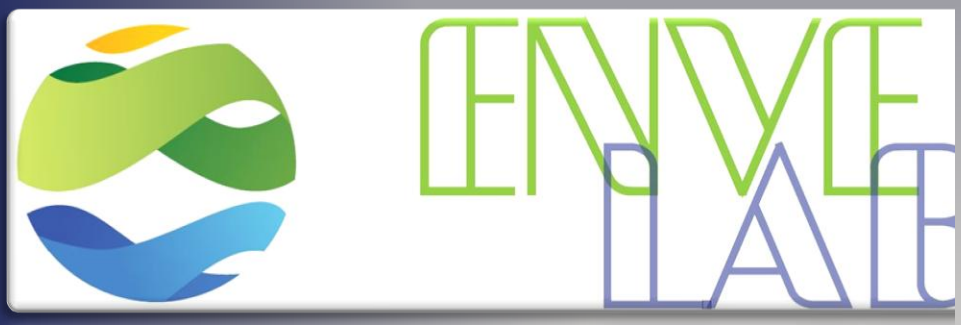
2012

EnvE-Lab annual report



Edited by

Associate Professor Dimosthenis Sarigiannis, Director

Who we are: an introduction

The Environmental Engineering Laboratory (ENVE Lab) was established at the Chemical Engineering department of Aristotle University of Thessaloniki (AUTH) in the second half of 2011. Its objective is to become an international center of reference for environmental engineering addressing the interactions between environment and human health and exploiting this knowledge to the design of novel chemical processes and products servicing the sustainability objectives.

Thus, the main thematic areas of ENVE Lab are:

- Environment and health – development of integrated methodologies to assess the impact environmental pollution may have on human health
- Advanced technologies for monitoring environmental pollution and waste management
- Industrial ecology approaches to the design of industrial systems with reduced ecological footprint

Our work paradigm is based on extensive collaboration with international scientific networks including universities, research centers, regulatory authorities and industry from all over the world.

Within AUTH, ENVE Lab collaborates with the Analytical Chemistry Laboratory of the Chemical Engineering department and the Environment Laboratory of the Chemistry department, the Laboratory of Applied Thermodynamics and the Laboratory of Heat Transfer and Environmental Engineering of the Mechanical Engineering department, as well as with the Biochemistry laboratory of the Medical School.

Particularly close collaboration has been established with the Natural Resources and Renewable Energy laboratory of the Chemical Process and Energy Research Institute of the Centre for Research and Technology Hellas. This collaboration encompasses three international projects running over the last couple of years.

In Europe, ENVE Lab collaborates with over fifty universities and research centers in the UK, Germany, France, Italy, the Netherlands, Spain, Belgium, Finland, Norway, Portugal. The Lab is an active member of the Mediterranean Scientific Association for Environmental Protection (MESAEP), forging thus close links with environmental scientists from across the Mediterranean.

On a more global scale, good collaborative links have been established with the US Environmental Protection Agency (US EPA) and the National Institutes for Environmental Health Science (NIEHS) focusing on the development of operational methodologies and novel tools towards unraveling the exposome, i.e. the totality of exposures from conception onwards, simultaneously identifying, characterizing and quantifying the exogenous and endogenous exposures and modifiable risk factors that predispose to and predict diseases throughout a person's life span.

Finally, we collaborate with Beijing University and Nanjing University in China to assess the health effects of climate change mitigation and adaptation policies, as well as with the Beijing Academy of Sciences on exploring the link between atmospheric particulate matter and human health using satellite-derived estimates of particulate pollution.

The main source of funding for ENVE Lab is the European Commission's RTD framework programs and the European Chemical Industry Council through its Long-Range Research Initiative (CEFIC-LRI).

I hope you will enjoy receiving our 1st annual report and that reading it will open up new, interesting scientific questions. We shall be happy to work with you to answer these and roll further back the boundaries of error in our understanding of the world. As Berthold Brecht put it in the *Life of Galileo* "*the main objective of science is not to open the door to infinite wisdom but to roll back the boundaries of infinite error".*

Assoc. Prof. Dimosthenis Sarigiannis

Laboratory director

EnvE-Lab "scientific signature" – Integrative human well-being and health protection from environmental stressors through environment-wide mechanistic associations

EnvE-Lab aims at developing integrated methodologies and knowledge management systems that can effectively shed light on the interactions between human health and the environment. Our concept brings together state-of-the-art advances in environmental monitoring, human biomonitoring and systems biology, exposure monitoring technologies and advanced tools for computational analyses of the exposure-to-health effect continuum. The above are put together in a novel exposure biology-based methodology translated into an integrated computational platform and knowledge management system, which is at the core of the "*EnvE-Lab Assessment Platform - ELAP*". Expanding the applicability domain of ELAP to a wide variety of environmental stressors is a key issue for its scientific soundness and policy support impact. Several sub-compartments of ELAP are put to test through their application in a number of population studies across different exposure settings in Europe and worldwide tackling relevant health endpoints. In addition to the technical research and the continuous development work, horizontal activities will provide the infrastructure necessary for setting ELAP in its policy context. The necessity of using ELAP as a novel tool for interpretation of environment and health data in order to better understand the mechanistic relationship between lifelong exposure to environmental stressors and health response, has been widely recognized by the scientific and chemical industry community.

Better understanding of environmental fate, exposure and toxicity mechanisms is required to ensure refined exposure and risk characterization, e.g. the precise quantification of exposure scenarios and circumstances that might set-up a background for potential adverse effects on humans. However, the way that social cost increases for increasing the maximum benefit in terms of exposure reduction is exponential; there is a threshold beyond which social cost increases disproportionally to social benefit.

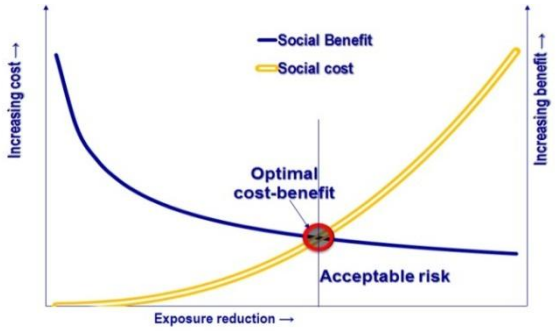


Figure 1. Cost-benefit curves regarding exposure/health risk assessment

The aim of refining the overall assessment is to identify this optimal point, so as to design cost-effective public health protection policies.

The assessment process can focus on several instances as follows: hazard potency of a substance, its uses and mobility in the environment (affecting the amount that the population groups will come into contact), the biologically effective dose of the compound reaching the target tissue and finally the response of the human body to this dose. All these processes, are determined strongly by the interaction of the physicochemical properties of the substance with physiological attributes (e.g. susceptibility to xenobiotics or variability of exposure strongly depend to inter-individual differences). Thus, well targeted interventions at different stages of the source-to-outcome continuum, ensure the optimal management of chemicals in the environments in terms of quantities released and intended (or not) uses. Lastly, this analysis would guide the new chemical synthesis process in industry.

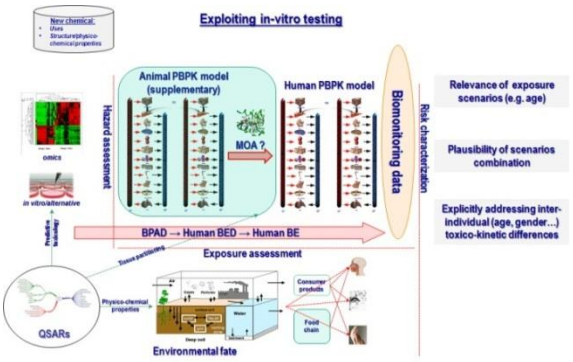


Figure 2. Integrating exposure and toxicology for refined risk characterization

Integrated exposure from multiple sources, pathways and routes – The INTERA and TAGS projects

The INTERA project -

The Integrated Exposure for Risk Assessment in Indoor Environments (INTERA) project funded by the CEFIC-LRI programme, aimed to improve our understanding of human exposure to air pollutants in indoor environment by defining optimal methodologies for predicting indoor exposure to chemical contaminants and their inter-relationships.

