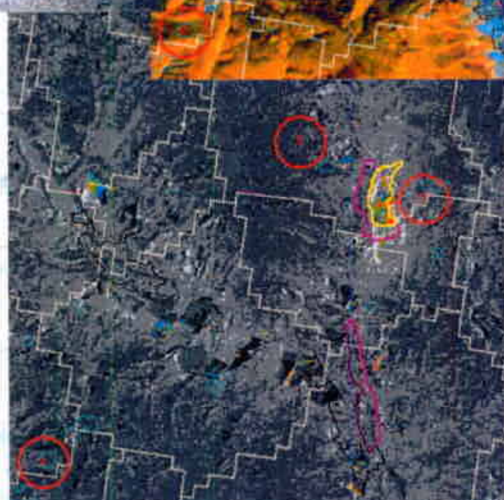
OPTIONS FOR COMPILING AN INVENTORY OF MINING WASTE SITES THROUGHOUT EUROPE

Based on conclusions drawn from the

JRC Enlargement Project PECOMINES

INVENTORY, REGULATIONS AND ENVIRONMENTAL IMPACT OF TOXIC MINING WASTES IN PRE-ACCESSION COUNTRIES



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LEGAL NOTICE

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Inventory, Regulations and Environmental Impact of Toxic Mining Wastes in Pre-accession Countries

1. Rationale

Mining waste is known to be amongst the largest waste streams in the EU and it ranks first in the relative contribution of wastes in many Central and Eastern European Countries.

There is a substantial gap in consistent information on European level, how mining wastes in EU member states and Candidate Countries are managed, of which nature their major hazards are and where the sites generating largest hazards are precisely located, including those that have been abandoned.

However, this information would be needed to assess the large range of environmental impacts caused by mining wastes and their emissions in a coherent way across the different policies related for instance to the protection of water (WFD) and soil resources (soil thematic strategy), which in both cases relies on and requires to a good deal spatial, often catchment based information.

Consequently a new Directive on the management of waste from the extractive industries (COM(2003) 319 final) was proposed by the Commission. It specifically focuses on the aspects of waste management, prevention of soil and water pollution and the stability of waste management facilities in a long term perspective covering the time span from licensing, to active operation, closure and remediation of mineral extraction sites

While this governs mainly active sites of mineral extraction and primary processing, it is known that in Europe mining wastes from historical activities are widespread. These remains originate in many cases from activities, which cover time spans from the last ten to hundred years, back to several centuries and in some cases even more than 2000 years.

Many of these historical waste sites have to be considered "orphan" sites, for which no liability can be assigned to former operators or any legal successor. Moreover, it is known from existing records but also from recent research projects, that this "burden of the past" in numerous cases may constitute a serious threat to the environment and human health.

Against this background, Article 19 of the proposed Directive provides for an exchange of information between Member States on methods of carrying out inventories and rehabilitating closed waste facilities that are a cause of serious pollution to the environment.

2. Present situation

Presently no reliable synoptic picture of number, extent, distribution and emissions from mining waste sites exists, neither for EU member states nor for the Candidate Countries.
Lack of information is not the fundamental problem, but available data are often scattered (different responsibilities and/or ownership), are heterogeneous and lack standardisation in terms of parameterisation, formats and geographical reference systems. Hence, the core task lies in the harmonised collection and standardised compilation and evaluation of existing data and in connecting them to a geographical reference system compatible with other relevant European spatial data sets.

3. Demonstration of a pragmatic approach by the PECOMINES project

Against this background the PECOMINES project undertook it to conceptualise and demonstrate a standardised regional **inventory** of waste sites from mineral mining in Pre-Accession countries in relation to catchment areas. Thus it becomes possible to develop a concept for regional **impact assessment** allowing to link the site/source related indicators with spatial information at catchment scale.
The PECOMINES inventory combines site specific information coming from existing data bases in the candidate countries, which is harmonised through the PECOMINES questionnaire and put into a relational data base.
Through the attribute of the geographical site coordinates the questionnaire information is linked with geo-referenced spatial information on the distribution and extension of waste material exposed to the surface, being mainly derived from remote sensing data.
This information is linked to existing relevant standardised spatial data layers available at European level, such as CORINE Land Cover, GISCO river networks and catchments, European Soil Database etc., thus adding the spatial dimension to the inventory of mining waste at regional scale.
Technical solutions are the following:

- The method follows a **tiered approach**, i.e. first an inventory of mine waste is carried out for *potential hazard* assessment. This is where most of information exists and data has the least uncertainties;
- An internally consistent **glossary** of terms has been developed. Consistency has been achieved between scientific and regulatory terminology;
- For standardised data acquisition of conventional archives and records, a questionnaire including a digital data entry application was developed;
- Following identification of mine sites and selection of 'hot spots' by national experts, focused inventory of the impacted environment is carried out;
- An independent **remote sensing identification** of sites which are characterised by anomalous concentrations of both ferro-oxy-hydroxides (Fe-Ox) and secondary clay minerals (OH-CL) by applying selective principal component analysis (PCA) to geo-referenced Landsat-TM reflectance channels is carried out at country wide scale. Co-occurrence of both types of anomaly is significantly indicative for most cases of waste material from

metal mining or ore processing but also for other types of mineral deposits (e.g. lignite) where pyrite bearing material is frequently associated leading to acidification.

- Application of the remote sensing technique allows for a rapid screening of large area coverage and provides independent, geo-referenced information about accumulations and distribution of mining materials bearing increased acidification potential. Integration of these anomaly maps with existing data sets from the conventional data acquisition (see above) and additional, readily available relevant spatial data layers such as CORINE LC, GISCO rivers and catchments, administrative boundaries, European Soil Data Base and others, allows for cost efficient country wide integrated assessment in a DPSIR framework. A first indicator to specify levels of acidification potential at catchment level has been proposed and is further investigated.

4. Results/Output

Questionnaire based data collection has been performed for the 10 Central-Eastern European Candidate Countries in close collaboration with national institutional partners having responsibility for regulatory and inventories as well as with scientific institutions.

The full processing chain including the integrated use of questionnaires and field archive data, national spatial data bases, remote sensing techniques and European data layers (CORINE LC etc.) has been implemented for large parts of Slovakia and Romania (North-West).

- Inventory questionnaires including guidelines have been prepared, sent to and returned by all PECOMINES Steering Committee institutions (10 countries).
- A database with information on the mining waste 'hot spots' in the 10 investigated Candidate Countries has been compiled.
- The integrated remote sensing method has been successfully tested and applied on large areas of Slovakia and of Northern and Western Romania (total area covered in the test approximately 120000 km^2).
- The reliability of the results has been demonstrated and validated against a national, digital data base of site specific information of mining features in Slovakia and on environmental "hot spots" both in Slovakia and Romania as provided by the national institutional partners. An interesting observation, underpinning the added value of the remote sensing anomalies, is the fact that the geo-statistical correlation between different conventional data sets (e.g. between CORINE LC mineral extraction sites and the national Slovakian data base) is less significant than the correlation of their respective features with the remotely sensed anomalies.

