G Model
ECOENG-4838; No. of Pages 5
ARTICLE IN PRESS
Ecological Engineering xxx (2017) xxx–xxx
Contents lists available at ScienceDirect
Ecological Engineering
journal homepage: www.elsevier.com/locate/ecoleng

Pulverizing aerator in the process of lake restotation

Stanisław Podsiadłowski, Ewa Osuch*, Jacek Przybył, Andrzej Osuch, Tatiana Buchwald

Poznań University of Life Sciences, Institute of Biosystems Engineering ul. Wojska Polskiego 50, 60-627 Poznań, Poland

ARTICLE INFO

Article history:
Received 19 February 2017
Received in revised form 4 June 2017
Accepted 14 June 2017
Available online xxx

Keywords:
Lake restoration
Pulverizing aeration
Góreckie lake

ABSTRACT

In 1995, the Institute of Agricultural Engineering of the Agricultural University in Poznań launched research on an integrated lake restoration technology, whose core was a wind-powered aerator capable of oxygenating also the bottom layers (the hypolimnion) of deep lakes. The aerator uses energy from the Savonius rotor mainly for water pulverizing, causing the release of gases such as hydrogen sulphide or methane, which usually result in complete water saturation and replace them with oxygen. Even the early studies showed the constructed device to be highly efficient in improving oxygen conditions in the bottom zone. Moreover, the research made it clear that the device should be equipped with an autonomous system designed to inactivate phosphorus, one of the principal factors determining the rate of lake degradation. In 2013 the first wind-driven pulverizing aerator equipped with such a new system was installed at Góreckie Lake.

The research describe results of the process of the restoration of Góreckie Lake with using pulverizing aerator system conducted regularly from 2013 to 2015. It was the aim of this work. The results show that the efficience of pulverizing aerator with a phosphorus inactivation system and the efficiency of the coagulant dosage depend on the wind speed from the determined range of the speed. The technical specifications causes that the device uses only energy of the wind, which is the main advantage of the whole system.

1. Introduction

The main threat to lakes in temperate zones are factors increasing the rate of eutrophication (Harper, 1992), as they lead to deoxygenation of the deeper layers of water, hypolimnion and metalimnion in particular, which results in mass phytoplankton growth and the general deterioration of water quality (Vollenweider, 1976; Gołdyn et al., 2014). This, in turn, affects the abundance and health of fish communities. The balance between complex (organic) compounds and the oxygen in the body of water is disturbed (Bonsdorff et al., 2002). Natural oxygenation of deep water layers is a relatively slow process, because it relies on the diffusion of oxygen from the epilimnion layer. In summer months, when bottom deposits reveal relatively high biochemical activity, the intensity of the diffusion processes is largely insufficient (Nash and Halliewll, 2000; McGechan and Lewis, 2002; Koschel, 2011). Oxygen depletion leads to a reduction of the redox complex in bottom sediments and release of phosphorus adsorbed on the iron and manganese compounds into the water column (Sondergaard et al., 2002). Such internal loading can be an important source of phosphorus degrading the lake, especially in summer (Gołdyn et al., 2010).

According to Environmental Status Report only about 3.8% of Polish lakes have a very good water quality (Soszka et al., 2003). The majority of Polish lakes have good and moderate status (36.6% and 38.9%, respectively), but still 20% are classified in poor or bad status. The noticeable degradation process of lakes began about thirty years ago due to unsustainable agricultural practices, mass-tourism and communal and industrial sewage discharge. Nowadays, lake restoration is regarded as a feasible but costly alternative which can be effected by (Wiśniewski, 2000; Wetzel, 2001; Klapper, 2003):

- renewal of the entire water mass,
- removal of upper layers of bottom sediments, especially in the profundal zone,
- extraction of hypolimnetic water (*hypolimnetic siphoning*),
- oxygenation of the near-bottom waters using aeration equipment; presently wind-powered aerators are used.

Oxygenating of hypolimnion waters is one of the most frequent methods of lake restoration (Lossow et al., 1998). Aerators were initially used in sewage treatment plants, but the growing problem of lake eutrophication triggered the widespread use of the

* Corresponding author.
E-mail address: ewa.osuch@up.poznan.pl (E. Osuch).

http://dx.doi.org/10.1016/j.ecoleng.2017.06.032

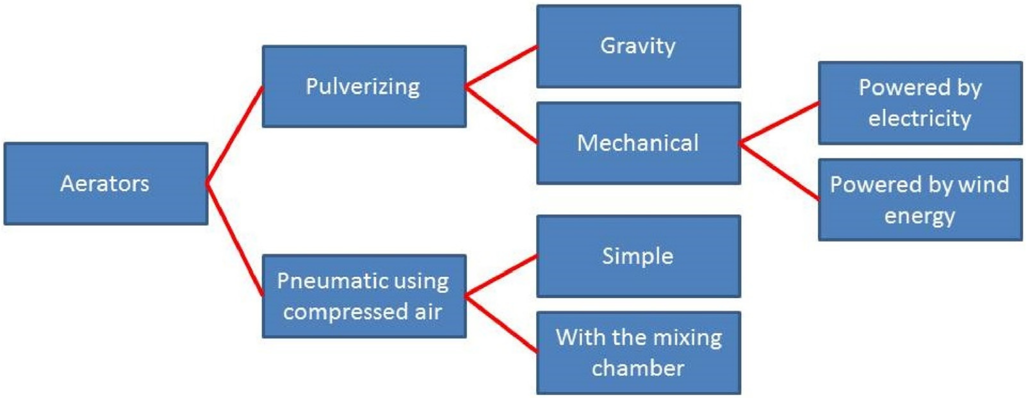

Fig. 1. Types of aerators (acc. to Podsiadłowski, 2001, modified).

equipment also in inland waters. Basically, there are two groups of aerators depending on the operation principle, namely pulverizing and pneumatic aerators (Fig. 1).