To this aim ENVE-Lab developed a broadly applicable, comprehensive and easily accessible indoor exposure and risk assessment methodology based on a full mechanistic approach along the sources-to-dose continuum.

The methodology designed to assess aggregate exposures to chemicals in the indoor environment has been implemented in a flexible and user-friendly web-based modelling platform which is a key component of project ad that allows the inter-connection between the steps of the full-chain assessment.

The modelling platform is accessible via a web-based user interface http://www.intera.cperi.certh.gr/main.php and includes five main modules:

Indoor Air Quality module, linking sources to indoor concentrations, taking into account the physicochemical processes in indoor settings: dispersion, ventilation, gas-particle-dust partitioning, etc.

Exposure module including several models for the dermal, inhalation and oral routes, taking into account time-μenvironment-activity patterns and inhalation rates based on activity, gender and body weight.

Internal dosimetry module, which computes aggregate exposure linking temporal patterns to internal dose through a generic Physiology Based PharmacoKinetic (PBPK) model. It estimates the internal doses of contaminants and their metabolites at the target tissue lowing assimilation of biomarker data, which is emerging from national and European biomonitoring programs.

Uncertainty and variability of exposure and risk determinants are assessed along the full-chain assessment through hierarchical modelling using Markov Chain Monte Carlo technique.

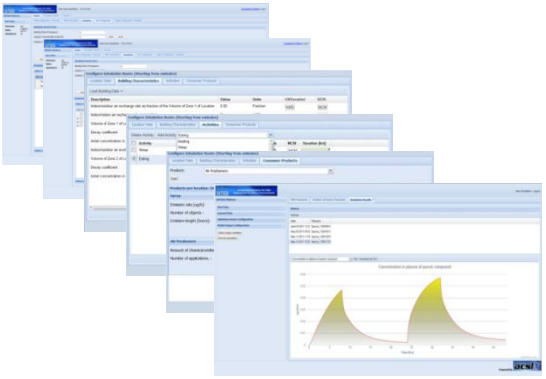


Figure 3. INTERA software interface

Database module containing several types of data ranging from human physiological parameters to emission data. Data are stored along with their geographical information in order to allow users to build realistic exposure scenarios to represent typical exposure conditions for specific countries and/or cities in Europe.

The INTERA methodology was applied and tested in three different case studies selected on the basis of relevance and novelty of the issue, different and multiple pathways and routes of entry and different chemical. These were DMF (dimethyl fumarate, dermal route), phthalates (multi-pathway exposures), and BTEX (benzene, toluene, ethylbenzene and xylenes, with mixture effect).

The overall scope was to derive population exposure levels to these chemicals (both external and internal) in indoor settings according to different geographical locations in Europe.

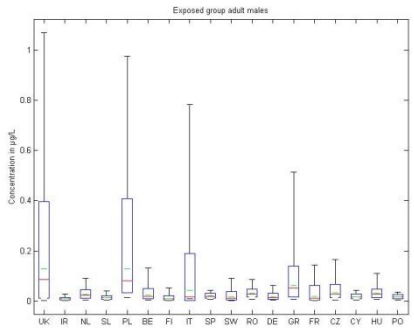


Figure 4. Whisker plot of benzene metabolite (BO, PH, HQ) concentration in bone marrow for adult males (max, min, 95%, 5%, median (red) and mean (green) estimates)

The project was completed in April 2012.

The TAGS project -

The objective of the project was the development of a tiered approach to aggregate exposure assessment and the compilation of a computational platform, able to perform quantitative aggregate exposure assessments for environmental and consumer products following a full chain approach (including emission-migration, media concentrations, exposure and internal dosimetry). The use of biomarkers to verify model predictions, to reconstruct population exposure and allocate to apportion exposure to sources (reverse modeling) constituted a part of the tiered approach and the accompanying guidance. The tiered approach guides the user through the preparation of the exposure assessment.

The methodology for quantitative aggregate exposure assessment is implemented into a computational platform, the core of which is a synthetic dynamic modeling environment able to track and describe in mathematical terms all the steps of the full chain approach, implementing both mechanistic (e.g. dispersion models, Physiology Based ToxicoKinetic Models) and probabilistic methodologies (Markov Chain Monte Carlo or maximum likelihood estimates) based on outcome optimization and the current status of knowledge and data availability. The project was completed in April 2012.

A very interesting application of the project was the bisphenol-A (BPA) case study. BPA, is an organic compound with two phenol functional groups. It is used to make polycarbonate plastic and epoxy resins, along with other applications. Since BPA is a known estrogenic, an increasing concern about the use of BPA in consumer products starts to rise since 2008. As a result, several governmental regulatory bodies issued questioning on its safety, while in 2010 the United States Food and Drug Administration (FDA) raised further concerns regarding exposure of fetuses, infants and young children. In the European Union, BPA use is banned in baby bottles since mid-2011. BPA is subjected to 2 major controversies that regard the actual toxicological threshold that needs to be taken into account as well as its BPA toxicokinetic behavior. Within the TAGS methodology, BPA was investigated as a case study.

Exposure assessment of several exposure scenarios including multiple pathways (releases in the environment during production and processing, transfer through food chain, uses in consumer products e.g. baby bottles and medical equipment), and routes (oral, inhalation and dermal) indicates that there is no scenario of concern (Figure 5).

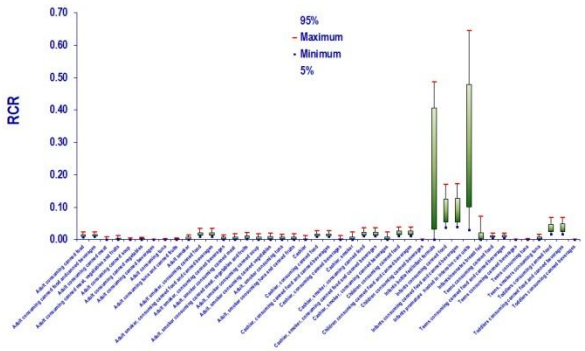


Figure 5. Risk Characterization Ratio under several environmental/consumer exposure scenarios

However, incorporation of more advanced modeling tools and toxicokinetic considerations substantially facilitated by our generic two generation PBTK model, revealed significant bioavailability differences. These are attributed to a) the ontogeny of the enzymes employed to BPA detoxification and b) due to the lack of first pass metabolism when BPA is inhaled. Under this refined assessment two exposure scenarios were identified as potentially problematic, namelly infant milk formula bottle-fed neonates and neonates hosted in intensive care units (Figure 6).

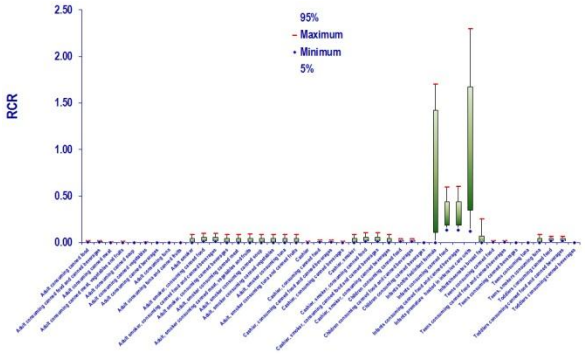


Figure 6. Risk Characterization Ratio under several environmental/consumer exposure scenarios – enhanced methodology incorporating toxicokinetics.

