Pergamon

Wat. Sci. Tech. Vol. 38, No. 12, pp. 163–170, 1998.

0273–1223/98 $19·00 + 0·00

PII: S0273-1223(98)00819-1

SURVEYS MONITORING THE SEA AND BEACHES IN THE VICINITY OF DURBAN, SOUTH AFRICA: A CASE STUDY

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ABSTRACT

A microbiological surveillance programme was initiated in Durban, South Africa, to provide an objective assessment of changes in the local seawater quality before and after the commissioning of two submarine outfalls in 1969 and has been ongoing until the present day. A classification system including *Escherichia coli* I, helminthic parasite ova, pathogenic staphylococci, salmonellae, shigellae, and salinity was used. This system, functioning as an audit, has proved useful in detecting problem areas which may have passed unnoticed in the routine *E coli* I assessments performed by the Durban Municipality. The salient features that have manifested themselves are (a) alterations in the seawater quality have been shown to be invariably a consequence of changes effected upon the shore or meteorological events and (b) that measuring more than one indicator of water quality, plus the use of salinity as a physical parameter for assessing the dilution or impairment of pristine seawater, has proved valuable. © 1998 Published by Elsevier Science Ltd on behalf of the IAWQ. All rights reserved

KEYWORDS

Marine water quality; surf waters; *Escherichia coli* I; helminth parasite ova; staphylococci; salmonellae; salinity.

INTRODUCTION

A microbiological surveillance programme was initiated in Durban, South Africa, to provide an objective assessment of changes in the local seawater quality before and after the commissioning of two submarine outfalls in 1969. Durban's beaches rank among the city's prime assets, visited annually by many thousands of local and overseas tourists. Durban is South Africas main general cargo and container port, handling 26 million tons worth more than R50 billion each year. This amounts to 65% of total revenue earned by all South African ports and makes Durban the busiest port in Africa (Mayo, 1996) Durban is also being subjected to increasing socio-demographic stress. The CSIR initiated the microbial assessments of the surf zone between the Mgeni River and Isipingo Beach (Figure 1) in 1964. The investigation typically involved four surveys per year: three attenuated surveys of the more sensitive beaches (16 sampling sites) and one full survey (29 sampling sites). A classification system including *Escherichia coli* I, helminthic parasite ova, pathogenic staphylococci, salmonellae, shigellae, and salinity was used. This is referred to here as the CSIR system. It is compared graphically with a system using only faecal coliforms and also a system using only salinity as guides in assessing water quality.

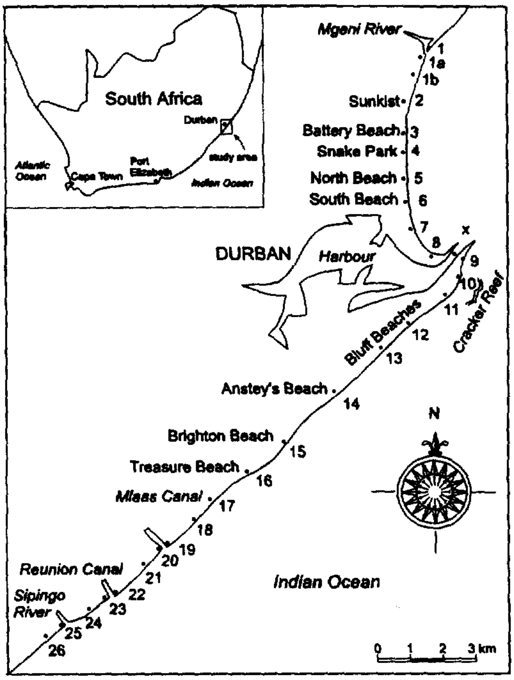

Figure 1. Location of sampling stations.

