrial coastal region in order to disentangle the sources of pollutants sources, localizing different anthropogenic sources and highlighting the potential use of lichens to distinguish between different types of anthropogenic sources.

The high spatial resolution of our environmental data allowed for detection of critical exposure levels at unexpected sites. Moreover, our results identified important areas where health studies on local populations need to be focused, and where environmental levels of PAH need to be monitored over time in order to protect human health.

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Oral Presentation

CHEMICAL SONDES USING LOW COST SENSORS:

PROJECT AIMS AND OUTLINES

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Abstract

Atmospheric composition measurements in the tropical tropopause layer (TTL) and upper troposphere lower stratosphere (UTLS), are fairly sparse. They require specialised equipment, such as instrumented aircraft or large balloons, and these platforms are expensive to run and operate intermittently, and therefore cannot provide continuous or long-term measurements. Although satellites can provide this level of coverage, they have a finite operational lifetime, are expensive to operate, and encounter limits to their information retrieval; especially in the UTLS due in part to the radiative properties of clouds and the spatial gradients of the species encountered there, leading to errors and lower resolution vertical measurements compared to in-situ observations.

The TTL (and UTLS generally) are important regions of the atmosphere, as they are sensitive to changes in climate (through anthropogenic activity for example) which can influence the radiative, transport and chemical processing occurring there. As the interface between the stratosphere and troposphere, changes in the TTL structure and chemical composition can effect the composition of the stratosphere (e.g. O_3 and H_2O) in turn changing the radiative environment, with potential feedbacks on tropospheric climate.

At present, the only routine profile measurements in the TTL, are provided by the global ozonesonde network with a small number of ground-based lidar measurements. Again, these methods are limited by their spatial coverage and the range of species measured. Extending these existing networks by making it feasible to conduct wide-ranging composition profile measurements, would have the potential to revolutionise atmospheric measurement programmes.

This project will develop and deploy for the first time lightweight, low cost (expendable) multi-species chemical sondes, to address the limitations in composition measurement as described. The sondes will incorporate new electrochemical (EC) sensors for CO, O_3, NO_x, SO_2, and a novel miniature optical cavity CO_2 instrument launched on standard meteorological balloons. The package will be suitable for use in global sonde networks, e.g. Global Climate Observing System (GCOS), and for stand-alone use, with applicability to short-term monitoring (pollutant transport, chemical processing) and long-term monitoring (trend detection and climate change).

This presentation will introduce the technologies behind the project, and explain the planned phases of the project and potential problems to overcome; from development and construction, laboratory testing and validation, through to our plans for initial deployment.

Oral Presentation

NDIR SENSORS: TRENDS AND APPLICATIONS

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Abstract

Within the field of gas measurement two distinct trends can be distinguished, each having its implications on new possibilities for adoption of NDIR technology.

The trend towards smaller size, lower cost and lower power requirements opens up new application areas for employment of NDIR sensors for gas measurements. Miniature size sensor modules are now available [1] that fit the requirements of new types of sensor applications:

- Combination sensors that measures several important parameters for IAQ
- Networked sensors, wireless and bus powered
- Personal IAQ monitors and air cleaning devices for personal use

Another trend in NDIR sensing is towards higher precision measurements. New material combinations and assembly methods have enabled the design of stable, high-precision sensor modules, still keeping the per-device cost at a reasonable level compared to competing sensor technologies.

These new types of modules, with their relatively small size, are being developed [2] for different applications including:

- Automotive sensors for alcohol detection
- Methane and carbon dioxide sensors for environmental monitoring

Both of these trends are pushing sensor developers hard to come up with solutions for:

- Reducing material and assembly costs
- Minimizing size while maintaining measurement performance
- Decreasing sensor power consumption
- Improving measurement performance and sensor stability

The future potential for this development lies in the new market possibilities that could open up when size, cost and power consumption go down, or when measurement performance is increased. Application areas and products that were not previously possible to realize can now be designed and manufactured thanks to new technology.

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Oral Presentation

A VERSATILE OUTDOOR PLATFORM FOR MOX FIELD TESTS

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Abstract
MOX gas sensors are suitable for detecting a wide range of oxidable and reduceable gases. Their low cost and mass production capability make them interesting for many applications. Special data acquisition techniques allow for operating MOX sensors selectively and even for improving on sensitivity. Some interesting fields of application however pose significant challenges regarding target gas concentration – this holds true especially for monitoring of air pollutants in indoor or immission control scenarios. In order to undertake research in this field, integrated field test systems are needed for testing sensors, electronics and algorithms in the context of the application. Based on experience in indoor air quality [1, 2], the authors devised an outdoor system which shall combine field-proven sensor electronics and data acquisition with means to stand the challenges of outdoor installation. While a first prototype series is tested in the scope of a governmental immission monitoring project, the aim is to provide a reliable and at the same time flexible basis for studying new sensors in the field.

Background
The principle of MOX sensors relies on the chemical interaction between oxygen absorbed on the active sensor surface and the surrounding atmosphere. Those redox reactions depend strongly on the surface temperature of the sensor. Modulating the surface temperature is an effective means to increase selectivity and sensitivity of MOX sensors [3, 4].
Research on indoor air quality monitoring with MOX sensors in the frame of the MNT-ERA.net project VOC-IDS has shown that identification and quantification is possible even for very low concentrations of target gases down to the sub-ppb range. While these results are promising, interfering gases from various sources in the field impair the overall performance by dominating sensor reaction. Intelligent data processing can partly solve the problem, improvements in sensor technology are needed for reliable applicability [5, 6].
Data processing with temperature modulated MOX sensors is mainly based on statistical methods which interpret signal patterns. Apart from identification and quantification of single substances, these pattern recognition techniques can also be used for odour evaluating purposes.

Figure 1. Complete outdoor field test unit.

Field test system
The field test device (see Figure 1) incorporates sensors, electronics and control as well as pneumatic elements to expose the sensors to outdoor air. Whereas the main measurement components are inherited from indoor device development, key issues in the outdoor system

are weatherproof operation and power supply. Fully stand-alone operation of two MOX sensors and a humidity and temperature sensor with freely configurable data recording to a memory card is a built-in feature, the system can be extended by an external wind sensor and an optional communication module.

Outdoor tests

In order to achieve a meaningful result from the sensor patterns, correlations have to be recorded between sensor response and human perception. This is to be done via a set of prototypes distributed in an area of periodically reported odour nuisance.

