ESTE – Systems for Response to the Nuclear Accidents and Evaluation of Radiological Impacts

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Abstract.

ESTE (**E**mergency **S**ource **T**erm **E**valuation code) is a name given to the group of programs, which serve as instruments for source term evaluation and calculation of radiological impacts in case of nuclear accident, or as instruments for impacts evaluation of operational radiological effluents from nuclear installation. One of these systems, called ESTE EU (Europe), is a specific geoinformation system for the assessment of radiological impacts on the territory of a selected country (e.g. Czech Republic or Bulgaria) in case of any radiation accident outside or inside this country. This information system is developed for the Crisis Staff of the country, with very essential GIS based; it also contains information about every single European nuclear power and research reactor. The program allows to model the dispersion of radioactive clouds both in small-scale and in meso-scale. ESTE EU enables the user to estimate the prediction of the source term (release to the atmosphere) for any point of radiation/nuclear accident in Europe (for any point of the release, but especially for the sites of European power reactors). The system is connected online to the numerical weather prediction for a considerable part of Europe as well as to the measured dose rates across the Europe. It is possible to define various source terms (releases of radionuclides in the form of radioactive puffs), with diverse nuclide composition, different heights of release, points of release and/or times of release. Information about the threat of impact (especially about urgent protective measures) to the territory of the country is automatically generated by the system. Once calculated is the map of modelled radiological situation (the map of "real impacts"), regularly compared with real monitoring data and consequently corrected.

Another system of the ESTE group is the so-called ESTE AI (=Annual Impacts). The main objective of this system is to calculate radiological impacts caused by normal operational airborne and liquid effluents from nuclear installation. Doses to the members of critical groups of inhabitants in the vicinity of particular nuclear plant are calculated and as a result, the critical group is determined. Collective doses are calculated as well. Program calculates doses to the whole population of a selected country (e.g. Slovakia) from the effluents of the specific plant. Beyond-border impacts (e.g. to the population of neighbouring countries - Czech Republic, Austria and Hungary) are calculated and published, too. Release points of effluents are placed to their real specific points (precise spatial reference). Applied atmospheric dispersion model enables us to model "calm conditions" (with very low or negligible wind speed). GIS approach allows us to effectively manage and update important information about agricultural production and about number of inhabitants sorted by age in villages inside the 100 km zone. This should be updated annually. Specific information about agricultural production is ready to be updated yearly by our own application of remote sensing method from the selected satellite data (e.g. Terra, SPOT) and from project Corine Land Cover (Landsat satellite).

Keywords: nuclear accident, emergency, crisis staff, radiological impacts, source term, routine radioactive effluents, critical group, doses, global nuclides, GIS

1 Introduction

"ESTE" is a GIS based group of instruments for modelling and calculation of radiological impacts caused by accidental or operational releases of radioactive substances into the environment.
ESTE EU is used by the Crisis Centre of Czech Republic under the State Office for Nuclear Safety (SÚJB) Prague as well as by the Crisis Centre of Bulgarian Republic under the Nuclear Regulatory Agency (NRA), Sofia. System ESTE Annual Impacts is implemented in and used by Nuclear Power plant Bohunice in Slovakia.

2 ESTE EU

ESTE EU (Europe) is the instrument for the emergency preparedness at the national level. ESTE is both a geoinformation system and software for the source term assessment (= release of radioactive gasses and aerosols to the environment) and for the calculation of radiological impacts in case of a nuclear accident anywhere across the Europe. Dispersion of radioactive puffs is calculated in European scale.

