

Preliminary Report from the Application of Bentophos® to the Silbersee (November 2006 – October 2007)

Introduction

Following the reduction of nutrients in the Silbersee through the removal of deep water, the Institut Dr. Nowak was commissioned by the Stuhr community to effect a permanent reduction in nutrient levels by removing the phosphate.

During 2005 about 18 kg of phosphorus was removed by pumping up and discharging water from the deepest parts of the lake. However, large quantities of the phosphate nutrient are deposited in the sediment of the lake. These can only be reduced very slowly by water removal. A permanent reduction of the phosphate level to the degree required would have taken many years.

Removing the deep water was also out of the question as the resulting reduction in the water level, particularly in the summer, can effect the bathing industry. Dryness in the fringe zones could also damage the natural coverage and destroy the habitats of birds, fish and insects.

It was only considered possible to prevent blooms of blue-green algae through more advanced measures. Blue-green algal blooms had occurred in previous years and led to temporary bans in swimming. Consequently, between 14th and 15th November 2006, a quantity of 21.5 tonnes of Bentophos® was applied to the lake to immobilise the phosphorus.

Situation during the treatment period

In the period before the application of Bentophos, the water was visibly stratified. Below 5 metres, anaerobic conditions had formed (Diagram 1). Prior to the application, destratification commenced as a result of strong winds and by the time of the application the Silbersee was completely mixed. Aerobic conditions extended to the bottom of the lake at 7 m and the pH became stable at a value of 7.6.

This created favourable conditions for the removal of phosphate because a large part of total phosphorus existed as orthophosphate and was distributed evenly over the entire water column. Upon applying Bentophos, it was therefore possible to achieve the maximum phosphate binding efficiency during the slow settling phase through the water column (*Diagram 2*).

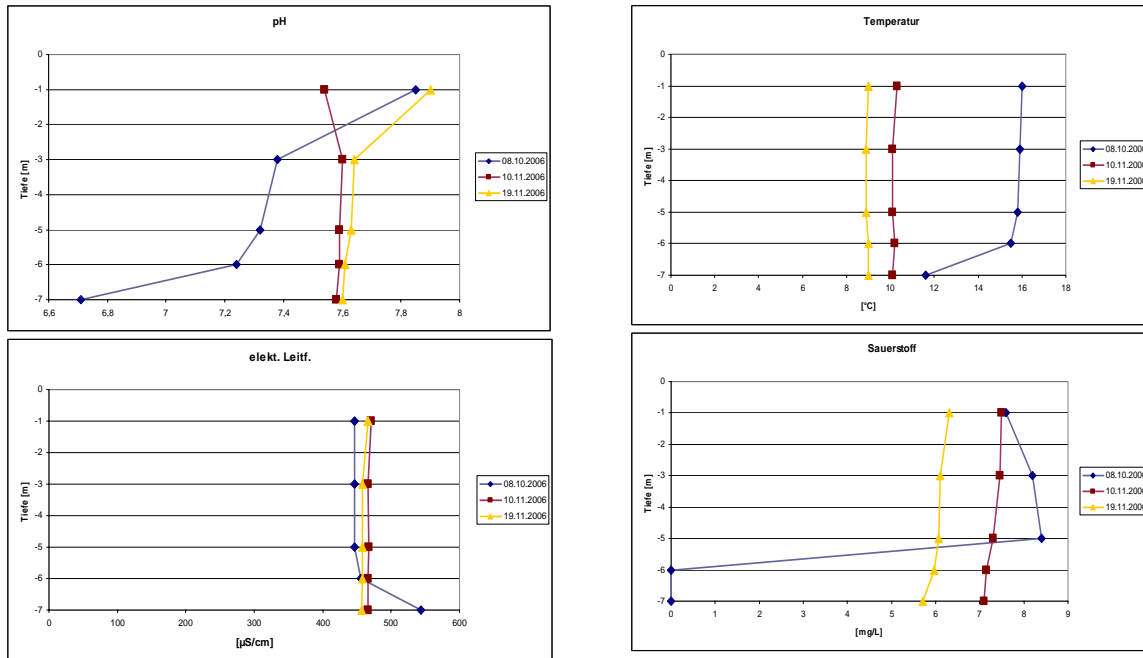


Diagram 1: Water Chemistry Parameters: pH, electrical conductivity, temperature and oxygen

