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EXPLOITATION

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WP5 - LIGHTWEIGHT AERIAL REMOTE SENSING

DELIVERABLE D5.3
AIRBORNE MISSION PLANNING
FOR THE DEMO SITES

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SEVENTH FRAMEWORK PROGRAMME

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1. INTRODUCTION

The objective of ImpactMin is to develop new methods and a corresponding toolset for the environmental impact monitoring of mining and mining-related activities via airborne and geophysical remote-sensing methods. This report is primarily focused towards explaining the justification of airborne remote sensing methods used at the three demo-sites where an airborne campaign is planned: Mostar Valley site, Rosia Montana and Kristineberg. Mining operations (past and present) have a significant environmental impact, which can be monitored using extensive, labor-intensive and costly ground based field observations. The primary emphasis, however is based on the positive results derived from the similar examples with airborne remote sensing and geophysical data, suggesting a significant potential in the application of stand-off detection to monitor the environmental impacts caused by mining operations. The principal case for supplementing satellite remote sensing (discussed in accompanying deliverable 4.3) with airborne measurements for environmental monitoring stems from an inadequate resolution (spatial, spectral) of satellite data to address observables in a relatively small and highly-detailed area. The role of airborne spectroscopic data therefore fits the niche between the regional satellite assessment and ground point-sampling.

2. DEMO SITE IMPLEMENTATION PLAN

WP 5.3 Preparatory work for demo-site implementation (Photon, GFMO, VITO)

- Analysis of the available information for each test area (see IMPACTMIN deliverables 4.1 and 4.3); definition of the additional information that needs to be collected (either by literature study, field work or remote sensing) in order to characterise the extents of the pollution and its related phenomena on a local scale → site overview, environmental impacts, data availability, data needs
- Determination how, in the different test areas, these parameters can be identified and monitored using Airborne RS-technology and supporting ground observations. → data collection
- Definition of field sampling and analytical methods in order to support and complement the remote sensing observations → field sampling and analytical methods

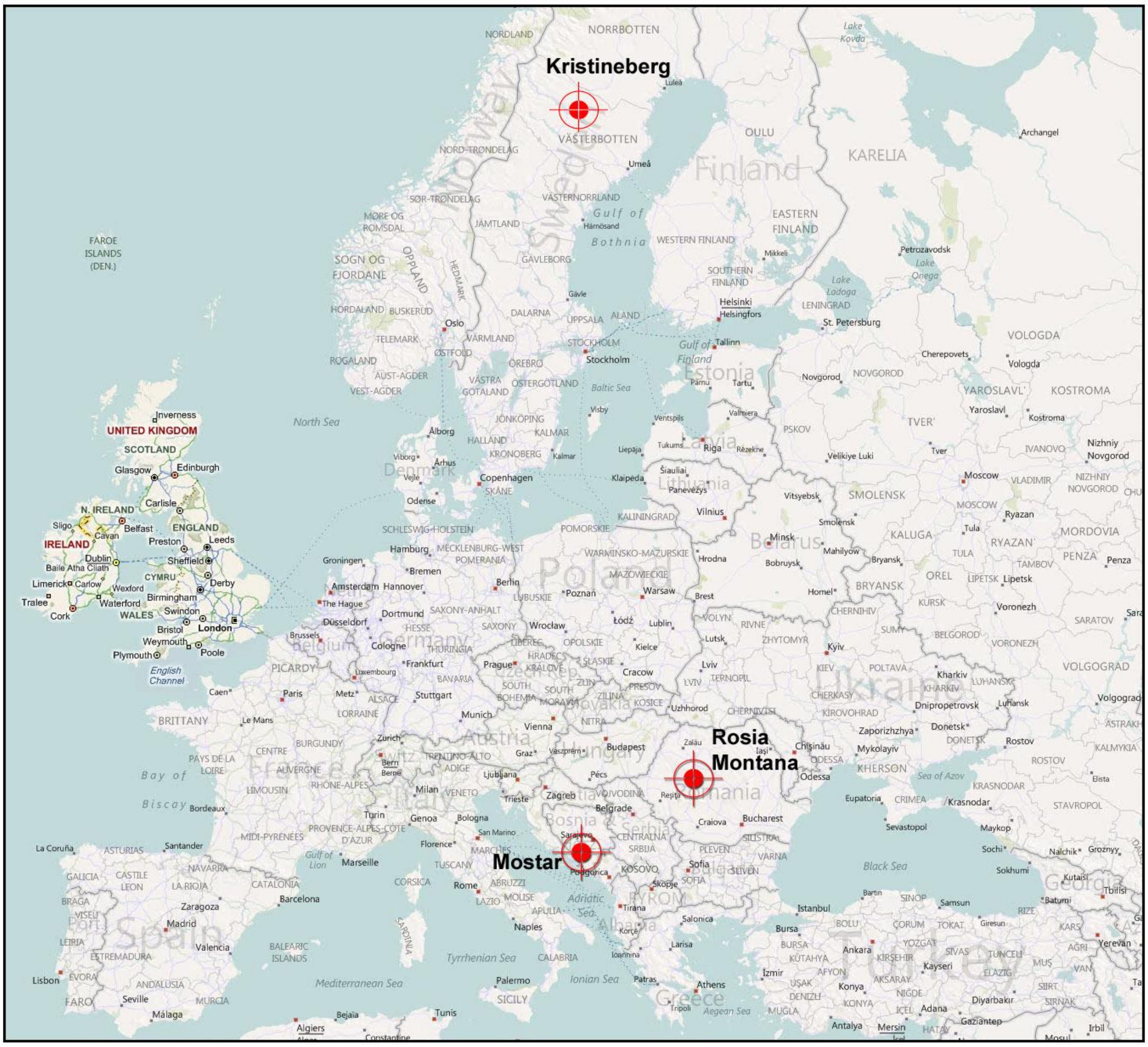

Figure 1 – IMPACTMIN study sites slated for coverage with airborne campaigns.

The demo-site implementation plan requires a detailed description of the different study areas considered in the ImpactMin project. An in-depth site overview description is therefore given and the potential environmental impact for each demo-site is described in function of :

a. The potential impacts and magnitude of a number of pathways in which the surrounding environment and communities can be exposed to the harmful effects of pollutants associated with mining and minerals processing activities.

   The pathways/vectors identified in the course of Deliverable 5.1 include:

   - airborne transport of pollutants such as dust, smelter emissions, gases, vapours;
   - mass movement of "solid" wastes (generally tailings containing heavy metals, organic waste and toxic compounds);
   - mass movement of liquid, or semi-liquid wastes (again, generally tailings containing heavy metals and toxic compounds and/or large quantities of debris);
   - waterborne transport of wastes as suspended solids and as dissolved materials.

b. The relevance of the direct and indirect environmental variables related to mining activities as defined and described in previous deliverables (4.1 and 5.1).

A summary of the direct and indirect environmental variables related to mining activities, as defined and described in deliverables 4.1 and 5.1., is given in Table 1.

Observable	Type	Method	Direct	Indirect
Gas, aerosol, dust, smoke	Atmospheric	Hyperspectral	X	
Water turbidity, clarity	Hydrologic	Hyperspectral	X	
Surface pollutants	Material	Hyperspectral and Gamma Ray	X	
Plant health, biodiverstiy	Biosphere	Hyperspectral		X
Heavy metal pollution	Material	Hyperspectral		X
Acid mine drainage	Material	Hyperspectral	X	
Organic pollution	Hydro-Biosphere	Hyperspectral, Gamma Ray		X
Land Stability	Geology	Hyperspectral		X

Table 1 – Summary of direct and indirect variables pertinent to mining activities.

Data availability varies from site to site, ranging from previous studies (e.g. soil and water sampling) to general, regional-wide assessments (e.g. hydrography, land-use studies). As a whole, the Mostar Valley and Kristineberg sites have significantly more accessible information than Rosia Montana site.

Data collection will vary from site to site: airborne electro-optical survey on UAV for Kristineberg, airborne hyperspectral and gamma-ray for Mostar, and possible airborne hyperspectral and/or airborne gamma-ray for Rosia Montana site. The remotely sensed data are to be backed up with significant ground-based fieldwork in soil sampling, soil and plant spectroscopy, water-quality and water-spectroscopy studies. The goal of the additional surveys is to directly correlate airborne measurements with quantifiable, field-observable phenomena in several control regions.

MOSTAR VALLEY SITE, Bosnia and Herzegovina

The sections below discuss some of the main observables and evaluation strategies for the Mostar Valley sites of interest, with particular accent given to the Vihovici Coal Mine site.

Site overview

The 'Vihovici Coal Mine' is located in the Mostar Valley, Bosnia and Herzegovina. The mine was exploited by 'Rudnici mrkog uglja' (Brown coal mines of Mostar), a state-owned company, but is inactive since 1991. The mine had entered production in 1901, first as an underground operation, but from 1963 on, open pit mining was performed. In total, 11 million tons of brown coal (lignite) were extracted from the mine. 3.5 million tons were produced by surface exploitation (open pitting). The total area of the mine site is 76 ha, with 43.2 ha surface operations and an open pit of 7 ha. The mine was used as public solid waste dump from 1992 – 1995. Illegal waste dumping continued until 2007, when a remediation program was started and in 95% of the mine area some of the surface waste was removed. Underground coal fires were (apparently) extinguished by water and fly-ash pumping.
The mine is located in a karst landscape, with associated typical structures (e.g. caverns, sinkholes, dolines). Geomorphology of the region is also dominated by alluvial formations along the Neretva River. The climate is a semi-arid, Mediterranean climate. Surface cover is sparse and consists of low-lying Mediterranean shrubs (wild pomegranate mainly). There are five general zones of Neogene layers: sandstone, breccia, sand-gravel clays, sand marls and limestone. The main carbon-coal seam is composed of direct bottom and roof layers and a carbon layer with interlayer and refills of muck. The geology of the area consists of Perm-Triassic strata, ranging from plaster-anhydrites, unconsolidated limestone, clay and mudstones, which are compressed during folding episodes and exposed on the surface and thrusted upon Mesozoic rocks.

Environmental impacts

The full impact of the mining and industrial legacy in Mostar may never be fully known. As many other sites in Bosnia and Herzegovina, the Mostar region has been heavily industrialized in resource-extraction, smelting and defense sector and various sites have been closely co-dependent (e.g. Vihovici coal was burned to provide energy to the Aluminij aluminum factory, which was then providing the aluminum to the Soko aircraft factory). The effects of this close relationship are still evident in Mostar, but Vihovici mine had and has the closest impact to the Mostar urban area, which has closed in onto the former mine grounds.

The mining operations themselves have extended underneath and around the city of Mostar. Newer (post 1995) sections of town have been largely built on top of the old mine-waste tailings and refuse piles, encroaching even onto the perimeter of the former open-pit. Furthermore, former mine workings and tunnels are in contact with the ground-water (karst environment) and direct or indirect contact with the Neretva river.

The problem of the former mine increased when it was transformed into an unregulated municipal waste-dump and when the underground coal (and organic material) fires ignited, spewing hazardous gas in the middle of an urban area. The area was ameliorated in 2007-2009 through the combined municipal and international assistance effort (see KFW reports 2007 and 2009). However no follow-up has been performed to see how effective these remediation efforts were. This report will intend to lay out the case and need for continued monitoring of a former mine and associated areas in the Mostar valley and their overall impact to the environment.

Pathways of exposure

Among the sites and operations present in the Mostar Valley, it is clear that the dominant pathway of exposure – at all levels of interest – is via waterways (fluvial transport). A secondary pathway of importance appears to be the potentially-toxic particulate pollutant transport as dust or gas from the potentially still active coal-burning fumaroles.

Some of the potential impacts and magnitude of these pathways in Mostar Valley, Bosnia and Herzegovina are outlined below:

- *Waterborne transport of wastes*

Much of the Mostar region exhibits limestone karst geology and as a result groundwater migration – and the migration of any subsurface pollutants – is often rapid due to the existence of underground watercourses. Karst springs are common throughout the territory and surface watercourses are generally swiftly flowing.

Sewage and waste-water control systems are generally in poor condition and waste and waterborne pollutants, often arising from areas of waste disposal, are a serious concern for the environment and public health in the country. Currently, municipal waste is being collected in about half of the urban municipality in an organized fashion, but rural municipalities are generally not included in waste collection. Large quantities of waste are reportedly being dumped illegally at roadsides, rivers, abandoned mines (inclusive of Vihovici, and other prospects not encompassed in the mine-remediation effort) and so forth, posing threats to public health and the environment. Large quantities of municipal waste in Mostar were re-buried at the Vihovici site and are still present in the location raising the possibility of continued leaching into the water system (Civil Society Promotion Center of Sarajevo, 2002; KFW report, 2009).

Among areas of significant pollution from land-based activities, hot spots are listed as the sewerage system and wastewater treatment plant in the town of Mostar, Vihovici pit mine and associated prospects not included in the remediation effort, red mud disposal areas associated with the aluminium factory in Mostar, and the Neum-Klek area on the coast (Figure 2). Further, the Federal Ministry of Physical Planning and Environment report that approximately 300 000 hectares are currently being contaminated by anthropogenic activities, while some 50 000 hectares are severely contaminated. (Federal Ministry of Physical Planning and Environment BiH, 1998).

Impact significance to the project: HIGH

Figure 2 – Some of the important features and localities in the Neretva river watershed from Mostar Valley, Bosnia and Herzegovina to the Neretva River Delta and Adriatic Sea in Croatia.

Figure 3– Flood waters (2010/11) in the vicinity of Vihovici mine

- *Airborne transport of pollutants*

By the early 1990s, the use of low grades of coal and lignite in the region's industrial and electric power generation facilities had raised the emission of sulfur dioxide in some areas to levels that were reportedly twice those recorded in Western Europe. Concentrations of SOx and NOx were consistently in excess of safety guidelines set by the World Health Organisation (WHO) and uncontained emissions from the nonferrous metals processing plants and smelters also contributed to regional acid rain (Steblez, 1994c). Moreover, such sites often contributed to serious local/sub-regional heavy metals contamination of the environment as a result of fallout (cf. UNEP, 2004b for examples).

The Vihovici coal was considered to be in the higher-grade brown-coal category, but still plagued with a fair share of impurities and sulfur content, which when ignited, resulted in notable quantities of SOx/NOx/COx gasses introduced into the environment. Some of the leached heavy metals were also present in the mine-waste tailings as well as by-products of associated aluminum refining facility in Mostar valley.

