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**CHARACTERISATION OF AEROBIC BIOTREATMENT
OF MEAT PLANT EFFLUENT**

A thesis presented in partial fulfilment of the requirements for the degree of

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by

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ABSTRACT

This study investigated the bio-kinetics of a meat-processing wastewater in an activated sludge system. The main pollutant loading of the wastewater under investigation was characterized as 1350 mgCOD/L, 70 mgNH₄-N/L, and 127 mgTKN/L in average.

The respirometric method and aerobic batch methods were used to evaluate the biodegradability and the kinetics of carbon removal and nitrification of meat-processing wastewater in an activated sludge system.

The readily biodegradable COD accounts for 15~17 % of the COD in meat-processing wastewater, while the inert portion, including soluble and particulate, accounts for another 10 % of the COD. Approximately, 1/3 of the meat-processing wastewater composition is in soluble/fine colloidal form and the remaining 2/3 is in particulate form.

For heterotrophs growing on soluble meat-processing wastewater, the determined values of kinetic constants for carbon removal were 0.63 mgcellCOD/mgCOD for the observed COD based yield coefficient (Y_H), 0.40 mgVSS/mgCOD for the observed mass (VSS) based yield coefficient (Y_o), 1.4 for COD/VSS ratio, 3.3 day⁻¹ for the maximum specific growth rate ($\mu_{H,MAX}$), and 10 mgCOD/L for the half-saturation constant (K_s). The death-regeneration decay coefficient of heterotrophs (b_H) was 0.38 ~ 0.49 d⁻¹. For heterotrophs growing on unfiltered meat-processing wastewater, the relationship between S_o/X_o and the observed corresponding specific growth rate (μ , d⁻¹) was found to

fit a Monod type function. The maximum specific growth rate of heterotrophs in unfiltered meat-processing wastewater was determined as 9 d^{-1} , while the half-saturation constant was found to be 22.

In regard of nitrification, the maximum specific growth rate of autotrophs in soluble meat-processing wastewater was $0.56 \sim 0.71 \text{ d}^{-1}$.

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CHARACTERISATION OF AEROBIC BIOTREATMENT OF MEAT PLANT EFFLUENT

Chapter 1 Introduction

1.1 The New Zealand Meat Industry

Over three hundred thousand tonnes of New Zealand beef and veal are exported to eighty-five countries around the world annually. This market including the Pacific Region, European Region, North America, the Caribbean, Middle East, South East Asia, Japan and Korea, brings important contributions to the national income of New Zealand. ⁽²⁾ The inspected cattle slaughtering, including adult cattle, calves and vealers, was 2.5 millions carcasses in average (was 3.06 million and 2.86 million for the years 1993 and 1994 respectively). ^(1, 2)

The New Zealand meat industry is under increasing pressure from environmental authorities due to the influence of the resource conservation movement reflected in regulations made by local authorities.

1.2 Environmental Concerns of the Meat Industry

Environmental concerns that may be related to the meat industry include the eutrophication and depletion of dissolved oxygen in aquatic systems, ammonia toxicity, contaminated drinking water (due to the nitrification products, nitrate and nitrite), odour release (H_2S , NH_3 and fecal material), and waste disposal. To meet domestic regulations as well as global trade guidelines and standards, such as Environmental Management and Auditing System, EMAS, ISO 9000 and ISO14000, the industry management needs to act and address these issues now to achieve compliance with both forms of regulations.

1.3 Treatment of Meat-processing Wastewater

High level of organic nitrogen (protein), fat and large amount of organic matters characterize the quality of primarily treated meat-processing effluent. With respect to pollution parameters, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN), total suspended solid (TSS) and fat are

all (sedimentation) and dissolved air flotation (DAF) are widely used primary treatment techniques in the New Zealand Meat industry. Secondary treatment techniques include physiochemical treatment systems (PCTs, such as pH adjustment and/or addition of precipitants) and biological treatment systems (such as anaerobic/aerobic lagoons or tanks, irrigation, and artificial wetlands) are also commonly used in the New Zealand meat industry. ^(1,3,4,5) Trickling filters and sequential batch reactors have also been employed in the recent decade. ^(6,7) In general, only about 50% of pollutants (COD and TKN) are removed by means of PCT techniques, and about 50% to 90% of COD and TKN is removed by the biological treatment systems. ^(3,4,5,6,7) Amongst these techniques, the activated sludge treatment system is considered to be the best option for simultaneous removal of carbonaceous and nitrogenous oxygen demand. ^(14,15,17,19)

