AIR TRITIA - GIS FOR THE AIR QUALITY ASSESSMENT IN VAST REGION

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Abstrakt

Hodnocení kvality ovzduší se provádí pomocí kombinace měření a matematického modelování. Pro tyto účely je nutné pořídit, zpracovat, analyzovat a vizualizovat velký objem heterogenních prostorových dat. Pro tyto účely je v našich pracích využíván ArcGIS. Výhodou využívání ArcGIS je možnost automatizace a standardizace procesů díky skriptům v jazyce Python využívajících arcpy. To rovněž umožňuje integrovat prostorové analýzy s matematickými modely a dalšími analytickými nástroji.

V současné době je zlepšování kvality ovzduší v nadměrně znečištěných oblastech řízeno na místní úrovni bez respektování hlavních příčin znečištění a bez optimalizace opatření ke zlepšení. Znečištění ovzduší nezná hranice, pro jeho efektivní řízení je tak nezbytně nutná mezinárodní a regionální spolupráce. Cílem projektu Air Tritia je vytvořit mechanismus mezinárodního řízení kvality ovzduší na pomezí Česka, Slovenska a Polska prostřednictvím rozvoje společné informační databáze, nástrojů pro řízení a predikce a strategií kvality ovzduší.

Abstract

The air quality assessment is provided by the combination of measurements and mathematical modelling. There is a need to acquire, process, analyze and visualize large volume of heterogeneous spatial data. The ArcGIS software is utilized for this kind of work. Great advantage of the ArcGIS in in the possibility of standardization and automation of modelling processes via Python scripts with the arcpy module. This approach also allows seamless integration of spatial analyses with mathematical models and another analytical tools.

The air quality management in polluted regions is currently performed at the local level with just the basic knowledge about origins of the air pollution and without proper cost-benefit analyses of possible remedies. The air flow is not limited by borders, therefore it is necessary to have international and inter-regional cooperation in the air quality management. The goal of the Air Tritia project is to create a mechanism for the air quality management in the Polish-Czech-Slovakian border area via development of universal information database, management tools for air quality assessment, predictions and creation of effective strategies leading to the improvement of the air quality.

Klíčová slova: znečištění ovzduší; kvalita ovzduší; modelování; GIS

Keywords: air pollution; air quality, modelling, GIS

INTRODUCTION

Air Pollution

The air pollution is one of the most severe environmental issues. Both acute and chronical exposure to heightened levels of air pollution negatively affects nature, properties and primarily human health. The WHO estimates that around 7 million people die every year from exposure to fine particles in polluted air that penetrate deep into the lungs and cardiovascular system, causing diseases including stroke, heart disease, lung cancer, chronic obstructive pulmonary diseases and respiratory infections, including pneumonia.

Ambient air pollution alone caused some 4.2 million deaths in 2016, while household air pollution from cooking with polluting fuels and technologies caused an estimated 3.8 million deaths in the same period. WHO recognizes that air pollution is a critical risk factor for noncommunicable diseases (NCDs), causing an estimated one-quarter (24%) of all adult deaths from heart disease, 25% from stroke, 43% from chronic obstructive pulmonary disease and 29% from lung cancer. [1]

The Air Tritia project

The Tritia region consists of Moravian-Silesian region in Czechia, Silesian and Opole voivodship in Poland and Žilina region in Slovakia. The current status of the region has been determined by existence of vast hard coal deposits which resulted in high concentration of heavy industry (mining, metallurgy, heavy chemistry, heavy machinery, etc.) as well as high population density in the region. These factors and coal based energy mix lead to high air pollution levels. The Tritia region is one of the most air polluted regions of the EU.

