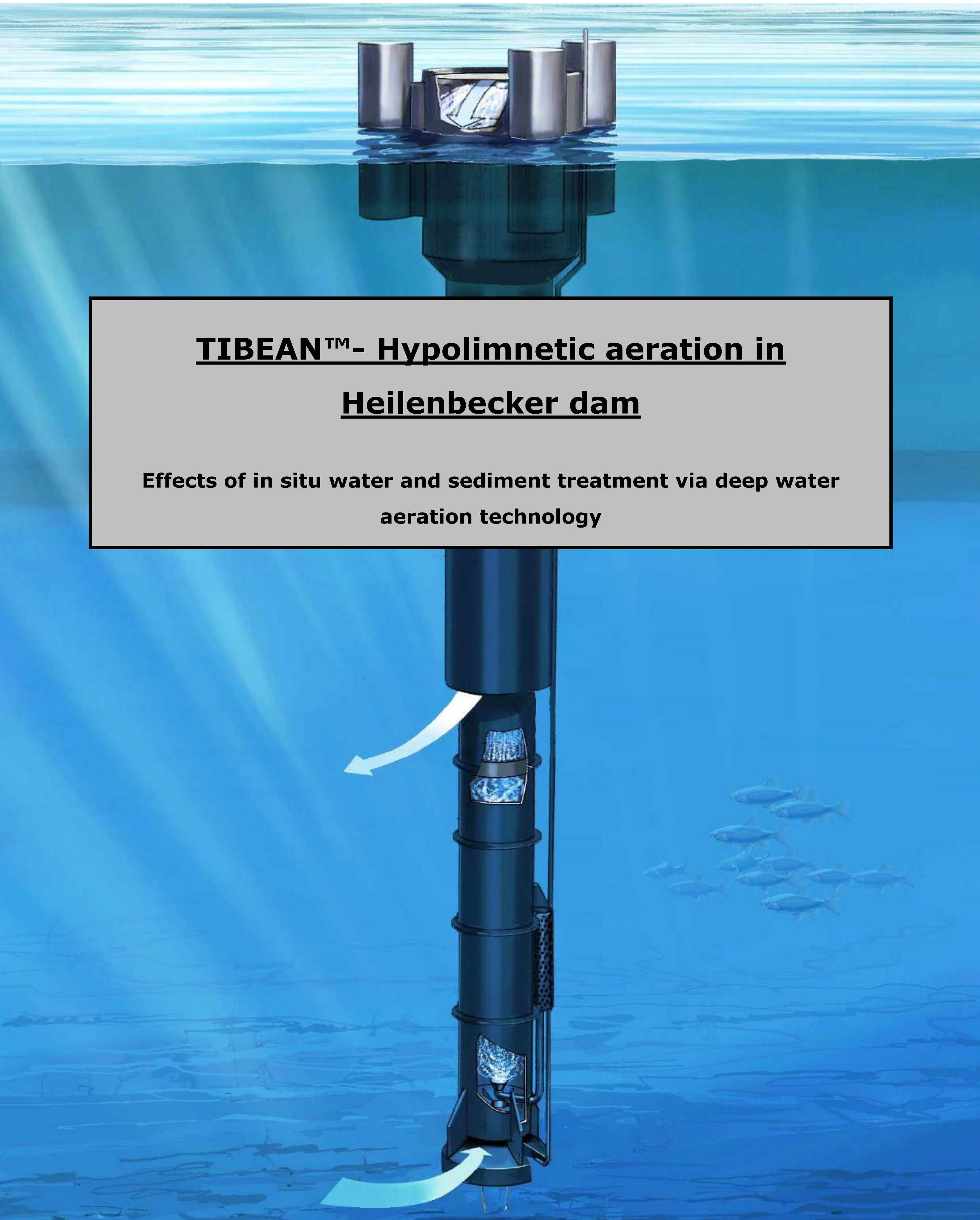


TIBEAN™- Hypolimnetic aeration in Heilenbecker dam

Effects of in situ water and sediment treatment via deep water aeration technology

