



ISWEE'11

## Treatment of Water Supplies by the Technique of Dynamic Aeration

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### Abstract

The problems of water quality are related to the decrease in the dissolved oxygen content, particularly in the lower layers. These lower layers may deteriorate significantly if the dissolved oxygen consummated in biochemical processes is not renewed by surface aeration or photosynthesis.

Thermal stratification of lakes and reservoirs can result in substantial hypolimnetic oxygen depletion, which may have a negative impact on the cold-water fisheries, the drinking- water treatment process, and water quality downstream of hydropower reservoirs.

The main purpose of this study is to show the effect of hypolimnetic aeration and destratification mode to improve the concentration of oxygen dissolved and level of phosphorus in the depths of the lake.

The 10.3 km<sup>2</sup> of the water of Hallwil lake are an important tourist center for the canton of Lucerne (Switzerland). Before its restoration in the winter of the year 1985/1986, this lake eutrophication showed significant disruption of aquatic activities, and pollution damage to its various uses, and thus inhibited the development of tourism in the region. Thus, the long periods of stratifications, associated to an important amount of an organic material (principally phosphorus), were originally caused by frequent anoxic phases of the deep layers. This anoxia could be noted beyond 3 m of depth.

For this, the Swiss Federal Institute for Aquatic Science and Technology (Eawag) in Switzerland, to address the eutrophication of Hallwil lake, put into service in the winter of 1985/1986, an installation of a aeration system in two alternate modes of aeration namely by a aeration system in winter by destratification mode and aeration hypolimnetic in summer (air / pure oxygen).

Through the exhibition of the different results of the chemical parameters (dissolved oxygen, total phosphorus) in the two aeration modes, we were able to ensure an improvement of the lake water quality

As a result, the average value of oxygen dissolved and the amount of phosphorus is found in the range of allowed values are:

- Winter Season:  $[O_2]_{\min} \geq 8 \text{ g/m}^3$  ;  $[P_2]_{\max} \leq 0.15 \text{ g/m}^3$
- Summer Season: (30 m  $\geq$  H  $\geq$  15 m):  $[O_2]_{\min} \geq 5 \text{ g/m}^3$  ;  $[P_2]_{\max} \leq 0.13 \text{ g/m}^3$

Consequently, we can conclude that both techniques aeration method has contributed radically in valuable way to improve the amount of dissolved oxygen and decrease the concentration of phosphorus in the deep layers of the lake.

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**Keywords:** destratification; hypolimnetic aeration; dissolved oxygen; phosphorus; lake.

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## 1. Introduction

The problems of water quality are related to the decrease in the dissolved oxygen content, particularly in the lower layers [1, 2]. These lower layers may deteriorate significantly if the dissolved oxygen consumed in biochemical processes is not renewed by surface aeration or photosynthesis [2, 3].

Thermal stratification of lakes and reservoirs can result in substantial hypolimnetic oxygen depletion, which may have a negative impact on the cold-water fisheries, the drinking-water treatment process, and water quality downstream of hydropower reservoirs [4, 5, 6].

There are two large categories of artificial aeration of lakes: destratification mode and hypolimnetic aeration [6, 7]. In the first case, the entire lake is mixed, usually by release of compressed air from a perforated air line laid along the bottom of the lake [7, 8], and in the second case, the objective is to maintain thermal stratification, while oxygenating the hypolimnion [8, 9, 10]. These restoration techniques can be used separately or in combination. In the case of separately used systems, an artificial mixing of the water column during the cold season and an input of air/oxygen into the hypolimnion during summer in order to preserve the thermal stratification [4, 11].

The highly noted eutrophication of this lake was first related to the exogenous supplies of nutritive compounds extremely important and dominated by phosphorus. Thus, the long periods of stratifications, associated to an important amount of an organic material (principally phosphorus), were originally caused by frequent anoxic phases of the deep layers. This anoxia could be noted beyond 3 m of depth.

The 10.3 km<sup>2</sup> of the water of Hallwil lake are an important tourist center for the canton of Lucerne (Switzerland). Before its restoration in the winter of the year 1985/1986, this lake eutrophication showed significant disruption of aquatic activities, and pollution damage to its various uses, and thus inhibited the development of tourism in the region.