Toxicology of chemical mixtures in the environment and consumer products – The connectivity approach

The current paradigm for the assessment of the health risk of chemical substances focuses primarily on the effects of individual substances for determining the doses of toxicological concern in order to inform appropriately the regulatory process. These policy instruments place varying requirements on health and safety data of chemicals in the environment. REACH focuses on safety of individual substances; yet all the other facets of public health policy that relate to chemical stressors put emphasis on the effects of combined exposure to mixtures of chemical and physical agents. This emphasis brings about methodological problems linked to the complexity of the respective exposure pathways; the beyond than additive effect of mixtures, (the so-called 'cocktail effect'); dose extrapolation, i.e. the extrapolation of the validity of dose-response data to dose ranges that extend beyond the levels used for the derivation of the original dose-response relationship; the integrated use of toxicity data across species (including human clinical, epidemiological and biomonitoring data); and inter-individual susceptibility variation associated to both genetic and environmental factors.

A possible way forward to overcome the current gaps in knowledge that could act as obstacles to the definition of a plausible regulatory approach to chemical mixture risk assessment would be to use a tiered approach as follows:

(a) *Use dose addition to calculate a hazard index taking into account interactions as default option for hazard quantification and risk assessment.*

(b) *In data-rich situations use more sophisticated tools, including mechanistic, biology-based modeling that takes into account the biologically effective dose of the mixture components at the target tissues and incorporates system-wide response data across the dose-response range using information derived from –omics technologies – the connectivity approach.*

The integrated methodology described above was applied to the estimation of public health risk of leukemia from co-exposure to a quaternary mixture of volatile organic chemicals (BTEX) commonly found in indoor and, to some extent, outdoor air. The so-called BTEX mixture was chosen as a good model for studying the efficacy of, and refining, the multi-layer integrated approach outlined in this work since benzene has been accused of carcinogenic properties (especially in attacking the bone marrow resulting thus in leukemia) and neurotoxicity; The indoor air mixture characterizing indoor air in Europe according to the INDEX study was applied on lung epithelial cells (A549), at different doses over different periods of exposure (4 and 24 hours) and mixture composition. Results showed modulation of several gene families and indicated a dose-response relationship (Figure 7). The extent of modulation was proportional to the time of exposure, and to the increase of the toluene:benzene ratio.

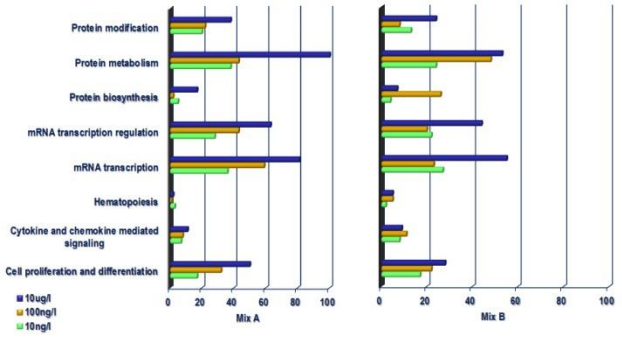
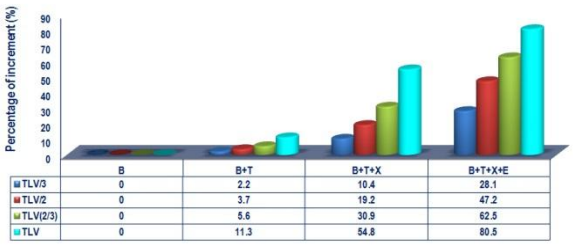


Figure 7. Gene modification under BTEX co-exposure

In terms of internal exposure, by employing the BTEX quaternary mixture PBPK/PD model. From the model it was found that the interaction effect (competitive inhibition) due to concurrent exposure can be better appreciated when the exposure levels are higher with respect to typical environmental exposures. This is the case for occupational exposure characterized by exposure levels of the same order of the Threshold Limit Value (TLV) for all the four substances composing the mixture.



	B	B+T	B+T+X	B+T+X+E
TLV/3	0	2.2	10.4	28.1
TLV/2	0	3.7	19.2	47.2
TLV(2/3)	0	5.6	30.9	62.5
TLV	0	11.3	54.8	80.5

Figure 8. Effect on internal dosimetry under various levels of BTEX co-exposure

Integrated methodology for assessing health effects from air pollution – The TRANSPHORM project

TRANSPHORM brings together internationally leading air quality and health researchers and users to improve the knowledge of transport related airborne particulate matter (PM) and its impact on human health and to develop and implement assessment tools for scales ranging from city to Europe.

To enhance the methodology for HIA and to establish a robust link between exposure to PM and the mechanisms of several diseases, we need to incorporate several methodological steps. This includes

a) particle size distribution deposition across the depth of the human respiratory tract (HRT) - link to the endpoints of relevance and translation. PM of different diameters tend to deposit at different depths across the respiratory tract, with the smaller diameter particles (especially Ultra Fine Particles –UFPs-) to deposit at the lowest part (alveoli), being subjected to translocation to the systemic circulation (Figure 9).

b) particokinetics of UFPs translocated within the systemic circulation and estimation of biologically effective dose reaching the target tissue (e.g , always with respect to the mechanism of action)

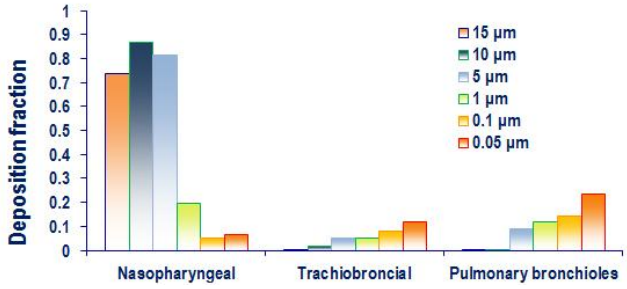


Figure 9. PM size segregated HRT deposition

c) internal dose of toxicants adsorbed in the particles (e.g. PAHs) and toxicokinetic fate upon entrance to the systemic circulation. Incorporation of internal dose in health risk estimates, requires also the incorporation of time-activity patterns, being in total a more individual oriented method, enhancing the framework of the full chain analyses. While being challenging, because to apply results at a European level would be data-intensive, and we anticipate important gaps in data (mostly) and evidence, we consider this to be an important step forward.

Translating external exposure into HRT deposition, allows us to better identify the links between air pollution and disease, as well as to realize the need for refined measurments, beyond the ones of coarse and fine particles, since larger differences on lower diameters particles – and consequently to HRT deposition – are not always reflected by fixed monitoring sites data (Figure 10).

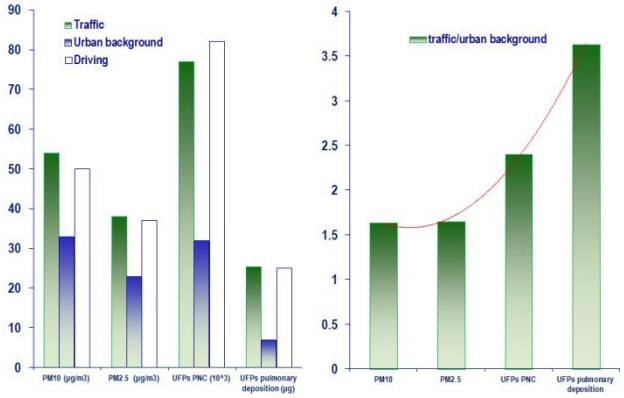


Figure 10. Investigating non-linearity among different PM exposure metrics

In the frame of TRANSPHORM, a PM source apportionment study is currently ongoing with parallel measurements in Thessaloniki and Rotterdam. PM_{10} and $PM_{2.5}$ are measured simultaneously at three urban (traffic, urban background and shipping) and one rural site. Beyond gravimetric analysis, chemical analysis includes PAHs, heavy metals and ions, as well as assessment of PM toxicity through oxidative potential (Reactive Oxygen Species analysis). Mass concentration results up to now are illustrated in Figure 11.

