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Characterisation of oil-industrial contamination using aerial and thermal images

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ABSTRACT: Oil industrial petroleum and heavy metal contaminations caused by the former and present human activity are dangerous environmental problems, because these materials can reach the underground water and accumulated in the agricultural plants. GIS and remote sensing methods were used to map the location of near-well soil disposals using aerial photos, and thermal images were taken and analysed to find the location of fractures on the underground pipeline. The amount of the deposited waste material and the rate of the human effect was calculated and mapped.

1. INTRODUCTION

There are currently over 20,000 registered contaminated sites in Hungary. The estimated cost of the remediation of these known sites is approximately 2 billion USD. The delineation of the contaminated areas and their associated sources is an extremely complex process due to the different types of contaminants and their associated persistence and migration, as well as the media in which the contamination is present (e.g. in soil, vegetation, and groundwater).

The aim of the research program was to clearly identify and locate the suspected and unknown contaminated areas and their corresponding sources at an oil-industrial field. The project utilised state-of-the-art techniques in remote sensing, material science, geostatistics, information management, and cartography.

The exploration of natural oil and gas began in the mid 1960's in the southern part of Hungary. The Algyõ Oil and Gas Field (ca. 24 km2) belongs to the Hungarian Oil and Gas Company Ltd. (MOL) and is the largest oil and gas field in the country (Figure 1-2.). The oil-field is situated to the north of Szeged. Some wells are in the city area.

There are in excess of 1000 oil wells within this field. During the intensive drilling operations, various additive materials containing high levels of heavy metals (Cr, Pb, etc.) were utilised. These contaminants were deposited in the area of the existing wells. In one so called "near-well soil

Figure 1. Geographical location of the investigated area (black square at Szeged)

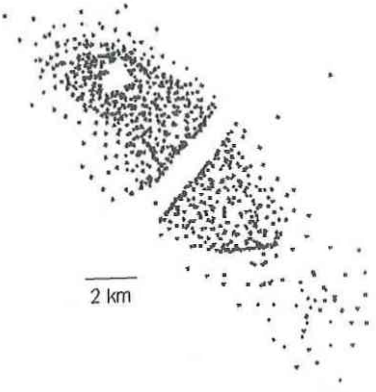

Figure 2. Location of oil, gas and thermal water wells.

disposal" area, varying amounts of contaminant material (ranging from 100 to 1000 m^3) were deposited at each well. Due to the lack of precise maps, the locations of the former disposal sites have been forgotten. The goal of the research programme was to identify, locate, and map the positions of disposals, and to subsequently assess the effects of selected representative (4-5) contaminants by complex analytical methods (remote sensing, geo- and hydro-chemical analysis, GIS based environmental modelling, etc.). These analytical tools and modelling results will then be deployed as a continuous monitoring system covering the entire oil field.

2. ENVIRONMENTAL CONTAMINATIONS

2.1. Mapping of near-well soil disposals

The use of aerial remote sensing methods coupled with field data acquisition allowed us to identify contaminated areas in a time- and cost-effective manner. Aerial photos (1950, 1981, 1989, 1995) gave detailed information about the position of near-well soil disposals (Mucsi 2000).

All aerial photos were transformed into the same map projection system, which is presently used in Hungary.

The first series, acquired in 1950, was chosen from the time before the industrial activity. In Figure 3 small agricultural parcels can be seen.

The analysis of these photos was very useful, because some natural phenomena can be localised on these images, which can be distinguished hardly from the antropogenic forms on the later images (See the light grey patches on the left side of the airphoto on Figure 2.).

The aerial photos show a totally changed landscape from 1981. This time was the most active period of the oil industrial research and exploitation. With Russian technology very deep wells (more than 1800) were drilled into the Earth's surface. During the intensive drilling operations, various additive materials containing high levels of heavy metals (Cr, Pb, etc.) were utilised. These contaminants were deposited in the area of the existing wells.

In one so called "near-well soil disposal" area, varying amounts of contaminant material (ranging from 100 to 1000 m^3) were deposited at each well.

Because of the unknown environmental effect of the additive materials and the missing environmental plans these disposals were not mapped correctly. GIS methods and database system operations were used for the reconstruction of the location of the disposals. According to the drilling technology used, additive materials were used only at the wells deeper than 1800 m before mid 80's.