Contend

Figures

Tables

1 Eutrophication

As a result of elevated nutrient inputs the trophic level of many lakes increases continuously. Elevated phosphorus concentrations may lead to stronger algae growth and a corresponding increase in oxygen consumption in the deep zones. Thus an **oxygen deficit** in deep water is created in stratified, eutrophic lakes during summer stagnation.
In the **anaerobic environment** of deep water sludge accumulates, while concentrations of ammonium, iron, manganese and toxic hydrogen sulfide increase in the water body.
The hypolimnion is now not only hostile, but the anaerobic conditions also cause increased phosphate dissolutions from the sediments into the deep water. These additional nutrient loads create further problems after the next full circulation.
Particularly in terms of drinking water production in reservoirs and dams with respect to the existing regulations of the German **Drinking Water Ordinance** (TrinkwV 2001), these deteriorations in water status are a serious problem. The deep water aeration can prevent this process.

2 Hypolimnetic aeration

Via hypolimnetic aeration, the oxygen demand of deep water is covered by oxygen from the atmosphere without destroying the lake's natural **stratification** (Fig. 1). Thus the deep water gets aerobic, the phosphate dissolution is reduced significantly and the mineralization of sediments improves.
Years of scientific evidence show that it is possible to keep the deep water aerobic all year round via technical ventilation measures and thereby to recover the natural balance of lakes effectively.

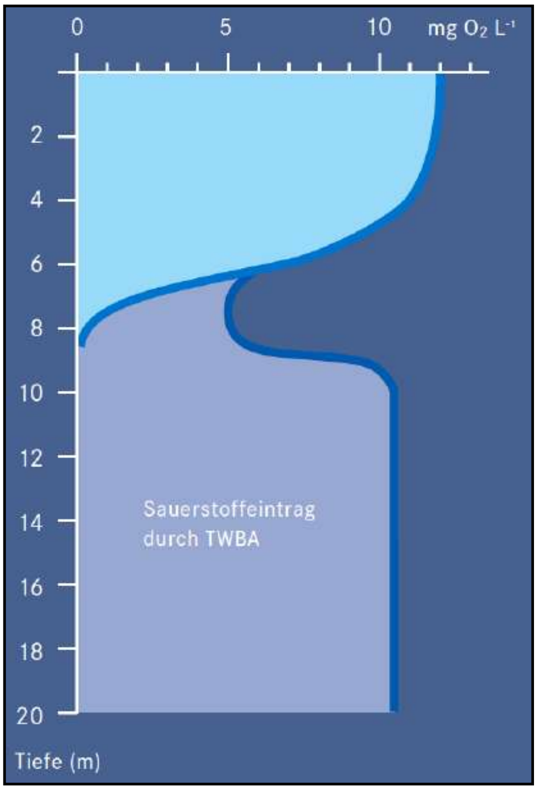


Fig. 1: Typical oxygen profile during summer with and without deep water aeration (TWBA)

2.1 TIBEAN™

TIBEAN™ stands for the german „Tiefenwasser Belüftungsanlage" (TWBA) which means **„deep water aeration system"**.

The TIBEAN™ - series are floating plants. They consist of one or more upstream pipes, where the water is aerated