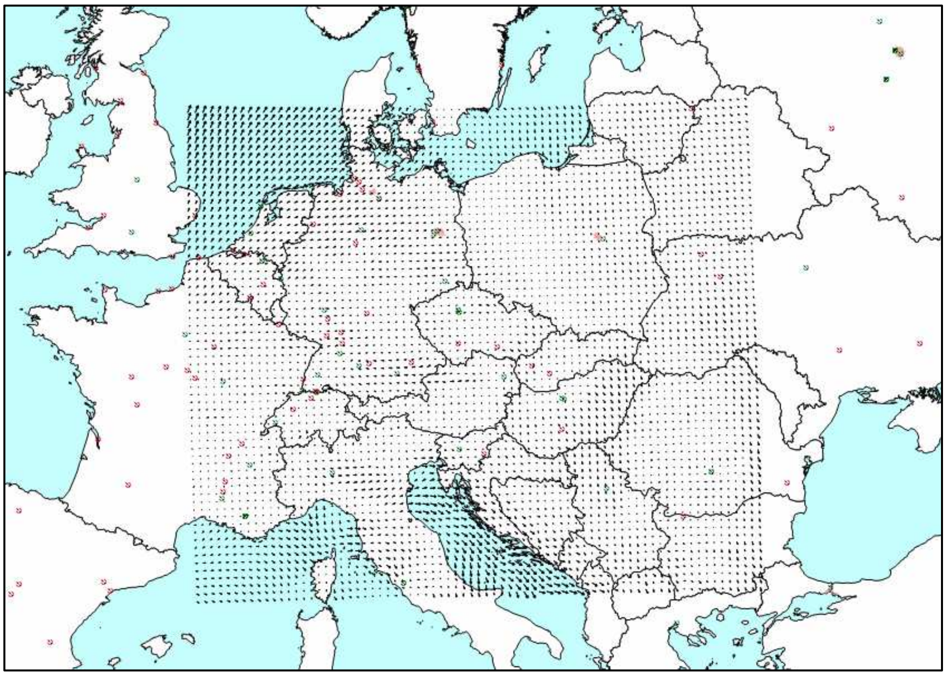

Fig. 1. Region covered by numerical weather prediction in ESTE EU (GRIB format). Displayed are wind vectors at the height level about 500 m above the terrain

The main tasks of the system are:
- to evaluate (to assess) the source term (accidental release of radioactive substances into the atmosphere);
- to model dispersion of radioactive puffs in European scale and evaluate the activities, doses, dose rates and avertable doses of radiological impacts;
- to evaluate and to recommend protection measures at the territory of interest;

ESTE EU is a complex geoinformation system. It contains a lot of information about each European nuclear power reactor and research reactor, for example specific layer with location of each reactor, basic scheme of containment of the reactor, nuclear and technological data about the reactor and the power plant.

System is connected online to the following sources of data (Fig.2.):

1. Meteorological data: the numerical weather prediction for a considerable part of Europe, prediction of meteorological parameters for up to next 48 hours (or more) is inserted automatically twice a day; in the GRIB format (GRIdded Binary) (Fig.1.);
2. Measured dose rates across the Europe (from European monitoring system EURDEP-EUropean Radiological Data Exchange Platform) (Fig.3).

Tool for entering the measurements manually (measured dose rates, meteorological data with exact spatial position) is also integrated in the system. Another possible source of input is the "EDR (Emergency Data Resource)" file in XML format, which could be delivered to the ESTE EU from any other ESTE system. EDR file contains information about real release or about predicted release (radionuclide composition of the release, timing, geographical coordinates, effective height of release, etc.).