Of particular importance to the project is to examine the effects of underground coal-fire extinguishing campaign. As noted in the final report of the KFW, the total heat energy stored is dependent on the heat capacity of the rock and the heated-up volume. Typically a volume of rock was heated up over the years. Due to the small heat conduction in those rocks, heat can only be slowly extracted (in 1-2 years). If this is not completely extracted it may cause re-ignition. It is also possible that the coal fires ignite burning-of the waste deposit or even that the heated rock would cause chemical reactions within the waste deposit which could produce hazardous gases and combustion residues. The composition and location of the waste deposit is not finally clear for the whole site and previous investigations have showed inconsistent results. If the hundreds of thousands cubic meters of waste (Nuic et al, 2007) which have not been found already, really have been deposited they could interact with the coal fire zone. The burning of the coal causes a reduction of volume which leads to subsidence damages. New fractures may develop and destabilize the existing steep slopes further more. This will be dangerous for visitors, buildings etc. dependent how the area will be used.

Impact significance: MODERATE TO HIGH

- *Mass movement of wastes*

The area of South Eastern Europe, including Mostar valley exhibits levels of intensity sufficient to cause concern for the stability of mining hazards. In particular, the stability of tailings impoundments throughout the region is an issue - in the event of mild earthquakes such impoundments can fail (UNDEP). A regional seismic-hazard map showing risk in the region is provided in Figure 4. It indicates that earthquakes of moderate to high intensity can be anticipated for all countries in the region. Roughly 20% of the region experiences events of very high intensity.

Furthermore, an above average rainfall may propagate collapse of existing revetments and overfill of holding capacity resulting in a spectacular collapse and evacuation of mine waste. A large quantity of water and mine waste is held by an earthern-berm / cliff on the east side of the Vihovici mine (Figure 5). Similarly a large quantity of red-mud is held in a depo above Mostar valley in a similar impounding area (Figure 6). The overall conditions of the impoundments and ensuing risk in the case of mass-wasting is unknown at this point. Geotechnical stability of red mud storage is also unknown. Significant risk of groundwater and surface water pollution from solid waste: 40–60 kg mixed solid wastes per ton Al, SPL - 50% refractory material, 50% carbon, impregnated with aluminum and silicon oxides and cyanide compounds (about 400 ppm), skim, dross, fluxing slags, and road sweepings.

Impact significance: MODERATE, but possible cross-border effect as Croatia is 30-40km d/s on Neretva River (See Figure 2).

Figure 4 – Seismic risk in the Western Balkans (City of Mostar indicated with the red dot)

Observables to detect environmental impacts

The use of imaging spectroscopy allows entire mining districts and associated areas to be screened quickly to identify potential zones of problem in mine waste or unmined rock outcrops, often through subtle changes in the reflectance spectra of minerals and surface cover indicating major differences in chemistry with spectral information acquired from an airborne platform or associated field/laboratory measurements:

Figure 5 – Vihovici pit wall and 300m distance to Neretva River

Figure 6 – Red mud storage area above the Mostar Valley

Iron-minerals

Iron is often the most abundant contaminant in mine water, particularly in coal mine drainage. Apart from its contribution to acidity, excess iron in watercourses can have several other environmental impacts:

- Iron, much as many other metals, is a trace element needed by humans and other vertebrates. But when organisms take up large amounts of iron, acute and chronic toxic reactions occur, such as peroxidation of lipids followed by damage to protein structures. As a chronic toxin, iron can cause haemochromatosis, cirrhosis of the liver, vascular congestion and eventually death (Frazer, 2005).

- Turbidity caused by iron precipitates (ochre) reduces the incidence of light in the water body, impeding photosynthesis in these areas and causing food chains to break down. The biodiversity of affected areas declines and may finally upset the balance of the ecosystem, a readily visible effect of mine water contamination.

The iron mineral absorptions are readily identifiable with hyperspectral imagery both in the soils and in water and can be used to highlight the areas of possible concern.

Heavy metals

The toxicity and effect of heavy metals on the environment is known and has been heavily documented in the past and has been a subject of a Framework Program 6 ESPREME (Estimation of willingness-to-pay to reduce the risks of exposure to heavy metals and cost-benefit analysis for reducing heavy metals occurrence in Europe).

Even though concentrations of heavy metals vary by coal seam and geographic region, a variety of metals are associated with it, which are either found in the coal directly or in the layers of overburden and inter-layers between different coal seam. The mobility of heavy metals in coal mine waste piles depends not only on their current states and the stability of their host minerals (usually clays), but also on the properties of the coal itself. In the process of coal mine waste-water interaction (meteoric and groundwater), sulfides that contain heavy metals first break down and release metals, which are then adsorbed and complexed by the iron oxide-hydroxide colloid resulting from pyrite oxidization and organic matter (naturally occurring in the coal). During the natural weathering of coal mine waste, only a small fraction of the metals are released to the environment immediately; most of them still remain in the residual material and release material over lengthy time period (Dang et al,. 2002).

Metals appear in the municipal solid waste stream from a variety of sources: batteries, consumer electronics, ceramics, light bulbs, house, dust and paint chips, lead foils such as wine bottle closures, used motor oils, plastics, and some inks and glass can all introduce metal contaminants into the solid waste stream. In small amounts, many of these trace elements (e.g., boron, zinc, copper, and nickel) are essential for plant growth. However, in higher amounts they may stunt or decrease plant growth. Other trace elements (e.g., arsenic, cadmium, lead, and mercury) are of concern primarily because of their potential for bioaccumulation in the organism.

Unfortunately, it is rather difficult and laborious to detect runaway heavy-metals in the environment, because they do not usually exist in their pure form but rather in a soil-water-vegetation matrix as waste rock materials, sediments or as a result of soil deposition. Instead of detecting the minerals themselves, imaging spectroscopy can be also used to detect the composition and condition of vegetation (where applicable), which can then be used to interpret the mineral deposits or metal composition of the soil in the area where the vegetation is growing.

Radionuclides

There are anecdotal inferences that in Mostar Valley, and particularly Vihovici region are potential concentrations of radionuclide resulting from radioactive waste (left over from former defense industry in the region) or from the use of Depleted Uranium (DU) munitions.

Furthermore, some of the brown coals and lignite beds are known to contain above-average concentrations of radioactive elements (U, Th) precipitated from ground water and deposited as a reaction of organic carbon. Some of the coals in the region are enriched in Uranium and have been subject to studies for extracting Uranium (Kulenovic, pers comm. 2008).

The gamma-ray spectrum data should highlight the areas of concern with elevated counts in equivalent Uranium (eU) data and total air count radioactivity data.

Gas Detection

Even though stand-off gas detection using hyperspectral imagery is mainly performed in the thermal infrared region, some of the gasses that may be associated with still-burning coal seams in Vihovici mine may be detected in hyperspectral VNIR-SWIR imagery. Bo~~r~~th CH_4 (methane) and CO_2 have absorption features in the reflective portion of the spectrum (e.g. Pieters and Englert, 1993; Roberts et al., 2010), but the direct detection is difficult against the non-homogenous background because CO_2 is already present in the atmosphere and CH_4 has a very narrow absorption band~~s~~ that may be masked by other absorptions (de Jong, 1998).

The intent is to use the high spatial and spectral resolution of the airborne sensor coupled with the ground-based observations to develop training sites and sets for the detection of possible fumaroles resulting from the underground coal fires.

Organic Waste

There are still occurrences of organic waste being dumped in the wider Vihovici region. Some of it is animal-carcass waste and some of it related to wild dumps of motor oil, diesel fuel contaminated soils, transformer oil (PCBs) and other potentially dangerous substances. Some of the organic-wastes (e.g. hydrocarbons) have observable characteristics in reflected solar spectrum, which may allow for their successful detection and eventual remediation (Kuehn et al., 2004).

Soil-stability

Reflectance spectra are exploited to delineate zones of problematic mineralogy, particularly in the instance of hydrophilic clays (e.g., montmorillonite, illite) which tend to contribute to landslide propagation either by increasing the loading factor of the slope or serving as a lubricant in plane motion. By applying HSI, it is possible to determine the presence of sulfates (e.g., jarosite) which can be indicative of acid-dissolution and weathering of surface rocks, presence of iron oxides and hydroxides (e.g., goethite, limonite) often indicative of water-rock interactive processes and weakening of surface layers and/or changes in the cohesiveness of the revetment. The combination of both image and point spectra allow us to determine the extent of the problematic zones as well as the type of vegetative cover as an indirect observable in determining the propagation-likelihood of mass-wasting within the observed area.

This type of observation is mainly geared towards pit walls and revetments holding the pit lake in Vihovici, and the overall cohesiveness of other barriers holding the mine waste in the Mostar Valley region.

Water quality

Flowing along the hydraulic gradient through different groundwater and surface water pathways, the mine water affects and pollute environmental water settings (groundwater, streams, lakes, coastal and marine water) across municipal, regional and national borders. As a result of this, some of these impacts can persist for centuries after mine closure. Classical practice in dealing with industrial pollution discharges may not be fully suited to regulation of the impacts of mining on the water environment.

It was shown previously that water pollution caused by mine water and mine waste at any given water recipient downstream is determined by both the source emission and the subsequent hydrological transport and hydro geochemical retention/attenuation of emitted pollutants. These pathways comprise complex structure through soil water, groundwater and surface water systems. This further results in a coupled monitoring and prediction of water flow and pollutant transport with attenuation processes on a catchment scale. Since the monitoring program for mining environmental impacts plays a crucial role in future water resources management (under WFD) and sustainable mining, new innovative monitoring techniques must be carefully analyzed and proposed to decision makers for future environmental compliance of mining activities.

Mining activities inevitably disrupt preexisting hydrological pathways within the geologic strata. All types of mining have the potential to directly disrupt groundwater flow (Booth, 2002), which in turn can affect surface waters that are in hydraulic continuity with the affected groundwater system. In most cases the impacts on the natural water systems arising from the mining activities tend to be relatively localized and limited compared to other mining related impacts such as those associated with dewatering. Many of these impacts can be anticipated before they happen and mining companies should be able to mitigate them and provide detection based monitoring.

Mining impact from mines which went through the closure process, such as the Vihovici site in Mostar, result from the seepage of contaminated leachate from waste rock piles and tailings dams. This is a significant cause of surface and groundwater pollution in many mining areas. This form of pollution can persist long after site operation cease. Moreover, previously created mine waste deposits have suddenly begun to generate acidic leachates many years after they have been left unattended. The Impact coming from abandoned mines can eventually lead to renewed environmental impacts, following the recovery of groundwater levels (a process called "rebound") to the preexisting base level of drainage.

Very often the mine sites give a rise to heavy loadings of suspended sediments in receiving water courses resulting in increased turbidity and decreased light penetration. This directly affects the primary producers in aquatic ecosystems like different algae by inhibition of photosynthesis, and in turn reduces the food availability for the macro invertebrate community in surface waters and alters the fish population that feeds on them (Newcombe and MacDonald, 1991). The use of hyperspectral sensors at different scales can provide innovative way of properly monitoring such important environmental impact of surface waters. At present, the results of spectroscopy are limited to measuring those substances or conditions that influence and change optical and/or thermal characteristics of the surface water properties. Suspended sediments, chlorophylls, coloured dissolved organic matter (CDOM), temperature, and oil are water quality indicators that can change the spectral and thermal properties of surface waters and are most readily measured by remote sensing techniques.

Substances (i.e. nutrients, metals) that do not change the optical and/or thermal characteristics of surface waters can only be inferred by measuring surrogate properties (i.e., chlorophylls) which may have responded to an input of chemicals. Increases in water quality parameters such as chlorophyll a, turbidity, total suspended materials (TSM), and nutrients are symptomatic of eutrophic conditions.

Data availability

- Topographic maps related to Mostar Valley and Vihovici
- Airborne Orthophoto Images - resolution 0.5m, year 2007
- ASTER rainbow Digital Elevation Model (20m resolution)
- Existing 20kW and 110kW power lines (including location of poles)
- Existing information for the Vihovici site, described in D5.1 Report and referenced within this text as KFW Report (2005 – 2008).
- Satellite imagery for the demo site and surrounding area, and extensively described in D4.3 Report ‘Satellite mission planning for the demo-sites’.

Data collection needs

Combined high-resolution hyperspectral/gamma-ray survey is required to classify the areas of interest at Vihovici abandoned brown-coal mine near Mostar, Bosnia and Herzegovina with regards to the surface mineralogical, vegetative, hydrologic and anthropogenic cover. The narrow band-passes (5-10nm) and high spatial resolution (1m or better) of the airborne hyperspectral imager is expected to allow definition of the discrete observable parameters of surface materials, in particular contaminants related to mining (clays, sulfates), organic materials (hydrocarbon polution) and overall surface-waste composition of the mine closure area near Vihovici (some of the surface refuse is mine-related and some of it is municipal in origin).

Furthermore, by using better-defined atmospheric parameters and narrow band-pass of the instrument, the intent is to map the distribution and location of possible toxic-gas emitting fumaroles (CO, H_2S, CO_2, SO_2) which may still be present as a result of underground burning of coal seams in Vihovici region.

Lastly, any effluence of toxic substances into Neretva river, via surface or subsurface pathways is bound to generate detectable response, particularly because the rivers are fairly clean. Using the yellow-blue region ti NIR regions of EM spectrum covered by the hyperspectral imager, it is intended to identify the zones of increased nutrient load, increase in dissolved solids or other phenomena suggestive of surface or subsurface contamination of the karst watershed.

Gamma-ray spectroscopic data can be flown in conjunction with hyperspectral data to offer additional information about the overall geology, but also to identify hot spot zones indicative of industrial and military waste deposition at 1:10000 scale. There are anecdotal reports of radioactive waste dumped at Vihovici region before, during and after the 1992-1995 war (e.g. Fichtner report, 2006), especially as a product of weapons testing and manufacturing of a nearby Soko industrial facility. Additionally there are anecdotal reports of both Yugoslav and intervening NATO forces using depleted-uranium munitions in the wider region, which have been a topic of specalized environmental and health studies (e.g. Jia et al., 2006, Sumanovic-Glamuzina, 2003). Using a high resolution, densely-spaced radiometric survey, possible presence of radioactive materials present in or around Mostar could be detected and further substantiated or disregarded. In addition, the coals-sequences and other occurrences of hydrocarbon deposits in the Central Dinarides region, reportedly contain above-average radiation levels (e.g. Kljajic et al., 1996, Hrvatovic, 1999) as a result of uranium deposition as a result of precipitation from the surrounding geological strata in the vicinity of hydrocarbon contacts.

The main challenges to the Mostar site are the low-altitude of required airborne operations and data acquisition over a heavily urbanized area. Operating in a congested area, with overhead infrastructure (e.g power-lines) in a relatively narrow mountainous valley, requires careful mission planning and safety considerations to minimize any potential risk on the ground.

