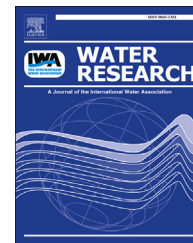




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Analytical methods for soluble microbial products (SMP) and extracellular polymers (ECP) in wastewater treatment systems: A review

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ABSTRACT

Effluents from biological processes contain a wide range of complex organic compounds, including soluble microbial products (SMP) and extracellular polymers (ECP), released during bacteria metabolism in mixed culture in bioreactors. It is important to clearly identify the primary components of SMPs and ECPs in order to understand the fundamental mechanisms of biological activity that create these compounds, and how to reduce these compounds in the effluent. In addition, these compounds constitute the main foulants in membrane bioreactors which are being used more widely around the world. A review on the extraction of ECP, characterization, and identification of SMPs and ECPs is presented, and we summarize up-to-date pretreatments and analytical methods for SMPs. Most researchers have focused more on the overall properties of SMPs and ECPs such as their concentrations, molecular weight distribution, aromaticity, hydrophobic and hydrophilic properties, biodegradability, and toxicity characteristics. Many studies on the identification of effluent SMPs show that most of these compounds were not present in the influent, such as humic acids, polysaccharides, proteins, nucleic acids, organic acids, amino acids, exocellular enzymes, structural components of cells and products of energy metabolism. A few groups of researchers have been working on the identification of compounds in SMPs using advanced analytical techniques such as GC–MS, LC-IT-TOF-MS and MALDI-TOF-MS. However, there is still considerably more work needed to be done analytically to fully understand the chemical characteristics of SMPs and ECPs.

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Abbreviations

BAP	biomass-associated products
BOD	biochemical oxygen demand
COD	chemical oxygen demand
DOC	dissolved organic carbon
ECP	extracellular polymers
EEM	fluorescence excitation-emission matrix spectroscopy
FTIR	Fourier transform infrared spectrometry
GC	gas chromatography
GC–MS	gas chromatography-mass spectrometry
GFC	gel-filtration-chromatography
GPC	gel-permeation chromatography
HPLC	high performance liquid chromatography
LBECP	loosely bound extracellular polymers
LC-IT-TOF-MS	liquid chromatography- ion trap- time-of-flight- mass spectrometry
MALDI-TOF-MS	matrix-assisted laser desorption ionization time-of-flight mass spectrometry
MW	molecular weight
SEC	size exclusion chromatography
SMP	soluble microbial products
TBECP	tightly bound extracellular polymers
TOC	total organic carbon
UAP	utilization-associated products
UASB	upflow anaerobic sludge blanket
UF	ultrafiltration

1. Introduction to soluble microbial products (SMP) and extracellular polymers (ECP)

Conventionally, biologically based systems have been the most commonly used processes to treat wastewater in recent years. However, biological wastewater treatment systems are often operated under non steady state conditions due to frequent changes in influent flow rate and composition. Activated sludge grows under dynamic conditions in different zones of the reactor even if the whole system can be considered in steady state. The microbial activity changes in non steady state conditions resulting the formation of a variety of microbial products. Effluents from biological processes contain a wide range of complex organic compounds including SMP and ECP (ECP are also referred to in the literature as EPS – extracellular polymeric substances) (Lapidou

and Rittmann, 2002). “SMP” has been defined as the pool of organic compounds that are released into solution from substrate metabolism and biomass decay, and ECPs often constitute only a small part (~20%) of the total SMPs (Aquino and Stuckey, 2008; Barker and Stuckey, 1999), and they do not contain known intermediates such as volatile fatty acids or compounds in the influent. SMP were divided into two categories: utilization associated products which are produced during normal metabolism of feed organics inside the cell, and which are then excreted into the bulk phase, and; biomass associated products which are produced during cell lysis and contain cell wall fragments, especially ECP (Barker and Stuckey, 1999). The amount of SMPs is typically estimated by subtracting the chemical oxygen demand (COD) due to intermediate VFAs and residual substrate, from the soluble effluent COD (Aquino et al., 2009) as in the following equation.

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