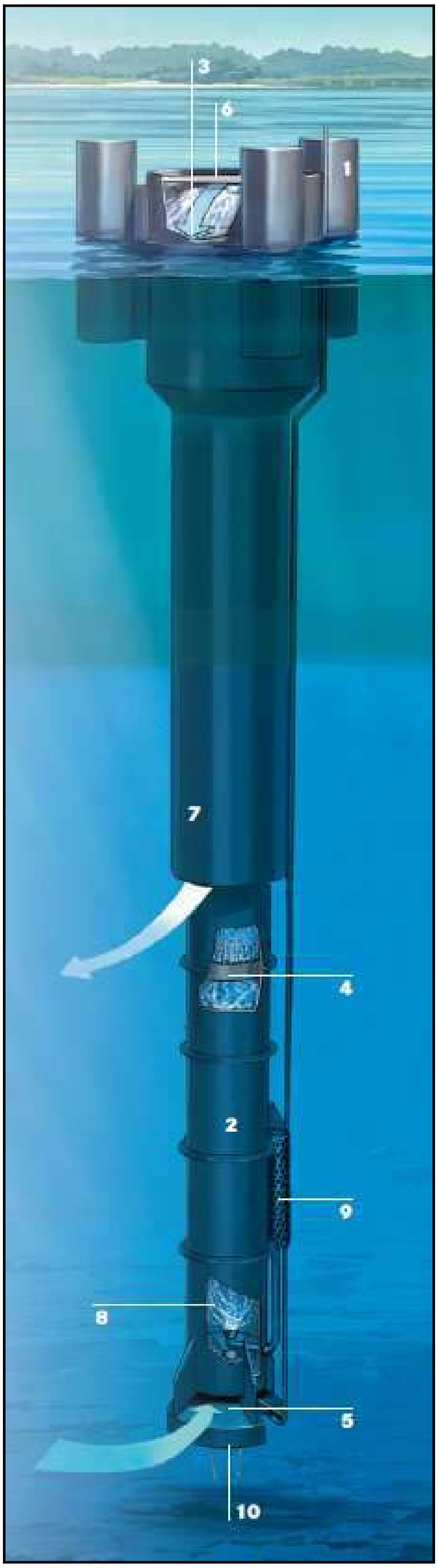


Fig. 2: TIBEAN™ construction and function

while rising up, a degassing chamber where the aerated water is freed of gases and one or more downstream pipes where the vented, degassed water is pumped back into the hypolimnion. In the degassing chamber additional nutrient absorbers and/ or nutrient precipitation devices can be implemented.

2.2 Technology

At the lower end of the plant atmospheric air is inserted into the water by an ejector. A mixture of water and oxygen is forced upwards in the upstream pipe. At the end of the upstream pipe the mixture flows into the **degassing chamber**. Residual gases are separated from the **oxygenated water**. The gas escapes into the atmosphere, the oxygenated water flows back through the downstream pipe. The outlet provides a laminar flow and a horizontal outflow into the hypolimnion.
Thanks to the flow and mass transfer calculations which are performed in the context of the technical configuration, the optimal set-up can be determined.

2.3 Individual parts

1. Floating tanks
2. Upstream pipe (Telescope)
3. Degassing chamber
4. Mixing device
5. Suction fence
6. Covering fence
7. Downstream pipe
8. Oxygen input
9. Submersible pump with ejector
10. Main ballast tanks

2.4 Material

TIBEAN™ can be made of PE/ PP (Polyethylane/ Polypropylene), stainless steel and an Al/Mn- alloy. Thanks to best properties almost all facilities are made of thermoplastic materials (PE, PP) and thus are **UV, weather** and **frost resistant**.

2.5 Purpose

TIBEAN™ systems are **highly variable** and cover a very wide range of applications with an oxygen input from 1.5 to 60 kg/h, an application depth of 5 to 45 m and a flow rate from 600 to 7500 m^3/h.

Fig. 3: Different types of the TIBEAN™- series

The objectives for water body restoration or aquatic therapy can vary, depending on the priority. Therefore the possibilities of deep water aeration systems as TIBEAN™ are diverse:

- Conservation of deep zones as **aerobic habitat** for fish and other higher organisms.
- Reduction of **nutrient concentration** in surface waters.
- Prevention of **sludge formation**, increased **ammonium production** and the formation of **toxic hydrogen sulphide**.
- Cost reduction for **drinking water production**.
- Targeted treatment of deep water with **coagulants**.

2.6 Planning and design

Since 1990, our partner company Polyplan GmbH (engineering consultants for energy and environmental technology) develops systems for restoration of lakes. We as the installation department of Polyplan GmbH grew steadily since 1990 and have been outsourced as an independent company in January 2011 with headquarter in Bremen. Polycon GmbH operates various deep water aerators for public and private clients in Germany and many European countries.

Thanks to our experience and evaluation of various series of measurements, we have a three-dimensional program to calculate velocities, mass transfer and distribution of suspended solids in the hypolimnion. Calculations and adjustments are repeated until the systems effectiveness is optimized.

Against this background, our engineers and scientists are able to develop new designs and variations of the systems to meet our customer's requirements.
The final design of plants is carried out in different phases. The first step should always be a morphometric measurement of the water body in order to assess the depth profile and the associated requirements for the technical design, and later on to determine the optimal location of the plant.