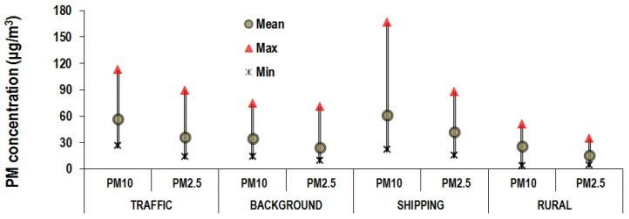


Figure 11. PM_{10} and $PM_{2.5}$ concentrations (mean-max-min values) for all cites

Integrated methodology for assessing health effects from climate change mitigation policies – The URGENCHE project

Urban Reduction of GHG Emissions in China and Europe (URGENCHE) is a project aiming to develop and apply a methodological framework for the assessment of the overall risks and benefits of alternative greenhouse gas (GHG) emission reduction policies for health and well-being in China and Europe.

In URGENCHE, a team of internationally recognized scientists in the areas of health risk assessment, urban energy demand and supply scenarios, urban planning, environmental science and epidemiology – in close collaboration with city partners in both Europe and China – develops and applies a methodological framework for the assessment of the overall risks and benefits of alternative greenhouse gas (GHG) emission reduction policies for health and well-being.

These GHG reduction policies may affect public health in various ways, such as the choices made regarding the selection of fuels and means for space heating and transport, building codes to improve thermal efficiency, or urban development and zoning. A methodological framework will be developed and applied. This framework considers GHG emission reductions of energy demand and supply and transport scenarios in urban areas, the effect of these policies, and subsequently the impacts on human health and well-being.

The GIS-based approach takes into account the advances made in integrated assessment in a large range of studies in Europe over recent years (many with participation of the project partners). The impact on human health and well-being of GHG policies may be the result of changes in exposure patterns of the urban population to environmental contaminants such as ambient and indoor air pollution as well as changes in housing, urban green spaces, workplaces, transport and lifestyles. Distribution of the impacts across different socioeconomic groups will be addressed. Results will be demonstrated for the year 2030 on a business-as-usual and two GHG emission reduction scenarios with emphasis on transport and buildings.

URGENCHE will deliver a validated, methodological framework to assess urban GHG policies with the greatest co-benefits for health and well-being in cities ranging in population from 50,000 to 10 million, across various climatological conditions and differences in socio-economic background.

The methodology for estimating exposure and associated risks (expressed in mortality) was applied in Thessaloniki. With regard to indoor air quality, the effect of buildings energy certificates was investigated (affecting indoor/outdoor air exchange rate), as well as the potential use of biomass combustion, combined also to dominant indoor air emission sources such as smoking. Calculations were based on the differences of PM2.5 indoor concentrations.

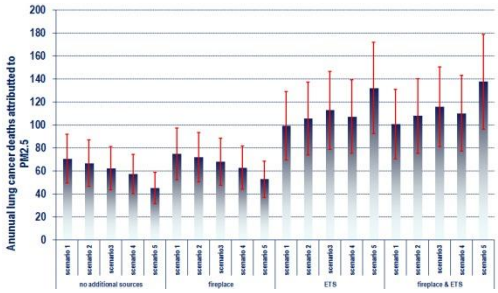


Figure 12. Annual lung cancer deaths attributed to indoor $PM_{2.5}$

Similarly, NOx and benzene outdoor concentrations were modeled for the existing traffic conditions (fleet composition and traffic load, as well as the associated health risks. Future work includes the investigation of the effect of the Thessaloniki metro to ambient (and indoor) air quality, overall exposure and the associated health effects to the local population.

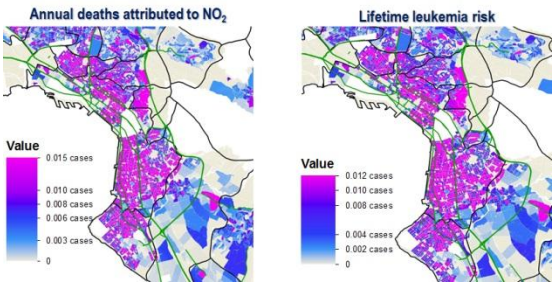


Figure 13. NO_X attributed mortality and leukemia risk under current traffic scenarios in Thessaloniki

Advanced satellite data fusion for ground-level $PM_{2.5}$ estimation and related health impact assessment

The work developed in the frame of EU-funded projects ICAROS, ICAROSNET and SMAQ dealt with the development of a novel methodology aiming at providing a comprehensive estimate of tropospheric pollution from particulate matter at different spatial and temporal resolutions at the urban to regional scales needed to provide a spatially-resolved health impact assessment.

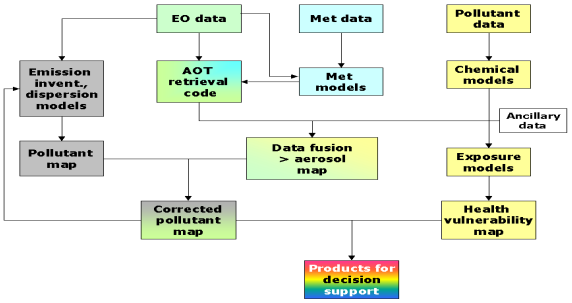


Figure 14. Conceptual representation of the advanced satellite data fusion system

Current state of the art in air quality assessment and management comprises analytical measurements and atmospheric transport modeling. Earth observation from satellites provides additional information through the calculation of synoptic air pollution indicators, such as aerosol optical depth (AOD). The method developed integrates these three information sources through suitable data fusion techniques providing a comprehensive estimate of tropospheric pollution from particulate matter. Information filtering is used to reduce the error of the fusion algorithm and to produce the best possible estimate of tropospheric aerosol loading. Linking the latter with epidemiological data and activity modeling, allows reckoning the geo-referenced health risk form fine and ultra-fine particulate matter.

The key to the success of the data fusion approach developed is the combination of physical and chemical process modeling that allows linking physical (e.g. optical) properties of tropospheric aerosol with the atmospheric physical-chemical processes that determine total mass concentration, size distribution and chemical composition of particulate matter. Assimilation of these data sources with ancillary data including classification of population vulnerability to the adverse health effects of particulate pollution in the ambient air integrates them into an optimally managed environmental information processing tool, which can be used for integrated air pollution monitoring and air pollution health assessment at the urban and regional scales.

The method permits the estimation of PM concentration from high to moderate spatial resolution ranging from 10 m to 4 km covering a domain as large as 80-100 x 80-100 km^2. The model we developed was applied in Athens (Greece), Munich (Germany), Rome (Italy), Budapest (Hungary) and the regions of Western Macedonia (Greece) and Lombardy (Italy) covering a broad spectrum of climatic conditions, pollution patterns and land use types.

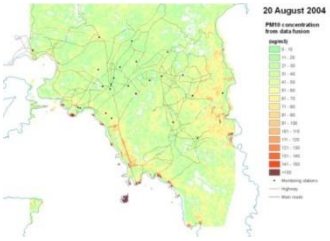


Figure 15. Application of the fusion system in Athens

The results showed that the conceptual model for tropospheric aerosol formation and fate in the atmosphere that has been developed based on experimental analyses across different European sites allows highly accurate estimates of particulate pollution and their health effects at high to moderate spatial resolution providing a valid approach for overcoming the pitfalls of current atmospheric observation systems and allowing to reduce the overall error to levels lower than the current atmospheric models as well as the pollutant concentration maps produced by spatial interpolation of measurements from the ground.

Its translation into a prototype computational platform is being used in W. Macedonia, Greece, where it has proven its efficacy in accurate estimation of tropospheric aerosol. Its use represents a valid alternative to conventional air quality monitoring, which necessitates the employment of dense and, thus, costly analytical measurement networks reducing significantly the operational cost of air quality management.

Research in uncertainty for health impact assessment studies

Uncertainty is a multi-faceted characterization about data or predictions made from data that may include several concepts including error, accuracy, validity, quality, noise and confidence and reliability.