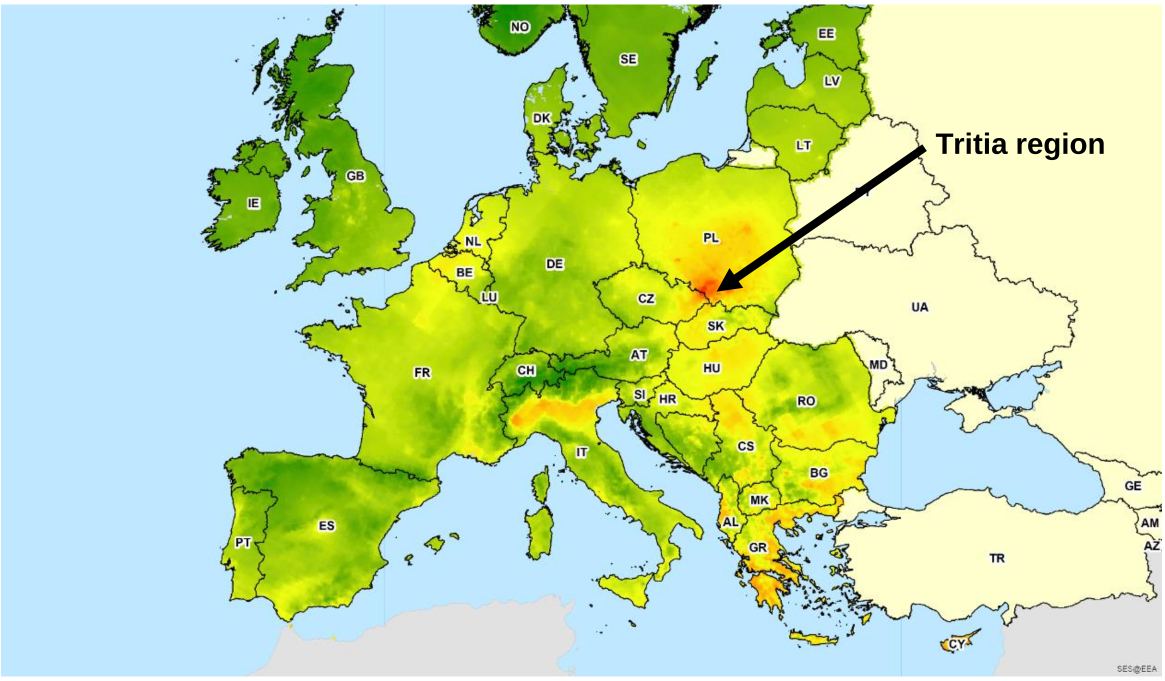

Fig. 1. The annual average PM10 concentration in the EU, 2015 [2]

Although the air quality in the region has improved significantly since its peak in 1970s, the air quality is still the issue which needs to be solved. The air pollution respects no border, so it is necessary to solve the issue in international and inter-regional cooperation. The goal of the Air Tritia project is to develop common information database of the air pollution in the Tritia region and to develop tools for effective air quality management, predictions and creating strategies which would lead to most effective remedies, the evidence based policies.

The Air Tritia project is focused on four main regional pollutants – particulates (PM_{10}, $PM_{2.5}$), nitrogen oxides and benzo(a)pyrene which is used as a marker of cancerogenous polycyclic hydrocarbons, focus years are 2006, 2010 and 2015 [3].

GIS and modelling

The key part of the Air Tritia project is the air pollution dispersion modelling which pollution dispersion modelling from known air pollution sources with air quality monitoring data.

The mathematical modelling of the real world phenomena can be considered as a kind of geoinformation technology because these models process spatial data. The GIS software can be utilized to cooperate with mathematical models in three main ways:

- Input data processing;
- model data representation and algoritmization;
- visualization and analysis of model results.

The ADMoSS system was developed to deal with the data processing, visualization and analysis for air pollution dispersion modelling in vast regions with high detail. [4] The ADMoSS combines Gaussian air pollution dispersion model Symos '97 [5] with the ArcGIS software. The ArcGIS software is utilized as the main tool of the modelling process while the pollution dispersion model is utilized as an external "black box" service. The GUI of the ArcGIS is used mainly for input data processing a visual control of the data, the *arcpy* Python module of the ArcGIS is used for process automation in the form of Python scripts. The modelling process is well documented and easy to be repeated and replicated thanks to these scripts.

1 DATA PROCESSING

The air pollution dispersion modelling process depends heavily on a number of input spatial datasets which need to be processed before the modelling. There are several types of utilized spatial datasets:

- Pollution sources data – industrial sources data, domestic heating data, car transport data;
- air pollution measurements data;
- geographical data – elevation data, road network, building, address points, administrative units, etc.;
- meteorological data – wind speed, wind direction and thermal stability of atmosphere based on terrain determined regions.

1.1 Pollution sources

The industrial sources data are obtained from national emission inventories. The key part of the data is the spatial information, geographic coordinates of every smokestack and/or outflow. These coordinates are usually incomplete and contain errors. There is a need to check sources position. The GIS allows to visualize the data over a basemap or an aerial imagery and over an administrative units' data to find errors and to find the proper source position.

