The 1st phase of the project “The national inventory of contaminated sites” (NIKM) is focused on methods of contaminated and potentially contaminated sites inventory and on a categorization of priorities. Four-year project is to provide tools and methodological background for proper inventory (2nd phase) [1]. The aim is to create (in 2009-2012) a unified data base with the necessary application superstructures, to develop a methodology for identification and inventory of sites, to prepare procedures and manuals, to verify the functionality of outputs, including technical support and to develop the 2nd phase project. The project is supported from the EU Operational Programme Environment 2007-2013.

Inventory methodology is to be verified in three test areas (3 squares of size 50x50 km), i.e. in a total area of 7,500 km² (9.5% of CR area). In each area two independent field teams equipped with different support facilities (i.e. PC vs PDA) will test a newly developed application platform. Works of the project are currently being conducted in three basic directions - Application Solutions, Transformation of partial data sources and Raster platform (all the maps and images in vector form). Outcomes of work on platforms represent inputs into main part - Inventory Methodology (including field verification).

Fig. 1 Test areas (A,B,C) within NIKM project. Blue shade lining - areas covered by aerial photos from the years 1937 to 1938.

**Raster Platform**

Project raster platform operated at least until 2015 and compiled findings and recommendations for inventory methodology are the required outputs. Image data are processed in the following thematic areas:

- Aerial photographs - current orthophoto
- Historical orthophoto (50s, 30s)
- Satellite imagery - (multispectral, hyperspectral)
- Creation of derivates of images, enabling
  - Identify each depicted effects between different types of data
  - Make visible structures which otherwise are difficult to observe
  - Show the spatial and historical context of areas of interest.

The aim is to develop a set of methodologies for the use of orthophotos and satellite data:

1) A uniform methodology for the visual interpretation of the current color orthophotos;
2) A uniform methodology for multitemporal analysis of historical and current orthophotos;
3) Analysis tool for processing hyperspectral data, methodology, creating a basis of spectral libraries, benchmarking;
4) The methodology for processing multispectral data (controlled by different types of classifiers - probabilistic, contextual, ANN ...). Evaluation of using a combination of spectral library and multispectral feature space, etc.

The methodology for the visual interpretation of the current colour orthophotos (concluded a pilot phase)

We have focused on the search of objects of interest with symptoms of potential contamination particularly where vegetation is grown.

We have the first results of the pre-evaluation in the test areas. Available aerial photographs were supplemented by several sets of satellite images, information was obtained from certain bands of infrared and thermal radiation. Images from satellites SPOT (France) RapidEye (Germany), Landsat 7 (USA) and QuickBird (USA) were tested.

Aerial orthophoto and satellite images were imported into ArcGIS environment (provided by comp. ESRI), a single composite map was created and within it a new thematic layer comprising information interpreted from images. This information is located as the so-called object of interest, to which is attached in the form of a table of attributes a basic information about actual or potential contamination.

Types of objects of interest were defined and their occurrence in the test areas identified in the current pre-evaluation of orthophotos was statistically evaluated – see Table 1.

<table>
<thead>
<tr>
<th>Contamination type</th>
<th>code</th>
<th>numer of objects</th>
<th>per cent %</th>
</tr>
</thead>
<tbody>
<tr>
<td>industrial park with an impact on the environment</td>
<td>a</td>
<td>17</td>
<td>0,3</td>
</tr>
<tr>
<td>illegal dump/landfill</td>
<td>c</td>
<td>1</td>
<td>0,0</td>
</tr>
<tr>
<td>dunghill</td>
<td>h</td>
<td>1283</td>
<td>19,5</td>
</tr>
<tr>
<td>silage pit</td>
<td>j</td>
<td>523</td>
<td>8,0</td>
</tr>
<tr>
<td>abandoned quarry</td>
<td>l</td>
<td>46</td>
<td>0,7</td>
</tr>
<tr>
<td>abandoned property</td>
<td>o</td>
<td>299</td>
<td>4,6</td>
</tr>
<tr>
<td>suspicion of illegal dump site</td>
<td>p</td>
<td>4300</td>
<td>65,4</td>
</tr>
<tr>
<td>Landfills included in current inventory SEKM</td>
<td>s</td>
<td>28</td>
<td>0,4</td>
</tr>
<tr>
<td>scrapyard</td>
<td>v</td>
<td>44</td>
<td>0,7</td>
</tr>
<tr>
<td>abandoned agriculture object/farm house</td>
<td>z</td>
<td>20</td>
<td>0,3</td>
</tr>
<tr>
<td>unrecognized</td>
<td>n</td>
<td>10</td>
<td>0,2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>6571</strong></td>
<td><strong>100</strong></td>
</tr>
</tbody>
</table>

Table 1 Statistics on identified objects of interest
In result a new data layer - PreKM – was created. It is serving as a base for subsequent field survey (to be run from 2010 to 2011). Information about areas of interest has the form of spot signalling. PreKM layer in all three test areas contains about 6600 records in total.

