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BIOLOGICAL PHOSPHORUS REMOVAL
FROM A PHOSPHORUS RICH
DAIRY PROCESSING WASTEWATER

A thesis presented in partial fulfilment of the requirements

for the degree of

Doctor of Philosophy

in

Environmental Engineering

at

Massey University

Turitea Campus, Palmerston North,

New Zealand

PAUL O. BICKERS

2005



CANDIDATE'S DECLARATION

This is to certify that the research carried out for my Doctoral thesis entitled "Biological Phosphorus Removal From a Phosphorus Rich Dairy Processing Wastewater" in the Institute of Technology, Massey University, Palmertson North, New Zealand is my own work and that the thesis material has not been used in part or in whole for any other qualification.

Candidate's Name

Paul Oliver Bickers

Signature

PO Bickers

Date

26/06/04



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This is to certify that the research carried out for the Doctoral thesis entitled "Biological Phosphorus Removal From a Phosphorus Rich Dairy Processing Wastewater" was done by Paul Oliver Bickers in the Institute of Technology, Massey University, Palmerston North New Zealand. The thesis material has not been used in part or in whole for any other qualification, and I confirm that the candidate has pursued the course of study in accordance with the requirements of the Massey University regulations.

Supervisor's Name

Rao Bhamidimarri

Signature

Date

26/06/04



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Supervisor's Name: Rao Bhamidimarri

Signature: *POBickers*

Signature: *RBMA*

Date: *26/06/04*

Date: *26/06/04*

ABSTRACT

A phosphorus rich wastewater, typical of a dairy processing site producing milk powder, was biologically treated in a continuous activated sludge reactor.

A literature review indicated there was a vast amount of information on the mechanisms of the Enhanced Biological Phosphorus Removal (EBPR) process and its application to domestic wastewaters, but little successful research on its application to dairy processing wastewater.

The biodegradability of the wastewater organic fractions was assessed due to their impact on the EBPR process. Continuous anaerobic fermentation tests were used to determine the concentration of volatile fatty acids that could be generated, as these are required for successful EBPR. A fermenter hydraulic retention time of 12 hours and a temperature of 35 °C generated the highest concentration of volatile fatty acids, with an acidification rate of 65% (based on 0.45µm filtered COD).

To permit improved dissolved oxygen control and increased flexibility, a multi-zone reactor was designed. A fermentation stage was also incorporated prior to the activated sludge reactor. This reactor was operated with anaerobic, anoxic and aerobic zones at an SRT of 10 days and stable biological phosphorus removal was achieved. A maximum of 41.5 mg P/L was removed and phosphorus release and PHA storage occurred in both the anaerobic and anoxic zones. The soluble COD consumed in the unaerated zones (anaerobic + anoxic) totalled 484 mg COD/L on the day of the zone study (day 158). The aerobic sludge phosphorus concentration averaged 7.0% mg P/mg VSS after system optimisation. The anaerobic volume was doubled in order to increase the anaerobic consumption of volatile fatty acids. This change increased the amount of soluble COD consumption in the unaerated zones to 632 mg P/L after 40 days but did not result in a significant increase in biological phosphorus removal.

In the next series of trials, the concentration of nitrogen in the wastewater was decreased and the anoxic zone removed. This change did not improve the amount of biological phosphorus removal, which was 35 mg P/L at an SRT of 10 days. The effect of different sludge retention times was then investigated. Increasing the SRT to

15 days resulted in little change in phosphorus removal (34.5 mg P/L). Decreasing the SRT to 5 days resulted in the loss of EBPR.

The medium term effect on the EBPR process by removing the fermentation stage was also assessed using an AO configuration at an SRT of 10 days. The amount of phosphorus removed decreased slightly after 34 days to 34 mg P/L, but the soluble COD consumed in the anaerobic zone increased to 624 mg P/L.

It was concluded that a stable EBPR process could be established when treating a dairy processing wastewater with a continuous activated sludge reactor. The biological stability was sensitive to changes in the solids retention time and the removal of the fermentation stage.

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ABBREVIATIONS AND NOMENCLATURE

AAO	Anaerobic-Anoxic-Oxic
AO	Anaerobic-Oxic
ASM1	Activated Sludge Model No. 1
ASM2	Activated Sludge Model No. 2
BNR	Biological Nutrient Removal
BOD	Biochemical Oxygen Demand (mg/L)
COD	Chemical Oxygen Demand (mg/L)
DO	Dissolved Oxygen (mg/L)
EBPR	Enhanced Biological Phosphorus Removal
GAO	Glycogen Accumulating Organisms
HRT	Hydraulic Retention Time (d)
MLSS	Mixed Liquor Suspended Solids
MLVSS	Mixed Liquor Volatile Suspended Solids
MUCT	Modified University of Cape Town
NUR	Nitrate Uptake Rate
OUR	Oxygen Uptake Rate
P	Phosphorus
PAO	Polyphosphate Accumulating Organisms
PHA	Poly- β hydroxyalkanoates
PHB	Poly- β hydroxybutyric Acid
PHV	Poly- β hydroxyvaleric Acid
RAS	Return Activated Sludge
RBCOD	Readily Biodegradable Chemical Oxygen Demand
S _A	Fermentation Products as Acetate Equivalents (mg/L)
SBCOD	Slowly Biodegradable Chemical Oxygen Demand
SCVFA	Short Chain Volatile Fatty Acids
S _F	Fermentable Readily Biodegradable Substrates (mg/L)
S _{II}	Inert Soluble Substrate (mg/L)
SOUR	Specific Oxygen Uptake Rate
SRT	Sludge Retention Time (d)

S_{SI}	Readily Biodegradable Substrate (mg/L)
SVI	Sludge Volume Index (ml/g)
S/X	Substrate to Biomass Ratio
TKN	Total Kjehldahl Nitrogen (mg/L)
TSS	Total Suspended Solids (mg/L)
UCT	University of Cape Town
VFA	Volatile Fatty Acids
VSS	Volatile Suspended Solids (mg/L)
X_{SI}	Slowly Biodegradable Substrate (mg/L)
Y_H	Heterotrophic Yield Coefficient (mg Cell COD/mg COD consumed)
Y_{HD}	Anoxic Yield Coefficient (mg Cell COD/mg COD Consumed)
Y_{PO4}	Ratio of Phosphorus Released to COD consumed (mg P/mg COD)