Annual Report 2013

Environmental Engineering Laboratory

ENVElab

Edited by:
Assoc. Professor Dimosthenis Sarigiannis, Director

Welcome message

2013 – A year of challenges and success

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.

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 and Analytical Chemistry Laboratories 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 three years.

In Greece ENVE Lab has been providing scientific support to the Ministry of Development, the Ministry of Environment, Energy and Climate, and the Ministry of Health and it has forged working links with the environmental consultancy ENVIROPLAN S.A.

ENVE Lab supports the long-range research initiative of CEFIC (the European Federation of Chemical Industry) by leading 3 projects on integrated exposure and risk assessment. The Lab is an active member and since 2013 it has assumed the Presidency 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 World Health Organization European Center for Environment and Health, the US Environmental Protection Agency (US EPA), the National Institutes for Environmental Health Science (NIEHS) and the School of Public Health of the University of California at Berkeley 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.

During 2013 the main challenges included monitoring and facing the problem of increased air pollution from biomass combustion for space heating in large urban centres (induced by the energy poverty of the population coupled to the financial crisis) and launching two new projects on the exposome and environment-wide associations with health status of the EU population. ENVE Lab was the main contributor to the Air Pollution Scientific Committee established by the Ministry of Health for the period 2013-2016 that came up with the bundle of measures for protection of the population and abatement of acute particulate pollution episodes in Greece. The Lab contributed to the expert Working Group on biomass boiler certification on behalf of the Ministry of the Environment, Energy and Climate. On the international level, ENVE Lab was a temporary advisor to the WHO on human biomonitoring, combined exposure to health stressors in the indoor environment, and environmental health economics.

I hope you will enjoy receiving our 2nd annual report and that reading it will open up new, interesting scientific questions. We shall be happy to work with you to answer them and roll further back the boundaries of error in our understanding of the world.

Assoc. Prof. Dimosthenis Sarigiannis
Laboratory director

Scientific Signature:

2013 – A Year of integration

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.

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. 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 1), in accordance to the "safe by design" principle.

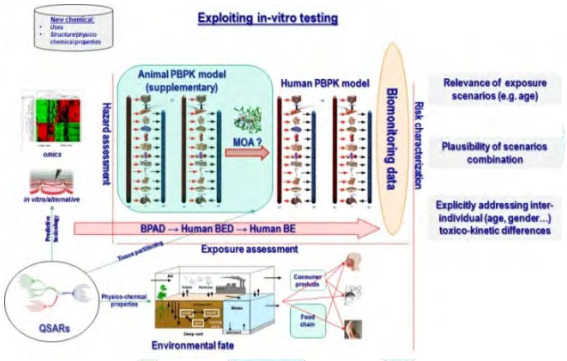

Figure 1. Integrating environmental contamination, human exposure and toxicology for refined risk characterization

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, regulatory and chemical industry community; EnvE-Lab's resilience in supporting this scientific signature, as well as dedication to a solid work ethics model, was rewarded by the number of different projects granted last year, namely:

INTEGRA - European Chemical Industry Council (CEFIC)

HEALS - FP7 project

CROME – LIFE project

CheRRIE – INTERREG project

These projects follow the scientific principles described above, yet they focus on different aspects of the "**source-to-outcome**" continuum. These projects (in collaboration with the existing projects URGENCHE and TRANSPHORM) they act in a synergistic manner so as to further develop the holistic approach of EnvE-Lab.

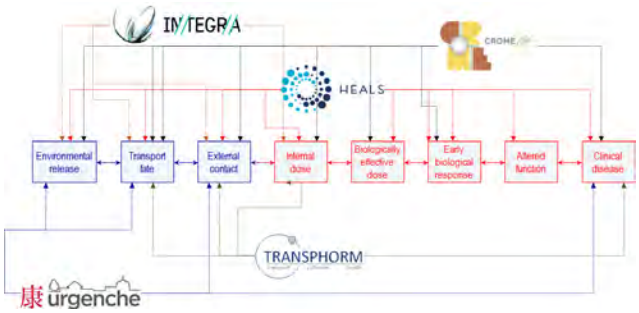

Figure 2. Involvement of EnvE-Lab projects across "source to effect" continuum

Highlight of the year 2013 - Biomass smog in Thessaloniki

Over the last couple of years, the use of biomass as heating source was allowed in Greece as a CO_2-neutral means of space heating in the large metropolitan areas of Athens and Thessaloniki affecting more than half of the country's population. At the same time the use of light heating diesel was heavily taxed. In the same period Greece faces a financial crisis with significant repercussions on the average household income. That combination of parameters resulted to increased use of biomass for residential heating in year 2012, followed by a significant increase of ambient air, indoor air and exposure to PM10 and PM2.5. EnvE-Lab aimed to quantify the health and socioeconomic effects related to that shift from light heating diesel to biomass burning, as well as to evaluate alternative scenarios of residential heating energy share. The extensive study of the biomass burning attributed PM problem to Thessaloniki air quality raised public awareness (TV interviews, newspaper articles), which in turn resulted to policy interventions (two Joint Ministerial Decrees); these aspects are presented in more detail in other chapters of the EnvE-Lab 2013 annual report.

For the purposes of the biomass smoke PM attributed problem analysis, a complex methodological framework incorporating measurements and modelling was implemented (Figure 3).

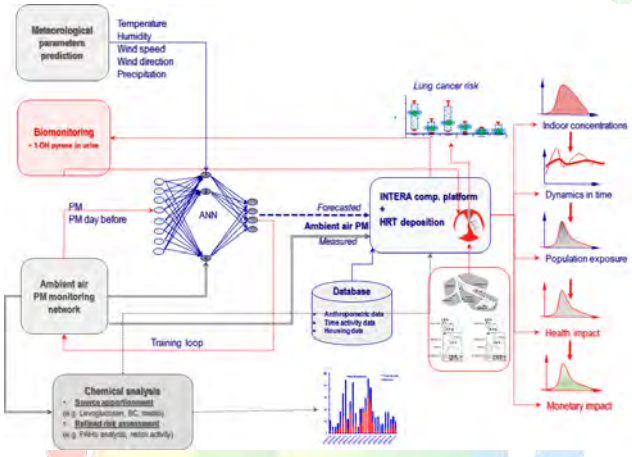

Figure 3. Conceptual representation of the methodology

The overall methodology comprises a set of ambient and indoor air measurements, chemical analysis of PM (for assessing PM source apportionment, as well as toxicity) and a comprehensive modelling framework for assessing individual and population exposure, deposition to the human respiratory tract, health and socioeconomic impact, as well as an air quality forecasting model based on Artificial Neural Networks.

The inter-day variability regarding the sampling sites is illustrated in Figure 4 and Figure 5. Both PM2.5 and PM10 concentrations tend to rise significantly during the transition from the warm to the cold period. The latter was marked by the lower temperatures starting in mid-November. The concentrations at the traffic station (53.1 and 29.5 ug/m^3 for PM10 and PM2.5 respectively) were constantly higher than the concentrations at the background station (30.6 and 19.4 ug/m^3) during the warm sampling period because of the high traffic load, which is the dominant emissions source in the urban area under study.

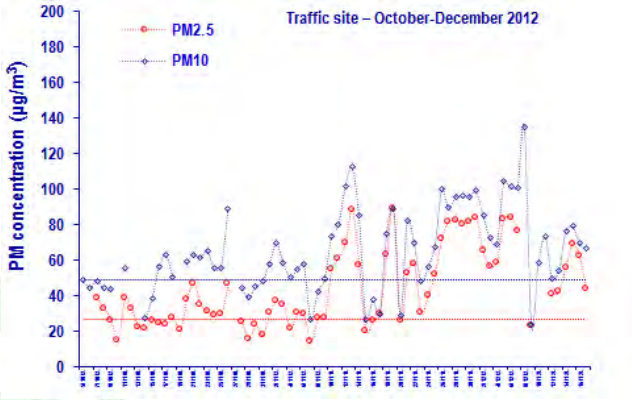

Figure 4. PM concentration in the traffic station

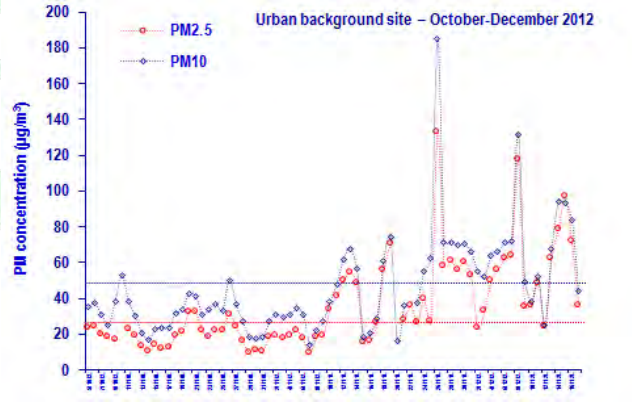

Figure 5. PM concentration in the urban background station

This is the combined result from direct tailpipe emissions and re-suspension processes (movement of vehicles, loading and unloading operations). However, during the cold period, PM concentrations increase rapidly at the urban background sites, becoming eventually higher than the ones at the traffic sites, most of the days exceeding the thresholds (for both PM10 and PM2.5) proposed by the 2008/50/EC guide values. A key process that changed the usual PMx profile in Thessaloniki as soon as the mean ambient air temperature fell below 10°C was the apparently widespread use of biomass as fuel for domestic heating. In order to determine how much biomass combustion contributed to the mass concentration of PMx in the ambient air black carbon (BC) and levoglucosan were quantified analytically.

Results for different size fractions of PM are shown in Figure 6.

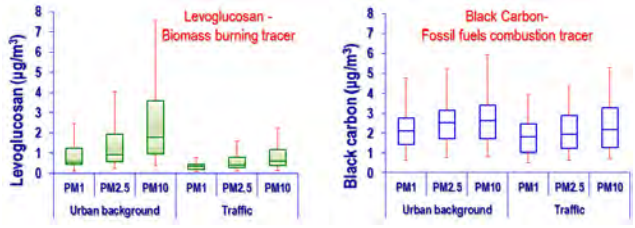

Figure 6. Measurements of levoglucosan and BC analysis for the urban background and the traffic station. Similar BC concentrations reflect the similar traffic component contribution. However, the significant differences in levoglucosan concentrations reflect the significantly higher biomass burning emissions for domestic heating

The BC content in PMx sampled at the urban background sites were 25-30% higher than the corresponding values at the traffic sites, revealing that combustion processes additional to traffic-related internal engine combustion contribute to the observed PMx values.

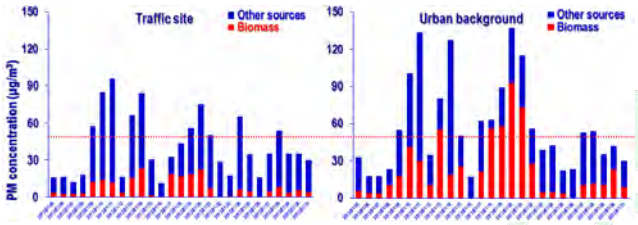

Figure 7. Biomass burning contribution in two distinct sites (traffic and urban background) in the city of Thessaloniki based on the levoglucosan found onto PM during wintertime. Higher concentrations of PM and levoglucosan in the urban background site verify the strong component of biomass emissions, accounting of about 36% of measured PM

Levoglucosan (a well-known biomass marker) found in PMx at the urban background sites was between 90 and 120% more than the corresponding values near intense traffic. The contribution of biomass combustion to PM mass concentration varied significantly with an average value of 34% and maximum values up to 70% especially when extreme pollution incidents occurred (mean daily concentration of PM10 close to 150 ug/m^3). Biomass contribution to PM mass concentration was much higher at the urban background sites than close to intense traffic.

Indoor PM concentrations are close to the ones of the outdoor air if no strong emission source (e.g smoking indoors or combustion) is present (see figure 6). When biomass combustion is a method of choice for domestic heating (i.e. through the use of fireplace and/or woodstove), the indoor PMx concentrations tend to rise significantly. Similar results were obtained also for the days of the cold period, where the fireplaces burned for 3-5 hours daily on the average. In this case, average daily indoor concentrations tended to be similar or higher than the ones in the ambient air, with an average daily increase of about 10 ug/m^3 and 14 ug/m^3 for PM2.5 and PM10 respectively (Figure 8) compared to the houses where the fireplace was not in use. However, this variability depends on many parameters, such as the daily duration of fireplace usage, the type of woods and to a smaller degree the intensity of burning. It is noteworthy that a very close agreement was noticed between the measured and the modeled concentrations.

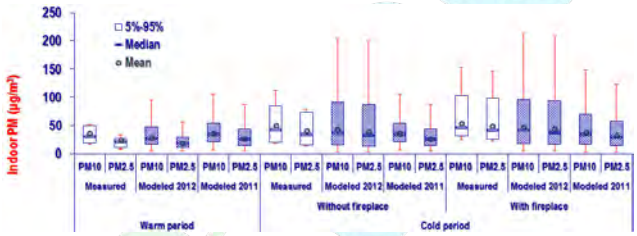

Figure 8. Indoor PM concentrations (measured and modeled)

Very interesting results were obtained by the PNC measurements during the time when fireplaces were used (Figure 9).

