OPTICAL PROPERTIES OF OPEN CAST LIGNITE MINING LAKES IN CENTRAL GERMANY

Judith BOINE, Cornelia GLÄßER
Martin Luther University Halle Wittenberg, Germany
Institute of Geography
boine@geographie.uni-halle.de
glaesser@geographie.uni-halle.de

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ABSTRACT

The aim of the study is the characterisation of the optical properties of mining lakes. These optical properties will be used to the classification of remote sensing data and the spatial and temporal monitoring of these lakes.
Absorption properties of yellow substance and tripton were measured in the laboratory. The backscattering properties of tripton were retrieved by the measured reflectance spectra and known backscattering spectra of water and phytoplankton. The absorption measurements and the averaged backscattering properties were used to simulate the measured reflectance spectra of mining lakes.
It will be shown that the optical properties of mining lakes are very different to natural inland water. Furthermore variations exist between the different types of mining lakes too. At the basis of the different absorption and backscattering properties of tripton mining lakes were classified in four groups in dependency of the pH value and the inorganic content of the suspended matter. The modelled reflectance spectra are quite similar to the modelled reflectance spectra.

KURZFASSUNG

Ziel dieser Untersuchungen ist die Charakterisierung der optischen Eigenschaften von Tagebaurestseen, welche für die Klassifizierung von Fernerkundungsdaten und ein Monitoring dieser Seen Anwendung finden sollen.
Das Methodenspektrum umfasst die Bestimmung der Absorptionseigenschaften von Gelbstoff und Tripton im Labor, sowie Messungen des Reflexionsgrades im Feld. Mit Hilfe der gemessenen Reflexionsspektren und den bekannten Rückstreuspektren von Wasser und Phytoplankton wurden die Rückstreueigenschaften des Triptons berechnet. Aus den Absorptionsspektren und den gemittelten Rückstreuspektren erfolgte die Modellierung der Reflexionsspektren für verschiede Seen.
Es kann gezeigt werden, dass die optischen Eigenschaften der Tagebaurestseen sich einerseits signifikant von denen natürlicher Binnengewässer unterscheiden, es aber auch zwischen den Tagebaurestseen Unterschiede gibt. Auf Grundlage der unterschiedlichen Absorptions- und Rückstreueigenschaften von Tripton wurden die Tagebaurestseen in Abhängigkeit vom pH-Wert und dem prozentualen Anteil von anorganischer Substanz in vier Gruppen untergeteilt. Die modellierten Reflexionsspektren sind den gemessenen Reflexionsspektren sehr ähnlich.

1 INTRODUCTION

Remote sensing methods enable the estimation of water quality parameters in inland and coastal waters because the optical properties of these waters are known. Remote sensing methods for mining lakes exist only few experiences and optical properties of mining lakes are not available. Therefore the optical properties have to investigate for a successful development of remote sensing methods.
The applications of remote sensing methods of mining lakes are necessary for the spatial and temporal monitoring of hydrochemical and hydrobiological data and for a control of water quality. This is important since mining lakes especially acid mine lakes are a world-wide existing problem, because of the acid mine drainage (AMD) system. The oxidation of pyrite and marcasite, minerals that are commonly associated with lignite, and the ascending of ground water or the flooding with surface water were founded the AMD system. The sediment chemistry and the kind of flooding (ground or surface water) are important for the chemical and biological development of mining lakes and leads to a high dynamic in there properties.

2 TEST SITE

The test sites are parts of the deposit of Eocene Lignite (bituminous brown coal) in the Central Germany region (200 km in south of Berlin). The lignite appears over large areas in great quantities in at least two seems, approximately 5 to 15 meters thick. Marine Tertiary sediments and Pleistocene Glacigen sediments cover them. The marine sediments in particular, but also the lignite itself, are rich in pyrite and marcasite. A highly acid pore water (pH 2.5–4), caused by the oxidation of the pyrites, leads to reactive properties in the in the initial mineral composition. Intensive acid mine drainage processes are founded, which the hydrochemical properties of the mining lakes influenced strongly.

3 METHODS

At several days a lot of data were sampled at different sampling points like pH value, Secchi depth, DOC, suspended matter, chlorophyll and others under different seasonal aspects. Furthermore reflectance spectra (R(0-)) were measured in different depths and extrapolated to the water surface. A detailed description of the field and analytical measurements are given in Boine et al. 1999.
The absorption coefficient of yellow substance and tripton were estimated in the laboratory. The methods and results are described in Gläßer et al. 2000 in detail.