  It should also be noted that the remote sensing data processing itself is fully independent and does not require any a priori knowledge of mining areas or mining hot spots for calibration purposes.
- Overlaying the results of the remote sensing anomaly screening with the vector information from CORINE LC highlights the potential to add significant value to CORINE LC in terms of spatial resolution and better differentiation of mineral extraction sites, associated dumps and processing facilities.

- Thus a standardised frame of spatial reference regarding mining waste issues throughout Europe could be realistically established, being from the beginning compatible with other spatial reference data layers available at and used by the European Commission/EUROSTAT and the EEA
- A ranking method for mine waste hazard assessment has been developed based on obtained inventory data, where a parameter of "iso-hazard (IH) is defined as log(times standard exceeded) + log(emission rate m^3/day) and its value has a meaning of a potential to pollute equal amount of good quality water per day.

5. Tentative estimates of cost

The approach aims at this stage primarily to provide a rapid, highly standardised way to provide at country level a geo-referenced review inventory of areas affected by recent and historical mining activities, which should lay the basis for a rational and efficient prioritisation of areas which require more detailed investigation and intervention to protect the environment and human health.
Consequently the method is to a large extend based on existing data that are available and/or accessible for the national institutions in charge and are assumed not to generate major costs for data purchases. The required technical expertise of thematic (i.e. geo-scientific) disciplines, geomatics, remote sensing and GIS is typically well developed in geological surveys or private consultant companies in all member States and Candidate Countries, who should have no major problems in adapting to some technical requirements of the processing chain, receiving technical documentation and a short training/instruction on a few specific technical aspects.
It is clearly recommended that the work should be performed by national experts.

The following tentative figures of costs refer to our experience on the Slovakian test exercise.
Collection of existing national data including compilation of questionnaires, extraction of digital data on mining features from national data base and establishment of data base: **4 to 6 person/months**
Geometric and atmospheric pre-processing, PCA processing of Landsat-TM data: ca. 3.5 full frames and integration with additional data layers: **3 person/months**
Site specific and statistical validation of remote sensing anomalies, generation of anomaly and indicator maps: **4 to 6 person/months**
Data collection and remote sensing processing can/should be performed in parallel.
The costs of 1 Landsat-TM full scene frame are currently in the order of 500 Euros/full frame. For a country like Slovakia this results in moderate costs even assuming a multi-temporal frame with 3 observation dates (minimum costs 1750 Euros, 3 dates 5250 Euros). We would like to remind to the availability of the IMAGE 2000 data set, which will provide a fully geo-referenced Landsat mosaic

of Europe (enlarged EU) and is close to completion. This could possible form a reference layer.
For large countries, such as Poland or Romania, with large and wide-spread mining areas the amount of required man-power (person-months) and satellite data costs may be increased by a factor of 2 to 3, equally for the costs for satellite data.

6. Conclusions

The approach to collect standardised information on mining sites and related wastes from existing data bases through a harmonised and guided questionnaire appears to be a feasible option to compile a regional scale, geo-referenced inventory of potentially hazardous mining waste sites. Linked with the physically based remote sensing mapping of mining related anomalies, the data base gains the spatial dimension, which is needed to connect the tabular attributes with other spatial data sets e.g. on land use, soil and water resources.
The remotely sensed anomalies are obtained independently from existing ground truth and add value by filling gaps in existing records and data bases and improving spatial coherence.
This is considered an important step towards the developments of concepts for regional environmental impact assessment at catchment scale as needed for the integrated assessment of EU policies related to waste management, environmental protection (e.g. of water and soil resources) and health.
Since the EU-EEA IMAGE 2000 project, in preparation of the CORINE 2000 project, is currently preparing a geo-referenced mosaic of Landsat-TM data, covering the entire area of the EU and of the Candidate Countries, an relatively quick application of the approach to the entire region would not be an unrealistic option as far as it regards the acquisition of satellite data.

More details may be found on http://viso.ei.jrc.it/pecomines_ext/index.html

An illustrated outline of the major elements of the described data collection and remote sensing based data integration chain is given in the annex on the following pages.

Annex: Illustrated outline of the major elements of the described data collection and integration chain

Mining waste facilities and associated problems exhibit in manifold ways, spatial scales and dimensions. Are there possible ways to collect and analyze information in such a way that common criteria for assessing the problem and for prioritizing action across the EU Member States can be defined.
In short: HOW TO HARMONIZE?

