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ESTIMATION OF THE FATE OF MICROBIAL WATER QUALITY CONTAMINANTS IN A SOUTH AFRICAN RIVER

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ABSTRACT

The aim of this study was to evaluate the validity of assumptions, regarding assimilative capacity for microbial contaminants, implicit in microbial water quality management in South Africa. A one dimensional steady state stream water quality model, assuming first order decay of microbial water quality variables, was employed in an attempt to describe and predict microbial water quality in the chosen catchment. Based on the faecal coliform counts the results indicated that the processes of decay and dilution were inadequate to yield water quality which complied with South African and international guidelines for the domestic and recreational use of water. It was also found that a first order decay model can, with fairly limited data, allow a manager to investigate different microbial water quality scenarios in a cost-effective manner.

KEYWORDS

Water quality modelling; microbial water quality; *E.coli;* faecal coliform counts.

INTRODUCTION

Microbial quality of surface water bodies in South Africa is currently controlled by regulation of the microbial quality of effluents discharged, based on *E.coli* levels. Guidelines for domestic and recreational water use have been developed in the South African Water Quality Guidelines (Department of Water Affairs and Forestry, 1993). The processes of dilution and die-off of microbial pollutants and the assimilative capacity of rivers for these pollutants are assumed to be adequate to safeguard the microbial quality of water bodies.

Evolving water quality management policies require prediction of the instream fate of pollutants, and the effect of the resultant water quality on recognised water uses. From a water quality perspective, the relationship between the waste load input and the resulting water quality response is best described by a mathematical model of the water system (Thomann and Mueller, 1987). It is expected that this approach will also be used to address the problem of microbiological water pollution on a wider scale (Department of Water Affairs and Forestry, 1991).

This study aims to evaluate the validity of assumptions regarding assimilative capacity for microbial contaminants. It also assesses the use of mathematical modelling tools for the investigation and management of microbial water quality. The application of a one dimensional steady state stream water quality model to a suitable South African catchment, and development of recommendations to assist in the setting of microbial guidelines will be addressed.

METHODOLOGY

Study catchment. The Rietspruit catchment was chosen as a suitable site. The Rietspruit river is located at the downstream end of the Vaal River Barrage catchment in the Pretoria-Witwatersrand-Vereeniging province of South Africa. Microbial contaminants enter the river by inputs from sewage treatment works and informal settlement areas. The river also receives inputs from industrial and mining areas. The primary water uses in the catchment are domestic, with informal settlements using untreated river water for drinking and washing, and recreational users in the downstream Loch Vaal impoundment who fish and boat.

Microbial water quality monitoring. Monitoring of faecal coliforms was carried out over a two year period (from winter 1991 to summer 1993). Fortnightly samples were taken of all the point sources entering the river as well as from points along the river and were analyzed using the membrane filtration technique and m-FC agar (APHA, AWWA and WPCF, 1989).

Model and input requirements. The QUAL2E model (Brown and Barnwell, 1987) was selected as a suitable model for the reasons summarised in Table 1.

Table 1. Selection of QUAL2E as a suitable water quality management model

QUAL2E Model	Advantages for use as a management tool
Public domain	Low cost; readily available
Widely used	Reliable; familiar to many modellers
Well documented	"Modeller friendly"; easy to run
Simulates one/many variables	Flexible; general purpose
Uncertainty analysis	Allows for simulation of "what if" scenarios
Minimal data requirements	Can be more readily applied
First order coliform decay	Adequately models microbial water quality
Deterministic	Can be applied under many conditions;
Steady State	Does not require intensive data collection

The QUAL2E model requires inputs of: hydraulic data, from either instream depth and velocity measurements or stage discharge flow measurement; water quality data, including 'headwater' (conditions at the upstream boundary) and point source (tributaries and effluent discharges) information. *In situ* membrane diffusion chamber studies (de Wet *et al.*, 1994) were used to determine faecal coliform decay rate constants to be used in the model.

RESULTS AND DISCUSSION

The faecal coliform levels as measured during the two year period of the study, are shown in Figure 1. The key factors affecting the microbial water quality are inputs from sewage treatment works (e, sn, so, v) and informal settlement areas (draining into tributary kr). The results show processes of decay and dilution were inadequate to yield water quality which complied with South African and international guidelines for domestic and recreational use.