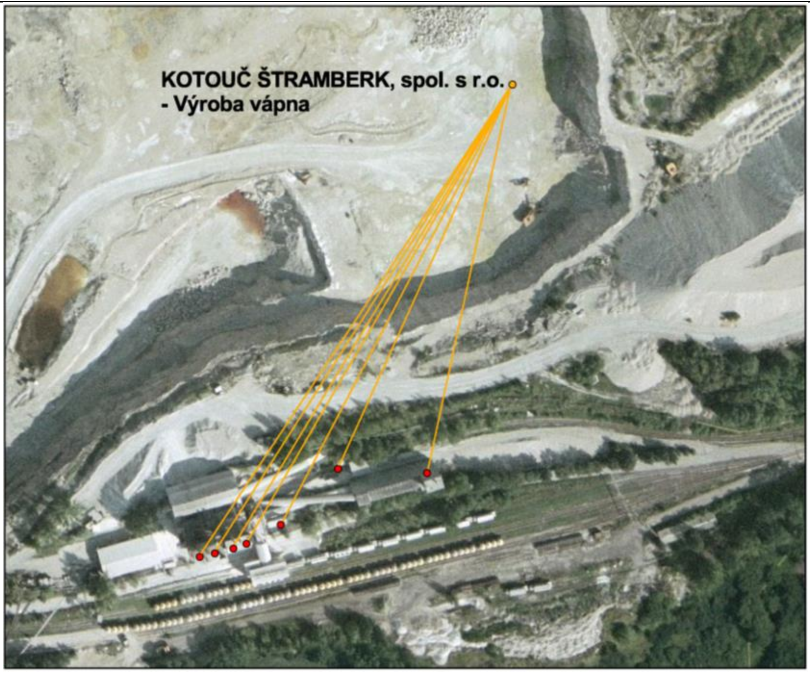

Fig 2. Proper pollution source positioning

The domestic heating pollution determination is based on census data which refers about the number of stoves and their fuels. These data are accessible as an aggregates to administrative units. The developed GIS analysis allows to estimate number and position of stoves. The analysis is based on building layer attributes and if a building has an address. The pollution is than uniformly spread on estimated buildings with stoves in every administrative unit and aggregated to square shaped area sources with the 100 m size.

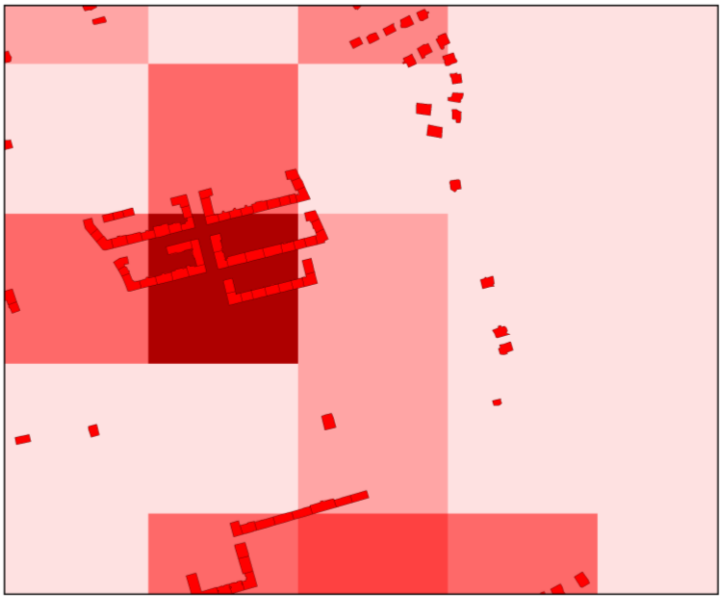

Fig 3. Aggregated pollution sources

The car traffic pollution is based on traffic intensity data which are obtained from traffic intensity surveys and traffic flow modelling. Every road is split into 50 m long sections for the sake of modelling.

1.2 Meteorological data

The meteorological data enters the modelling in the form stability wind rose which represents the probability of every combination of temperature stability of the atmosphere (5 classes), wind speed (3 classes) and wind direction (9 classes). The data are heavily dependent on terrain configuration. This is the reason why the area of interest needs to be split into meteorological region based on terrain configuration. The area of the Air Tritia project was split into 46 meteorological region where every region has its own stability wind rose.