For this, the Swiss Federal Institute for Aquatic Science and Technology (Eawag) in Switzerland, to address the eutrophication of Hallwil lake, put into service in the winter of 1985/1986, an installation of a aeration system in two alternate modes of aeration namely by a aeration system in winter by destratification mode and aeration hypolimnetic in summer (air / pure oxygen) [12, 13].

The main purpose of this study is to show the effect of hypolimnetic aeration and destratification mode to improve the concentration of oxygen dissolved and decrease the content of phosphorus in the depths of the lake

## 2. Materials and Methods

In 1986, the system of the diffuser «Tanytarsus» (Figure 1) is installed as a final ultimate technique of restoration to fight the anaerobic middle found in the lake [12, 13]. This system is alternated between two modes of artificial aeration, the first is the aeration by the system of destratification using big air bubbles; and the second is the hypolimnetic oxygenation, using respectively tiny bubbles of air or oxygen.

The restoration in the Hallwil lake uses a circular diffuser bubbles plume (Figure 1) and ejects air or oxygen. These systems are more suitable for deep lakes where the charge of dissolved bubbles in the hypolimnion and the momentum generated by the plume are sufficiently weak to avoid a significant erosion of the thermocline.

The six (06) diffusers of figure 1, have a diameter of 6.5 m each, and are located in a circular configuration of 6.5 m diameter near the middle of the lake (Figure 1 and table 1). Every diffuser uses air or oxygen during summer season for the hypolimnetic aeration mode and air during the cold season for the destratification aeration mode.

Table 1 shows the characteristics of the lake as well as the system of the diffuser that has been installed in the Hallwil lake, when the destratification system and the hypolimnetic oxygenation is set.

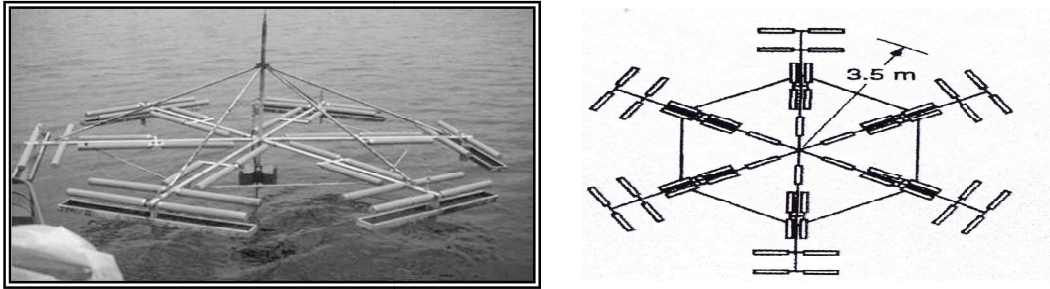


Fig. 1 One of the six diffusers of Tanytarsus that has a diameter 6.5 meters [12, 13].

Table 1: Special characteristics of the Halwill lake and the system of the diffuser [12, 13]: The gas pressure is 1 bar; temperature is 0°C.

Parameters	Value
Maximum depth (m)	46.5
Average depth (m)	28.9
Surface (106 m <sup>2</sup> )	9.9
Total Volume of water (106 m <sup>3</sup> )	285
Shape of the des diffusers	Circular
Number of the diffusers	6
Diameter of the diffuser (m)	6.5
Average depth of the diffusers (m)	46
Gas flow of all diffusers (Nm <sup>3</sup> . h-1)	46-148(O <sub>2</sub> )
Maximum depth (m)	180 (air)

**3. Results and**

**Discussion.**

*3.1. Case of aeration by destratification mode*

- Oxygenation

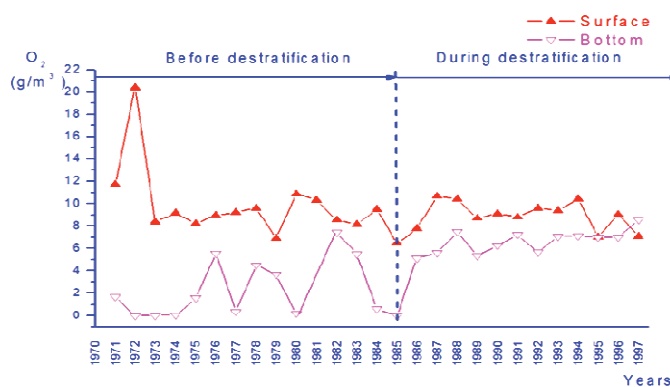


Fig. 2 Chronological evolution of the dissolved oxygen between the surface and the bottom before and during the aeration by destratification mode [12].