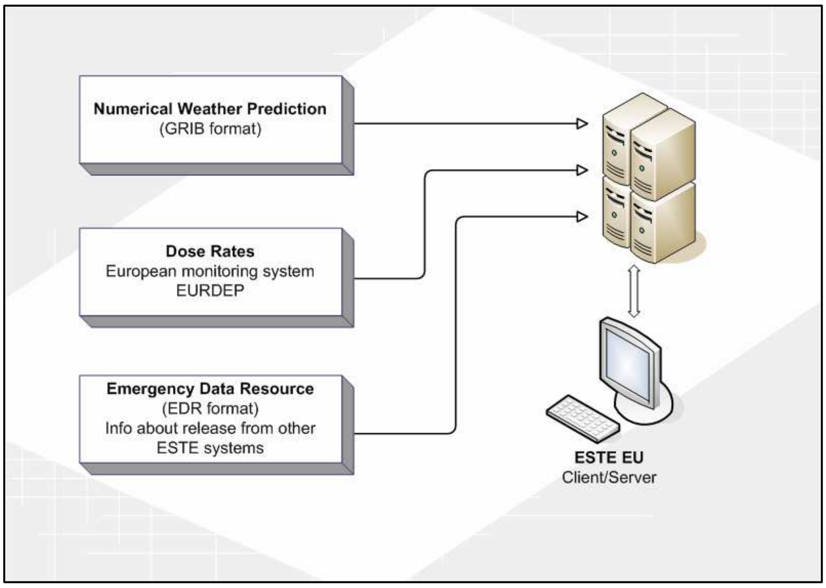

Fig. 2. Scheme of input data for the ESTE EU system

ESTE EU calculates the prediction of radiological impacts modelled on the area of Europe. Predicted impacts of predicted release (expected, but maybe never realized release) are calculated and displayed on the map for various time steps since the expected start of release for up to 7 days. Predicted release is such release of radioactivity to the atmosphere of the environment, which is predicted (expected according to some technological symptoms already detected), but probably was not realized yet.

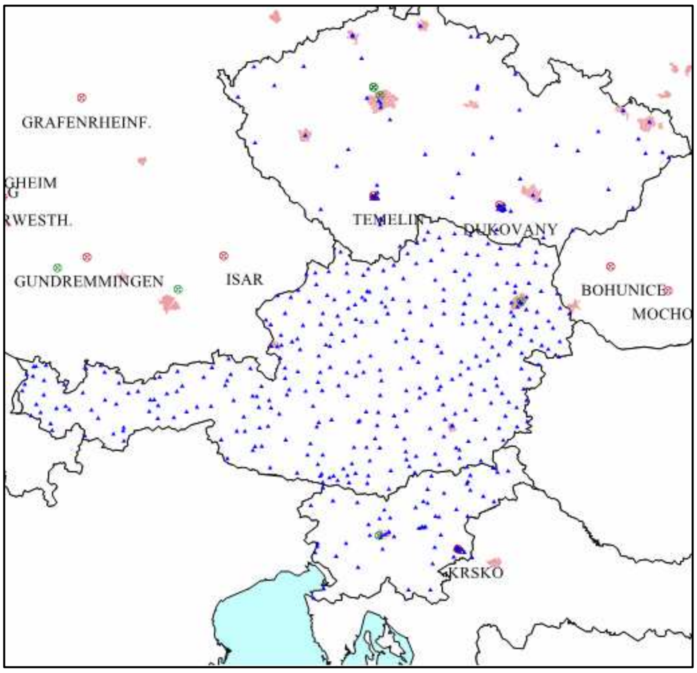

Fig. 3. Example of monitoring points of dose rates - EURDEP system in Czech Republic, Austria and Slovenia

System also calculates the real impacts of estimated real release. Real release is a release of radioactive substances into the atmosphere, which was actually observed and symptoms were detected. Real impacts are modelled as impacts before as well as after correction. Correction means data assimilation: on the base of monitored dose rates, calculated impacts are recalculated and assimilated to the truly known (measured) radiological situation on the terrain.

