

APPLIED INFORMATION TECHNOLOGY ON REMOTE SENSING DATA INVESTIGATION OF RED MUD CATASTROPHE

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1. SUMMARY

Data collection with the help of remote sensing is significant in the field of gathering information about the environment quickly and effectively. In case of the red mud disaster in Ajka, Hungary Oct. 4, 2010 our group of researchers carried out an extensive remote sensing data collection with the co-ordination of Science Council of the Committee of the Government Coordination Commission, applying the most up-to-date technologies of remote sensing and data processing. In this publication besides the main points in planning and executing air shots we also summarize the results of data processing with image analysis during the evaluation of the catastrophe and the compensation period.

2. INTRODUCTION

Hungary's largest ecological disaster took place on October 4, 2010 at 1:30 p.m. when the western dam of cassette X of the mud reservoir, belonging to a privately owned company, Magyar Alumínium Zrt (Hungarian Aluminum Co.), had ruptured [17]. Our group of researchers carried out an extensive remote sensing data collection with the co-ordination of Science Council of the Committee of the Government Coordination Commission, applying the most up-to-date technologies of remote sensing and data processing.

Besides remote sensing with the help of visible (VIS) devices, studies applying Near Infrared (NIR), Far Infrared (FIR) cameras, and hyper-spectral (HYS) devices are getting more and more common [8], [10]. Applying FIR cameras (with a band of 8 μ m-14 μ m) has become a general routine in the remote measurement of temperature in case of objects, based on thermal radiation [1], [8]. There are frequent inspections for identification of faulty spots with the help of devices of different manufacturers, mainly in the fields of electric network, machines and health care. The use of FIR cameras for martial and provost purposes is also remarkable. In Hungary

there are investigations based on not only VIS, NIR and FIR recordings, but in the common fields. For aeronautic and on-the-spot measurements we have developed, tested and applied devices with high resolution and an ability to record multi-spectral/hyper-spectral image data. We have worked out unique diagnostic and data processing methods to make the optimal integration of images deriving from different methods and sensors possible. This complex knowledge allows us to evaluate and reconstruct events having happened genuinely and also plays a great role in prevention. With the help of control studies disasters could be avoided.

The major difficulty of the task derived from the fact that there has not been such a mud catastrophe in the history of mankind, which could make the planning and execution of remote sensing assessment, based on existing scientific and other works. Revising recent catastrophes, the results of a similar case and a study on technologies applied in case of oil disasters were indirectly used during the planning stage of work.

The first ecological disaster was the Aznalcóllar mine-tailings spill. It was one of the largest environmental pollution accidents in Spanish history. Although this disaster have been dealt with by a number of scientific studies [5], [6], [7], the Spanish catastrophe happened in the territory of a national park, isolated from inhabited areas, whereas the Hungarian catastrophe occurred in an inhabited and cultivated area. This way we had to face unique problems during our evaluations aiding the post-damage rescue work.

The phase of planning was aided by studies dealing with sensors used in aeronautic assessment, in case of oil catastrophes [12], [13], [14], and by works dealing with spectral data processing methods [9], [15]. However, our major help was the 2-decade professional (planning, flying and data processing) experience of the participating team.

