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The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

TECHNICAL BRIEF

Water pollution

Exploring microbial pathogens in water resource sediments

A completed Water Research Commission (WRC) study has successfully grown essential knowledge about the dynamics of microbial pathogens in water sediments.

Background

Aquatic ecosystems and water resources are still being subject to serious microbial pollution. The dynamics of microbial pathogens in water resource sediments and the extent of accumulation of pathogens that might take place in different type of sediments are not well known.

Knowledge is also required about how the pathogens in sediments are associated with different input loads or how they may be remobilised to contribute to unsafe irrigation water, recreation and drinking water. The possible outcome could be a misleading estimation of the associated public health hazard.

There are also no obvious options available for measuring or management of remobilised pathogens under different climate scenarios. Given that the infectious risk of waterborne pathogenic organisms is associated with human exposure above a certain infectious dose, this lack of knowledge can hold serious consequences for human health and water management.

In order to understand and better inform policy regarding water resource sediments, a modelling approach was used in conjunction with laboratory experiments and field observations to characterise the sources, accumulation, die-off growth and remobilisation of microbial pathogens in sediments.

Thus the aims of this WRC project were to, among others, characterise and model the pathogen loads from point, non-point and land use practices in a selected area; characterise the remobilisation dynamics of pathogens in water resource sediments in selected areas; and develop simulation models based on the outcome of the hypothetical models and the process that drive the remobilisation of pathogens from sediments to ultimately predict pathogen loads under different climatic conditions.

Methodology

Ten sampling sites were selected along the Apies River, with the first site located downstream from the Daspoort Wastewater Treatment Works in Pretoria, and the furthest downstream site located in the North West Province, close to Makapanstad. The Apies River is one of Tshwane's major natural resources and its water quantity and quality are severely impacted by human activities.

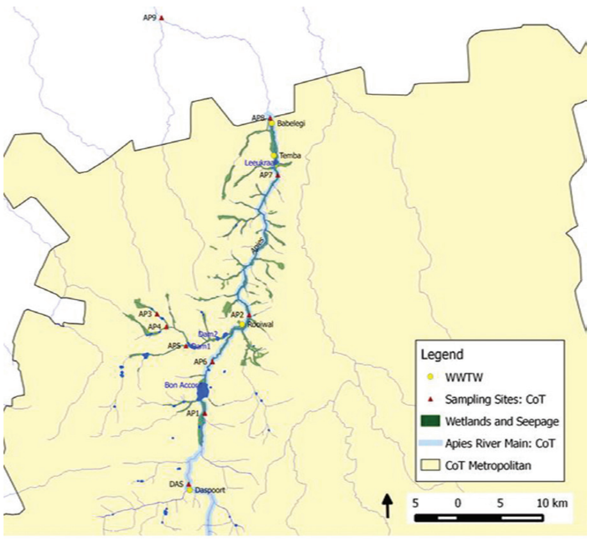

Figure 1: The location of sampling sites along the Apies River.

Water and sediment samples were collected manually during the dry and wet season. The water samples were analysed for the presence of the three bacterial pathogens (*Salmonella sp.*, *Shigella sp.* and *V. cholera*). In addition, *E.coli* (indicator bacteria) counts were measured at each of the nine sites.

The study comprised two separate modelling components of the Apies River study site that covers in total about 95.8 km of river stretch. The one modelling component focused on the parameterisation of an area weighted model to capture land-based pollution sources in the Apies River catchment areas and their potential contribution to the observed pollution loads in the river.

The second modelling component focused on the characterisation of the in-stream flow conditions during the wet and dry seasons. This was done to determine whether flow conditions in the individual stretches of the Apies River where the sampling sites were located supported the resuspension of pathogens attached to different sized and types of river bed sediment material and transport of this material downstream during the dry season.

Main results

The sediment and water microbial data collected as part of the field sampling campaign in the project were used in both the modelling components. The results obtained from the microbial survival laboratory work done as part of the project were used to support the interpretations of an analysis of the field data using a multi-regression model.

