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A METHOD FOR THE PRIORITIZATION OF AREAS EXPERIENCING MICROBIAL POLLUTION OF SURFACE WATER

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ABSTRACT

The increased threat of faecal pollution in recent years and the high priority of protecting human health by the government led to the initiation of a national microbial monitoring programme for surface water in South Africa. According to the design of the programme, monitoring sites had to be selected in order to assess the status and trends of faecal pollution. Issues of efficiency and cost-effectiveness dictated that the monitoring would focus on areas with the greatest risk. A method based on relevant land and water use information (e.g. level of water supply and sanitation, agricultural practices, surface runoff, recreation) was developed for the selection and prioritization of these areas. A measurement scale was described for all sensitive uses to ensure the objectivity of the selection process. For the prioritization purposes, weights were assigned to the different uses according to their impact. This was done by means of the simple multi-attribute rating technique (SMART). The method was found to be useful for the identification of high-risk areas but the availability and reliability of the data are some of the major constraints.

KEYWORDS

Microbial pollution; surface water; land use activities; water uses; prioritization.

INTRODUCTION

The microbial quality of surface water is of great concern in a number of areas in South Africa. Many communities lack appropriate sanitation infrastructure. The problem is not confined to rural areas where it is roughly estimated that as many as 85% of the population do not have adequate sanitation services. Due to the inflow of people from rural areas and neighbouring countries, large informal settlements have developed in and around the urban centres. It is estimated that as much as 31% of the urban population, 7.6 million people, could be without appropriate sanitation services (NSTT, 1995). This has serious implications for the utilisation of surface water for domestic, recreational and agricultural purposes as it poses a risk of contracting waterborne diseases (Verma and Srivastava, 1990).

The Department of Water Affairs and Forestry (DWAF) is the custodian of South Africa's water resources with the aim to ensure the fitness of use on a sustained basis. In the light of the importance of microbial water quality the development of a national microbial monitoring programme to assess the faecal pollution of surface water resources has been initiated. The aim of this programme is to provide the information needed by the Department to assess the status and trends of faecal pollution of surface water. This information will be used to plan strategies and allocate resources to manage the associated health risk. According to the design of the programme, the type of areas where monitoring should be initiated, to meet the aims of the programme, had to be determined. Due to the non-conservative behaviour of microbial constituents it would not be feasible to sample at locations spaced evenly on a geographical basis throughout the country, on major tributaries or below the confluences of streams as is often done with chemical constituents (Price, 1975; Keith, 1990). The logistical problems associated with microbial monitoring and the enormous pressure on the human and financial resources of the Department also played a role. New monitoring programmes have to be demonstrated to be both efficient and cost-effective. A decision was taken that monitoring will be focussed on areas with the greatest risk of an impact of faecal pollution on the population. A procedure for the comparison of areas and the selection of those with the highest priority was needed. This study describes the approach and conceptual development of such a method.

APPROACH

Land uses have an impact on the microbial quality of the surface water in a catchment. Water uses, on the other hand, provide information on the possible risk associated with the use of microbially polluted water. The approach followed for the identification of high-risk areas was to use information on land and water use activities in the catchments for selection and prioritization. In order to locate these areas, the land uses that could affect the microbial quality of surface water, as well as the sensitive water uses, needed to be identified. Incorporating all possible uses would require the collection of a large amount of data that could be very costly. Thus the focus was only on those with the greatest impact. To ensure that the prioritization was objectively applied to all areas, the uses had to be characterised by means of measurable attributes that could be verified independently.

LAND USES

The supply of adequate sanitation to all communities remains one of the main concerns of the government in South Africa (NSTT, 1995). Informal settlements, often associated with no or limited sanitation services, typically develop in close proximity to rivers such that direct faecal contamination of surface water takes place. Problems have also been associated with existing sanitation infrastructure. During a study performed in a peri-urban area it was found that a number of wastewater treatment plants have difficulty even in meeting the relaxed effluent standard of 1,000 faecal coliforms/100mL (Venter *et al.*, 1997). This situation is often the result of rapid urbanisation and consequent overloading, staff and operational problems, poor maintenance or financial constraints. Faecal pollution of rivers due to surface runoff is also a major problem in many areas in South Africa. The lack of sanitation is often the major contributor but other difficulties also play an important role. In many areas blocked sewer lines contribute to non-point source faecal pollution. In some areas, the bucket system is still in operation and pollution due to spillages and handling is a common occurrence. Livestock farming can also lead to the contamination of runoff.

The following land uses were therefore identified to have the greatest potential for faecal pollution of surface water sources:

- households without sanitation infrastructure
- inefficient, poorly maintained/operated or inappropriate sanitation infrastructure
- dense settlements and the associated surface runoff
- intensive farming with livestock

WATER USES

It is estimated that 70% of the South African population had water supply coverage by the end of 1994 (WHO, 1996). The policy of the government is to ensure that all South Africans should have access to basic water supply services and increased investment in this area has improved the situation. There are, however, still areas where people are using untreated surface water for domestic purposes due to the lack of reliable water supply infrastructure. Some households may also use surface water as an alternative source, due to the fact that surface water may be more convenient to access. Some communities are supplied with surface water after partial treatment. In many instances disinfection is absent, not properly controlled or followed by filtration which is necessary for the removal of pathogens such as protozoan parasites. The water may, therefore, still pose a health risk to members of the community, especially small children, the elderly or the sick. Apart from the use of surface water for normal full and partial contact recreation, many people are also exposed to surface water through other activities such as the washing of laundry. Another possible exposure to contaminated surface water could be through the irrigation of crops that will be consumed raw. A number of cases exist where a waterborne disease, such as cholera, has been contracted when contaminated fresh vegetables were consumed (Mosley and Khan, 1979).