3.1 Foundations of the modelling of reflectance spectra

The modelling of the reflectance spectra R(0-) is determined after the following equation (Gordon et al. 1975)

$$R(0-) = 0{,}32 * \frac{b_b}{a + b_b} \qquad (1)$$

In remote sensing application remote sensing reflectance R(0+) will be used. With the relation

$$R(0+) = 0{,}544 * R(0-) \qquad (2)$$

the R(0-) spectra were transformed in R(0+) spectra (Lindell et al. 1999).

The application of equation (1) changed equation (2) to

$$R(0+) = 0{,}174 * \frac{b_b}{a + b_b} \qquad (3)$$

a	total absorption coefficient [m^{-1}]
b	total backscattering coefficient [m^{-1}]

$$a = a_w + a_{440nm} * a_y^* + C_{chla} * a_{ph}^* + C_{tr} * a_{tr}^* \tag{4}$$

$$b_b = b_{bw} + C_{chla}^{0,8} * b_{bph}^* + C_{tr}^{0,8} * b_{btr}^* \tag{5}$$

a_w	absorption of water [m^{-1}]
a_{440nm}	absorption of yellow substance at 440 nm
a_y*	specific absorption of yellow substance [m^{-1}]
C_{chla}	concentration of chlorophyll a [$\mu g l^{-1}$]
a_{ph}*	specific absorption of phytoplankton [$m^2 mg^{-1}$]
C_{tr}	concentration of tripton [$mg l^{-1}$]
a_{tr}*	specific absorption of tripton [$m^2 g^{-1}$]
b_{bw}	backscattering coefficient of water [m^{-1}]
b_{bph}*	specific backscattering coefficient of phytoplankton [$m^2 mg^{-1}$]
b_{btr}*	specific backscattering coefficient of tripton [$m^2 g^{-1}$]

3.2 Determination of the backscattering coefficient

The total backscattering coefficient could not measure directly. For this reason it will be determine by change of equation (3) (Lindell et al. 1999).

$$b_b = \frac{R(0+) * a}{(0,174 - R(0+))} \tag{7}$$

The backscattering coefficient of water and phytoplankton were taking at the Excel program Biopti of Hoogenboom (without year)[1]. From this follows with equation (5):

$$b_{btr} = b_b - b_{bw} - b_{bph} \tag{8}$$

Refer to Lindell et al. (1999) specific backscattering coefficients were determined through:

$$b_{bph}^* = \frac{b_{bph}}{C_{chla}^{0,8}} \tag{9}$$

$$b_{btr}^* = \frac{b_{btr}}{C_{tr}^{0,8}} \tag{10}$$

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[1] We thanks Arnold Dekker and Erin Hoogenboom for the use of the Excel program Biopti.

4 RESUTLS

4.1 Absorption properties

The absorption of yellow substance can be described as an exponential function. As an initial step the slope S is estimated to 0,0487 for acid mining lakes and to 0,0224 for neutral mining lakes between 350 nm and 450 nm (Gläßer et al. 2000). In natural lakes the properties of suspended matter are characterised by a high content of phytoplankton and detritus. The content of inorganic components is not considerable with exception of shore areas. But the suspended matter of mining lakes is more influenced by mineral precipitation than by phytoplankton. Therefore the specific absorption of tripton in mining lakes is much more higher than the specific absorption of natural lakes (Figure 1). By means of these absorption spectra the mining lakes could be divided into four groups. Absorption spectra with similar shape were combined. The composition of tripton is subject for further research in order to clear the differences between the mining lakes. In acid lakes and in inorganic neutral lakes a shoulder exists at 490 nm by the mineral precipitation.