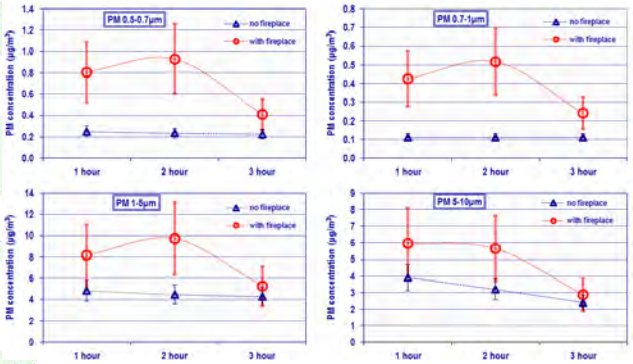

Figure 9. Indoor PM concentrations with and without the operation of a fireplace

During fireplace operation, PM concentrations increased significantly, with an average rise of 6 and 3 ug/m^3 for the fractions PM1-5 and PM5-10 respectively. Depending on the fireplace combustion conditions (type and humidity of woods, placement of woods within the fireplace, intensity of burning) the PM concentrations might become as high as 30-40 ug/m^3. Rapid increase in the particle number is characteristic for particles of smaller aerodynamic diameter; namely, the concentration of PM0.5-0.7 particles undergoes a 5-fold increase). Personal exposure variability follows a similar pattern to indoor concentrations (Figure 10). A very interesting result is that for 2012, exposure to PM of population living in houses not equipped with fireplaces is higher than the one for people living in a house equipped with fireplace for year 2011 during the cold season.

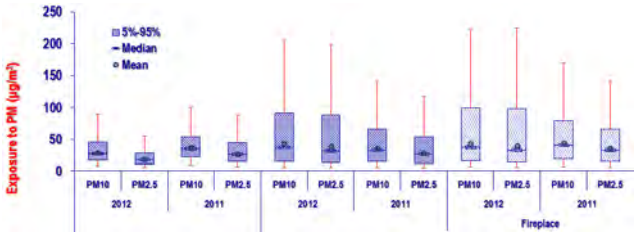

Figure 10. Overall PM exposure estimated by the INTERA platform

Beyond average exposure, intra-day variability of exposure was also investigated. A typical intra-day winter time profile of an exposed individual living in a house with fireplace is presented in Figure 11.

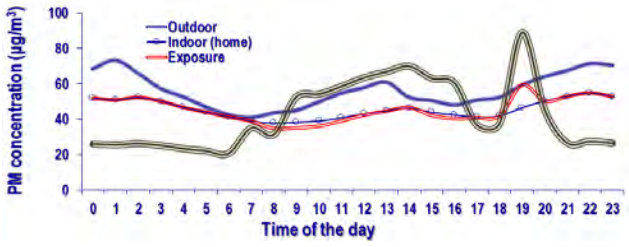

Figure 11. Intra-day variability of ambient and indoor air, personal exposure and intake

Figure 11, however, shows that actual PM intake (as expressed by the grey line that represent exposure concentration modified by the activity relevant inhalation coefficient) occurs mostly during daytime. During sleep inhalation rate is lower; thus, despite the elevated outdoor concentrations, actual intake is lower than the one estimated by the monitoring ambient and indoor air concentrations.

The forecasting ANN model performed very well considering that the explanatory variables accounted for more than 90% of the observed values. The overall performance of the developed ANN was validated against an independent validation set, including measurements at different traffic and background sites within the city. The results of the validation of the ANN model are illustrated in Figure 12.

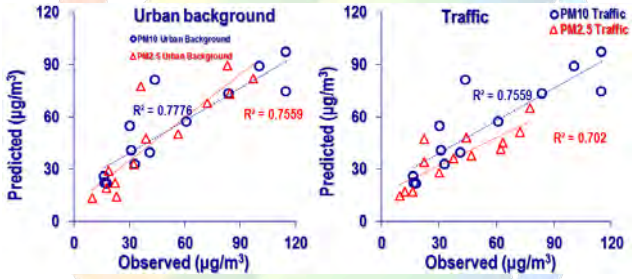

Figure 12. Performance of the forecasting ANN model for an independent validation set

Annual mortality was estimated based on well-known (considered by WHO) concentration-response functions. Expected mortality in winter 2012-2013 is increased by 40% compared to the winter 2011-2012. Alternative energy share scenarios mitigate this effect.

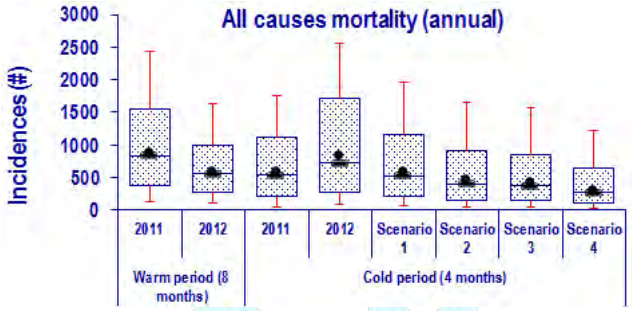

Figure 13. Estimated annual mortality due to PM exposure under current situation and "what if" scenarios.

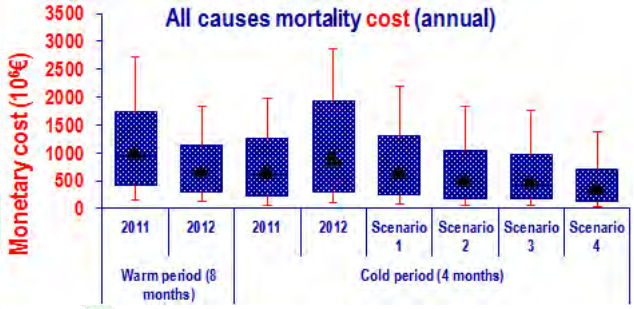

Figure 14. Estimated socioeconomic cost of PM attributed mortality based on total welfare change

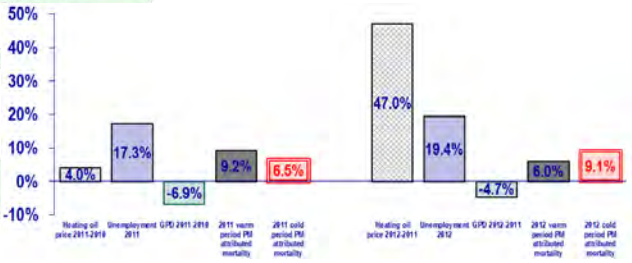

Figure 15. Socioeconomic dimension of financial crisis and the relevance to mortality associated socioeconomic costs between the cold periods of 2011-2012 and 2012-2013 seasons

Based on the results of the study and taking into account the importance of public health and the related socioeconomic cost, specific interventions are recommended, such as:

- Reduction of the price of light heating diesel
- Financial motivations for the light heating diesel to be replaced by natural gas

If biomass continues to be used, then we need to take into consideration the followings:

- Closed fireplaces are more efficient in terms of performance/PM emissions and indoor PM emissions are almost negligible.
- Emission factors for fine particles are highly dependent on the fuel characteristics and burn conditions (smoldering vs. flaming), as well as fuel moisture content and burning conditions.

HEALS

Health and Environment-wide Associations based on Large population Surveys

Health and Environment-wide Associations based on Large population Surveys (HEALS) is a research project funded under the EU Framework Programme FP7 topic "Assessing individual exposure to environmental stressors and predicting health outcomes: paving the way for an EU-wide assessment" (www.heals-eu.eu).

Figure 16. HEALS consortium

With a European financial contribution of 11.5 M€, a total budget of almost 14.9 M€ and a duration of five years HEALS represents the most important FP7 project funded by the European Union on environment and health topic. The project sees the participation of twenty nine international scientific leading institutions belonging to fourteen European Countries and the United States (Figure 16). EnvE-Lab co-ordinates the project providing scientific leadership and coordinating the scientific strategy and ethical aspects of the project.

The overall aim of HEALS is the refinement of an integrated methodology and the application of the corresponding analytical and computational tools for performing environment-wide association studies (EWAS) in support of EU-wide environment and health assessments. To this aim HEALS will integrate in an innovative approach a comprehensive array of novel technologies, data analysis and modeling tools that support efficiently exposome studies.

In this light the HEALS approach will bring together and organize environmental, socio-economic, exposure, biomarker and health effect data; in addition, it includes all the procedures and computational sequences necessary for applying advanced bioinformatics coupling thus effective data mining, biological and exposure modeling so as to ensure that environmental exposure-health associations are studied comprehensively. The main focus of the project will be on susceptibility windows during growth (including pregnancy) and on vulnerable population such as young, elderly, socio-economically disadvantaged, gender and ethnic minorities.

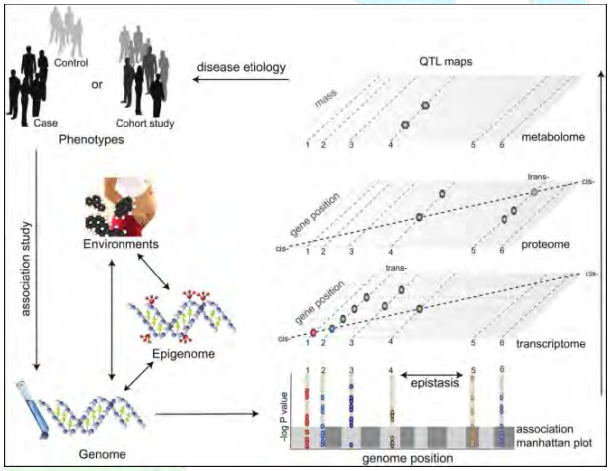

Figure 17. Conceptual representation of HEALS methodology

The overall approach will be verified and refined in a series of population studies across Europe including twin cohorts. The overall population size involved in these studies is up to ca. 335,000 individuals tackling different levels of environmental exposure, age windows of exposure, and socio-economic and genetic variability. The approach developed will be applied in a pilot environment and health examination survey of children including singletons and sets of twins with matched singletons covering ten EU Member States (the EXHES Study). The lessons learned will be translated into scientific advice towards the development of protocols and guidelines for the setting up of a European environment and health examination survey.

The project started officially on October 1, 2013. The kick-off meeting took place on October 23-25 at the University Pierre and Marie Curie in Paris.

A second major event was organized at the Bavarian Medical Doctors' Association in Munich on December 17-18, 2013. It was the first of a series of training events aiming at improving the interdisciplinary communication and the exposome concept among the project partners.

CROME

Cross-Mediterranean Environment and Health Network

CROME (www.crome-life.eu) stands for *Cross-Mediterranean Environment and Health Network* and it is a 42 months demonstration project started in July 2013 funded under the EU LIFE+ Programme 2007-2013.

The project, coordinated by EnvE-Lab, has been funded with a European contribution of 880 K€ over a total budget of 1,760 K€ and see the participation of four international Institutions of four different Mediterranean Countries (Greece, Italy, Spain and Slovenia).

CROME aims at demonstrating a technically feasible integrated methodology for interpretation of human biomonitoring data that will allow to quantitatively assess the impact on human health due to acute/chronic exposure to chemicals acting as neurodevelopmental and neurological toxicants and/or human carcinogens such as toxic and organic substances.

Figure 18. Opening event in Thessaloniki on 24 October 2013, associated with the first scientific workshop

The main environmental problem targeted by CROME-LIFE is the assessment of the impact on human health due to exposure to chemical agents originating either from environmental contamination (air, soil, water), or from consumer products (food contact materials, construction materials, cosmetics, clothes, etc.) through multiple routes, namely inhalation, ingestion and dermal contact. Under this perspective CROME-LIFE will demonstrate the implementation of an operational methodology for linking biomonitoring data with environmental and epidemiological observations in four different Countries in southern Europe (Greece, Slovenia, Italy and Spain) in order to refine the assessment of health impacts attributable to environmental stressors / contaminants of man-made nature.

The real benefit of CROME-LIFE for environmental and public health authorities in the four demonstration sites will be that using the project methodology and tools authorities will enhance their ability to take well targeted, cost-effective measures tackling the environmental health problems upon which the project focuses.

The CROME-LIFE team met for the Kick-Off meeting on 23 October 2013 in Thessaloniki at the premises of the coordinating beneficiary, the EnvE-Lab of Aristotle University of Thessaloniki. A public open event associated with the first scientific workshop was organized in Thessaloniki on 24 October 2013 (Figure 18) as a major dissemination event which has seen the participation of many representatives of the local authorities, academics, NGOs and of two recognized international leaders Institutions in the environment and health scientific field. The opening event was covered by local television channels and the related videos were shown during the prime time news sections. As a result of the project publicity several articles on the science of CROME were published at the science section of the largest Greek weekly newspaper, TO VIMA. Other articles were published in numerous electronic versions of some of the most important local newspapers pertaining to mercury contamination of fish in the Eastern Mediterranean and the respective human burden as found by biomonitoring studies. A multi-page article on the science of CROME was published at the Science section of the largest Greek weekly newspaper, TO VIMA.

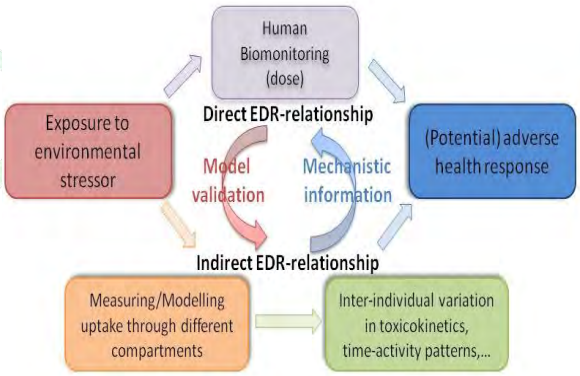

Figure 19. CROME methodological framework "middle out approach"

First scientific results of the project comprised the definition of the methodological framework which is based on what is known as the *middle out* approach. The CROME-LIFE methodology starts by estimating exposure using human biological monitoring data and works its way both forward to disease and backwards (using reverse dosimetry) to environmental exposures (Figure 19).