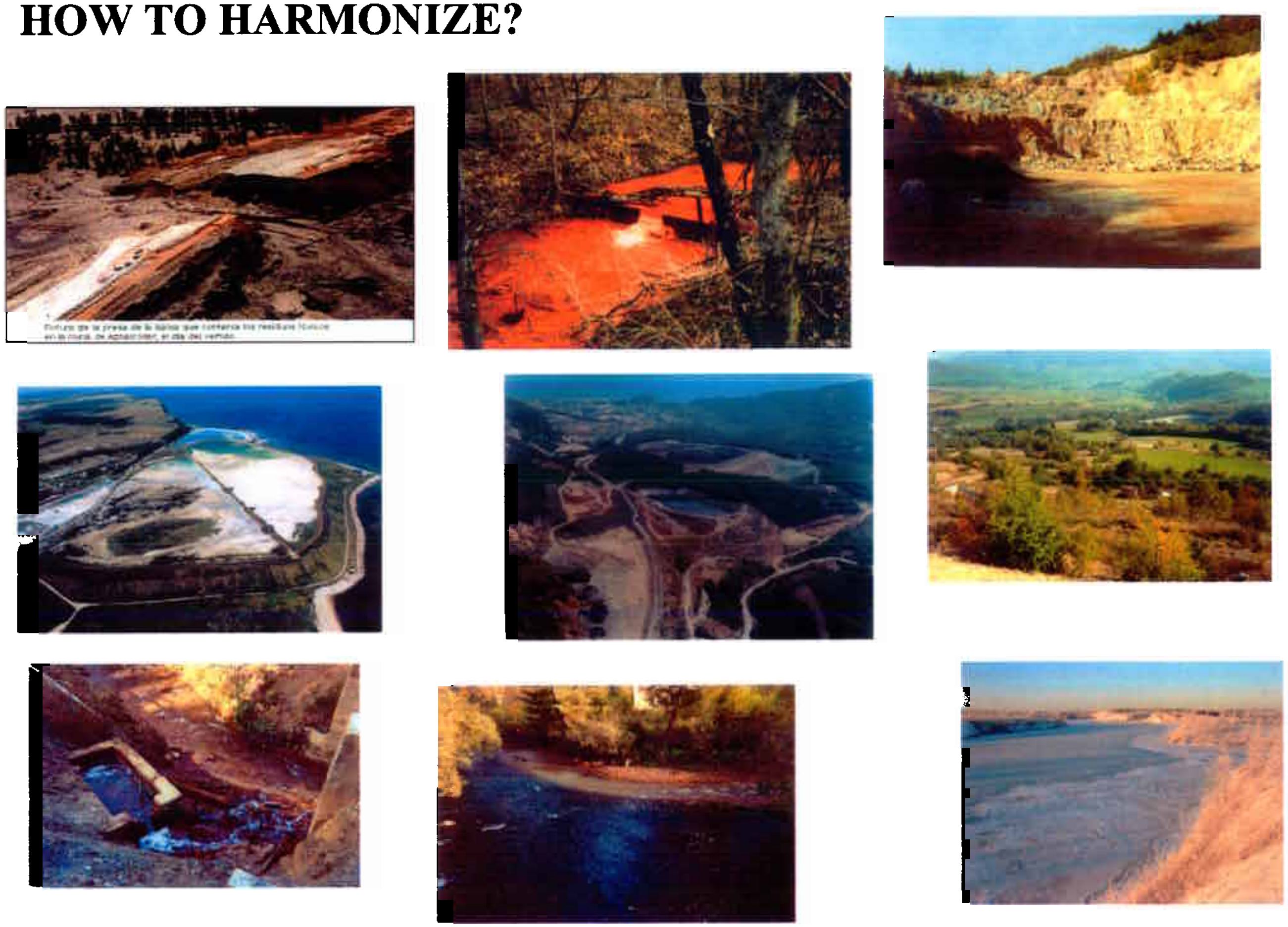


Figure 1: Examples of the variability of visual expressions of mining waste features in different European landscapes

The first step proposed is the standardized compilation of existing information of conventional archives and records through a questionnaire including a digital data entry application

MINING WASTE INVENTORY QUESTIONNAIRE

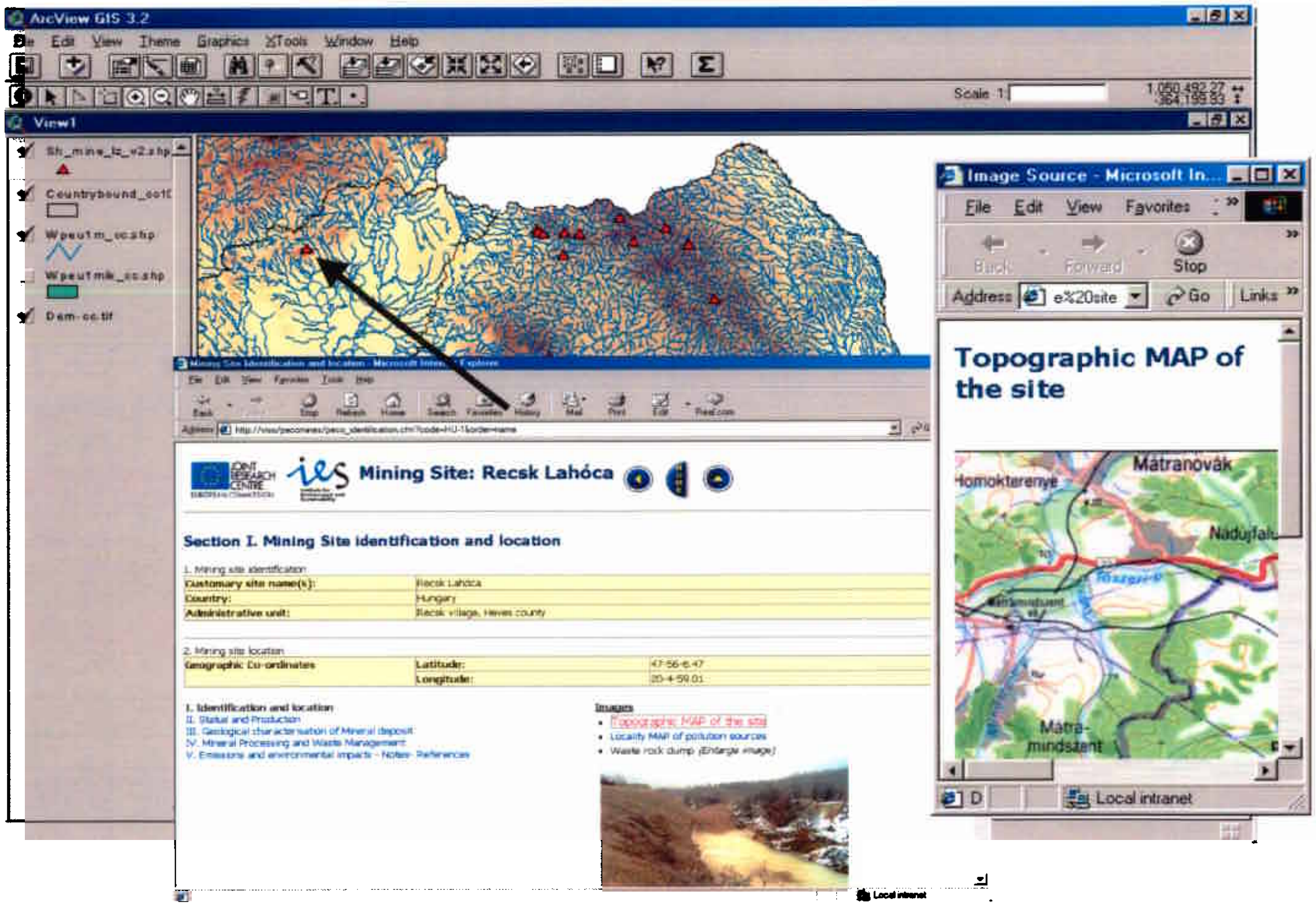


Figure 2: Example for PECOMINES user interface for information derived from questionnaires from 10 countries

Information about the type and volume/quantity of waste materials can be translated in a model of hazard to mobilize toxic substances beyond accepted concentrations expressed as potential to pollute a given amount of good quality water per day.