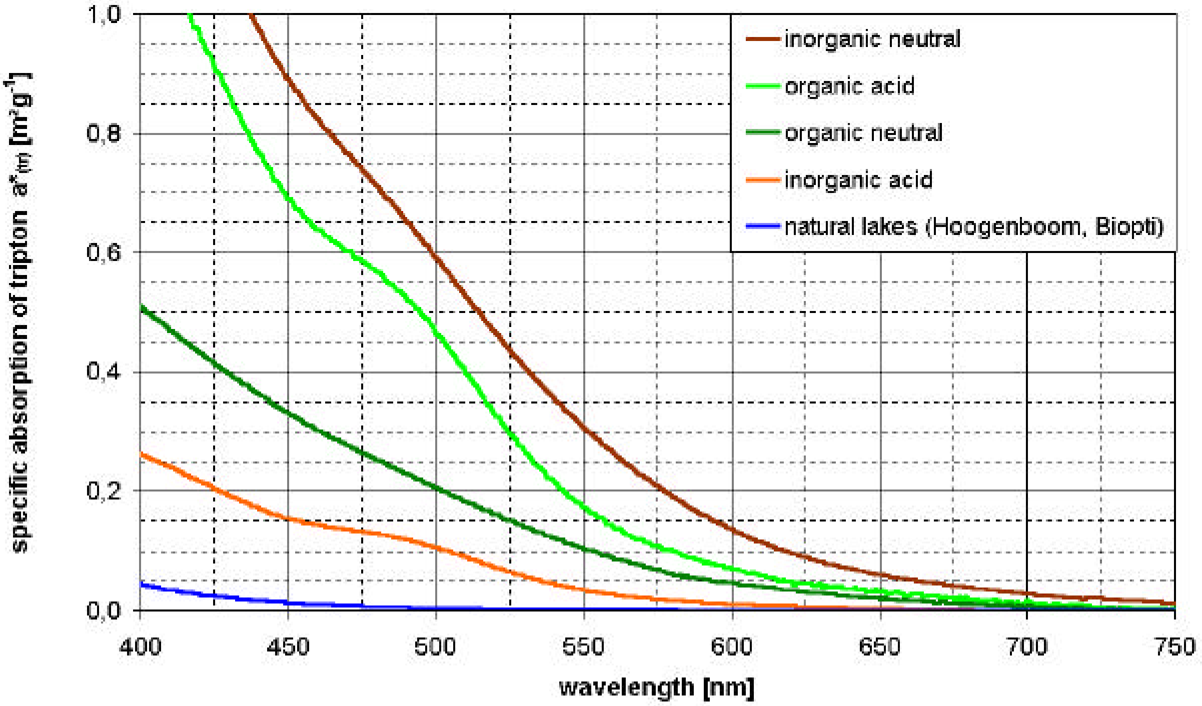

Figure 1. Specific absorption spectra of tripton of mining lakes

The specific absorption of phytoplankton of mining lakes is similar to the corresponding value of natural inland lakes. But in the acid mining lakes an additional peak exists at 650 nm. This peak relates to a higher concentration of chlorophyll b. The modelling of the reflectance spectra was carried out with the absorption spectra of Hoogenboom, because the chlorophyll b peak is negligible at the reflectance spectra.

4.2 Backscattering of Tripton

The classification of the mining lakes into four groups was proved to the analysis of the backscattering spectra too (Figure 2). The very high backscattering of tripton in inorganic neutral lakes is very surprisingly. But this is caused by the mineral precipitation in these lakes. The precipitation is very fine and the grains are absolutely small. Furthermore, the increase of the spectra of organic lakes at 700 nm is unexpected also. However Lindell et al. 1999 in turbid waters found similar results. Probably this is attribute to the content of phytoplankton, but this is also subject for further research. The backscattering properties of inorganic acid lakes and organic neutral lakes are similar to natural lakes between 400 nm and 700 nm. In this wavelength region backscattering is independent of wavelength. The backscattering properties are explored not much by wavelength between 750 nm and 850 nm.

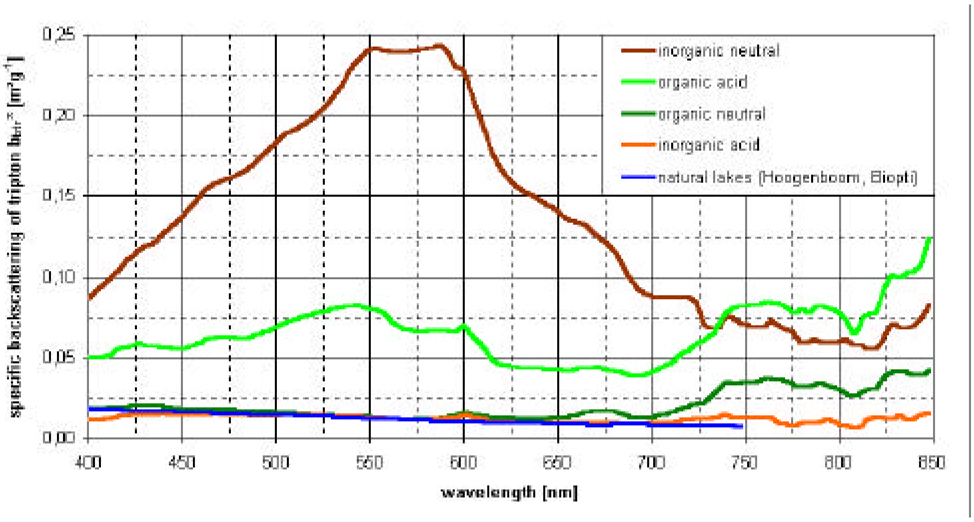

Figure 2. Specific backscattering of tripton in mining lakes

4.3 Modelling of reflectance spectra

The modelling of reflectance spectra R(0+) was made into the four groups and was calculated after equation (3) with the introduced absorption and backscattering spectra. Each group is characterised by the pH value and percentage content of inorganic suspended matter (Table 1).