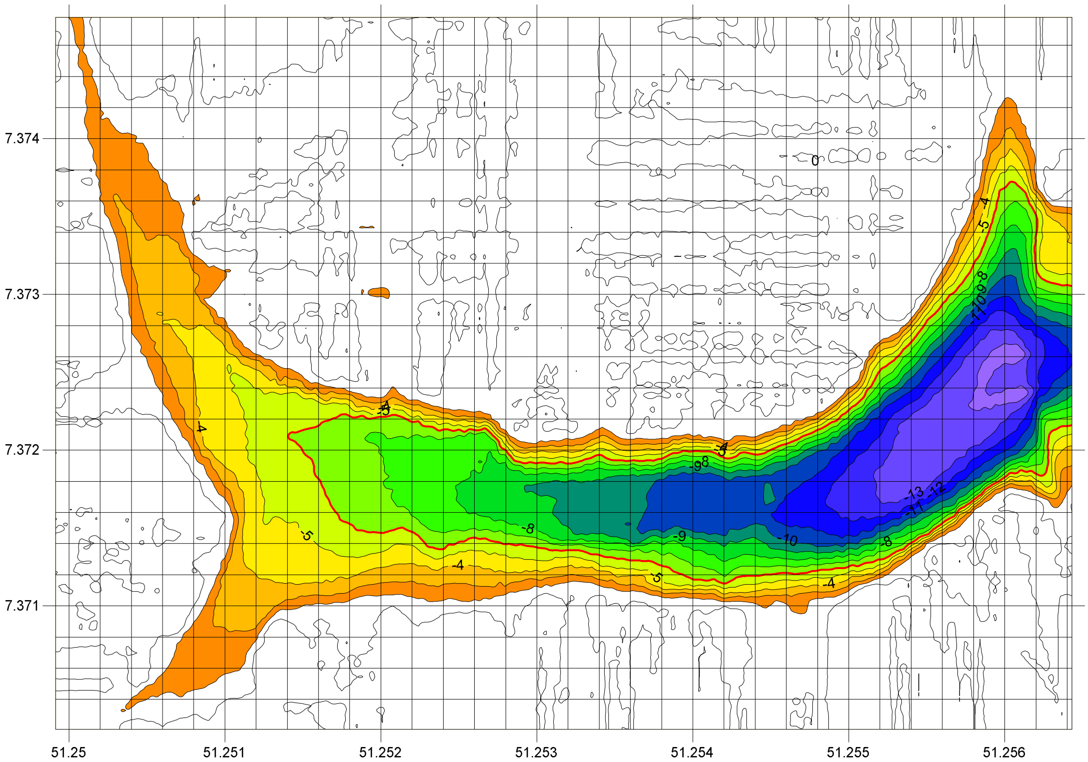


Fig. 4: Morphometrics of Heilenbecker dam

The first estimation of required system performance can statistically be based on an expected O_2 demand of 7 kg/h per 100 000 m³ hypolimnic volume. Concrete assessments must be based on the determination of the **temporal oxygen variation** in hypolimnion based on chemical parameters.

3 Heilenbecker dam

The Heilenbecker dam has been built between 1894 and 1896 adjacent to the cities Ennepetal and Breckerfeld in Ennepe- Ruhr district. It is the oldest dam of southern Westphalia. The reservoir was planned by one of the leading dam pioneers Prof. Otto Intze, whom many retaining structures in the Sauerland and in Bergisch Land owe their existence.
Originally Heilenbecker dam was a water reservoir for the hammer mills and grinding figurines, which were located along the River Heilenbecke. Nowadays, however, it serves primarily as the drinking

water supply and the Ruhr heightening at low tides. The dam is operated by the Heilenbecke- water association. With a maximum capacity of 450 000 m^3, the water surface of the reservoir is 8.5 ha and the maximum depth is 14 m.