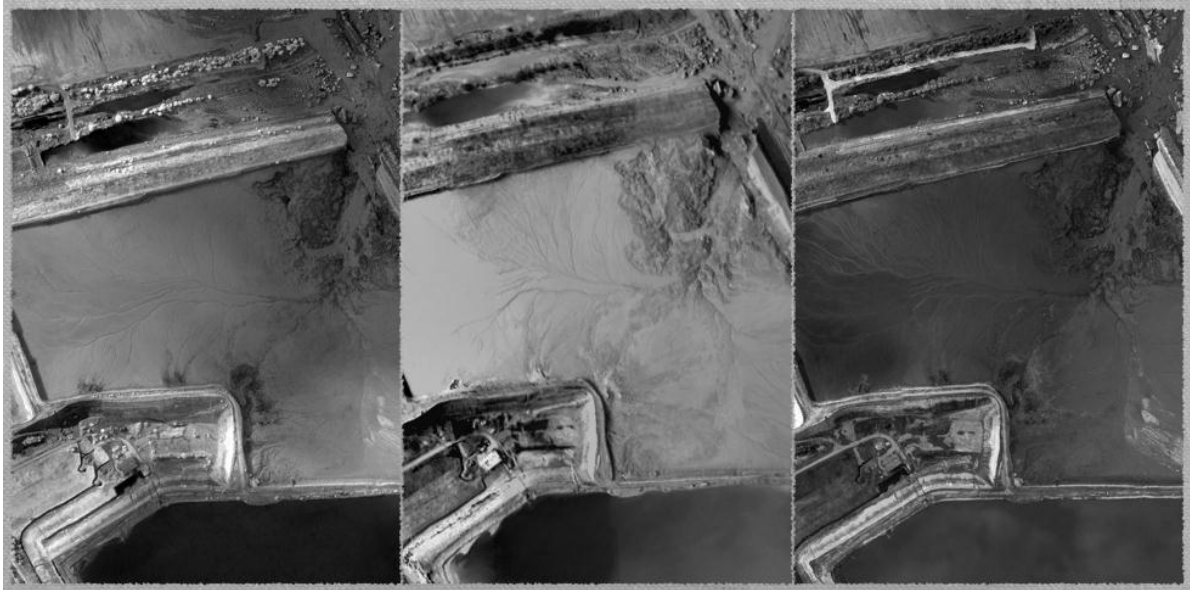


Figure 1.
Main type of images of data collection with the help of air-shot
Near Infrared (NIR, left), Far Infrared (FIR, middle) and Visible (VIS, right)

3. DATA COLLECTION, RECORDING AND PROCESSING

During the planning of remote sensing data we aimed to gain short-, mid- and long-term results. The main (short-term) purpose of remote sensing recording was to monitor the investigation of environmental damage, to locate the area of contamination precisely, to estimate the concentration of substances in the mud and to estimate the status of the flooded area. We also aimed to provide geodetic data acquired with the help of remote sensing, necessary for high-resolution visual information gained from specific spectral ranges and for the realistic post-modelling of the event (mid-term). Our further goal was to provide information helping to reveal the causes leading to the tear of the dam wall and to make proposals on further studies to be carried out. During the recording of images we put an emphasis on recording accurate and precise data, also applicable to long-term studies and inspection. Recordings were carried out in the course of 2 days, with the help of 3 planes.

The peculiarity of this event needed unique planning and implementation. Data collection with the help of remote sensing – according to the complex aims – was carried out by a number of experts participating the project. Besides, we paid special attention to on-the-spot data collection at the time of air-shots, to the opportunity of

processing the different remote-sensing technologies and to the collection of data corresponding both short and long term processing goals. Figure 1. shows basic data about the images gathered during our flights and air-shots. Before the assessment of images the necessary pre-processing tasks had been carried out: synchronization in time and place, filtration of optical and sensor-made noise, radiometric and geometric correction. During the processing of data we partly used our innovative programs (Spectral Fractal Dimension (SFD) based processing [2], [16], processing of FIR images [8]), and also special GIS and image processing software (ITT ENVI, Specim CaliGeo, Erdas Imagine, ESRI ArcGIS).

4. RESULTS

The evaluation of data provided by different remote sensing technologies was carried out in parallel, in consideration of the seriousness of the situation, applying unique and integrated data processing methods. With the help of our own method based on the fractal system we identified the noisy bands, the optimal image bands from among the hyperspectral, VIS, NIR and FIR images [9], [10], and also the muddy areas based on Spectral Fractal Dimension curves [2], [3], (Figure 2.).