	Inorganic acid	Organic acid	Inorganic neutral	Organic neutral
pH value	< 5	< 5	□ 5	□ 5
percentage content of inorganic suspended matter	< 40 %	□ 40%	< 40 %	□ 40 %

Table 1. Classification of mining lakes by means of pH value and percentage content of inorganic suspended matter

Figure 3 shows one sample per type of mining lakes of modelled and measured reflectance spectra R(0+). The correlation between the measured and modelled reflectance spectra is very high.

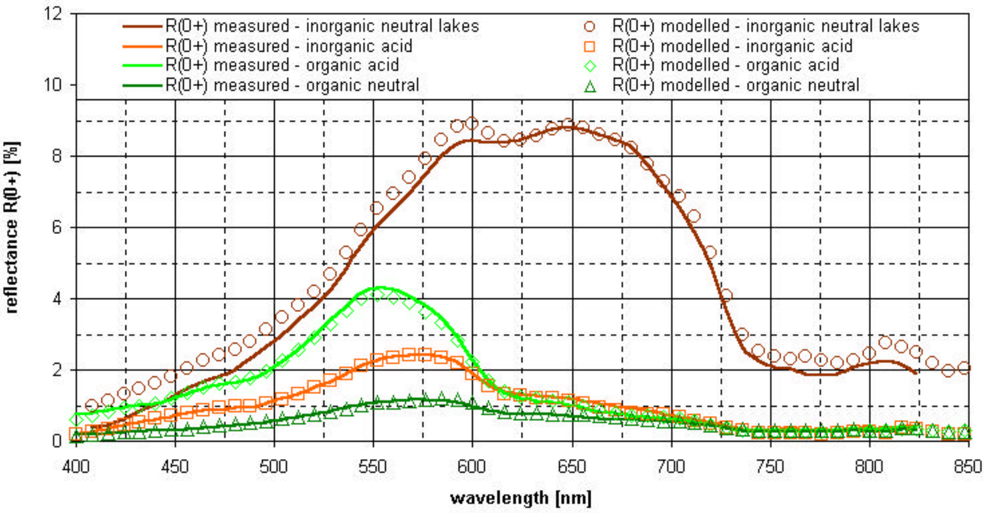

Figure 3. Modelled and measured reflectance spectra of mining lakes

Between the four types of mining lakes exist very strong distinguishes. The differences refer to the intensity and the shape of the reflectance spectra. In the main the intensity and the maximum of the reflectance spectra is caused by the absorption of water and tripton and by the backscattering of tripton. An influence of yellow substance exits only in the blue region of the spectra (see Figure 4 and 5). In general the position of maxima of reflectance spectra depends on more by the absorption than by the backscattering. But the intensity of reflectance spectra is more shaped by backscattering than by absorption.

