

## **An integrated approach to the management of water quality in a developing South Africa**

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**Abstract** The majority of South Africans live in rapidly developing communities with inadequate or poorly functional services. Pollution from these developing communities has severe economic and health implications for downstream users and impacts on the natural functioning of river ecosystems. Water quality problems from developing communities arise where wastes produced in the community, reach the surface or groundwater resource, or where destruction of the riparian zone and river habitats occur. The key to sustainable management of pollution from developing communities lies in addressing the physical causes of water quality problems while the sustainability of these physical interventions rests on addressing the institutional and socio-economic factors contributing to the problem.

### **INTRODUCTION**

Water pollution is a major contributor to environmental degradation in urban areas. Maintaining and upgrading urban waterways to meet population growth and changing communities' expectations, are becoming an increasingly important value for government authorities, demanding research with regard to the factors that affect water quality and degrade channels and water storage systems.

Water pollution from developing communities has severe economic and health implications for downstream users and impacts on the natural functioning of water ecosystems. The natural functioning and diversity of the water environment, on which all humans ultimately depend, is also severely impaired by pollution from developing communities. Public awareness of this situation is minimal in some urban centres and only a few attempts have been made to develop and/or implement strategies addressing the causes of environmental degradation due to water pollution. Given the rapid urbanization typical of most South African cities and the backlog in services in many of the poorer communities, this problem is likely to grow in the future. A strategy to manage the water quality from developing communities is therefore a most urgent priority.

During the past thirty years many studies have been conducted worldwide to determine the quantitative and qualitative characteristics of stormwater discharges and their impact on receiving waters (Qureshi & Dutka, 1979; Field, 1985; Guillemain *et al.*, 1991). The emphasis of these studies has been on the similarity between

stormwater runoff and sewage and their inherent potential health hazards. In recent years several studies, investigating urban runoff pollution, have also been conducted in South Africa (Simpson & Stone, 1988; Wright *et al.*, 1993; Jagals, 1994).

In the study by Qureshi & Dutka (1979) the microbiological quality of urban stormwater runoff was investigated at three different locations in southern Ontario, Canada. Microbial densities in this water were similar to those found in dilute raw wastewater. The recovery of pathogenic bacteria further substantiated the existence of health hazards. The results indicate the seriousness of urban stormwater runoff as a major factor in non-point source pollution of receiving waters.

Jagals (1994) studied the effects of diffuse effluents from Botshabelo on the microbiological quality of water in the Modder River, South Africa. The results from the study have shown that urban stormwater outfall contributes far greater microbiological pollution than the effluent from the sewage works outfall originating in the same urban area.

These studies all succeeded in indicating the magnitude of contamination of stormwater runoff and its potential health risk. A growing need exists now to concentrate on the *production, delivery* and *transport* of pollutants and to identify appropriate technological solutions to manage the pollution problem.

## PURPOSE OF THIS STUDY

Water quality problems from developing communities arise where wastes produced in the communities reach the surface water or groundwater. The process is a conceptual continuum whereby wastes are produced by certain activities in the community, delivered to the surface water and groundwater, and are transported by the water and simultaneously affect the water quality. Wastes from developing communities are mostly associated with four waste types: sewage waste, grey water, stormwater and solid waste. The processes leading to pollution, result from the physical breakdown of one or more of these waste types, and are mostly associated with inadequate or poorly functional services. This includes inappropriate sanitation for the density of the community, no facilities to dispose grey water, poor operation and maintenance of services, sewer blockages, littering, and poor design of waste removal services. However, the physical causes of pollution are situated within the socio-economic and institutional environment of the settlement. These issues tend to exacerbate or directly cause the physical problems. Important institutional concerns re addressing the problems are: a lack of funds within the Local Authority; a lack of capacity to maintain the services; and a diversion of resources to other priorities. Socio-economic issues include non-payment for or illegal use of services, vandalism and a lack of awareness with regards to the proper use of the services.

Ultimately water quality problems arising from developing communities can be managed, using an integrated approach based on scientific investigation, community involvement and engineering expertise, in order to minimize pollution problems to the extent that the receiving water environment objectives can be maintained on a sustainable basis.

**STUDY AREA**

The study area is located within the municipal areas of Bloemfontein, previously one of South Africa’s so called apartheid cities, with a railway line dividing the city into a eastern (black) and western (white) sections (Krige, 1998). The eastern block consists of Mangaung, Heidedal and Bloemspruit. Even though the shift of political power from the National Party in 1993 to the ANC in 1994, influenced the dismantling of the spatial patterns of the past, a variety of informal spatial processes eroded the apartheid boundaries during the period 1986–1994 (Krige, 1998). The significance of these processes was and still is the process of land invasion, which largely accounts for the fact that the number of stands in Mangaung increased from 20 270 in 1990 to more than 46 000 by the end of 1997. This more than doubling of the number of stands within seven years has substantially increased the pressure on bulk services and infrastructure and funds are simply not available to provide basic services such as water and sewerage. Significant progress has been made with the upgrading of infrastructure in “formal” Mangaung, where the study area is located (Fig. 1). Informal settlements have also been upgraded, resulting in 14 700 households obtaining land security and electricity and 4132 households acquiring fully serviced stands and core housing (Krige, 1998). However, the provisions of water and sewerage for the formalized informal settlements as well as the lack of progress and of funds for housing are a major cause for concern.

