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A SITUATIONAL ANALYSIS OF THE MICROBIAL WATER QUALITY IN A PERI-URBAN CATCHMENT IN SOUTH AFRICA

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ABSTRACT

A situational analysis of a peri-urban catchment experiencing microbial water quality problems was carried out using data collected over two and a half years. The water and land use in the area was determined. The main sources of pollution were identified and the effects of dilution and bacterial die-off on water quality were evaluated by modelling the level of faecal coliforms along the length of the river using the QUAL2E model. As a result of the assessment, water quality goals were set for the catchment and suggestions were made for the improvement of microbial quality. Certain areas of the catchment are densely populated and both developed and informal settlements exist. Water is mainly used for domestic and recreational purposes. The river receives diffuse source discharges as well as point source discharges from four wastewater treatment plants and an industrial site. Assessment of indicator organism and pathogen analyses indicated that the main factors affecting the microbial quality were discharges from the sewage plants and runoff from informal settlement areas. The industrial activities in the catchment did not have a major effect. Modelling runs predicting faecal coliform levels demonstrated that bacterial die-off did not result in a significant improvement to the microbial water quality in the catchment. © 1997 IAWQ. Published by Elsevier Science Ltd

KEYWORDS

Microbial water quality; catchment management; water quality modelling; QUAL2E.

INTRODUCTION

The microbial quality of South Africa's surface water resources has been under increasing threat of pollution in recent years. Rapid demographic changes have coincided with the establishment of human settlements lacking appropriate sanitary infrastructure. This especially applies to peri-urban areas surrounding the larger metropolitan centres in the country, where many such settlements have developed without proper water supply and sanitation services. People living in these areas, as well as downstream users, often utilise the contaminated surface water for drinking, recreation and irrigation creating a situation which poses a serious health risk of contracting waterborne diseases (Verma and Srivastava, 1990). The microbial quality of surface waters is currently controlled by regulation of the quality of effluents from point sources discharged into surface water bodies. The regulatory standard is based on nil *E. coli*/100mL. A relaxed standard of

1,000 *E. coli*/100mL is applicable in special cases but is rarely met. No in-stream water quality standards exist and in most areas authorities rely on dilution and die-off to safeguard the quality of surface waters. The effectiveness of managing surface water quality in South Africa by only controlling point source pollution is questionable. The situation in which an increased threat to the surface water microbial quality is evident calls for active management of in-stream microbial quality within specific catchments. Microbial quality can only be managed effectively after a situational analysis of the catchment is done. Information, such as the level of microbiological pollution in the river and the contribution of point and non-point sources, is needed to identify the main sources of pollution. This study describes a situational analysis of the microbial quality in a peri-urban catchment as a suggested basis development of a plan to actively manage the microbial quality.

MATERIALS AND METHODS

Study catchment - the Rietspruit catchment (Figure 1) lies in the Gauteng province close to Johannesburg. It is a small (1,120km^2), densely populated (1,000 people/km^2) catchment which contains developed and developing areas. The river draining the area receives point source inputs from sewage treatment plants as well as effluent from both manufacturing industries and mines. Diffuse source pollution inputs come from informal settlement areas and limited agricultural activities in the area. The major point sources and tributaries into the Rietspruit are discharges from four wastewater treatment plants (E, SN, SO and V). The industrial effluent enters the river at Y and the two tributaries are Kleinrietspruit (KR) and Leeuspruit (LS). Kleinrietspruit drains a developing area and the quality of the water is a result of diffuse pollution sources in the area. Underground mine water is discharged into the upper reaches of the Leeuspruit. The primary water uses in the catchment are domestic and recreational. Informal settlements use untreated surface water for drinking and washing, and recreational users in the downstream impoundment use the water for fishing and boating.

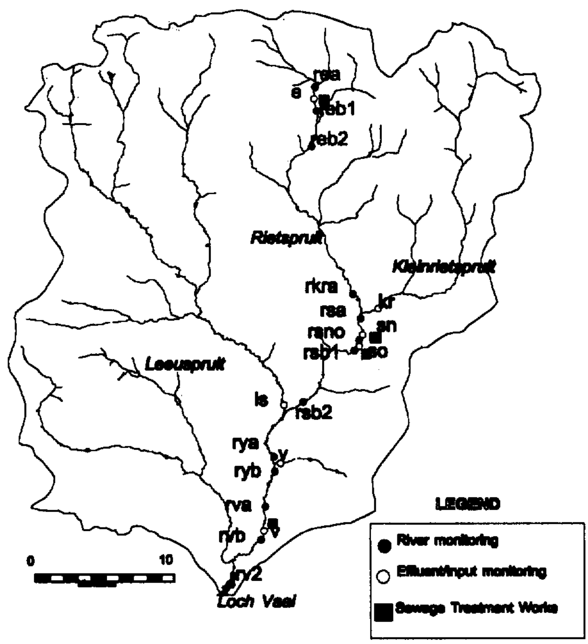

Figure 1. Map of the Rietspruit catchment and sampling points.