Data collection

The detection of environmental impacts will be mainly carried out with airborne instrumentation with support of field and laboratory measurements that can calibrate and validate remotely-sensed imagery in several control station / sites.

The hyperspectral airborne component will be carried out with a combined visible-near infrared (VNIR) and short-wave infrared (SWIR) sensing system operating in 420 – 2500 nm spectral range, with over 300 spectral bands, and ground resolutions of 1m and 2m. The ultimate goal is to cover the immediate site of interest with high resolution passes, while the areas of regional concern in Mostar Valley are to be covered with 2m passes. The exact parameters of collection are provided in the associated image data management appendix. The airborne fligths need to be accompanied with ground measurements at the time of the overflight supporting the atmospheric correction of the airborne hyperspectal images:

- sun photometer measurements for AOT and water vapour content

- VNIR-SWIR reflectance measurements of at least two reference targets (1. Low albedo target and 2. High albedo target). The selected reference targets should fulfill the following requirements:
    - Sufficiently large (at least 5x5 pixels but the larget the better to avoid adjacency effects
    - Homogeneous
    - Lambertian
    - Featureless

  Good candidates for reference targets are asphalt, concrete, sand, beach.

The gamma-ray airborne component will be carried out with a light-weight gammaray system at 50 m line spacing over Vihovici mine.

The supporting data collection on the ground will be carried out simultanaeously on the water and in selected surface locations in Mostar Valley. The verification and truthing sites will be determined from prior field survey of the sites including geologic mapping of the surface cover in Vihovici and appraisal of control points on Neretva river. The supporting data will mainly consist of reflectance spectrum measurements using point-spectra spectroradiometers operating in VNIR-SWIR spectral region. Additional measurements will be also performed on the sites:

Field sampling and analytical methods

Water quality retrieval

The airborne campaign will be complemented by the ground truthing, ground sampling and water quality campaign on the ground, as presented in this section. The methods will be optimized and adjusted with the progress of the airborne operations in the area. Observables that have to be monitored resulting from previous site descriptions are: minerals, acid mine drainage, vegetation stress, soil pollution and water quality.

Inland waters, like those under investigation for the impact of mining activities, are optically complex because of the presence of Algae, Total Suspended Matter (TSM) and coloured dissolved organic matter (CDOM) and their combined influence on the water-leaving reflectance spectra. This implicates that several standard algorithms in use for water quality retrieval from the open ocean are not suited for these waters. With the advent of new sensors with improved spectral, spatial and radiometric resolution, these optically-complex waters have been studied in detail and new improved algorithms and approaches have been developed to retrieve water quality parameters in these complex waters. They range from simple site-specific empirical to purely analytical algorithms. In the analytical approach the water constituent concentrations are physically related to the measured reflectance spectra using sophisticated radiative transfer models (e.g. Hydrolight). These radiative transfer models are being used to generate Look-Up-Tables or train sophisticated neural networks to retrieve concentrations values.

The semi-analytical approach uses simplified bio-optical models that describe the relationship between water reflectance and the concentration of constituents and their Specific Inherent Optical Properties (SIOPS). A well-known bio-optical model is the one developed by Gordon (1975):

$$R(0-,\lambda) = f * \frac{b_b(\lambda)}{a(\lambda)+b_b(\lambda)}$$

with a(λ) the spectral total absorption coefficient at wavelength λ (m^{-1}), $b_b(\lambda)$ the spectral total backscattering coefficient at wavelength λ (m^{-1}) and f an empirical factor which depends on solar and viewing geometry and volume scattering in the water. These models are then inverted - e.g. matrix inversion (- to derive concentration values.

These analytical and semi-analytical approaches are based on our physical knowledge of the radiative transfer in waters and should be more robust and more widely applicable than the empirical models. In practice these algorithms seem to be highly sensitive to errors in the atmospheric correction and sensor noise. Under the same conditions empirical band ratio or band difference algorithms sometimes have surprisingly good results. Another important advantage of the empirical models is that the inherent optical properties of the water constituents do not have to be known upfront which makes the field measurements more straightforward as only focus should go to concentration measurements of TSM and algae particles.

For the field campaign related to the study of water quality it is important to emphasize that the ground reference data is captured at the same time as the overflight. This because of the large temporal variation in concentration values in river systems and the variable atmospheric conditions influencing the sky-water interface reflectance (Sky reflectance) which need to be corrected for. It is advised to acquire multiple flight lines in order to better align ground data with simultaneous airborne measurements.

As indicated above there are several ways to study the water quality for those constituents which are optical active. The choice of the applied algorithm determines to a certain degree also the required field measurements. (Semi-)Analytical models require the Specific Inherent Optical Properties (SIOPS) of each water constituent as an input while empirical models only need a statistical relationship between the measured water leaving reflectance and the concentration values of those constituents under consideration. Both models however require high quality concentration measurements and water leaving reflectance spectra for model calibration and validation. Protocols for these measurements, including the SIOPS measurements, are described in detail in existing protocols like REVAMP or SIMBIOS (http://www.brockmann-consult.de/revamp/pdfs/REVAMP_Intercal_report_final.pdf) (http://oceancolor.gsfc.nasa.gov/DOCS/)

The following section gives an overview of the most common field measurements (and attached processing method) for water quality studies. For a more complete overview the reader is referred to the protocols mentioned above.

1. *Water samples*

Equipment: dark plastic bottles, cooling system, GPS

Description: The water should be sampled from vessels or pontoons ca. 50cm below the water surface. The water samples should be stored in dark bottles and kept cool using dry ice immediately after sampling. Since the exact overpass of the airplane mostly deviates from the planned overpass times, some additional samples must be taken between the planned sampling positions. To determine the exact position of the vessels a GPS should continuously log the position.

2. *Water-leaving reflectance (Rw)*

Equipment: ASD spectrometer or RAMSES spectrometer, spectralon reference panel

Description: The water-leaving reflectance is measured with an ASD (Analytical Spectral Devices, Inc.) FieldSpec FR spectrometer (Figure 6) aboard the vessel or from a pontoon. The downwelling irradiance above the surface (E_d(a)) is measured using an almost 100% reflecting Spectralon reference panel. Then, the water-leaving radiance (L_w(a)) is measured by pointing the sensor at the water surface at 40° from nadir, maintaining an azimuth of 135° from the solar plane to minimize sun glint. Downwelling sky radiance (L_{sky}(a)) is measured at a zenith angle of 40° to account for the skylight reflection. Note that also other instruments exist to measure water leaving reflectance, one of which is also the RAMSES instrument (Figure 7). RAMSES consists of 3 TriOS spectroradiometers for the measurement of subsurface upwelling irradiance (E_u-), downwelling irradiance (E_d-) and upwelling radiance (L_u-). This arrangement allows the calculation of R_w either by a conversion of the upwelling irradiance (with a Q factor=4.4) or directly by the upwelling radiance measurement.

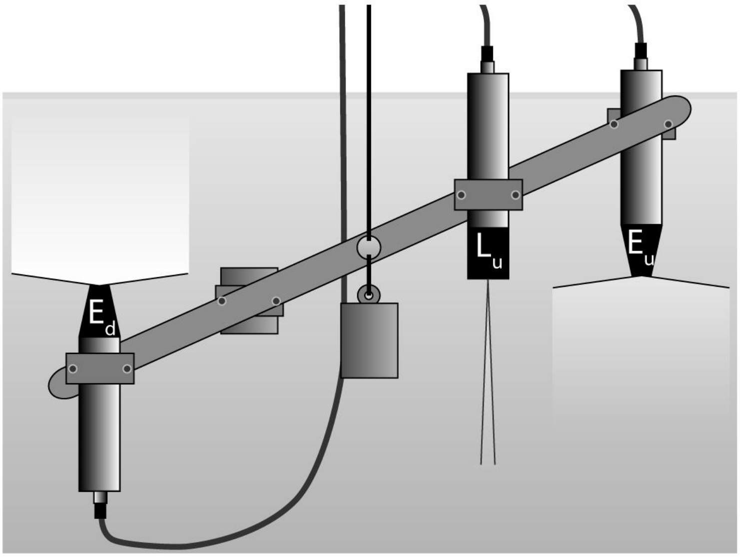

Figure 7 - Ramses instrument scheme

Figure 8 - ASD equipment measuring the Sky radiance

3. *Back scattering of suspended materials ($b_{b,p}$)*

Equipment: BB3 or AC-9
Description: The BB-3 metermeasures the back scattering and records information at three wavelengths: 440 nm, 595 nm and 780 nm. To be able to use the data, one should correct for inaccuracies due to the absorption losses in the measurements. Typical absorption characteristics can be obtained via absorption measurements of water samples retained on a filter (see below). The AC-9 equipment will measure both the water attenuation and absorption characteristics of the water from which one can derive the scattering (b_p) of the materials in suspension. To convert the derived scattering coefficients towards backscattering the ratio of scattering (b_p) to backscattering ($b_{b,p}$ /b_p) should be known. This ratio is commonly set to 0.01833 in literature, but one should be careful in adopting this value for other locations.

Figure 9 - BB3 equipment

4. *Secchi-depth*

Equipment: Secchi-depth
Description: A Secchi disk (**Hiba! A hivatkozási forrás nem található.**) is a white circular disk, approximately 25 cm in diameter, attached to a line marked with a stripe at 25 cm intervals and a broader stripe (or double stripe) at each full meter. A lead weight (~5 kg) is attached to the bottom of the rig to maintain the disk in a horizontal orientation as it is lowered and raised through the water. The disk should be lowered through the ship's shadow on the side away from the sun to reduce surface glint. The observer pays out the line, lowering the disk until it just disappears from his view and then raises it until just the depth where it again becomes discernable. The depth indicated by the line markings at the water surface when the disk disappears from the observer's view isrecorded as Secchi depth in m and is related to the total suspended material (TSM) concentration and turbidity.

Figure 10 - Secchi disk in the water

5. *Aerosol optical thickness, water vapour content*

Equipment: Sunphotometer
Description: The aerosol optical thickness and water vapour content are two of the most important parameters which should be known to correct for the contribution of the atmosphere to the measured at-sensor radiance. A sunphotometer measures both the aerosol optical thickness and water vapour content of the atmosphere. The instrument should be positioned at a stable and open location and aimed directly at the sun.

6. *General atmospheric conditions*

Equipment: Camera
Description: At each location pictures should be taken from the sky to get an overall impression of the atmospheric conditions. The pictures below were taken during in field campaign at the river Scheldt, Belgium.

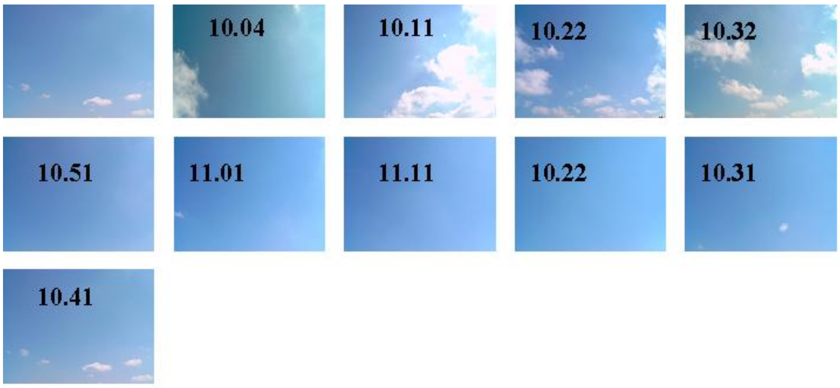

Figure 11 - Pictures from the sky taken at pontoon Sint Anna, Belgium

The water samples taken during the time of overflight can be used for the following measurements in the lab:

1) Concentration measurements

The method for Chlorophyll (CHL) analysis is the reference method ASTM D-3731-87 (2004) – Standard practices for measurement of chlorophyll content of algae in surface waters. Following this method the water samples should be filtered using 0,22 µm millipore filters and cleansed with acetone. They are homogenized and filtered again using 0,22 µm millipore filters. The extracts are transferred to the wells of 96 well plates and the fluorescence is measured in an automated system as an estimate of the chlorophyll content. The system should be calibrated by a chlorophyll standard solution.

Another possible methodology for CHL analysis, commonly applied in the literature, are being done using the High Performance Liquid Chromatography (HPLC) method. This method is fully described in the REVAMP protocols

TSM concentration is determined by filtering 250 ml of the water on Whatman GF/F glass fiber filters according to the European reference method EN 872 (2005).

2) Absorption measurement of algae (a_{CHL}) and Non-Algae Particales (a_{NAP})

The water samples, which should be filtered at the day of the field campaign are used to measure the absorption of the Algea and Non-Algae Particle constituents in the water samples. If these measurements can't be excecuted just after filtration, the filters should be frozen immediately. The specific absorption spectra of particles, non-algae particles and algae can be measured using an integrating sphere attached to an spectrometer following the methods described by Tassan and Ferrari (1995). The fraction of a light beam passing through and reflected by the filtered sample is measured inside the integrating sphere. Later on, the absorbance on the total suspended material can be derived and can be transformed to give the absorption coefficient in suspension (a_{TOT}). The samples are bleached with a 1% NaClO solution for 4 min. resulting in a depigmentation from which the a_{NAP} can be measured. Afterwards, a_{CHL} can be derived by subtracting the a_{NAP} from a_{TOT}. Examples of equipment to be used to measure a_{CHL} and a_{NAP} are the Uvikon 930 dual beam spectrophotometer or an ASD attached to a LICOR integrating sphere (Figure 10).