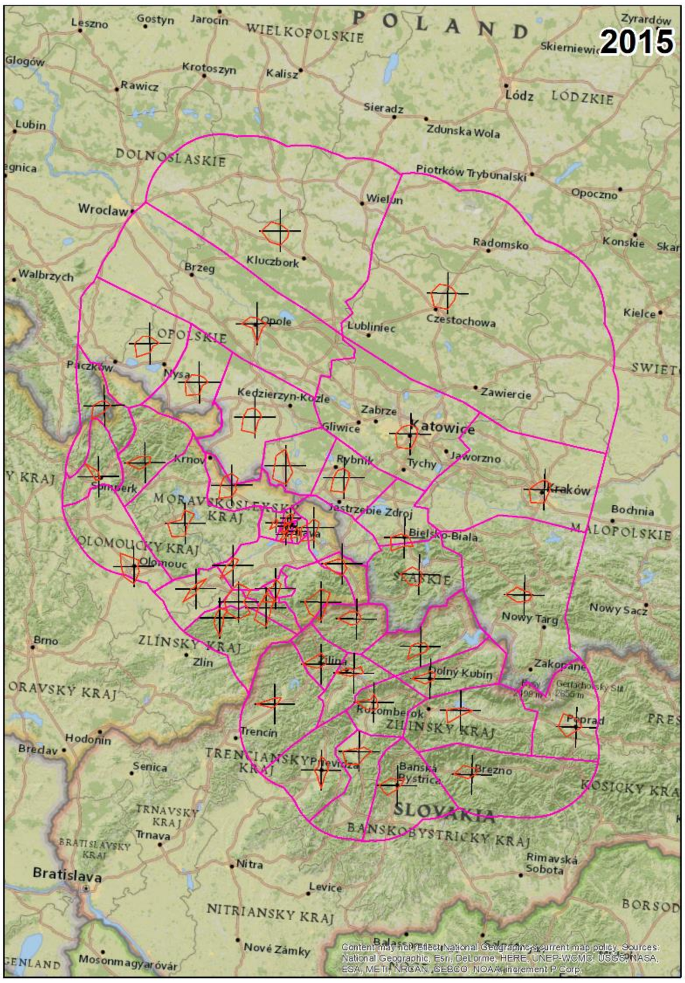

Fig. 4. Meteorological data regions and wind roses

2 AIR POLLUTION DISPERSION MODELLING

There is a need to perform a detail modelling in the vast area of interest with up to hundreds of thousands of pollution sources. It is impossible to perform such calculations on PCs or workstations. The Symos ’97 model is a source-receptor model. It means that the model calculates pollution from every source in input dataset in every point of the receptor mesh. Although model SW does not allow parallel calculations by itself, the the set of pollution sources in every modelling tasks can be split into a group of subsets which can be calculated separately on parallel clusters. Partial results are later summed together.

The most efficient way of the source data splitting is splitting by source position. When sources are split by regular “fishnet” layer the subsets contain localized clusters of sources with set stability wind rose and generally local effect. Every subset may have its own receptor mesh which is dense around sources and sparse in the rest of the area of modelling. This algorithm allows to keep the precision of modelling while reducing the time of calculation by more 1000x.

There were two parallel clusters which were used for the modelling in the Air Tritia project. Metacentrum is a virtual parallel cluster which combines the computational power of smaller clusters ran by Czech research and educational institutions [6]. Salomon is the large cluster of the VŠB-TU Ostrava [7].

When the modelling is completed, all partial results are interpolated into a raster covering whole area of interest and summed together. Modelling results are adjusted by the *in situ* measured pollution data.