Sediment on the river bed harbours pathogen cells consistently as was shown by the nearly all year-round presence of *E.coli* during both the wet and dry seasons. It can be concluded that sediment and, especially, sediment on the riverbed is an important reservoir of pathogens in the Apies River.

Temperature was found to be an important environmental variable contributing to the fluctuations observed in *E.coli* concentrations in the water at one of the sampling sites for which sufficient data were available.

The survival experiments done with only controlling for temperature in the laboratory study provided the temperature threshold values for the *E.coli* bacillus to survive the longest period of time in the sediment. It was assumed that the temperature values measured in the water during the field sampling campaign are representative of the temperature values in the sediment and that temperature will have the same effect on the *E.coli* cells in the water than those in the sediment.

The laboratory results showed that *E.coli* preferred cooler conditions in comparison to other pathogens, i.e. it survived for close to a month in the sediment at temperatures between 4-20°C with a preference for temperatures close to 4°C.

Temperature values above 20°C were consistently measured at all sampling sites during the wet season whereas temperatures below 10°C were most often measured at the sampling sites located on the tributaries and at the site located downstream from the Bon Accord dam outlet.

The field measurement temperature values indicate that the environmental conditions in the Apies River are less supportive of long survival times of the *E.coli* pathogen in the sediment and water, especially during the hot wet season. The cooler conditions during the dry season support the longer survival times of the pathogen in the water and especially the sediment.

These results support the findings by the weighted area model that land based sources and especially diffuse sources consistently replenish the pathogen loads observed in the river during the wet season. It was also for this reason that the in-stream flow modelling component focused on the flow conditions during the cooler dry season when the potential sources of pathogens could be limited to mainly point sources (i.e. outflows from wastewater treatment works) and the potential resuspension of the riverbed sediment material shown to harbour *E.coli* during the dry season.

An area weighted model to estimate the likely contribution of land-based point and diffuse sources to the observed pollution loads in the Apies River was developed as part of the project. The model confirmed the significant contribution of diffuse land-based sources to the observed pathogen loads in the water column during the wet season and the significant contribution of point sources to the observed pathogen loads in the water column and in the sediment during the dry season.

This highlighted the complexity associated with the separation of the contribution of land-based sources from that of sediment material on the riverbed which harbours pathogens to the observed pathogen loads in the water column during different seasons.

The final report also describes an in-stream flow model to determine whether the flow conditions during the wet and dry seasons could have contributed to observed pathogen loads as a result of the resuspension of riverbed sediment material to which the pathogens are assumed to be attached to. The point simulation models consist of a set of equations to determine the minimum flow conditions required for sediment material of a specific size to be resuspended and transported downstream.

The use of hydrological flow models in different software packages was also investigated as part of the project. The lack of hydraulic geometry and river morphology data as well as measurements of the concentration of sediment material and type in the water, and the number of cells attached to different sediment types and sizes for the study area necessitated an alternative approach to simulate the resuspension of sediment material and explain the sources of observed pathogen loads in the water column.

A combination of an empirical and analytical approach was used. The empirical approach was used to estimate the likely flow conditions in the individual stretches where the sampling sites were located and the inputs required for the equations used in the analytical approach. The analytical approach entailed the use of known equations to estimate the minimum flow rate required at a specific site for sediment material in the size range 0.02-0.25 mm to be resuspended and transported downstream.

The error associated with the flow estimates is unknown due to a lack of measured data. Part of the empirical approach involved the analyses of the relationships of observed *E.coli* concentrations in the water between upstream and downstream sites. The hypothesis was investigated whether suspended material to which *E.coli* was assumed to be attached to was transported downstream on the same day during the dry season.

No statistical significant correlations between upstream and downstream sites for *E.coli* could be found, indicating that the flow conditions during the dry season do not favour the transport of suspended material to which *E.coli* is assumed to be attached to.

Further reading:
To order the report, ***Microbial Pathogens in Water Resource Sediments: their Dynamics, Risks and Management*** (**Report No. 2169/1/15**) contact Publications at Tel: (012) 330-0340, Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.