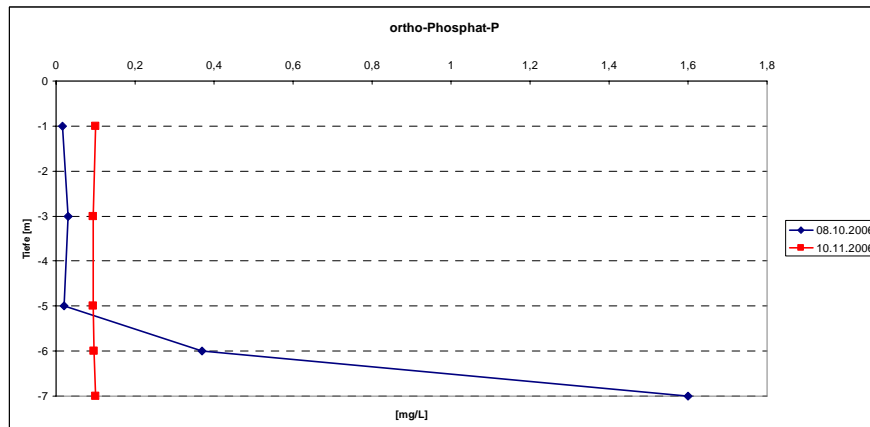


Diagram 2: Distribution of $\text{PO}_4\text{-P}$ before the application of Bentophos on 14-15 November 2006

Trends in phosphorus concentrations following the application

The lake's water was monitored regularly following the application of Bentophos. One month after the application, orthophosphate in the water column had fallen below detection levels. Total phosphorus concentrations in the lake's water were also reduced by 80% and are currently 38 $\mu\text{g P/L}$ (Diagram 3).

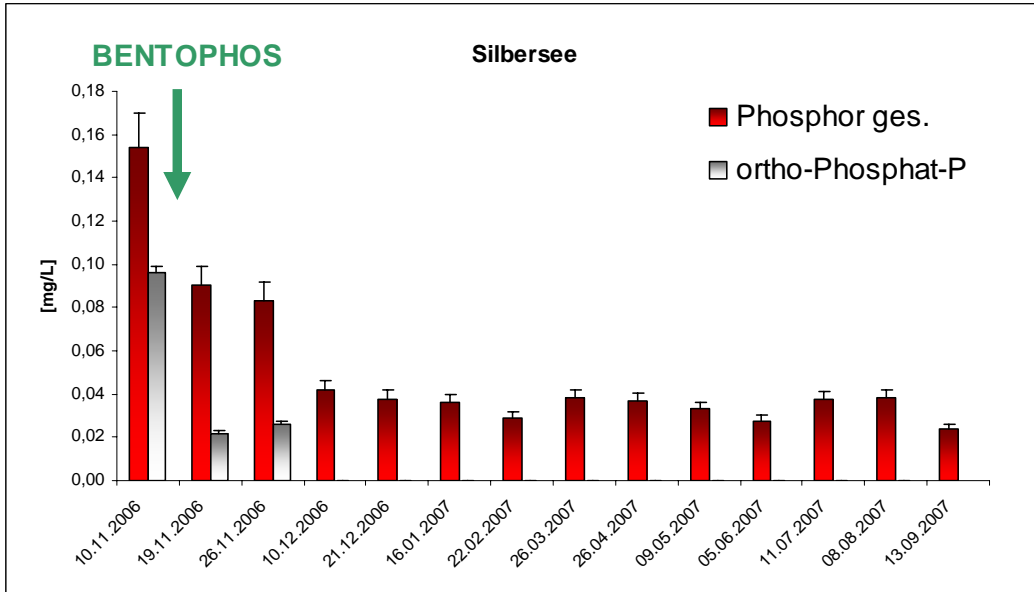


Diagram 3: Concentrations of total phosphorus and PO₄-P before and after application

Examinations of the sediment indicate a very stable situation in relation to phosphorus. As a result, it is not expected that the bound phosphate will be re-released from the sediment.

