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Sustainable reduction in the flux of microbial compliance parameters from urban and arable land use to coastal bathing waters by a wetland ecosystem produced by a marine flood defence structure

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Abstract

'Natural' treatment systems such as wetlands and reed beds have been proposed as sustainable means of reducing fluxes of faecal indicator organisms (FIOs) to recreational and shellfish harvesting waters. This is because FIO fluxes to coastal waters from both point (effluent) and diffuse (catchment) sources can cause non-compliance with microbiological standards for bathing and shellfish harvesting waters. The Water Framework Directive requires competent authorities in the member states to manage both point and diffuse sources of FIOs in an integrated manner to achieve compliance with 'good' water quality as defined in a series of daughter Directives.

This study was undertaken to investigate the relative sources of FIOs to the popular bathing waters around Clacton, UK. In this predominantly arable (mainly cereal cropping) farming area, the principal land use predictor, explaining 76% of the variance in geometric mean presumptive *Escherichia coli* concentration at sub-catchment outlets during the bathing season, was the proportion of built-up (i.e. urbanised) land in each sub-catchment. This new finding contrasts with earlier studies in livestock farming regions where the proportion of improved grassland has proven to be the strongest predictor of microbial concentration. Also novel in this investigation, a flood defence wall has been built creating a wetland area which discharges every tidal cycle. The wetland produces over 97% reduction in the flux and concentrations of FIOs to the marine recreational waters. Also, FIO concentrations in water draining through the wetland to the sea were similar to concentrations measured in six UK sewage treatment plant effluents subject to secondary (biological) treatment followed by UV disinfection.

Keywords: Bathing water; Faecal indicator; Coliform; Enterococci; Arable; Urban; Land use; Coastal defence; Wetland; Natural treatment; Sustainable pollution reduction; Microbial pollution; Built-up

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1. Introduction

Bathing water compliance locations are defined as 'protected areas' by the Water Framework Directive (WFD) (CEU, 2000). Articles 10 and 11 of the WFD imply that the competent authorities are responsible for the design of a 'programme of measures' designed to ensure the combined effects of point and diffuse sources of faecal indicator organisms (FIOs) do not cause non-compliance with existing Directive *Imperative* (i.e. mandatory) standards (CEC, 1976). However, new and tighter 'health-based' microbiological standards have been outlined by WHO (2003), CEC (2002), CEU (2004) and Kay et al. (2004). These proposals suggest a process of 'profiling' of point and diffuse sources of FIOs affecting recreational receiving waters to provide an initial risk assessment and facilitate targeted remedial measures where locations are at risk of episodic non-compliance (WHO, 1999). The legal requirement to comply with existing *Imperative* microbiological standards and the potential for expensive 'infraction' proceedings by the European Commission have encouraged the widespread installation of sewage effluent disinfection at many UK bathing water compliance locations. Both UV light and micro-filtration have been installed to treat secondary effluents prior to discharge to coastal bathing water receiving environments. Such systems can be highly effective in reducing the faecal indicator flux in treated effluents but they are expensive and of questionable 'sustainability' given their high energy demands for power generation either to drive pumps for micro-filtration or artificial irradiance in the case of UV systems.

Appreciation of the importance of diffuse pollution from agriculture is increasing in the policy community (DEFRA, 2002, 2003). Previous research by the present authors (Wyer et al., 1994, 1996, 1998), has demonstrated that rivers and streams are often important sources of the FIOs which may affect the quality of bathing waters at adjacent identified monitoring sites assessed for compliance with the current EC Directive 76/160/EEC (CEC, 1976). This problem is likely to increase as new, tighter, microbiological standards are applied to bathing waters in the European Union (CEC, 2002; WHO, 2003; CEU, 2004). In this paper the faecal indicator organism sources and loadings in a stream system draining to a coast, protected from sea flooding, in the east of England is considered. Earlier UK research has concentrated on catchments dominated by livestock farming and draining directly to the sea. In this case, the stream system is impounded behind a sea wall during high tide and water is released via a sluice except as the tide rises above the level of the outlet. The investigation follows the general catchment budget approach described by Wyer et al. (1998). In addition, concentrations of faecal indicators are assessed in relation to land use in the catchment.

There is some contention concerning the role of wetland systems in faecal indicator attenuation and/or generation. Recently Grant et al. (2003) suggested that a Southern Californian coastal marsh could be a source area for the generation of enterococci and Abulreesh et al. (2004) noted the role of wildfowl populations in elevating FIO concentrations in urban amenity wetlands in the UK. Steets and Holden (2003) commented that the 'generation' hypothesis was contrary to the more accepted assumption of FIO attenuation through wetland ecosystems as observed by Edwards et al. (2005) and Kay and McDonald (1980).

2. Materials and methods

2.1. Study catchment and monitoring programme

The 94 km^2 Holland Brook catchment is located near Clacton in Essex, England (Fig. 1). The stream system drains an area of gently rolling countryside of low relief (maximum altitude 39 m O.D.), which contains some urbanized areas, including parts of the towns of Clacton and Frinton. The lower reaches of Holland Brook flow through an area of freshwater grazing marsh and meadow. This area, known as Holland Marsh, contains local nature reserves. It lies below mean high water level and is protected by a sea wall. The stream discharges to sea via a sluice (Holland Sluice) for approximately 4 h before and after low water. Fig. 1 shows the 16-stream water quality monitoring points selected in the catchment. Sample points 1–5 were chosen to enable a comparison of faecal indicator inputs to Holland Marsh (sites 2–5) with output of Holland Brook from the sluice (site 1). The remaining sites comprised a sequence of sub-catchment sites on the main stream (sites 6–10) and a series of tributaries (sites 11–16). These sites, together with the five 'budget' sites (sites 1–5), were used to investigate relationships between land use and water quality. The sites were chosen to reflect the range of land use in the catchment and to be accessible for sampling (e.g. at road bridges).

The sites were monitored during an 8-week period commencing at 09:00am GMT on 1 June 1998. The locations were routinely sampled during dry-weather (base flow) conditions and during hydrograph response to rainfall (high flow). Sites were visited on at least 25 occasions during the study period. Generally, at least eight high-flow samples were obtained at each site although the number of samples from site 16 ($n = 9$) was lower because this stream was dry for substantial parts of the study. This allowed faecal indicator organism concentrations (C) to be characterized as geometric mean (GM) values under base-flow (C_b) and high-flow