Pneumatic aerators pump air into a water layer. They are becoming obsolete because of high energy consumption and relatively low efficiency, which is due to pumping air into the layer of water already saturated with hydrogen sulphide or methane.

Pulverizing aerators propel water into the air. The simplest type of pulverizing aerators do not require an external power source but simulates a waterfall effect based on the kinetic energy of the flowing water. Mechanical splash aerators used in sewage treatment plants and fish ponds are usually electrically-driven, and wind-powered when used in lakes. Importantly, pulverizing aerators spray water in the air, where air is overabundant, making the process of gas diffusion easier. As a result of rising energy prices and intensified human impact on the environment, scientists have been working on new methods of water restoration based on renewable energy sources, especially wind, simultaneously scrutinizing the process of natural self-restoration. A lot of research has been done in order to find technologies that could initiate and stimulate processes that might trigger new food chains (starting also in the hypolimnion), which remove excess of organic matter from the most vulnerable layers of a lake (Bormans et al., 2016; Grochowska and Brzozowska, 2015; Minella et al., 2015; Niemisto et al., 2015; Wesołowski and Brysiewicz, 2015). Consequently, the two main fields of the research are:

(1) increasing the efficiency of gas exchange during the aeration process (replacing H_2S with O_2),
(2) harnessing wind energy to power aeration (Podsiadłowski, 2005).

2. Description of the device

The influence of wind speed on aeration efficiency of the pulverizing device is regarded as the most vital indicator of aeration efficiency and was described earlier (Podsiadłowski, 2008b); nonetheless, precise data regarding pulverizing aeration at different wind speeds had been unavailable. The installation of the phosphorus inactivation system in the aerator was the moment when the data proved to be extremely useful. In this paper, aeration efficiency has been presented as mean water flow capacity in the suction hoses of the aerator. The operating principle of the pulverizing aerator is based on using energy obtained from the Savonius wind turbine for gas diffusion, namely for the pulverizing of hypolimnetic water, during which H_2S and other gases are replaced by oxygen. Thanks to this technology, water flowing through the aerator may absorb up to seven times more oxygen, which makes it possible to develop the so-called intensive aeration zone (Podsiadłowski, 2005). This zone tends to translocate relatively frequently due to naturally occurring lake tides, which has been proven by our earlier study (Podsiadłowski, 2008a). The aeration process in deep lakes with a well-defined thermal stratification (Fig. 2) is, however, different from the same process occurring in shallow lakes (Fig. 3).

In the hypolimnetic waters of deep lakes with a well-defined thermal stratification (Fig. 2), the oxygenated water zone develops, which leads to the oxidation of complex compounds and to surviving of benthic macroinvertebrates. Shallow lakes differ from deep lakes in this respect, because the aeration devices are used to remove the deoxygenated near-bottom layer, with sharp oxycline, which develops during summer months as a result of intensive microbiological processes in the sediment-water interface. Limiting the gradient of the oxycline is crucial for initiating and maintaining the process of lake restoration (Klapper, 2003).

Consistent oxygen supply to the over-bottom waters of lakes by means of wind-powered pulverizing aerators make it possible to inactivate phosphorus released from the bottom sediments on oxidised metal compounds (Sondergaard et al., 2002). Innovation of this method consist on the pulverizing aerator was equipped with the phosphorus inactivation system capable of dosing the coagulant rates correlated with pulverization efficiency (Podsiadłowski, 2008a).

The general purpose of the study was to determine the relations between coagulant dosage, aeration efficiency and wind speed in

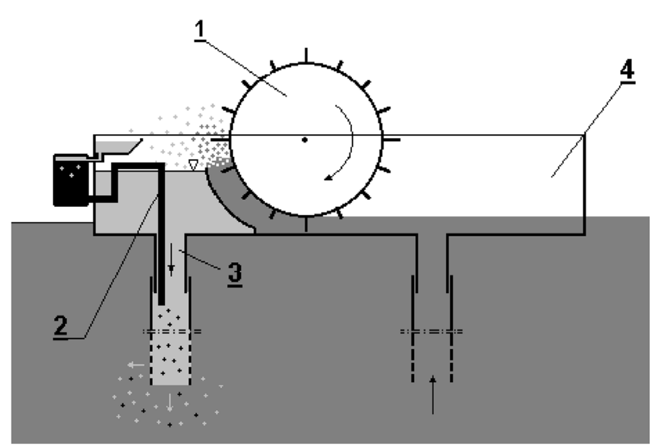

Fig. 2. Pulverizing aerator with a phosphorus inactivation system: 1 – impeller, 2 – coagulant dispenser, 3 – pressing section, 4 – suction section (acc. to Osuch and Podsiadłowski, 2012).