BIOTRANSFORMATION OF SEWAGE IN A TRICKLING FILTER

Prepared as part of a Envirolink
contract for scientific services

by

Margaret Leonard

September 2009

Client Report
CSC 0906

BIOTRANSFORMATION OF SEWAGE IN A TRICKLING FILTER

Science Programme Manager

Margaret Leonard
Project Leader

Wendy Williamson
Peer Reviewer

DISCLAIMER

ACKNOWLEDGMENTS

This report has been funded through the Foundation for Research, Science and Technology's Envirolink scheme.

.

TABLE OF CONTENTS

FIGURES

1. INTRODUCTION

Gisborne District Council is installing a sewage treatment system in the city. A review of the options has taken into account a number of issues, which include cost and the cultural values. The preferred option which is seen to address these issues is biotransformation of sewage through treatment in a biological trickling filter. The effluent will be directly discharged to the ocean, without the typical additional process of settling the solids in a clarifier, which produces a liquid and solid phase.

In order to inform the discussion around cultural issues regarding the nature of the trickling filter effluent, the council has requested a description of the biotransformation process that occurs during treatment on the trickling filter and the nature of the solids present in the treated effluent. In this report we summarise the process of "biotransformation" of the particulate and dissolved organic contaminants into biomass. Information of the removal of the organic matter by treatment and data on the physical nature of the particulates discharged in trickling filter effluent is presented to illustrate the changes which occur.

2. TRICKLING FILTER PROCESSES

The idea of purifying sewage by trickling it over rocks has been around for over 100 years. The key method by which treatment occurs is through the development of a biofilm. Biofilm development is most commonly observed in rivers, as brown or green biofilms on rocks that make them slippery. As river water becomes more contaminated with sewage, the biofilm becomes more noticeable.

In a trickling filter the micro-organisms in the biofilm metabolise the biodegradable component of the dissolved and particulate contaminants in sewage. This process provides the carbon and nutrients necessary for microbial cell growth. Other microorganisms then use the micro-organism cells as their food source, and in turn become a food source for organisms higher up the food chain.

The trickling filter consists of spraying ("trickling") settled or screened sewage over beds of rock, or more commonly nowadays, plastic, media (Figure 1). The rocks become coated in slime, which is continuously removed, or sloughed off, and renewed. The sloughed-off material is discharged in the effluent.

Figure 1 Trickling filter bed using plastic media for secondary sewage treatment

2.1. Contaminant removal – "biotransformation"

Traditionally, the organic matter in wastewater is measured as the five-day biochemical oxygen demand (BOD_5). In sewage 40-80% of BOD is particulate (Parker et al. 2006) and the remainder dissolved BOD: the composition of the sewage depending on the community it services. The trickling filter removes 40-70% of this BOD, (Tchobanoglous et al., 2003) by adsorption and microbial cell growth.

In trickling filters, microorganisms establish a strong attachment to the uneven surface of the media (rocks, stones or plastic) and biofilms develop above the plane of the media, to a depth of about 2 mm. Small organic molecules diffuse into microbial cells in the biofilm, providing carbon and nutrients for microbial cell growth. To remove the larger sized molecules and particulate BOD, these particles must be trapped in the biofilm, so they can be degraded into small enough particles for diffusion to occur. The larger molecules and particulates become trapped in the biofilm by a 'glue' (extracellular polymeric substances – EPS) secreted by the microbial cells. The EPS also attach the micro-organisms to the media (Boltz et al 2006). The synthesis of EPS growth needs high concentrations of dissolved oxygen and fresh EPS dominates at the outer surface of the biofilm where oxygen concentrations are highest. Figure 2 shows bacteria, denoted by the black ovals with pilli, connecting individual bacteria; the whole colony would be enveloped in EPS.