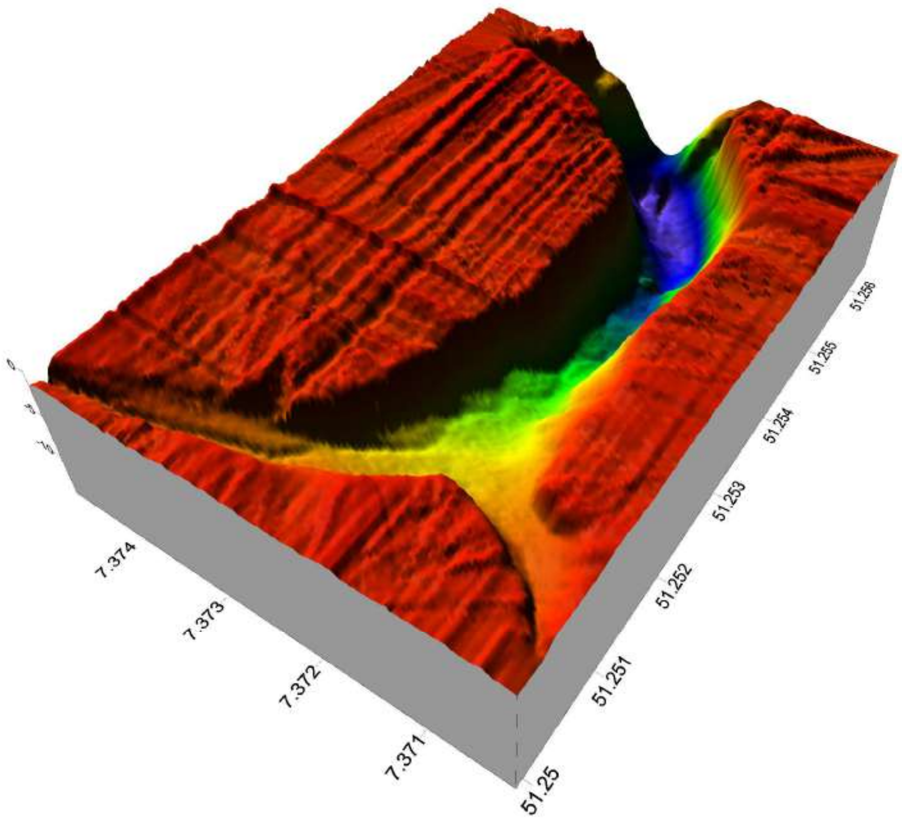


Fig. 5: 3-D illustration of the morphometrics

Below the retaining wall the water is cleaned in a filtration unit and the natural downward slope transports the water to the supply area.

The dam is a gravity dam made of rubble masonry with a height of 19.5 m, a crest width of 4.1 m and a crest length of 205 m (before renovation: 2.8 m and 162 m). Between 1988 and 1990 it was renovated, reinforced and provided with a patrol. It also received a cut-off wall of concrete, wall drainage, a new mural crown and new operating facilities.

The dam was declared a technical and historical monument of more than local importance, which must be reserved and kept in operation for scientific and architectural-historical reasons.

With an approximately 2.4 km long loop road the dam is a popular area for walkers and joggers.

4 Aeration concept

For aeration of the hypolimnion of Heilenbecker dam, in June 2012 two deep water aerators from the TIBEAN™- series were installed by the company Polycon GmbH and taken into operation on 06.19.2012. The aerators are designed as telescope plants which allow adjusting the suction depth from 11 to 13.5 m to ensure the safe operation of equipment at fluctuating water levels.

Fig. 6: Final on-site mounting: telescopic element

The first plant was placed centrally in the basin about 30 m away from the dam. The second plant was placed 50 m behind the first plant in the extension of the deepest channel of the dam's basin.
The plants will be leased for the present 10 years by the WBV- Ennepetal Milspe.

Fig. 7: Installation of the first plant

4.1 Plant operation

Both deep water aeration plants are identical and are specifically designed for this application. The oxygen input in the deep water is 6.8 kg/h per plant (Tab. 1).

Tab. 1: Rated output per plant

Rated output per plant	
Volume flow rate pump	30 m³/h
Volume flow rate water (ejector)	432 m³/h
Volume flow rate air (ejector)	27 m³/h
Resulting oxygen input	6,8 kg/h

By operating both plants the overall oxygen input in the deep water is 13.6 kg per hour. In both cases, the water is enriched to approximately 80 % oxygen saturation. Since the deep water near the dam is much less saturated (17 %), the flow rate of the first plant was reduced in order to also reach an O_2 enrichment of 80 % (Tab. 2). This measure was also necessary to ensure low rates of sediment remobilisation near the dam in order to avoid the increased discharge of particles in the drinking water filtration unit.

