Multispectral investigations of acid mine lakes of lignite open cast mines in Central Germany

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ABSTRACT

This study shows multispectral investigations of open cast mining residual lakes. To characterise the spectral signature of these mining lakes, fieldbased spectroradiometric and airborne imaging multispectral measurements with the Compact Airborne Spectrographic Imager (*casi*) in combination with water sampling were made. As a final result the *casi* data should be classified according to investigated hydrochemical and hydrobiological properties.

INTRODUCTION

The reclamation problem exists world-wide for mining areas. It is one of the most intense intervention into an environmental system. The intense exploitation of lignite in open cast mines leads to a high mass deficit which must be compensated after the close of a mine. In Central Germany after the re-unification many lignite open cast mines were closed and reveals a particularly large reclamation demand.

The mass deficit can be filled by dumped sediment and by ground or surface water, which often results in essential problems, i.e. in terms of the water quality. Thereby the chemical properties of the lakes depends on the condition of these dumped sediments. Very acidic lakes are caused by the oxidation of pyrite and marcasite minerals of the sediments and by the ascending ground water. Due to deposit of different sediments there are small scale variations in the lake. Owing to the filling with different waters like ground and surface water the open cast mining lakes are subject of very high dynamics. Consequently acidic lakes distinguish from natural lakes strongly. Instead of high chlorophyll concentrations very low pH value caused by high metal iron and high sulphate content are given in acid mine lakes.

First experiences with remote sensing of acid lakes based on empirical investigations of some water parameters are presented [Repic et al. 1991].

We want to provide also an analytical approach to the investigation of acid mine lakes.

The results of the investigations give a contribution to a spatial observation, more economical reclamation and monitoring of the lignite open cast mining areas in Central Germany.

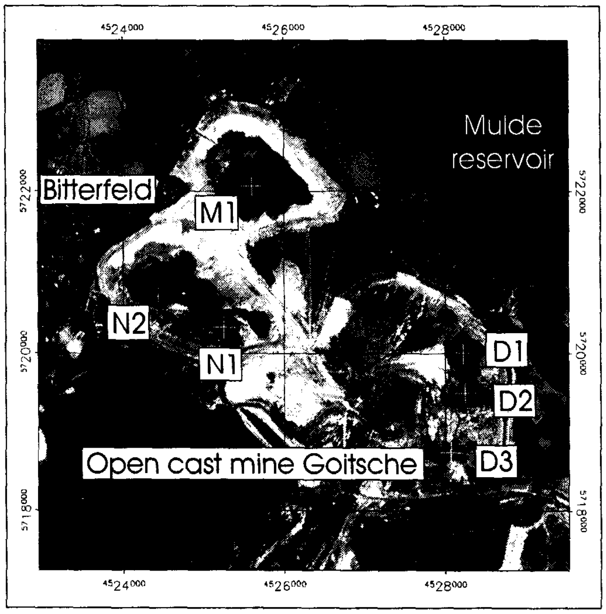

Fig. 1 IRS 1C Pan scene of the test site 08.08.1998.

STUDY AREA

The study site is the mining area Goitsche located in Central Germany near Halle and Bitterfeld (Fig.1). In this area mining activities occurred prior to 1990. The site consists of three water bodies formed as a result of open cast mining and ascending ground water. Due to deposit tertiary and quaternary sediments the lake types are very different.

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DATA ACQUISITION

Water sampling and spectral field measurements were made at six sampling stations at the three lakes simultaneously to the *casi* flights in order to obtain and analyse chemical composition data in 1998. Data acquisition was realised on clear sunny days.
The location of sampling points is shown in Fig. 1.

Water quality parameters

At each sampling station vertical profiles of pH value, conductivity, dissolved oxygen and temperature additionally to the redox potential sampled by a multilevel sonde at 1 m depth intervals were made. Also secchi depth was measured and water samples were collected from the surface down to the secchi depth of the lake. Titration acidity was measured after the water sampling. A part of water was filtered through a 0,45 μm filter. All samples were sealed and transported to a laboratory. In the laboratory water samples were analysed for total Fe, dissolved Fe(II), dissolved Fe(III), Na, Al, Cd, Cu, Cr, Fe, Mn, Ni, Zn, K, Ca, Mg, Mn, sulphate, chloride and DOC/TOC (Tab. 1).

Tab. 1 Selected water parameters.

Location	pH value	Secchi depth [cm]	Total dissolved iron content [mg/l]	Sulphate content [mg/l]
N1	2,90	70	96,60	1921,3
N2	3,00	60	103,70	1892,1
M1	3,30	115	11,78	644,7
D1	7,20	365	0,00	1696,9
D2	6,75	95	0,07	802,5
D3	6,30	40	0,00	996,0

Spectral field measurements

The spectral field measurements were carried out with a field spectrometer (OCEAN OPTICS SD1000, 200 μm optical fiber, 652 channels from 300 to 1000 nm at 1.1 intervals and 25° field of view).
The upwelling radiance was determined with a self designed equipment in different depths depth (5, 15, and 25 cm) (Fig. 2). Ten spectra were collected for each depth and averaged to increase the signal-to-noise-ratio. All spectra were measured nadir and referenced to a reflectance standard.

The relation between upwelling radiance and downwelling irradiance reveals reflectance spectra (Fig. 4a). The reflectance spectra in different depth were extrapolated to the water surface (Fig. 3).