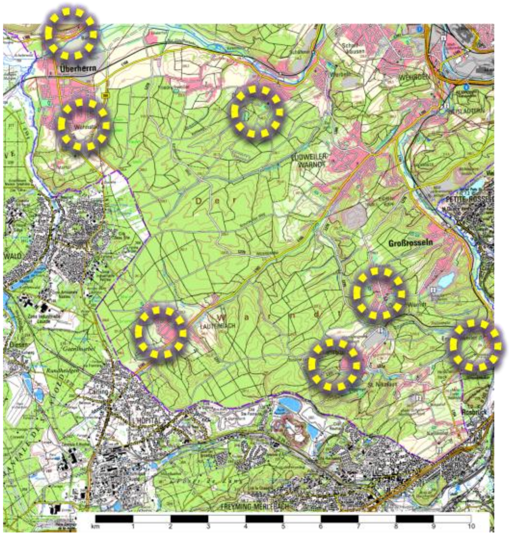

Figure 2. Distribution of systems in a field test area.

Outlook

As the field test platform constitutes a new development from the technological aspect as well for the application field, first installations of the prototypes aim at a proof of concept.
Further work will cover sensor selection, electronics durability and other technical aspects as well as statistical correlation of measurement data and results from a human test panel. Eventually, a working fully featured system could be used as a basis for downscaling to a application specific device. Apart from MOX sensors, other sensor principles shall be considered and included if useful for certain applications.

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Oral Presentation

A SILICON-ON-INSULATOR (SOI) PLATFORM FUNCTIONALIZED BY ATOMIC LAYER DEPOSITION (ALD) FOR HUMIDITY SENSING

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Abstract

The *More-than-Moore* mutation of micro-electronics pushes further the traditional Moore's law by addressing new technological challenges, allowing the migration from the printed circuit board level to package (system-in-package or SiP) or chip (system-on-chip or SoC) levels [1]. These advanced packages incorporate a wide range of components as sensors, actuators, biochips, RF link, high power/voltage, energy harvesters, etc.

Into this trend, there is a need to develop low cost, low power and reliable sensors with integrated electronics interface for applications from ambient to above 200°C [2-3], able to operate in harsh environments. A miniature system is required for in-situ monitoring. An SOI technology is required to withstand high temperature on the contrary to standard CMOS sensor [4-5]. And a micro-hotplate technology allows easy expansion of the devices into arrays of sensors and their circuitry. In addition to water vapour, CO_2, O_2 and CO have to be monitored with a gas system on a chip, for the methane combustion monitoring specific application. This gas sensing SoC will push to market new metal oxides-based technologies, able to detect all the above gases and still remain compatible to SOI-CMOS technology. Moreover, the embedded heater can be used for temperature dependence cancellation and pulse-width modulation (PWM) layer activation.

For humidity sensing, aluminum oxide (Al_2O_3) has been demonstrated to be an excellent material, even in most industrial gases [6] while polymer-based sensor cannot withstand high temperatures. An Al_2O_3-ceramic miniaturized humidity sensor offers high temperature and humidity range, resistance against chemicals, short time response. Moreover, atomic layer deposition (ALD) of Al_2O_3 allows simple post-process operations compared to optical detection [7] and less common materials as WO_3 [8], porous silicon [9], carbon nanotubes [10] or TiO_2 nanotubes [11]. ALD Al_2O_3 deposition step gives conformal and continuous films on semiconductor devices, ensuring thickness control at the monolayer level and excellent dielectric films.

For water vapour measurements, the interdigitated electrodes (IDE) of the SOI micro-hotplates were functionalized with 25 nm–thick Al_2O_3 deposited by thermal ALD at 150°C. The sensor behaviours were analysed during 48h-long measurements in climatic chamber from 25°C to 85°C and from 35%RH to 95%RH. Z-to-f transducer measurements show up to a 5x oscillating voltage frequency decrease, from 100 kHz to 20 kHz, at 85°C and for 35% to 95%RH variation.

The novelty of our sensor can be summarized in the combination of the following five points: (1) one-step ALD post-processing; (2) measured operating humidity range from 35%

relative humidity (RH) to strong condensation (3) rapid adsorption/ desorption time; (4) low power SoC integration in SOI-CMOS process and (5) high temperature working range extension availability.

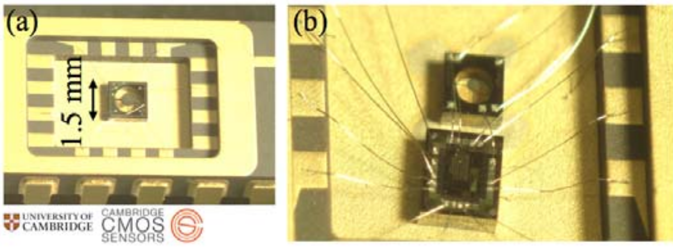

Figure 1. Multifunctional suspended SOI micro-hotplates for point-of-care flue gas analysis: (a) sensor alone and (b) with SOI readout interface.

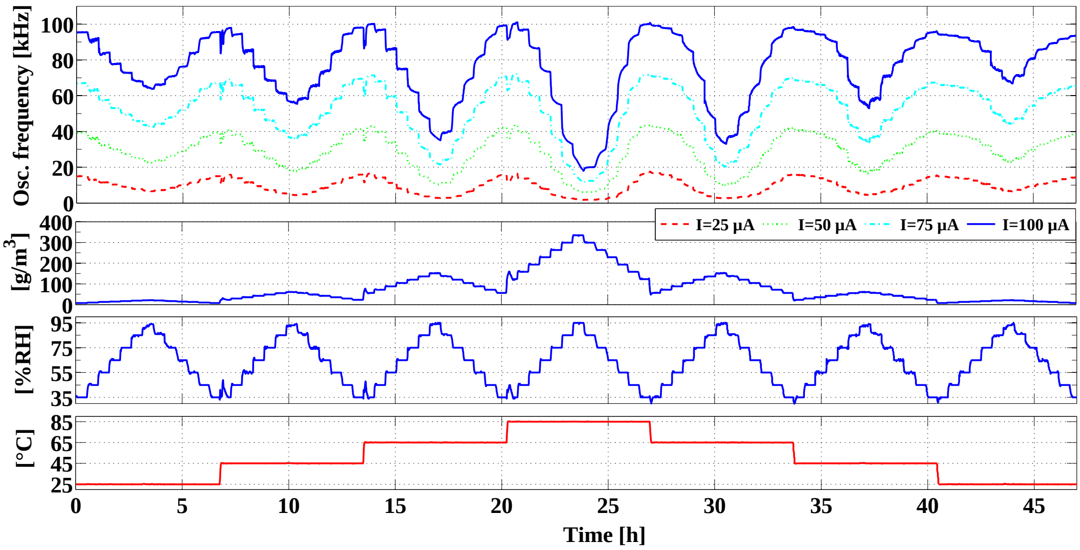

Figure 2. Oscillating voltage frequency output according to %RH and T, for the read-out interface wirebonded to the microhotplate humidity sensor as presented on Fig. 1(b).