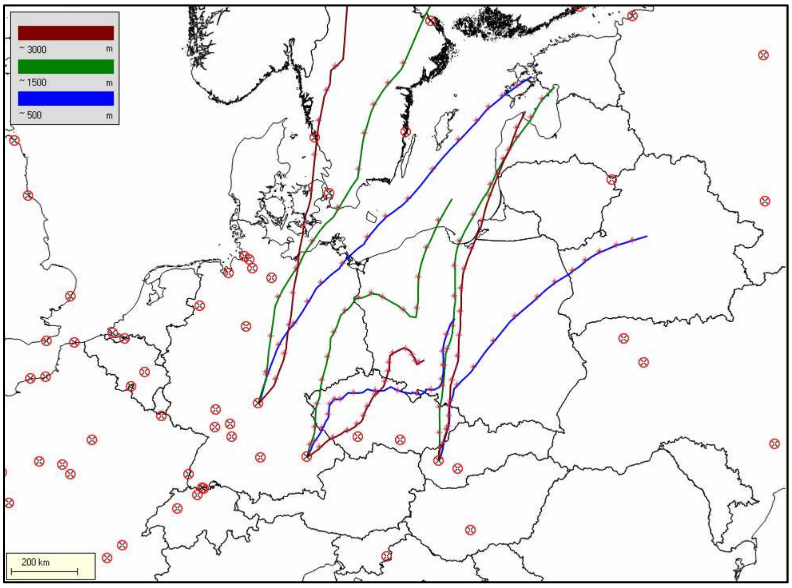

Fig. 4. Calculated hypothetical trajectories from possible point of release NPP Grafenrheinfeld, Isar and Bohunice. All power plants are in the vicinity of Czech border.

Furthermore, trajectories of hypothetical puffs are calculated. Trajectory stands for the curved path of the centre of (hypothetical or real) radioactive puff in the atmosphere. Trajectories are modelled from the beginning of hypothetical release up to the next 7 days. Trajectories can be calculated from any point on the map and their starting time can be adjusted to present, past or future time (depending on the available meteorological data). For the calculation of trajectories and impacts, the nearest known numerical weather prediction data (the nearest in time as well as on the map) are used.

Real impacts are impacts, which are calculated after application of algorithm for assimilation of modelled calculated radiological impacts to the results of real monitoring. In this manner, real impacts displayed on the map are in compliance with known results of monitoring. The calculation step is 60 min. Every puff is spread and moved according his actual trajectory in 60 minutes intervals.

Dispersion of released activity across Europe in ESTE EU is described and solved by Lagrange puff trajectory model (PTM) and Lagrange Particle Model. The module for the calculation of a great set of dosimetric parameters on the map of Europe was developed and is implemented in ESTE EU.

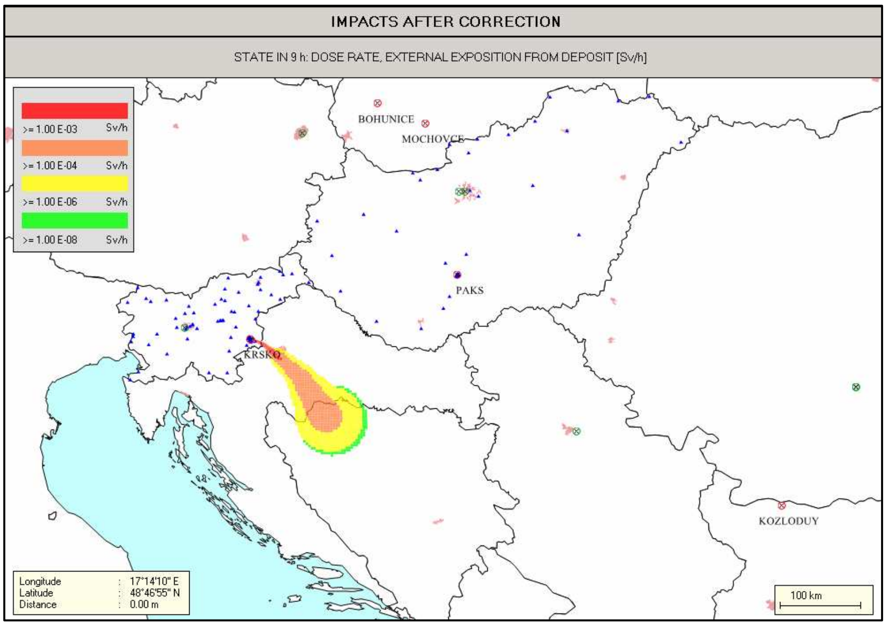

Fig. 5. Calculated radiological impacts due to hypothetical release from nuclear power plant Krsko in Slovenia

3 ESTE Annual Impacts

ESTE AI (Annual Impacts) serves as the legal instrument for evaluation of radiological impacts caused by radioactive airborne or liquid effluents from nuclear installations due to their normal operation (routine releases), in a middle European scale. The system is implemented at and used by NPP Bohunice and by all nuclear installations at the site Jaslovské Bohunice (for example by former and now decommissioned plant A-1, by nuclear fuel repository Bohunice, etc.).