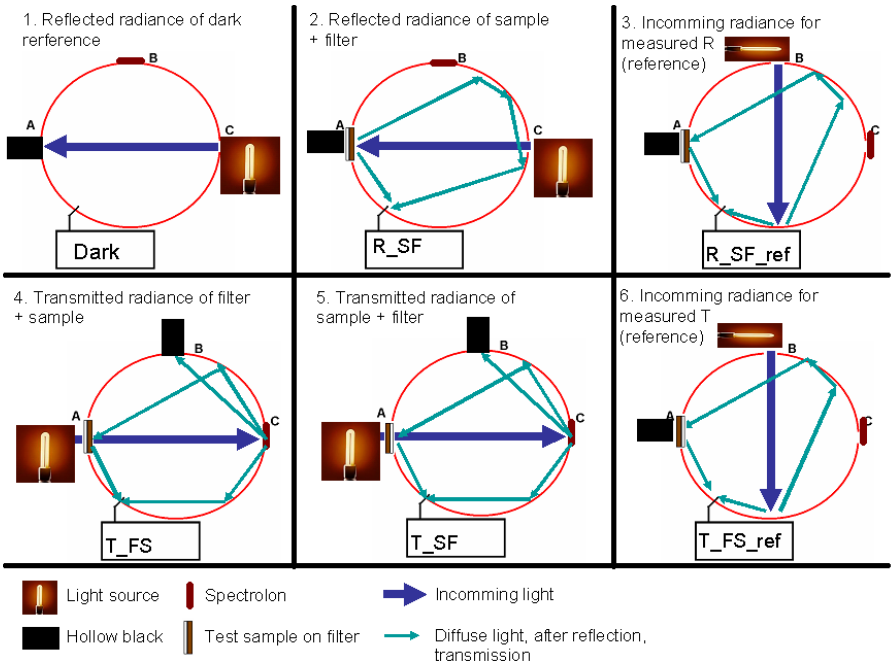

Figure 12 - Schematic overview of the steps involved to measure a_{NAP} and a_{TOT} with the ASD and LICOR integrating sphere

3) Absorption measurements of CDOM

To measure the absorption coefficient of CDOM, the water samples are carefully filtered with 0.2 µm pore size filters (Whatman Nuclepore Membrane 47mm). Before filtration, all the filtration material should be dried in the oven at 450°C for 4 hours, to remove any organic matter. Beam attenuation of the filtered water is measured in a 10 cm transparent cuvet using an Ocean Optics spectrometer or a Uvikon 930 dual beam spectrophotometer. It is generally accepted that the absorption is the only relevant optical property for CDOM and as such the absorption of CDOM can be assumed to be equal to the measured attenuation.

In Table 2 one can see an overview of the measurements and involved equipment for optical water quality measurements:

Measurement	Instrument
Position	GPS
Water leaving reflectance (Rw)	ASD/RAMSES/..
Specular reflectance (Rsky)	ASD/RAMSES/..
Secchi-depth	Secchi-meter
AOT(Visibility), Water vapour	Sunphotometer
Backscattering TSM	BB3, AC9,..
Absorption CHL-a	ASD+ LICOR/ Uvikon dual beam spectrophotometer
Absorption TSM	ASD+ LICOR/ Uvikon dual beam spectrophotometer
Absorption CDOM	Ocean Optics equipment/Uvikon dual beam spectrophotometer
Concentration TSM/CHL	European reference method EN 872 (2005). HPLC or ASTM

Table 2 - Overview of the measurements and involved equipment for optical water quality measurements

Soil:

Position	GPS
Surface reflectance cal.	ASD + Spectralon
Surface reflectance target	ASD
Surface cover type	Geologic/Pedologic chart
Downwelling radiance	ASD RCR
Absorption CHL-a	ASD+ integrating sphere

Table 3 - Overview of the measurements and involved equipment for soil measurements

Results and Limitations

The main expected result of the airborne campaign is the overall snapshot of the current state of affairs with regards to post-resource exploitation state in the Mostar Valley,

The snapshot will have four benefits:

1. Ascertain the success of 2007-2009 remediation at the Vihovici Mine site and point to the areas that are yet to be addressed or have been missed / re-activated from the first remediation attempt
2. Establish the baseline for Neretva river as a result of resource extraction before Vihovici, after Vihovici, below the city of Mostar and below the industrial area in the southern Mostar Valley.

3. Establish the current environmental baseline for the Mostar Valley and preliminarly evaluate other sites that may have problematic occurrences in the future (i.e. red mud storage).

The results from the airborne campaign will strengthen the observables from the spaceborne campaign and give additional elements of evidence towards understanding the past, current and future activities and developments in Mostar Valley.

The main limitation in the project is the ability to observe the listed phenomena, stemming from the facts that the City has grown on top of the abandoned mine lands. Additional challenges are pertaining to the other areas of resource extraction that are still in use and limit the access and evaluation on the ground. Hence, while some of the sites in Mostar Valley may be well covered with information, others may not earn the same scrutiny due to various temporal, budgetary and political concerns. Conducting this type of survey in an active and vibrant urban community is quite challenging and the dynamnic nature of observables may not always offer conventional interpretations, leaving some of the results and conclusions vague and extrapolative.

Legal Framework

Beside the City of Mostar and the Canton, this project has wider applicability and effect upon the stakeholders in Bosnia and Herzegovina. The resource-extraction activities are not simply the local problem, but also fall under the jurisdiction of various Entity and Cantonal Ministries with environmental responsibilities,.

State level – There are no laws or other regulations on the environment at the State level.

Entity level – Annex 2 to the new State Constitution stipulates that all laws that were in force in Bosnia and Herzegovina when the Constitution comes into effect and that are not inconsistent with it may remain in force. For the period 1996-2002, before new legislation was passed, this was important for the environment because it confirmed the standing in both entities of the Law on Physical Planning, passed in September 1987 (Official Gazette SR BIH 9/87). This Law was general and covered all major components of the environment. It dealt with the overall issues of urban planning, physical planning, the environment and building.The Federation of Bosnia and Herzegovina's new Laws on Physical Planning (Official Gazette F BiH 52/2002) and on Construction (Official Gazette F BiH 55/2002) go farther and include, for example, requirements for strategic environmental assessment " to protect the environment adequately spatial planning documentation is being prepared" (art. 8) and environmental assessment or environmental permits for new construction (art. 27, para. 4, and art. 41, para. 6).

Local Level – The principal stakeholders here are:
- Herzegovina-Neretva Ministry of Economy, Entrepreneurship and Agriculture
- Herzegovina-Neretva Ministry of Health, Labour and Public Welfare

Separate laws on the environment and environmental media were drafted after 1998 for each of the entities, with financial support from the EU Community Assistance, Reconstruction, Development and Stabilisation Programme (CARDS). Considerable effort was made to harmonize them in order to avoid future difficulties with implementation. Both packages of laws have been discussed and approved by the Inter-Entity Steering Committee for the Environment. The contents of these laws are not identical, but are very similar and there are no differences as far as technical issues and goals are concerned.

These laws are:
• The Law on Environmental Protection;
• The Law on Air Protection;
• The Law on Water Protection;
• The Law on Waste Management;
• The Law on Nature Protection; and
• The Law on the Environmental Fund.

The new laws reflect European practice. They are to a large extent harmonised with the goals and the principles of EU environmental legislation. (UNECE, 2004, pp 20-21).

KRISTINEBERG SITE, SWEDEN

The discussion in the sections below outlines the main environmental observables and evaluation of sites in Kristineberg mine area, Sweden.

General overview

Kristineberg is located in the Middle Boreal sub-zone, approximately 175 km south-west of Luleå in the Lycksele municipality of Västerbotten County, northern Sweden. The Kristineberg mine is part of the Skellefte mining district, one of three major mining areas in Sweden. The population of the Kristineberg municipality is 12,506 within an area of 5636 km^2. The landscape is dominated by coniferous forest (mainly Scots pine and Norway spruce), forest-mire complexes, mires and waterbodies. The vegetation period is on average ca. 150 days and the length of snow cover period is 150 days. The annual mean temperature is 1-2°C (February: -7 °C, June: 12 °C). Annual mean precipitation is ca. 600 mm.

The Kristineberg mining area (~300 ha) comprises a large tailings area and five mines, a large central industrial area that includes an old concentrator and three open pits. The mine has been operating since 1918. The mill was closed in 1991 due to decreasing tonnage to the mill and increasing milling costs as a consequence of closure of a number of small mines. Today, the ore is transported to the Boliden concentrator using 50-ton highway trucks, which are also used for transportation of backfill tailings to the mine. The mill capacity was gradually expanded from the original level of 300 000 tonnes per year, up to 1 million tonnes per year, a level that prevailed during the 1970´s and 1980´s. Today the main products recovered from the ore are zinc, copper and lead concentrates. The five ponds in the mining area are located along a valley between two mountain ridges (Figure 13). Initially, the tailings were deposited in two ponds, no 1 and 2, along the Rävlidmyrbäcken creek, which was diverted to bypass the ponds. In the 1950s, these ponds were filled up, and a new pond, no 3, was constructed south of the confluence between Rävlidmyrbäcken and Vormbäcken. Later, a fourth pond was constructed downstream. The ponds 3 and 4 contain most of the tonnage. A fifth pond, pond 1B, was constructed to be used as an intermediate storage pond for low grade pyrite and pyrrhotite, that was intended to be sold for sulphuric acid production. As the market for such products never developed, the material was left in the pond. At closure, the tailings area consisted of five individual ponds containing pyrite-rich tailings, including three old drained ponds containing weathered tailings (ponds 1, 1B and 2); one recently operated pond containing unweathered material (pond 4); and one pond also containing substantial quantities of precipitates from the treatment of acidic mine water (pond 3).

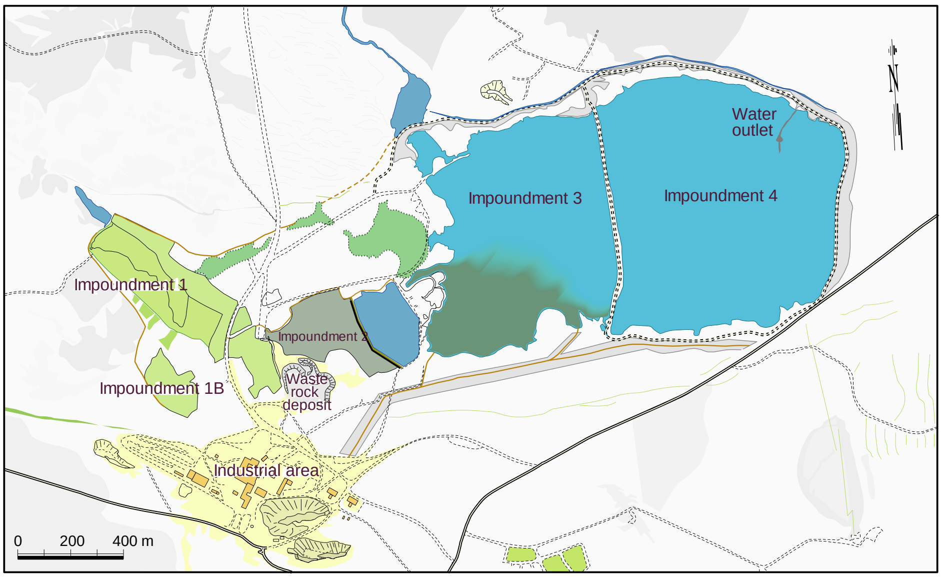

Figure 13 - Site map of the Kristineberg mining area showing the different ponds (impoundments).

The bedrock consists of ca.1.9 Ga metamorphosed orebearing volcanic rocks overlain by metasedimentary rocks. The metasupracrustals display a marked foliation and extensive sericitization. Pyrite-rich massive sulphide ores are intercalated within a stratigraphic unit consisting of mainly basic volcanic and redeposited volcano-clastic rocks.

Common ore minerals are pyrite (FeS_2), chalcopyrite ($CuFeS_2$), sphalerite (ZnS), galena (PbS) and magnetite (Fe_3O_4). Common gangue minerals include quartz (SiO_2), sericite ($KAl_2(AlSi_3)O_{10}(OH)_2$), chlorite ($(Fe,Mg,Al)_{4-6}(Si,Al)_4O_{10}(OH)_8$), talc ($Mg_3Si_4O_{10}(OH)_2$), biotite ($K(Mg,Fe)_3(AlSi_3)O_{10}(OH)_2$), and calcite ($CaCO_3$) (Holmström et al., 2001).

The dominating soil type in the area is till with incidence of gravel, sand, peat or none or thin cover of quaternary deposits.

Environmental phenomena

The ore mined in Kristineberg is not processed in Kristineberg. Therefore, in the Kristineberg area, two main pathways of pollutants can be identified:

- Waterborne transport of wastes as suspended solids and as dissolved materials
- Airborne transport, mainly in the form of dust

In Kristineberg, like in the Mostar Valley, the dominant pathway of pollutants is via water. This is of special concern in regions like northern Sweden that are characterized by a high incidence of lakes, rivers and wetlands.

Impacts and magnitudes

The impacts and magnitudes of impacts on recipients in the Skellefte mining district in general and the Kristineberg area in particular have comprehensively been summarized by Höglund and Herbert (2004). The information given below outlines the main aspects. Since waterborne pollutants and their impact on the environment are the main concern at Kristineberg, they are under focus in this report.

Waterborne

The water leaving impoundment 4 enters the small river Vormbäcken (Figure 14). Vormbäcken starts downstream from the lake system Sörsjön-Holmträsket-Norrsjön, almost 2.5 km upstream from the outlet from the mine area at Kristineberg, and flows for approximately 40 km before joining the river Vindelälven at Vormsele. Vindelälven is a primary tributary to the river Umeälven, which in turn enters the Bothnian Sea at Umeå.

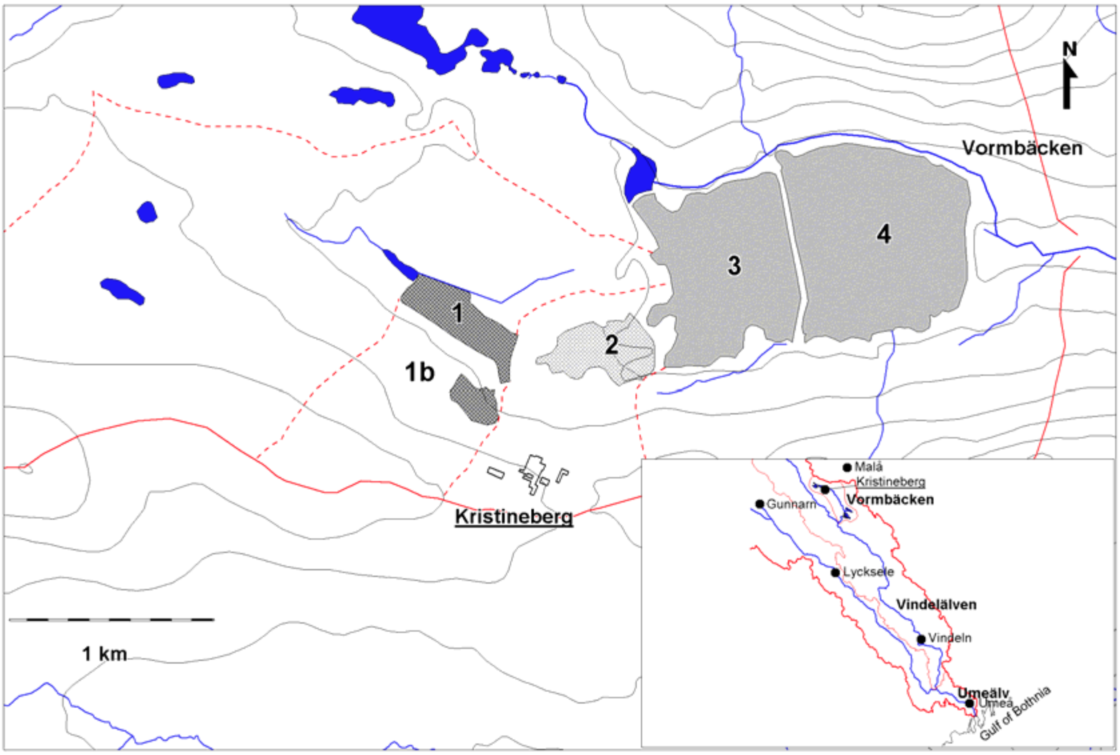

Figure 14 - Local water catchment area at Kristineberg. The dashed lines marks identified sub-catchment areas. From Höglund and Herbert (2004).