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Oral Presentation

VOLATILE ORGANIC COMPOUND DETECTION BY POLYMER-NANOSTRUCTURED CARBON COMPOSITE

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Abstract

In European Union are regulations that determine and limit volatile organic compound (VOC) emissions in the air. Directive 2008/50/EC on ambient air quality and cleaner air for Europe regulate the upper and lower threshold for benzene and give recommendation of several VOC to be measured as ozone precursors. However each EU member state shall have their oven measures for VOC control in the air indoors and outdoors [1]. In United States Occupational Safety and Health Administration have determined several exposure limits like PEL, TWA, IDLH and STEL for VOC concentration at workplaces. Despite the fact that VOC control regulations exist there are not suitable, easy handling equipment for in-situ monitoring of VOC concentration in the air. One of possible solution could be a sensitive, fast response sensor for reasonable price.

Previous research studies have shown that polymer-nanostructured carbon composites (PNCC) and conductive polymers have promising sensitivity to VOC [2-4]. Here presented results are for PNCC, which is made of insulator - polyisoprene (Pi) and conductive filler - carbon nanoparticles (CB) or multiwall carbon nanotubes (MWCNT). Conductive PNCC is obtained by gradually increasing filler concentration in the composite until conductive grid into the composite is obtained. Conductance increase with the filler concentration rise is explained on the base of percolation theory. Studies on PNNC conductive structure and percolation critical parameters have shown that for composites, which are meant to be applied as gas sensors, essential is homogenous filler dispersion and comparably small filler aggregates, which form the conductive grid. Scanning electron microscopy image of Pi-MWCNT composite with 7 mass parts of filler are shown in Fig.1, where individual MWCNT forming the conductive grid can be seen.

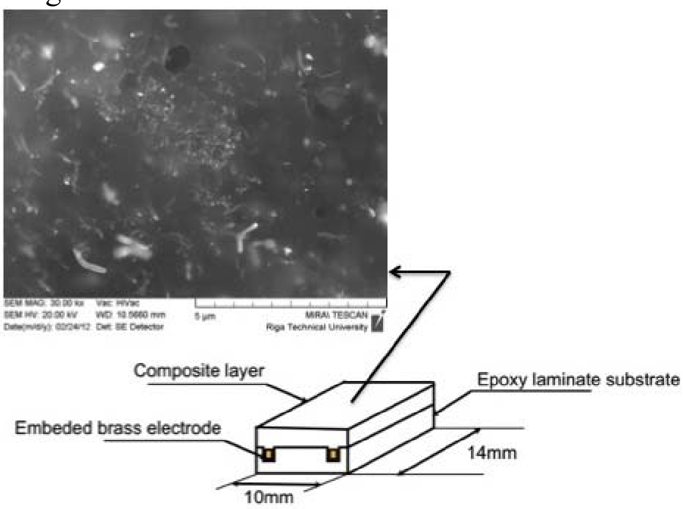

Figure 1. SEM image of Pi-MCNT7 composite and geometrical dimensions of PNCC sample.

PNCC sensitivity to VOC has been determined (see Fig.2). PNCC response to the presence of VOC is read as electrical resistance change of the composite. The sensing mechanism of the composite is explained as follows. When PNCC is exposed to VOC, molecules of volatiles diffuse into the composite. This induces swelling of the composite matrix. As a result distance between aggregates of conductive filler increases and tunneling currents decrease. It can be seen from Fig. 2 that the composite can sense different concentrations of VOC. Experimental results show that detection threshold of Pi-CB8 composite with 40µm thickness is 40 ppm in case of toluene. The sensor effect is reversible, when source of VOC is removed the composite electrical resistance returns to the initial value.

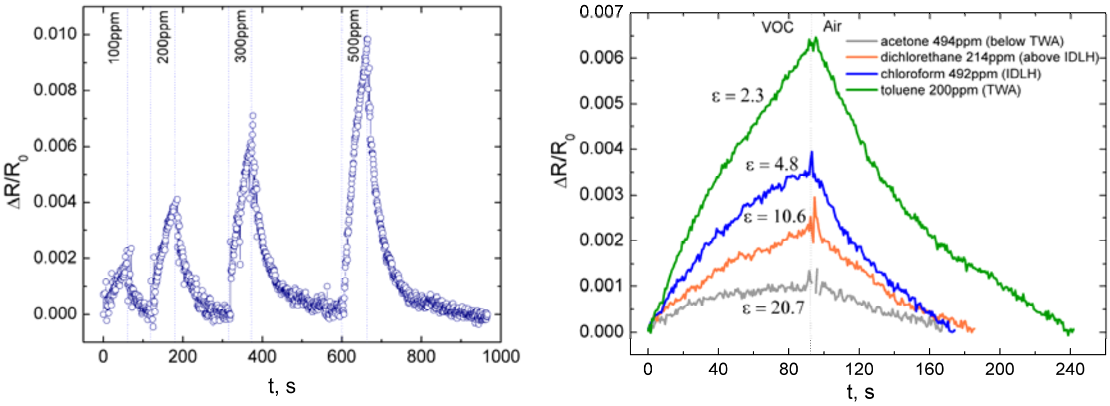

Figure 2. *(on the left)*Pi-CB8 composite relative electrical resistance change in time, when the composite exposed to different concentrations of toluene. *(on the right)* Pi-CB4.4 composite relative electrical resistance change in time, when the composite exposed to different VOC.

From Fig. 2 (*on the right*) can be seen that the composite shows remarkable difference in response, when exposed to diverse VOC. Difference in response is explained by composite polymer matrix compatibility with VOC. Compatibility can be evaluated by comparing Hansen solubility parameters or dielectric permittivity *ε* values (indicative method). Obtained results indicate that Pi-NCC is more suitable for nonpolar (low *ε* values) VOC detection, where higher response is shown.

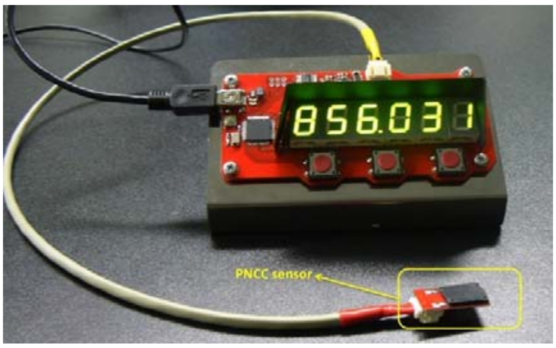

Figure 3. Device prototype with integrated PNCC sensor element (Pi-CB8).

At Riga Technical University device prototype is elaborated (see Fig. 3). The prototype has following functions: measurement of PNCC electrical resistance, possibility to set initial resistance, measurement of relative electrical resistance in time, adjustable measurement time.