Monitoring - microbial water quality was monitored for two and a half years. Samples were taken upstream and downstream of a discharge point or inflow of a tributary (Figure 1). Indicator organisms (faecal coliforms FC, coliphages, standard plate counts) were monitored on a fortnightly basis at all samples points using standard methods (APHA, 1995). Pathogens (*Giardia, Cryptosporidium* and enteric viruses) were only monitored at selected sampling points situated along the lower reaches of the river. The protozoan parasites were analysed after filtration by staining the samples with an indirect fluorescent-linked antibody (Kfir *et al.*, 1995). Enteric viruses were determined by observing cell cultures for typical cytopathic effects. The effects of dilution and bacterial die-off on the microbial quality were also studied by modelling the level of faecal coliforms along the length of the river using the QUAL2E model as described by Hohls *et al.* (1995).

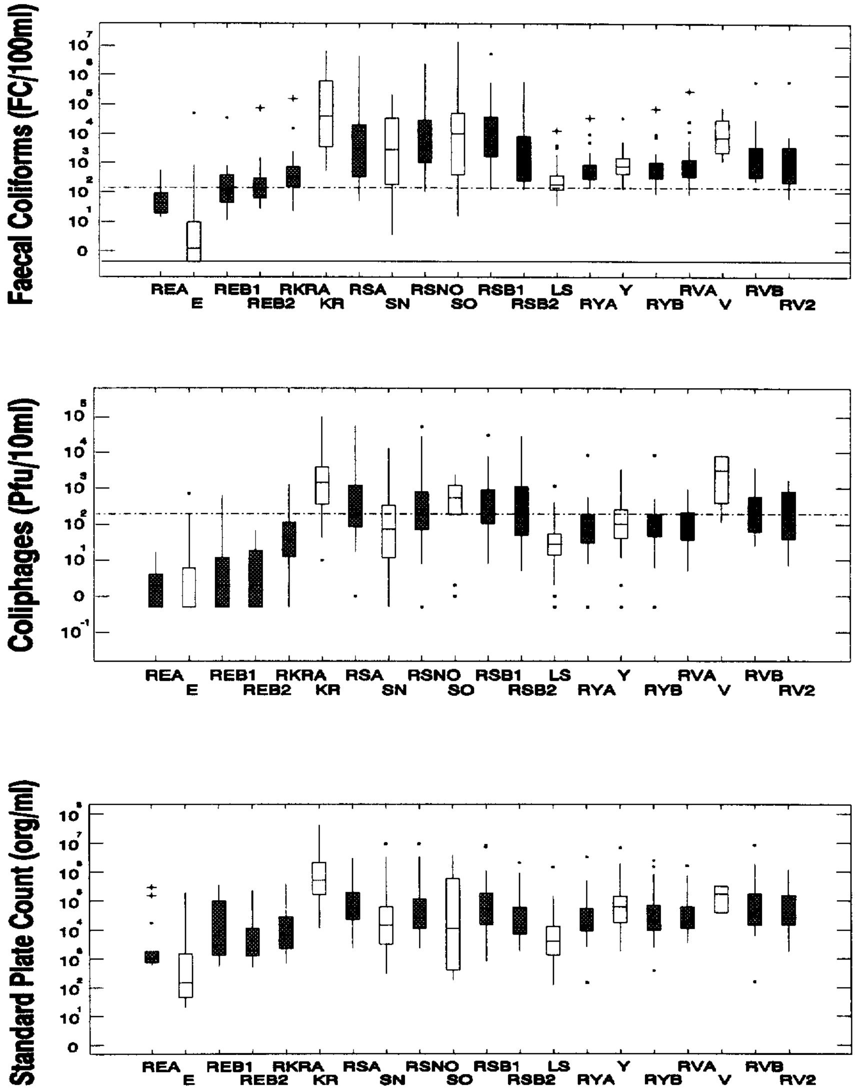

Figure 2. Variations in the microbial indicator levels measured at different sampling points over a period of two and a half years. [Instream sample = shaded bars; Sources = unshaded bars; ———— Effluent standard; _._._. Water quality guideline: Contact recreation].