Total lanthanum concentrations in the lake water were measured at 100 µg/L following the application. These dropped during the monitoring period to 4 µg/L (Diagram 4). Despite the very windy period after the Bentophos® application with winds of more than 9 Bft, no resuspension of the material in the lake has been observed. This also means that both lanthanum and phosphate have been deposited solidly in the sediment.

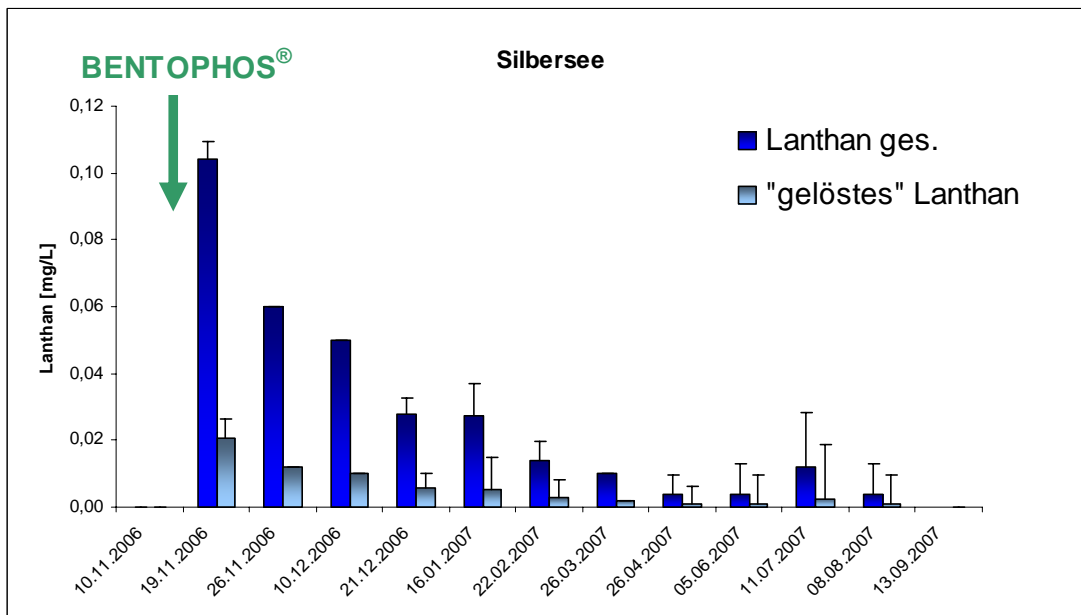


Diagram 4: Lanthanum content in lake water since the application

Ecological toxicity assessment of lanthanum

In order to properly assess the use of a material containing lanthanum in bodies of water, ecological toxicity examinations were carried out in the institute in relation to the acute toxicity of lanthanum.

To do this, the effective concentration, in which lanthanum has a toxic effect on the test organisms, was measured in accordance with the guidelines of the DIN standards for the appropriate tests.