Proposal of criteria for systems of ranking and comparing hazardous mining waste sites based on assessment of emission potential

A parameter IH (isohazard) is defined as:

log (times standard exceeded) + log(emission rate, m^3/day)

and its value has a meaning of a potential to pollute equal amount of good quality water per day

Possible classification of hazardous sites with respect to the emissions potential

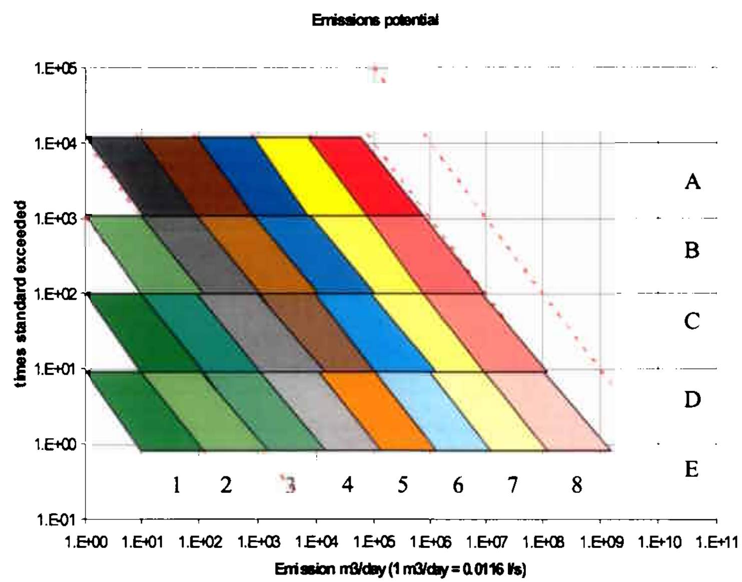
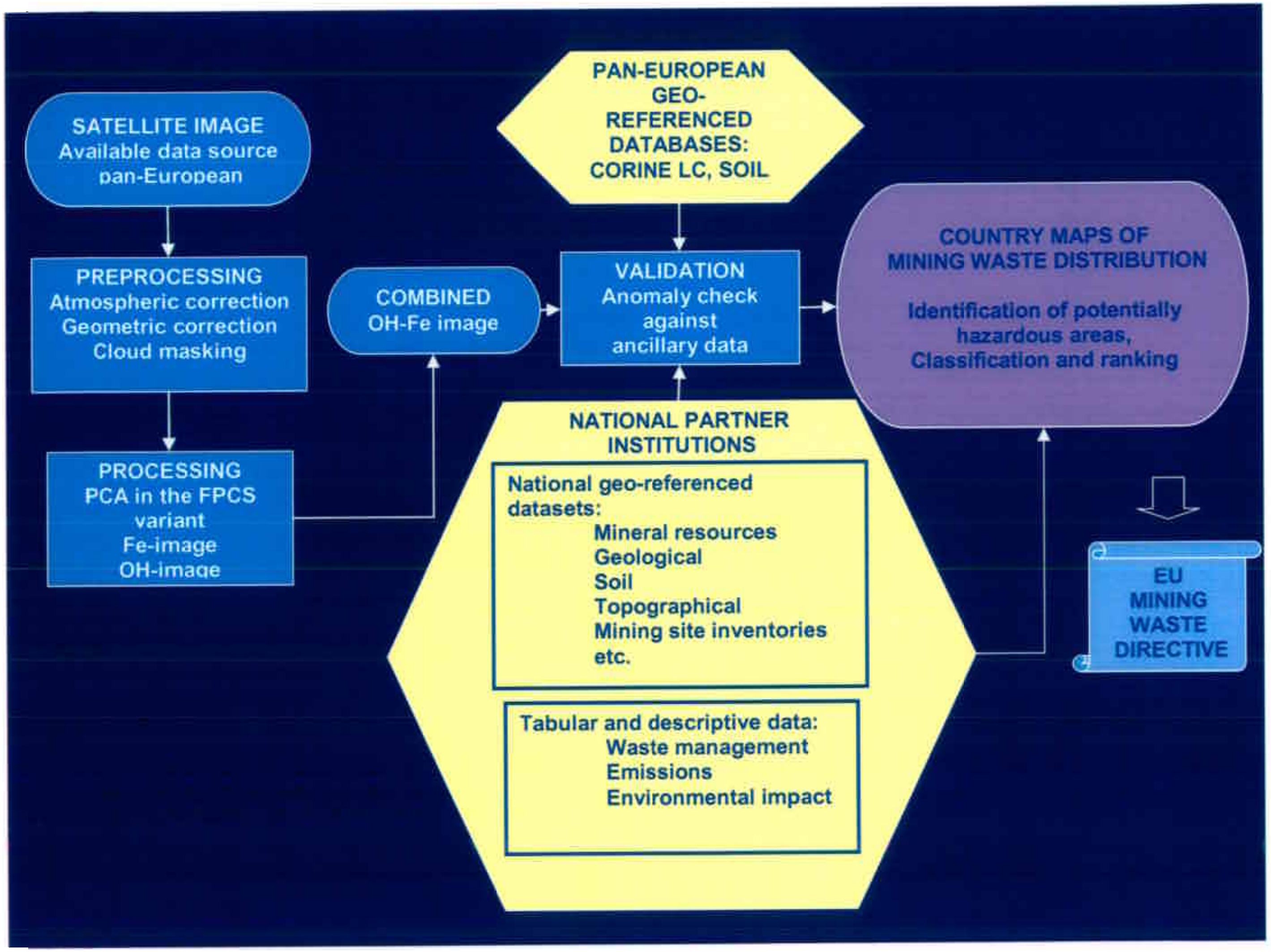


Figure 3: Outline of iso-hazard model to characterize the source potential to pollute the environment



Although the before mentioned information is frequently associated to geographical reference coordinates of known mining sites (typically point co-ordinates), it is not geo-graphically explicit in terms of spatial distribution and limits of waste accumulations. However, through the attribute of the geographical site co-ordinates the questionnaire information is linked with geo-referenced spatial information on the distribution and extension of waste material exposed to the surface, being mainly derived from remote sensing data. Landsat-TM data are available for the whole of Europe, e.g. in the Image 2000 mosaic which has been implemented in collaboration between EEA, the Commission and the Member States.

Figure 4: **Overview of PECOMINES methodology for remote sensing based large scale mapping of mining wastes**