CheRRIE

Chemical and Radiological Risk in the Indoor Environment

The Chemical and Radiological Risk in the Indoor Environment (CHERRIE) is an 18-month project funded under the European Territorial Cooperation Programme Greece- Bulgaria 2007-2013 INTERREG IV programme. The project overall budget is 1,226 K€ and will be funded by ERDF with a total contribution of 1,042 K€. Cherrie will start officially on January 1, 2014. Four Greek and two Bulgarian partners will participate; the lead beneficiary is the Bulgarian Academy of Sciences and EnvE-Lab assumes the scientific coordination of the project.

An increase in respiratory health problems and allergies as well as lung/thyroid cancer incidence has been observed over the last fifteen years in South-eastern Europe including Central-South Bulgaria and Northern Greece. Much of this increase has been attributed to environmental hazards. The large amount (80%) of time the population spends indoors may have a compounding effect on this problem.

In parallel, there is a clear need that all EU Member States meet their climate change targets. In the case of Greece and Bulgaria this means increasing energy conservation in building and private dwellings. In Greece this is served by the advent of the Energy efficiency certificates in the building sector. The implementation of this policy leads to improved insulation in dwellings and thus increased potential for impoverishment of indoor air from chemical and radiological hazards. The financial crisis in Greece and the demanding financial situation in Bulgaria enhance material recycling.

This project will perform a thorough assessment of the current chemical and radiological risks of building materials and will set up a comprehensive database of building material properties that would affect the respective attributable risk. Furthermore a grid-based computing infrastructure will be set up to support effective scientific and stakeholder networking in order to better protection public health so as to provide a significant service to public health improvement in both countries. In this light Cherrie will provide necessary knowledge infrastructure to support intelligent choice of materials and identification of new market opportunities whilst protecting public health.

The main expected results will be the improvement in the quality of the materials used in building construction and/or refurbishing in the trans-boundary regions resulting from a more systematic and thorough information available to the building constructors who will be able to base their purchasing decisions for raw materials on the findings of this study and avoid those that are found to have increased levels of radioactivity and chemicals emissions.

Quantitative health impact related to the use of building materials will be quantitatively assessed calculating the final radiological and toxic burden of the population from exposure to ionizing radiation of radionuclides and toxicants in different places both in Greece and Bulgaria. The final results expressed as an annual dose rate (external gamma-radiation, radon, VOCs, formaldehyde and other carcinogens and allergens indoors), illustrating the final whole body burden of the population compared to the international standard of radiological protection (in the case of radiological hazards) and reference doses or their biomonitoring equivalents (in the case of chemical hazards). The system for human exposure to indoor physical and chemical stressors/ health impact assessment and management will be largely based on already existing computational and data reception/management platform (INTERA) developed by EnvE-Lab in the frame of the CEFIC-LRI funded project INTERA.

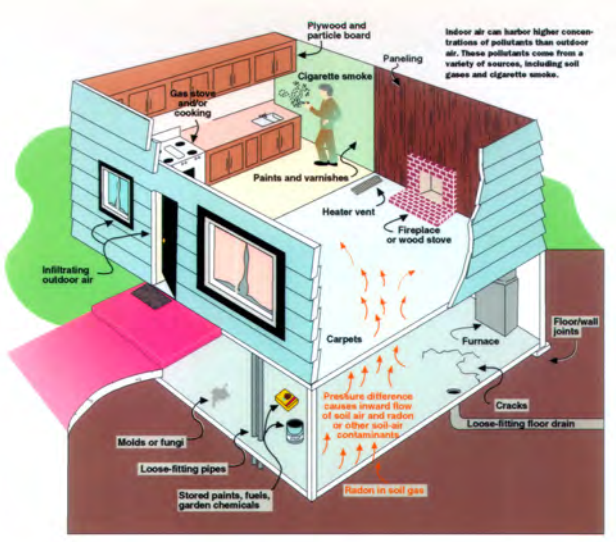

Figure 20. Typical sources of air pollution within a residential building

Furthermore the project outcomes would be expected to serve as a community-based scientific and technical infrastructure for performing such types of studies in other areas of the two countries (beyond the trans-boundary regions), thus enhancing both the scientific expertise in the countries and the level of public and consumer health protection across the Greece-Bulgaria border.

INTEGRA

Integrated External and Internal Exposure Modelling Platform

The INTEGRA project -

The *Integrated External and Internal Exposure Modelling Platform* (INTEGRA) is a project funded by the CEFIC-LRI programme, aimed to bring together all available information within a coherent methodological framework for assessing the source-to-dose continuum for the entire life cycle of substances covering an extensive chemical space (www.integra-lri.eu). The major component of INTEGRA will be a flexible and user-friendly web-based computational platform that integrates environmental fate, exposure and internal dose dynamically in time allowing to differentiate between biomonitoring data corresponding to steady exposure patterns as opposed to acute, one-off exposures (Figure 21). The platform will be largely validated using human biomonitoring data from Europe and the USA.

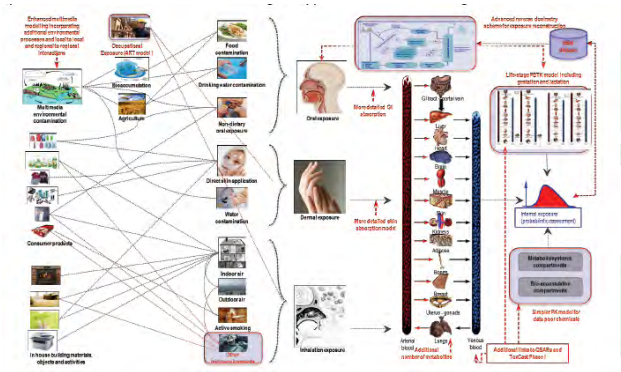

Figure 21. INTEGRA conceptual representation

The project started on January 1, 2013 and has a total budget of 299 K€ entirely funded by CEFIC for a duration of 27 months with the participation of four leading Institutions in Europe coordinated by EnvE-Lab.

The INTEGRA methodology (and the relevant computational platform) is a clear advance in terms of indoor micro-environmental interactions (contamination exchange between gaseous, particles and dust phases, chemical reactivity), towards an integrative exposure assessment framework which allows to capture the dynamics of biological processes involved and to reduce unnecessary conservatism contributing to a more comprehensive cost/benefit analysis and efficient risk management.

INTEGRA allows the multimedia interaction between different spatial environmental scales, taking into account environmental releases and related processes at global, regional and local scale, up to the level of personal microenvironment. In addition, the implementation of equally refined tools for internal dosimetry, allows Risk Characterization based on internal dosimetry metrics; these provide the capability to exploit the Tox21 *in vitro* testing results, providing a new Tier of analysis that incorporates refined exposure (tissue dosimetry) and toxicity testing (Biological Pathway Altering Dose – BPAD), starting from multiple scales environmental contamination.

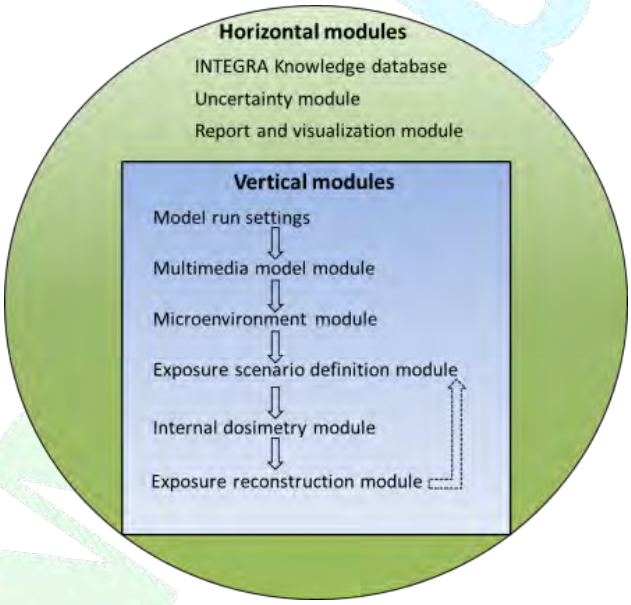

Figure 22. Modules of INTEGRA computational platform

The functional specifications of the INTEGRA computational platform has been defined after extensive consultation with identified stakeholders. To this aim a series of international scientific events were followed and co-organised by the INTEGRA team during the year to better embed the work of the project within international efforts towards improved risk assessment of chemicals. The INTEGRA platform will be a multimodular software following the open architecture paradigm especially designed to execute aggregate exposure assessment. The platform will enable the integration and assimilation of model and data needed to execute a "full-chain" aggregate exposure assessment focusing on both environmental and occupational exposure to a single chemical. It will encompass three horizontal modules and six vertical modules, each addressing a step along the source-to-dose (external and internal) continuum (Figure 22).

QSARs

A major area of work within the INTEGRA project is the development of Quantitative structure–activity relationship models (QSARs). QSAR models are regression or classification models used in the chemical and biological sciences and engineering. QSARs form a relationship between biological effects and chemistry of each chemical and comprise three parts:

- The activity data to be modeled,

- The data with which to model and
- A method to formulate the model.

The biological effects are normally the property to be modeled, which are linked with the physical or structural chemistry of the molecules. QSAR methods are used particularly for the estimation of physicochemical properties, biological effects as well as understanding the physicochemical features governing a biological response.

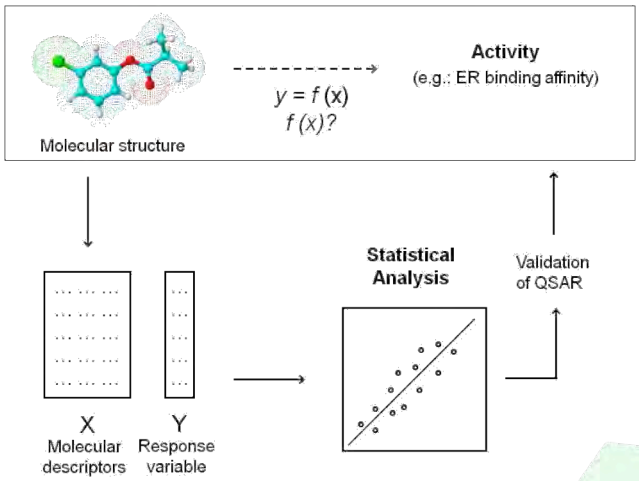

Figure 23. Basic methodological scheme for deriving a QSAR

The input parameters required for solving the set of Physiologically Based Pharmacokinetic (PBPK) model equations are either species- specific or chemical-specific and should reflect biological or mechanistic determinants of absorption, distribution, metabolism and elimination (ADME) of the chemical being modeled. The species-specific parameters, for example, relate to alveolar ventilation rate (Q_p), cardiac output (Q_c), tissue blood flow rates (Q_t) and tissue volumes (V_t) should be within the documented range for the particular species and life stage. The chemical-specific input include partition coefficients (blood:air (P_{ba}), tissue:air (P_{ta}) or tissue:blood (P_{tb})) as well as metabolic parameters such as the maximal velocity (V_{max}) and Michaelis affinity constant (K_m) or the intrinsic clearance (V_{max}/K_m). These physicochemical parameters should have been obtained on the basis of independent measurements (in vitro, in vivo) or using algorithms in the valid domain of application, like QSARs. In particular, in the case of a chemical for which pharmacokinetic parameter database is either incomplete or lacking, the internal dose cannot be reliably estimated. The internal dose measure associated with a particular exposure scenario could vary from anywhere between zero (theoretical minimum) and the potential dose (theoretical maximum). This large uncertainty is due to the fact that there is a lack of precise knowledge regarding the key chemical-specific determinants of ADME. Since these parameters, together with the physiology of the animal species, determine the pharmacokinetics of chemicals in biota, integrated QSAR-PBPK models can effectively predict or identify the possible range of internal dose.

EnvE-Lab research focuses on the estimation of an expanded QSAR model in order to predict physicochemical parameters of a large group of chemicals. Up until now, a unified algorithm by Peyret, Poulin and Krishnan has been examined, which is applied both for environmental chemicals and drugs and predict the rat tissue:blood, tissue:plasma water and tissue:plasma partition coefficients for liver, muscle and adipose tissue. The predicted values are very close to the experimental ones, obtained from literature. Generally, the algorithm applies quite well to acidic compounds and neutrals. It should be mentioned that there have to be improvements regarding the prediction of strong bases' parameters.

Furthermore, attention is given at Abraham's solvation equation:

$$\log SP = c + r \cdot R_2 + s \cdot \pi_2^H + a \cdot \Sigma\alpha_2^H + b \cdot \Sigma\beta_2^H + v \cdot \log V_x$$

where SP: a biological property for a series of solutes.

The equation above can be solved by multiple linear regression (MLRA), to yield the constants c, r, s, a, b and v, which are used to characterize the receptor area involved. Not every term in the equation may be significant, and each term is analyzed using students t-test. The properties of the solvent phase are constant and the various interactions are described by particular solute parameters, namelly:

R_2 is an excess molar refraction that can be determined simply from a knowledge of the compound refractive index, π_2^H is the compound dipolarity/polarizability, $\Sigma\alpha_2^H$ is the solute effective or summation hydrogen-bond acidity, $\Sigma\beta_2^H$ is the solute effective or summation hydrogen-bond basicity, V_x is the McGowan characteristic volume that can trivially be calculated for any solute simply from a knowledge of its molecular structure.