The major tributaries to Vormbäcken are drainage from the lake Holmtjärn, and the rivers Kimbäcken, Svältamyrbäcken, Svartbäcken, and Rökån. Approximately 14 km downstream from the Kristineberg mine, Vormbäcken joins Rökån. Before entering Vindelälven, Vormbäcken flows through the 8-km^2 lake Vormträsket. The difference in elevation between Sörsjön-Holmträsket-Norrsjön and Vormsele is about 130 m. The catchment area of Vormbäcken is approximately 370 km^2. In the catchment, the vegetation is dominated by coniferous forests and wetlands. The soil is moraine, and the bedrock is mainly composed of granite (Brånin et al., 1976). Mining activities have taken place at several locations in the uppermost part of the catchment area since the 1940's. The Kristineberg mine is the only mine in the area that is still active. The mines at Rävliden, Hornträsket, and Kimheden have all been reclaimed. However, recently the Maurliden mine has been opened.

In the case of Vormbäcken, the water quality at Vormsele is to a large extent the result of mixing the original river water with the water leaving impoundment 4, surface water from the tributaries, and groundwater from the rest of the catchment area.

In this part of Sweden, the flow of water in running waters exhibits a distinct peak during snowmelt, which typically occurs in May (SMHI, 1979). At the sampling station Storkalven (immediately downstream from Hornträsket), the flow of water in Vormbäcken usually varies between 0.06 and 4 m^3/s (Brånin et al., 1976). The average flow is 0.4 m^3/s. At Vormsele, the flows have increased to 0.9-25 and 4 m^3/s, respectively. The discharge from impoundment 4 is also greatest during snowmelt. Widerlund et al. (2001) reported discharges of 0.37 m^3/s in May 1999 and 0.25 m^3/s in September the same year. The mixing ratio between the river water and the water leaving impoundment 4 was greater during high flow events (12:1 in May 1999) than during periods of low flow (3:1) (Sjöblom et al., 2003). This probably reflects that the catchment area of impoundment 4 is small in comparison to that of the river upstream from the spillway.

Upstream from the Kristineberg mine, the river water has a pH close to 6, and the water contains approximately 6 mg DOC/l and 0.2 mg Fe/l (Sjöblom et al., 2004). A substantial part of the Fe has been found to occur in particles of 1 kDa – 0.2 µm size (Forsberg, 2002). At present, the concentrations of Cd, Cu, and Zn in the river water are elevated already upstream from the outlet from the mining area at Kristineberg (Figure 15) (Sjöblom et al., 2001). This is probably due to a combination of earlier mining activities and the local geology (cf. Runnells et al., 1992). During normal operation of the water treatment facilities at Kristineberg, the treated water actually dilutes the river water with respect to the trace metals mentioned above (Sjöblom et al., 2001). However, the treated drainage is a significant source of Ca to the river water. Sampling in 2000 (Sjöblom, 2003) showed that the concentration of Cd, Cu and Zn in all of the tributaries investigated was much lower than those encountered in Vormbäcken. The natural tributaries accounted for between 4 and 12% of the loadings of Zn, Cu and Cd to the system. For lead, they accounted for between 11 and 17%. Lead appears to be mobilised from the catchment area during periods of high flow. The contribution of Fe, Al, and Mn in the river at Aspliden (that is, background upstream of the discharge from Kristineberg together with the discharge) is about half the total loading (October, 2000). For arsenic, the natural tributaries account for at least twice the loadings measured at Aspliden (where discharge is completely mixed with river water). The contribution of groundwater to the total load in Vormbäcken is also thought to be high (especially for As).

Figure 15 - Mixing-point of spillwater and the recipient, river Vormbäcken, at Kristineberg.

Importance: HIGH

Airborne

Dust is an important source of airborne pollutants, especially in open pit mines. The distribution of airborne pollutants in the Kristineberg area is therefore probably only a minor problem at parts of the Kristineberg mine that are unvegetated. Dust formation might however be a problem at the open pit mine Maurliden that is located in the vicinity of Kristineberg. In Kristineberg and Maurliden, the risk for dust formation has to our knowledge not been quantified. Also the chemical properties of the dust are unknown.

Importance: LOW to MODERATE

Mass-Wasting

Unlike in the Mostar Valley, the Kristineberg area is characterized by low to very low risk of mild earthquakes. Also the type of bedrock makes natural mass-wasting of rocks unlikely. The main risk from tailings that are deposited in the Kristineberg impoundments is waterborne. However, at Kristineberg and Maurliden, waste rocks are deposited in the mining area and sealed by mainly moraine and soil. If the slope of the waste rock piles is too steep, there is risk that they collapse. Hence, it is important to construct these piles in a way that avoids mass-wasting.

Importance: MODERATE

Observables

In the Kristineberg area, UAVs will be used to quantify dust distribution, slope of waste rocks and the effects of waterborne pollutants on productivity and biodiversity of aquatic and riparian vegetation.

Dust

Dust distribution at Kristineberg is probably only a minor problem but of environmental relevance at the open pit mine in Maurliden that is located in the vicinity of Kristineberg. At Kristineberg, dust formation is prevented by a) water saturated tailing impoundments and b) soil sealed impoundments. Dust and aerosol formation and spread at Aitik, a large open pit mine in northern Sweden is especially a problem after long periods without precipitation (Lindvall 2005). Dust, if deposited on vegetation shifts the colour of leaves from green to greyish. Hence, in the Kristineberg area, we expect to quantify the wind-induced spread of dust by using aerial photographs from UAVs.

Waste Rocks

To avoid mass-wasting, the slope of waste rock piles must be below a critical value. It is therefore important to monitor the slope of existing waste rock piles. The UAVs can be used to generate a surface model of the waste rock piles, thus documenting the present slope. Recurrent remote sensing with UAVs can be used to monitor the slope of the piles and to detect potential risks of mass-wasting.

Biodiversity

Main focus of the remote sensing campaign in the Kristineberg area will be on biomass and biodiversity of aquatic and riparian vegetation. So far, it is unknown if waterborne pollutants in Vormbäcken, the recipient of the Kristineberg mine, affect biodiversity downstream of the mining area. Natural wetlands in the Kristineberg area appear to be of minor importance for the immobilisation of priority pollutants (Sjöblom et al, 2003). However, so far the concentrations of priority pollutants (e.g. Cd, Cu, and Zn) has not been related to the total biomass of wetland vegetation. Such an area- and total biomass-based assessment is necessary to evaluate the actual potential of aquatic and riparian vegetation for the immobilization of pollutants. In a recent study, the LTU-team successfully used the UAV technique to quantify the total amount of trace elements incorporated in *Phragmites australis* (common reed) in Boliden, a mining area in the Skellefte mining district (Chlot et al., unpublished).

Aerial photographs have frequently been used for quantifying the distribution of vegetation and changes in vegetation cover (Ihse, 1995; Ihse, Rafstedt, & Wastenson, 1993; Paruelo & Tomasel, 1997; Valta-Hulkkonen, Kanninen, & Pellikka, 2004). Species identification has however been restricted by too low spatial resolution (generally >1 m). The UAV technique applied in ImpactMin allows for high resolution (ca. 5 cm) aerial photography that will result in high accuracy and high precision identification of species and quantification of cover and biomass of vegetation stands.

Detection methods

In the Kristineberg area like in Mostar Valley, detection will be carried out with airborne instrumentation, supported and validated by field and laboratory measurements.

The Smartplanes Personal Aerial Mapping System (PAMS) used in Kristineberg is a small Unmanned Aircraft System (UAS) designed specifically for aerial survey and mapping. The application areas can be divided into two main categories:

- Rapid Mapping, high resolution georeferenced photo mosaics on-site and:
- Precision Aerial Survey, high accuracy surface models and true orthophoto mosaics.

The system consist of:

- SmartOne Unmanned Aircraft (UA)
- Ground control station (GCS) with Mission Planning and Flight Control software
- Digital camera with calibrated optics and special software
- Aerial mapping software for automated on-site production of georeferenced high resolution photo mosaics
- Processing service (web access) generating digital surface models and true orthophoto mosaics
- Support services (pilot training, maintenance and technical support)

The standard camera type currently used in PAMS is a Canon Ixus 70 consumer camera with calibrated optics (table) and customised software for aerial mapping.

As with most consumer cameras the optical resolution drops significantly towards the edges of the image. However since the area of interest is mapped with a high degree of overlap (80% both along and cross track) it allows for the use of the close-to-nadir portions in the resulting mosaic which has the highest resolution.

In normal conditions the effective resolution when measured on high contrast targets is about 7-9 cm from 200 m altitude above ground. Since the individual colour bands are interpolated from the Bayer-type pattern the effective colour resolution is lower, in the order of 15-30 cm. The high degree of overlap also allows for blurred images to be excluded. In practice a pixel size of 5 cm is normally used for mosaics from 200 m.

Field sampling for validation of the UAV remote sensing data will be conducted simultaneously with the UAV sampling. Whereas sampling of the rock waste piles is restricted to the mining area, sampling of dust and vegetation will also be conducted outside the mining area. Vegetation will be sampled within three areas along the Vormbäcken system. As reference, sampling will also be performed in a river system not affected by mining activities but characterized by similar bedrock, quaternary deposits and topography as the Vormbäcken system. Localities for dust sampling cannot be determined a priori but depend on the prevailing wind direction during summer 2011.

Results and Limitations

In Kristineberg, like in the Mostar Valley, the main expected result of the remote sensing campaign is a snapshot of the environmental conditions in the near field (mining area) and far field (area outside the constructed deposits).

The snapshot will result in the establishment of baselines for:

1. Vegetation cover, biomass, and species diversity in the near and far field of Kristineberg. These estimates will be used to quantify the potential of pollutant immobilization by aquatic and riparian vegetation.
2. Dust spread and cover in the near and far field. These estimates will be used to quantify the dust-derived input of pollutants to the landscape in the far field.
3. Mass-wasting risk of waste rock piles in the near field.

The main factor of uncertainty in the project is the ability to detect dust cover. Dust cover is weather dependent. Hence, it is essential for this parameter to identify the right point in time to perform the airborne campaign. Ideal for the dust estimation would be a period of 2-3 weeks without precipitation prior to the campaign. Since the UAV system is flexible, we are confident, based on weather reports, to identify the most suitable date for the campaign.

For validation of vegetation cover, biomass, and diversity it is important to validate the remote sensing campaign with a sufficient number of replicates during the field campaign.

Legal Framework

The environmental problems of mining activities are not only of local, but of regional and national concern. In Sweden, mining activities are mainly controlled by the Swedish Environmental Code (Swedish: *Miljöbalken*). The Environmental Code came into force on 1 January 1999. It replaced fifteen previous environmental acts, which were amalgamated into the Code. The Environmental Code constitutes a modernised, broadened and more stringent environmental legislation aimed at promoting sustainable development.

The purpose of the Environmental Code is to promote sustainable development which will assure a healthy and sound environment for present and future generations. To achieve this, the code shall be applied so that:

- human health and the environment are protected against damage and detriment, whether caused by pollutants or other impacts
- valuable natural and cultural environments are protected and preserved
- biological diversity is preserved
- the use of land, water and the physical environment in general is such as to secure long term good management in ecological, social, cultural and economic terms

- reuse and recycling, as well as other management of materials, raw materials and energy are encouraged so that natural cycles are established and maintained.

The Environmental Code contains environmental quality standards (EQS), which are a new feature in Swedish environmental legislation. EQS are regulations concerning the quality of land, water, air and the environment in general. Whereas the previous environmental legislation was only aimed at minimising and alleviating environmental disturbances, as far as was reasonable, the Environmental Code with EQS places direct demands on the final result.

The overall goal of Swedish environmental policy is to hand over to the next generation a society in which the major environmental problems in Sweden have been solved, without increasing environmental and health problems outside Sweden's borders. Sixteen environmental quality objectives describe the state of the Swedish environment which environmental action is to result in. These objectives are to be met within one generation, i.e. by 2020 (2050 in the case of the climate objective).

Additional to the Environmental Code and the environmental quality objectives, it is important that the exploitation of natural resources is in line with EU Directives. The main EU Directive regulating mining is the Mining Waste Directive (European Commission 2006). Waterborne transport of pollutants is of main concern for ore exploitation. Mining should thus meet the demands of the Directive of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy, the so-called Water Framework Directive (WFD) (European Commission 2000).

ROSIA MONTANA SITE, ROMANIA

The sections below give an insight into the ongoing challenges and evaluation strategy at Rosia Montana Site, Romania.

Site overview

Rosia Montana mining district, located in the Apuseni Mountains in Transylvania, Western Romania hosts a renowned gold and silver deposit, one of the most important in Europe. It belongs to a region known as the Golden Quadrilateral in the Apuseni Mountains. In the last 2000 years, the ore was traditionally mined underground, in galleries of various shapes and dimensions. The underground operation ceased in 1970, when an open pit mine started to develop in Cetate and Carnic areas. As much of the high grade ore veins were previously exploited by galleries, the remaining material has relatively low contents of gold. Under these circumstances, the mine was largely subsidized by the Romanian State until 2006, when it was closed (Figure 16).

The altitudes in the study area range between 670 m (Abrud River) and more than 1000 m (Carnic hill). The climate has continental temperate features, with cold winters, down to -20°C, and significant snowfall accumulation. Due to the elevation, the summer is not very hot, temperatures are not exceeding 30°C. Precipitation fall (rain and snow) ranges between 600 and 883 mm.

Rosia Montana gold-bearing geological structure is very close to Rosia Poieni, where a porphyry-copper massive ore body occurs. In spite of their proximity, no genetic link was documented between the two structures (Figure 14). Four ore bodies were intensively investigated by Rosia Montana Gold Corporation (RMGC) in the last years: Cetate, Carnic, Orlea, Jig.

