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Behavior of polymeric substrates in an aerobic granular sludge system

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ABSTRACT

Particulate and slowly biodegradable substrates form an important fraction of industrial wastewater and sewage. To study the influence of suspended solids and colloidal substrate on the morphology and performance of aerobic granular sludge, suspended and soluble starch was used as a model substrate. Degradation was studied using microscopy, microelectrode measurements, batch experiments and long term laboratory scale reactor operation. Starch was removed by adsorption at the granule surface, followed by hydrolysis and consumption of the hydrolyzed products. Aerobic granules could be maintained on starch as sole influent carbon source, but their structure was filamentous and irregular. It is hypothesized that this is related to the low starch hydrolysis rates, leading to available substrate during the aeration period (extended feast period) and resulting in increased substrate gradients over the granules. The latter induces a less uniform granule development. Starch adsorbed and was consumed at the granule surface instead of being accumulated inside the granules as occurs for soluble substrates. Therefore the simultaneous denitrification efficiencies remained low. Moreover, many protozoa and metazoans were observed in laboratory reactors as well as in pilot- and full-scale Nereda® reactors, indicating an important role in the removal of suspended solids too.

1. Introduction

Particulate substrate is often an important fraction of the organic material in municipal and industrial wastewater. In The Netherlands for example, 50% of the influent COD (chemical oxygen demand) in municipal wastewater treatment plants (WWTP) consists of particulate slowly biodegradable COD (Roeleveld and Loosdrecht, 2002). In mountainous regions (Alpine countries) this percentage can be higher, due to steep-slope sewers and thus shorter retention time in these sewer systems (van Nieuwenhuijzen et al., 2004).

The large molecules of slowly biodegradable COD need to be hydrolyzed extracellularly to soluble components before they can be used by the bacteria in a wastewater treatment system, because of which heterotrophic growth is often limited by the much slower process of hydrolysis (Dold et al., 1980; Orhon and Çokgör, 1997; San Pedro et al., 1994). Nutrient removal (denitrification and phosphate removal) is in many cases limited by the extend of these hydrolysis processes and therefore, depends on the ratio of dissolved and particulate COD (Morgenroth et al., 2002). As a consequence, the design of biological sewage and industrial wastewater treatment, as well as the assurance of the desired effluent quality should account for the hydrolysis of the organics (Orhon and Çokgör, 1997).

A relatively new method for treatment of sewage and industrial effluent is the aerobic granular sludge technology,

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presently mostly studied in well-controlled laboratory scale reactors fed with glucose or acetate and ammonia mixtures (Beun et al., 1999; De Kreuk et al., 2007; Liu et al., 2005). A limited number of studies have been published on laboratory scale reactors treating sewage or industrial effluent and/or wastewaters resembling those, containing more complex substrates (e.g. malting effluent (Schwarzenbeck et al., 2004b), dairy wastewater (Arrojo et al., 2004; Schwarzenbeck et al., 2005) and sewage (De Bruin et al., 2005; De Kreuk and Van Loosdrecht, 2006)). Granule formation on these wastewaters occurs well, but the granules tend to have more filamentous structures on their surfaces (Fig. 1H). It is observed in these reactors that -particulate COD is removed effectively by the granular sludge. It is therefore questioned how this conversion can occur, since the particulate COD cannot diffuse into the granular sludge. It could be hypothesized that the more porous structure of granular sludge grown on wastewater is related to the conversion of particulate COD.