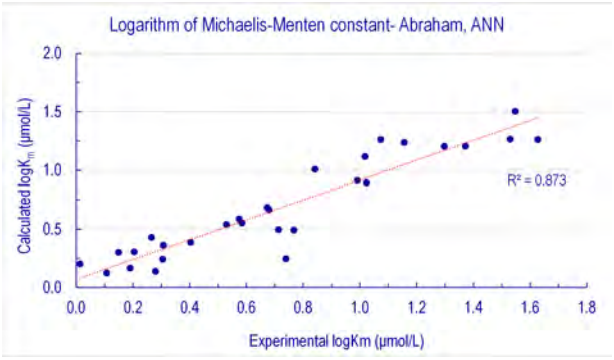

Figure 24. Observed vs predicted Michaelis - Menten constant values for selected low volatile compounds

Up to now, these QSARs seem to perform well for a number of chemical families, relevant to the aims of INTEGRA.

A major breakthrough came from the use of Artificial Neural Networks coupled to Abraham's solvation equation for predicting biological/biochemical properties such as blood-tissue partition coefficients, Maximal Velocity (V_{max}) and Michaelis - Menten constant.

This was a remarkable advance, since till now, prediction capability of the Michaelis - Menten constant was rather poor (R^2 up to 0.35); with our coupled ANN - Abraham's solvation equation method for the investigated group of chemicals R^2 went up to 0.87 (Figure 24), which is by far higher to any other existing methodology.

The improved performance of ANN-Abraham's equation combination can be ascribed to its capacity to represent mathematically the complex interactions of biochemical micro-processes, which are lumped into the Michaelis-Menten constant.

Exposure reconstruction

The establishment of relationships among events along an exposure chain, health evaluation as well as risk assessment is the key issue to understand how the exposure of environmental chemicals effect on public health. Although daily, Biomonitoring Data (BD) are reported in order to evaluate the internal exposure, the gap between the correlation of external exposure and BD stills remain. That procedure to estmate the relationship between internal and external exposure is termed as "Exposure Reconstruction" (ER) or "reverse dosimetry". Exposure reconstruction is an ongoing scientific research field and various computational techniques have been formulated such Deterministic Inversion, Stochastic Inversion/Bayesian Approach, Exposure Conversion Factor Approach, Discretized Bayesian Approach and Bayesian Markov Chain Monte Carlo in order to give a solution to the problem.

Considering that these techniques are the foundations for developing new and improved approaches ER, a conceptual/computational framework was been developed based on Bayesian Markov Chain Monte Carlo combined with a generic Physiological Based Pharmacokinetic (PBPK) model (Figure 25).

The analysis of the developed ER framework consists of 3 basic steps. At first the prior parameter distribution, the joint probability distribution, the population model and the determination of the measurement model have to be specified.

At the next step exposure is calculated using MCMC simulation considering the observed biomonitoring data. Finally, the evaluation of the results is realized using MC simulation, with emphasis to the comparison of prior and posterior distribution as well as parameter independence.

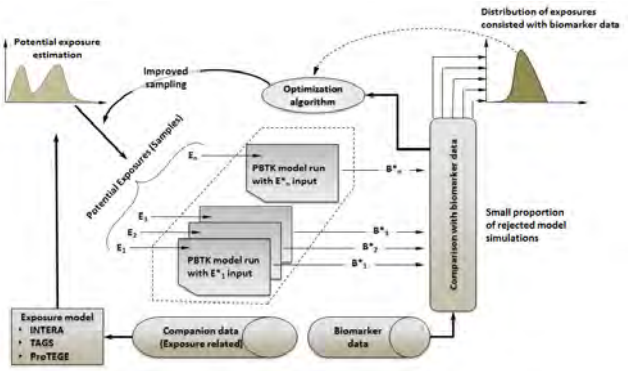

Figure 25. Optimization-aided exposure reconstruction based on HBM data using time-evolving PBPK models

MCMC simulation (Figure 26) refers to a class of iterative simulations in which the random variables of interest are drawn from a sequence, or chain, of distributions that eventually converge to a stable posterior distribution.

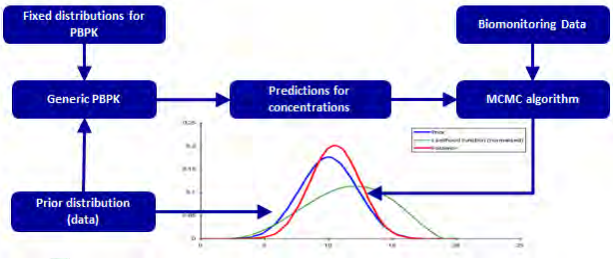

Figure 26. Conceptual/computational framework for the exposure reconstruction

Moreover, Differential Evolution (DE) and MCMC algorithms have been combined to this problem for the first time. Differential Evolution Markov Chain is a population MCMC algorithm, in which multiple chains run in parallel. In fact DE is a simple genetic algorithm for numerical optimization in real parameter spaces. As a result, this combined computational framework speeds up the calculation and convergence, even for nearly collinear parameters and multimodal densities.

The results of the simulation corresponded very well to a dataset of synthetic data, as well as to real biomonitoring data (Figure 27).

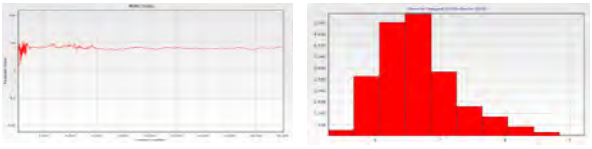

Figure 27. MCMC simulation convergence and Posterior Distribution for dose

A detailed multi-compartmental skin penetration model

Skin is a complex organ and a living membrane. Mathematical models of skin have been developed in order to predict and to measure the transportation of chemicals, drugs and cosmetics via skin structure. These models play a significant role in analyzing experimental data and in reducing the number of experiments.

Considering that skin is a major barrier of human body against exposure to environmental and consumer toxicants, the precise assessment of actual uptake through skin is essential for the refinement of aggregate exposure and risk characterization.

The skin has been modeled with a two layer structure: Stratum corneum (SC) and viable epidermis (VE). The stratum corneum has been described with a "bricks and mortar" structure.

Additionally, the skin's model leverages the latest and emerging results on homogenization theory and rates of binding to produce a broad mechanistic SC model that quantifies transient solute binding in terms of coexisting free and bound concentration fields, and is parameterized at the microscopic scale.

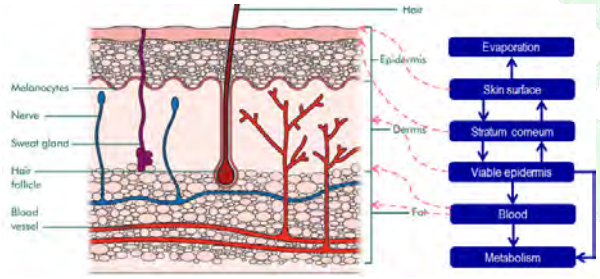

Figure 28 Skin's multi-compartmental model

The developed skin model incorporates the majority of the complex processes characterizing skin permeation and absorption, related to its complex structure and physiology.

The detailed skin model has been coupled to a generic multi-compartmental life-time human two generation PBPK model that describes internal dosimetry from the moment of conception, during all the gestation till birth and through time life.

The model was applied in the case of Bisphenol A (BPA) and its contact with human skin. BPA is one of the highest industrial volume chemicals produced worldwide. The major volume of BPA is used for the production of polycarbonate plastic as well as a basic component in production of the epoxy resin. Additionally, BPA has been found in thermal paper of sale receipts and money.

The major question related to skin absorption of BPA is the potential bioavailability differences that might arise compared to oral exposure, which is considered as the dominant exposure route for the majority of exposure scenarios considered. This concern arises from the fact that oral intake of BPA is accompanied by an extensive and very rapid first-pass metabolism (phase II glucuronidation), resulting in very low bioavailability. On the contrary, modelling studies have indicated that inhalation exposure to BPA results in 6-fold higher bioavailability compared to oral exposure. To elucidate potential differences, we investigated the difference in steady state plasma concentration for a given dose, using the EFSA Tolerable Daily Intake (TDI) of 50 ug/kg_bw/d as the reference point. We also simulated the concentration time profile of an oral dose of 50 g/kg/day (which corresponds to the TDI) in blood and liver. In blood, the free plasma BPA concentration after oral dose of 50 ug/kg_bw/d is equal to 0.16 ug/L, while the corresponding free plasma concentration after the administration of the same dose dermally is up to 0.3 ug/L. In contrast, peak concentration in the liver is 14 fold higher after oral as compared to dermal administration of the same dose, due to the well-known first pass metabolism of BPA.

Moreover, the intra-day time course of BPA between an exposed individual from the general population (assuming an oral daily intake of 1.5 ug/kg_bw/d) and a cashier receiving an additional dose of 71 ug/day (the worst case scenario) during a 10-hour shift has been evaluated (Figure 29).

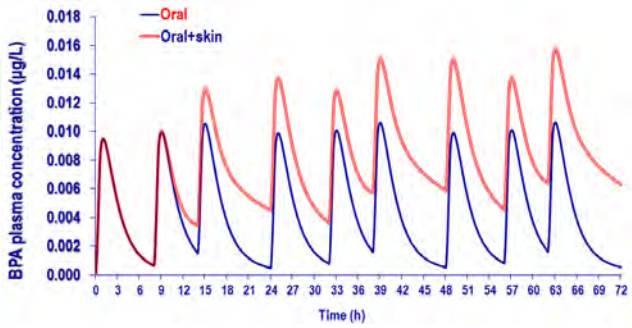

Figure 29. Diurnal concentrations are higher only by 60% than the exposure levels corresponding to the typical EFSA exposure scenario

Additional investigation of the potential bioavailability differences that might exist because of dermal administration showed that BPA does not pose concern, since the lack of first-pass metabolism is decompensated by the slow rate of absorption, the extent of skin metabolism and more significantly to the low exposure. All the above lead to the conclusion that dermal consumer exposure scenarios related to BPA arising from paper recycling (except the case of thermal paper for cashiers), might be considered as negligible compared to oral uptake.

URGENCHE

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.

Under the perspective of urban transportation, the co-benefits to urban air quality, noise and public health were investigated from the introduction of greenhouse gas (GHG) emission reduction policies to the city of Thessaloniki and the Great Thessaloniki Area (GTA). The traffic related policies implemented, included the introduction of underground rail in the city centre and changes in vehicle composition, i.e. allowing a larger share for the diesel engine passenger cars, the hybrids and the electric cars.

Air and noise pollution were assessed for a baseline scenario in year 2010 and two future scenarios in year 2020, a business-as-usual (BAU) and a GHG emission reduction scenario (CO2 scenario). This assessment was carried under an integrated methodological framework, composed of a series of interconnected models and repeated for the years 2010 and 2020. The models used, included the (a) SIBYL, to project vehicle stock numbers; the (b) VISUM, to simulate traffic flow as a result of changes in travel demand; the (c) COPERT IV, to compute the pollutant emission (PM10, PM2.5, NO_2, NO_x, O_3, CO and benzene) per vehicle engine and type; the (d) OSPM to compute pollutant concentrations in traffic corridors; the (e) CALPUFF, to compute pollutant concentrations on motorways and urban/peri-urban roads; and the (f) NMRB-2008, noise model to evaluate traffic noise generation and its propagation from traffic corridors and motorways under the ISO 9613-1 and the 9613-2 constraints.

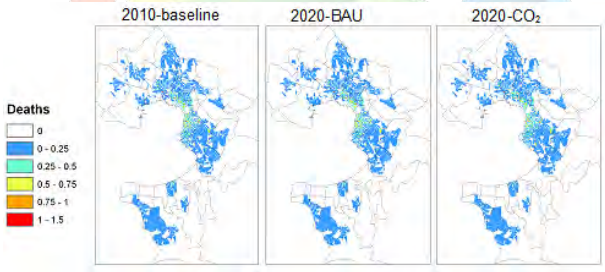

Figure 30. Spatial distribution of annual number of deaths attributed to PM_{10} in 2010, 2020-BAU and 2020-CO_2

Exposure to air population was assessed via the inhalation pathway and its health impact was estimated by concentration response functions on high resolution population data (per building block, differentiated by age and gender). The health end points computed include annual mortality attributable to PM10 and NO_2 exposure and the leukemia lifetime expected cases due to benzene exposure, which were aggregated at the municipality level (Figure 30).

Noise was computed from the shortest distance of Source (e.g. motorway) to the Receptor (e.g. building block of a particular height) and its exposure was weighted by the population and differentiated between each municipality in the Thessaloniki Area. The health end points computed include, sleep disturbance, sleep annoyance due to road transport and myocardial infractions.

The impact of the Greenhouse Gas (GHG) emission reduction scenarios to health was identified to be significant. Simulations show that traffic flow will decrease by 33% on roads in direct proximity to the metro line (e.g. Monastiriou, Egnatia, Nea Egnatia, Delfwn), by 44% on roads within the historic center and by 22% in all adjacent roads to the historic centre. These reductions in flow were further amplified by changes in the traffic mode, where diesel, hybrids and electric cars will constitute 22%, 7.7% and 2% respectively, to the total vehicle fleet.

