A simplified model of pathogenic pollution for managing beaches

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Abstract

Existing models for urban runoff water quality and dispersion in the coastal zone are cumbersome for application to everyday management of beach use. A simplified model is therefore proposed and tested using a case study. The model captures the key physical processes involved in mixing and dispersion of pathogenic pollution at beaches, and should therefore have some generality. Simulations using the model are shown to adequately reproduce measurements at the case study site. The utility of the model is demonstrated by analysing a specific case of poor water quality at one of the beaches and by using it to estimate the reduction in pollution loadings needed to meet water quality guidelines.

Keywords: beach-water quality model, pathogenic pollution, storm-water runoff, *E. coli*

Introduction

Pollution of coastal waters can have negative impacts on public health and the tourism industry. Water-borne pathogens (i.e. disease-causing organisms) can be transmitted when people come into contact with polluted water. Sources of pathogenic pollution at beaches include sewer outfalls, storm-water drains and rivers. Studies by Wright et al. (1993) and Mardon and Stretch (2004) have highlighted how such pollution can render beaches in the Western Cape and KwaZulu-Natal unsuitable for recreational use.

Monitoring beaches for pathogenic pollution typically involves testing for the presence of indicator organisms such as *Escherichia coli* (*E. coli*) and/or *Enterococcus*. Water quality guidelines (e.g. US EPA, 1986; COM, 2002; DWAF, 1995) specify limits, based on epidemiological studies, for indicator concentrations. Weekly or fortnightly water sampling is usually required to implement these guidelines. Mardon (2003) found that there was no significant correlation between successive fortnightly samples at a case study site (Durban, South Africa) indicating that the timescale for changes in pathogenic pollution in the near-shore zone was much shorter than the sampling interval. Therefore high levels of pollution may occur undetected between sampling times. However, more frequent sampling is costly and microbiological analysis of the samples takes 24 h to 48 h to complete anyway (*Standard Methods*, 1992). Therefore a model to predict pathogen levels at beaches between sampling is required to effectively manage exposure risks. Models are also useful for addressing "what-if" scenarios concerning future changes.

US EPA (1999) reviewed the application of water quality models to beaches. The review discusses urban runoff quality models (e.g. SWMM, HSPF), as well as models of dispersion and mixing in receiving water-bodies (e.g. SMTM, QUAL2E, CORMIX). These models are not generally well suited for application in the South African context due to a lack of detailed data for set-up and calibration, particularly for the more complex models. Coleman and Simpson (1996) adapted aspects of the HSPF and SWMM models for urban runoff quality predictions in South African catchments. However, this type of model, intended for aiding storm-water management and design, is too detailed and unwieldy for beach pollution. The aim of the present study was therefore to investigate and develop a simplified model that does not require extensive input information, but can adequately predict beach pollution for management purposes.

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Model formulation

From a modelling perspective, pollution dispersion in the near-shore coastal environment involves complex processes such as wind-generated surface advection, wave-driven long-shore currents, cross-shore mixing processes due to wave and tidal forcing, and localised effects such as rip currents. Both mixing and natural decay processes reduce pollution within the nearshore zone: e.g. light, through photo-oxidation, can be a major factor in bacterial population changes (Chamberlin and Mitchell, 1978). The model described herein greatly simplifies these processes but is not a pure "black box" approach – a connection to the main underlying physical processes is maintained in the hope of achieving some generality and to help with parameter estimation. The model is formulated in state-space form. *E.coli* concentrations were used as state variables for the case study reported here, but other water quality indicators can probably be used, subject to appropriate testing and calibration.

A more detailed discussion of aspects concerning the model formulation and development, particularly the representation of the underlying physical processes and model estimation procedures, is given in Mardon (2003).

The model structure

The beach zone is modelled as a series of cells (see Fig. 1) with specified physical characteristics, i.e. length, volume and orientation. The size of the cells determines the extent of spatial averaging in the model since each cell is assumed to be homogeneous with