BACKGROUND

In 1964, the City of Durban was discharging 90×10^3 m^3/d wastewater from the harbour mouth with the outgoing tides, while the discharge from a sewer on the Bluff into the surf-zone amounted to 20×10^3 m^3/d. In addition, there existed more than 90 beach pipes and stormwater drains, about one third of which carried contaminating material on to the beaches and into the surf (Livingstone, 1990). The area is characterised by the Mgeni River in the north, with Station 1 being situated in the mouth of the river. Station X is at the mouth of the Durban Harbour and the stations between these include beaches popular for swimming and surfing. These activities also pertain at the sampling stations to the south until the Mlaas Canal - bracketed by Stations 19 & 20 - enters the surf zone. This canal transverses areas characterised by heavy industry and informal settlements. The Reunion Canal - bracketed by Stations 22 & 23 - enters the surf a little lower down the South Coast.

In 1968/69 the pair of submarine pipelines was commissioned with their attendant treatment plants. The harbour effluent was diverted to the new complex and pollution from the minor outfalls was progressively halted or their wastes similarly joined to the new works. The system of water quality gradation was applied to the surf-zone to measure the efficacy of the new pipelines, providing an "after" picture (Livingstone, 1982). The monitoring programme has been maintained, with minor alterations, to the present day.

The surveillance programme was designed to provide additional information (to Durban's Medical Officer of Health) for the management of the coastal recreational facilities. It also functioned as an independent audit of the surveys performed by the local authorities. Sampling of the surf was not biased or selected for favourable or unfavourable conditions, for seasonal variation of beach use nor to accommodate vagaries of wind, tide or current. The latter were, however, recorded while sampling as they may influence stations adjacent to waterways by transporting indicators along the shore (Livingstone, 1990). The classification system designed by the CSIR uses a suite of microorganisms. The system would not be cost-effective as a routine monitoring tool, but, as an audit, it has the potential to detect anomalies that may be missed when only using a single indicator organism. The indicator system was used solely as an objective measurement of pollution and not an excursion into the realms of "health hazards" with the attendant complexities of epidemiology and minimum infective dosage (Livingstone, 1990).

THE CSIR SYSTEM OF CLASSIFYING SEAWATER QUALITY

Prior to the development of South African Water Quality Guidelines, a system of classifying seawater employing a suite of indicators was evolved to assess any changes in the local surf affected by domestic wastewater discharges. This classification was based on a system of adverse scoring (Tables 1 & 2), each indicator selected and scored on a value of 4. The design of the system accords the same basic score of 4 to indicators of particular pollution significance, even if the recovery of such indicators is not common. The closer the sampling site to the source of sewage pollution the greater the possibility of isolating more than one, or all of these indicators; their frequency of occurrence and numbers is governed by proximity to the discharge point and efficacy of the sewage treatment process.

Although the system employs stringent criteria for classifying recreational waters of a very high standard, it has been so designed to detect even the smallest changes in that quality. And while the standards required for water to be rated as Class I are extremely rigorous, Class II is also acceptable for recreation and completely in accordance with public health principles.

Table 1. Evaluation of indicators

Indicator	Degree	Value
E coli/100mL	0 - 10	1
	11 - 100	2
	101 – 1,000	4
	>1,000	8
Parasite units/250mL[1]	1 - 7	4
	>7	8
Staphylococcus aureus/50mL[2]	Present (+)	4
Salmonellae/240mL	Present (+)	4
Salmonella typhi/250mL[3]	Present (+)	4
Shigellae/250mL	Present (+)	4
Salinity ‰[4]	<34	4

[1] Parasite units - measured as numbers of the ova of *Taenia* and *Ascaris* species. They provide a quantitative measure of the grosser degrees of sewage pollution. These entities can remain in seawater for several hours before becoming unrecognisable, about 5% of the eggs surviving 30h (Livingstone, 1978). Other ova of human parasites are reported as of possible interest to coastal management authorities.

[2] *Staphylococcus aureus* - well known to be a nose and throat pathogen and commensal, and is found in the excreta of about 30% of normal individuals (Wilson *et al*, 1984). Their presence in water indicates recent pollution or contamination.

[3] *S typhi* - would contribute a total value of 8, scoring 4 under salmonellae and 4 under *S typhi*

[4] Salinity - the accretion of fresh water, not necessarily contaminated, is assessed as a diluent and therefore a detractor from pristine seawater quality (which normally exhibits salinity ca 35‰).