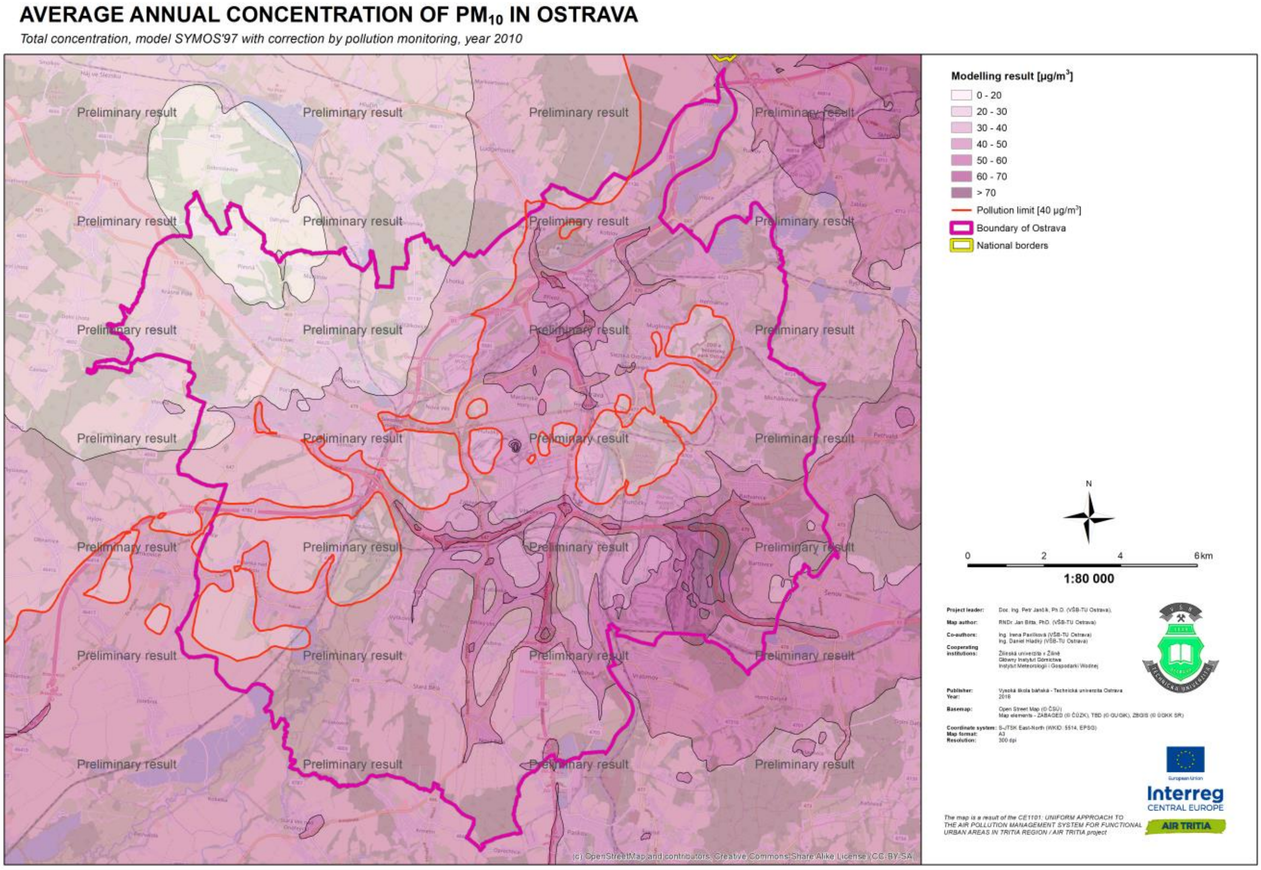

Fig 5. Result of modelling example

3 ANALYSIS AND VISUALIZATION OF RESULTS

The results of modelling are contained as raster datasets. This allows to easily analyze the results – determine areas above pollution limits, pollution hotspots, dominant pollution sources, etc.