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ABSTRACTS
OF
POSTER PRESENTATIONS

Poster Presentation

A Portable Low-Cost High Density Sensor Network for Air Quality at London Heathrow Airport

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Abstract

The growing demand for air travel in the UK has led to calls for ways to address the effects of increasing activities in airports in London. London Heathrow airport (LHR) is the largest airport in the UK and in recent years has been operating close to full capacity resulting in consideration of building a third runway to ease the burden at the airport. Such an expansion would be subject to meeting several criteria including local air quality challenges. Air quality issues associated with the airport include particulates (e.g. $PM_{2.5}$, PM_{10}), carbon monoxide (CO), oxides of nitrogen (NO, NO_2), sulphur dioxide (SO_2) and volatile organic compounds (VOCs), and these are associated with different sources including aircraft activities and road traffic within and outside of the airport. Although it is well known that airports contribute to poor air quality, part of the challenge is to quantify contributions from these different sources.

The work presented here shows the utility of low-cost high density sensor networks in addressing this challenge. We have shown in previous studies the application of low-cost electrochemical sensor network instruments in monitoring air quality pollutants including CO, NO and NO_2 in an urban environment. In this paper we extend this to include modified versions of these instruments which incorporate additional species such as O_3, SO_2, VOCs, CO_2 as well as size-speciated particulates (0.38 to 17.4 µm). Meteorological data including temperature, relative humidity, wind speed and direction are also recorded. For this paper, we focus on LHR, although the technique has much wider applicability.

A network of 30 sensor nodes is being deployed for over 16 months in and around LHR as part of NERC funded Sensor Network for Air Quality (SNAQ) project. We present here some of the early results from the deployment showing source attribution associated with different operational modes at LHR. Regional pollution episodes influenced by macro meteorology are also presented. In this paper we show how SNAQ can provide measurement data useful for validation of air quality models currently used for LHR, the generation of emission inventories for the airport as well as pollution source attribution within and around LHR.

This work shows the first attempt at using high density spatial network of low-cost sensor network within LHR, thereby facilitating the quantitative and qualitative analysis of air pollution in real world operations at LHR.

Poster Presentation

GAS SENSING CHARACTERIZATION OF CMOS INTEGRATED NANOCRYSTALLINE SNO_2-AU THIN FILMS

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Abstract

In recent years a growing demand in cost-efficient solutions for indoor and outdoor air quality monitoring has led to various sensor strategies [1]. Gas sensors based on metal oxides (MOX) are the weapon of choice and have been under close investigation [2]. Their notable advantages are low-cost and simple production, high sensitivity and fast response to numerous gases [3]. Furthermore, metal oxide gas sensors can be integrated into CMOS technology. As previously reported by our group [4], SnO_2 thin-films have been directly deposited on a CMOS chip and thereby proven its quality for CMOS integration [5]. Despite its numerous advantages the most challenging issue is cross-sensitivity to different gases and humidity. To reduce these confounding factors the sensing material can be functionalised by deposition of noble metal nano particles. In this work conductometric measurements were performed on CMOS integrated SnO_2 – Au functionalised gas sensors (Fig. 1). The sensor material was deposited by spray pyrolysis at 400°C upon a microhotplate (a CMOS integrated structure to adjust the sensors temperature). The sensing layers were structured by photolithography and ion etching. The functionalization of the SnO_2 layers was conducted by evaporation of a 2 nm thin gold film. In a subsequent step the sensing layers were tempered at 400°C, which resulted in the formation of Au nanoparticles. In Fig.2, the sensor performance is shown for ethanol and a hydrocarbon-mix (acetylene, ethane, ethene, propene) at different humidity levels. Results considering various humidity levels, temperatures, testing gas species as well as TEM investigations of the sensors will be presented in detail.

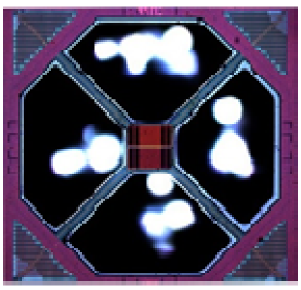

Figure 1: Microhotplate with SnO_2 - Au sensing layers (ams

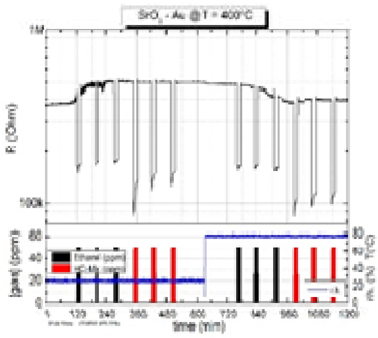

Figure 2: Resistance of SnO_2 - Au sensor exposed to ethanol, a hydrocarbon mixture and two different humidity levels. Sensing layer temperature T = 400°C.

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Poster Presentation

OUTDOOR TEST PLATFORM FOR MOX SENSORS

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Abstract
MOX gas sensors are suitable for detecting a wide range of oxidable and reduceable gases. Their low cost and mass production capability make them interesting for many applications. Special data acquisition techniques allow for operating MOX sensors selectively and even for improving on sensitivity. Some interesting fields of application however pose significant challenges regarding target gas concentration – this holds true especially for monitoring of air pollutants in indoor or immission control scenarios. In order to undertake research in this field, integrated field test systems are needed for testing sensors, electronics and algorithms in the context of the application. Based on experience in indoor air quality, the authors devised an outdoor system which shall combine field-proven sensor electronics and data acquisition with means to stand the challenges of outdoor installation. Aside from taking part in EuNetAir - Air quality Joint-Exercise Intercomparison, the prototype series is currently being tested in a governmental immission monitoring project.

Figure 1. Weather proof housing (left) and inner workings (right) with measuring box (right, framed).

Background
The principle of MOX sensors relies on the chemical interaction between oxygen adsorbed on the active sensor surface and the surrounding atmosphere. Those redox reactions depend strongly on the surface temperature of the sensor. Modulating the surface temperature is an effective means to increase selectivity and sensitivity of MOX sensors. Sensor technology is a key issue for this technique as short time constants are vital for fast transient operation [1, 2].
The sensor front-end for MOX sensors has to drive the heater and to measure the sensor response. Temperature control has to be applied for reproducible sensor operation; a variable target value allows for temperature modulated operation. As the sensing layer changes resistance with temperature and sensor reaction, the measuring circuit has to be precise over a wide input range. Individual adjustment to the corresponding sensor type is advisable.
Combining sensor electronics with a central control unit into an integrated test system facilitates stand-alone operation of temperature modulated MOX sensors. Successful application of such systems to indoor air quality assessment has been shown in MNT-ERA.net project VOC-IDS. Main objective in this project was the identification and quantification of very low concentrations of hazardous substances in the sub-ppb range [3-5].

