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THE ASPECT OF ENERGETIC UNCOUPLING OF MICROBIAL GROWTH IN THE ACTIVATED SLUDGE PROCESS – OSA SYSTEM

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ABSTRACT

A practical application of the concept of uncoupling between catabolism and anabolism during microbial metabolism has been studied in the case of a modified activated sludge system, called OSA (Oxic-Settling-Anaerobic). The OSA system consisted of an oxic completely mixed tank, followed by a settling tank and an anaerobic tank, situated in the returned sludge circuit of the OSA system. The periodic passageway of facultative aerobic activated sludge microorganisms through the anaerobic zone created conditions of uncoupled growth, indicated by ATP stock depletion and resulted in a consecutive reduction of activated sludge production.

KEY WORDS

OSA system, energetic uncoupling, catabolism, anabolism, ATP, sludge production.

INTRODUCTION

The role of adenosine triphosphate (ATP) as an intermediate between substrate oxydation process (catabolism) and biomass synthesis reactions (anabolism) is well known (Mandestam and McQuillen, 1982). The relationship between ATP formation by catabolism and synthesis of cell material (anabolism) shown in Figure 1 testifies to some degree of coupling between both processes.

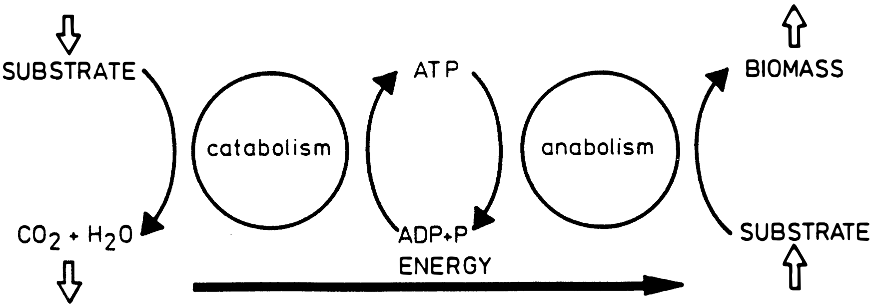

Fig. 1. Simplified relationship between catabolism and anabolism.

Is this coupling tight? Do we have to suppose that the reactions of anabolism are always controlled by catabolism ones and vice-versa? Is it possible to use an uncoupling in wastewater treatment practice? In order to find an answer to these questions, we established the main objective of this study as a search for a relationship between anaerobic conditions in the activated sludge process, uncoupling of catabolism and anabolism due to the anaerobic starvation and consequent reduction of excess sludge production.

THEORY

The question of tight coupling of catabolism and anabolism during microbial metabolism has been subjected to numerous controversies in the last thirty years.

Senez (1962) observed that under some conditions growth rate was limited by the rate of biosynthesis and energy produced in excess during microbial metabolism was wasted. He called this phenomenon "uncoupled growth". The same observations were made by Stouthamer and Bettenhaussen (1977) who concluded that there existed a discrepancy between ATP production and its consumption by biosynthesis. They noted that a part of ATP produced was dissipated. On the other hand, Harrison and Maitra (1969) and Harrison and Loveless (1971) showed that the condition of uncoupled growth could be induced during the transition between anaerobic and aerobic growth conditions and that the yield coefficients were thus considerably lowered. Strange et al. (1963) and Patterson et al. (1970) pointed out that anaerobic conditions markedly reduced the amount of intracellular stock of ATP. The synthesis of ATP which occurred when the bacteria were transferred from anaerobic to aerobic conditions was extremely rapid.

Numerous researchers stressed that uncoupling of catabolism and anabolism, defined by Senez (1962) as "uncoupled growth", resulted in reduction of biomass yield coefficient (Forrest, 1969; Tempest and Neijssel, 1981). Belaich et al. (1972), Stouthamer (1977) and Tempest and Neijssel (1984) concluded that for numerous organisms, anabolic processes did not control catabolic activity and consequently there was no tight coupling between both processes. Chudoba et al. (1991) and Chudoba and Capdeville (1991) pointed out that anaerobic conditions induced an exhaustion of intracellular stock of ATP under anaerobic starvation. Its resynthesis under aerobic conditions was accompanied by reduction of excess sludge production.

MATERIALS AND METHODS

Graphical presentation of two laboratory continuous-flow units used in this study is shown in Figure 2. A CAS (Conventional Activated Sludge) system was operated as a control unit. Table I gives the composition of synthetic wastewater, whereas Table II shows technological parameters of both activated sludge units.

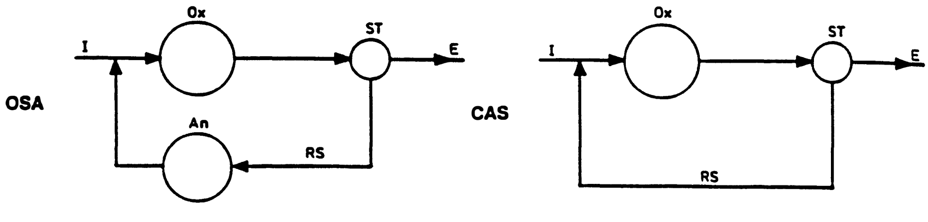

Fig. 2. Experimental units (I-influent, E-effluent, RS-returned sludge, ST-settling tank, Ox-oxic tank, An-anaerobic zone).