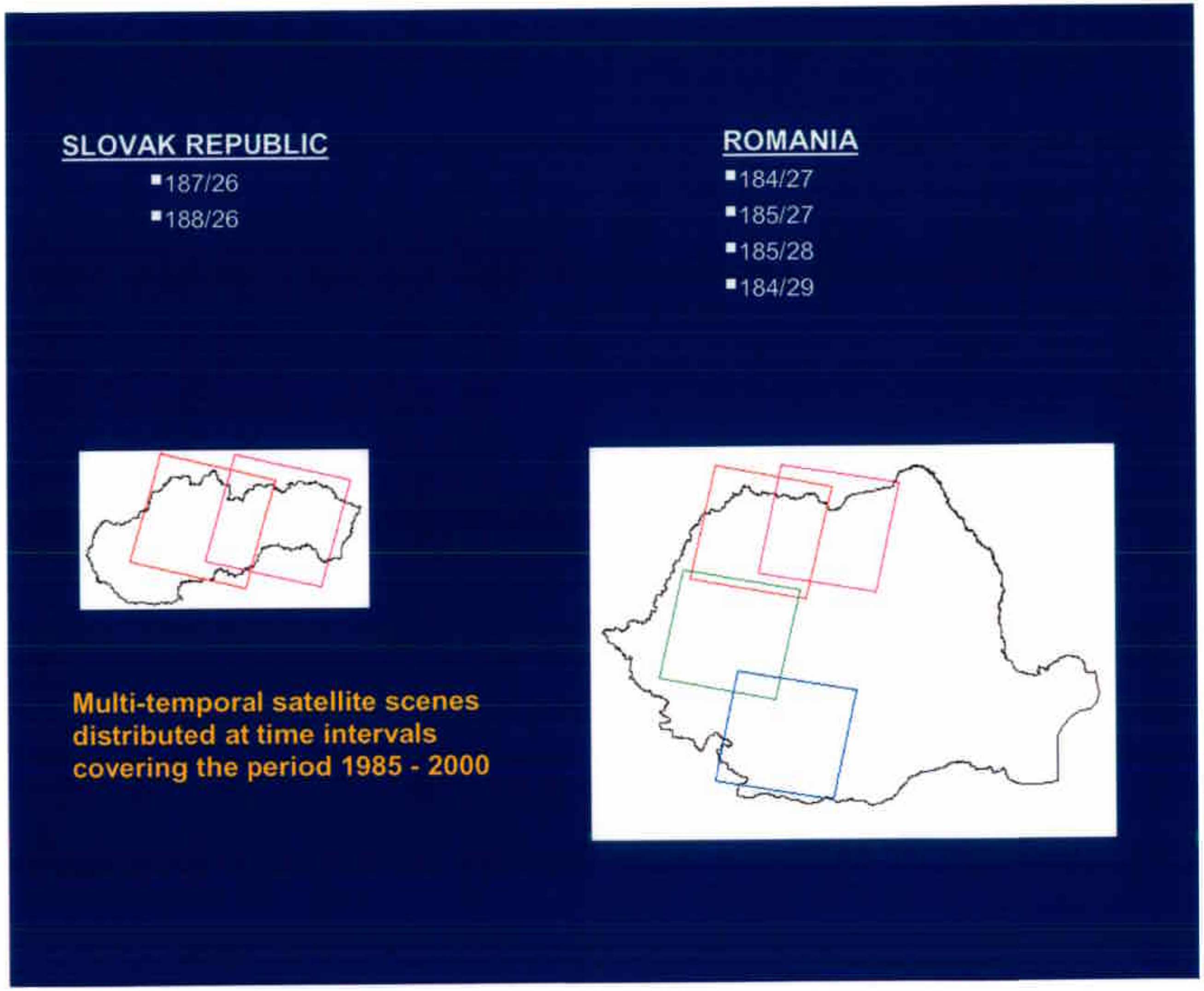


Figure 5: Landsat-TM coverage used for testing the integration of remote sensing of mining sites with in-situ information

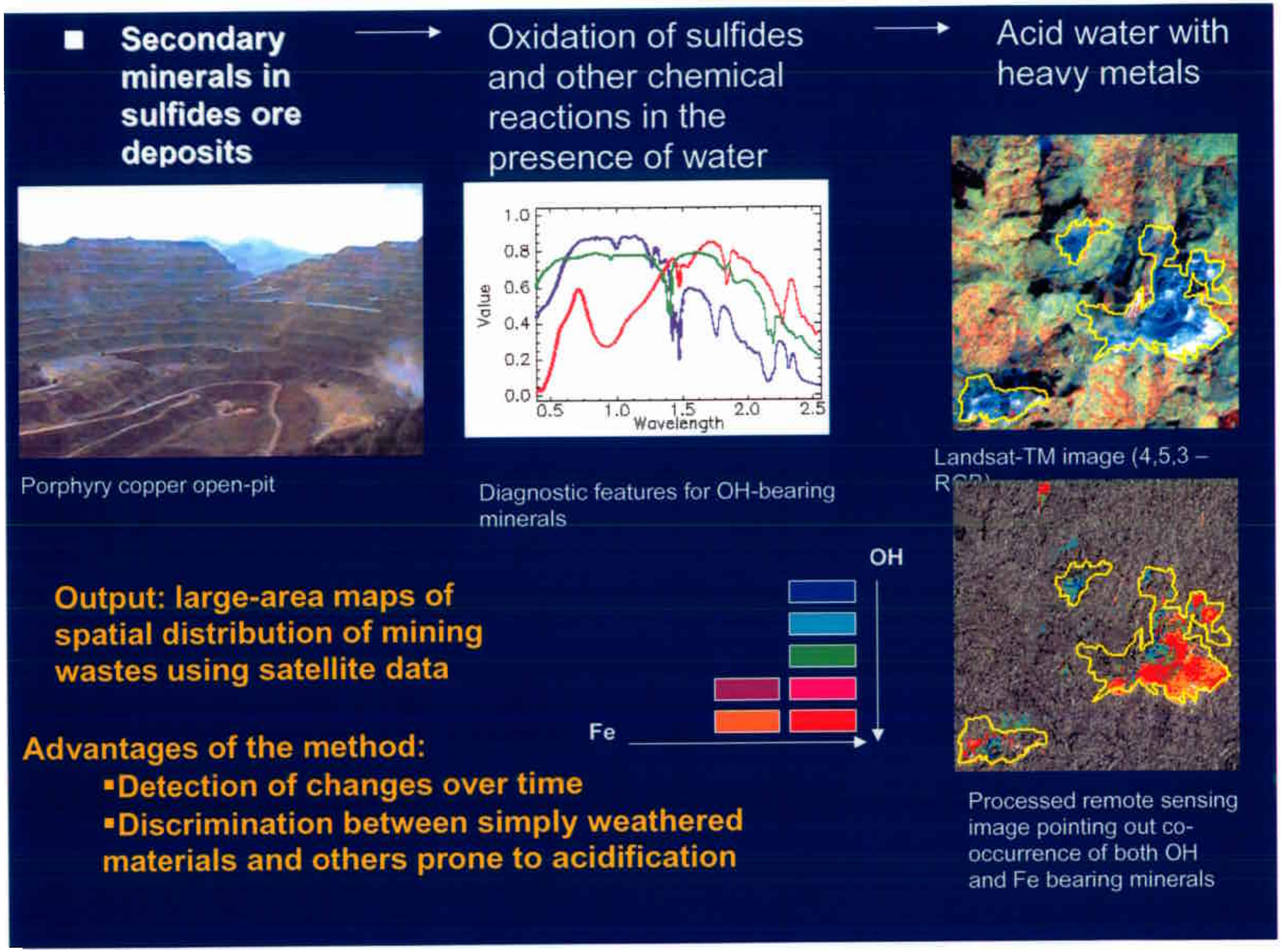
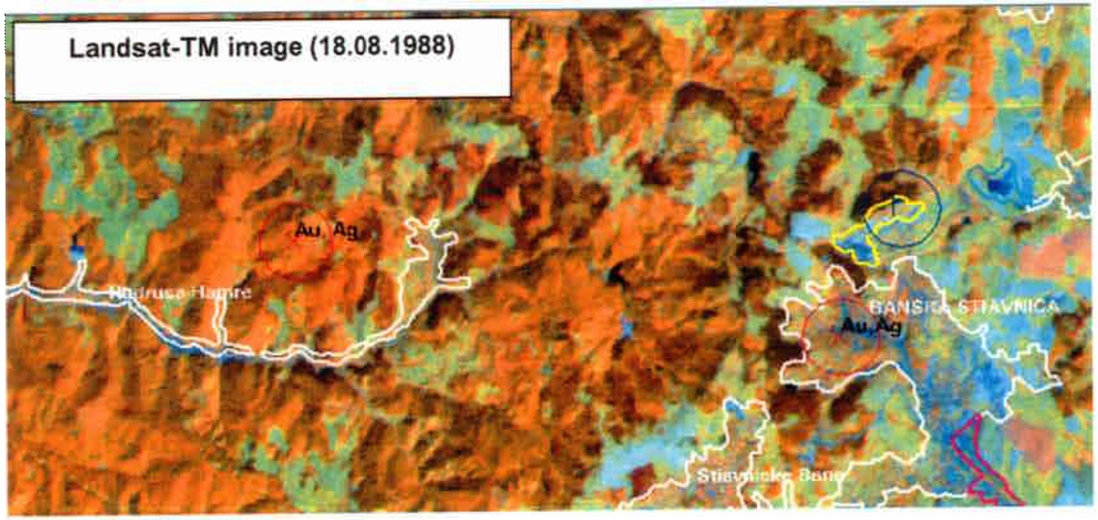
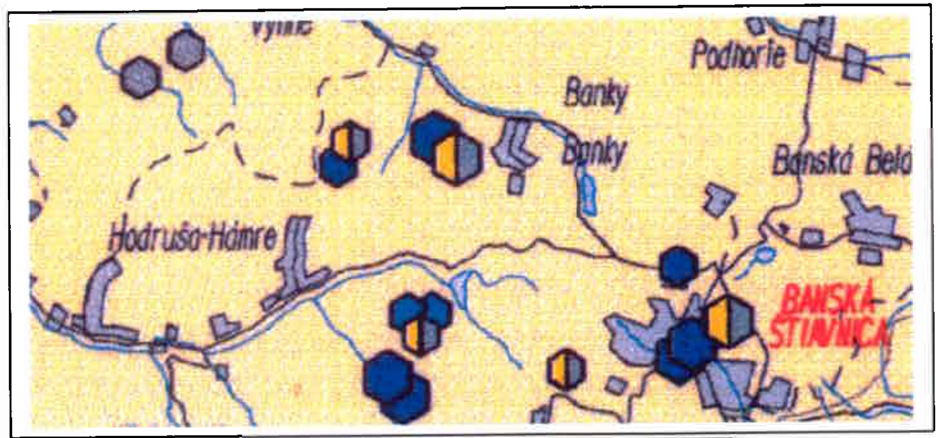