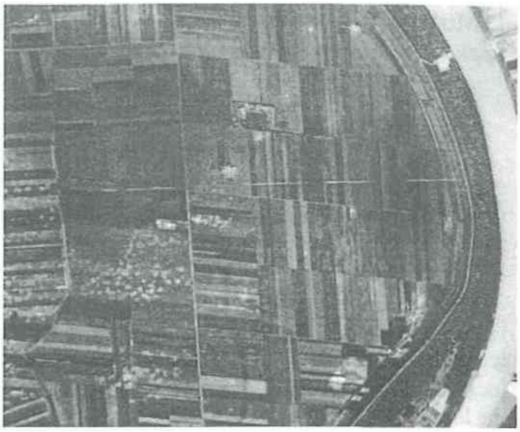

Figure 3. Part of the investigated area on an aerial photo acquired in 1950

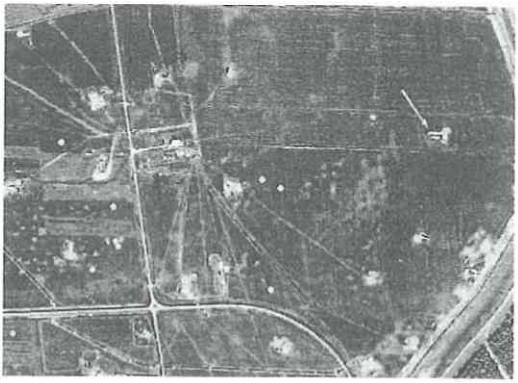

Figure 4. Oil wells on the oil-field in 1981. The white arrow shows to a near-well soil disposal. White circles are the location of the new wells.

The existing geographical co-ordinates of the wells were the geometrical data in GIS, the time of drilling, the depth of the well, and other attribute data were put into the database system. Attribute data selection method was used to preselect the wells with potential near well disposal. The surrounding of the wells was investigated on the aerial photos (1981) and the outline of the discovered (opened or covered) disposal was digitised manually from the screen.

Today there are 513 oil wells on the investigated area and 201 near well soil disposals were mapped according to the above mentioned method.

A part of the investigated can be seen again from 1995 in Figure 5. The underground pipeline network can be seen on the originally colour infrared image as bright grey lines because of the disturbed upper soil layer.

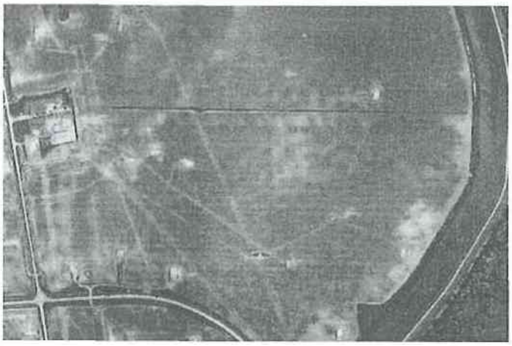

Figure 5. Oil wells on the oil-field on 26th May 1995. Disposal shown on Fig. 4. is covered by soil.

The surrounding surface of the well are used to cultivated field. In lack of the knowledge underground material different plants were planted on these surfaces. The Cr-content of soil samples and plants can be seen on the Figure 6.

The samples were analysed in the soil chemical laboratory in the Department of Physical Geography, University of Szeged.

2.2. Pipeline fractures and network monitoring

Besides searching for the contaminations caused by the technology used before 1985, the environmental monitoring has to be continued over the oil field because of the transportation of natural resources via the pipeline network system.

The corrosion caused by groundwater, the physical effect (heavy track movement) and last but not least the illegal pipeline boring (gasoline robbery) can cause soil and groundwater contamination.

Different materials of different temperature, e.g. hot thermal water (60-70 °C), warm natural oil (30-60°C) and very cold liquid gas are carried on the pipeline system. The thermal contamination and the direct effect of pipeline fractures can be measured by thermal camera.

On a cold day on 18th February 2000, a night flight was organised over the oil-field to show the possibilities of thermal image capturing and processing in environmental monitoring.

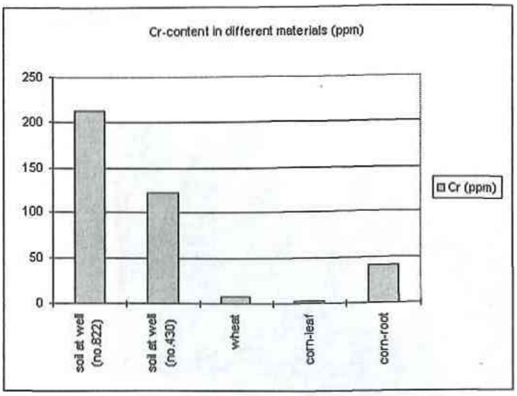

Figure 6. Cr-content of different materials

Unfortunately in this winter and spring there was large amount of inland water (more than 300.000 ha) on the Great Hungarian Plain, especially on its southern part. Water on the surface disturbs the acquisition and eliminates the thermal effect of the pipeline on to the soil.

The camera was handled manually, so in this step the correct photogrammetric image processing with geometrical correction was not the aim of study, we tried to find such phenomena, which can prove the efficiency of the thermal images.

Three very interesting thermal images are presented in the following figures. The first one illustrates the differences of the thermal characteristics of an oil-well and a thermal well (Figure 7.).

In Figure 7. the thermal effect of the underground pipeline can be seen slightly. The surface temperature is about 8-9 °C higher over the pipeline than in its surroundings.

Due to the relatively high soil temperature, the upper soil layer dries out, the vegetation does not grow as under normal conditions because of the necrosis (Figure 8.)