Land use in the catchment is 20% light industrial and 80% residential accommodation and green areas. The industrial area has a variety of industries such as textile manufacturing (including furniture and plastics), while the residential area

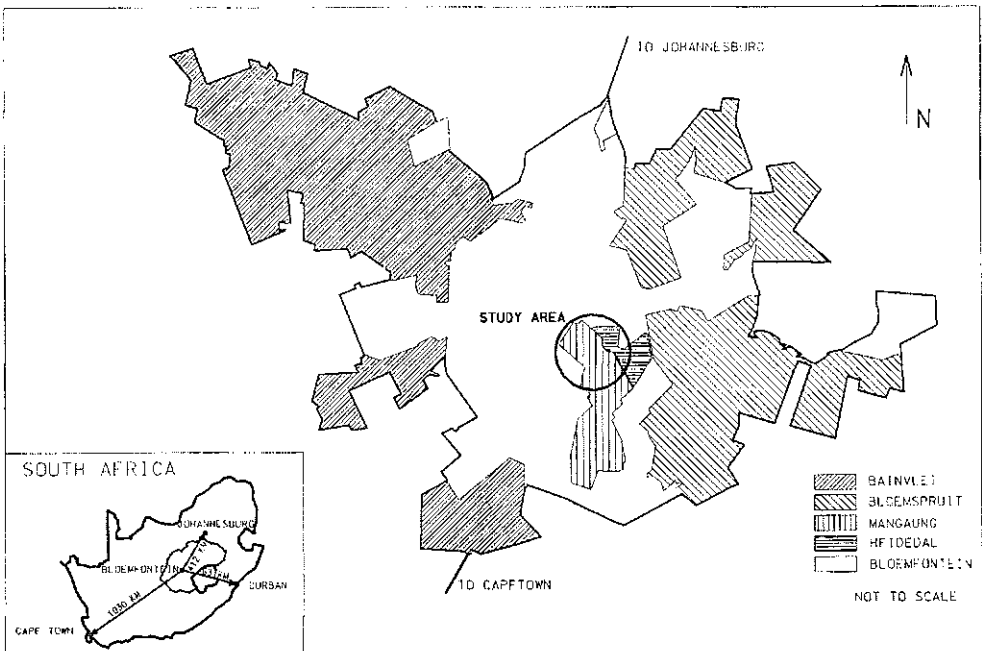


Fig. 1 Location of the study area.

comprises of middle- and low-cost housing, as well as core and organized squatter housing. In the residential area there is also a number of informal activities, e.g. informal agriculture and backyard industries. Livestock grazing on the banks of the Fonteinspruit are mostly dairy cattle, goats and chicken. Backyard industries are mainly food vendors, vehicle mechanics and animal slaughters. Construction and structural maintenance activities relevant to the upgrading of the community include housing, roads and pipelines. The transport network consists of three “main roads” with the other connectors are mainly dirt and gravel roads.

The Fonteinspruit drains a catchment of 11.21 km<sup>2</sup> with a mean annual rainfall of in the order of 500 mm. Rainfalls during the summer months, October–April, amount to 86% of the total, and are mainly in the form of nocturnal thunderstorms. Therefore the summer runoff is relatively high and most of the discharge is in the form of stormflow. The geology consists mainly of the Karoo system with mudstone, shale and sandstone being the main rock types. The topography is unbroken and the height above sea level is 1390 m (Botha, 1981). The Fonteinspruit is a natural water course running from the so-called Bloudam, a small reservoir, through Mangaung, and confluence with the Bloemspruit at the lower end of the drainage basin (Fig. 2). Runoff from the suburbs enters the Fonteinspruit as indicated in Fig. 2.