It was estimated that for the municipality of Thessaloniki, the expected decrease (%) in the annual number of deaths for the GHG scenario were 8% and 11% attributed to the PM10 and NO_2 respectively and 27% to the leukemia lifetime expected cases due to Benzene. In comparison, for the municipality of Panorama, the expected % decrease in the annual number of deaths for the GHG scenario are 1% and 23% from PM10 and NO_2 respectively and 33% to the leukemia lifetime expected cases due to benzene (Figure 31).

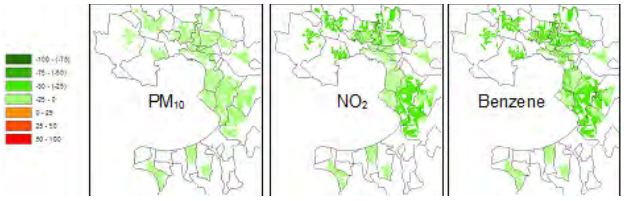

Figure 31. Decrease (%) in the annual number of deaths for the GHG scenario

Similarly the highest reductions in sleep annoyance due to road transport noise and the myocardial infractions were identified in the municipality of Thessaloniki, where the aforementioned policies have the highest impact.

TRANSPHORM

Transport related Air Pollution and Health impacts - Integrated Methodologies for Assessing Particulate Matter

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.

A mechanistic framework for assessing carcinogenic risks from PAHs

Genotoxic effects of inhaled particulate matter (PM) are mainly attributed to absorbed polycyclic aromatic hydrocarbons (PAHs). Human respiratory tract (HRT) deposition of a specific particle depends on its aerodynamic diameter. Thus, xenobiotics contained in finer particles can easily be transferred in human body via systemic circulation. Benzo[a]pyrene (B[a]P) is the only PAH classified as known carcinogen to humans by IARC.

EnvE-lab investigated the carcinogenicity risk from polycyclic aromatic hydrocarbons (PAHs) in particulate matter, in the area of Thessaloniki, Greece. A 6-month campaign (October 2012 – mid-April 2013) of ambient air PM measurements was carried out. PM1, PM2.5 and PM10 particles were collected in Teflon filters using low flow air samplers in two air pollution monitoring stations, representative of urban/residential and traffic influenced pollution respectively.

Nineteen individual PAHs were analyzed by GC/MS and concentrations in air were calculated for both monitoring stations. Potential cancer risk due to exposure to the mixture of urban ambient air PAHs was calculated using the toxicity equivalent factor (TEF) approach based on Benzo(a)pyrene (B[a]P) (Figure 32).

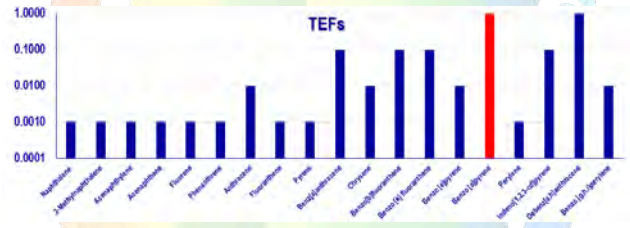

Figure 32. Toxic Equivalent Factors (TEFs) for the different PAHs, on the assumption that the TEF for B[a]P is equal to 1

The TEQ (Toxicity Equivalent Quotient) (carcinogenicity equivalent, in ng/m^3) was calculated by multiplying the concentrations of each compound in the PAH mix with the respective TEF for cancer potency relative to BaP. Daily inhalation rate (*IR*) and deposition fractions of particulate matter to the main regions of the respiratory system were calculated for eight age groups of human population. The ultimate cancer risk was estimated for each age group using the CEPA Inhalation Unit Risk (*IUR*) for B[a]P.

The results showed that PM (PM1, PM2.5, PM10) and PAHs concentrations, during the cold period, were higher in the urban background monitoring station than in the traffic station. This pattern was attributed to biomass combustion, which can be considered as the primary source of PAHs in the populated areas of Thessaloniki during the last two years winters.

Table 1. TEQ/[PM] ratios for the two monitoring stations

TEQ/[PM] (10^{-2} ng/μg)					
Urban			Traffic		
$PM_{1.0}$	$PM_{2.5}$	PM_{10}	$PM_{1.0}$	$PM_{2.5}$	PM_{10}
11.3	9.49	7.53	13.5	10.4	7.51

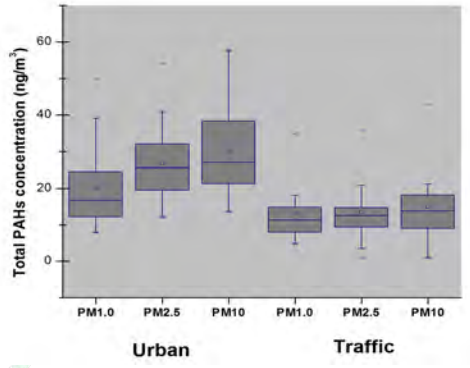

Figure 33. Total PAHs concentrations for the two monitoring stations.

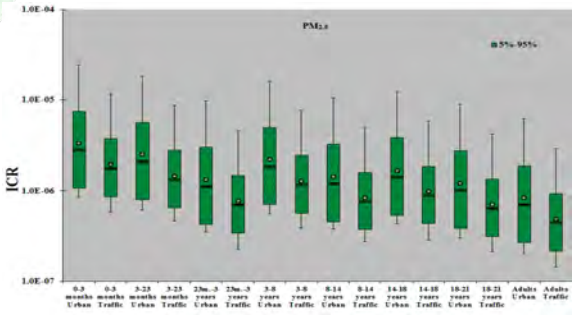

Figure 34. ICR calculated for each age group

The thoracic deposition fraction, along with *IR* and body weight (*BW*) of each age group are critical parameters for assessing the potential cancer risk. The thoracic PM deposition fraction, estimated via HRT software (MPPD v.2.11), proved to be higher in infants and children even for the PM_{10} fraction, as the upper respiratory tract of adults has the ability to withhold most of the coarse particles (PM2.5-10).

Significant risk (*ICR* > 10^{-6}) was estimated for every age group, while higher *ICR* was estimated for infants and children.

The variances observed between different age groups suggest that the integrated mechanistic approach we applied is able to describe in more detail the interaction between atmospheric pollutants and health effects among human population.

Enhanced exposure metrics for PM health associated studies based on Oxidative Potential

PM is a well-recognized health threat, as shown by several well established associations between ambient air PM and mortality or morbidity. However, there is still room for improving these associations, by better understanding the intermediate steps, including actual exposure to PM, internal dosimetry and elucidation of potential mechanisms between exposure and disease. The mechanism by which fine particles cause death and disease is largely not known. It has been suggested that the particles retained in the deep lung cause inflammation which, in turn, releases bioactive substances into the bloodstream causing coagulation of the blood. Thus, such mechanisms may cause respiratory and heart-related disease and death. Particulate matter through an oxidative stress mechanism causes a sevenfold increase in Nf-κB activation in human airway epithelial cells. Nf-κB is a transcription factor that can induce gene transcription in a variety of pro inflammatory cytokines, enzymes that generate mediators of inflammation and immune receptors. Oxidative stress mediated by particulate matter may result from direct generation of Reactive Oxygen Species (ROS) from the particle surface, where transition metals or organic compounds affect the mitochondrial function of inflammatory cells. The subsequent damage to DNA may explain how increased cancer risk is induced by particulate matter.

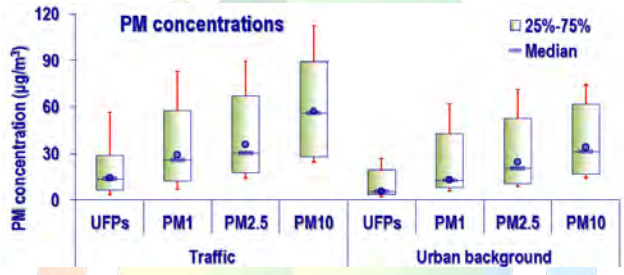

Figure 35. PM concentrations per site and size

The study includes a set of PM measurements performed over a two month period (October-November) in 2012 (including PM10, PM2.5 and PM1), exposure modeling including deposition across respiratory tract and assessment of PM size specific oxidative potential through the (ROS) method using the DDT assay. The PM measurements were carried out in two urban sites in the city of Thessaloniki; the first one at the curbside of an intensively trafficked road (Egnatia Avenue, Venizelou square) and the second one at the suburbs of the city (Eptapyrgio), representing the urban background concentration (Figure 35).

Exposure and intake of PM was estimated through the computational platform INTERA, taking into account time activity patterns, locations encountered (thus concentrations of indoor locations) and inhalation rates. Internal exposure of PM in terms of deposition at different regions of the HRT was carried out using the Multiple-Path Particle Dosimetry (MPPD) model (Figure 36).

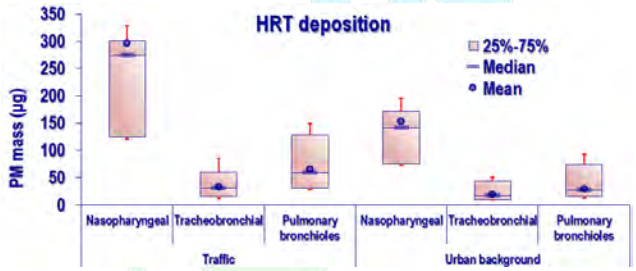

Figure 36. HRT PM deposition per site and HRT region

Dithiothreitol (DTT,) is commonly used as a cell-free measure of the oxidative potential of particles. In this assay, redox-active chemicals in particulate matter (PM) oxidize added DTT to its disulfide form and the linear rate of DTT loss is used as a measure of the oxidative capacity of the PM. ROS potential was higher (per mass of particles) for particles of smaller diameter (Figure 37).

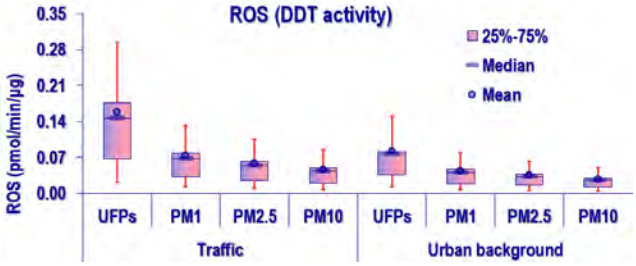

Figure 37. Oxidative Potential per site and size

Based on the PM size specific oxidative potential and the deposition across HRT, the "region specific oxidative stress index" is calculated as the product of the size specific mass deposited to the HRT region, multiplied by the oxidative potential of this size specific PM (Figure 38).

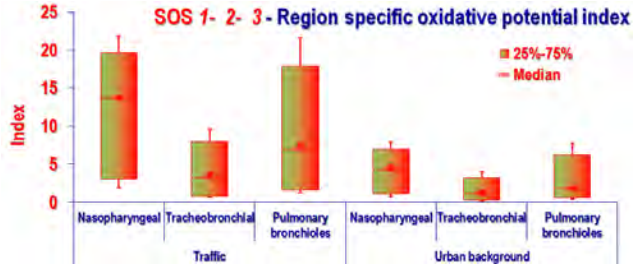

Figure 38. Region specific oxidative stress index

Overall, the methodology proposed above, derives a novel exposure metric that incorporates more refined dose metrics and toxicity potency of PM.

In this way, environmental data (collected PM) are translated into a more informative exposure metric, able to better differentiate the actual risks people are run by living in different areas of an urban setting, as well as to the region of HRT which is relevant to the health outcome of interest; these differences are amplified up to a factor of 5 instead of a factor of 1.5 compared to the use of environmental concentration levels (Figure 39).

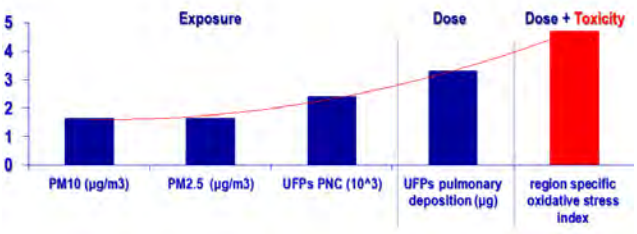

Figure 39. Differentiation of actual exposure/risk factors between two urban sites by using different exposure metrics

Uncertainty assessment

Uncertainty was quantified in a hierarchical manner, taking into account uncertainties in emissions, concentration and health impact from exposure to PM10 and PM2.5.

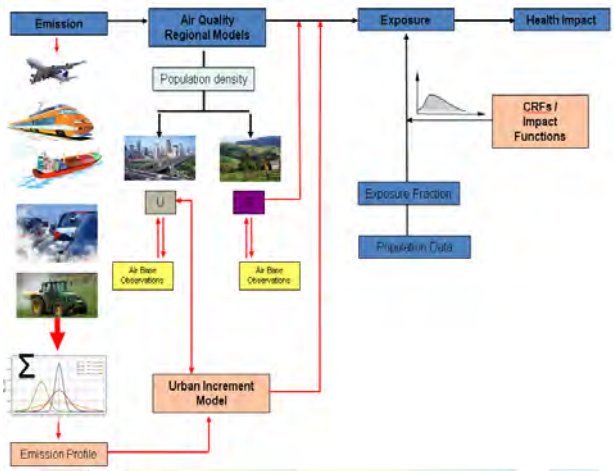

Figure 40. Overview of the full chain uncertainty assessment

For the emissions part, uncertainty was attributed to the use of emission factors. Uncertainty in source strength was presented in the form of the standard deviation to mean ratio per transportation mode and country. For the concentration part, an urban increment model was used as surrogate to complex regional air quality models (EMEP, SILAM, LotusEuros, CMAQ) where the most influential variables were identified via global sensitivity analysis. In addition, Airbase observations were used to determine the regional model fit in rural and urban areas, and hence estimate the uncertainty in model performance per pollutant and country. Lastly, with regard to the exposure assessment, normal/lognormal distributions were associated to the relative risk used by way of a Monte Carlo simulation to deduce the final health impact.