RESULTS

The level of indicator organisms are shown in Figure 2. High levels of all were found at the outlets of three of the four wastewater treatment facilities (SN, SO, V) in the catchment as well as in the KR tributary. The average levels for faecal coliforms and standard plate counts measured at KR were the highest. The average level of coliphages measured in the effluent of V was the highest. A definite increase in the level of all indicator organisms was noticed in the instream measurements downstream of the confluence of the KR with the Rietspruit. The wastewater treatment works E showed the lowest levels of indicator organisms compared to all the sources including the industrial sources (Y, LS). The average levels measured at E were also lower than the in-stream values measured along the river.

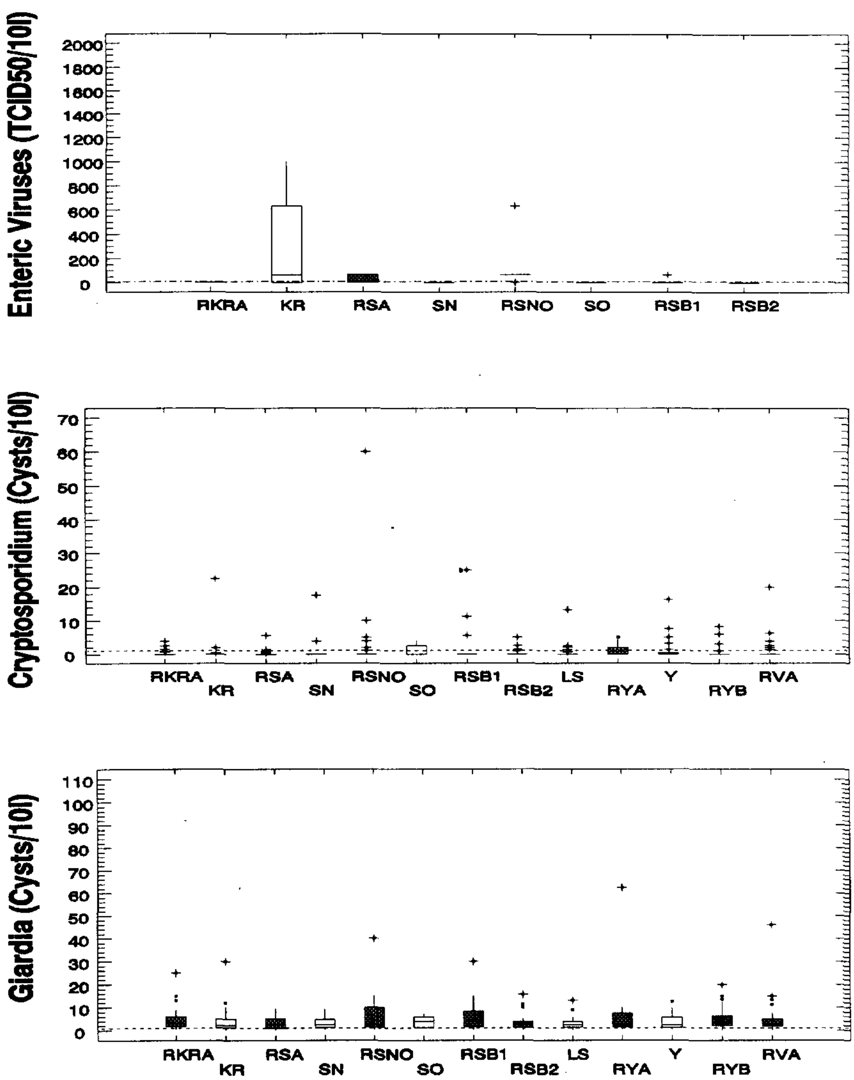

Figure 3. Variation in microbial pathogen levels measured at different sampling points over a period of two and a half years. [Instream sample = shaded bars; Sources = unshaded bars; ----- Water quality guideline: Domestic and Contact recreation]

The levels of *Giardia* cysts, *Cryptosporidium* oocysts and enteric viruses were determined at a number of selected sampling points and the results are shown in Figure 3. High levels of enteric viruses were detected on a number of occasions in the Kleinrietspruit. No viruses could be detected in the other two point sources (SN, SO) monitored. During the study period (oo)cysts were detected at all the in-stream and source sample points. The level of *Giardia* cysts detected during this period was higher than that of the *Cryptosporidium* oocysts. Figure 4 shows the typical results of a modelling run to predict the level of faecal coliforms along the river. The modelling was based on various input data e.g. stream flows, the quality of head waters, sources and abstractions, as well as decay rate constants determined by *in situ* membrane diffusion chamber studies (de Wet *et al.,* 1995).