Uncertainty assessment tools are usually presented in a qualitative and a quantitative form, categorized into four levels (steps). The qualitative part summarizes all sources in a matrix, annotating direction, level of uncertainty and appraisal of the knowledge-base robustness. The quantitative tools possibly used include, sensitivity methods, error propagation techniques via Taylor expansion, Monte Carlo Modelling, Fuzzy methods and Bayesian modelling.

It is noted that the uncertainty present in these levels is accurately quantified and minimized based on elaborate statistical techniques. Therefore, the most important routes sources and pathways are delineated and further investigated.

Selected methods:

1) Sensitivity analysis methods are used to quantify the variation in model output that is caused by specific model inputs. Amongst others the optimal methods are the global sensitivity algorithms that take into account all the variation ranges of the inputs and apportion the output uncertainty to the uncertainty in the input factors (Figure 16).

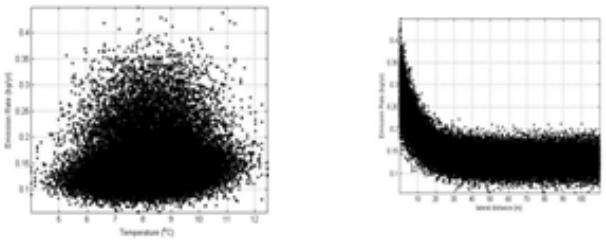


Figure 16. Global sensitivity scatter plots used to compute the contribution of input parameters to the estimated output (here pesticide emission)

2) A Monte Carlo simulation (MC) involves a large number of simulations from the distribution of the input parameters in the model that are combined to obtain values for the output parameters. For example, based on the distribution of the output, a risk level representing the high end (*e.g.*, 95th percentile), central tendency (*e.g.*, mean and median), or any other desired level of probability can be identified (Figure 17).

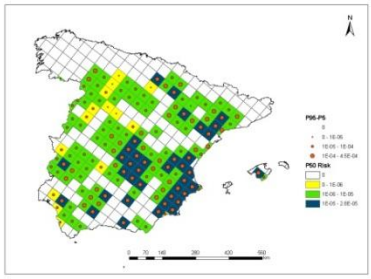


Figure 17. Health Risk and the associated uncertainty resulting from pesticide application on crops in Spain

3) The most complex and exhaustive way of integrating uncertainty in a model is framed in a Bayesian perspective. The Bayesian philosophy considers that all uncertainty can be described by means of probability distributions, and is thus highly parametric. The basic concept of Bayesian philosophy is that of conditional distribution. The data (if available) are actively used and are assigned a probability distribution conditional on some parameters (*e.g.* data can be Gaussian conditional on the values of the mean and the variance). Moreover each parameter has a probability distribution (prior) that can include different degree of subjectivity the prior distribution will reflect higher probability to the values suggested by the expert or by the literature.

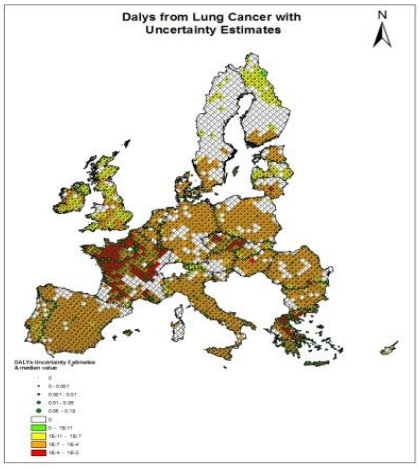


Figure 18. Computed DALYs and the associated computed uncertainty as a result of pesticide application in Europe

Life Cycle Analysis – The case study of municipal waste management

Waste has always been associated with human activity and is a necessary evil in any developmental process. Nowadays, the diversity and sheer quantity of wastes generated by industries and municipalities pose serious risks to both human health and the environment.

It is imperative therefore to use and create awareness among local authorities, manufacturers, companies and generally society of the available varied technologies evolved to treat and recycle wastes and convert it to wealth.

In particular municipal solid waste (MSW) management is regulated though a number of general principles and international directives encouraging prevention, recycling, treatment and final disposal. Life cycle assessment (LCA) is a system analysis tool used to describe the environmental impacts of products and processes while assessing the material and energy flows throughout their lifetime. The basic phases of an LCA are the collection of the data on all environmental interventions in the unit processes (inventory phase), the conversion of inventory data into environmental effects (impact assessment phase) and the interpretation of the results in relation to the objectives of the study. MSW streams of Athens and Thessaloniki and waste management technology feature have analyzed by using LCA. Hence, alternatives scenarios solutions have compared with that current situation in order to meet the twin goals of human and environmental conservation and sustainable development.

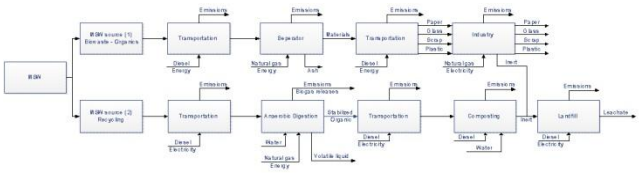


Figure 19. Waste management scenario: Waste is pre-treated and pre-sorted into biodegradable and non-biodegradable material for further anaerobic digestion and composting. Residues end in landfill. Plastic, paper and ferrous material are recycled

The comparative LCA for the current situation and alternatives solutions has enhanced and supported with material flow accounting, gross energy requirement, emergy intensity, emission and release intensity and morbidity or mortality indicators.

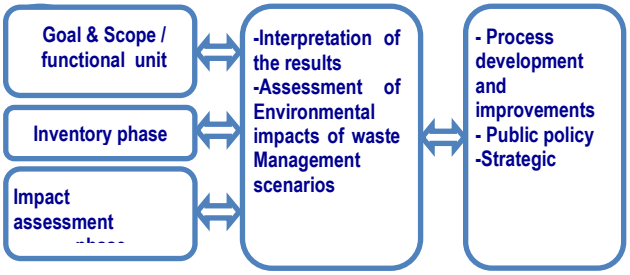


Figure 20. Life cycle assessment is conducted according to ISO 14040 series.

However, not all options are equally benign to the local environment and to the health of the local population, since both the former and the latter are still affected by non-negligible local emissions. With regard to public health impacts, adverse effects on respiratory health, congenital malformations, low birth weight and cancer incidence were estimated Figure 21.

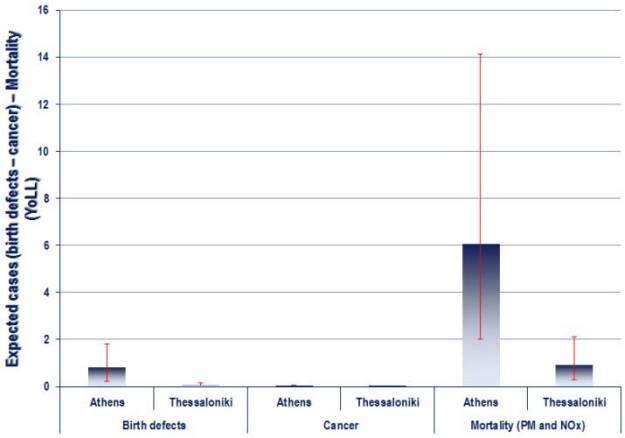


Figure 21. Health impact assessment of main MSW options

A significant and not intuitive result is the fact that life cycle analysis produces different conclusions than a simple environmental impact assessment based only on estimated or measured emissions. Taking into account the overall life cycle of both the waste streams and of the technological systems and facilities envisaged under the plausible scenarios analyzed herein, alters the relative attractiveness of the solutions considered. Furthermore, waste treatments leading to energy recovery provide an energy output that, in the best case, is able to meet a significant but not high percentage of the urban power demand.

Environmental management and energy recovery systems – anaerobic digestion

Anaerobic digestion (AD) of organic materials proceeds in the absence of oxygen and the presence of anaerobic microorganisms. It occurs in three stages, Hydrolysis/ Liquefaction, Acidogenesis and Methanogenesis.

