

# A proposed chemical mechanism for biological phosphate removal in activated sludge treatment of wastewater

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## Abstract

This paper presents an alternative for the "all biological" phosphate removal model. It is postulated that a chemical substance in wastewater reacts with orthophosphate under anaerobic conditions to make the so-called luxury uptake of phosphorus possible in biological nutrient removal (BNR) activated sludge plants. Experimental evidence indicates that the reaction product, an organic phosphate, is the phosphate species that is taken up by organisms in the process of biological phosphate removal. The research on which this paper is based, forms part of a Ph.D. study and further research to confirm the initial observations and to identify the chemical agent involved in biological phosphorus removal is continuing.

## Keywords:

## Introduction

Biological phosphate removal in activated sludge processes was first reported by Levin et al. (1972), Barnard (1974) and Fuhs and Chen (1975), amongst others. Since then extensive research by a great number of people has led to the generally accepted model of phosphate uptake in activated sludge processes designed for biological phosphate removal. An up-to-date account of this is given by Grady et al. (1999).

Explanations had been offered for excess phosphate removal, e.g. that activated sludge organisms, especially *Acinetobacter*, could use stored energy in the form of poly-phosphate while passing through an aerobic zone (Nicholls and Osborne, 1979). Gerber et al. (1986), in laboratory experiments, demonstrated the role of acetates and other short-chain carbon compounds in biological phosphate removal processes.

Knowledge of the biological as well as biochemical aspects of phosphate uptake is fundamental for a thorough understanding of this complicated process. However, there appears to be something lacking in the model for biological phosphate removal. Terms such as "luxurious phosphate uptake" and "excess phosphate removal", which are used in the present context, appear to indicate that there is some kind of contradiction in the existing model. In this respect, the following comment is noteworthy: "A nutrient removal plant is a complex system in which the different system elements, processes and compounds often exhibit interaction in a complex manner; resolution of one problem may bring into focus, or create, another problem - it is most unlikely that a 'final' solution will ever be attained" (Wentzel et al., 1991).

In the present study evidence was found of the role of an unidentified organic substance X in sewage effluent that apparently has gone unnoticed to date because there is no mention of it in the literature. The substance in question could exist in a reduced state

under conditions of low redox potential (-30 mV) or in an oxidised state under conditions of relatively high redox potential (+40 mV). The presence of the oxidised organic substance X can be demonstrated in effluents such as trickling filter effluent. When a sample is acidified by adding 10% H<sub>2</sub>SO<sub>4</sub> and KI solution in the presence of X, iodine is liberated which could be titrated with 0,025 N Na<sub>2</sub>S<sub>2</sub>O<sub>3</sub>, using starch as indicator. Control samples of trickling filter influent liberate no iodine when treated in a similar way, even when nitrate is added to obtain approximately the same NO<sub>3</sub>-N concentration as is present in the trickling filter effluent.

X can also be produced chemically in settled sewage. When settled sewage, after addition of 10 mg/l NO<sub>3</sub>-N, is left in contact with Fe granules, formation of X can be demonstrated after about 1 h. A similar result is obtained when 1% (v/v) saturated HgCl<sub>2</sub> is added to settled sewage in order to prevent any biological activity.

Without elaborating on the proposed chemical mechanism at this stage, it should be pointed out that formation of X is accompanied by a reduction of nitrate to ammonia. It appears that Fe metal in this case acts as catalyst for the chemical reduction of nitrate to ammonia by a yet-to-be-identified substance in sewage effluent, which itself is oxidised in the process.

## Proposed chemical model for the role of X in biological phosphate removal

Progress with identification of X is in an advanced stage and will be reported at a later date. For the present the different oxidation states of X will be indicated by X<sub>ox</sub> and X<sub>red</sub>. It is postulated that X in sewage effluent is involved in a chemical reaction with dissolved orthophosphate in the anaerobic stage of the activated sludge process. Under low redox conditions such as those that exist in the anaerobic zone, the oxidation state of X could be indicated as X<sub>red</sub> and the resulting reaction product with orthophosphate, as X<sub>3</sub>PO<sub>4</sub>. The formation of X<sub>3</sub>PO<sub>4</sub> is considered a prerequisite for phosphate uptake in the biological phosphate removal process. In the case of the oxidised state, i.e. X<sub>ox</sub>, no reaction with dissolved orthophosphate would be possible.

The laboratory tests discussed below were performed in an attempt to demonstrate the proposed chemical mechanism.

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