Tab. 2: Specifications of plant operation

Plant operation	Plant 1	Plant 2
Flow rate of air/ water- mixture	186 m³/h	415 m³/h
O_2- saturation at the inflow	17 %	42 %
O_2- saturation at the outflow	80 %	77 %
Resulting O_2- enrichment	63 %	35 %

5 Effects of hypolimnetic aeration

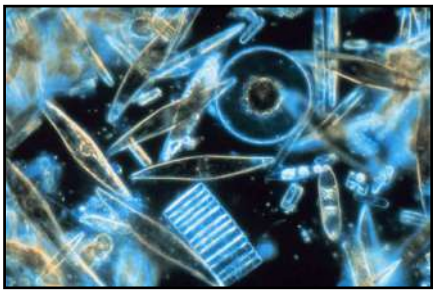
Basically, a reliable assessment of the long term effects of hypolimnetic aeration in the Heilenbecker dam requires data from at least one full year of operation. So far the observation period covers only about 6 months of operation so that the data presented below should be considered as preliminary results.

These preliminary results, however, already suggest significant positive effects and trends. The observation period of the presented parameter is from June to September of the years 2011 and 2012. All measurements refer to the raw water extracted from the dam; the samples were taken below the thermocline at a depth of 10 m. The water sampling and analysis was conducted on behalf of the WBV- Ennepetal Milspe by the Hygiene Institute of the Ruhr (Institute of Environmental Health and Toxicology). These data were kindly provided by WBV Ennepetal Milspe for our evaluation.

5.1 Adjustment of plant output

After the installation of new deep water aerators an **optimization phase** is required in order to adapt the system's performance and the operating time to the real conditions of the water body. During this initial phase, the plant output may be set too high, leading to a temporary mixing of deep and surface water. Due to this mixing nutrient- and oxygen- rich hypolimnic water may enter the trophogenic zone and in worst case causes a short period of increased algae growth.
During the start up phase in Heilenbecker dam such a temporary mixing occurred and thus lead to an increased algae growth at the end of August. The resulting increased aerobic decomposition manifested in a lowered pH (average 2011: 8.5, average 2012: 7.4), and slightly elevated ammonia and nitrite levels.
After adjusting the plant output, further mixing was prevented and the values were stabilized.

5.2 Chlorophyll a- und seston concentration



The parameter "seston" includes living and nonliving matter bigger than 4 microns (samples are screened prior to analysis). For the living matter following organisms are counted: Cyanophyta, Bacillariophyceae, Chlorophyta, Chrysophyceae, dinoflagellates, Ciliata, Rotatoria and Crustacea.
Nonliving matter can consist of chitin parts, sponge needles, plant hairs, macerated plant parts, cellulose fibres, detritus, iron, manganese, sand or pollen.
The chlorophyll a concentration is commonly used as an indicator for the phytoplankton biomass.

The following two figures clearly indicate a **direct relationship** between plant output and plankton/ seston concentrations.
Figure 8 shows the decreasing chlorophyll a concentration with rising or consistently high plant output between June and early August, followed by a reduction of plant output with increased concentrations between late August and late September.