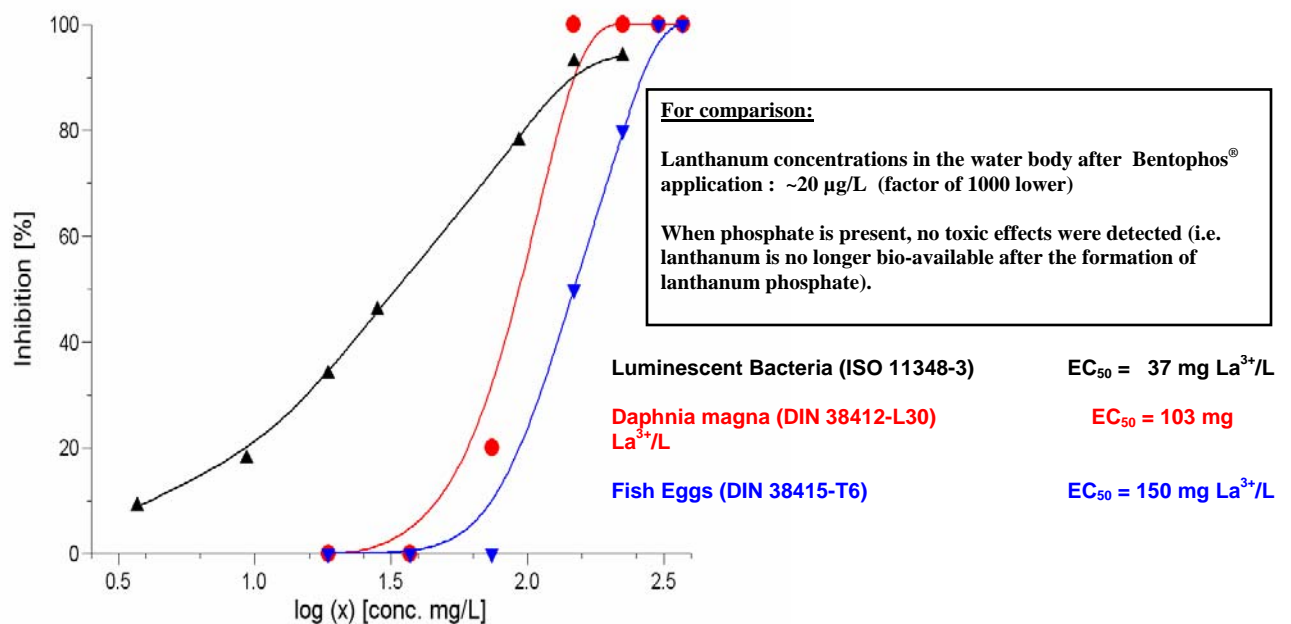


Diagram 5: Dosage to effectiveness relation between lanthanum and the corresponding test organism

Results:

The effective concentrations for the test organisms (EC50) were at least 1000 times higher in the investigations than the highest lanthanum quantity measured in the lake water of the Silbersee (*Diagram 5*). With the addition of phosphate, which is present in the Silbersee in the appropriate quantities, no toxic effect was detectable at all. After combining with phosphate, the lanthanum is not bioavailable. The quantity of lanthanum used in the Silbersee therefore has no toxic effect on the organisms in the lake.