1.4 Design and Modelling of Activated Sludge Treatment Systems for the Meat Industry

Although the New Zealand meat industry has significant experience in biological treatment of the meat-processing wastewater, there is little literature on the kinetics of the biological treatment of meat-processing wastewater. On the other hand, engineers often find limitations of time and budget hinders their exploration of the potential solutions for design by testing a lab-scale reactor or a pilot plant. Hence, they frequently turn to mathematical models to define the best feasible design. Appropriate parameters and constants are essential to the reliability of their modelling. Consequently, the information of substrate (meat-processing wastewater) components and process kinetic constants are crucial to a successful design.

1.5 Major Assumptions

This study is based on an assumption that the activated sludge models and their major theories associated with domestic sewage can be applied to meat-processing wastewater, including the following:

- (1) The organic matter in a meat-processing wastewater can be subdivided into a number of categories: non-biodegradable organic matter, which includes inert soluble organic matter (S_i) and inert suspended organic matter (X_i), and biodegradable matter, which includes readily biodegradable materials and

slowly biodegradable materials (X_s); Amongst these, soluble inert organic matter contributes to the effluent organic concentration, while particulate inert organic matter becomes a part of the (volatile) suspended solids in the activated sludge system, and neither of them are involved in any conversion process; Readily biodegradable materials are mainly soluble matter, while slowly biodegradable materials are mainly particulate matter;

- (2) The growth of activated sludge in GF/C filtered (soluble) meat-processing wastewater follows Monod's equation: ⁽⁴⁵⁾

$$\frac{1}{X} \frac{dX}{dt} = \mu = \mu_{MAX} \frac{S}{K_s + S} \quad (2-13)$$

where

μ = specific growth rate (day^{-1}),

μ_{MAX} = maximum specific growth rate (day^{-1}),

X = microorganism concentration (mg/L),

S = growth-limiting substrate concentration,

K_s = half-saturation constant (mg/L);

- (3) The growth of activated sludge in the unfiltered meat-processing wastewater follows a modified Monod type equation (equation 4-1) – a modified Strenstrom's equation, ⁽⁵¹⁾ which later was related to the rate expressions for hydrolysis of slowly biodegradable substrate in the Task Group Model No.1: ⁽¹⁹⁾

$$\mu = \frac{\mu_{H,MAX,overall} \bullet (S_o / X_o)}{K_{S_o/X_o} + (S_o / X_o)} \quad (4-1)$$

where

μ = specific growth rate of activated sludge growing on unfiltered wastewater

$\mu_{H,MAX,overall}$ = maximum specific growth rate of activated sludge growing on unfiltered wastewater

S_o = initial COD concentration of unfiltered wastewater

X_o = initial concentration of biomass, COD based

K_{S_o/X_o} = half-saturation constant for utilizing unfiltered wastewater

- (4) Decay of activated sludge in meat-processing wastewater is a death-

regeneration process: The death of biomass results in the release of slowly biodegradable substrate (X_s) that can be recycled back to soluble substrate used for cell growth. ⁽²⁸⁾

1.6 Objectives

In order to meet the challenge of discharging effluents which comply with the strengthened environmental standards as cost-effectively as possible, information of biological treatment kinetics are crucially required.

To assist the optimum design of activated sludge systems for meat-processing wastewater, it was decided this thesis to provide information as follows:

- (1) The characteristics and biodegradation of meat-processing wastewater; and
- (2) The kinetic constants of carbon removal and nitrification for meat-processing wastewater in an activated sludge system.