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Dewatering in biological wastewater treatment: A review

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A B S T R A C T

Biological wastewater treatment removes organic materials, nitrogen, and phosphorus from wastewater using microbial biomass (activated sludge, biofilm, granules) which is separated from the liquid in a clarifier or by a membrane. Part of this biomass (excess sludge) is transported to digesters for bioenergy production and then dewatered, it is dewatered directly, often by using belt filters or decanter centrifuges before further handling, or it is dewatered by sludge mineralization beds. Sludge is generally difficult to dewater, but great variations in dewaterability are observed for sludges from different wastewater treatment plants as a consequence of differences in plant design and physical-chemical factors. This review gives an overview of key parameters affecting sludge dewatering, i.e. filtration and consolidation. The best dewaterability is observed for activated sludge that contains strong, compact flocs without single cells and dissolved extracellular polymeric substances. Polyvalent ions such as calcium ions improve floc strength and dewaterability, whereas sodium ions (e.g. from road salt, sea water intrusion, and industry) reduce dewaterability because flocs disintegrate at high conductivity. Dewaterability dramatically decreases at high pH due to floc disintegration. Storage under anaerobic conditions lowers dewaterability. High shear levels destroy the flocs and reduce dewaterability. Thus, pumping and mixing should be gentle and in pipes without sharp bends.

1. Introduction

Municipal and industrial wastewater contain high amounts of COD, nitrogen, and phosphorus, which are usually degraded or removed by biological wastewater treatment (Lindrea and Seviour, 2002). The activated sludge process is by far the most common process, but alternative processes such as biofilm systems or granules systems also exist (de Bruin et al., 2004). An integrated part of the biological wastewater treatment is the solid–liquid separation, where the treated water is separated from the activated sludge. In the conventional activated sludge process, this is done by clarifiers, but there is an alternative: membrane bioreactors, where a membrane is used instead of the clarifier (Brindle and Stephenson, 1996; Lindrea and Seviour, 2002). The outcome of the process is treated wastewater (effluent), return sludge, and excess sludge.

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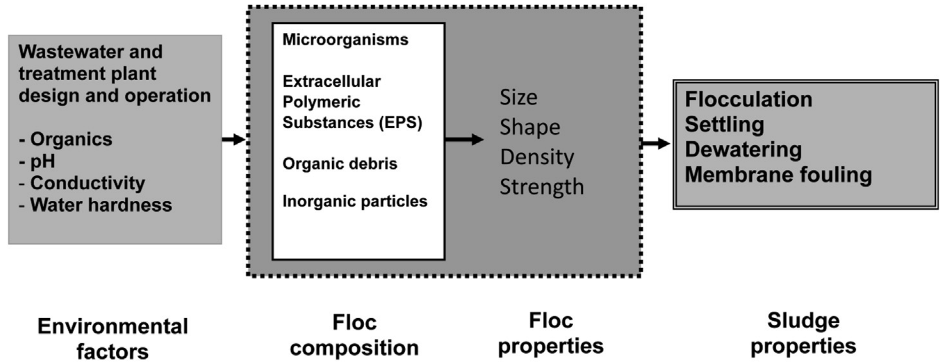

Fig. 1 – Overview of parameters that directly or indirectly influence sludge properties.

In some cases, excess sludge is transported to digesters for sludge reduction and bioenergy production. However, in many cases, other types of sludge handling takes place, e.g. transportation to agricultural fields or drying and incineration. Since the water content of excess sludge is high, it must be dew before further handling, typically by belt filters, filter press, decanter centrifuges, and sludge mineralization beds (Sørensen and Sørensen, 1997). Thus, several solid–liquid separation processes are involved in wastewater treatment for separating sludge from the treated wastewater as well as for sludge dewatering. The dewatering process is costly, and the composition and properties of the sludge are important for the separation process (Bruus et al., 1992; Sørensen and Sørensen, 1997; Chu et al., 2005).

This paper reviews the existing literature on sludge dewaterability, i.e. sludge filtration and consolidation. Fig. 1 summarizes the key parameters that affect various sludge properties such ad dewaterability. Sludge contains flocs, and sludge properties are mainly determined by the size, shape, density and strength of the sludge flocs. Thus, an understanding of the sludge flocs is crucial for a more general understanding of sludge dewatering. Flocs, on the other hand, consist of microorganisms, extracellular polymeric substances (EPS), organic debris and inorganic particles. Some of the components are produced during the biological process and some of the components come from the influent. Further, floc density and strength are influenced the content of e.g. catons and inorganic particle and also by shear forces and thereby indirectly by the design and operation of the plant.

The floc properties not only influence sludge filtration and consolidation but also other processes such as flocculation, settling and membrane fouling, i.e, literature data show that sludge components that cause problems in filtration and consolidation also cause problems in other types of separation processes (e.g. sedimentation, centrifugation, sludge mineralization bed, and membrane bioreactors). Thus, many of the conclusions from this paper are of generic value for all solid–liquid separation processes for biological sludges.

2. Sludge composition

Biological activated sludge consists primarily of biological flocs that are formed by growth of microorganisms and by adsorption of particles from the influent. The flocs consist of microorganisms, either as single cells, filamentous bacteria or microcolonies, organic fibers, inorganic particles (salt and sand), and extracellular polymeric substances (EPS). The typical size of the flocs is 129 ± 109 μm (Mikkelsen and Keiding, 2002) – see sketch of a typical sludge floc in Fig. 2.

Sludge flocs have a fractal-like structure and are kept together by DLVO forces (van der Waals and electrostatic forces), non-DLVO-forces (bridging, hydrophobic forces), and physical entanglement (Namer and Ganczarczyk, 1994; Cousin and Ganczarczyk 1999; Nielsen, 2002). EPS components are particularly important for the floc properties. The EPS components are a mixture of different macromolecules, e.g. proteins, humic-like substances, polysaccharides, nucleic acids and lipids and contribute with 40–60% of the total dry matter of the flocs (Nielsen, 2002). They are negatively charged, and the charge density has been measured to be 0.2–1 meq/g EPS (Keiding et al., 2001; Mikkelsen and Keiding, 2002; Reynaud et al., 2012). Different methods exist for EPS extraction and analyses, and it is often difficult to compare literature data. Nevertheless, it is generally accepted that EPS can be classified as tightly bound EPS (TBEPS), loosely bound EPS (LBEPS), and suspended EPS. Further, a dynamic equilibrium has often been found between loosely bound and suspended EPS components (Nielsen and Jahn, 1999; Comte et al., 2006; Dominguez et al., 2010). The electrostatic interaction

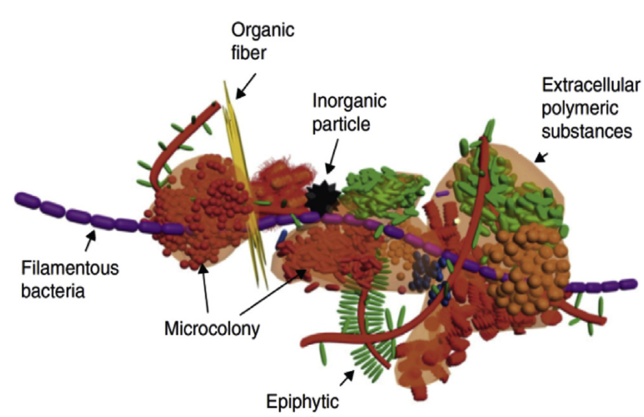

Fig. 2 – Schematic picture of activated sludge flocs (the ideal floc) from Nielsen et al. (2012).