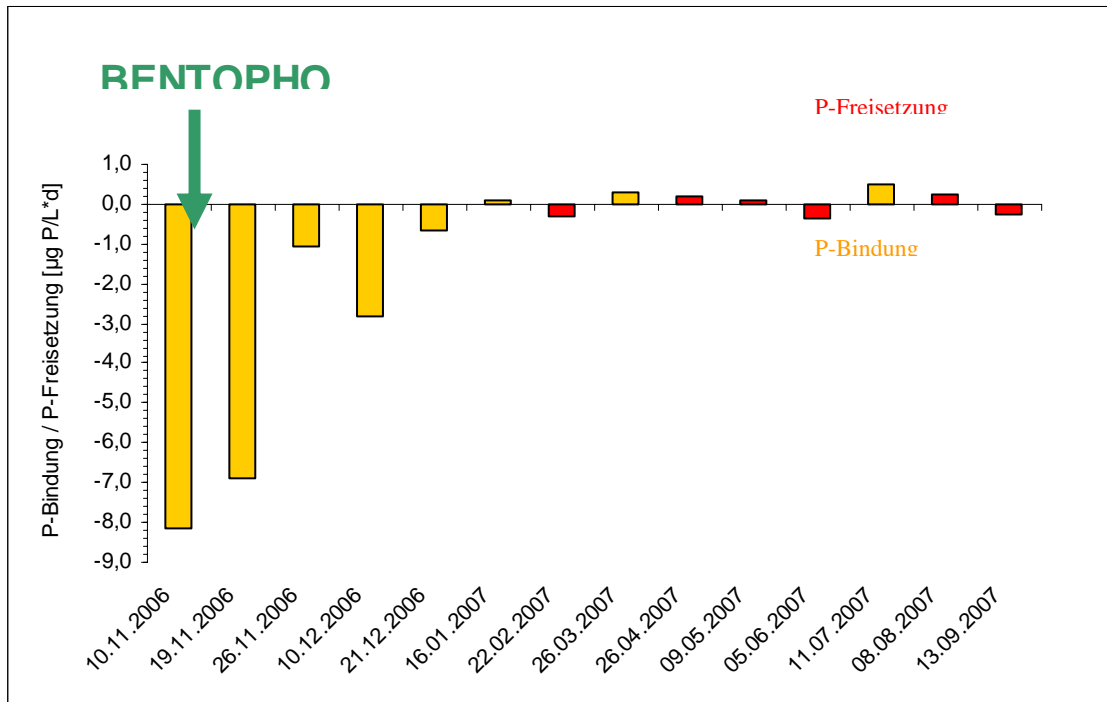


Diagram 6: Adsorption and Release of P in the Hypolimnion of the Silbersee

Evaluation

The results from the investigation after the Bentophos application provide a positive image about the development in the Silbersee. The objectives of the restoration measures have been completely achieved to date:

- Within a month of the application of 21.5 t of Bentophos to the Silbersee, 100% of ortho-phosphate and 80% of total phosphorus was removed from the water column
- Since the application, ortho-phosphate levels have remained below detection limits and total phosphorus levels have remained constant at around 35 µg/L, despite the rise in temperature in the water column, the stratification of the lake and the development of anoxic conditions in the hypolimnium. This indicates that the re-release of phosphorus from the sediment has been almost completely prevented.
- There have no effects on the flora and fauna in the Silbersee through the use of lanthanum.
- In relation to its phosphorous content, the trophic status of the lake changed from a strongly eutrophic to a mesotrophic condition within a period of two months. (*Diagram 7*)

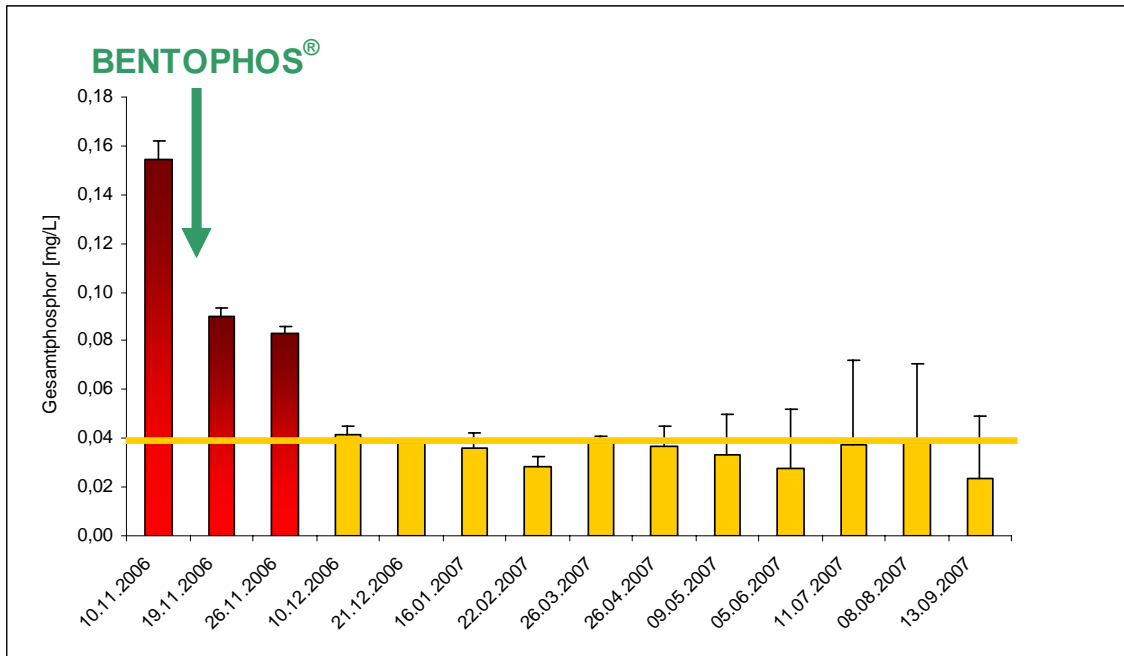


Diagram 7: Distribution of Total Phosphorus in the Water Column