Table 2. A system of classifying seawaters by indicator value

Indicator values	Class	Description
1 – 4	I	Excellent
5 – 8	II	Acceptable
9 – 16	III	Unacceptable
>16	IV	Poor

MATERIALS AND METHODS

Sampling - water samples were collected in sterile 250mL wide-mouth glass reagent bottles with ground glass stoppers and overlapping rims, containing sodium thiosulphate to neutralise any residual chlorine or chloramine. Clean plastic containers holding 6g selenite brilliant green (SBG) enrichment broth powder were used for the isolation of salmonellae and shigellae. Samples were collected 2m from the shoremost lip of a newly broken wave. Collected water was decanted into the plastic bottles for salmonellae isolation and into glass bottles for the balance of the bacteriological analyses. A further sample was retained in the collection bottle for parasite and salinity determinations. All samples were transported to the laboratory as rapidly as possible.

Test procedures

1. Faecal coliform and *Escherichia coli*/100mL - the analytical procedures are documented in APHA (1995).
2. Parasite units/250mL - the supernatant of the samples was discarded and the centrifuged deposits examined microscopically for *Ascaris* and *Taenia* spp ova.
3. Salmonellae and shigellae/250mL - the selective method was described in Livingstone (1964, 1982).
4. *Staphylococcus aureus*/50mL - selected volumes of water were membrane-filtered (usually 50mL), the membranes placed on *Staphylococcus* medium No 110 (Difco), supplemented with NaCl 25g/L and sodium azide 0.05g/L, and incubated at 37°C for 43h. A selection of yellow and orange colonies were subcultured on to Dnase agar (Oxoid) plates and incubated at 37°C for 24h. 1N HCl was flooded over the plates. The cultures that exhibited a zone of translucence around the colonies were gram stained; gram positive cocci were tested with agglutination reagent (Staphytect Test Reagent - Oxoid) to confirm the presence of *Staphylococcus aureus.*
5. Salinity - readings were made on an electrical conductivity meter, calculated using standard seawater (IAPSO Ocean Scientific International) and recorded in parts per thousand (‰).

RESULTS AND DISCUSSION

The entire data set from 1964-1996 was subjected to IDW interpolation using Archinfo programming software. Isograms were generated depicting the water quality of the surf zone at the 29 sampling stations in space *vs* time. The position of the station numbers was ascertained from GPS readings to give the X-axis and the date of sample was presented on the Y-axis. Figure 2 represents the water quality of the surf zone according to the CSIR system. Figure 3 employs the faecal coliform index, based on the EU bathing water Directive (EEC, 1976) and the South African Water Quality Guidelines (DWAF, 1995) which recommends that there be less than 100 faecal coliforms/100mL in 80% of samples and less than 2,000 in 95% of samples. These guidelines cannot be strictly applied to this survey due to the insufficient number of samples taken per year. Figure 4 depicts the salinity measurements.

Figures 2 and 3 clearly demonstrate the marked improvement in water quality after the commissioning of the submarine outfalls in 1969 and the persistent problem of poor surf water quality in the areas surrounding the mouths of the inland waterways. In almost every instance, where high bacterial levels were found, there was a concomitant decrease in salinity, indicating the intrusion of terrigenous water into the surf zone. Surf zone systems tend to be closed ecosystems and, although substantial mixing occurs within these, exchanges of new seawater from beyond the breaker zone takes place relatively slowly (Lord *et al.*, 1989). Acknowledgement that a proportion of bacteria can remain in a viable but non-recoverable state for a period of time after exposure to seawater (Xu *et al.*, 1982) permits us to assume that reduced salinities, even in the absence of bacterial numbers, highlights potential sources of contamination. This is indicated by the similarities between the three systems as demonstrated by the isograms.