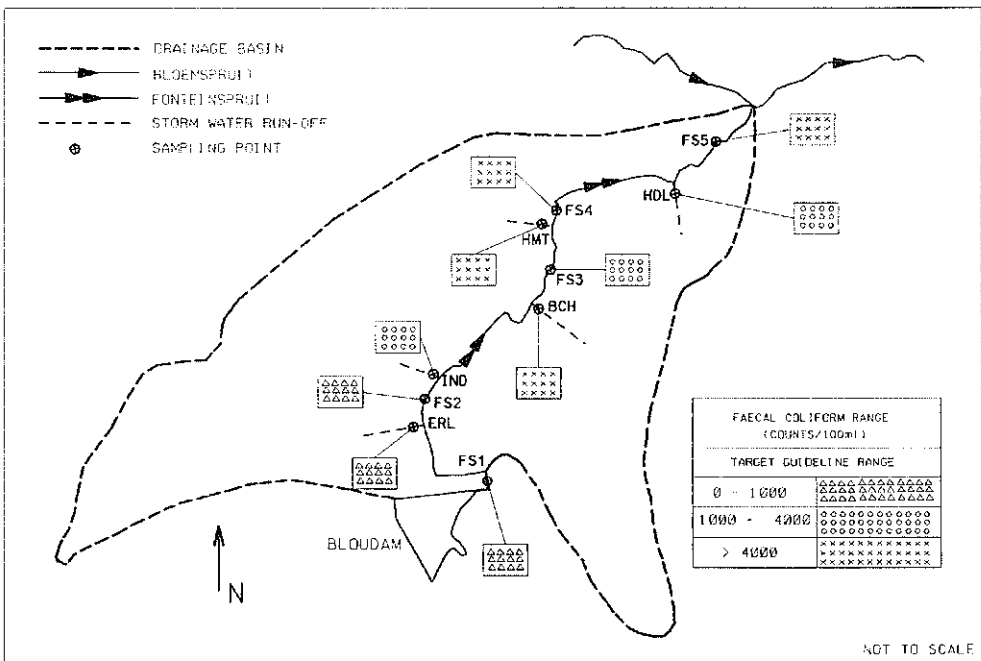


Fig. 2 The Fonteinspruit drainage basin.

**METHODOLOGY**

The basic methodology underpinning the whole project is the selection of appropriate management interventions to improve the water quality of the drainage basin. In order to do this, the first step is to identify the nature and extent of the water quality problem

from the drainage basin. Secondly, to identify the physical causes of pollution, e.g. poor operation and maintenance of services, sewer blockages, littering, and poor design of waste removal services, to name but a few. The final step in managing the water quality effects of the community is to address the institutional and socio-economic factors that contribute to the physical problems so that the sustainability of these physical interventions can be insured.

Ten sampling points were selected to cover the main channel and stormwater runoff from the drainage basin. Sampling started in February 1998 and the water quality of the drainage basin monitored fortnightly. All water samples refer to surface water samples at depths of less than 250 mm. Sampling commences just after 0800 h on sampling days, which are predetermined for a sampling period of 18 months. Two sterile samples, collected in whirlpaks, are taken at every sampling point. Technikon Free State does the microbiological analysis of the water and the Institute for Ground Water Studies (UOFS), does the chemical and physical analysis of the water. Every sample is immediately packed into cooling facilities to lower the sample temperature to between 5–10°C. Samples are then taken to the laboratories at the Technikon Free State and the Institute for Groundwater Studies within two hours of collection.

## RESULTS AND DISCUSSION

As the drainage basin is mainly residential, linked with the lack of infrastructure and poor sanitation, a shift in emphasis is needed when considering potential contaminants (Wright *et al.*, 1993). Toxins, such as heavy metals, pesticides and herbicides become less important, but there is an additional emphasis on organics, nutrients, bacteria and pathogenic micro-organisms.

Indicators generally recommended for the assessment of the microbiological safety of recreational water include total coliform bacteria, faecal coliform bacteria, *Escherichia coli*, enterococci and bacteriophages. The indicators used in this study to indicate the level of microbial pollution is shown in Table 1. Faecal coliforms represent a selected group of total coliform bacteria which is more specific for faecal pollution than the wider group of total coliforms (Jagals, 1994). For the purpose of this study the faecal coliform target guidelines for intermediate contact (Table 2) were used (Department of Water Affairs and Forestry, 1996). Intermediate contact with the water of the Fonteinspruit by residents of the community is common practice.

From Table 1 and Table 2 (which shows the water quality guidelines for recreational use) it is evident that the water in the Fonteinspruit generally exceeds the limits recommended. If the data of the other two indicator organisms analysed in this study, Faecal enterococci and *Clostridium perfringens* are compared with the South African guidelines for recreational use, it also generally exceeds the limits.

The major source of pollution is litter and faecal contaminants that abound throughout the catchment. Even in the areas where regular refuse collection takes place there is a generally untidy appearance with extensive litter and informal dumps. Residents also make use of the sewer system to dispose of their refuse resulting in blockages and spillages, which in turn results in high microbial pollution. The virtually uncontrolled presence of domestic animals, and livestock and informal trading, adds considerably to the pollution threat.