Test platform for outdoor use

The outdoor test platform shown in Figure 1 is currently equipped with two MOX sensors which are controlled and measured independently. Electronics can be modularly chosen for macro-structured MOX sensors or micro-structured types. Heater base resistance can be adjusted according to the respective sensor, heater power can be up to 6 W each. Target temperature can be adjusted 255 steps over a matched temperature range with a time resolution under 100 ms.

Sensor resistance is measured using constant voltage at the sensing layer, with near-to-linear resolution over three decades. This data can be recorded with a sampling rate up to 10 kS/s and 11 bit resolution.

For ambient condition monitoring, a combined humidity and temperature sensor is included in the system. It is located pneumatically after the pump (see Figure 2) which can deliver a flow rate of up to 800 mL/s. As wind speed and direction play an important role in atmospheric dispersion, an external anemometer / wind vane can be connected to the system.

All sensor data is recorded locally to a memory card which also contains configuration data and measurement parameters; a multi-purpose data interface allows for extension with a communication module.

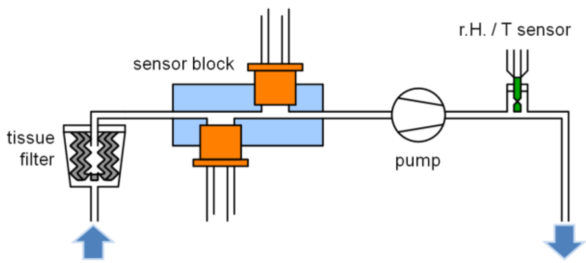

Figure 2. Pneumatic configuration.

Outlook

As the approach of applying temperature modulated MOX sensors to immission measurement is quite new, the first results shall give a proof of concept and a basis for further work in this field. Sufficient sensitivity of the overall system on immission site and durability of sensors and electronics have to be checked in a first step. Afterwards, response patterns in respect to reference measurements and feedback from human panels will be correlated. Stepwise improvement on every aspect of the system shall lead to a fully featured test device which then can be downscaled to application specific solutions.

Apart from being equipped with MOX sensors, the modularity of the system allows for adaption to and combination with other types of sensor and sampling units, so that a broad range of experiments and applications is possible.

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Poster Presentation

INDOOR AIR QUALITY ASSESSMENT IN ELDERLY CARE CENTERS IN PORTO, PORTUGAL

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INTRODUCTION

According to the United Nations estimates, the total number of people aged 65 years and older was 506 million in 2008 and is anticipated to double to 1.3 billion by 2040, accounting for the 14 percent of total global population. This trend explains the increasing demand of long-term care services [1] such as elderly care centers (ECCs). Furthermore, considering that persons who are 65 years or older, often spend a considerable percentage of their lives indoors, it is clear that the possibility that adverse indoor climate can influence their health status cannot be ignored. This paper presents results which have been produced within the GERIA ongoing project 'Geriatric study in Portugal on Health Effects of Air Quality in Elderly Care Centers', by measuring and characterizing indoor air quality (IAQ) and thermal comfort (TC) in 22 ECCs in Porto, Portugal. The aim of the study was to evaluate 1) the IAQ and TC in a representative sample of ECCs in Porto as compared with international standards, 2) to study the variability among different spaces within single ECCs, and 3) how buildings characteristics may affect the extent of indoor air pollution or thermal regulation.

METHODOLOGIES

Of a total of 58 ECCs, located in Porto urban area, 38% (n =22) accepted to participate in this study. Indoor environmental parameters were measured twice, during winter and summer, starting from November 2011 till August 2013, in 141 ECCs rooms within dining rooms, drawing rooms, medical offices and bedrooms. These areas were assessed for IAQ chemical (CO_2, CO, Formaldehyde, TVOC, PM_{10}, $PM_{2.5}$) and biological contaminants (total bacteria and fungi). TC parameters were measured following ISO 7730:2005 (PMV and PPD indexes). The monitoring phase included daytime air sampling (starting at 10 am and continuing for at least 4 h to 8h during normal activities) conducted discretely to minimize nuisance to normal resident's activities. A walk-through building questionnaire was performed prior the monitoring and outdoor samples were also collected for comparison. Classical statistical methods were used to estimate means, medians and frequencies (percentages) in order to obtain insight into the ECCs characteristics and environmental monitoring results within and between buildings. The variables were tested for normality with Shapiro-Wilk test. Mann-Whitney (U) test and Kruskal-Wallis (H) for independent samples were conducted for seasonal effects assessment, indoor/outdoor and within buildings location differences. It was also performed a student t-test for the variable 'air temperature'. A 0.05 level of significance was used for all analyses. All data were analyzed using IBM SPSS 21.0.

RESULTS AND DISCUSSION

The 22 ECCs were located in the urban area of Porto city, most of them (n=17) in heavy traffic areas. A total of 716 elderly lived in these centers with a range of 7 to 136 occupants per building. As regards construction characteristic, 66% were an adaptation to ECC of an existing residential building, and 40% were also developing activities of day care centers for elderly. Most of them were built in stone masonry construction (49%) with single pane windows (87%). Only 30% had roof and walls insulation, while 61% of the sampled presented condensations and infiltrations along walls and roofs inside the buildings. All ECCs were smoke-free. Regarding the ventilation type, 87% had mixed ventilation (natural ventilation in the rooms along with exhaustion systems in the kitchen and bathrooms) while 13% had only natural ventilation in all the indoor areas. The overall $PM_{2.5}$ mean concentration of the 22 ECC was above international reference levels (35 µg/m^3) in both seasons. These findings showed as this parameters is critical for air quality, both for its sensitivity and for its possible influence on human health. Other studies [2, 3] have found, high levels of $PM_{2.5}$ in similar indoor environments, and the link with lung function [4] and respiratory diseases such as COPD [5, 6] has been quite demonstrated. Although all the other indoor air pollutants were within the reference levels peak values of PM_{10}, TVOC, CO_2, bacteria and fungi exceeded the reference levels, compromising indoor air comfort and worsening the already existent respiratory chronic diseases. TVOC, Bacteria, CO and CO_2 showed significantly higher indoor levels compared to outdoor, in both seasons. Indoor PM_{10}, TVOC, Bacteria and CO_2 present significant differences between seasons ($p < 0.01$). TVOC, bacteria and CO_2 show significant variation between ECC rooms ($p < 0.01$) and 4% of fungi samples were positive for pathogenic *Aspergillus species*. The winter PMV index is below references and between the 'slightly cool' and 'cool' (-2) points in the thermal sensation scale, which may potentiate respiratory tract infections. PPD and PMV indexes show significant differences by room and by season ($p < 0.01$). The building characteristics 'Insulation', 'Heating Ventilation' and 'Windows frames' appear to be the most influential parameters on IAQ and TC. The environmental parameters most commonly affected by building characteristics are the 'Bacteria', 'Fungi', 'Temperature', Relative Humidity', and 'PPD index'.