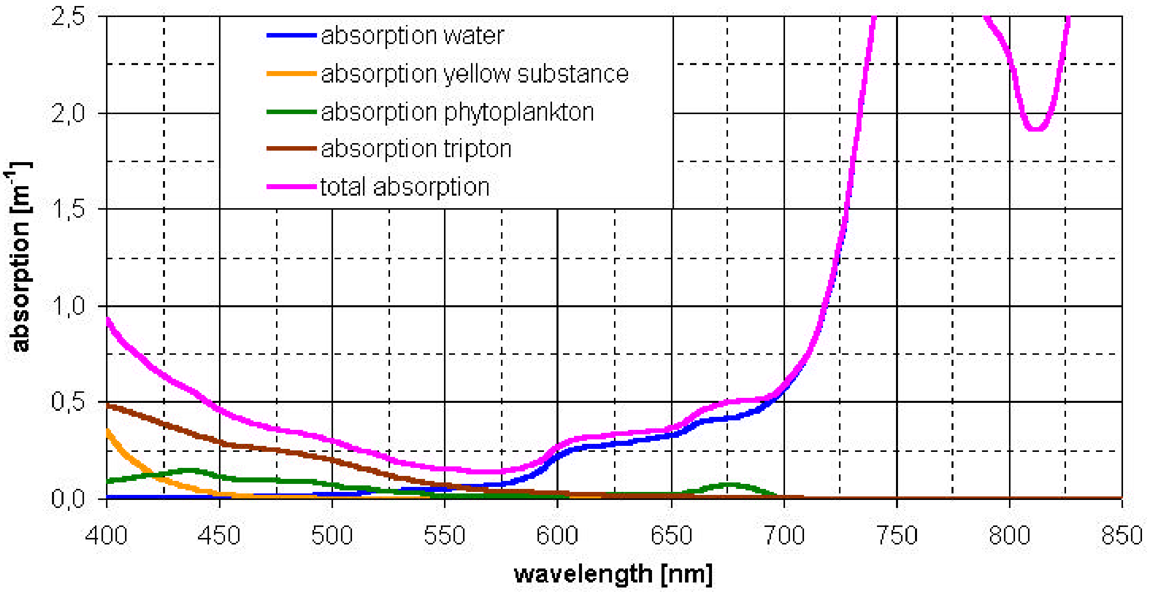

Figure 4. Absorption spectra of organic acid mining lakes

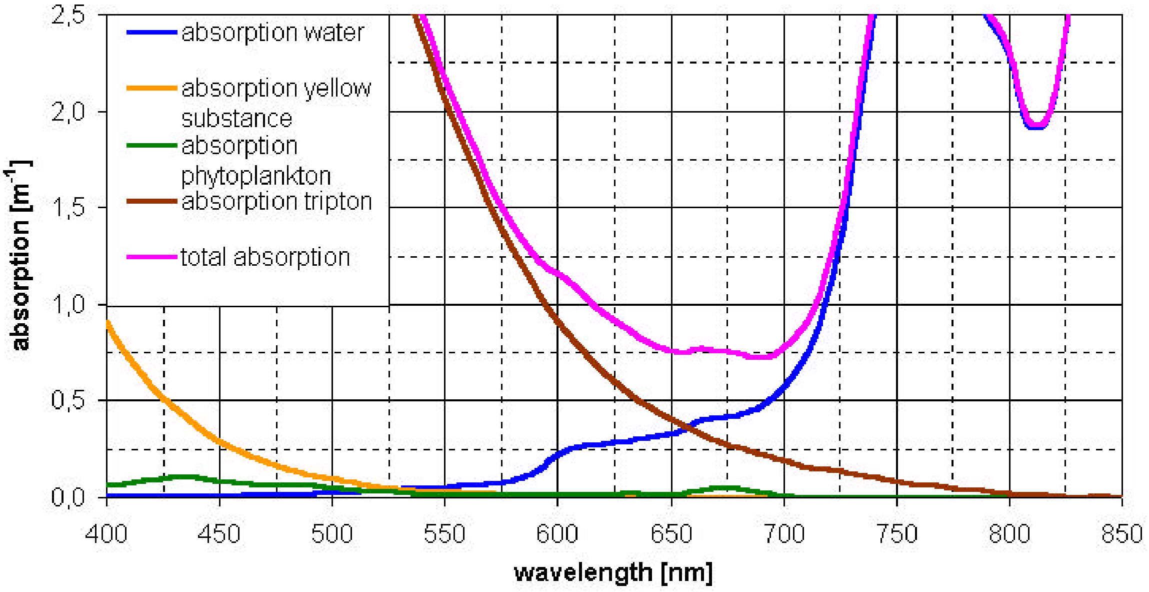

Figure 5. Absorption spectra of inorganic neutral mining lakes

Mostly only one maximum exists at the reflectance spectra. Because of the strong absorption of tripton of neutral inorganic lakes two maxima exist one caused by the backscattering and one caused by the absorption of tripton. In the reflectance spectra of acid lakes a shoulder exits between 450 nm and 500 nm.

The absorption minimum of water and the backscattering of suspended matter cause the maximum at 812 nm.

5 CONLUSIONS

In this exploratory study modelling was used to simulate the reflectance spectra of mining lakes. The optical properties of the water constituents used were measured in the laboratory. The simulations show a good comparison with the measured reflectance spectra.

This database and the fundamental comprehension represent a good basis for the support and validation of empirical and analytical modelling of optical remote sensing data for mining water quality monitoring. But the model must be validated thoroughly with field and laboratory measurements.

This work has shown that the optical properties of natural lakes cannot be used for the modelling of reflectance spectra of mining lakes. Furthermore, this study pointed out that the mining lakes have to be classified into four main groups. The modelling has been taken into these four groups.

These first investigations of optical properties of mining lakes open new perspectives in the issue of spatial and temporal monitoring of the lakes and moreover in the assessment of the ecological situation in this damaged area.

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