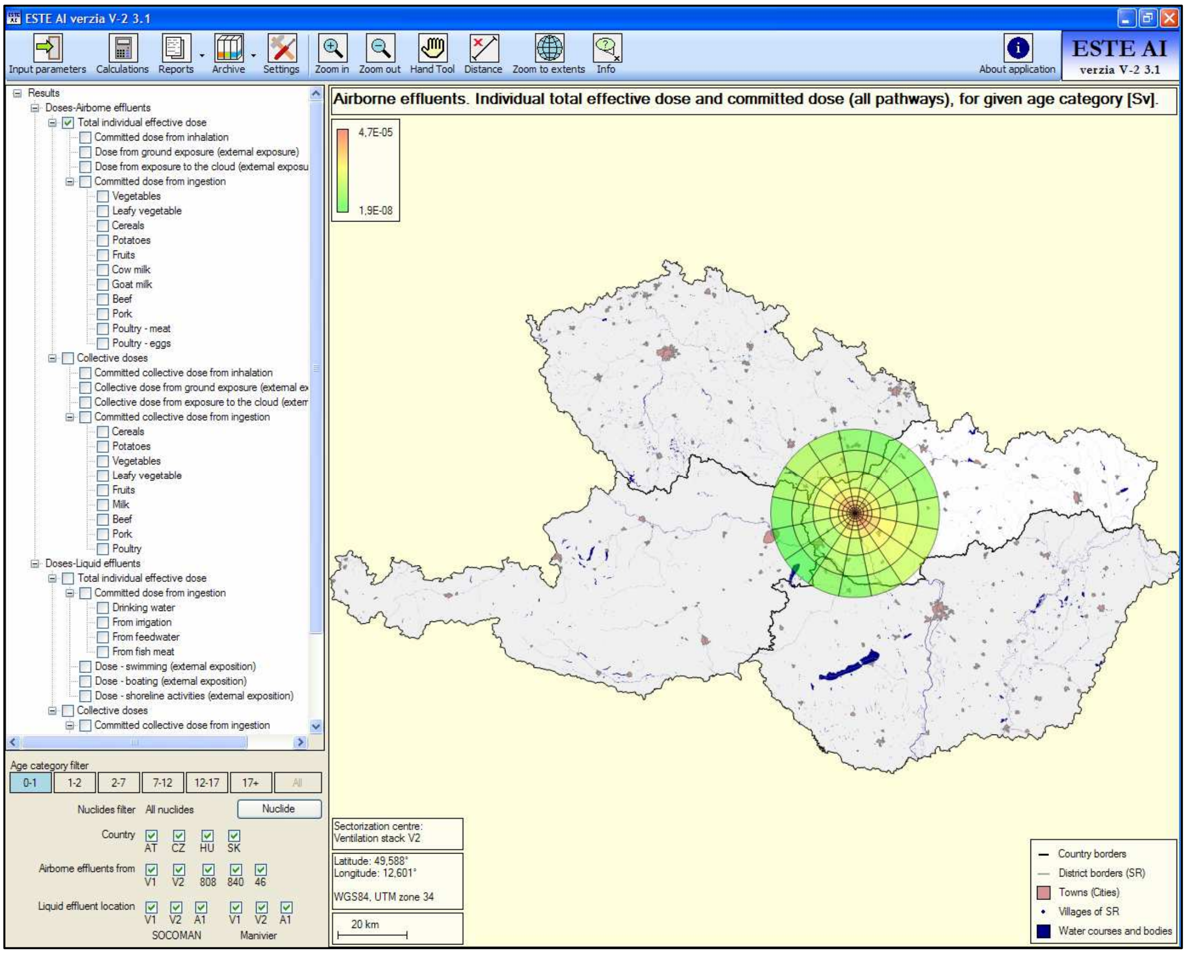

Fig. 6. Example of calculated and displayed results of individual doses caused by radioactive effluents from Bohunice nuclear site.