CONCLUSIONS

Our study suggested that attention is needed to $PM_{2.5}$ particle fraction, as well as, peak concentrations and fungi species that might compromised IAQ comfort. To prevent low indoor temperatures and discomfort, especially on winter season, simple measures could provide health benefits to ECC residents and workers, such as insulating ceilings, walls, and windows, maintaining natural and passive ventilation, solutions that are common in Portugal due to the advantage of the country's generally mild weather.

ACKNOWLEDGEMENT

Our current research is supported by GERIA Project (www.geria.webnode.com): PTDC/SAU-SAP/116563/2010 and a PhD Grant (SFRH/BD/72399/2010) from Foundation for Science and Technology (Fundação para a Ciência e Tecnologia - FCT).

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ESSEM Domain

COST Action TD1105

European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability - EuNetAir

1st EuNetAir Air Quality Joint-Exercise Intercomparison

Aveiro, 13 - 27 October 2014

IDAD - Institute of Environment & Development, Campus Universitário, Aveiro, Portugal

AGENDA	
13 October 2014 - Monday	**Start of the 1st EuNetAir Air Quality Joint-Exercise Intercomparison**
09:00 - 10:00	**Group meeting: Technical requirements for Joint-Exercise Intercomparison**
10:00 - 12:00	**Installation of AQ sensors**
12:00 - 13:00	*Lunch*
13:00 - 15:00	**Installation of AQ sensors (cont.)**
15:00 - 17:00	**Planning the outputs of the 1st EuNetAir Air Quality Joint-Exercise**
19:00	*Social Dinner*
13 - 27 October 2014	**Experimental Campaign in AQ Mobile Laboratory in Aveiro city**
27 October 2014 - Monday	**End of the 1st EuNetAir Air Quality Joint-Exercise Intercomparison**
09:00 - 10:00	**Group meeting: Technical constraints of the Joint-Exercise Intercomparison**
10.00 - 12.00	**AQ sensors removal**
12.00 - 13.00	*Lunch*
13:00 - 15:00	**AQ sensors removal**
15:00 - 17:00	**Outlook on the results of the 1st EuNetAir Air Quality Joint-Exercise**
17:00 - 18:00	**Planning future activities**
18:00	**Closure of the Joint-Exercise Intercomparison**

COST is supported by the EU Framework Programme

ESF provides the COST Office through a European Commission contract

EUROPEAN COOPERATION IN SCIENCE AND TECHNOLOGY

Background and goals

About COST Action TD1105 EuNetAir

COST Action TD1105 *EuNetAir*, a Concerted Action on *New Sensing Technologies for Air-Pollution Control and Environmental Sustainability*, is a running Networking funded in the framework *European Cooperation in the field of Scientific and Technical Research* (COST) during 2012-2016.

The main objective of the Concerted Action is to develop new sensing technologies for Air Quality Control at integrated and multidisciplinary scale by coordinated research on nanomaterials, sensor-systems, air-quality modelling and standardised methods for supporting environmental sustainability with a special focus on Small and Medium Enterprises.

This international Networking, coordinated by ENEA (Italy), includes over 80 big institutions from 28 COST Countries (EU-zone: *Austria, Belgium, Bulgaria, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Israel, Italy, Latvia, The Former Yugoslav Republic of Macedonia, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovenia, Spain, Sweden, Switzerland, Turkey, United Kingdom*) and 7 International Partners Countries (extra-Europe: *Australia, Canada, China, Morocco, Russia, Ukraine, USA*) to create a S&T critical mass in the environmental issues.

1st EuNetAir Air Quality Joint-Exercise Intercomparison, Aveiro, Portugal, October 13-27, 2014

COST Action TD1105 *EuNetAir* is organizing the first *Air Quality Joint-Exercise Intercomparison on Evaluation and Assessment of Environmental Gas/PM MicroSensors versus Standardised AQ Referenced Methods through an Experimental Urban Air Quality Monitoring Campaign* to be held in Aveiro (Portugal) on 13 - 27 October 2014. This Joint-Exercise will be organized under management of IDAD - Institute for Environment and Development, and University of Aveiro, coordinated by Prof. Carlos Borrego.

The main goals of the 1st EuNetAir Air Quality Joint-Exercise Intercomparison are:

- To evaluate AQ micro-sensors measurements against standardised AQ methods
- To study and assess protocols and methods devoted to low-cost gas sensors for AQC with definitions of guidelines for standards
- To develop guidelines for AQ micro-sensors comparison against standardised AQ methods
- To establish joint publications and networking activities (e.g. meeting on results, others)

An Air Quality Mobile Laboratory will be placed at an urban traffic location in Aveiro city centre (https://mapsengine.google.com/map/edit?mid=zwt19PZ1SwtE.kHCx6behQ1s8) in the scope of the Experimental Urban Air Quality Monitoring Campaign, to conduct continuous measurements with standardized equipment and referenced analyzers of the following variables: CO, NO_x, O_3, SO_2, PM_{10}, Benzene, VOC, temperature, humidity, wind velocity/direction, solar radiation, precipitation (rain).

All COST Action *EuNetAir* partners are kindly invited to install their microsensors and sensor-systems side-by-side with air quality standardized equipment in the IDAD Air Quality Mobile Laboratory and to perform the 2-week Experimental Urban AQ Monitoring Campaign at Aveiro city.

A **Call for Participation** has been opened to invite producers/manufacturers of high-performance AQ devices and researchers/scientists from Action partnership and MoU-signed Countries including NNC approved institutions. COST Action will financially support at least *1 person* from each involved team for networking activities, and no funding for research is established.

An **Application Form** as Technical Draft (containing: *Name of Participant Institution*; *Names of the Institution Members that will travel to Aveiro*; *Requests/Specifications for Sensors/Equipment Installation*; *Gas/Variables Measured*; *Other Remarks*) is cordially requested from the interested Researchers/Experts to be submitted to the Action management by deadline of **30 September 2014** to:

- ***Michele Penza***, Action Chair, ENEA, Brindisi, Italy: michele.penza@enea.it
- ***Carlos Borrego***, Local Organizer, IDAD, Aveiro, Portugal: cborrego@ua.pt
- ***Ana Margarida Costa***, Local Co-Organizer, IDAD, Aveiro, Portugal: amcosta@ua.pt

More Information:

Dr. Michele Penza
MC Chair/Proposer of *COST Action TD1105 EuNetAir*
ENEA - Italian National Agency for New Technologies, Energy and Sustainable Economic Development
Technical Unit for Materials Technologies - Brindisi Research Centre
PO BOX 51 Br-4, I-72100 Brindisi - ITALY
Email: michele.penza@enea.it