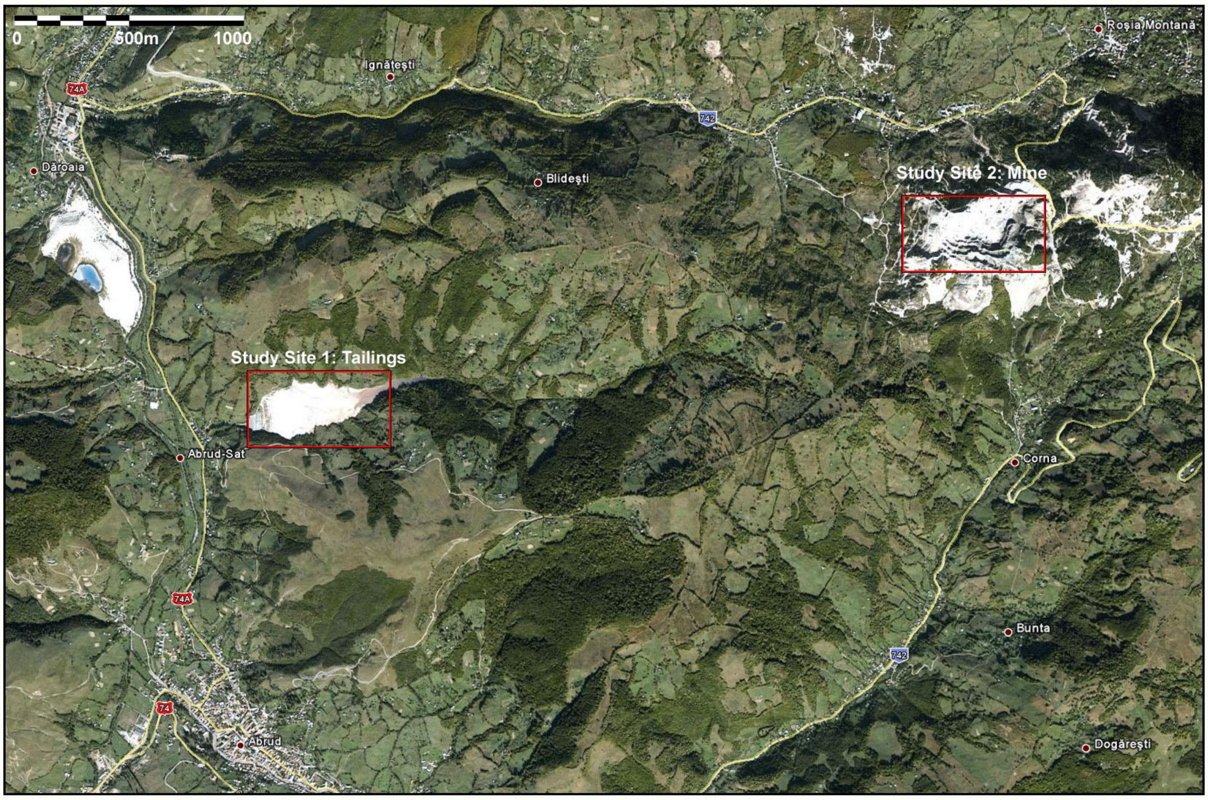

Figure 16 – Rosia Montana and targets of exploitation

Environmental impacts

The remnant environmental impact mainly consists of :

- pollution of surface waters, mainly streams, and some stagnant water bodies;
- to a lesser extent, still significant in some areas, pollution of shallow groundwaters;
- land use change as a result of mining operations, deposition of tailings and waste rock.

Pathways of exposure

Some of the potential impacts and magnitude of these pathways in Rosia Montana are outlined below:

- *Waterborne transport of wastes*

Acidic water is the main source of environmental pollution in Rosia Montana area. The rocks rich in sulphur-containing minerals, exposed to oxygen and water, generate weak sulphuric acid solutions, able to dissolve the heavy metals. The acid mine drainage (AMD) process is extensively represented in the mining area, due to the large exposed surfaces of mineralised rocks, tailings, and waste materials. The old galleries, with a total length of around 140 km, release about 20 l/s of acid waters to the streams in the area (RMGC database). Rosia stream is the most affected by the acidic waters format the outlet of the galleries. A relevant example in this regard is the Adit 714, that releases brown water with a pH down to 2 (Figures 17). The pollution propagates downstream, to Abrud and Aries rivers (Figure 18), and can be instrumentally, and in part even visually, documented on tens of km (Bird, 2005).

Impact significance: HIGH

Figure 17 – Adit 714 releasing contaminated water.

Figure 18 - Abrud River (left) joining the Aries River. The suspension-load generated by the mining sites upstream is rather obvious.

- *Airborne transport of pollutants*

The air pollution is limited for the moment, as the mine does not operate. Dust can be mobilized from the open pits, waste dumps and the dry tailings management facilities. The fine fraction may contain various minerals, and heavy metals in a certain extent. Currently there is no air monitoring system functioning

Impact significance: LOW

- *Soils, Land-use and Mass-wasting:*

In the framework of a baseline conditions study conducted in 2003-2005, 153 soil samples were collected from the mine surrounding area and the contents of the following heavy metals were determined: Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Zn. The returned results were compared to the reference values of MAPP Order/1997 regarding the normal contents of these chemical elements in soil (VN) and values representing alert (PA) and response thresholds (PI) for sensitive soil use. A predominant feature of these analytical data is the fact that they have low values, generally below the alert or response thresholds.

The mining project to be developed (Rosia Montana Project) proposes an Industrial Zone which comprises a total area of 1,257.31 ha. This Zone includes all the areas where the mining activities will develop, waste rock piles, facilities for milling and processing the ore, a tailings management facilty (TMF), water treatment facilities etc. Many of these surfaces were previously outside the area impacted by mining and related operations. From this point of view, ImpactMin project has the unique opportunity to observe the current state of the environment in the area where the mining project is proposed to be developed. The data that ImpactMin will produce will greatly increase the knowledge of the baseline situation before mining starts.

Presently, the main land areas impacted by mining consist of:

- Two open pits : Cetate (19.75ha) and Carnic (5.2 ha)
- Waste dumps (see table below).
- Two tailings management facilities : Saliste and Gura Rosiei

NAME	Area (m^2)	Area (ha)
23 August Dump	3479.45	0.348
Afinis Dump	1137.78	0.114
Aurora Dump	739.62	0.074
Cirnicel Adit Dump + 910m	11976.86	1.198
Dump Adit + 938m	9738.43	0.974
Gauri Dump	20796.64	2.080
Hop Dump	53683.79	5.368
Iuliana Dump	6273.84	0.627
Manesti Adit + 795 Dump	33468.07	3.347
Napoleon Dump	2677.33	0.268
Orlea Dump	43678.50	4.368
Piatra Corbului +960m Dump	1445.21	0.145
Piatra Corbului Dump	850.48	0.085
Rakosi Dump	21366.06	2.137
Valea Verde Dump	73039.24	7.304
Verkes Dump	5549.66	0.555

Table 4 - Waste rock dumps in Rosia Montana area.

The ore bodies which have been exploited at Rosia Montana, contain many voids (galleries, rooms) resulted from the previous underground operations. Many of them are unstable and the risk of collapse is considered as fairly high, although the seismicity of the study area is very low.

Impact significance: MODERATE

Observables to detect environmental impacts

Mineralogy

Iron minerals, especially oxy-hydroxides are ubiquitous in mining areas, and this is also the case in Rosia Montana. Observing the iron minerals distribution over the area, will enable a precise quantification of the exposed surfaces.

Acid mine drainage and pollution of surface waters

After 2000 years of mining, the old waste rock deposits are not easily recognizable. Our expectation is to obtain a better characterization of the deposits in terms of spatial position and volume, impact on the near environment, including acid mine drainage.

Water quality can be assessed by observing its turbidity, especially in streams. Downstream of Rosia Montana, streams are clearly impacted by the acid water, revealed by colour and turbidity (fig. b). Beside streams, the aerial survey may focus on the ponds existing in the proximity of the mining area, and on the shallow water bodies existing in the open pit and on the TMFs.

Vegetation stress

Vegetation stress due to mining is mainly an indirect consequence of altering environmental variables. Many mine wastes are structureless, prone to crusting, and low in organic matter and essential plant nutrients (P, N, K). They mostly have low water-holding capacity, and contain contaminants such as salts, metals, metalloids, acid, and radionuclides. If the waste is left uncovered, few mine wastes can become colonized by plants. Due to the often alkaline character of mine substrate, nutrient availability is reduced because many elements are poorly soluble at high pH and deficiencies of trace elements such as copper, manganese, iron and zinc may occur. Many plants will not be able to tolerate the alkaline pH values greater than 8.5. Goetz et al. (1983) have shown that stress factors like heavy metal uptake affect reflectance spectra at the leaf and canopy level. Field studies have demonstrated that changes in vegetation spectra can be metal-induced due to geochemical stress (Collins et al. 1983, Kooistra et al. 2003) or the occurrence of old waste deposit sites (Sommer et al. 1998). Spectral changes occurred in both visible and near-infrared parts of the spectrum. As a result, optical remote sensing potentially offers tools to detect and monitor heavy metal contamination of soils in an indirect way. Moreover, a number of recent studies have indicated the advantages of using discrete narrowband data from specific portions of the spectrum, rather than broadband data, to obtain the most sensitive quantitative or qualitative information on crop or vegetation characteristics (Thenkabail et al., 2002). Therefore, it is intended to use hyperspectral imagery to detect vegetation stress in the Rosia Montana mining area.

Data availability

Data to be used within the project are partially provided by RMGC and partially acquired by the ImpactMin consortium. The following categories of data are currently available:

- Topographic maps related to RMGC mining project
- Airborne Orthophotoplan - resolution 0.5m, year 2005
- ASTER rainbow Digital Elevation Model (15m resolution)
- Topography map (equidistance 2 m) from Spectrum Survey and Mapping
- Land use map from Spectrum Survey and Mapping

- Delineation of protected areas from Spectrum Survey and Mapping
- Location of lakes, forests and buildings from Spectrum Survey and Mapping
- Existing 20kW and 110kW power lines (including location of poles) from Spectrum Survey and Mapping
- Monitoring data for surface- and groundwater from the mining project area
- Soil survey data from the mining project area
- Initial conditions study for the proposed Rosia Montana Mining Project (RMP)
- Satellite imagery for the demo site and surrounding area, and extensively described in D4.3 Report 'Satellite mission planning for the demo-sites'.

Data collection needs

At the 1st interim meeting of the ImpactMin project in Split, Croatia it was agreed by the consortium members to work on revising the standing statement of the DoW and adapt, adjust and overcome the challenges presented.

The consortium members have proposed to:

a) Initiate proposal writing for collection in Romania under EUFAR program, semi-independent from ImpactMin proposal and time/legal constraints placed upon it.
b) collect ground-based spectral data and correlate it with high-resolution satellite data. The proposed method is in-line with novel methods of remote sensing and spectroscopic data acquisition and bridges an important gap between the ground-based data collection and remote sensing assets available in the areas where airborne data collections may not be viable.

Data collection

The procedure for obtaining satellite (spaceborne) data and ground-based measurements often do not meet with the same scrutiny as airborne collections as they are either regulated by international treaties, have decreased resolution or are easier to verify or constrain in the authorized zone of collection. It is also often occurrence that aircraft are not available to carry the required sensor package or the cost of acquisition may be prohibitively expensive. As an alternative to airborne collections, it was proposed to acquire high-resolution, ground spectroscopy in a grid-pattern and then translate it/append the available imagery data creating pseudo-hyperspectral digital image fused from ground-based measurements and spaceborne imagery data, which eventually a state-of-the-art data (image) acquisition method (Figure 19).

The satellite data that exhibit the high spatial resolution (e.g. 0.5 – 3m) are often of limited spectral resolution and do not extend past the Near Infrared Range (NIR). However, by adding ground-spectral elements to their spatial detail, one could get better idea of the target characteristics and possibly even append some of the information derivable from the satellite imagery. This particular element is testing the success of data fusion discussed in both WP 4 and 5 in combining disparate datasets to increase the overall usable knowledge from individual components.

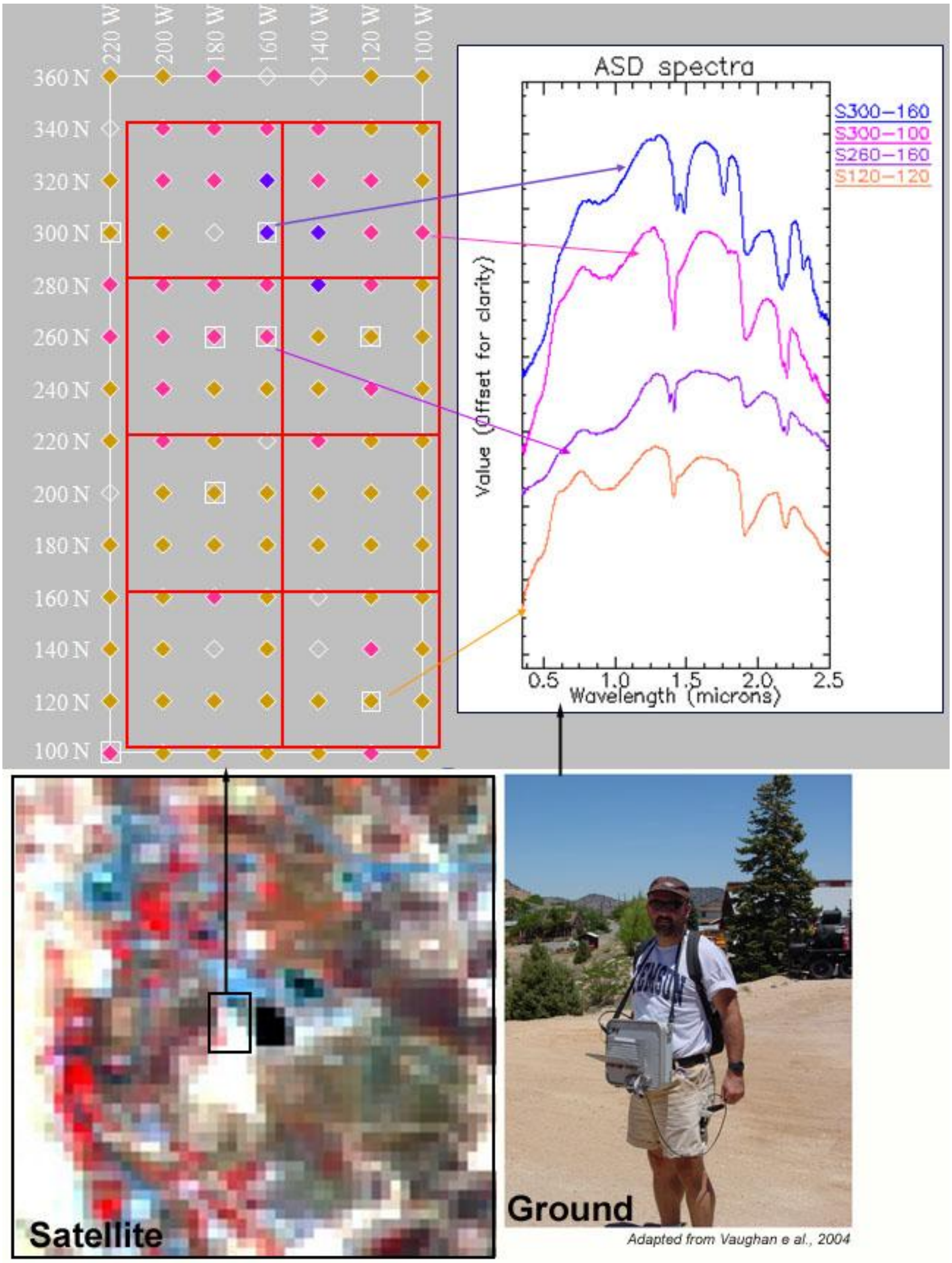

Figure 19 – Elements of satellite and ground-based information fusion.