Very cold and relatively warm objects can be seen on Figure 9. The huge tank station and technological centre are located in the western part of the oil-field. Liquid gas is in the dark pipelines (very cold, bellow -40 °C), and relatively warm gas and oil are deposited in the spherical and cylindrical tanks.

The level of filling can also assessed (white and grey ribbons on the side of cylindrical tank on the left bottom corner of the Figure 9.)

According to this image the side-looking aerial thermal images, beside the ground measurements, can be used for the monitoring of tank stations also.

There was not seen a thermal image of a pipeline

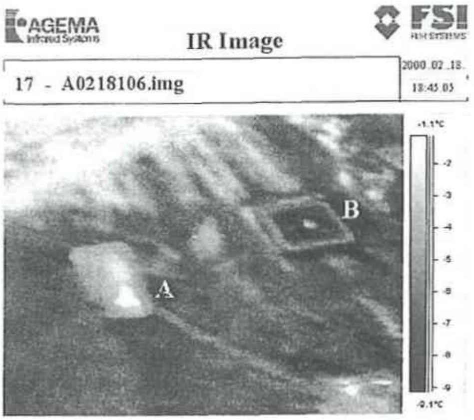

Figure 7 An oil-well (A) and a thermal-well (B) on a thermal image acquired on 18th February 2000.

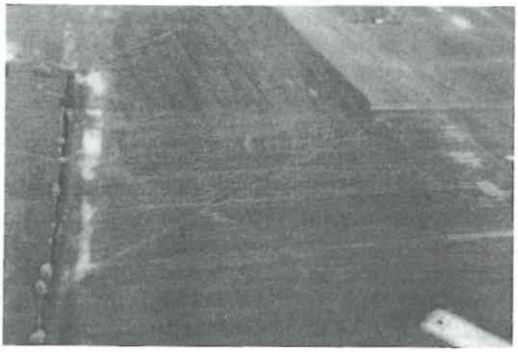

Figure 8. Crossing lines on a wheat field, which show the thermal effect of pipeline on vegetation (originally colour slide taken in 16th April 2000).

fracture before this flight, but a knot on a macaroni was imagined and looked for on the thermal images.

The direction of motion of the outflowing material and its thermal effect (thermal contamination) onto the soil depend on the size and position of the fracture on the pipe.

Because of the different densities of the gas, oil and water, they can be visualised on the surface at different times after the accident. So it is very important to discover the fractures in a very short time after their formation. The thermal images can be useful in the early recognition of the pipeline fractures.

In our flight a hot-knot was discovered on a thermal water pipeline not so far from a greenhouse. The ground investigation proved this fact (Figure 10.).

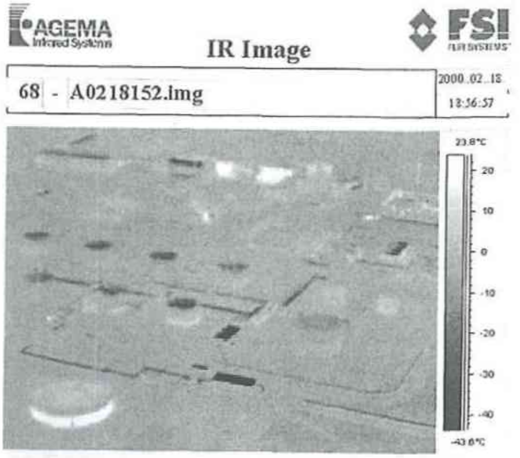

Figure 9.View of the main technological centre.

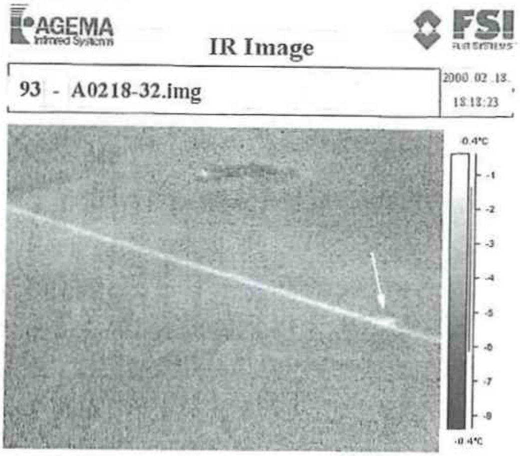

Figure 10. Hot-knot (thermal contamination effect of the fracture) on a thermal water pipeline (at white arrow).

CONCLUSIONS

The aerial photos and thermal images together with GIS methods are useful for environmental monitoring, especially locating and mapping of unknown waste disposals. Thermal images can be used to find a pipeline fracture at an early stage, therefore the environmental damage can be reduced.

REFERENCES

Mucsi L et al. 2000. Environmental monitoring of oil pipeline network using thermal spectroscopy and GIS methods - *Proceedings of the 3rd AGILE Conference*, Helsinki, pp. 137.