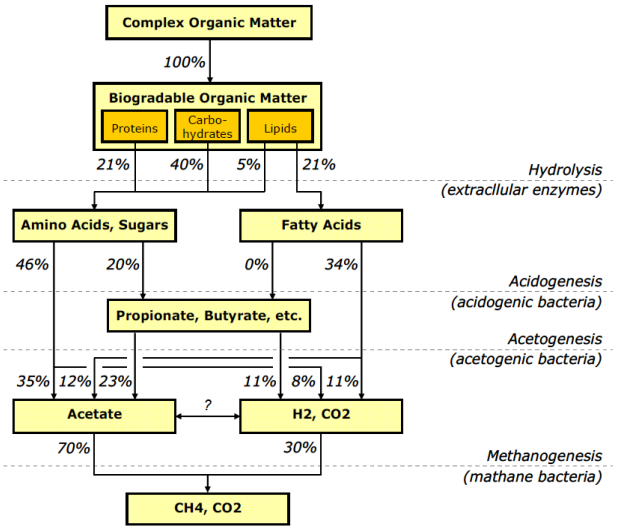


Figure 22. Anaerobic digestion process

The EnvE-Lab apparatus contains four anaerobic bioreactors, volume of 6.5 L each one, equipped with stirrers for waste agitation. The digesters are one stage which can operate both as a CSTR and a Batch work reactors.

EnvE-Lab research deals with anaerobic digestion from biodegradable matter in order to produce biogas (waste to energy). Especially, the Organic fraction of Municipal Solid Waste (OfMSW) was used as a feedstock trying to optimize their operation considering the percentage of wastes and inoculums.

The four anaerobic digesters give to EnvE-Lab the independence to compare different feedstock and conditions at the same time aiming at optimizing the design of integrated AD systems for different operational conditions, feestock composition and treatment goals.

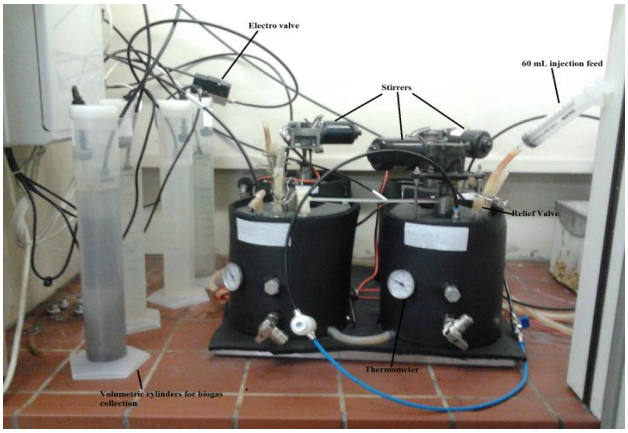


Figure 23. Anaerobic bioreactors

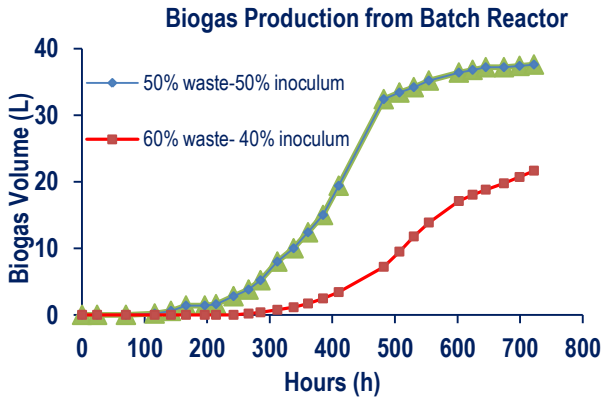


Figure 24. Biogas production from a batch work bioreactor using as feedstock the OfMSW 50% and inoculums 50%

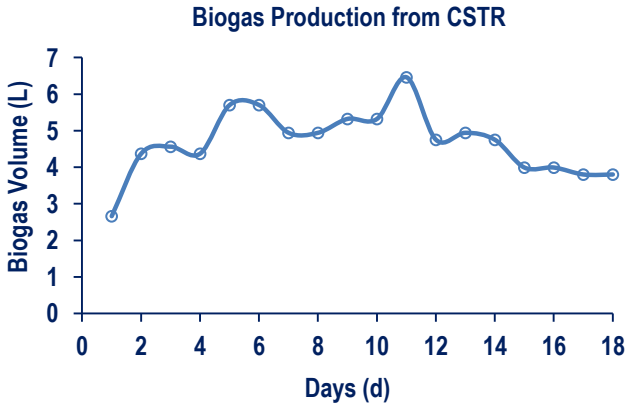


Figure 25. Biogas production from a CSTR bioreactor using as feedstock 0.2L/d of optimal waste

Environmental management and energy recovery systems – Analysis of sustainable biodiesel production from waste cooking oil – the bioenergy and human health link

This research aims to correlate bioenergy and human health, through the study of frying process of frozen pre-fried potatoes in sunflower oil, which will be subsequently used as a raw material for biodiesel production.

The depletion of fossil fuel reserves, especially oil, and the environmental impact of emissions from fuel combustion led the scientific community to focus on sustainability and to search for alternative renewable forms of energy. At the same time, discussion is raised on the importance of diet for human health which is related to serious diseases such as CHD (Coronary Heart Disease) and CVA (Cerebral Vascular Accident).

This study investigates the process of biodiesel production through based-catalysed transesterification. The study also examines deep frying of frozen pre-fried potatoes with sunflower oil, which is a common practice in fast food restaurants. However, the main idea of this research can be applied to other types of frying, foods and vegetable oils.

The originality of this study is the correlation of the quality of the raw material for biodiesel production, and in particular waste sunflower oil, and the way it affects the quantity of the based catalyzed in biodiesel production and human health after consumption of fried food. This is achieved by measuring the change of the percentage composition in FFA (Free Fatty Acids) and FA (Fatty Acids) in vegetable oil, and the calculation of the total catalyst cost, in relation to the number of frying cycles, for up to 75 frying cycles.

The main findings of this research are the equation of the change of the percentage mass composition in FFA, SFA (Saturated Fatty Acids) and PUFA (Polyunsaturated Fatty Acids), of sunflower oil as a function of the number of frying cycles. In addition, with the use of the same sunflower oil in up to 23 cycles of deep frying of frozen pre-fried potatoes at 190 °C, the FFA composition of sunflower oil after frying does not exceed 0.5%. No additional catalyst is required for biodiesel production. SFA do not exceed 14.4%, whereas the PUFA remain at a relatively high percentage (57.1%), of total FA, thus decreasing the LDL (Low Density Lipoprotein) cholesterol concentration and the risk of CHD and CVA. Finally, the equations for the calculation of the quantity of the catalyst required for biodiesel production, provided by Van Gerpen et al., for oils with a FFA composition over 0.5%, which are in relation to mass percentage of FFA, have been converted in relation to the number of frying cycles.

