Available online at www.sciencedirect.com

ScienceDirect

European Journal of Protistology xxx (2016) xxx–xxx

European Journal of PROTISTOLOGY

www.elsevier.com/locate/ejop

Protists as bioindicators in activated sludge: Identification, ecology and future needs☆

Wilhelm Foissner*

University of Salzburg, Department of Ecology and Evolution, Hellbrunnerstrasse 34, A-5020 Salzburg, Austria

Abstract

When the activated sludge process was developed, operators and scientists soon recognized protists as valuable indicators. However, only when Curds et al. (1968) showed with a few photographs the need of ciliates for a clear plant effluent, sewage protistology began to bloom but was limited by the need of species identification. Still, this is a major problem although several good guides are available. Thus, molecular kits should be developed for identification. Protists are indicators in two stages of wastewater treatment, viz., in the activated sludge and in the environmental water receiving the plant effluent. Continuous control of the protist and bacterial communities can prevent biological sludge foaming and bulking and may greatly save money for sludge oxygenation because several protist species are excellent indicators for the amount of oxygen present. The investigation of the effluent-receiving rivers gives a solid indication about the long term function of sewage works.

The literature on protist bioindication in activated sludge is widely distributed. Thus, I compiled the data in a simple Table, showing which communities and species indicate good, mediocre, or poor plant performance. Further, many details on indication are provided, such as sludge loading and nitrifying conditions. Such specific features should be improved by appropriate statistics and more reliable identification of species. Then, protistologists have a fair chance to become important in wastewater works.

Activated sludge is a unique habitat for particular species, often poorly or even undescribed. As an example, I present two new species. The first is a minute (~30 μm) *Metacystis* that makes an up to 300 μm-sized mucous envelope mimicking a sludge floc. The second is a *Phialina* that is unique in having the contractile vacuole slightly posterior to mid-body. Finally, I provide a list of species which have the type locality in sewage plants.

Keywords: Activated sludge; Ciliates; *Metacystis mucosa* n. sp.; *Phialina serranoi* n. sp.

Introduction

Farming needs about two thirds of the earth's freshwater and the industry takes further 23%. To produce 1 kg corn requires 1300 l water and 15,000 l are needed to produce 1 kg beef. An US-American consumes about 250 l/day, a European about 160 l, and an African only 20 l (Helmholtz-Zentrum 2011).

Most of the used water comes back as wastewater contaminated with organic and inorganic materials. Several methods have been developed to clean wastewater (Fig. 1) but all imitate the self-purification in running waters: the wastes are degraded by organisms, mainly bacteria, to minerals, water, CO_2, heat and new biomass, e.g. bacteria. This needs a lot of oxygen which must be added to the wastewater treatment plants to obtain "activated = oxygenated sludge" composed

☆Plenary lecture on occasion of the VII European Congress of Protistology. This is an extended version of the conference paper from Foissner (2014b).

*Tel.: +43 66280445615.
E-mail address: wilhelm.foissner@sbg.ac.at

http://dx.doi.org/10.1016/j.ejop.2016.02.004
0932-4739/© 2016 Elsevier GmbH. All rights reserved.