The water uses identified to be the most sensitive to faecal pollution of surface water and to be included in the prioritization were:

- drinking of untreated surface water
- drinking of surface water after partial treatment
- full or partial contact recreation
- irrigation of crops to be consumed raw

PRIORITY RATINGS

Areas had to be prioritized based on the land and water use information collected for the area. Not all these uses had the same impact on the microbial quality of the water or associated risk of disease. In order to ensure that the prioritization process will be as objective as possible, the assignment of weights to the identified land and water uses was based on the simple multi-attribute rating technique (SMART) (Goodmin and Wright, 1991). The first step was to determine a measurement scale for the land and water uses selected followed by the assignment of weights in terms of their importance.

Table 1. Assignment of measurement values for intensive farming enterprises

Description of intensive farming enterprise	Measurement value	Relative sizes of	
		Cattle feedlot	Piggery
Large scale unit with no waste handling practices in place	100	>10,000	>2,000
Medium scale unit with no waste handling practices in place	60	5,000 - 10,000	500 - 2,000
Small scale unit with no waste handling practices in place	30	<5,000	<500
All units with appropriate waste handling practices in place	0		

Land uses - households without sanitation infrastructure as well as households with inefficient, poorly maintained/operated or inappropriate sanitation infrastructure were measured according to the same scale. In this case 0 was used when no household in a settlement fell into this category and 100 was assigned whenever 100,000 or more households were identified. For surface runoff the percentage coverage was taken directly as the measurement value. The attribute of intensive animal farming enterprises was measured by means of direct rating as shown in Table 1.

The next step was to rank the attributes according to their impact based on the consensus of a technical team and thereafter the weights were normalised as shown in Table 2.

Table 2. Original and normalised weights for land use information

Land uses	Original weight	Normalised weight
No sanitation infrastructure	100	53
Inefficient sanitation infrastructure	60	43
Intensive farming enterprises	6	3
Percentage surface area covered	2	1
Total	168	100

Water uses - the same process was followed for quantifying the water use information. The utilisation of untreated or partially treated surface water was calculated per household and the same scale as described above for the sanitation information was used. The measurement of the recreational activities, the third attribute, used another scale. For this attribute the value 0 was assigned to situations where nobody used surface water for full or partial contact recreation. A value of 100 was assigned whenever 10,000 people per week or more used surface water for full or partial contact recreation.

The last attribute, irrigation of crops to be consumed raw, had to be measured using different criteria. In this case certain assumptions on production and consumption had to be made. Lettuce was used for the scale as it represents the worst case scenario because the exposure risk during the ingestion of other raw produce (e.g. cabbage, tomato) will be less. The average lettuce production figure used was 15,000kg/ha or 30,000 lettuces when assuming an average weight of 500g. When the assumption was made that, on average, one household or four people would be exposed per lettuce, 1ha relates to the exposure of 120,000 people. For this attribute the value 0 was assigned to the situation where nobody would be exposed to raw vegetables irrigated with surface water. A value of 100 was assigned whenever 500,000 people (4ha) or more were exposed to raw vegetables irrigated with surface water.

The next step was the ranking of the uses followed by normalisation of weights as was the case for the land use information (Table 3).

Table 3. Original and normalised weights for water use information

Water uses	Original weight	Normalised weight
Drinking of untreated water	100	50
Full/partial contact recreation	50	25
Irrigation of crops to be eaten raw	30	15
Drinking – partial treatment	20	10
Total	200	100

Finally the relative weight of all land use information in comparison to the weight of the water use data was determined to be 4:6, giving a larger weight to the water use information when determining the priority value of an area. This will help to identify areas where a serious risk to the health of the population exists and monitoring and management actions can be directed towards such areas.

DISCUSSION

During the testing of the method in a few areas a number of constraints were identified. The availability and reliability of data was of concern. Sanitation and water supply problems are mostly associated with underdeveloped or informal areas that often change on a continued basis. If available, data for these areas should always be verified because even recent data could be outdated. In many cases data can only be obtained by means of personal visits to an area. The large weight assigned to the water supply and sanitation data necessitates that the data should be verified. The measurement scale for the data allows for some variability and, if necessary, the number of households could be estimated. These estimations should, however, not differ from the actual number by more than 1,000 households because larger errors could distort the final priority value.

Information on the surface area coverage of settlements was difficult to obtain, the only means being the manual interpretation of aerial photographs. This is an expensive and time-consuming process. In the light of the low weighting assigned, it would be better to measure the potential for surface runoff differently e.g. with population densities.

Once the priorities have been calculated the described method will be evaluated. This will be done by comparing the priority values to the microbial water quality as measured in selected areas.

CONCLUSIONS

The described approach gives a means of objectively selecting areas for incorporation in the microbial monitoring programme. The method can also easily be adapted for use under other circumstances once the crucial land and water uses and their impacts have been identified. If problems are experienced with the availability or reliability of the data, other measurable attributes for the water and land uses can be adopted. Care should, however, be taken to ensure that all areas are selected and prioritized according to the same criteria.

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