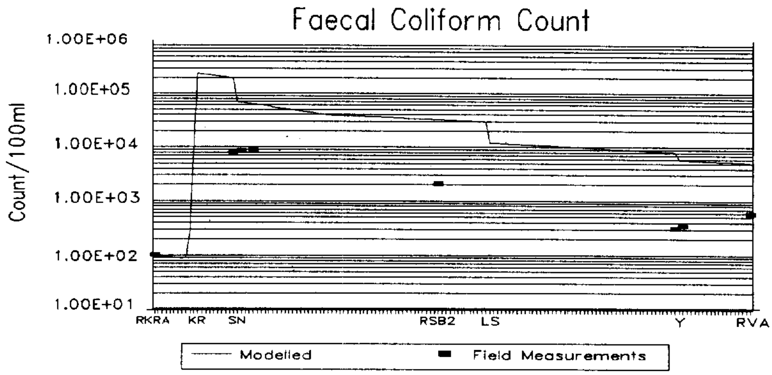

Figure 4. Modelling of faecal coliform levels in the Rietspruit on 21 July 1992.

DISCUSSION AND CONCLUSIONS

Assessment of indicators in the river indicated that the main factors affecting microbiological quality were the runoff from settlement areas and the inputs from wastewater treatment plants. The poorest microbial quality was measured in the Kleinrietspruit, a tributary which drains a formal settlement and adjacent informal settlement areas. The poor water quality in this tributary is largely the lack of formal sanitation facilities and/or blocked sewers. In South Africa the microbiological quality of wastewater treatment plants discharges is controlled by the general effluent standard of nil *E. coli*/100mL with a relaxed standard of 1,000/100mL applicable in special cases. Only one wastewater treatment plant (E) met the relaxed effluent standard most of the time while the other three plants had difficulty in meeting these standards during the whole monitoring period. As expected, the industrial and mining discharges which entered the river via the Leeuspruit tributary and the point source Y activities in the catchment did not negatively affect the microbial water quality of the river. In fact, these sources even had some dilution effect which improved the water quality. The major impact on quality of the river was found at the river reach from where the Kleinrietspruit flows into the main stream until after the inflow of the treatment plant SO. The modelling runs (Figure 4), where quality data were combined with flow measurements, also showed that these three sources resulted in a deterioration of the quality of the river. The level of parasites were not impacted by a single source but the levels measured in the river were rather the combined contribution of all the sources. The higher levels of *Giardia* than *Cryptosporidium* detected was in accordance with other studies in South Africa (Kfir *et al.,* 1995).

Recently, South African water quality guidelines (DWAF, 1996) were developed for a number of water uses including microbiological values. From the data it can be seen that, based on the guideline value of 0/100mL faecal coliforms, the water in the Rietspruit cannot be used directly for domestic purposes. It is also not ideally suited for full-contact recreation, since the levels of microbes measured at some of the points exceeded the target guideline range or level. For the longest stretch of the river the FC levels did not fall within the guideline range of 0-150/100mL set for full-contact recreation. The average level of FC was

>2,000/100mL in the middle reach of the river. At this level there is a high risk of contracting gastrointestinal illness as a result of full-contact recreation or direct consumption of untreated water.

One of the long term goals for this catchment should be to strive towards improving the microbial water quality in the catchment to a level that lies within the target guideline range set for full contact recreation in the South Africa Water Quality Guidelines (DWAF, 1996). Modelling runs predicting FC levels revealed that bacterial die-off did not improve the microbial quality significantly due to the relatively short retention time of water in the catchment and that dilution by river tributaries and other discharges to the river only had a limited effect as can be seen in Figure 4. This gives a clear indication that effort should be put into improving the microbial quality of point source discharges such as wastewater treatment plants. The point sources contribute a major portion of the flow in the river, especially during the dry season, and, if these effluents are of a good microbial quality, they would serve to improve the water quality by means of dilution. Measures to reduce microbial pollution of diffuse sources, such as the improvement and maintenance of water supply and sanitation infrastructure or the construction of artificial wetlands for limited treatment, could be considered. The ongoing participation of involved communities are, however, vital for the success of any programme to limit the diffuse source pollution in a catchment. In contrast to most of the monitoring studies of surface water in developed countries (Groot and Schilperoort, 1984; Herricks, 1984), where the status and trends in the general quality of water resources are surveyed, this study demonstrates how monitoring of microbial water quality in developing countries, where the active management of the microbial quality of surface water is needed, could be carried out. In this situation the effect of individual activities on the microbial water quality needs to be assessed to form the basis of a management plan. Although the use of modelling is an optional part of the situational analysis, it is a valuable tool to assess the effect of the various sources on the quality of the entire catchment and could be used in both the development and implementation of catchment management plans.

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