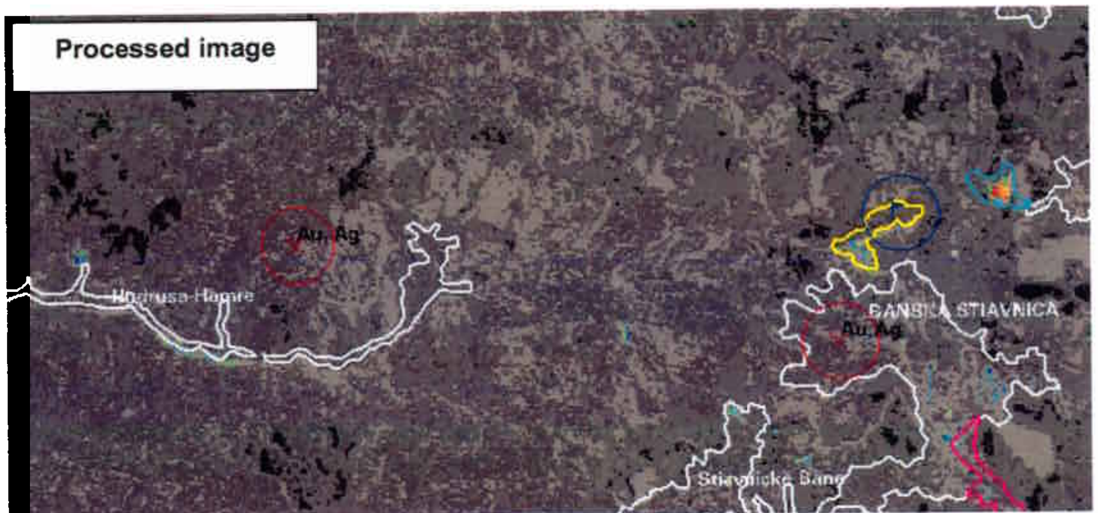
Figure 6: Outline of mineral spectral features detected in the remote sensing approach to identify and map mining waste anomalies

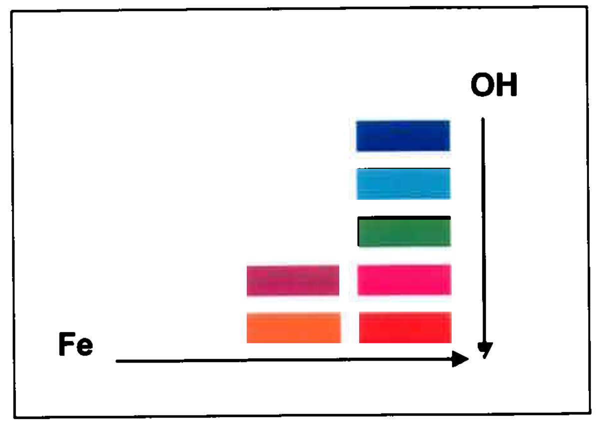
Figure 7: Site specific validation of RS results – Example BANSKA STIAVNICA (SLOVAKIA)