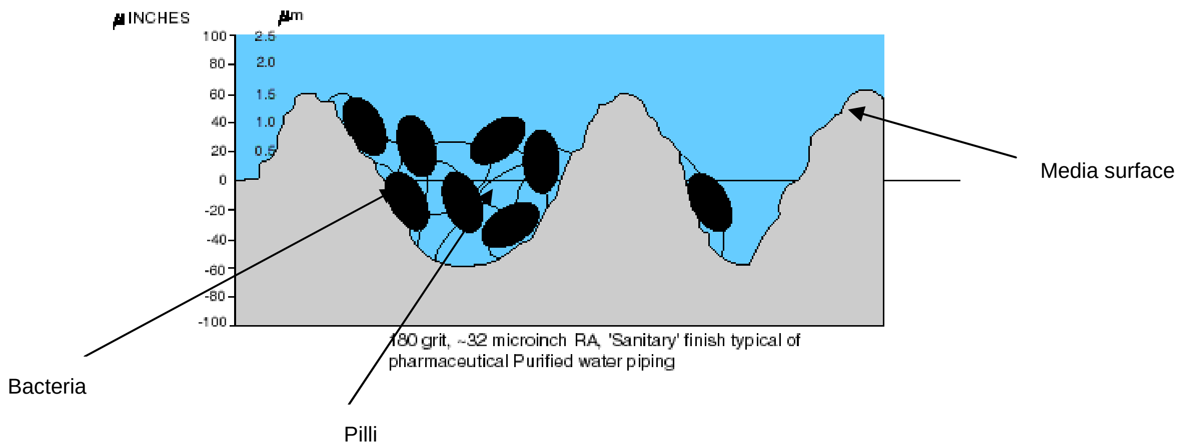

Figure 2 Establishment of a biofilm

Enzymes bound to the microorganism cells in the EPS break down the particulates through hydrolysis, into smaller and smaller units (Confer and Logan, 1998), until the compounds are small enough to diffuse across the cell membrane. For example, proteins are progressively hydrolysed into polypeptides, then peptides, then the component amino acids. Once the molecules can diffuse across the membrane they are used for cell growth: i.e. "bio" transformation of the contaminants in sewage into biomass of microorganisms. As the cells grow they secrete more EPS and consequently the biofilm grows. During growth, oxygen diffusion through the biofilm reduces until anaerobic conditions develop at the media surface, at which point the biofilm sloughs off and is discharged in the trickling filter effluent. The microbial cells form the basis of a food chain within the trickling filter. Protozoa, for example, graze the microbial cells which also cause the biofilm to be sloughed off.

In a pilot plant study it was found that increasing the rate at which the sewage is applied to the trickling filter (hydraulic loading) reduced the biofilm biomass, but the increased "shearing" action of the higher flow increased sludge production (Battistoni et al. 1992). Operation of the trickling filter is a balancing act: higher BOD loads accelerate biofilm growth increasing the removal of dissolved organics, but consequently increasing the particulates (sloughed biofilm) in the effluent (Särner, 1986). Lower surface loading rates mean that there are more large particles in the effluent and fewer small particles. There is also an interaction between dissolved and particulate organics with particle adsorption to the biofilm surface decreasing the removal rate of dissolved organics (Särner, 1986).

2.2 Changes in the physical characteristics after treatment

One of the key physical characteristics which can be measured before and after treatment in the trickling filter, is the change in the sizes of the particles. Treatment mechanisms, such as adsorption, bioflocculation (Boltz et al., 2006) and the biofilm sloughing off, either by the development of anaerobic zones on the media surface or by protozoa grazing the biofilm, are likely to produce larger particles.

Particulates can be counted by number, volume or mass. However, as there are a very high number of very small particles, counting by number underestimates the contribution of the larger fraction (Schuber & Günthert, 2001, Marquet et al., 2007). Comparisons of trickling filter influent (sewage) and effluent showed that (80%) of particulates in influent were <0.1mm by volume (80%), and only 10% >0.1mm (Marquet et al., 2007). However, after treatment in the trickling filter the particle size distribution changed with 88- 90% of particulates, >0.1mm, by volume (Levine et al., 1985, Marquet, et al., 2007).