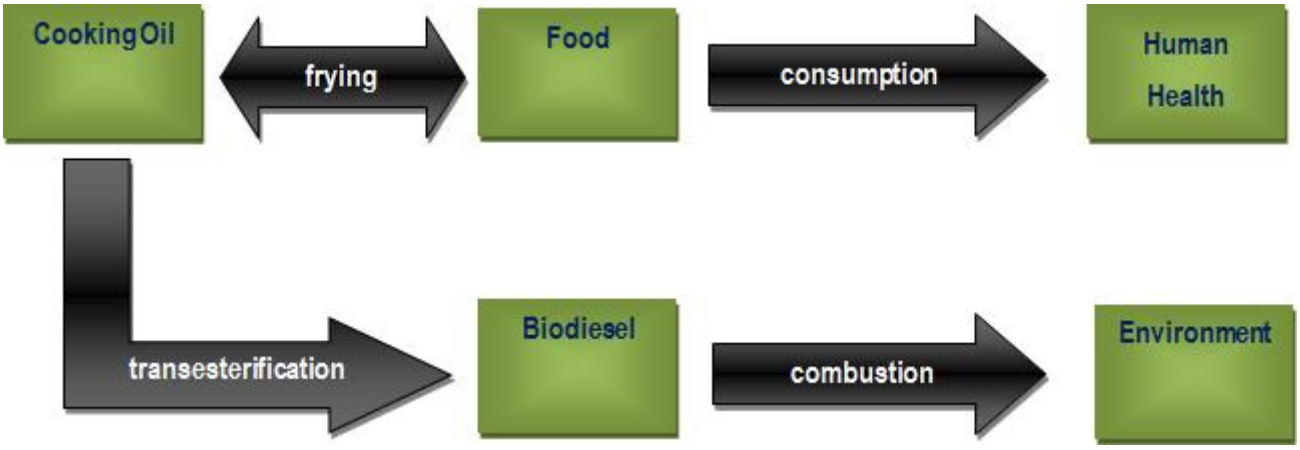


Figure 26. Conceptual representation of analysis of sustainable biodiesel production from waste cooking oil – the bioenergy and human health link

Publications and Conferences

Journal Publications

Sarigiannis D, Kontoroupis P, Solomou E, Nikolaki S, Karabelas A: **Inventory of pesticide emissions into the air in Europe.** *Atmospheric Environment* 2013, ***in press***.

Karakitsios SP, Sarigiannis DA, Gotti A, Kassomenos PA, Pilidis GA: **A methodological frame for assessing benzene induced leukemia risk mitigation due to policy measures.** *Science of the Total Environment* 2013, **443:**549-558.

Sarigiannis DA, Karakitsios SP, Antonakopoulou MP, Gotti A: **Exposure analysis of accidental release of mercury from compact fluorescent lamps (CFLs).** *Science of the Total Environment* 2012, **435–436:**306-315.

Sarigiannis DA, Hansen U: **Considering the cumulative risk of mixtures of chemicals - A challenge for policy makers.** *Environmental Health: A Global Access Science Source* 2012, **11**.

Sarigiannis DA, Karakitsios, S.P., Gotti, A.: **Exposure and risk characterization in European indoor environments related to benzene and formaldehyde.** *Fresenius Environmental Bulletin* 2012, **21**:3160-3167.

Handakas EJ, Sarigiannis DA: **Solid waste management: a systems approach.** *Fresenius Environmental Bulletin* 2012, **21**:3160-3167.

Theofanidis S, Papagiannakis A, Semelidis S, Sarigiannis DA: **Integrated recycling of municipal solid waste in Thessaloniki.** *Fresenius Environmental Bulletin* 2012, **21**:3160-3167.

Sarigiannis D, Samaras Z, Vouitsis I, Karakitsios S, Kalaitzis V: **Mechanistic Exposure Assessment of Ultrafine PM.** *Epidemiology* 2012, **23**.

Sarigiannis D, Karakitsios S, Gotti A: **Tags: A Computational Tool Towards Tiered Aggregate Exposure Assessment.** *Epidemiology* 2012, **23**.

Sarigiannis D, Gotti A, Karakitsios S, Kontoroupis P, Nikolaki S: **Intera Platform: A Tool for Mechanistic Risk Assessment of Indoor Air Pollutants.** *Epidemiology* 2012, **23.**

Books

Karakitsios SP, Sarigiannis DA, Gotti A. *Benzene and its Derivatives: New Uses and Impacts on Environment and Human Health*. Chapter: **"Refining exposure and health risk assessment of benzene", pp. 245-295.** NOVA Publishers, ISBN: 978-1-62100-026-6.

Conference presentations

D. Sarigiannis, S. Karakitsios, A. Gotti
Biological Equivalent-based risk assessment - the case of BPA and HCHO
SOT's 51st Annual Meeting
San Francisco 11-15/3/2012, USA

D. Sarigiannis, S. Karakitsios, A. Gotti
DEHP exposure assessment
SOT's 51st Annual Meeting
San Francisco 11-15/3/2012, USA

D. Sarigiannis, S. Karakitsios, Alberto Gotti
The exposome approach for assessing the risks imposed by selected volatile contaminants of environmental tobacco smoke (ETS)
SOT's 51st Annual Meeting
San Francisco 11-15/3/2012, USA

D. Sarigiannis, S. Karakitsios, A. Gotti
A dynamic physiology based pharmacokinetic model for assessing lifelong internal dose
2012 AIChE Annual Meeting
Pittsburgh, 28/10-2/11/ 2012, USA

Dimosthenis A. Sarigiannis, Graziella Cimino Reale, Angelo Collotta, Elisa Roda, Paolo Mustarelli, Teresa Coccini, Luigi Manzo
Toxicogenomics effects of water-soluble carbon nanotubes
2012 AIChE Annual Meeting
Pittsburgh, 28/10-2/11/ 2012, USA

D. Sarigiannis, S. Karakitsios, A. Gotti
Indoor air concentrations of PM2.5 and PM10 in European micro-environments and associated health risks
Air Quality 2012 Conference
Athens, 19-23/3/2012, Greece

D. Sarigiannis, S. Karakitsios, A. Gotti
INTERA platform for mechanistic risk assessment of indoor air pollutants – VOCs Europe-wide assessment
Air Quality 2012 Conference
Athens, 19-23/3/2012, Greece

D. Sarigiannis, S. Karakitsios, A. Gotti, P. Kassomenos, G. Pilidis
Urban VOC abatement policy health impact assessment
Air Quality 2012 Conference
Athens, 19-23/3/2012, Greece

D. Sarigiannis, M. Antonakopoulou, E. Handakas, A. Gotti, S. Karakitsios
Life cycle assessment of municipal waste management options
4th HSWMA International Conference
Athens, 19-23/3/2012, Greece

D. Sarigiannis
Emerging exposure science approaches and chemical safety assessment
ICCA-LRI and UK HPA Workshop – Technologies to Inform Chemical Safety Sciences
Budapest, 12-13/6/2012, Hungary

D. Sarigiannis, A. Gotti, S. Karakitsios
INTERA platform: a tool for mechanistic risk assessment of indoor air pollutants
24th ISEE Annual Conference
Columbia (South Carolina), 26-30/8/2012, USA

D. Sarigiannis, Z. Samaras, E. Vouitsis, S. Karakitsios, V. Kalaitzis
Mechanistic Exposure Assessment of Ultrafine PM
24th ISEE Annual Conference
Columbia (South Carolina), 26-30/8/2012, USA

D. Sarigiannis, S. Karakitsios, A. Gotti
Tags: A Computational Tool Towards Tiered Aggregate Exposure Assessment
24th ISEE Annual Conference
Columbia (South Carolina), 26-30/8/2012, USA

D. Sarigiannis, S. Karakitsios, A. Gotti
A tiered approach for aggregate exposure assessment
22th ISES Annual Conference
Seattle, 28/10-1/11/2012, USA

D. Sarigiannis, Z. Samaras, E. Vouitsis, S. Karakitsios, V. Kalaitzis
Mechanistic Exposure Assessment of Ultrafine PM
22th ISES Annual Conference
Seattle, 28/10-1/11/2012, USA

D. Sarigiannis, S. Karakitsios, A. Gotti
Enhancing biological equivalents by biologically effective dose using a generic PBPK model - the case of BPA and DEHP
22th ISES Annual Conference
Seattle, 28/10-1/11/2012, USA
D. Sarigiannis, A. Gotti, S. Karakitsios
INTERA platform: a tool for mechanistic risk assessment of indoor air pollutants
22th ISES Annual Conference
Seattle, 28/10-1/11/2012, USA