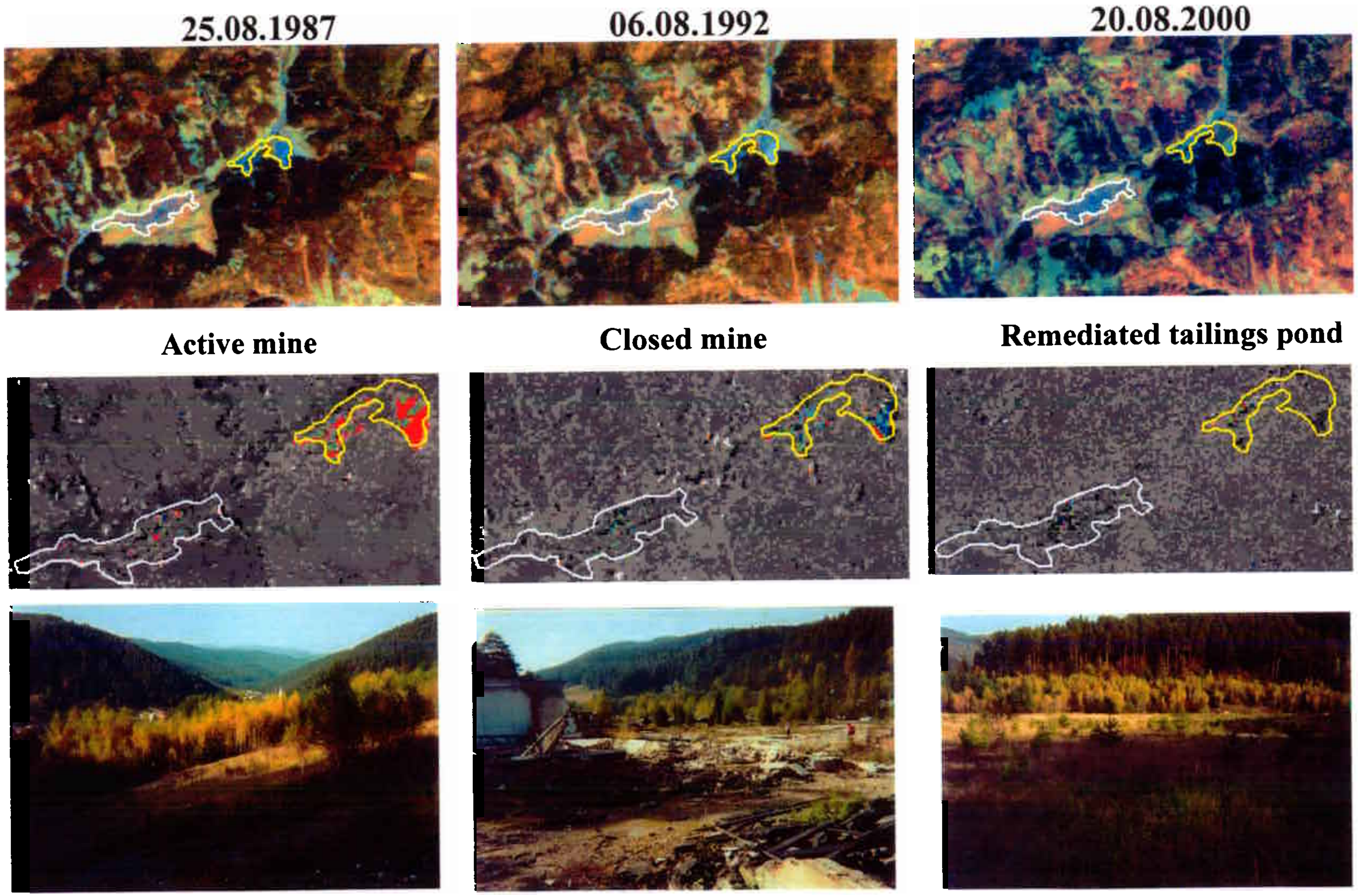
Map of mineral fuels and metals





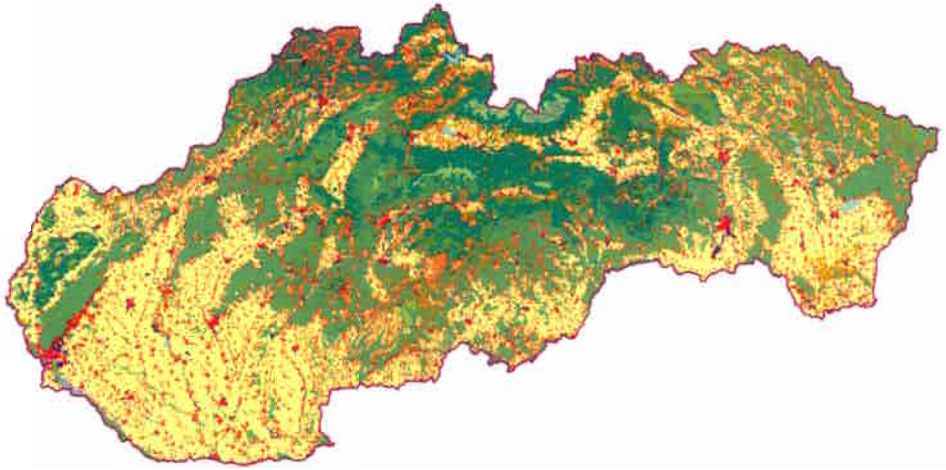
Overlaying remotely sensed anomalies with other related data layers, e.g, CORINE LC classes concerning mineral extraction sites, waste dumps or national resource maps shows that known features are clearly and correctly spotted but also that anomalies are also occurring more frequently in disseminated patches in the perimeters of mining regions than in other areas

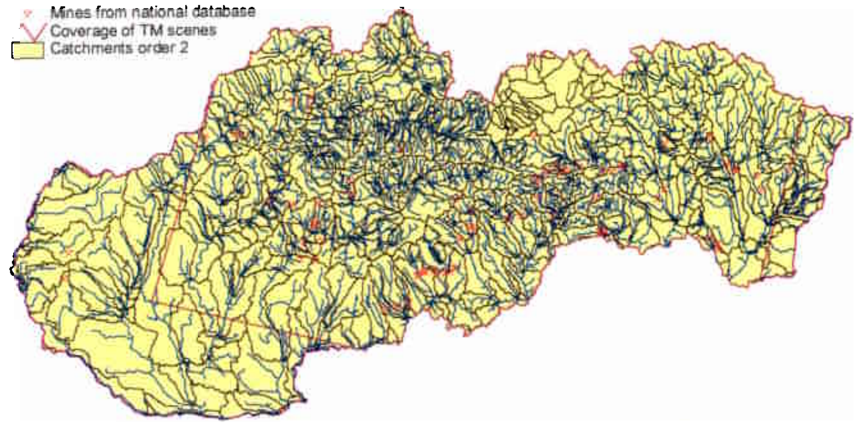
Figure 8: **Site specific validation of RS results: temporal change at Smolnik site**