For now, only about 30 local investigations to verify the interpretation of aerial photographs (in test areas) were conducted.

**Historical orthophotomaps and the methodology for Multi-temporal analysis of historical and current orthophotos** (under development)

There were used aerial photographs from the first nationwide aerial photo coverage performed in the first half of the 50's, which covers almost the entire territory of the CR (90%). Uncovered spaces were complemented by images from the closest next period. The entire territory of the Czech Republic was covered.

Images from pre-war aerial photo coverage from the years 1937 to 1938 (which covers about 50% CR) were treated only for the test areas (see Fig. 1).

Orthophotographs were supplied by GEODIS Brno, spol. s r.o. [2]. The resolution is up to 50 cm (for pictures in the 50's), respectively 1 meter (30's).

An Internet-based map application (see fig. 2, 4, 5, 6) was prepared by CENIA. It was tested by 50 experts and representatives of institutions interested in the issue. It is planned an evaluation of tests on a thematic seminar on the form of expert panel discussion. A full disclosure to the general public is envisaged.

Fig. 2 Historical orthophotomap in the map application “Contaminated sites” [www.kontaminace.cenia.cz](http://www.kontaminace.cenia.cz)

Historical orthofotomap “50’s”, consists from 88.5% of images dated 1950 to 1956. Images from the years 1952-1954 then forms 64,3% of the total number of photo (20 317). With the exception of one photo from 1996, for the missing areas there were used in small scale additional images from around years 1938-1970. Fig. 3 and 4 provide visualization of aerial photo dating.

Historical orthophotomap “30’s” was created only in the test areas. Test areas B and C are not complete because they were not covered by aerial photographs. The total area of orthophoto “30’s” is 5649 km². 1996 images were used; the total coverage of test areas is 75.3%.
Fig. 3 Dating of aerial photo coverage composing historical ortofotomap “50's” prepared by supplier GEODIS [2]

Fig. 4 Dating of aerial photo coverage composing historical ortofotomap (50's) in the map application “Contaminated sites” www.kontaminace.cenia.cz

The map application “Contaminated sites” contains also a layer with contaminated sites inventory (SEKM system/database) and two layers of Landsat images (ETM+635 and ETM+321) – see fig. 6.

Fig. 6 Compositions Landsat ETM+635 and Landsat ETM+321 on the map application “Contaminated sites”
Multi-temporal analysis of the current interpretation of orthophoto

The method consists in comparing geometrically corrected images of the same area taken at different times. The result is an image of change, which is then further interpreted. We can obtain an artificially created image, in which time changes are visible. It is e.g. possible to find already non-existing objects, to identify the nature of the changes on the site and to infer whether the remediation was done or not, etc. [3].

The output of new data layer describing the evolution of number and areal density of contaminated sites in the area in the statistical scale. Another combined product originates by linking of output analysis on photomap interpretation with the output on multi-temporal analysis.
Fig. 9 An example of the use of multitemporal analysis. Differential images of historical and current orthophotos on the site Landfills Ejpovice

Fig. 9 Aerial photos from different time – industrial dumps - Landfill Ejpovice

**Analytical tool for processing hyperspectral data (work started)**

The task includes preparation of analytical tool and methodology, creating a basis of spectral libraries and benchmarking. The main features and characteristics of this work are:

- Based on the use of spectral analysis of the earth's surface.
- Hyperspectral images have hundreds of very narrow spectral bands.
- Analysis consist of: contaminated sites searching or assigning them to their image on photo, the detection of spectra of these places and their comparison with the spectral library of known objects or materials.
- Detection of reference contaminated sides and production of their spectral library.
- Reverse procedure to detect contamination in the area where the hyperspectral images are available.
- So far processing the satellite Hyperion hyperspectral data been done.
Fig. 10 An overview of available Hyperion images in Czech Republic

Fig. 11 Reference contaminated site (stockpile of coal) in Tišice (30 km N from Prague) and its spectral profile.

Fig. 12 Reference contaminated site Hradištěsko (small municipal waste landfill in the forest, 20 km S from Prague) and its spectral profile

**The methodology for processing multispectral data (work started)**

The procedure follows a driven classification method - determination of the known image samples (the training areas), so that important spectral characteristics of the given phenomenon in a known location was clearly captured.

The classification algorithm of the processing is governed by these samples and finds objects of interest based on training areas wherever it occurs in the analyzed image. Thus it can be simultaneously detected large number of objects of known properties, provided that it is paid sufficient attention to the selection of training areas.
The tool resulting from this method and usable for the project will be a layer of identified objects of interest.

**Bibliography**