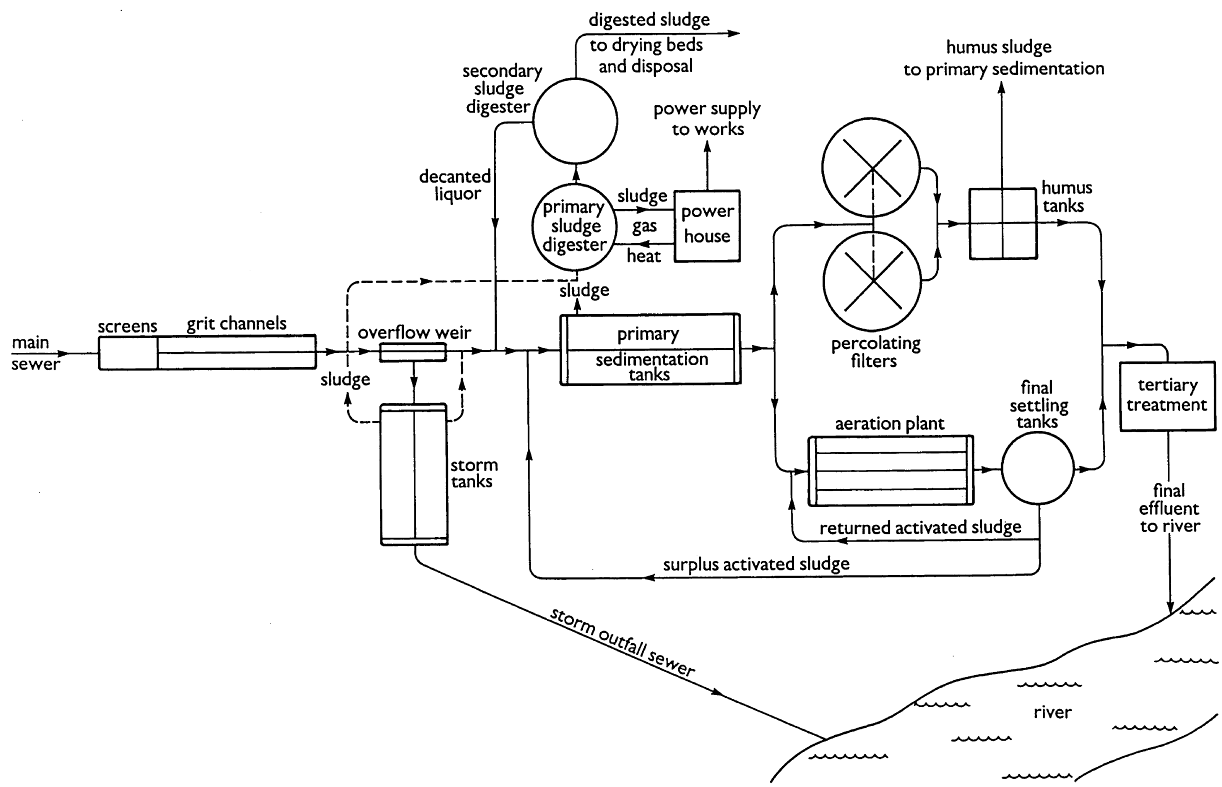

Fig. 1. Flow diagram and layout of a typical sewage-treatment work (from Curds 1992).

of about 0.5 mm-sized flocs made of inorganic and organic materials covered by a thin layer of active organisms, such as bacteria, fungi, and protists (Arregui et al. 2013; Curds 1992; Liebmann 1936, 1951, 1958; Mudrak and Kunst 1994; Pauli et al. 2001; Uhlmann 1982).

The most expensive process is the oxygenation of the activated sludge. Here, protists can help to minimize oxygenation because many of them are excellent oxygen indicators (Berger et al. 1997). The activated sludge process is frequently disturbed by "sludge foaming" and "sludge bulking", that is, part of the sludge flocs does not settle and contaminate the plant effluent, respectively, the river in which the effluent is discharged. Here, protists can serve as an early and late warning tool when the river shows signs of overloading (Berger et al. 1997; Curds 1992; Ganner et al. 2002; Liebmann 1936, 1951; Uhlmann 1982).

This review should stimulate students and group leaders to join an interesting, applied branch of protistology. It does neither review the technical basics of wastewater treatment works (for reviews see, e.g., Bayerisches Landesamt für Wasserwirtschaft 1999; Uhlmann 1982; Imhoff and Imhoff 1993; Fig. 1) nor the important role bacteria and fungi play in the activated sludge process (for reviews see, e.g., Arregui et al. 2013; Eikelboom and van Buijsen 1992; Kunst et al. 2000; Lemmer and Lind 2000). I shall concentrate on protists, i.e., the release from the taxonomic impediment, including the description of two new ciliates from an Austrian sewage plant; brief chapters on industrial wastewaters and on indices for the presentation of microscopic sludge analyses; and a detailed table on the species and communities indicating specific parameters of plant performance.

A brief history

Historically, one might recognize three principal periods in using protists as indicators in wastewater purification. The periods are connected with technical innovations in the water works and the increasing concern of the society about the heavy pollution of many rivers and lakes by organic and inorganic wastes in the industrialized countries.

The Age of Discovery and Exploitation may be set between 1914 and 1950 when Ardern and Lockett (1914) created the term "activated sludge" and researchers recognized the importance of protists in cleaning the wastewater during the activated sludge process (Barker 1942, 1943; Liebmann 1936).

The Age of Bloom may be set between 1950 and 2000. It started with the revision of the saprobic system by Liebmann (1951, 1958), who recognized the usefulness of protists as indicators of water pollution when combined with metazoans and some physico-chemical parameters. These and other data were used by Curds (1966) and Curds and Cockburn (1970a, b) to update bioindication in wastewater treatments plants. Their faunistic and experimental studies lay the ground for a scientific treatment of the field. They showed which ciliate

Please cite this article in press as: Foissner, W., Protists as bioindicators in activated sludge: Identification, ecology and future needs. Eur. J. Protistol. (2016), http://dx.doi.org/10.1016/j.ejop.2016.02.004