ESTE AI calculates the individual and collective doses inside the 100 km zone around the nuclear installation (in the specific sectors) as well as calculates the collective doses to the inhabitants of the entire Austria, Hungary, Slovakia and Czech Republic outside the 100 km zone:

- Collective effective doses from ingestion of foodstuffs exported from inside the 100 km zone to outside the zone;
- Collective effective doses to the population of Slovakia, Czech Republic, Austria and Hungary from the discharge of tritium (global impact, outside the zone);
- Collective effective doses to the population of Slovakia, Czech Republic, Austria and Hungary from the discharge of C-14 (global impact, outside the zone), for this purpose evaluation of both forms of C-14 – inorganic and organic –is taken into account;
- Collective effective doses to the population of Slovakia, Czech Republic, Austria and Hungary from the discharge of noble gasses, mainly Kr-85 (global impact, outside the zone).

In the case of Bohunice site, the system serves for the calculation and modelling of impacts of each airborne effluents point (each stack itself) as well as for the combination of the sources of airborne effluents in any way (the ventilation stacks and liquid discharges to the Váh river and to the Manivier water stream). All impacts are calculated on the GIS base, all calculated results and map sources are built on geographical information system (Fig.7.). System requires various inputs to the specific calculations. First the latest statistical data (inhabitants, food consumption statistics, and agricultural production) are fulfilling the database. The location of agricultural crops and their specification in every sector is entering into the system. For this purpose, the Terra (and sensor Aster) satellite data from the area of Bohunice NPP were analyzed, classified and implemented into the ESTE AI (Fig.10.). The main advantage of this remote sensing analysis approach is the objectivity, quickness, ability of yearly iterations of the agricultural crops detection and the possibility of long-distance-research without a direct contact with the land. Furthermore, the data from the project Corine Land Cover 2000 are being used especially for the roughness calculation and visualizations (Fig.9.).