**Table 1** Geometric mean levels of microbiological indicator organisms of the water of the Fonteinspruit drainage basin for the period February 1998–September 1998 (counts/100 ml).

	Faecal coliforms	Faecal entero	<i>Clostridium perfringens</i>
FS1	247	163	71
FS2	298	179	56
FS3	1 129	450	365
FS4	7 337	2492	595
FS5	29 020	3567	317
ERL	93	31	2
IND	3262	168	22
BCH	26 456	3487	97
HMT	13 272	1713	99
HDL	1 276	536	60

**Table 2** Guideline for faecal coliforms to be used for intermediate contact recreation (counts/100 ml).

Faecal coliform target guideline range	Effects
0–1000	Health effects are indicated for intermediate contact with recreational water. If water contact is extensive, such as may occur for novice water-skiing or novice windsurfing, and if full body immersion is likely to occur, the more stringent guidelines proposed for full contact recreation might be more appropriate.
1000–4000	It may be expected that limited contact with water of this quality is associated with a slight risk of gastrointestinal illness. The upper limit of this range corresponds to the limit recommended by the Australian guidelines for at least four out of five samples collected over 30 days.
>4000	Intermediate recreational contact with water can be expected to carry an increasing risk of gastro-intestinal illness as faecal coliform levels increase.

Many different water quality criteria and guidelines have been published in the international and local literature. Different approaches and methodologies are used to derive criteria and guidelines, e.g. some criteria specify maximum concentrations for constituents fit for use, whereas others attempt to define the ideal concentration. Therefore, depending on the guideline or criteria used, answers can sometimes differ, by a factor of a hundred or more (Department of Water Affairs and Forestry, 1996). For the purpose of this study, surface water sampling positions for which existing water quality is known, were selected in order to establish a background reference for the water quality of the Fonteinspruit. Table 3 contains mean water quality data for the Fonteinspruit drainage basin, Palmiet River drainage basin, the Buffalo River drainage basin and the Polela River at Himeville. The first three cases in Table 3 illustrate urban impact on water quality (chemical composition). The fourth case, the Polela at Himeville, is an unpolluted mountain stream.

If the runoff from the Fonteinspruit is compared to the other runoff in Table 3, the higher values are reasons for concern. The higher nitrate and phosphate concentrations are mainly caused by seepage from leaking sewage pipes and overflows due to blockages of the sewer system. Informal domestic use of the river also adds to the high phosphate concentrations. Most of the squatter houses are close to the river and are not adequately serviced. The people, therefore, throw their grey water on the ground or directly into the river. The high concentration of phosphate is also evident when compared to the ideal limit for phosphate of  $0.1 \text{ mg l}^{-1}$ , which should be sufficient to

**Table 3** Concentrations ( $\text{mg l}^{-1}$ ) and mean chemical composition of the water from some South African rivers.

	$\text{NO}_3\text{-N}$	$\text{PO}_4\text{-P}$	pH	EC ( $\text{mS m}^{-1}$ )	TDS
Fonteinspruit	3.49	1.91	7.9	79.5	516.1
Palmiet River*	0.97	0.09	7.3	33.4	217.1
Buffalo River*	0.43	0.33	6.4	60.2	391.3
Polela River*	0.13	0.04	6.7	5.1	33.15

\*De Villiers (1985).

protect water against eutrophication (Department of Water Affairs and Forestry, 1996). The value of  $3.49 \text{ mg l}^{-1}$  is, however, well within the target nitrate limit of  $5 \text{ mg l}^{-1}$  for irrigation use (Department of Water Affairs and Forestry, 1996).

Even though the pH value (Fonteinspruit) is also higher compared to the other values in Table 3, it is still within the guideline range ( $6 < \text{pH} < 9$ ) for domestic water use (Department of Water Affairs and Forestry, 1996). The conductivity in the Fonteinspruit is nearly 8% higher than in the Buffalo River which is regarded as particularly sensitive and vulnerable (De Villiers, 1985). The value also exceeds the target guideline level for irrigation use,  $40 \text{ mS m}^{-1}$ , which will ensure that sensitive crops can be grown without any reduction in yield (Department of Water Affairs and Forestry, 1996).

Although aquatic ecosystems, such as the Fonteinspruit, are not considered to be water users, water, within certain quality ranges, is required to protect and maintain these ecosystems. Aquatic ecosystems are vulnerable to changes in water quality. There is uncertainty about the changes that these ecosystems can tolerate, and there are very few options for mitigating the effects of poor water quality. Therefore a precautionary approach is required to protect the health of aquatic ecosystems (Department of Water Affairs and Forestry, 1996). This approach means that active measures must be taken to avert or minimize potential risks of undesirable impacts on the environment. This study is an attempt to put this approach into practice with a definite result to minimize the risk the Fonteinspruit has on the environment.

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