This integrated full chain methodology has given an insight to the relative importance of each source of the chain, with respect to uncertainty until the final computed health end point (Table 2). From this assessment, uncertainty was found to vary between countries: total uncertainty was 49% for the all-cause mortality due to PM2.5, 47% due to cardiovascular mortality from PM2.5, 22% due to lung cancer risk from PM10 and 48% due to PM2.5.

Table 2. Contribution of uncertainty to each source of the full chain assessment

Sources – PM10&PM2.5	% in coefficient of variation	Other measures	Reasoning
Emission	27%	N/A	Aggregation of distributions
Concentration – regional models	N/A	3-4 sigma	Expert elicitation (Mikhail Sofiev) - diurnal, weekly, and seasonal cycles
Concentration – regional models in rural areas	EMEP 30% CMAQ 34%, SILAM 33%, EurosLotus 31%	N/A	Aggregation of lognormal distributions
Urban increment model	EMEP 22% CMAQ 21%, SILAM 22%, EurosLotus 21%	N/A	Aggregation of lognormal distributions
Uncertainty in Relative Risk	All cause mortality 1%, Cardiovascular mortality 3%, Lung cancer risk due to PM10 11% and due to PM2.5 13%	N/A	via MC to the Relative Risk
Total	All cause mortality 49%, Cardiovascular mortality 47%, Lung cancer risk due to PM10 22% and due to PM2.5 48%	N/A	Uncertainty propagation via MC, excluding some countries (HUN, POL, PRT, DNK, FIN, SVN, SVK).

Advanced satellite data fusion

$PM_{2.5}$ estimation and related health impact assessment

The work developed in the frame of the 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.

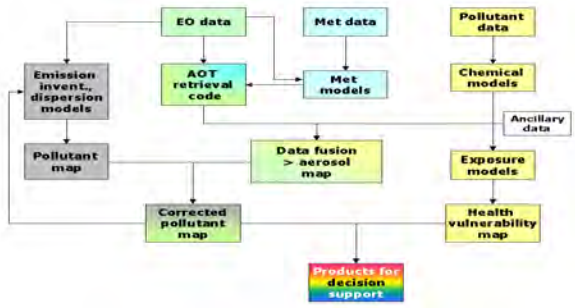

Figure 41. Conceptual representation of the advanced satellite data fusion system

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.

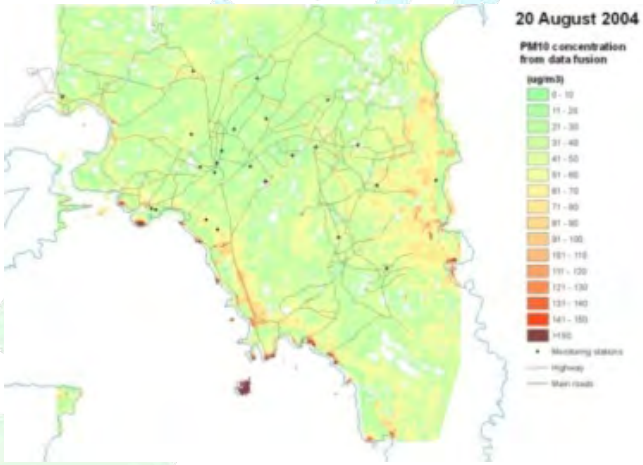

Figure 42. Application of the fusion system in Athens

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.

Indoor environment multiple risks

Combined or multiple exposure to health stressors in indoor built environments

The objective of this study (a task assigned by WHO to EnvE-Lab) was to undertake, summarize and present a systematic review of literature and project reports presenting evidence on multiple or combined risk exposure in indoor built environments. The review covered safety threats and injuries, indoor air pollution, use of household chemicals, noise, damp and mould, thermal conditions, crowding, inadequate hygiene standards, and harmful building and equipment/furnishing materials.

There is a lot of evidence and studies on non-occupational indoor risks. Often, however, the focus is on health outcomes of exposure to single stressors and multiple risks are often related to confounding in epidemiological studies. As a consequence, these studies, do not necessarily provide a good overview of multiple exposure to these health stressors and their association to adverse health outcomes per se. In fact aside of simple additivity of effects and some specific cases of exposure to at most two simultaneous stressors, which may enhance or counteract each other, the actual evidence on health effects of co-exposure to multiple stressors is limited.

Among the several health threats, exposure to multiple chemical agents still remains the silent threat: poor indoor environment quality (in terms of exposure to chemicals) is not always perceived by the occupants. As a result, occupants are continuously exposed to a cocktail of carcinogens (benzene, formaldehyde, PM-PAHs) and endocrine disruptors (phthalates, PCBs). The combined effects of these chemicals are still not sufficiently elucidated, since their physic-chemical and biochemical properties would favor multiple ways of interaction upon human uptake (Figure 43); there might be synergies in effect (e.g. PAHs and nitrosamines of ETS, both causing lung cancer), or they might inhibit each other's metabolism – this is the case for the almost ubiquitous indoors BTEX mixture. In any case, although further investigation on the mechanisms elucidating mixture toxicity is needed, no significant departure from additivity in the health effect assessment was observed for the concentrations encountered usually in non-occupational settings.

Combined exposure to chemical and biological agents in the indoor environment may result in increasing risk of adverse health effects. A case that stands out in this context, is the study of co-exposure to chemicals from carpeting and mould, which was conclusively shown to produce adverse health effects beyond additivity; indeed the observational data hint to synergistic mechanisms coming into play or to enhanced physiological susceptibility of adults to biological agents when co-exposed to phthalates and other organic chemicals emitted from building materials and consumer goods frequently used in residential settings indoors.

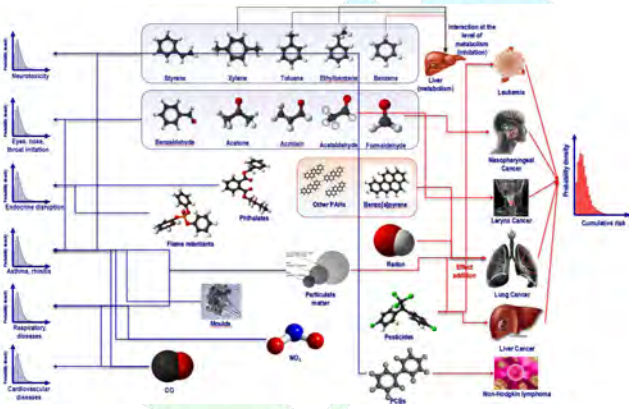

Figure 43. Multiple ways of interaction for chemicals

Children living in houses regularly cleaned with bleach and consequently exposed to volatile chlorination products were found to be less likely to have asthma and of being sensitized to indoor aeroallergens, especially house dust mite. These protective effects were independent of gender, ethnicity, previous respiratory infections, total serum immunoglobulin E (IgE) level and of family history of allergic diseases. Of great interest is the finding that the above protective effects were nullified by parental smoking, which also interacted with the use of bleach to increase the risk of recurrent bronchitis. Thus, cleaning with chlorine bleach appears to protect children from the risks of asthma and of sensitization to indoor allergens but when co-exposure to environmental tobacco smoke (ETS) occurs the risk of recurrent bronchitis increases.

Considering the complexity of the multiple stressors encountered in indoor environments, the proper identification of the effects of combined/cumulative exposure among them requires:

- integrated analysis of indoor environment quality assessment and other housing-related hazards clustered by type of indoor setting.
- identification of potential synergies of stressors on a mechanistic basis, using the latest advances in in vitro testing and computational toxicology.
- confirmation of these hypotheses by comprehensive environment-wide association studies (such as HEALS).

Connectivity

Toxicology of chemical mixtures in the environment and consumer products

The advent of new technologies in biological science and in the improved understanding of the mechanisms of response to toxicological insults at different biological levels provides novel possibilities to improve the current state of the art in health risk assessment. In particular, the combined use of -omics methodologies including genomics, proteomics and metabolomics may help to approach the source-to-outcome continuum more effectively In addition advances in computational toxicology methods and biological modeling help put together a systems approach for the derivation of dose-response functions and their effective application in risk assessment. The translation of this integrated thinking into a new paradigm for modern toxicology is known as connectivity approach. The connectivity approach to mechanistically-based risk assessment of environmental chemicals both as individual and as mixtures can be tackled with an integrated, multi-layer computational methodology, ideally comprising the following steps (Figure 44):

- Characterization of exposure factors quantifying the parameters that affect human exposure to environmental chemicals, such as time-activity relationships, seasonal and climatic variation, and consumer choice. These exposure factors can be used to derive aggregate and cumulative exposure models, leading in probabilistic exposure assessments.
- Current toxicological state of the art combines estimations of biologically effective dose (BED) with early biological events to derive dose-effect models, which can be used in combination with the probabilistic exposure estimates to derive biomarkers of exposure and/or effect. Combined use of epidemiological, clinical and genetic analysis data may shed light on the effect of risk-modifying factors such as lifestyle choices and DNA polymorphisms. Observation of real clinical data and/or results of biomonitoring, if coupled with the exposure/effect biomarker discovery systems, can produce biomarkers of individual susceptibility and thus allow estimations of individual response to toxic insults. Toxicogenomics and in particular transcriptomics and metabolomics/adductomics, is key to this kind of analytical and data interpretation process.
- The integrated analysis of the biomarker data (including results on biomarkers of exposure, effects and individual susceptibility) results in the integrated assessment of risk factors. Use of information on risk factors with molecular dosimetry data (i.e., estimation of the actual internal and BED of xenobiotic substance found in the target organ and, indeed, perturbing cellular response) enables population risk studies to be done, by converting generic exposure profiles into population risk metrics having taken into account inter-individual variability of response and exposure uncertainty.

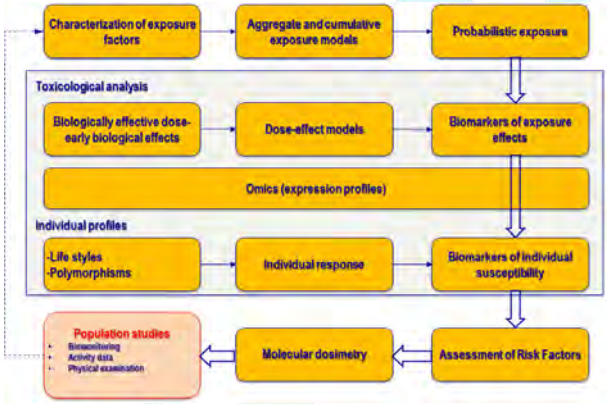

Figure 44. Connectivity – a multi-layered approach

Additional elements towards the implementation of the connectivity approach is the integration of multiple factors that comprise exposome, against genetics (e.g. susceptibility) and epigenetic alterations, in junction to dietary and other behavioral factors that affect overall exposure through metabolic profiling and systems biology integration (Figure 45). By understanding the individual exposome we can have a better understanding of the causal associations of individual disease, thus a more personalized prevention, as well as treatment of the disease. Personalized prevention and treatment are more efficient, thus improving overall health status and well-being, in addition to reduced socioeconomic burden from morbidity and mortality.

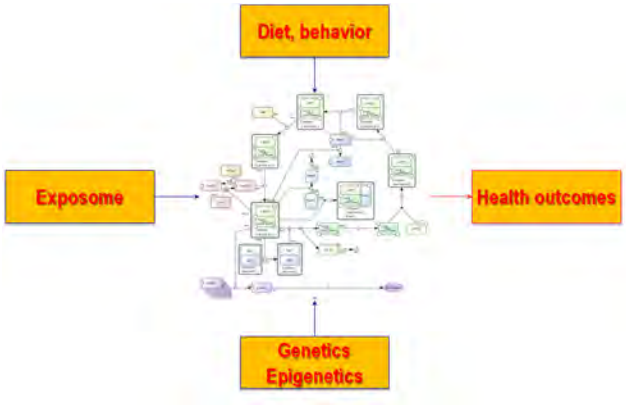

Figure 45. Metabolic profiling and systems biology integration

Life cycle analysis of municipal waste management

Industrial symbiosis options for reduced ecological footprint

Municipal solid waste (MSW) management is nowadays one of the biggest problems in both developed and developing countries. Prevention, recycling, treatment and final disposal of MSW are regulated through a number of general policy principles and international directives.

It is imperative therefore to create awareness among local authorities, manufacturers, companies and generally society of the available varied technological solutions.

Integrated waste management solutions using the concept of industrial symbiosis (IS) have been developed and evaluated taking into account the European and national waste management legislation. IS, as part of the emerging field of industrial ecology focuses on the flow of materials and energy through local and regional economies. IS engages traditionally separate industries in a collective approach to drawing competitive advantage involving physical exchange of materials, energy, water, and/or by-products. The keys to IS are collaboration and potential synergies offered by geographical proximity and industrial function.

Life Cycle Assessment (LCA) provides the methodological framework. LCA is conducted according to ISO 14040 Moreover, LCA used to describe the environmental impacts of products and processes while assessing the material and energy flows throughout their lifetime.