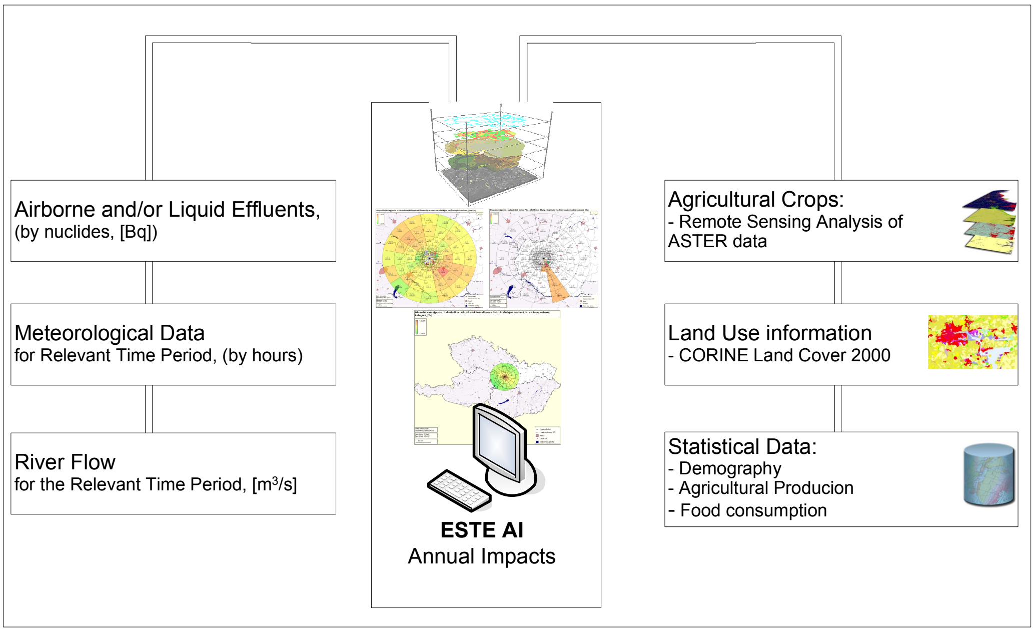

Fig. 7. Data Inputs into the ESTE AI system

In calculations of doses from external exposure to deposited activity on the ground, we assume that ground deposition from the effluent during the analyzed period (usually the annual effluent) will contribute to external exposure from the terrain for the next 15 years. It means that in each annual dose from external exposure to deposit, there is accumulated contribution to dose during next 15 years. This future contribution to dose from deposit is included in the impacts calculation from a given year, radioactive decay and other factors are also taken into account.

In calculation of doses to the member of critical group from ingestion of contaminated foodstuffs and from inhalation of air, 50 year or 70 year committed effective dose (according to the age category) are evaluated. We assume that in case of ingestion pathways the ground deposit of given nuclide remains deposited during the next 15 years (taking decay and other factors into account) and contributes to the activity in plants through the root uptake.

Furthermore, we assume that the member of a critical group consumes whole annual consumption of leafy vegetables from foodstuffs (even hypothetically) produced in the sector where he is living. In case of other agricultural products, we presuppose that the member of a critical group consumes 75% of his annual consumption from that sector and the rest is clean non-contaminated product.

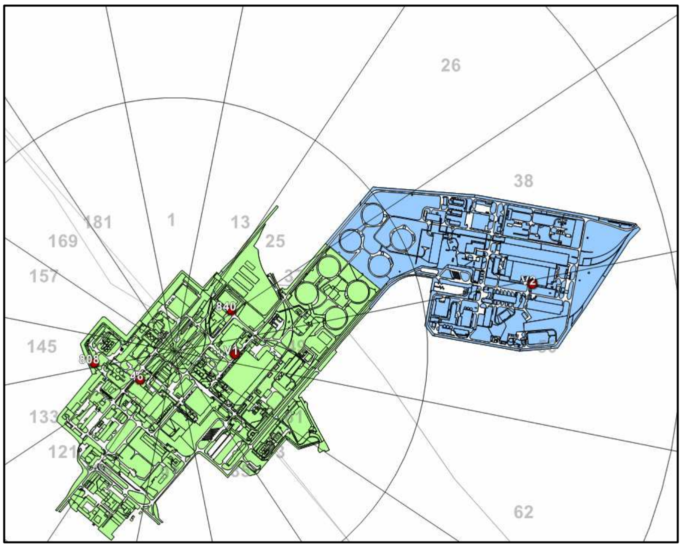

Fig. 8. Map of Bohunice site with points of routine releases to the atmosphere (red points)

We assume that the member of a critical group living in the village at the river shore consumes whole annual consumption of drinking water from the water well or from drinking water source into which the water from Váh River or Dudváh River (in case of Bohunice site) infiltrates (relevant transport factors are applied).

In calculation of collective doses from ingestion of contaminated foodstuffs, we only include the foodstuffs that are produced (or grown) in the given area. We assume that in case of collective doses the population living in that area consumes 50% of its consumption of vegetables from products that are produced in that sector and the rest are clean non-contaminated vegetables. In case of other products (e.g. cow milk) we assume that the population in that area consumes 10% of its consumption from foodstuffs produced in that sector - if these products are produced (or grown) in that area - and the rest are clean non-contaminated products.