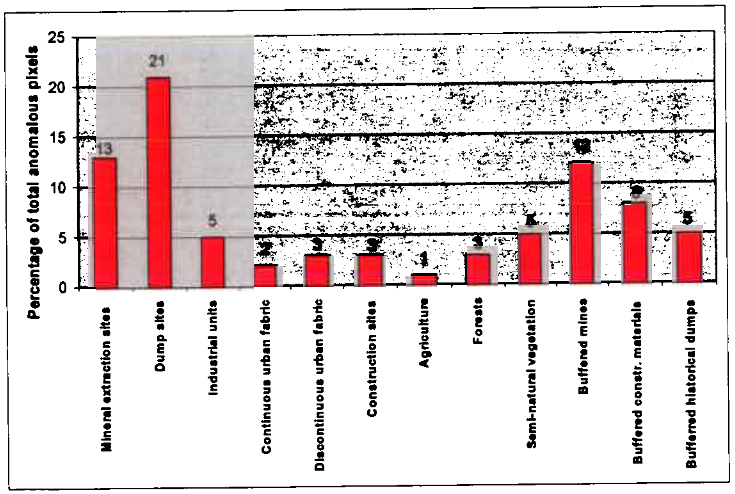


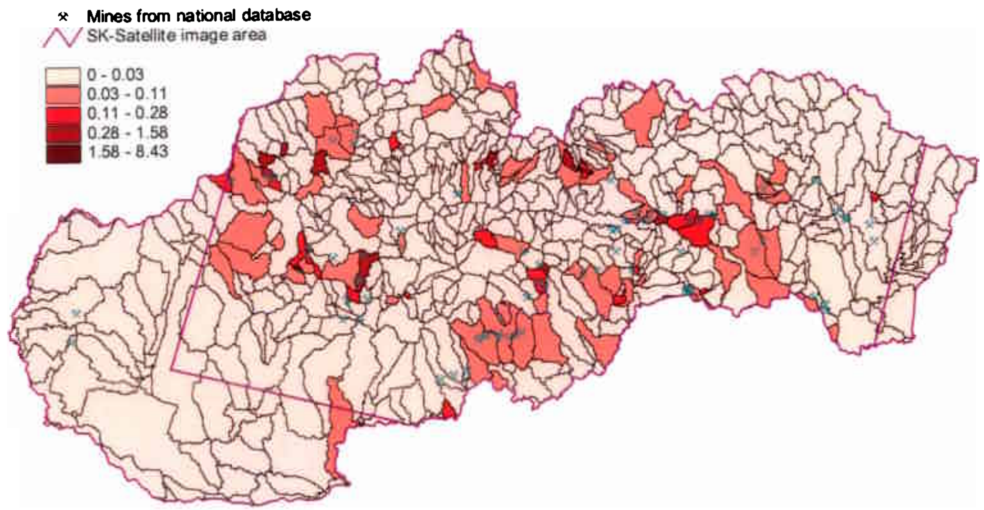
Also changes of anomalies over time can be highlighted, as in the case of the Smolnik mining site, where an old tailing pond was remediated and covered with buffering materials.

Figure 9: Statistical validation of RS results with other spatial data sets on mining feature









A first approach to a statistically based validation for a whole country was performed in Slovakia. Spatial coherence of remotely sensed anomalies against known mining waste features from national data bases and CORINE LC were evaluated and revealed significant correlation between the location of mining waste features and remote sensing anomalies. This confirmed in particular the validity of the 2 highest anomaly classes as indicator for accumulations of critical material. From this a first attempt was made to classify watersheds according to hazard as function of the appearance of critical anomalies per catchment.

The next step to be elaborated will be an extended spatial information system for enhanced integrated validation and evaluation of anomalies against multiple source data layers for a harmonized risked based evaluation of mining waste features and related indicators from country to Europe-wide scale.

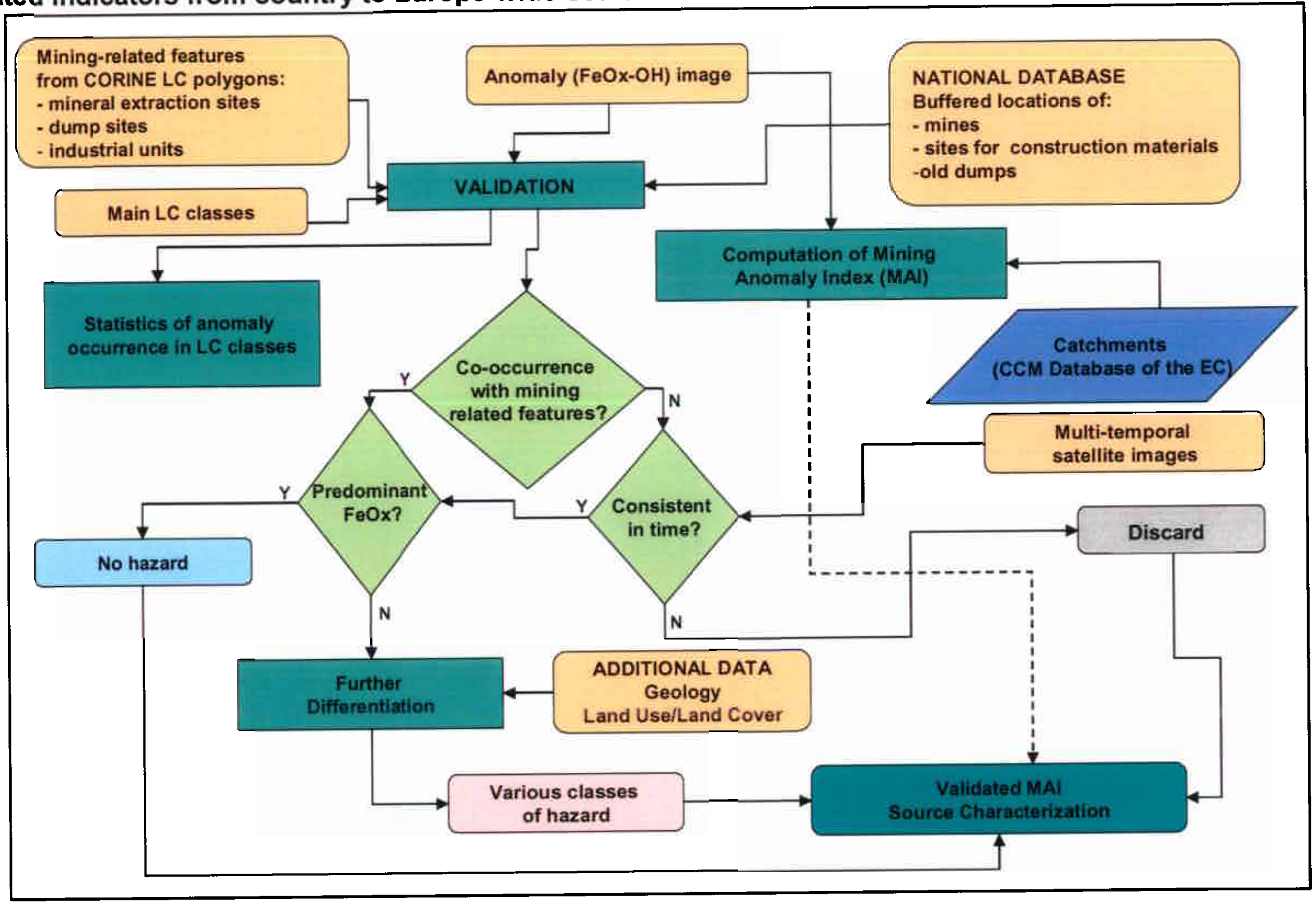


Figure 10: Flowchart for standardized validation and integration of remote sensing anomalies into a mining waste inventory

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