The re-sampled spatial resolution of World View 2 data is 1m, which is obtained by merging the 3.6m color and infrared data with 0.6 m panchromatic data resulting in a synthetic spatial resolution of 1m. Due to the volume and time constraints of acquiring the ground-data within the two hour solar-noon time window, it is proposed to collect the ground data every 5m along a 25m x 500m long swath covering the majority of study sites to establish mineralogy and/or gradient changes in the quantity and apparent concentration of acid-mine drainage forming minerals (Figure 16).

The data would be collected with a full-range ASD spectroradiometer using no foreoptic-module and collecting at 23.5 degree FOV every 5m, integrating the site on the ground of about 1m, which is the size of a resampled World View 2 data, at the distance of 5m, which is consistent with the raw-resolution of the RGB/IR data. Furthermore, it is easier to extrapolate and scale-factor the measurements in relatively even spans of 1-5-10m which can be further used to enhance and validate other spaceborne measurements. Every 25 square meter area would also be sampled with a soil sample for later chemical analysis of its mineral constituents, metallic-ion content, pH and so on to be used as an additional factor in evaluating the overall condition of the study site and contributing yet another layer of evidence towards the data fusion (Figure 20)

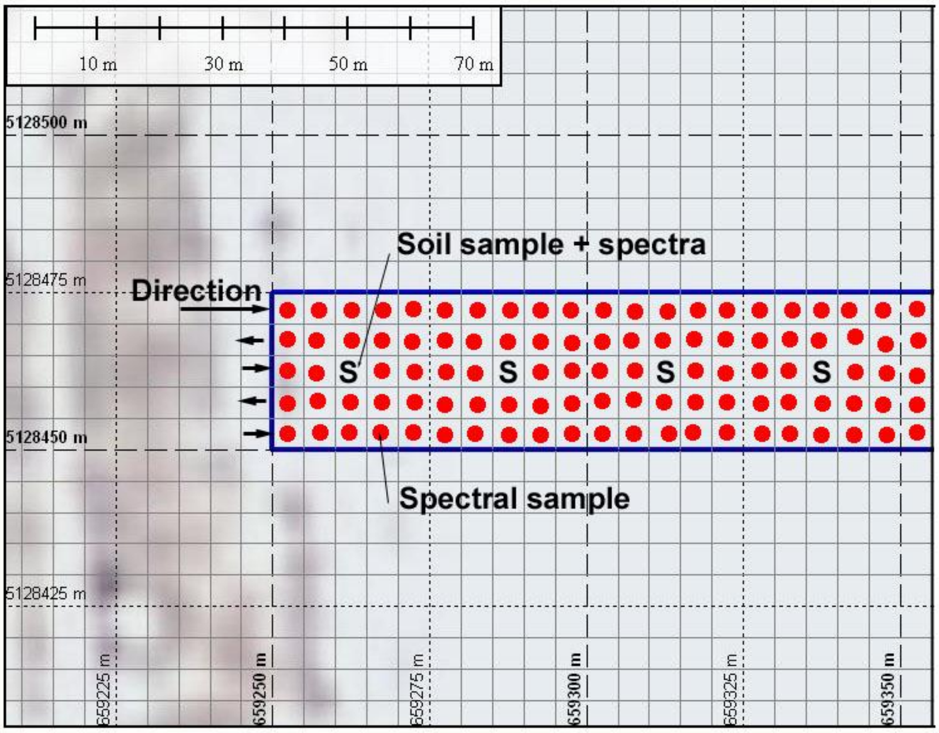

Figure 20 – Acquisition scheme for the spectral and soil samples in a zoomed-in region of the study site

The acquired spectral data would be tagged with GPS to ensure their positional accuracy and ability to translate them into a particular spectral grid that could be used to formulate a particular matrix for the data fusion, which would be the desired deliverable for the project (Figure 21).

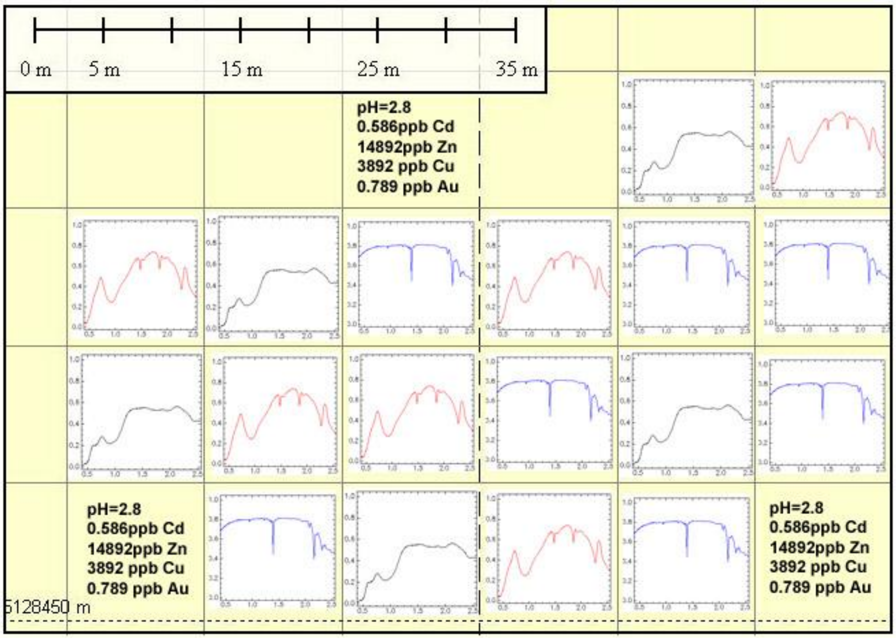

Figure 21 – Example of completed grid with spectral and geochemical information

The planned acquisition of ground-based spectra would ideally be scheduled for summer months (e.g. July/August) when the sites are relatively dry and exposed to the maximal amount of solar radiation. The available signal would be considered of high-quality to permit identification of mineral endmembers to aid in classification. The sampling location would be pre-surveyed in the advance preparation and the acquisition with ASD spectroradiometer would focus solely on the acquisition of spectra.

Field sampling and analytical methods

The ground-to-spaceborne operation described in the previous section will take precedence. The methods will be optimized and adjusted with the progress of the airborne operations in the area. Observables that have to be monitored resulting from previous site descriptions are: minerals, acid mine drainage, vegetation stress, soil pollution and water quality.

Minerals

X-ray diffraction

Samples of fine granular material will be collected from the weathering surfaces of the exposed rocks, iron-rich precipitates occurring along the streams, tailings deposits, etc. The X-ray polycrystalline diffraction technique (XRD) will be used in order to define the mineralogical composition of the concerned materials. The sample is grinded down to a diameter of 0.002 to 0.005 mm, and homogenized, as the crystals should be randomly distributed. The obtained material is pressed into a sample holder which is placed in the goniometer of the x-ray diffractometer. The obtained spectra are processed and interpreted by using specific software.

Ground spectra

A portable ASD infrared spectrometer will be used both for calibration of the remote sensing data and for systematic mineralogical characterization of the surface materials.

Gamma-ray spectrometry

An ORTEC digiBASE portable gamma-ray spectrometer will be used for calibration and validation of the airborne survey. The digiBASE is a 14-pin photomultiplier tube base for gamma-ray spectroscopy applications with NaI(Tl) scintillation detectors.

X-ray fluorescence

A handheld X-ray fluorescence spectrometer (XRF) will be used. It is suited for preliminary site investigations, on soils, sediments, dust, and other materials. It can screen Pb, As, Cd, Cr, and other metal concentrations in the field.

Acid mine drainage

- water analyses in the areas with acid leaching
- water analyses in streams (field multiparameter, AAS, ion chromatography)
- stream sediment/iron oxide precipitates analysis

Vegetation stress

- Chemical analysis of foliage in affected areas and in clean areas
- Handheld spectroradiometer reflectance measurements

  As changes in an ecosystem occur, alterations in foliar chemistry and membrane structure result in changes in vegetation spectral signatures (Rock et al., 1986; Martin and Aber, 1997; Entcheva et al., 2004).

  As compared with broadband, high-spectral-resolution reflectance parameters are much better correlated with the amount of foliar Chl (Carter, 1994; Carter et al., 1995; Carter and Knapp, 2001, Lichtenthaler, 1996) and with the amount of projected green leaf area of canopies and landscapes observed by RS platforms (Walter-Shea et al., 1992; Entcheva, 2000).

- Fluorescence measurements:

  Unlike reflectance, fluorescence emitted from the Chl is directly related to photochemical reactions and has been used extensively for the elucidation of the photosynthetic pathways (Lichtenthaler, 1988; Cerovic et al., 1999; Corp et al., 2003).

- Non- destructive chlorophyll measurements with SPAD or CCM-200 meter. The chlorophyll meter or SPAD meter is a simple, portable diagnostic tool that measures thegreenness or relative chlorophyll content of leaves. Meter readings are given in Minolta Company-defined SPAD (Soil Plant Analysis Development) values that indicate relative chlorophyll contents. There is a strong linear relationship between SPAD values and leaf nitrogen concentration, but this relationship varies with crop growth stage and/or variety, mostly because of leaf thickness or specific leaf weight. The linear relationship between nitrogen and SPAD values has led to the adaptation of the SPAD meter to assess crop nitrogen status and to determine the plant’s need for additional nitrogen fertilizer. SPAD readings indicate that plant nitrogen status and the amount of nitrogen to be applied are determined by the physiological nitrogen requirement of crops at different growth stages (extracted from Gholizadeh, 2009).

- Destructive chlorophyll extraction:

  In order to get a better interpretation of the spectral data related to the processes of plant leaves under stress, destructive chlorophyll a and b extraction was performed on eight infected and non infected leaves at regular time intervals (2, 8, 15, 17 and 22 days after inoculation). According to the method proposed by Sims and Gamon (2002), circular samples (0.65 cm^2) were excised from the leaves and subsequently used for extraction of chlorophyll a and b. The tissue samples were pulverized with a pestle and ground for a short time with some quartz sand. Per leaf punch, 2 ml acetone/Tris buffer (80:20 vol:vol, pH=7.8) was added and placed in a vortex for one minute. Subsequently, the samples were placed in a centrifuge (3000 R.P.M., 5 min, 5_C) to remove particulates and the supernatant was diluted to a final volume of 25 ml with the acetone/Tris buffer. Each sample for pigment analysis was placed in a cuvette and the absorbance of the extract solutions was measured with a Perkin Elmer LAMBDA 12 UV-VIS spectrophotometer (Perkin-Elmer, Inc., Boston, USA). The absorbance was measured at 537 nm, 647 nm, and 663 nm. Chlorophyll a and chlorophyll b concentrations were calculated using the extinction coefficients derived by Sims and Gamon (2002):

  $$Chla = 0.01373A663 - 0.000897A537 - 0.003046A647 \quad (1)$$
  $$Chlb = 0.02405A647 - 0.004305A537 - 0.005507A663 \quad (2)$$

  where Ax is the absorbance of the extract solution in a 1 m path length curve at wavelength x.

- Destructive leaf chemical analysis of heavy metal content (i.e., cadmium, zinc, copper and lead) with AAS (Atomic Absorption Spectrometry):

  The plant material (leaves) was disintegrated in a mill and the resultant powder dried at 65°C in a drying oven. The samples were then placed in 50 ml borosilicate squat beakers and ashed at 500°C until oxidation was complete (usually after about 3–4 hours). The ash was dissolved in 2M hydrochloric acid with gentle warming and with a final 1/50 ash/acid ratio. The solutions were analysed for copper, cobalt, zinc and cadmium by atomic absorption spectrophotometry using a hydrogen continuum lamp for automatic background correction. All concentration data were expressed on a dry mass basis.

Measurement	Instrument
Position	GPS
Canopy reflectance	ASD + spectralon
Leaf reflectance	leaf probe
Chlorophyll	CCM/SPAD
AOT(Visibility), Water vapour	Sunphotometer
Fluorescence	Fluorescence meter
Calibration	Reference targets
Absorption CHL	spectrophotometer, vortex, centrifuge, labo material
Absorption heavy metals	Spectrophotometer, hydrochloric acid, labo

	material

Table 5 - Overview of the measurements and involved equipment for vegetation stress measurements

Results and Limitations

Based on the spectral information collected from the ground, it is foreseen that a clearer appraisal can be obtained on the types and observation-ability of particular acid-mine drainage minerals on the surface. The spectral information can then be appended to spatial information and mineral maps produced showing the distribution and relative abundance of particular mineral species or endmembers. On the basis of this information, a more robust plan for subsequent in-situ imaging monitoring (using static-based hyperspectral instruments) can be designed and recommended to the end-user.

If the airborne missions are approved for Rosia Montana, and Romania in general under wider-reaching EUFAR proposal, the study can be complemented with airborne measurements.

Legal Framework

As a new EU member state, Romania is correlating its environmental legislation to the European regulations. The main regulation to be taken into account is the Environmental Protection Law, first issued in 1995, and repeatedly updated afterwards.
The main principles included in this law are as follow:

- prevention of the environmental risks;
- biodiversity conservation
- the polluter pays;
- improvement of the environmental quality;
- participation of the community to the decision-making;
- development of the international collaboration for environmental protection.

The mining activity is mainly regulated by the Mining Law first released in 2003 and subsequently updated. The flights with the purpose of remote sensing survey are regulated by the Governmental Order no. 912 from 2010.