Several activated sludge and biofilm studies have been described that used particulate starch (PS) and soluble starch

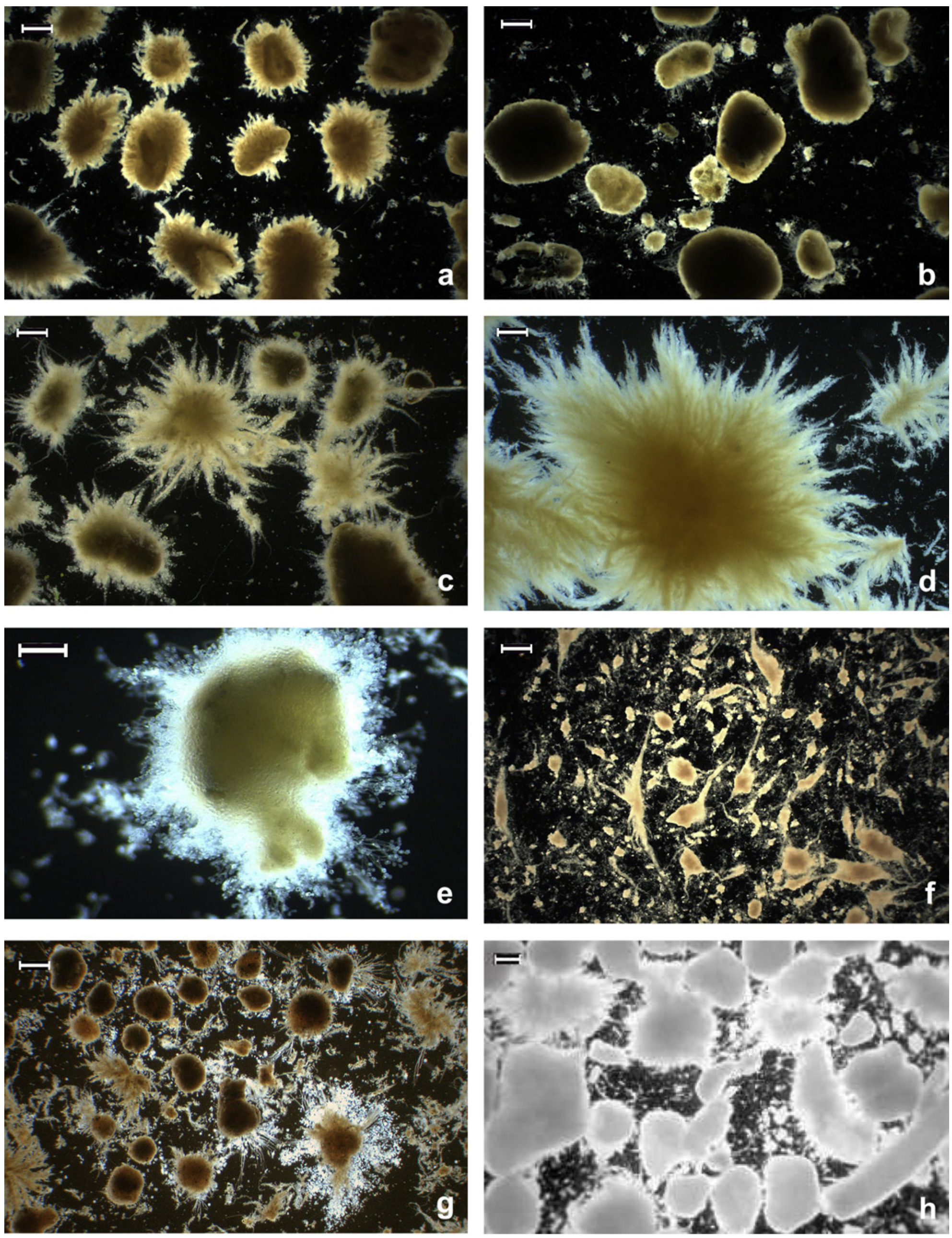

Fig. 1 – Granules present in the reactor fed with particulate starch (A, C), granules present in the reactor fed with soluble starch during the first operation period (B) and changed granules during a later stage (D), Protozoa blooming on the granule surface of granules fed with particulate starch (E); Granules present in Nereda® systems fed with influent with 10–20% suspended solids (F; food industry, The Netherlands); Granules formed in a Nereda® pilot plant fed with raw sewage (G; Hoensbroek, The Netherlands); Granules formed on dairy industrial effluent (Schwarzenbeck et al., 2005)(H) size bars 1 mm (A, B, C, D, F, G, H) and 0.5 mm (E).