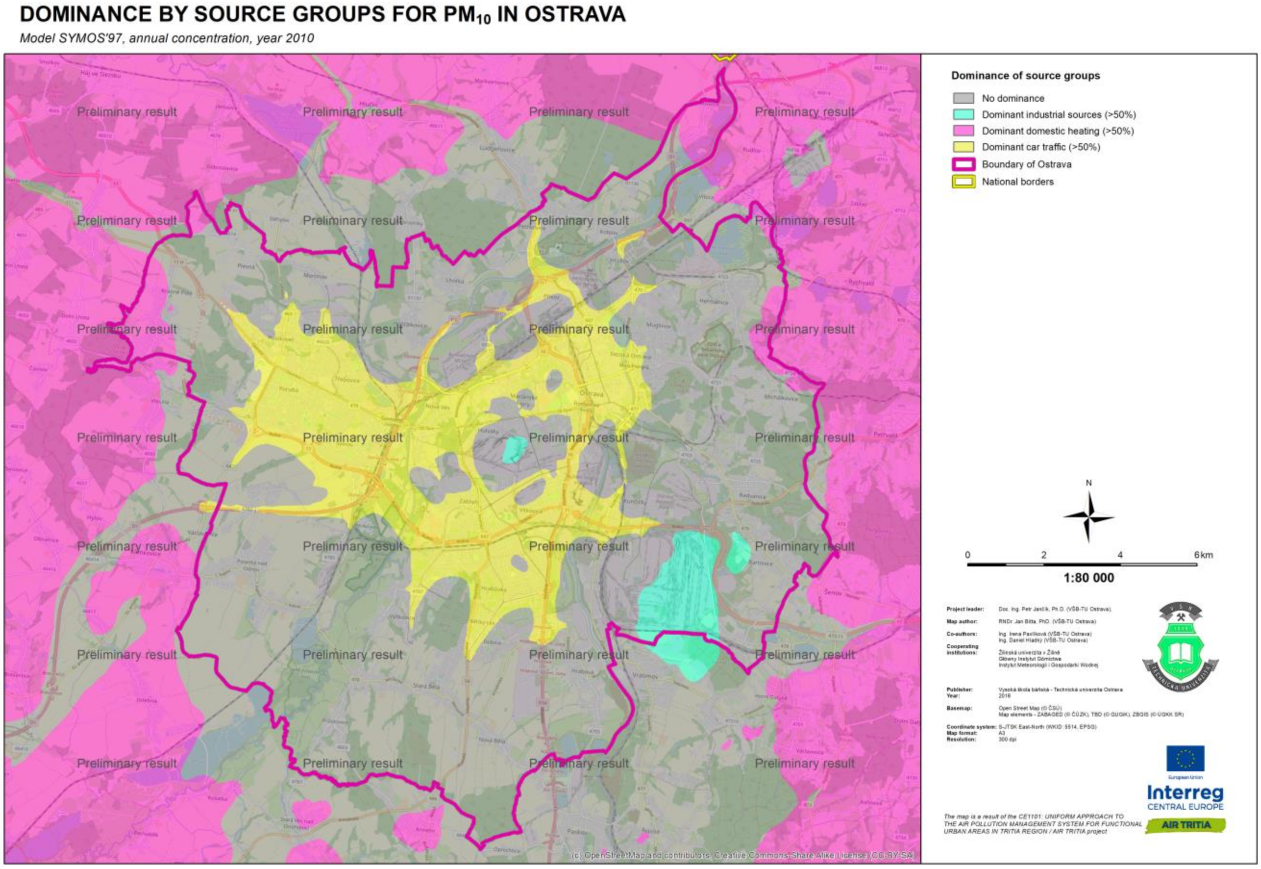

Fig 6. Analysis of dominant pollution source groups in Ostrava

The Air Tritia project modelling is focused on 3 modelling years, 4 pollutants, 3 group of pollution sources and 6 focus areas (whole region, Ostrava, Opava, Opole, Rybnik, Žilina). When results shall be presented hundreds of similar maps have to be created. This task can be also scripted via the arcpy. The map making script opens up the template project, imports proper datasets, sets the color scheme of results, sets legend values, sets texts, zooms to the area of interest and exports the map.

This approach makes the map making much more effective every time there is a need to redo maps (improved results, changes in template, etc.) the script can be re-run to produce new maps.

Results of the Air Tritia project are going to be published in the form of interactive maps which are going to be accessible via the web interface for both air quality professionals and general population. The beta testing version of interactive maps can be accessed at: https://labgis.vsb.cz/test

CONCLUSION

The Department of Environmental protection in industry has been focused on the air quality modelling since 1990s. The result of the works is the ADMoSS system which allows to perform detail air pollution dispersion modelling even in vast areas. The ADMoSS was recently utilized on the tri-state region Tritia to assess the regional air quality and dominant pollution sources.

The first part of the Air Tritia project assessed the current air quality situation in the Tritia region and determined main causes of, de facto, illegal conditions. The second part of the Air Tritia project which is being started now will be focused on potential remedies evaluation. The evaluation will consist of list potential remedies. The effect of every remedy will be calculated from emission, pollution concentration, financial and health benefit point of view. The goal is to provide the list of the most cost effective remedies which would radically improve the air quality in Tritia region.

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