The aerator did not bring a noticeable improvement of the oxygen concentration of the upper layer (Fig. 2), because this one is directly exposed to the atmosphere. Thus, oxygen concentration before and during the destratification is almost preserved.

We note as well that, the oxygen maximum concentration is observed before the action of the aerator, and more precisely in 1972; this is explained by the fact that in this period a great exchange of oxygen between the atmosphere and the la surface of water occurred, and that the climate was not icy as well.

Dissimilarity, at the bottom of the lake, the system of destratification has significantly contributed to the increase of the amount of the oxygen in this layer.

The discrepancy between the profiles of the oxygen content of the extreme layers shrinks more during the brewing, which proves that a mixing of these layers has occurred.

Before the restoration of the lake, the mean concentration of oxygen in the lake was about 5 g/m<sup>3</sup>, against 8 g/m<sup>3</sup> during the aeration.

- Total Phosphorus

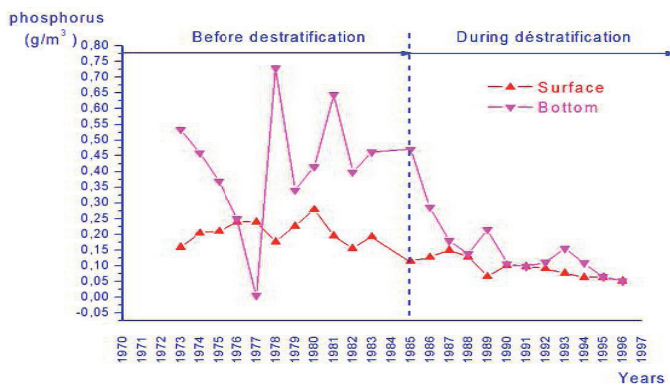


Fig. 3 Chronological evolution of total phosphorus between the surface and the bottom before and during the aeration by destratification mode [12].

Before the action of the aeration system, the discrepancies between the amounts of phosphorus of the bottom and the surface are more visible, whereas they vanish gradually during the aeration; this shows that the concentration of phosphorus is uniformed in the water of lake.

During the action of the aeration system, the deep layer of the lake undergoes a net decrease in phosphorus concentration; in contrast, the superficial layer of the surface shows a slight decrease in the phosphorus content (Fig.3).

The annual mean concentration of phosphorus before the aeration exceeds the value 0.40 g/m<sup>3</sup>, whereas it is below the value of 0.15 g/m<sup>3</sup> during the aeration of the lake.

### 3.2. Case of hypolimnetic aeration

- Oxygenation

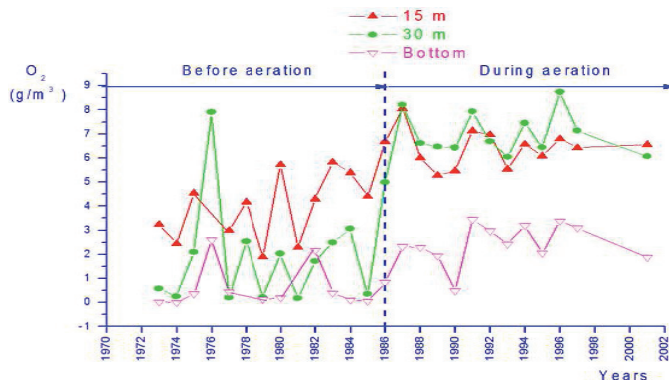


Fig . 4 Chronological evolution of the dissolved oxygen between the depths 15 m, 30 m and the bottom before and during the hypolimnetic aeration [12].

After the shift from the non aerated period to the aerated one, the depths 15 and 30 m of the bottom undergo an increase in the content in oxygen (Fig. 4), which is outstanding at the depth 30 m. This shows that the system of aeration has contributed to the improvement of the content in oxygen in these three zones. The mean oxygen concentration in the layer of the hypolimnion shifts from the value  $3 \text{ g/m}^3$  (before the aeration) to  $5 \text{ g/m}^3$  (during the aeration).

The highest contents in oxygen are observed in the intermediary and superficial layers of the hypolimnion. We can as well note that the profiles of the extreme layers of the hypolimnion are closer during all the period of restoration, which confirms that a complete mixing of the content in oxygen has occurred between these two levels.