Prof. Carlos Borrego
Local Organizing Committee Chair
IDAD - Institute for Environment and Development, Aveiro, Portugal
Campus Universitario Aveiro, Portugal
Email: cborrego@ua.pt

1st Air Quality Joint-Exercise Intercomparison of COST Action TD1105

Air Quality Campaign at Aveiro city centre
IDAD, Aveiro, Portugal

Aveiro, Portugal

COST Action TD105

1st EuNetAir Air Quality Joint-Exercise Intercomparison

Aveiro, Portugal, 13 - 27 October 2014

Application Form

COST Action TD1105 1st EuNetAir Air Quality Joint-Exercise Intercomparison
Applicant Form for Candidate Participants

Personal Details	
1. Surname	
2. First name(s)	
3. Gender	
4. Email	
5. Nationality of Applicant	
6. Institute/company	
7. Degree	Post-Doc, PhD-student, Master, Bachelor, PhD, ESR (< 8 years + PhD), etc. ***Select one only*** !
8. Institute/Company Country	
9. Address	
10. Postal address	
11. Telephone	
12. Fax	
13. Mobile	
14. Tutor of Host Institution	
15. COST Action TD1105 Team	Team (Country)

Background related to the COST Action (research activities, institute/company background in relation to COST Action, etc)

(Max 10 lines)

Personal Activities related to the COST Action TD1105

(Max 10 lines)

Involved member or interested participant of (please, sign one or more):

MC ☐ Management Committee

CG ☐ Core Group

SC ☐ Steering Committee

WG 1 ☐ Sensor Materials and Nanotechnology

WG 2 ☐ Sensors, Devices, and Systems for AQC

WG 3 ☐ Environmental Measurements and Air-Pollution Modelling

WG 4 ☐ Protocols and Standardisation Methods

SIG 1	☐	Network of Spin-offs
SIG 2	☐	Smart Sensors for Urban Air Monitoring in Cities
SIG 3	☐	Guidelines for Best Coupling Air-Pollutant and Transducers
SIG 4	☐	Expert Comments for the revision of the Air Quality Directive
OTHER	☐	

Requests for equipment installation

Variables measured

Remarks
(Max 5 lines, if any)

Here, I declare my interest to participate in the **1st EuNetAir Air Quality Joint–Exercise Intercomparison** supported by COST Action TD1105 EuNetAir at Aveiro, Portugal, 13-27 April 2014, under coordination and direction of IDAD - Institute of Environment and Development, Portugal.

I apply my candidature as team for the selection on a competitive basis of a supporting **grant** to participate to the 1st EuNetAir Joint-Exercise Intercomparison coming from the Countries signing the Action Memorandum of Understanding (MoU) and/or approved NNC institutions (www.cost.eunetair.it).

The grant will cover the travelling costs, hotel accommodation and meals only. No funding for research is supported.

Yours Sincerely,

City, Date (DD/MM/YYYY)

Name Surname

Signature ………………..….

VERY IMPORTANT

The official communications from COST Action management (Grant Holder and Action Chair) to the Applicants of the 1st EuNetAir Air Quality Joint–Exercise Intercomparison will be done by the e-COST system (https://e-services.cost.eu/).

Please, check and control your email account for this communication. COST Action TD1105 is not responsible for wrong email accounts and mistakes in the communications.

Application Form filled in the whole must be returned signed in pdf by email to ALL listed people:

- **Michele Penza, Action Chair, ENEA, Brindisi, Italy: michele.penza@enea.it** - **Carlos Borrego, Local Organizer, IDAD, Aveiro, Portugal: cborrego@ua.pt** - **Ana Margarida Costa, Local Co-Organizer, IDAD, Aveiro, Portugal: amcosta@ua.pt**
Date of sending Application to Action management: DD/MM/YYYY

Please, Applicant to the 1st EuNetAir Air Quality Joint-Exercise Intercomparison should provide own CV (max 1 page)

Name Surname, Country:

Expertise:

Current Research Activities:

List of Publications, if any:

For Grant Holder use only
Result of the Grant Application: **- Approved** **- Rejected**

COST Action TD1105

European Network on New Sensing Technologies for Air-Pollution Control and Environmental Sustainability - EuNetAir

WG Meeting

Aveiro (Portugal), 13 - 15 October 2014

Campus Universitário
3810-193 Aveiro
Portugal

- Meeting and Travel Information –

Local organizer:

Prof. Carlos Borrego
IDAD – Institute of Environment and Development
Campus Universitário, 3810-193 Aveiro, Portugal
http://www.idad.ua.pt/
Office: +351 234 400800
Fax: +351 234 400819
cborrego@ua.pt

Meeting and Travel Information

Hotel Information (refer to COST TD1105 - EuNetAir)

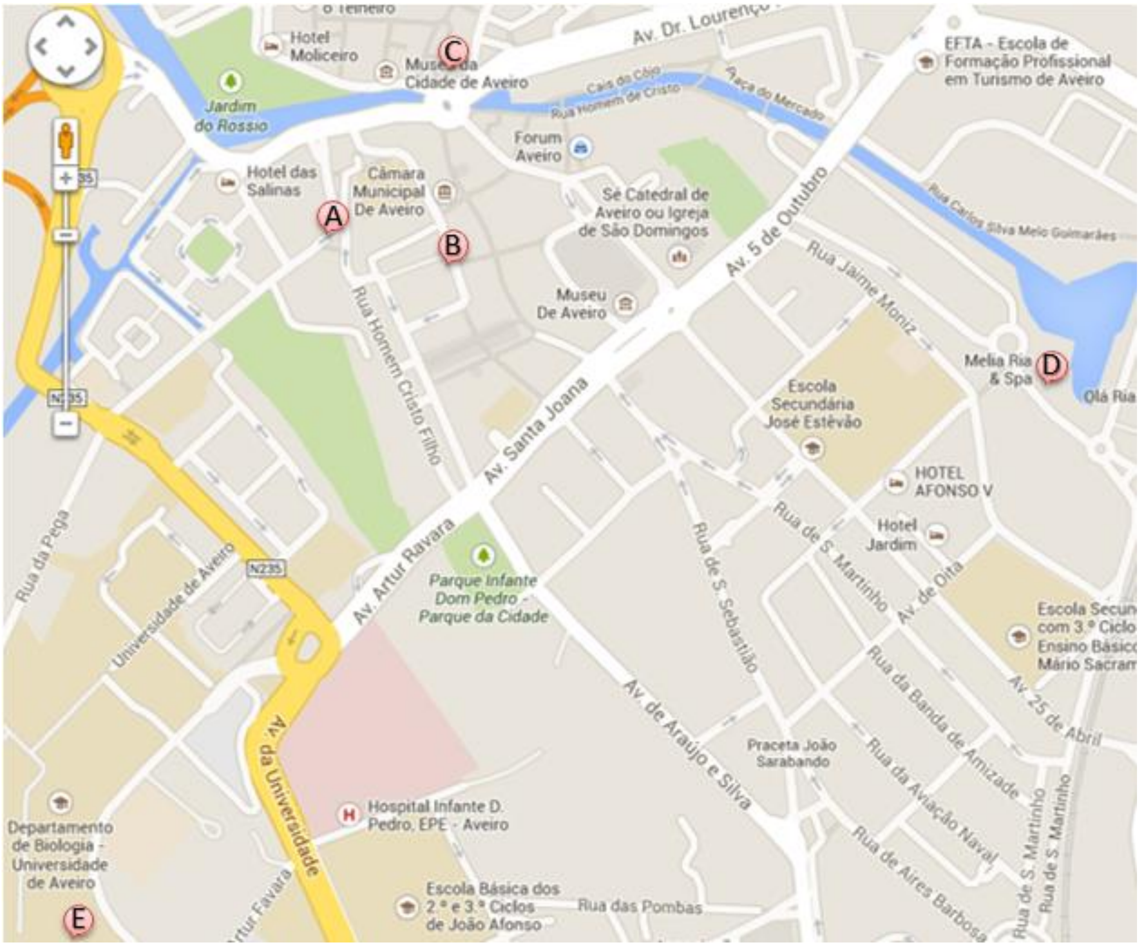
Hotels special booking prices were negotiated for this COST meeting. Reservations should be made directly with the hotel quoting "COSTTD1105_EuNetAir".