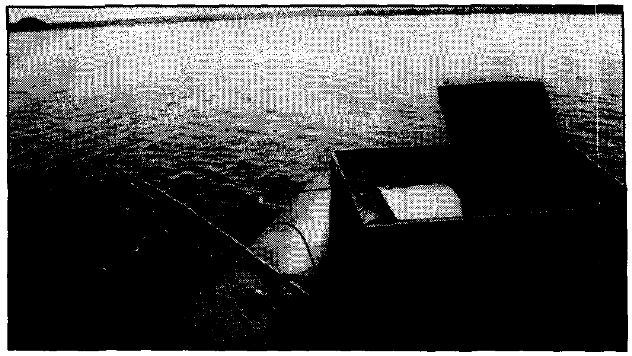


Fig. 2 Equipment for the measurement of upwelling radiance.

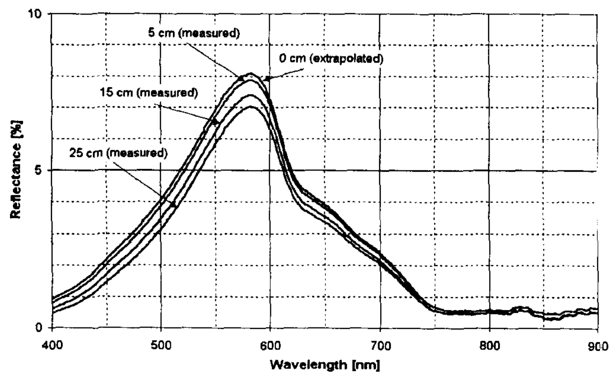


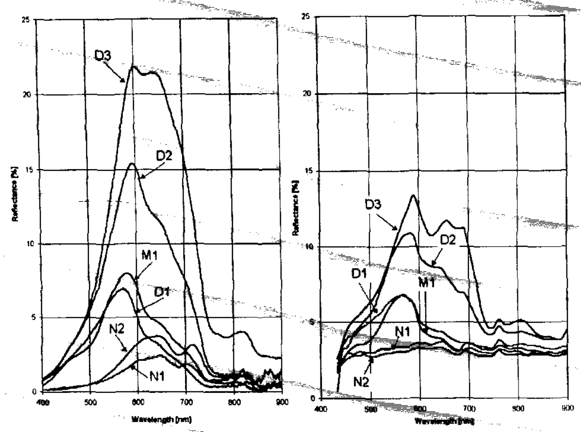
Fig. 3 Reflectance spectra measured at different depths and extrapolated to the water surface.

Imaging spectrometer measurements

The *casi* has been flown over the Goitsche area in the enhanced spectral mode with 48 adjacent non-overlapping bands with a 10.6 nm band with within the spectral range from 428 nm to 975 nm. Fig. 4b shows spectra of the same lakes and sampling locations as presented in Fig. 1., Fig. 4a and Tab. 1.

The test site Goitsche was covered by 6 flight tracks at 3 km flight altitude. The data were atmospherically, radiometrically and geometrically corrected for a correct investigation.
All flight tracks were tessellated to a mosaic.

The resulting remote sensing reflectance will be used for the water classification.



a) b)

Fig. 4 Reflectance spectra of mining lakes
a) with a field spectrometer
b) with *casi.*

Simultaneously to the spectral field measurements spectrophotometric laboratory measurements were carried out. The photometric measurements were performed at filtered and unfiltered water.

METHODOLOGY

For the retrieval of different water constituents from remote sensing data an inverse modelling technique will be used. For the inverse modelling approach the radiative transfer through water and atmosphere must be modelled. Then the modelled multispectral sensor signal can be compared with the measured signal. Inverting the function between the reflected radiation and the modelled water constituents enables the determination of the concentrations quantitatively. Therefore it is necessary to acquire inherent optical properties and corresponding concentrations of water constituents together with simultaneous measurements of multispectral radiance.

CONCLUSION

Two lakes (N, M) have a pH value of about 3 and the other two lakes have a pH value of about 6 as an issue of two different buffering systems. With pH value 2-4 exist a Fe buffer and with pH value 6-8 exist a bicarbonate buffer [Geller et al. 1998]. The lakes with pH value 3 shows a considerable quantity of iron in contrast to the other lakes (Tab.1).

This differences are given also in the reflectance spectra. Very acid locations (N1, N2) with a high iron content have a low reflectance maximum near 650 nm. Additionally a chlorophyll fluorescence peak is visible at 700 nm. The locations with pH about 6 (D1, D2, D3) and a very low iron content have a higher maximum near 600 nm. M1 has a pH 3.3, middle iron content and the reflectance maximum is also near 600 nm. Today, location M1 is flooded with water of river Mulde and as a matter of fact a higher pH value and lower iron content develops. The intensity of reflectance maxima is also very different and negative correlated to the secchi depth.
These variations open the possibility to characterise acid lignite open cast residual lakes with remote sensing methods.

Finally airborne remote sensing data should be classified according to the hydrochemical and hydrobiological properties of the open cast residual lakes. This classification should be done on the one hand between the single lakes and on the other hand within the lakes. For that purpose, a database of optical properties of the most important optically active water substances in the investigated open cast residual lakes should be set up. To enable this, the relations between the optical properties and the concentrations of the investigated water constituents must be determined. The input for the radiative transfer model MOMO must be specified prior to the radiative transfer calculations and the application of the generated database.

The application of remote sensing methods open new perspectives in the issue of spatial and temporal monitoring of acidic lakes.

ACKNOWLEDGEMENTS

This work is funded by the Centre for Environmental Research (UFZ) Leipzig-Halle (FKZ 04/98) since June 1998 and is supported scientifically by the Departments of Inland Water Research and Hydrogeology of the UFZ. Moreover a co-operation with the Lusatian and Central German Mining Administration Company (LMBV) exists.

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