The effect of nutrients on extracellular polymeric substance production and its influence on sludge properties

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Abstract

The effect of nutrients on extracellular polymeric substance (EPS) production and its impact on sludge properties and removal efficiencies were investigated in an in-depth field survey of wastewater treatment plants. Thereafter, laboratory studies were performed to evaluate the effect of a combination of nutrients - nitrogen and phosphorus and operational conditions on EPS production, and sludge settling and dewatering characteristics.

Multiple regression analysis was performed to assess the effect of variables in nutrient operational conditions on the EPS production and sludge properties. The field survey revealed that although filamentous micro-organisms were found in most of the sludge samples, they did not always cause sludge bulking. Further, it was observed that EPS production was lower in anaerobic than in aerobic processes. An evaluation of the effect of the deficiency and excess of nitrogen and phosphorus was conducted in batch experiments on synthetic wastewater with glucose as the carbon source. The study revealed that the EPS components, namely proteins and carbohydrates had a more profound effect on sludge properties compared to total EPS, with protein being more significant than carbohydrate. Both nitrogen deficiency (COD: N < 100:2) and nitrogen excess (COD: N > 100:10) improved the sludge properties. The optimum phosphorus ratio determined was COD:P, ranging from 100:3 to 100:5, at which sludge properties in terms of settling, dewatering and the final clarification improved.

Keywords: extracellular polymeric substance, activated sludge process, sludge properties, bio-flocculation

Introduction

In wastewater treatment systems, the biological treatment process is one of the most important and popular systems used for domestic and industrial wastewater treatment. Among the numerous available methods, the activated sludge process is one of the major biological wastewater treatment techniques. This process consists of two units: a bioreactor where organic waste is digested by micro-organisms, and a sedimentation basin where activated sludge is separated from the treated effluent. In the first phase, the active mass of micro-organisms in the aerated bioreactor convert the suspended and colloidal organic material to end-products such as carbon-dioxide, water and inert material. This is the carbon source utilisation phase. The second phase is the flocculation of the micro-organisms and other suspended or colloidal components into rapidly settleable biomass. Thus a clear, low biochemical oxygen demand (BOD) effluent can be obtained, with this phase playing an important role in the production of high-quality effluent. Biological aggregation provides a convenient and effective method for separation biological flocs from the mixed liquor medium, after they have fulfilled their metabolic role. Flocculation of biomass is responsible for changes in supernatant turbidity and variation in settling and dewatering properties. Therefore, the overall function of the activated sludge process depends largely on good flocculation and on the sedimentation behaviour of the sludge.

A detailed field survey conducted by Urbain et al. (1993) reveals that about 25% of the activated sludge treatment units have settling problems with the Sludge Volume Index - SVI > 150 or 200 mℓ/g. Poor settling of activated sludge results in the discharge of suspended solids into the receiving water, which is due to operational problems caused by the deflocculating biomass in the sedimentation basin. This deflocculation is due to lack of natural extracellular polymeric substance (EPS) flocculants within the biomass (Sheintuch et al., 1986).

EPSs produced by bacteria play an important role in controlling the flocculation and floc properties, including settling and dewatering (Bura et al., 1998). EPSs are macromolecular compounds that are found in the intercellular spaces of microbial aggregates. They originate from micro-organisms (excretion and lysis) and wastewater (biosorption). EPSs were identified as the major components of the activated sludge floc matrix. The mechanism of the biological flocculation is interpreted as a result of the interaction of those polymers that have sufficiently accumulated at the microbial surface during endogenous growth. The EPSs present a dominant bridging mechanism between the floc components, namely cellular, bio-organic, and inorganic compounds.

By controlling EPS production, the settling and dewatering of biomass can be improved. Various operational conditions can affect EPS production, such as nutrient concentration, sludge retention time, pH, the ratio of food/micro-organism (F/M) and hydraulic retention time. Controlling the nutrients of the feed wastewater has been identified as one of the methods of controlling EPS. The nature and concentration of nutrients affect the biodegradation of organic waste (Bura et al., 1998). Nutrients are necessary components for the growth of bacteria as well as to stimulate the production of surface biopolymer EPSs, which play a part in settling sludge. Until now, there have been only a few studies on the effects of nutrient balance (COD: N: P) on EPS production and composition, and settling and dewatering characteristics of sludge.

By optimising the nutrient ratio, EPS can be controlled. Thus, the efficiency of the secondary treatment process can be improved. This study focuses on the identification of the nutrient effect on EPS production and its significance on sludge properties in activated sludge processes.

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