In the lower level, the oxygen concentrations were almost null before the restoration of the lake, to take a minimum average value over  $2 \text{ g/m}^3$ .

Finally, the restoration of the lake has greatly contributed to the increase of the oxygen amount especially in the deep layers of the hypolimnion, where a strong requirement in oxygen is needed for the oxidation of the phosphorus and nitrogenous compounds generated by the sediments.

#### • Total Phosphorus

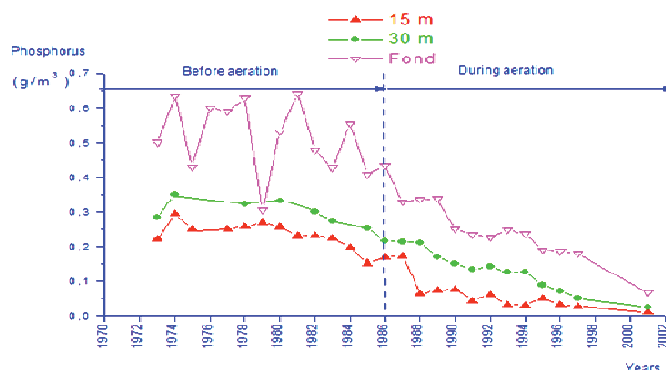


Fig. 5 Chronological Evolutions of total phosphorus in the levels 15 m, 30 m and the bottom before and during the hypolimnetic aeration [12].

The amount of phosphorus that the lake contained before the restoration has decreased in considerable way during the implementation of the aerator, for the three considered levels (Fig. 5). However, the diminution the most noted occurred at the level the most lower of the lake. Thus, the weakest concentrations of this component are observed in the depth 15 m; and the highest are those of the bottom layer. In the three levels, the maximum average contents of phosphorus before the restoration, reach the values de  $0.3 \text{ g/m}^3$ ,  $0.35 \text{ g/m}^3$  and  $0.62 \text{ g/m}^3$  respectively in the level 15, 30 and 45 m. During the restoration, these concentrations take the values  $0.18 \text{ g/m}^3$ ,  $0.20 \text{ g/m}^3$  and  $0.3 \text{ g/m}^3$  in the levels 15, 30 and 45 m respectively.

The average value of the phosphorus amount in the hypolimnion layer, exceeds the value of  $0.35 \text{ g/m}^3$  (before the aeration), while it is lower than  $0.13 \text{ g/m}^3$  (during the aeration).

#### 4. Conclusions

Through the exhibition of the different results of the chemical parameters (dissolved oxygen and total phosphorus) in the two aeration modes, we were able to ensure an improvement of the lake water quality. Thus, the study of the results of the measure campaign carried out since 1985; let's diagnose the effect of the two techniques of the aeration on the improvement of the Halwill lake state.

When recalling the aims that were expected for the Halwill lake, it is possible to dress the following conclusions:

- Purpose 1: Homogenization of the water column in the mode of aeration by destratification mode.

The brewing installations seem homogenize the water mass situated between the surface and the bottom of the implantation of the bubbling lines. This homogenization is confirmed by the profiles of dissolved oxygen.

- Purpose 2: improvement of the water quality for the fish living.

In the brewed region the hypolimnetic layer, the content in dissolved oxygen is maintained over a threshold that is necessary for the survival when the brewing is on. Accordingly, the oxygen profiles confirm this fact.

- Purpose 3: Diminution of the content in phosphorus in the deep zones.

The two aeration modes have significantly allowed the minimization of the phosphorus amount. The maximum content of this component dissolved in the lake is within the acceptance interval. This is being well validated for a long period by the evolution of phosphorus in the two modes of aeration.

- Purpose 4: comparison effects of the two aeration mode on the improvement of the lake water quality.

Both aeration techniques have contributed in spectacular way each one by its operational manner to the reoxygenation and the dephosphorisation of the deep layers of the lake.

Our study focused above all on phosphorus and oxygen elements, since they are the principal elements that determine the eutrophic state of the lake. In addition, the studied lake is well-known by an important charge of phosphorus.

To conclude, the majority of expected purposes are attained. Thus, due to the improvement of the oxygen status in the lake, the aquatic life becomes promising for all species.

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