Figure 46. 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.

Indicators of efficiency, effectiveness, and environmental and public health impacts are used to facilitate the comparative evaluation of the different MSW management scenario. Hence, material flow accounting, gross energy requirement, exergy and emergy intensity, local, regional and global emission and release intensity and morbidity or mortality indicators are used to support the comparative assessment.

The integrated framework was applied to the case of MSW management in the two larger cities in the country, Athens and Thessaloniki, with a special focus on energy and material balance, including potential global and local scale airborne emissions as well as groundwater and soil releases.

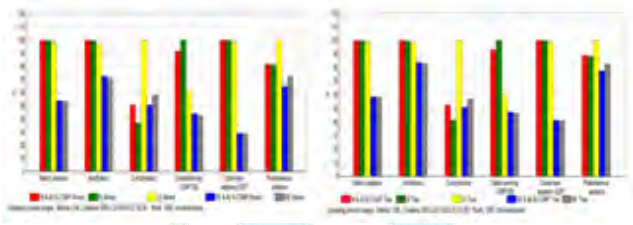

Figure 47. Impact categories of life cycle assessment for Athens and for Thessaloniki

Finally with regard to public health impacts, adverse effects on respiratory health, congenital malformations, low birth weight and cancer incidence were estimated.

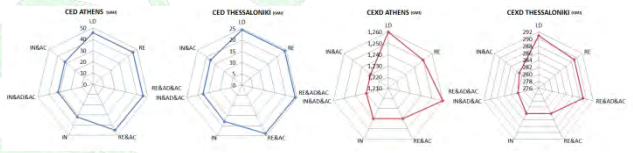

Figure 48 Cumulative Energy and Exergy Demand for Athens and for Thessaloniki

A significant and not intuitive result is the fact that integrated framework 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, modifies the relative attractiveness of the solutions considered. The results of the assessment based on selected impact indicators lead to the following conclusions: biological methods have the smallest abiotic matter, acidification potential, greenhouse gas effect, ozone depletion and photochemical oxidation among the waste management systems considered. In terms of energy and exergy demand biological methods prove to be more sustainable options. Landfilling was deemed the worst waste management strategy; other options for waste treatment coupled with energy and material recovery would result in very important benefits such as reduction of greenhouse emissions. However, not all options are benign to the local environment and to the health of the local population, since both can be influenced by non-negligible local emissions. As far as public health is concerned, adverse effects on respiratory health, congenital malformations, low birth weight and cancer incidences are still observed especially from incineration and landfilling.

Environmental management and energy recovery systems

Anaerobic digestion

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

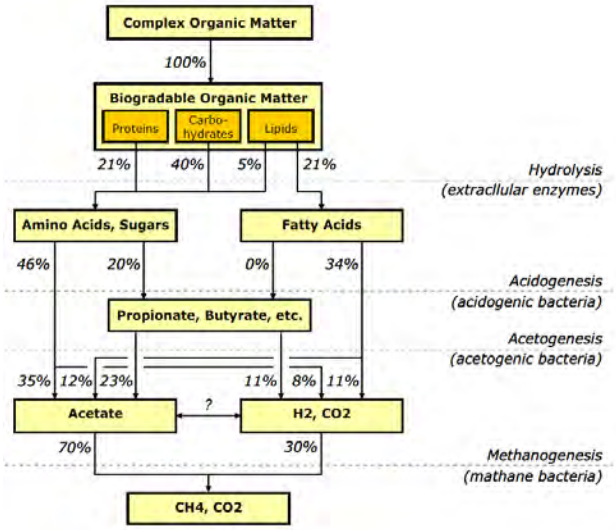

Figure 49. Anaerobic digestion process

The EnvE-Lab apparatus contains a system of coupled four anaerobic bioreactors, of 6.5 L in volume each, equipped with stirrers for waste agitation. The digesters are single- stage units, 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). In particular, the organic fraction of Municipal Solid Waste (OfMSW) was used as feedstock trying to optimize the reactor 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, feedstock composition and treatment goals.

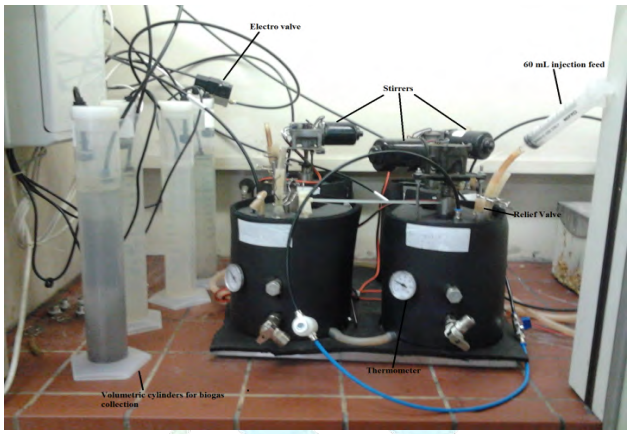

Figure 50. Anaerobic bioreactors

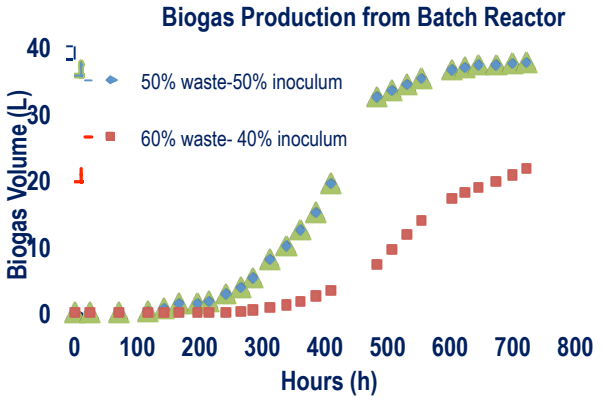

Figure 51. Biogas production from a batch work bioreactor using as feedstock the OfMSW 50% and inoculums 50%

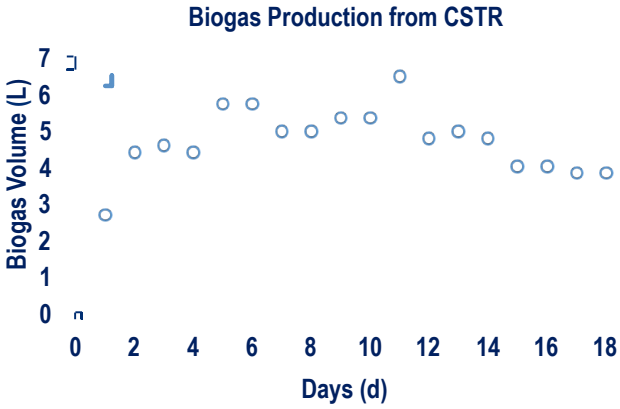

Figure 52. Biogas production from a CSTR bioreactor using as feedstock 0.2L/d of optimal waste

EnvE-Lab contribution to the society

Policy support

World Health Organization (WHO)

EnvE-Lab has established a close collaboration with the WHO European centre for Environment and Health, which includes:

- The development of integrated methodologies for health impact assessment, taking into account multiple air pollutants and noise, related to Green House Gases emissions policies. EnvE-Lab carries a long inheritance in integrated health impact assessment from previous projects such as HEIMTSA, HEREPLUS, INTARESE, 2FUN. Now, within the frame of the project URGENCHE, EnvE-Lab has developed an integrated framework for assessing the health impact of GHG policies in Thessaloniki, bringing together different tools of environmental modelling and monitoring, composing novel methodologies. The knowledge exchange between EnvE-Lab and WHO will be strengthened by the close collaboration on expanding the methodologies to other cities/case studies in China involved in the project; for this purpose an EnvE-Lab staff member will be visiting the WHO Europe headquarters in Bonn for 3 months in early 2014.
- The assessment of combined or multiple exposure to health stressors in indoor built environments. The objective of this study was to undertake, summarize and present a systematic review of literature and project reports presenting evidence on multiple or combined risk exposure in indoor built environments. The review covered safety threats and injuries, indoor air pollution, use of household chemicals, noise, damp and mould, thermal conditions, crowding, inadequate hygiene standards, and harmful building and equipment/furnishing materials. In terms of indoor settings the review covered residential buildings as well as day care centers and schools. The results of the stufy were presented and used as the main scientific background at a capacity building workshop geared to public authorities of the WHO Europe member states in October 2013. WHO entrusted EnvE-Lab with this task, because of our extensive experience and pioneering work on multiple stressors and more specifically chemical mixtures[1].
- Analysis of Environmental Health Economics, so as to quantify the socioeconomic dimension of environmental pollution. Greece is an excellent case study under this point of view, considering that the recent financial crisis has significantly altered the pattern of emissions and air pollution and introduced significant issues of environmental injustice.
- A further collaboration scheme deals with human biomonitoring, and more in detail with the optimal design of biomonitoring campaigns, as well as the exploitation of biomonitoring data through internal dose modelling.

Hellenic Ministry of Environment, Energy and Climate Change

The director of EnvE-Lab is member of the "Testing of Solid Biomass Boilers" Committee. The objective of this Committee is to establish testing standards for safety, performance and emissions to the environment. The work of the Committee is about to be accomplished by the end of January, after delivering the draft of a Joint Ministerial Decree related to the required specifications of new solid biomass boilers.

Hellenic Ministry of Health

The director of EnvE-Lab is member of the "Air Pollution" Committee, addressing issues of air pollution and Public Health, for the Hellenic Ministry of Health. The committee was setup in order to provide advice to the government on how to tackle the continuously increasing problem of biomass smog in Athens, Thessaloniki and in other Greek cities. EnvE-Lab carried out a series of measurements and analysis on biomass PM. In addition, we developed a composite Air Quality Index assessing air quality (based on PM concentrations) in Greek cities, under the public health point of view. The index was used so as to classify ambient air quality in 5 different classes; according to the index outcome, different mitigation actions have to be taken, starting from public awareness, up to restriction of industrial, traffic and domestic emissions. This bundle of measures were proposed by the Committee and adopted by the Hellenic government in the form of a Joint Ministerial Decree (KYA 3272, 23/12/2013) under the title "Short-term action plans to address air pollution by particulate matter" among Ministries of Health, Financial, Internal Affairs, Development And Competitiveness, Education And Religious, Administrative Reform And Government - Wellness - Infrastructure, Transport And Networks - Environment, Energy And Climate Change - Public Order And Protection Citizen - Shipping And Islands.

[1] 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.

EnvE-Lab dissemination events – Mass media

The extensive activities of EnvE-Lab on the hot environmental issues (PM pollution from biomass burning, mercury on Mediterranean fishes) have raised public awareness on the relation between environmental contamination and public health. As a result, the director was invited often to present his opinion about these topics in TV, while many newspaper articles were devoted on the work of the EnvE-Lab.

Figure 53. Newspaper article

Figure 54. Newspaper article

Figure 55. Newspaper article

Figure 56. Interview of EnvE-Lab Director, Prof. D. Sarigiannis regarding the biomass smog problem

Figure 57. Interview of EnvE-Lab senior scientist S. Karakitsios (on behalf of the director) regarding the biomass smog problem

Publications & Conferences

Journal Publications

Sarigiannis DA, Karakitsios SP, Kermenidou M: **PM exposure seasonal variability and related socioeconomic impact - Part II – Health and monetary impact.** *Science of the Total Environment*, under review.

Sarigiannis DA, Karakitsios SP, Kermenidou M, Nikolaki S, Zikopoulos D, Semelidis S, Papagiannakis A, Tzimou R: **PM exposure seasonal variability and related socioeconomic impact – Part I – Ambient-indoor air and personal exposure assessment**. *Science of the Total Environment*, under review.

Karakitsios S, Asikainen A, Garden C, Semple S, De Brouwere K, Galea KS, Sánchez-Jiménez A, Gotti A, Jantunen M, Sarigiannis D: **Integrated exposure for risk assessment in indoor environments based on a review of concentration data on airborne chemical pollutants in domestic environments in Europe**. *Indoor and Built Environment*, in press.

Sarigiannis D, Kontoroupis P, Solomou E, Nikolaki S, Karabelas A: **Inventory of pesticide emissions into the air in Europe.** *Atmospheric Environment* 2013, **75**:6-14

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.

Conference presentations

D.A. Sarigiannis, S. Karakitsios, M. Kermenidou, S. Nikolaki, **The effect of urban biomass combustion for space heating on PM exposure**, 2013 AIChE Annual Meeting, San Francisco, USA, 3-8/11/2013.

D.A. Sarigiannis, S.P. Karakitsios, A. Gotti, **Integrated external and internal exposure to chemicals: the INTEGRA computational platform**, 2013 AIChE Annual Meeting, San Francisco, USA, 3-8/11/2013.

D.A. Sarigiannis, E.J. Handakas, S.P. Karakitsios, **A multi-compartment skin penetration model coupled to a physiology-based biokinetic model for chemical exposure assessment**, 2013 AIChE Annual Meeting, San Francisco, USA, 3-8/11/2013.

D.A. Sarigiannis, P. Kontoroupis, E. Solomou, S. Nikolaki, A.J.Karabelas, **Probabilistic assessment of pesticide exposure via inhalation in Greece**, 17th International Symposium on Environmental Pollution and its Impact on Life in the Mediterranean Region, Istanbul, Turkey, 28/9-1/10/2013.