3. CONCLUDING REMARKS

The "Demo Site Implementation Plan" work package of the ImpactMin proposal presented in this overview outlines the basis and rationale for a tactical-level data collection at the sites in Bosnia-Herzegovina, Sweden and Romania in Spring-Fall period of 2011. The site assessment is somewhat similar in approach: moving from general information, established through background research and spaceborne remote sensing studies and moving towards detailed, tasked airborne and ground-based sampling approaches. The overall interest is to present an integrated chain of regional-to-local assessment of variables and observables associated with past, current and possibly future mining operations in various environments.

The tactical nature of the data collections makes this segment of the ImpactMin proposal probably the riskiest and most exposed to various changing conditions: from weather to legal challenges of operating and collecting data in an active and at times contentious environment. Hence, the report and plan are devised to "roll with the punches" and adapt to the acquisition situations arising in the air and on the ground.

The collection methods are definitely state of the art in their ability to quickly appraise the observables without laborious and expensive laboratory studies. As the events show, being able to assess the situation quickly and derive actionable information is of utmost importance in recording and estimating the influence on and within a changing environment(s).

Even more important goal, than simply being able to collect and evaluate the data is the ability to horizontally integrate various and at-times, disparate dataset and have them contribute portions of information towards understanding the larger whole. That ability to bridge the gap among the datasets and between the local to regional and tactical to strategic assessment is one of the unquestionable strengths of the ImpactMin proposal and this particular deliverable.

The analysis and evaluation of the collected data will present a snapshot in time the current situation in Mostar, Kristineberg and Rosia Montana, resulting from the past and current events. The newly acquired data will add numerous points on the assessment curve and will be used to validate previous measurements. But, it is also important to emphasize the information sharing and cross-pollination of ideas and observables among different, but yet very similar sites and understanding the pathways of exposure of mining related observables in the environment. The sites discussed in this report only make sense and contribute to the information understanding if they are considered in unison and all of the detected elements used and evaluated in their common context.

The limitations inherent to data processing, integration, evaluation and subsequent modeling will remain to pose a challenge to further research. However the level of detail and the appraisal of new technologies under creative and interdisciplinary approach will result in broken disciplinary barriers and limitations of the traditional evaluation approaches.

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Appendix 1 – Planned Execution of the Airborne Campaign in Mostar

Mostar valley is intended for near-contemporaneous collection of airborne hyperspectral, gamma ray and field sampling surveys, both on land and on the water. The campaign is slated for May 2011 time frame.

Hyperspectral

Hyperspectral imagery is intended to be used to assess the condition of the Vihovici pit lake (chlorophyll, water clarity, depth) and zones of possible interaction with the Neretva river. Also the presence of hydrocarbon waste, iron oxides, iron hydroxides and hydrophilic clays could be investigated. It would also be interesting to detect CO_2 effluents from underground coal fires.

Focus of the mission is placed on (in order of importance):

- lithology and geomorphology
- hydrology (runoff/water clarity)
- hazards (possible underground fires, landslide monitoring)
- interaction with urban zone
- dust
- vegetation cover

Mission Planning and Execution Timeline

In order to fully address the requirements listed, a successful airborne campaign should include the following elements. The procedure is also known as the tasking, collection, processing, exploitation and dissemination (TCPED) stream:

TASKING

1. Geologic background and historical information (T:-30 days)
2. Water bodies baseline data (T: -30 days)
3. Vegetation survey (density, areas of concentration) (T:-30 days)
4. Field reconnaissance of select sites and firming up of mission plans (T:-15 days)
5. Final Mission planning and firming up of overflights and cal. sites (T: - 10 days)
6. Final flight paths clearances and personnel rosters / stations (T: -7 days)
7. Equipment check and mobilization (T:- 2 days)

COLLECTION (D-day)

1. Evaluation of meteorological conditions (Go/No-go call from ground)
2. Airborne data acquisition over defined targets – overhead asset arrival
3. Initiate land detachment to set up collection of spectra on cal. sites
4. Initiate water detachment to begin collection of spectra and measurements

PROCESSING (D-day +)

1. Preliminary data evaluation and QC upon return to base (D-day +1)

2. Data pre-processing and calibration (D-day + 20 days)
    a. Radiance at sensor data
    b. ATCOR-4 / VELC derived reflectance
    c. Input Geometry and Geographic Lookup Table file geo-coding info
    d. Empirical line reflectance data
    e. Packaging and final QC
    f. Delivery and contractor report
3. Data reduction and processing for targets (D-day +30 days)

EXPLOITATION (+90 days and beyond)
1. Integration of multiple datasets (multispectral/hyperspectral)
2. Comparison with the derived spectral libraries
3. Comparison with the collected field data
4. Anomaly map and follow-up ground targets
5. Field checking of acquired data
6. Report and maps on for the target area

DISSEMINATION
1. Results and products, geospatial archive cross-reference
2. Technical reporting on the analysis and results

Upon initiating a study, every attempt should be made to assemble as much definitive background information as possible. The resulting informational framework is used to provide the context for interpreting the remote sensing data, but also derive elements for mission planning (See Appendix 2 for mission collect information questionnaire).
The field reconnaissance is important to derive important situational awareness elements in NAI, but also select suitable calibration locations and/or ground-reference points. The initial reconnaissance may also be used to yield the following types of information:

- SWIR range reflectance spectra from rocks, soils, sediments and vegetation (pre-collection)
- Solar spectra for reflectance calibration and vegetation spectra.
- Samples for XRD/XRF analysis (pre-collection)
- Reconnaissance geologic and surface maps over NAI
- Digital images of sample sites;
- GPS coordinates for the sample locations and control points.

Generally it is considered important to have a photographic record of the locations sampled as well as the general aspects of the terrain and vegetation in the area. These elements provide a visual reference to investigators involved in the mission planning as well as data compilation and evaluation. In the post-collection mode, this information may assist the image processors when classifications are determined.
Collection parameters
Other considerations and requirements for hyperspectral airborne data collections

- Collect within +/- 2 hours of solar noon, to ensure minimum shadows and maximum insolation

- Collect during clear and calm weather to maximize airborne platform stability
- Preferably collect in late spring when vegetation is active (for vegetation stress studies), but not overbearing to mask any ground components (i.e. mineralogy or effluent).
- Collect datasets in relatively high spatial resolution (1-3 m GSD) to allow discerning of areal and intimate mixtures of minerals, effluent and/or vegetation stress within individual target blocks, as opposed to regional mapping.
- Acquisition of field spectra over the named areas of interest for comparison with remotely sensed datasets in the areas of mining operations and also zones in the vicinity. It is intended to take about 100 readings from each of the sites containing various target types to include minerals, water, vegetation and man-made objects. If particular zones of interest are identified on the high resolution hyperspectral data (e.g. acid leach zones), additional ground spectra with samples for geochemical analysis (if any).

Analysis parameters:

- Texture, shape, color, frequency – basic division of elements and classification into categories (e.g. urban, agricultural, forest, wetlands, infrastructure). These elements are mainly based on qualitative elements of recognition and classification.
- Spectral classification – using physical, chemical and biological properties of surface materials to classify them quantitatively on basis of spectral differences (e.g. vegetation species, mineral species, condition and health of vegetation, clarity of water bodies, type of man-made material, certain pollutants etc.)
- Combined classification – using inputs from other types of data (i.e. multispectral, geospatial, ground-based etc.) derive combined interpretation products that draw upon individual observation capabilities to form a unified, horizontally-integrated dataset.

Ground campaign in support

The ground segment of the campaign is of supportive role and important for overall calibration of the data to match the exact radiance/reflectance values on the ground and water. The ground assets will move in to designated ground verification regions and commence data acquisition at the day of the overflight. The primary objectives would be to:

a) Occupy and acquire ground spectra on the calibration sites in Mostar Valley, primarily Vihovici region.
b) Occupy and acquire water spectra and associated measurements on Neretva River, before and after the Vihovici mine site, city of Mostar and the southern industrial area.
c) Take spectral measurements of the targets of opportunity that are noted in the vicinity of the study sites (e.g. vegetation, dumps).

Standards

This section describes some of the basic standards that are expected in the delivery of hyperspectral data. It is offered here as a guideline for what the final format of the data delivered to team members may appear as:

Raw Data

All sensor data is intended to be delivered in flat 16-bit unsigned integer binary format without file offsets. The byte layout must be little-endian. The spectral bands can be grouped in a band sequential format (BSQ) or band-interleaved by line (BIL) format.

Each binary file is accompanied with an ASCII header file. The file extension of the header file is ".hdr" and the file extension of the image file is ".img"

Header file layout – example

ENVI
description = {
Generated by [company name] }
samples = 2496
lines = 1806
bands = 2
header offset = 0
file type = ENVI Standard
data type = 2
interleave = bsq
byte order = 0
map info = {Belgian_Lambert_72 International_1924, 1.000000, 1.000000, 198849.900000, 212466.099723, 0.200000, 0.199446}
band names = {
band 1: 610.0 – 660.0 nm,
band 2: 765.1 - 776.9 nm }

Header file layout – Legend	
description	Enter your company name
Samples	number of pixels in a scan line
Lines	number of scan lines
Bands	number of spectral bands in this file
header offset	number of bytes reserved for header info (must be zero)
file type	must be ENVI Standard
data type	Must be 2 (unsigned 16bit integer)
interleave	Must be BSQ (Band Sequential)
byte order	Must be 0 (little endian)
map info	{Projection string, Datum string, X pixel offset (must be 1.0), Y pixel offset (must be 1.0), minimum X coordinate (center of the pixel), maximum Y coordinate (center of the pixel), resolution X, resolution Y}
band names	Specify the bandwidth in nanometer. Comma delimited list.

Quicklooks
A multi-band ENVI file (with data type = 1, i.e. unsigned byte) is necessary for quick orientation and visual check, containing 3 bands (band 0 = red beam, band 1 = green beam, band 2 = blue beam) with values in the range [0, 255] with an associated header (.hdr) file. Geo-coded/rectified quicklook, if possible should also be provided so the natural color images can be checked for positional accuracy on the ground.
Positional data (Geo-coding information)
The platform Position and Orientation System (POS) data that should provided. The type and manufacturer of the POS, the GPS receiver and the IMU shall be provided. The feed from the aircraft on-board positional system (e.g. Applanix, Novatel, Oxford) will be recorded and delivered in conjunction with the derived Input Geometry Map (IGM) and Geographic Look-up Table (GLT) files for the individual flightlines.
Radiance data
The data as it is recorded during image acquisition is raw camera response value and must be corrected for several issues such as electrical dark current, flat fielding, bad pixel occurrences etc. The calibration to radiance-at-sensor, therefore has several necessary steps that ought to be undertaken:

1. Removal of dark current; the removal of underlying electrical noise that is present in all electrical systems and if uncorrected prevents the accurate calibration of the data and subsequent high-fidelity spectral data.
2. Normalization of array response; the normalization of each element-response on VNIR and SWIR focal plane arrays, often referred to as "flat fielding." This procedure is normally accomplished by applying a proper laboratory calibration file and gain factor calculated for each and every detector on imaging arrays. The factors are computed from the radiance and wavelength calibration procedures to ascertain that the data is provided to +/- 5% of absolute radiance and within 1nm accuracy for spectral calibration
3. Bad pixel scrubbing; all CMOS based cameras suffer from bad and/or dead pixels on the imaging array, in which pixels do not respond linearly or predictably to the amount of incoming light. There are several identification/normalization algorithms that can and should be applied to the data to correct the bad pixels which can otherwise lead to false spectral and/or spatial anomalies.

Cross-linking
Link with the spaceborne campaign: Output of airborne data analysis will be used to calibrate/validate analysis of high resolution satellite imagery to compare the derived results and match for particular detected targets and/or anomalies.

Gamma-ray data

Airborne gamma-ray surveying is intended to be used to detect sources of enhanced radioactivity in the mine area and its surroundings. Enhanced radioactivity may be related to natural concentration of radionuclides in rocks (e.g. in coal beds), but also human contamination such as disposal of industrial waste, and to the presence of relics of ammunition used during the war.

In the latter two cases, the radioactive sources may be relatively strong, but also small in size. This puts some constraints on the resolution of the survey: In order to be able to detect small radioactive sources, we will have to fly slow (e.g 50km/hr) , low (e.g.50m. AGL) and narrow line spacing (e.g. 20m.).

Mission planning and Execution Timeline

TASKING (T: -)
1) Outlining survey area and rough draft mission planning (T: - 120 days)
2) application for flight clearance (T: -110 days)
3) compilation of geologic and other relevant information (T: -90 days)
4) Testing of aircraft and sensor (T: -60 days)
5) Final mission planning and survey specifications (T: -20 days)
6) Calibration of sensor (T: -10)
8) Equipment check and Mobilisation of aircraft and sensor (T:-3)

COLLECTION (D-day)
1) Evaluation of meteorological conditions
2) Calibration, measurement of atmospheric, cosmic and aircraft back ground
3) Airborne data acquisition over defined AOI
4) First pass data evaluation and QC upon return to base
5) Sample collection in field for ground reference (D-day +1)

PROCESSING (D: +)
1) Data preprocessing (d: +20 days)
    a) Dead-time correction
    b) Background correction
    c) Automatic gain correction
    d) Altitude compensation
    e) radioelement abundance calculations

2) Data processing
    a) flightline levelling
    b) smoothing
    c) gridding and contouring
    d) Microlevelling

3) Delivery and contractor report
EXPLOITATION (+60 days and beyond)
1) comparison with collected field data
2) Band ratioing and ternary plots
3) supervised classification
4) Integration with other datasets (geologic maps, field data, hyperspectral)
5) anomaly map and ground follow-up

Collection parameters:
Data collection requirements ensuring optimal results for the airborne Gamma-ray collections are:

1) High resolution data are required for identification of small point sources;
a) Low altitude (50m. or less)
b) Tight flightline spacing (20m. or less)
c) High sampling density along flightline: countrate 2 Hz, airspeed 14m/sec)
2) Collect during calm weather for aircraft stability and safety.
3) Collect during constant air pressure and temperature in order to avoid changes in air density
4) Collect in afternoon in order to avoid accumulations of Radon close to the ground due to early-morning still-air conditions
5) Relatively dry weather conditions. No recent rainfall, no dust
6) End of dry season in order to minimize vegetation effects
7) GPS/IMU for accurate recording of aircraft position.

Deliverables:
1) Line data: Point file with concentration of radio-elements and Total Count
2) Gridded maps of radio-elements and Total Count; Envi-format
3) Contoured maps for radio-elements and Total Count; Shapefile