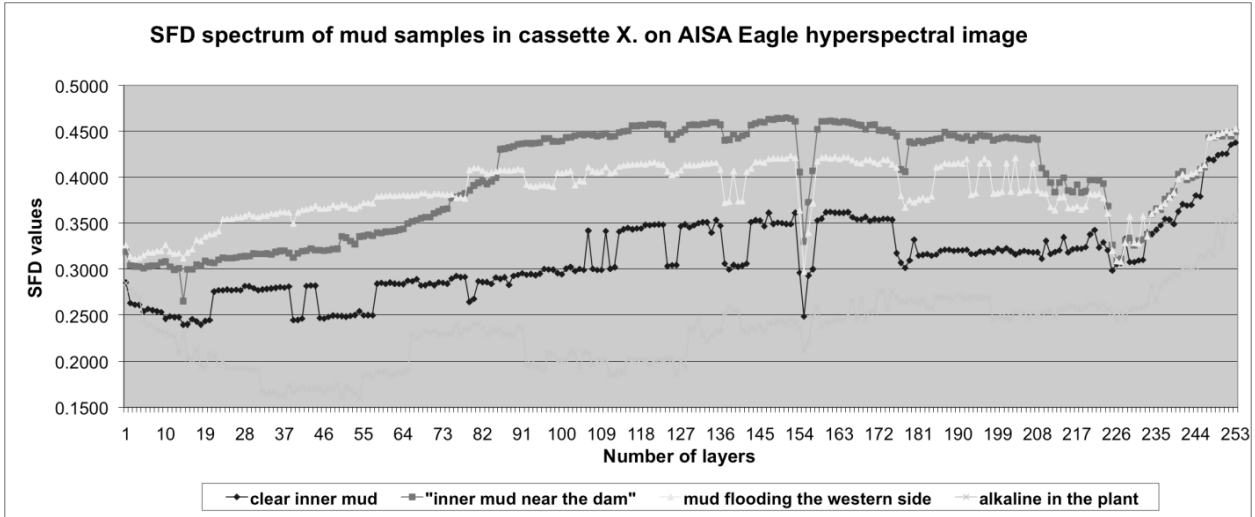


Figure 2.

'Spectral fractal fingerprints' of mud samples in the plant /Spectral Fractal Dimension values based on hyperspectral image data/

Based on the air-shots we have defined the movements involving the Northern wall of the dam together with their causes and we have localized the cut-off points and the slivering of the wall (Figure 3.), [4].

We have identified the wet, leaking areas in the images shot near the reservoir. During the lateral examination of the dam wall we studied clues alluding to cracks and leaks.

Examination of the joint wall of reservoirs IX and X was a key issue in terms post-damage rescue work and the security of surface examination. Based on the NIR and FIR air shots and photos

about the side of the dam wall we could state that there was no sign of leakage or tear. The status of the two reservoirs was stable seven days after the tear so further surface studies on the wall could be taken. Considering the reference surfaces we have managed to define the elevation of mud in the reservoir before the tear of the wall and also the amount of mud flooding out of the reservoir. The reference level of the mud in the reservoir before the tear was defined with the help of data gained with stereo evaluation of air-shots in September 2010. The area after the tear of the barrier wall was given by a measurement with LIDAR technology.



Figure 3.

Localization of cracks, breaks and slivering



Figure 4.
Hyperspectral mosaic (RGB) and areas covered by layers of different thickness

The volume between the two areas was defined by their intersection. The 'reconstruction' of the broken piece of wall was also made based on the shots above. We have also defined the cross-section and longitudinal section of the reservoir [4]. We applied different classes (end members) according to the surface cover. The wet phase, with dry matter content less than 30%, was defined separately. When applying the SAM, the angle value was optimized based on the control areas. After the area impoundment we defined the spectra correlating with the thickness of mud (in case of a mud with 30-70 percent by mass) with the help of regression analysis, based on on-the-spot samples. Based on the RMLI (Red Mud Layer Index) calculation from the 550 nm and the 682 nm band cassette we defined the threshold values for 4 thickness categories of previously marked areas (Figure 4.), [4].

5. CONCLUSION

After the evaluation of data from VIS, NIR and FIR air shots, and the discussion with decision-makers the disaster relief commissioner stated

that all damage windup and reconstruction work would be exclusively done or confirmed by the researchers of Hungarian Academy of Sciences (including our group dealing with air shots), controlled by the Scientific Council of the Government Coordination Commission. Fast and global air photography of the reservoir and its surroundings and the fast evaluation of data made it possible to carry out a precise and reliable status control. The results gained could be used during the damage windup. As a result of this examination suggestions were made for further surface inspection. Digital data recorded during the examination provide a good basis for future evaluation and are precise and adequate enough for future studies. This disaster revealed that in most countries there is not a plan for the aligned research in case of such catastrophe. Research methods for each workgroups have also been worked-out. The results mentioned above could be gained due to the aligned and collected work of research groups.

6. ACKNOWLEDGEMENT

It is the authors' pleasure to thank the members of the workgroup, who supported us with their prosperous work, but whose names could not be listed. We would also like to thank all participants in other work groups who supported our aeronautical recordings and the investigation of reliable data. We owe our deepest gratitude to Róbert Károly College, which provided financial support and also to the National Disaster Relief Committee, which controlled the practical realization of results.

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