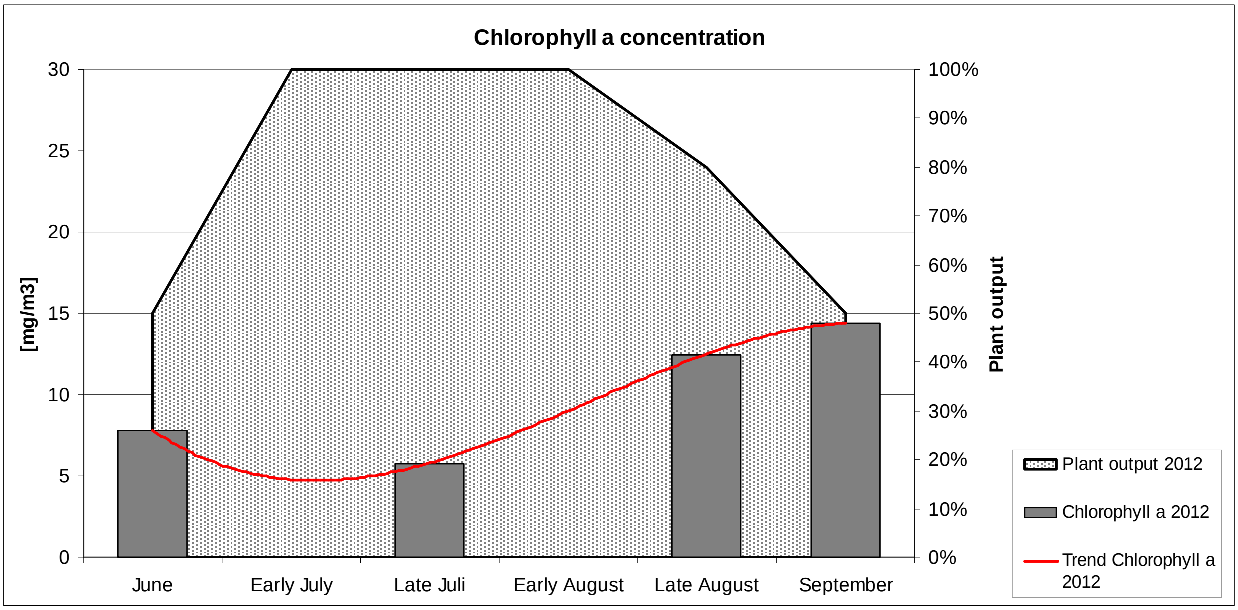


Fig. 8: Plant output and chlorophyll a concentration 2012

Analogous to chlorophyll a concentration, Figure 9 shows the relationship between plant output and seston concentration.

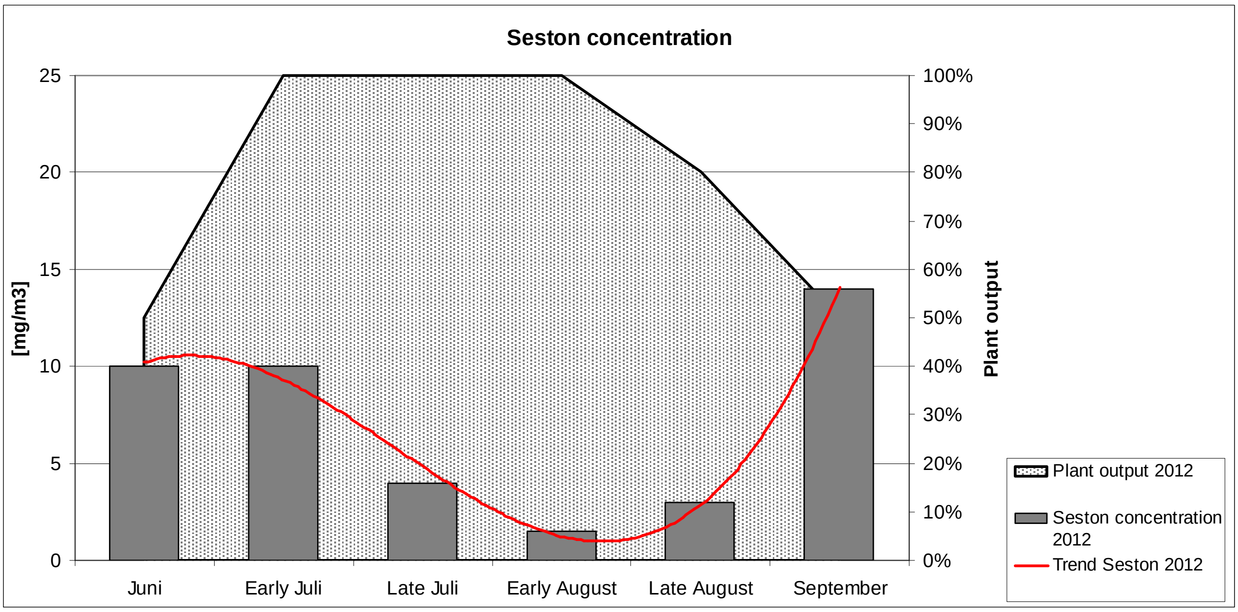


Fig. 9: Plant output and seston concentration 2012

Therefore it can be concluded that a rising or constant high plant output leads to decreasing concentrations of chlorophyll a and seston.