A - Hotel Aveiro Center | 2*
Address: Rua da Arrochela, Nº 6, Albôi, 3810 – 052 Aveiro, Portugal
Phone: + 351 234 380 390 **Fax:** + 351 234 380 391
Email: reservas@hotelaveirocenter.pt
Web: http://www.hotelaveirocenter.pt/
Prices: Single: 39.00€, Double: 50.00€, breakfast included
Walking time to the meeting venue: 10 minutes

B - Hotel Imperial | 3*
Address: Rua Dr. Nascimento Leitão, 3810-108 Aveiro, Portugal
Phone: +351 234 380 150 **Fax:** 234 380 159
Email: reservas@hotelimperial.pt
Web: http://www.hotelimperial.pt/
Prices: Single: 39.50€, Double: 55.00€, breakfast included
Walking time to the meeting venue: 10 minutes

C - Hotel Aveiro Palace | 4*
Address: Rua Viana do Castelo nº 4, 3800-275 Aveiro, Portugal
Phone: +351 234 421 885 **Fax:** +351 234 421 886
Email: geral@hotelaveiropalace.com
Web: http://www.hotelaveiropalace.com/
Prices: Single: Standard 52.00€|Superior 62.00€,
Double: Standard 62.00€|Superior 72.00 €, breakfast included
Walking time to the meeting venue: 15 minutes

D - Mélia Ria Hotel & Spa | 4*
Address: Cais da Fonte Nova, lote 5, 3810-260, Aveiro, Portugal
Phone: +351 234 401 000 **Fax:** +351 234 401 009
Email: melia.ria@meliaportugal.com
Web: http://www.meliaria.com/
Prices: Single: 76.00€, Double: 86.00€, breakfast included
Walking time to the meeting venue: 18 minutes



Meeting Venue Information

E - Departamento de Ambiente e Ordenamento, Universidade de Aveiro
Address: Campus universitário de santiago, 3810-193 Aveiro, Portugal
Phone: +351 234 370 349 **Fax:** +351 234 370 309
Email: dao.secretaria@ua.pt
Web: http://www.ua.pt/dao/

Travel Information

Flying to Portugal

The closest airport is Francisco Sá Carneiro International Airport in Oporto, located some 70kms to the north of Aveiro. Portela International Airport in Lisbon is located 250kms to the south of Aveiro. Both are operated by regular and by low-cost companies.

ANA airports information: http://www.ana.pt/en-US/Pages/Homepage.aspx

From Oporto to Aveiro

The journey from the airport to the railway station (called Porto-Campanhã, with direct rail connections to Aveiro) can be done by taxi for around 20€ and takes around 30 minutes. A less expensive way to reach the Porto-Campanhã railway station is to use the Metro, Violet (E) Line, which has a terminal at the airport. The trips between the airport and the railway station can be done by Metro for around 2€ and takes around 32 minutes (Z4 ticket).

Metro information: http://www.metrodoporto.pt/en/PageGen.aspx?SYS_PAGE_ID

The train journey to Aveiro takes about 40 minutes if you take the Alfa Pendular train (€ 14,20) and Intercidades (€ 11,70) or 1h15 if you take a regular train (€ 3,40). There are many trains running regularly to Aveiro from Porto.

Train timetables:
http://www.cp.pt/cp/displayPage.do?vgnextoid=87cbd5abe2a74010VgnVCM1000007b01a8c0RCRD&lang=en

From Lisbon to Aveiro

If you're arriving in Lisbon by plane, the best way to come to Aveiro is by train from Lisboa-Oriente railway station. To get to the train station, you can take a taxi, which takes about 10 minutes, or use the Metro, Red Line, which has a terminal at the airport. The trips between the airport and Oriente railway station take about 10 minutes and cost €1.40 (+ viva viagem card €0.50).

Metro information: http://www.metrolisboa.pt/eng/

The train journey to Aveiro takes about 2h05 if you take the Alfa Pendular train (€ 26,30) or about 2h20 if you take the Intercidades (€ 20,20). There are many trains running regularly to Aveiro from Lisboa.

Train timetables:
http://www.cp.pt/cp/displayPage.do?vgnextoid=87cbd5abe2a74010VgnVCM1000007b01a8c0RCRD&lang=en

To reach the University Campus

Aveiro railway station is located at 5 minutes taxi ride for around 5€ or about 20 minutes walking distance from the University Campus. To reach the Campus, you can also use the bus (green line) which departs at regular intervals from outside the railway station, for around 2€.

By road

From the north using the A1 motorway or from the east using the A25. Take the A1 motorway headed to Lisbon. Exit the A1 in the direction of Aveiro and take the A25. There are two exits to the city from the A25, first "Aveiro-Norte" and some kilometers further on, the "Aveiro" exit. This second exit is the best for reaching the University of Aveiro.

From the south using the A1 motorway. Take the A1 motorway in the direction of Porto. Exit the motorway at "Aveiro-Sul/Águeda" (exit 15) and follow the EN235 road directly to the University Campus. From the south, using the A8 and A17 motorways. Exit the motorway at "Aveiro-Sul" and follow the EN235 road directly to the University campus.

General Tourist Info: http://www.aveiro.eu/default.asp?lg=en