TRACER STUDIES OF A SUBSURFACE FLOW WETLAND

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ABSTRACT

The use of constructed wetlands represents an innovative approach to wastewater treatment. However, the treatment performance of constructed wetlands has been variable due to an incomplete knowledge of the hydraulic characteristics. Current design methods idealise constructed wetlands as plug flow reactors ignoring the existence of longitudinal dispersion, short-circuiting and stagnant regions. The overall effect will be a reduction of treatment efficiency at the outlet.

This thesis investigates the hydraulic characteristics of a subsurface flow wetland using a fluorescence dye tracer so as to determine the difference between theoretical and actual retention times and their effect on treatment efficiency.

A thorough review of the literature is undertaken, firstly examining wetland systems and their treatment mechanisms, it then reviews their hydraulic characteristics and design considerations while finally discussing dye tracing studies.

A series of dye tracing trials were undertaken on a pilot scale gravel bed wetland with a theoretical retention time of four days. The results from this research are presented as plots of dye concentration versus time at the outlet. These results are analysed in terms of chemical reactor theory and their implications on performance of various treatment mechanisms is discussed.

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CHAPTER 1

INTRODUCTION

Natural wetlands have been used for many decades as a discharge site for wastewater. In recent years, their natural treatment processes has been recognised. Today there are numerous wetlands in use for waste treatment with a strong trend towards artificial wetlands specially designed for this application. The use of constructed wetlands which mimic natural marshlands, represents an innovative approach to wastewater treatment (*Bharridimarri et al., 1991*). Constructed wetlands have potential to provide low-cost and low-maintenance biological treatment of wastewater (*Fisher, 1990*). However, the treatment performance of constructed wetlands has been variable. This variability is due to an inadequate understanding of how to optimise the physical, chemical and biological processes providing treatment and an incomplete knowledge of the hydraulic characteristics that typify constructed wetlands (*Fisher, 1990*).

The efficiency of wastewater treatment in constructed wetlands is largely dependent on the effective duration of contact between the pollutants and the microbial populations. This concept is common to any reactor system. The degree of treatment being directly related to the residence time and efficiency of contact. To obtain maximum treatment efficiency, it is necessary to maximise contact between the wastewater contaminants, the wetland media and the plant roots/stems and minimise short circuiting (*Steiner & Freeman, 1989*). Current design methods idealise the constructed wetland as a plug flow reactor and use a "residence time" based solely on the volume of the wetland cell and the flow-rate (*Stairs, 1993*).

This idealisation ignores the existence of longitudinal dispersion, short-circuiting and stagnant regions within the wetland cells. The result of these phenomena is that the fluid elements are not retained in the wetland cell for the theoretical retention time, rather there is a distribution of residence time. If a system is designed as plug-flow ignoring the of distribution of residence time, the overall effect will be a reduction of treatment efficiency at the outlet.

An insufficiently understood aspect of constructed wetlands design is the hydraulic regime. Currently used hydraulic design criteria in the field of constructed wetlands are largely theoretical. An appreciation of the hydraulic regime and actual detention time in a wetland system is a prerequisite to the understanding of the treatment mechanisms and the effectiveness of the purification provided by such systems (*Fisher, 1990).* By injecting a fluorescent tracer into the system, an assessment of the hydraulic regime can be obtained. Tracer methods have been used extensively in chemical reactor analysis and have been employed frequently in more conventional wastewater treatment technologies, such as stabilisation ponds (*Slade, 1992; Stairs, 1993).*

This thesis investigates the hydraulic characteristics of a subsurface flow wetland using Rhodamine WT (fluorescent dye tracer) so as to firstly, determine the difference between theoretical and actual retention times and their effects on treatment efficiency. Secondly, to show through the calculation of the treatment efficiency that the current assumption of wetland being an ideal plug-flow reactor is not valid.