**Integrated Assessment Modelling in Poland**

Works on air pollution transport models as well as Integrated Assessment Models have been undertaken in Poland in several groups, in some cases in cooperation with research groups from abroad. The presentation is focussed mainly on IAM type of models. There are some other groups in Poland who deal with air quality modelling, not mentioned in this presentation.

At the **Warsaw University of Technology** IAM activity started in 1992, when the concept of PRIMA (Pollution Risk Integrated Model Assessment) has been developed. The goal of developing national IAM was to include country specific environmental targets as well as to identify specific emission sources for abatement. PRIMA model has been applied under the Emission Abatement Strategies and the Environment (EASE) project (UE Copernicus Project, 1994-1997). Unlike the sulphur protocol to LRTAP Convention, which used national cost curves and aggregated emissions, PRIMA derived cost-effective abatement strategies, which identified individual emission sources for abatement. The model attempted to derive abatement strategies to protect the ecosystems within the so called *Black triangle* region of eastern Europe, contained along the mutual borders of Poland, Germany and the Czech Republic. PRIMA can be used for both optimised and scenario analysis and enables the policy makers to decide, which environmental receptors to protect. On this basis different model indicators can be used, as well as different objective function for the optimisation model. Taking into account the air pollution problem in the Black Triangle region, PRIMA attempted to minimize the exposure to both population and ecosystems. The model evaluates a population risk level based on the product of $SO_2$ concentrations and population density. The risk to vegetation is evaluated through an area valorisation index, which estimates region's sensitivity to pollution based on UN-ECE guideline values for critical levels of $SO_2$. The different land classification given in the land use maps of RIVM provides the source information for the area valorisation index. The calculations have been performed at a fine resolution of 10 km x 10 km. Following PRIMA, in 2000-2004 the ROSE (Risk Of airborne Sulphur species on the Environment) model was developed and implemented for the entire Polish area. ROSE model belongs to the family of an effect-based IAMs. The aim of developing the model was to investigate all possible environmental impacts of sulphur emissions ($SO_2$ and $SO_4^{2-}$ concentrations, total S deposition) and to minimize the existing risk by optimisation of the electric energy production distribution, with constant country electricity production. ROSE operates in the computational grid covering Poland (900 km x 750 km), which constitutes a part of the EMEP model grid, but with finer spatial resolution (30 km x 30 km). It comprises a suite of models: an Eulerian grid air pollution model (POLSOX-II) - used both for calculating comcentrations/depositios as well as for calculating source-receptor matrixes; statistical models for assessing environment sensitivity to the sulphur species and an optimisation model. Both critical levels and loads was applied for assessing sensitivity, while exceedances of critical values and current-to-critical value ratios were employed for assessing environmental risk. The optimisation model uses a heuristic method for global optimum search, namely an evolutionary computation one. It permits to formulate a multi-criterion goal function for describing the level of environmental risk and non-linear constrains. A significant reduction in environmental risk in Poland was predicted, as well as a reduction of $SO_2$ emission from coal-fired power stations by approximately 25% with constant country electricity output.

The experience of the **Systems Research Institute of the Polish Academy of Sciences** encompasses computer modelling of air pollution dispersion, mainly on urban and regional scale, as well as application of this type models as decision-support tools that enable an integrated analysis of cost-effectiveness and environmental impact related to specific emission reduction technologies. The optimisation techniques (also for distributed parameter systems) are used in the implementation and solving of environmentally oriented decision problems. The current two implementations pertain to the sulphur oxides pollution and the related emission abatement policies. The first problems considered concentrates on the selection of emission reduction technologies within a given set of power plants. Mathematically, this is a static, integer optimisation task. The second problem is formulated as the real-time emission control, based on minimization of an environmental cost function, by modification of emission level in the controlled sources (power plants), according to the changing meteorological conditions. The objective function depends on the current level of $SO_x$ concentration and the sensitivity of the area to this type of air pollution.

The methodology of the software system called RAINS Poland has been worked out together with the International Institute for Applied Systems Analysis (IIASA) from Laxenburg, Austria, under the Transboundary Air Pollution (TAP) project. Polish side of the project were: the **Gdańsk University of**

**Technology** (lieder of the project), the Institute of Meteorology and Water Management, Warsaw and the EnerSys, Warsaw. The first versions of RAINS-Poland model comprised the hottest Polish energy and environment settings, such as: (i) 16 broad-area emission sources (main Polish regions under the new administrative division), as well as 16 point emission sources (largest Polish power and cogeneration plants), with the potential of linear emission sources introduction in future, (ii) actual statistic and prognostic data for Poland according to fuel and primary energy consumption, as well as the corresponding data concerning the technologies of air pollution reduction, (iii) matrix of emissions/depositions for the assumed grid resolution of a 25x25 km being a sub-grid of the EMEP model, as well as the matrix of critical loads for acidifying compounds in a grid resolution of 25x25 km, (iv) necessary modifications of the basic model code that give the possibility of presenting the results of deposition calculation results in the form of graphs. Crucial contributions to preparing of the RAINS-Poland model were due to IIASA staff.

Integrated assessment modeling at **Academy of Mining and Mettalurgy in Cracow** is based on the IIASA methodology for emission and abatement costs calculations (RAINS/GAINS). For atmospheric transport of pollution the air quality system-Polyphemus is used (it is based on the Eulerian chemical transport model Polair 3D). Deposition and concentration of pollutants are mapped and put together with data on critical loads of acidity, eutrophication and people density distribution with the use of GIS. The special focus is on the energy sector.

The group from the **University of Wrocław, Department of Meteorology and Climatology** assessed the spatial patterns of yearly averaged air concentrations, as well as wet and dry deposition maps for the area of Poland, using the atmospheric transport model FRAME (Fine Resolution Atmospheric Multi-pollutant Exchange), developed in the United Kingdom (Centre for Ecology and Hydrology). At the presents stage, the final results of modeling the yearly average concentrations, dry and wet deposition of $SO_x$, $NO_y$ and $NH_x$ for Poland for the year 2002 has been obtained. The prognostic chemical variables calculated in FRAME are: $SO_2$, $NO_x$, $NH_x$, $N_2O$, PAN, heavy metals, and PM10, PM2.5. The model simulates an air column moving along straight-line trajectories. The atmosphere is divided into 33 separate layers extending from the ground to an altitude of 2500 m. Layer thicknesses vary from 1 m at the surface to 100 m at the top of domain. The model domain covers the area of Poland with a grid resolution of 5 km and grid dimensions of 160x160. The chemical scheme used in FRAME is similar to the one employed in the EMEP Lagrangian model.

A basic component of IAM is the environmental module, responsible for quantitative assessment of air pollution impacts and for setting environmental targets. The SONOX model developed at the **Institute of Environmental Protection** provides necessary input to such a module by generating maps of critical loads and their exceedances. The SONOX model replicates the sequence from emission of sulphur and nitrogen species through their atmospheric transport and deposition and finally to the examination of the exceedance of deposition tolerable by ecosystems. The model is of a modular structure combining sub-models representing the four basic processes: emission scenarios construction, development of atmospheric deposition patterns, calculating and mapping critical loads and identifying magnitude and geographical extent of critical loads exceedances. Integration of these modules by the main model consists in organisation of input and output data flow among the modules and in providing mapping procedures for the calculated quantities. The SONOX model was originally developed and applied to support the Polish contribution to the production of first pan-European critical load maps providing a scientific basis for the negotiations of the Oslo and Gothenburg Protocols of the Convention on Long-Range Transboundary Air Pollution. Besides the international relevance the program concept and structure enables a wide range of national and local environmental policy applications.