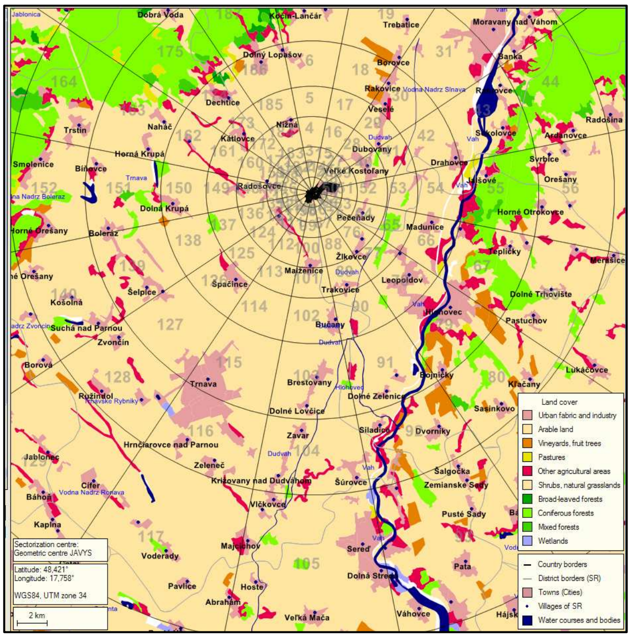

Fig. 9. Example of land cover layers implemented in the system

In calculation of collective doses from drinking water, we assume:

1. Town at the shore of the river: 10% of inhabitants consume their annual consumption of drinking water from water sources that are infiltrated by water from that river (e.g. in case of Bohunice site - Váh, Dudváh, partially Danube, transfer factors having in mind).
2. Village at the shore of the river: all inhabitants consume their annual consumption of water from water sources infiltrated by water from that river (again, transfer factors having in mind).

In calculation of collective doses from inhalation, we assume that all inhabitants living in that sector consume their whole annual consumption of air in that specific sector.

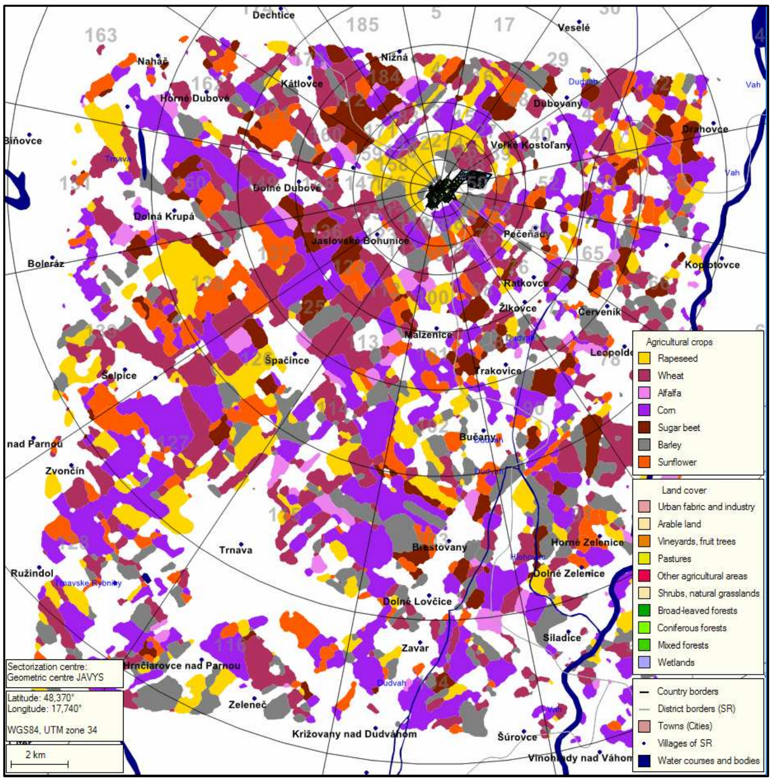

Fig. 10. Example of implemented analyzed satellite data about agricultural crops in the vicinity of Bohunice NPP.

Reference

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