Table I. Composition of Synthetic Wastewater

Component	COD (%)	Concentration (mg/l)
Saccharose	5	9.5
Methanol	20	26.7
Sodium acetate	20	53.5
Peptone	50	108.7
Yeast extract	5	12.2
$(NH_4)_2HPO_4$		20.0
$Na_3PO_4.12H_2O$		2.0
Allylthiourea		1.0

*) All components were dissolved in tap water

Table II. Technological Parameters of Activated Sludge Units

Parameter	Unit	Period II	
		OSA	CAS
Volume of the oxic reactor	l	5	5
Volume of the anaerobic reactor	l	4.75	-
Volume of the SST	l	4	4
Recirculation ratio		0.8	0.8
HRT in the oxic reactor	h	2	4
HRT of sludge in the anaerobic reactor	h	3	-
Sludge age (in the whole system)	d	5	5
Average SS (in the oxic reactor)	g/l	0.8	1.5
Average SS (in the whole system)	g	14.3	10.1
Volumetric loading	kg/m3.d	1.35	1.32
Sludge loading	kg/kg.d	0.92	0.66
Feed		synthetic substrate	
Average influent COD	mg/l	220	220
Average effluent COD	mg/l	26	22
Dissolved oxygen in the oxic reactor	mg/l	8	8
Temperature	°C	18±5	18±5
Ox.-red. potential in the anaerobic reactor	mV	-250	

RESULTS AND DISCUSSION

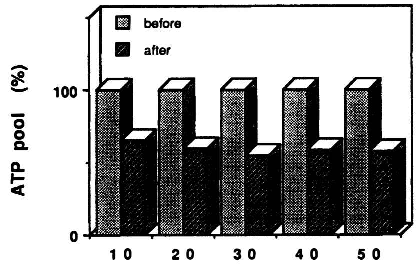

Fig. 3. ATP content in the sludge before and after the anaerobic reactor.

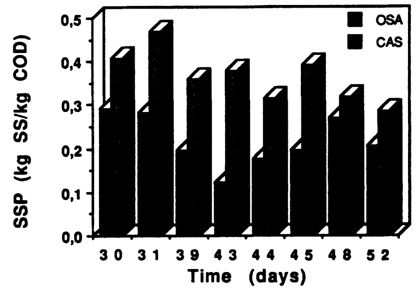

Fig. 4. Specific sludge production.

Figures 4 to 6 show clearly the difference between OSA and CAS systems as far as sludge production, phosphorus content in the sludge and phosphate removal efficiency are concerned. In addition, the analyses of both sludges by Neisser staining method revealed that the OSA biomass contained about 60% of polyphosphate accumulating bacteria (poly-P), contrary to 10% in the activated sludge from the CAS system. On the other hand, Figure 3 shows an important ATP consumption during anaerobic period. It is concluded that the anaerobically treated microorganisms are subjected to a physiological shock created by a lack of oxygen and food. Under the above conditions, they use ATP and polyphosphates as a source of energy. When they are returned to aerobiosis and supplied with exogenous substrate, they rebuild their energy reserves at the expense of growth. An important portion of substrate is oxidized in order to provide the energy accumulated in the cells and utilized later under anaerobic

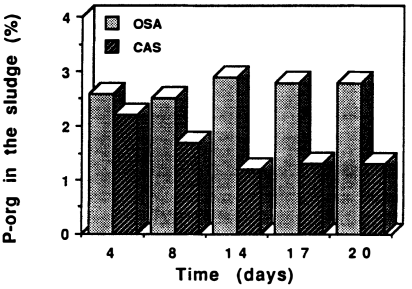

Fig. 5. Phosphorus content in the sludge.

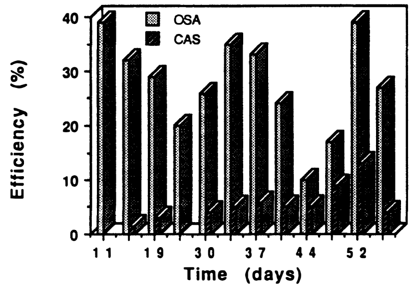

Fig. 6. Phosphate removal efficiency

conditions. It seems that the bacteria selected by these oxic/anaerobic conditions possess a certain kind of memory that enables them to regulate an overaccumulation of energy. This energy is thus stored by means of the intracellular ATP pool and the surplus is transferred in polyphosphates accumulated by poly-P bacteria. Consequently, this phenomenon may be explained by the presence of uncoupling of catabolism and anabolism, resulting in decreased sludge production (Fig. 4).

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