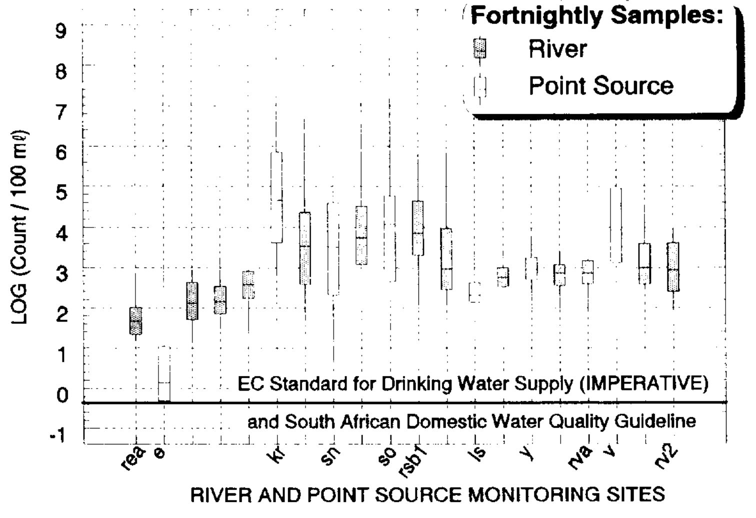

Figure 1. Box-and-whisker plot of faecal coliform counts in the Rietspruit river as measured over a period of two years.

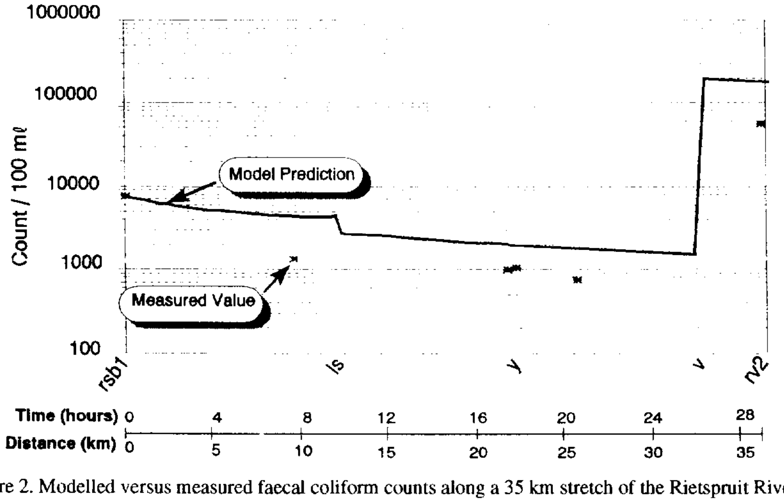

Figure 2. Modelled versus measured faecal coliform counts along a 35 km stretch of the Rietspruit River.

For the modelling the faecal coliform decay rate constants were determined at two sites in the river (de Wet *et al.*, 1994). The average measured constant fell within ranges reported in literature (Bowie *et al.*, 1985) as can be seen in Figure 3.

Results from a model run for one day determining the faecal coliform levels are shown in Figure 2. The modelled faecal coliform trend matches that observed in the river. The accuracy of model predictions is very dependent on how well point and diffuse sources are quantified, and the accuracy of flow measurements.

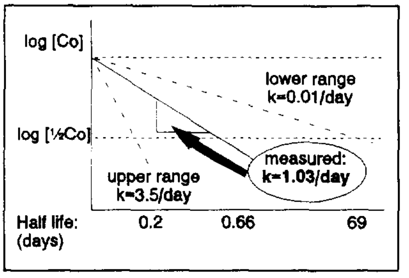

Figure 3. Comparison of measured versus literature decay rate constants.

Given the relatively short stretch of river being modelled, very little die-off was observed after short travel times. In the catchment being investigated, the primary improvement of microbial contamination came from dilution by river tributaries (ls) and other discharges to the river (y). Highly contaminated runoff from informal settlements was diluted by discharges from well-run sewage treatment works.

CONCLUSIONS

Management of microbial water quality is difficult because there are generally limited data available and because very few assumptions can be inferred from non-microbial water quality data. Each area of investigation therefore needs to be carefully assessed to determine site specific conditions and factors affecting microbial water quality management. Managers cannot assume die-off will effectively reduce the levels of microbial contamination in water, but should examine the options of managing inputs to the river as a means of dilution. In support of this, the use of a suitable model, such as QUAL2E, can, with fairly limited data, allow a manager to investigate different microbial water quality scenarios in a cost-effective manner.

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