According to the Hygiene Institute of the Ruhr (Institute of Environmental Health and Toxicology) the deep water aeration, showed the following positive trends with regard to the production of drinking water:

- **reduced numbers of algae**
- **reduced chlorophyll a contents**
- **reduced seston concentration**

5.3 Oxygen concentration

The O_2 concentration in the epilimnion depends to a large extent on the intensity of sunlight (photosynthesis) and the season, and tends to fluctuate dramatically throughout the day. The concentration in the hypolimnion, however, is independent from these fluctuations due to the stratification of the water body during summer stagnation, but is continuously reduced by ongoing reductive processes.

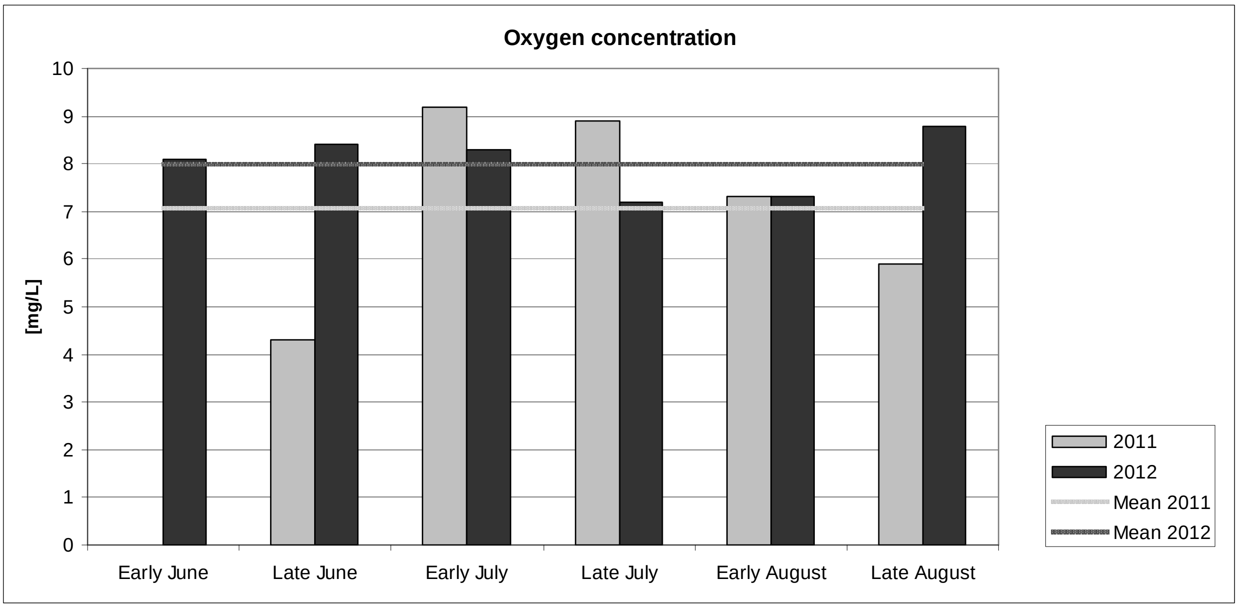


Fig. 10: Oxygen concentration 2011/2012

After commissioning the aerators there was a significantly **higher mean oxygen concentration** (8 mg/L) in 2012 compared to the same time span during summer stagnation in 2011 (7.1 mg/L) (Fig. 10).

5.4 Process safety and costs of drinking water production

Despite the aforementioned temporary excessive plant output, the deep water aeration significantly **improved the process safety** of the dam's filtration unit and caused **considerable cost savings** in the production of drinking water.

According to the Water Supply Association Ennepetal approximately 25 % less flocculants (polyaluminium chloride) were used after commissioning the aerators. Additionally the back flush intervals of the filtration units have been extended from 24 hours to 48 hours. This means a significant increase in process safety in terms of possible filter breakthroughs. The extensions of the back flush intervals lead to a reduction of water and energy consumption by about 10 %.

6 Contact

Do you have any questions?
Please do not hesitate to contact us at any time!

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