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Evaluation of Baffles for Optimisation of Waste Stabilisation Pond Hydraulics

**A thesis presented in partial fulfilment of the requirements
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ABSTRACT

Waste stabilisation ponds are a common form of treating wastewater throughout the world and they provide a reliable, low-cost, low-maintenance treatment system. A literature review undertaken highlighted the need for improved understanding of the hydraulics of such systems, and their upgrade. In particular, the application of baffles is not well understood beyond the use of longer, traditional baffles to increase the approximation to plug flow. The mechanisms and interactions behind baffles are not generally understood.

The work involved the use of CFD modelling to assess various pond designs. In addition to this, traditional tracer studies were carried out on a physical laboratory model, and on a full-scale field pond. These traditional studies highlighted the success of the computer modelling approach.

CFD modelling was used to model twenty pond designs, utilising various baffle lengths, number and position. These cases also studied inlet type and outlet position. In the second phase of the work, six of the CFD designs were tested in the laboratory setting. The final phase of work involved two tracer studies carried out on a field pond, utilising a modified inlet, then a combination of a modified inlet and the inclusion of a short (stub) baffle.

CFD modelling has shown to be an effective investigative and design tool. The addition of results from laboratory and field studies further emphasises the benefits of the CFD modelling. The work has also provided an understanding of key flow mechanisms and interactions that have previously been attributed to other factors.

Single baffles are not generally effective, and a minimum of two baffles will generally be required to achieve significant treatment improvements. The potential of short (stub) baffles has been shown, however they are sensitive to design changes and should be further researched.

Previous research has looked at the pond using a 'black-box' approach, this work seeks to open and explain the flow patterns within that 'black-box'.

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1. INTRODUCTION

This section will briefly introduce the need for the research, and the objectives and approach of the work.

1.1 The Need for the Research

Waste stabilisation ponds are a common technology used for treating domestic, agricultural and industrial wastewaters. They are common in New Zealand, but are also a low-cost, low-technology application for wastewater treatment in developing countries.

The overall efficiency of these systems is dependent on a number of factors. Watters (1971) cites biological factors as having been considered the most important, and hydraulic factors were given little attention. Over recent years, research has given more importance to hydraulic factors.

Hydraulic flow characteristics such as bulk flow patterns, short-circuiting, inlet and outlet positioning, presence of 'dead spaces' and the use of baffles are of significant importance to the overall efficiency of a pond system. Baffles can offer such improvements if properly designed. They can direct flow in such a way as to reduce hydraulic short-circuiting and the presence of dead spaces.

There are a great number of ponds used in New Zealand and throughout the world. These existing ponds are likely to be suffering from poor hydraulic, and therefore, treatment efficiency. This lack of efficiency can give ponds a bad reputation.

Despite the popularity of waste stabilisation ponds in New Zealand, and throughout the world, there is a clear lack of guidelines for engineers on the improvement of their hydraulic, and therefore, treatment efficiency. As they are in common usage, an improvement method that is efficient, and cost-effective, needs to be available.

1.2 Objectives and Approach

The aim of this research was to contribute to the improved understanding of baffle design and use in waste stabilisation ponds. The use of computational fluid dynamics (CFD) modelling as a design tool was also evaluated. The specific objectives of the thesis are given below:

- To investigate the use of baffles in waste stabilisation ponds in terms of:
 - Length of baffles
 - Number of baffles
 - Position of baffles
- To investigate the effect of inlet type, and outlet position
- To evaluate the use of CFD as a design tool to investigate various baffle configurations
- To apply the findings of the work into the field environment

To achieve the given objectives, the work was completed in three phases. In the first phase of work, a range of pond configurations was tested within the CFD environment. This produced an idea of the hydraulic and treatment efficiency of each configuration and allowed a large range of designs to be tested in a timely manner. The time and cost involved with laboratory models and field studies can often be prohibitive.

The second phase of the work involved taking some well-performing configurations from the CFD environment and testing them in a laboratory model pond. The use of CFD modelling as a design tool is relatively new to the field of waste stabilisation ponds, therefore the comparison between the CFD results and a traditional testing method was beneficial.

The final phase of work involved the implementation of two pond configurations in a full-scale field pond. The results were compared with those obtained from the CFD and laboratory modelling. The ultimate test of any design is how it performs in the field situation and therefore the field studies performed for this work offered the final test of the CFD modelling tool.