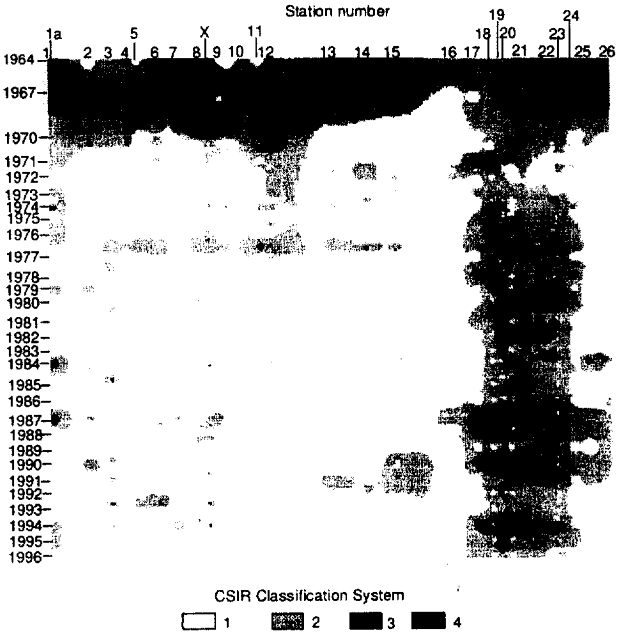

Figure 2. CSIR classification system.

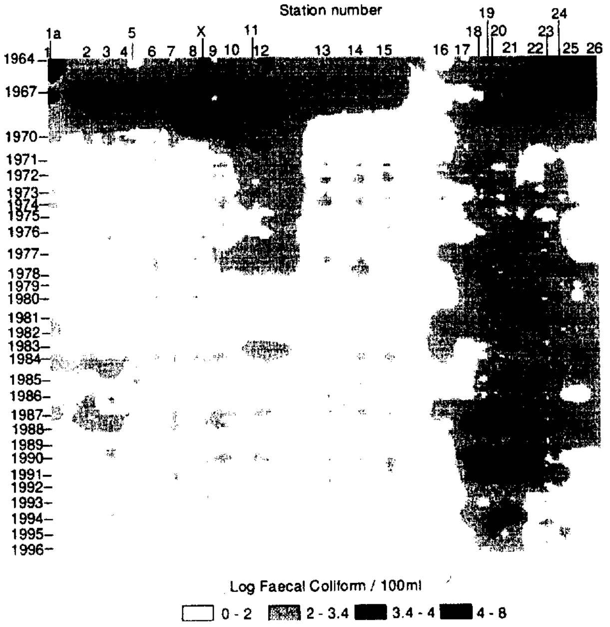

Figure 3. Faecal coliforms.

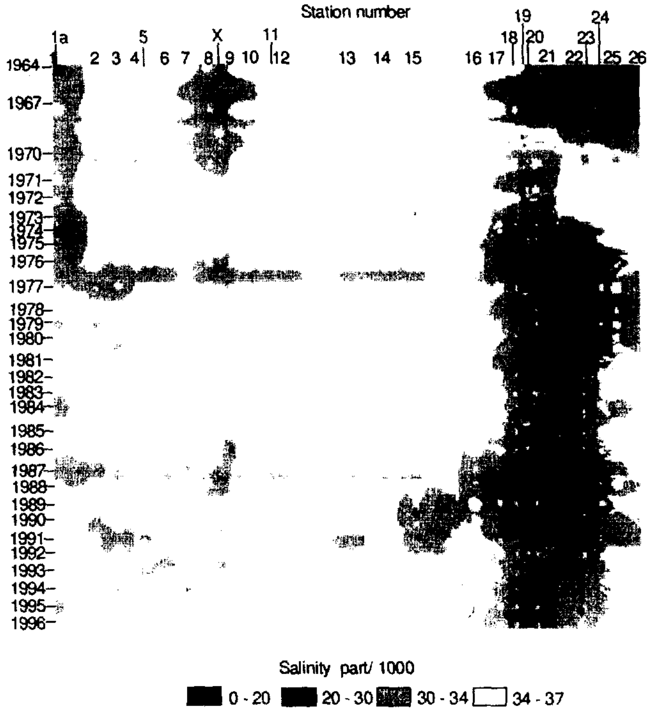

Figure 4. IDW interpolation of the salinity measurements between 1964 and 1996.