D. Sarigiannis, S. Karakitsios, A. Gotti,
Assessing benzene induced leukemia risk mitigation due to policy measures
11th PRE International Conference
Thessaloniki, 3-6/7/2012, Greece

D. Sarigiannis, S. Karakitsios, A. Gotti,
A mechanistic model for assessing environmental and internal exposure to DEHP
11th PRE International Conference
Thessaloniki, 3-6/7/2012, Greece

D. Sarigiannis, S. Karakitsios
Assessing the risks imposed by selected volatile contaminants of environmental tobacco smoke (ETS)
11th PRE International Conference
Thessaloniki, 3-6/7/2012, Greece

D. Sarigiannis, E. Solomou, P. Kontoroupis, S. Nikolaki, A.J. Karabelas
Environmental health impact assessment for plant protection products in the European Union
11th PRE International Conference
Thessaloniki, 3-6/7/2012, Greece

D. Sarigiannis
Satellite-assisted air-quality assessment: an integrated computational tool for air quality
11th PRE International Conference
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D. Sarigiannis, A. Gotti, S. Karakitsios
INTERA platform: a tool for mechanistic risk assessment of indoor air pollutants
11th PRE International Conference
Thessaloniki, 3-6/7/2012, Greece

D. Sarigiannis, S.A. Theofanidis, A. Papagiannakis, S. Semelidis
Integrated municipal solid waste management: The case of Thessaloniki
11th PRE International Conference
Thessaloniki, 3-6/7/2012, Greece

D. Sarigiannis, E. Handakas
Integrated municipal solid waste management: A systems approach
11th PRE International Conference
Thessaloniki, 3-6/7/2012, Greece

D. Sarigiannis, Z. Samaras, E. Vouitsis, S. Karakitsios, V. Kalaitzis
Mechanistic exposure assessment of traffic-originated ultrafine PM
19th TAP Conference
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D. Sarigiannis, S. Karakitsios, A. Gotti
The Tiered Aggregate Exposure Assessment (TAGS) platform: the case of population exposure to BPA
7th International Conference on Science of Exposure Assessment
Edinburg, 2-4/7/2012, UK

D. Sarigiannis, A. Gotti, S. Karakitsios
INTERA platform: a tool for mechanistic risk assessment of indoor air pollutants
7th International Conference on Science of Exposure Assessment
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K. De Brouwere, D. Sarigiannis, A. Gotti, S. Karakitsios
Mechanistic risk assessment of indoor pollutants: exposure to phthalates
7th International Conference on Science of Exposure Assessment
Edinburg, 2-4/7/2012, UK

D. Sarigiannis, A. Gotti, S. Karakitsios, P. Kontoroupis, S. Nikolaki
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Edinburg, 2-4/7/2012, UK

D. Sarigiannis, A. Gotti, S. Karakitsios, P. Kontoroupis, S. Nikolaki
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Exposure analysis of accidental release of mercury from compact fluorescent lamps (CFLs)
7th International Conference on Science of Exposure Assessment
Edinburg, 2-4/7/2012, UK

D. Sarigiannis
Addressing the exposome by an integrative approach
7th International Conference on Science of Exposure Assessment
Edinburg, 2-4/7/2012, UK

D. Sarigiannis
The contribution of the exposome concept to evidence on exposure body burden
Biomarkers Research Symposium
Newcastle, 8-9/5/2012, UK

M. Jantunen, D. Sarigiannis, A. Gotti, S. Karakitsios
Integrated Exposure for Risk Assessment in Indoor Environments - INTERA
10th Healthy Buildings International Conference
Brisbane, 8-12/7/2012, Australia

Laboratory personnel

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M.Sc., PhD (University of California, Berkeley, USA) is Associate Professor specialising on environment and health issues at the Department of Chemical Engineering of the Aristotle University of Thessaloniki, Visiting Professor at the Master's Program on Toxicology and Environmental Risk at the Medical School of the University of Pavia and senior scientist at the Chemical Assessment and Testing unit of the Institute for Health and Consumer Protection at the European Commission's Joint Research Centre (currently on leave). At the European Commission he has served as Scientific Coordinator of the IHCP, Action Leader for Consumer Product Safety and Quality and Community Reference Laboratory for Food Contact Materials, Action Leader for Human Exposure to Environmental Stressors and Health Effects and for Assessment of Chemicals at the European Chemicals Bureau, Scientific Assistant to the JRC Director General, Strategy Manager of the IHCP and as science advisor to the Greek Minister of the Environment. He was a principal contributor to the REACH Regulation and to the Environment and Health Action Plan and is currently member of the Health and Environment Working Party and of the Health Security Committee. He has been pioneering efforts to coupling biology-based modelling with toxicogenomics discovery systems for developing a mechanistically based understanding of the health risk of environmental chemical mixtures. He is member of the international forum for evidence-based toxicology, of the scientific committee for chronic risks of INERIS, and secretary-general of MESAEP. He has contributed to the IPs HEIMTSA, 2-FUN, NO MIRACLE, HENVINET and, CAIR4HEALTH, HEREPLUS, TRANSPHORM, GENESIS, TAGS and INTERA.

Dr A Gotti is a Physicist of the University of Milan with long experience in environment and health impact assessment, data assimilation and exposure modelling including physiology-based biokinetic modelling. He has 20 years of research experience; in the last ten years he has worked for the European Commission"s Joint Research Centre (6 years), for the Intedisciplinary Institute of Environmental Research in Athens (2 years) and for CERTH (2 years) in the frame of the projects INTARESE, SMAQ, HEIMTSA, 2-FUN, HEREPLUS, TAGS, INTERA.

Dr Spyros Karakitsios is an environmental health scientist, with studies in physics (degree), environmental and computational chemistry (M.Sc.) and applied biology (PhD) of the University of Ioannina, with an overall 10 years of experience in environmental/atmospheric process modelling and 4 years of experience in advanced human exposure science, health impact assessment and biologically-based models for human risk assessment.

Dr. Periklis Kontoroupis is an Environmental Engineer, his research activities focus on atmospheric pollution, exposure assessment, environmental risk and uncertainty assessment. He has participated in a number of projects including INTARESE, TAGS, INTERA and URGENCHE.

Mariela Antonakopoulou is a Chemical engineer with an M.Sc. from the Imperial College of London

Ermioni Solomou (M.Sc.) is a chemical engineer of Aristotle University of Thessaloniki with MSc in environmental science. Her research activities are focusing on atmospheric pollution and the impact of chemical substances on human health.

Spyridoula Nikolaki (PhD Student Researcher) is a chemical engineer (M.Eng) of the Aristotle University of Thessaloniki, with two MSc degrees, working on modelling and management of air pollution and on integrated health impact assessment.

Vasilios Kalaitzis (PhD Student Researcher) with research interest in the field of computational modeling with an emphasis on systems biology.

Marianthi Kermenidou is a Phd student. Her scientific field is indoor air pollution, chemical analysis, source apportionment and redox activity of airborne particulate matter.

Evaggelos Handakas is a Phd student of the Environmental Laboratory, Department of Chemical Engineering, Aristotle University of Thessaloniki, Greece.

Agni Mika Gavriilidou is a chemical engineer (M.Eng) of the Aristotle University of Thessaloniki, working on redox activity of airborne particulate matter.

Stauros Theofanidis is a graduate student of the Aristotle University of Thessaloniki, working on anaerobic digestion.

Stauros Semelidis is a graduate student of the Aristotle University of Thessaloniki, working on outdoor air pollution.

Apostolos Papagiannakis is a graduate student of the Aristotle University of Thessaloniki, working on PM measurements.

Dimitrios Zikopoulos is a graduate student of the Aristotle University of Thessaloniki, working on air pollution risk assessment.

Kyriakos Manoli is a graduate student of the Aristotle University of Thessaloniki, working on biodiesel production.

Dimitrios Chapizanis is a graduate student of the Aristotle University of Thessaloniki, working on traffic originated PM emissions.