The reported size distribution also depends on the operation of the trickling filter and the particle sizes which are of interest. Tchobanoglous (1983) focused on soluble BOD and concentrated particles between 0.0001mm and 0.012mm. He reported that images from a scanning electron microscope, showed similar “large” particulates (>0.005mm) in the influent and effluent of a trickling filter. This may have been an artifact of the very high loading rate to the trickling filter.

Small particulates in the trickling filter effluent are more dense and likely to contain inert material that the particulates greater than 0.1 mm (Zahid & Ganzcarczyk, 1990). The large particulates have a very open and porous (Zahid & Ganzcarczyk, 1990), which can lead to difficulties in removing them by settling. They are also very fragile, easily sheared into smaller particles by turbulent flow through pipes, giving rise to a change in particle size distribution towards the smaller sizes (Schubert & Günthert 2001).

3. SUMMARY

Trickling filters can remove 40-70% of sewage BOD. As sewage is fed over a trickling filter, dissolved and particulate contaminants are trapped in the biological “glue” secreted by the biofilm. Once trapped, the microorganisms degrade the organic matter into successively smaller particulates and/or molecules, until the molecules are small enough to diffuse through the cell, providing nutrients for cell growth. The removal of BOD therefore occurs by adsorption to the biofilm and diffusion into the cell, transforming the nutrients in sewage into microbial cell biomass.

Under low loading conditions, the effluent characteristic of a trickling filter has large particulates consisting of parts of the biofilm which has been sloughed off, and humus-like solids. Particle analysis shows a corresponding change in the size distribution with an increase in larger particulates in the tricking filter effluent, compared to sewage. These large particulates are the dominant size fraction. This is consistent with bioflocculation and the biofilm sloughing off the media.

The trickling filter changes the chemical and biological nature of sewage. The information provided in this report is to inform discussions about whether these changes satisfy cultural concerns.

REFERENCES

Battistoni, P., Fava, G., Gatto, A. (1992) High load trickling filters. Biofilm accumulation and sludge production *Water Science and Technology* 26 (9-11), 2405-2408

Boltz, J.P., La Motta,E.J., Madrigal, J.A. (2006) The Role of Bioflocculation on Suspended Solids and Particulate COD Removal in the Trickling Filter Process. *Journal of Environmental Engineering*, 758-763.

Confer, D. & Logan, B.E. (1998) Location of protein and polysaccharide hydrolytic activity in suspended and biofilm wastewater structures. *Water Research* (32)*1 31-38*

Eckenfelder, W. W. Jr. Industrial water pollution control. McGraw Hill, 1989

Marquet, R., Muhammad, N., Vairavamoorthy, K., Wheatley, A. (2007) Particle size distribution to assess the performance of trickling filters. *Process Safety and Environmental Protection* 85(1 B), 99-103

Parker, D.S., Newman, J.A., (2006) New Process Design Procedure for Dealing with Variable Trickling Filter Effluent Suspended Solids. *Journal of Environmental Engineering*, 506-513

Särner, E. (1986)Removal of Particulate and Dissolved Organics in Aerobic Fixed-Film Biological Processes *Journal (Water Pollution Control Federation)*, 58 (2), 165-172

Schubert, W., Wolfgang Günthert, F. (2001) Particle size distribution in effluent of trickling filters and in humus tanks *Water Research* 35 (16), 3993-3997

Taber, (1976) Wastewater Microbiology *Annual Reviews in Microbiology*, 30: 263-277

Tchobanoglous, G., Burton, F.L., Stensel, H. D. Wastewater engineering: treatment and reuse. Metcalf & Eddy. Chapter 7-3. 2005.

Tchobanoglous, G., Levine, A. D., Koltz, J. R. (1983). Filterable solids as a design parameter for wastewater treatment processes. Proc. 6th Symp on Wastewater Treatment, Montreal.

Zahid' W.M, & Ganczarczyk, J.J. (1990) Suspended solids in biological filter effluents *Water Research* 24 (2), 215-220.