Overall, the surf-waters of Durbans main bathing beaches usually exhibit water of Class I (excellent quality) except during episodes of flooding which can cause their temporary relegation to Class II usually as a result of depressed salinity levels. The system of water quality gradations reflects the effects of heavy rainfall in 1976 and the September-October 1987 floods. Class II water is, however, acceptable for bathing and other marine recreational purposes. The Mgeni River and the Reunion Canal, usually, and the Umlaas Canal, invariably, remain as intractable sources of contamination entering the marine environment. However, these foci are relatively remote from the main bathing beaches.

Between 1990 and 1992, a barely perceptible adverse trend in the overall water quality of the surf-zone in the region started emerging, subsequently found to be from the intermittent discharge of contaminated stormwater drains. In November 1992, despite the bare presence of *E coli* I (4/100mL), and an undiluted salinity (>34^{o}/oo) at Station 3, two hookworm eggs (one viable, the other non-viable) and one non-viable urinary tract *Bilharzia* ovum was detected microscopically. These ova, particularly the latter, are fragile in seawater and their presence implies very recent discharge into the ocean. Station 5 yielded a viable *Taenia* spp ovum. Station 6, again with very modest *E coli* I numbers, gave a heavy growth of *Staphylococcus aureus* and a depressed salinity of 33.70^{o}/oo implying recent accretion of non-saline water despite negligible preceding rainfall. The source of the contamination proved to be street washing to which a bacteriocide had been added. According to South African Water Quality Guidelines and international water quality criteria, these bathing beaches had attained a standard regarded as acceptable for safe recreation i.e. <100 faecal coliforms/100mL.As far as the authors are aware, Durban is the only place where additional indicators such as staphylococci, parasites and salinity are assessed routinely.

It is considered conceptually unsound to expect a uniform relationship between a faecal indicator and a pathogen that is not extremely prevalent in the population at large (Cabelli *et al.*, 1983). The lack of significant correlations between the presence of traditional indicators and pathogens (Grabow *et al.*, 1989; Araujo *et al.*, 1990 cited by Figueras *et al.*, 1997) has highlighted the inadequacy of indicator systems in assessing water quality and associated health risks. In this case study, the broad base approach of using a number of indicator and pathogenic organisms (selected for the specific dimension of information they provide), and salinity has proved valuable in determining profiles of microbial water quality.

With the advent of pavement squatters in the City, and attendant hygienic and waste disposal problems, some deteriorating of the surf-zone would be expected, especially during episodes of significant precipitation or the hosing down of streets. Several of the stormwater pipes discharge near popular bathing beaches. The vulnerability of the citys normally excellent main bathing beaches to stormwater pipes conveying pollution (however intermittent) to the surf-zone requires preventive measures: identifying the sources, educating citizens on basic hygiene principles and corrective engineering constructs.

CONCLUSIONS

Durbans bathing beaches provide a unique barometer of the citys well-being. The choices appear to be relentless and expensive: the city has to provide adequate sanitation (implying innovative basic housing) as energetically as possible to keep pace with the rising tide of informal residents whose numbers and activities should be regularised; and certain stormwater drains discharging in or near several bathing beaches should be typified as actual or potential sewers urgently requiring corrective measures.

This work has demonstrated that alterations in the seawater quality are invariably a consequence of changes effected upon the shore or meteorological events and that the CSIR system, which uses a suite of microbial indicators and the use of salinity as a physical parameter for assessing the dilution or impairment of pristine seawater, has proved to be invaluable in highlighting problem areas which, using a comprehensive system, would have passed unnoticed.

ACKNOWLEDGEMENTS

This work was undertaken under contract to the Durban City Health Department with close liaison between Dr DJ Livingstone (deceased) and the Medical Officers of Health, Dr CR Mackensie, Dr M Richter and Dr C Pieterse. Thanks are here accorded to Messrs T Meara, M Webster and A Singh for their GIS and graphic expertise and all colleagues at CSIR for their assistance and guidance.

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