D.A. Sarigiannis, S. Theofanidis, **Anaerobic digestion of organic municipal solid waste: a valid waste management option**, 17th International Symposium on Environmental Pollution and its Impact on Life in the Mediterranean Region, Istanbul, Turkey, 28/9-1/10/2013.

D.A. Sarigiannis, V. Handakas, A. Gotti, S. Karakitsios, **Life cycle analysis of municipal waste management: industrial symbiosis options for reduced ecological footprint**, 17th International Symposium on Environmental Pollution and its Impact on Life in the Mediterranean Region, Istanbul, Turkey, 28/9-1/10/2013.

D.A. Sarigiannis, V. Handakas, S. Karakitsios, **A detailed multicompartmental skin penetration model coupled to a physiologically based pharmacokinetic model for assessing exposure to endocrine disrupting chemicals**, 17th International Symposium on Environmental Pollution and its Impact on Life in the Mediterranean Region, Istanbul, Turkey, 28/9-1/10/2013.

D.A. Sarigiannis, S. Karakitsios, M. Kermenidou, A.F. Mika Gavriilidou, **SOS – lung region specific oxidative stress: a novel exposure metric for airborne PM**, 17th International Symposium on Environmental Pollution and its Impact on Life in the Mediterranean Region, Istanbul, Turkey, 28/9-1/10/2013.

D.A. Sarigiannis, Z. Samaras, E. Vouitsis, S. Karakitsios, **Mechanistic exposure assessment of ultrafine PM**, 17th International Symposium on Environmental Pollution and its Impact on Life in the Mediterranean Region, Istanbul, Turkey, 28/9-1/10/2013.

D.A. Sarigiannis, P. Kontoroupis, D. Chapizanis, S. Karakitsios, **Health impact assessment of the traffic related Greenhouse Gases (GHG) emission policies – the case study of Thessaloniki**, Greece, 17th International Symposium on Environmental Pollution and its Impact on Life in the Mediterranean Region, Istanbul, Turkey, 28/9-1/10/2013.

D.A. Sarigiannis, S. Karakitsios, A. Gotti, **A tiered approach for aggregate exposure assessment: the case of Bisphenol A**, 17th International Symposium on Environmental Pollution and its Impact on Life in the Mediterranean Region, Istanbul, Turkey, 28/9-1/10/2013.

D.A. Sarigiannis, S. Karakitsios, M. Kermenidou, R. Tzimou-Tsitouridou, **PM attributed mortality and morbidity due to biomass use in Thessaloniki – estimation of socioeconomic cost**, 17th International Symposium on Environmental Pollution and its Impact on Life in the Mediterranean Region, Istanbul, Turkey, 28/9-1/10/2013.

D.A. Sarigiannis, S. Nikolaki, M. Kermenidou, D. Zikopoulos, K. Plakas, S. Karakitsios, A.J. Karabelas, **Carcinogenicity risk of PAHs in Particulate Matter**, 17th International Symposium on Environmental Pollution and its Impact on Life in the Mediterranean Region, Istanbul, Turkey, 28/9-1/10/2013.

D.A. Sarigiannis, A. Gotti, S. Karakitsios, **INTERA platform: a tool for mechanistic risk assessment of indoor air pollutants**, 17th International Symposium on Environmental Pollution and its Impact on Life in the Mediterranean Region, Istanbul, Turkey, 28/9-1/10/2013.

D.A. Sarigiannis, S. Karakitsios, M. Kermenidou, S. Nikolaki, D. Zikopoulos, K. Plakas, S. Semelidis, A. Papagiannakis, R. Tzimou-Tsitouridou, **The impact of biomass burning during wintertime in the large Metropolitan area of Thessaloniki in Greece**, IMA 2013-Instrumental Methods of Analysis-Modern Trends and Applications, Thessaloniki, Greece, 15-19/9/2013.

D.A. Sarigiannis, S. Karakitsios, M. Kermenidou, **The effect of biomass burning on PM exposure during wintertime**, 2013 European Aerosol Conference (EAC 2013), Prague, Czech Republic, 1-6/9/ 2013.

D.A. Sarigiannis, Z. Samaras, E. Vouitsis, S. Karakitsios, V. Kalaitzis, **Mechanistic exposure assessment of ultrafine PM**, 2013 European Aerosol Conference (EAC 2013), Prague, Czech Republic, 1-6/9/ 2013.

S. Pateraki, T. Maggos, D.A. Sarigiannis, M. Kermenidou, S. Karakitsios, V.D. Assimakopoulos, A. Zagkosμ D.N. Asimakopoulos. **Chemical profile of wood burning PM2.5 and PM1 in the two largest cities of Greece, Athens and Thessaloniki**, 2013 European Aerosol Conference (EAC 2013), Prague, Czech Republic, 1-6/9/ 2013.

D. A. Sarigiannis, P. Kontoroupis, E.S. Solomou, S. Nikolaki, A.J. Karabelas. **Cancer risk due to pesticide use in Europe**, Conference of ISEE, ISES and ISIAQ, Basel, Switzerland, 19-23/8/2013.

D.A. Sarigiannis, S. Karakitsios, M. Kermenidou, **Enhancing PM epidemiological concentration-response functions by incorporating lung deposition and oxidative potential**, Conference of ISEE, ISES and ISIAQ, Basel, Switzerland, 19-23/8/2013.

D. Sarigiannis, P. Kontoroupis, N. Spyridoula, E. Solomou, M. Kermenidou, Spyros Karakitsios, **The impact of urban climate change policies on health under financial crisis conditions – the city of Thessaloniki**, Conference of ISEE, ISES and ISIAQ, Basel, Switzerland, 19-23/8/2013.

D. A. Sarigiannis, S. Karakitsios, A. Gotti, **Mechanistic assessment of external and internal exposure to DEHP**, Conference of ISEE, ISES and ISIAQ, Basel, Switzerland, 19-23/8/2013

D.A. Sarigiannis, S. Karakitsios, M. Kermenidou, **PM attributed mortality and morbidity due to biomass use in Thessaloniki – estimation of socioeconomic cost**, 4th International Conference on Environmental Management, Engineering, Planning and Economics (CEMEPE) and SECOTOX Conference, Mykonos, Greece, 24-28/6/2013.

D.A. Sarigiannis, S. Karakitsios, A. Gotti, **A tiered approach for aggregate exposure assessment – the case of bisphenol-A**, 4th International Conference on Environmental Management, Engineering, Planning and Economics (CEMEPE) and SECOTOX Conference, Mykonos, Greece, 24-28/6/2013.

D.A. Sarigiannis, V. Handakas, S. Karakitsios, **A detailed multi-compartmental skin penetration model coupled to a physiologically based pharmacokinetic model for assessing exposure to chemical compounds: the case of BISPHENOL-A**, 9th Greek Conference of Chemical Engineering, Athens, Greece, 23-25/5/2013.

D.A. Sarigiannis, S. Karakitsios, A. Gotti, **A tiered approach for aggregate exposure assessment: the case of Bisphenol A**, 9th Greek Conference of Chemical Engineering, Athens, Greece, 23-25/5/2013.

D.A. Sarigiannis, S.A. Theofanidis, **Anaerobic digestion of organic municipal solid waste: a valid waste management option**, 9th Greek Conference of Chemical Engineering, Athens, Greece, 23-25/5/2013.

D.A. Sarigiannis, P. Kontoroupis, D. Chapizanis, S. Karakitsios, **Health impact assessment of the traffic related greenhouse gases (GHG) emission policies-the case study of Thessaloniki**, Greece, 9th Greek Conference of Chemical Engineering, Athens, Greece, 23-25/5/2013.

D.A. Sarigiannis, P. Kontoroupis, E. Solomou, S. Nikolaki, A.J.Karabelas, **Probabilistic assessment of pesticide exposure via inhalation**, 9th Greek Conference of Chemical Engineering, Athens, Greece, 23-25/5/2013.

D. Sarigiannis, S. Karakitsios, Alberto Gotti, **Enhancing biological equivalents by biologically effective dose using a generic PBPK model - the case of BPA and DEHP**, SOT's 52nd Annual Meeting, San Antonio 10-14/3/2013, USA.

D. Sarigiannis, S. Karakitsios, Alberto Gotti, **Enhancing PM epidemiological concentration-response functions by incorporating lung deposition and oxidative potentia**l, SOT's 52nd Annual Meeting, San Antonio 10-14/3/2013, USA.

D. Sarigiannis, S. Karakitsios, Alberto Gotti, **Is indoor exposure to DEHP a health risk**? SOT's 52nd Annual Meeting, San Antonio 10-14/3/2013, USA.

D. A. Sarigiannis, S. Karakitsios, A. Gotti, **Beyond Biological Equivalents to Biologically Effective Dose**, SOT's 52nd Annual Meeting, San Antonio 10-14/3/2013, USA.

D. A. Sarigiannis, G. Cimino-Reale, T. Coccini, L. Manzo, **Genomic-level effects of carbon nanotubes,** Environmental Health 2013 - Science and Policy to Protect Future Generations, Boston 3-6/3/2013, USA.

D. Sarigiannis, S. Karakitsios, Alberto Gotti, Graziella Cimino-Reale, **The connectivity paradigm to cumulative risk assessment**, Environmental Health 2013 - Science and Policy to Protect Future Generations, Boston 3-6/3/2013, USA

D. A. Sarigiannis, S. Karakitsios, V. Kalaitzis, E. Vouitsis, Z. Samaras, **Mechanistic exposure and risk assessment of traffic-originated ultrafine PM,** Environmental Health 2013 - Science and Policy to Protect Future Generations, Boston 3-6/3/2013, USA.

Invited talks

European Technology Platform on Industrial Safety (ETPIS) Workshop: ***Environmental Health in Horizon 2020 building on the Cross-ETP on Industrial Safety***", Brussels, Belgium, November 27, 2013. Presentation entitled "***Exposome***".

Imperial College, Faculty of Medicine, School of Public Health, London, UK, November 15, 2013. Presentation entitled *"**Health and Environment-wide Associations via Large Population Surveys to Unravel the Exposome**"*.

University of California at Berkeley, Center for Occupational & Environmental Health, November 8, 2013. Presentation entitled *"**Health and Environment-wide Associations via Large Population Surveys to Unravel the Exposome**"*.

World Health Organization 2nd Symposium on "***Environmental Health and Economics***", Bonn, Germany, October 14-15, 2013. Presentation entitled *"**Key findings assessing the costs associated to health impacts of the austerity measures in Greece**"*.

World Health Organization training workshop on "***Multiple exposures and risks: evidence review, knowledge transfer and policy implication***", Bonn, Germany, October 16-18, 2013. Presentation entitled *"**Combined or multiple exposure to health stressors in indoor built environments -An evidence-based review**".*

World Health Organization Symposium on *"**Human biomonitoring survey as a tool for assessing early life exposures to priority chemical pollutants**"*. Bonn, Germany, September 18-19, 2013. Presentation entitled *"**HEALS project - New research initiative to characterize environmental exposures and health effects in children**"*.

ΤΕΕ
ΤΕΧΝΙΚΟ ΕΠΙΜΕΛΗΤΗΡΙΟ ΕΛΛΑΔΑΣ

Technical Chamber of Greece Workshop on "***Pollution from smog. The chronicle of poor choices, mistakes, impact, the solutions***", Athens, Greece, March 27, 2013. Presentation entitled "***The dynamics of urban smog pollution and its impact on public health: Socioeconomic analysis of the problem***".

Laboratory Personnel

Dimosthenis A. Sarigiannis, Director

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 over 20 years of experience in environment and health impact assessment, data assimilation and exposure modelling including physiology-based biokinetic modelling. In the last ten years he has worked for the European Commission"s Joint Research Centre, for the Intedisciplinary Institute of Environmental Research and for CERTH 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 (B.Sc.), environmental and computational chemistry (M.Sc.) and applied biology (PhD) of the University of Ioannina, with an overall 12 years of experience in environmental/atmospheric process modelling and 6 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.

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.

Marianthi Kermenidou (PhD Student Researcher) is Environmental Engineer, graduated from Democritos University of Thrace, Greece with a MSc degree. Her scientific field is indoor air pollution, chemical analysis, source apportionment and redox activity of airborne particulate matter.

Evangelos Handakas is a PhD Student Researcher, chemical engineer and civil infrastructure engineer with 2 M.Sc. degrees (MMAths and M.Eng). His research activities focus on the flieds of biological systems modelling, health impact assessment and exposure reconstruction.

Krystalia Papadaki (PhD Student Researcher) is a Chemical Engineer, graduated from Aristotle University of Thessaloniki, Greece. Her research activities focus on Quantitative Structure Activity Relationship modelling.

Dimitrios Chapizanis is a PhD Student Researcher. He holds a diploma in Chemical Engineering and his research activities focus on atmospheric pollution, exposure assessment and environmental risk.

Dimitrios Zikopoulos is a chemical engineer (M.Eng) of the Aristotle University of Thessaloniki, working on air pollution risk assessment.

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 chemical engineer (M.Eng) of the Aristotle University of Thessaloniki, working on anaerobic digestion.

Stauros Semelidis is an undergraduate student of the Aristotle University of Thessaloniki, working on outdoor air pollution for his Diploma Thesis.

Manolis Balis is an undergraduate student of the Aristotle University of Thessaloniki, working on multimedia environmental modeling of contaminants for his Diploma Thesis.

Natalia Kleopa is an undergraduate student of the Aristotle University of Thessaloniki, working on shipping emissions and their impact on health for her Diploma Thesis.