Faecal coliform, *Escherichia coli* or what?

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**Abstract**

The use of indicators for evaluating the microbiological quality of the marine surf-zone water is a worldwide practice. It is important that the indicator used, is the most relevant in relation to bathers’ health. It must be easy to detect and it must be cost effective. This paper reports the comparison between the occurrence of faecal coliforms and *Escherichia coli* in the marine surf-zone. Both are found to be good indicators for marine surf-zone water quality. The maximum acceptable count per 100 mL sample must be set separately for each indicator used in relation to bathers’ health risk.

*Keywords: microbial indicators, faecal coliforms, Escherichia coli, health risk, marine surf-zone, water quality.*

1 Introduction

The microbiological quality of seawater is a serious concern when human health is involved. The health risk, posed by the microbial activity in the marine surf-zone and coastal water is mainly through contact recreation like swimming, surfing, wind sailing, etc. and the consumption of uncooked marine organisms such as filter feeders (e.g. black mussels). The pollution of marine coastal waters has its existence in anything that enters the marine environment through river outlets and other natural features like volcanoes [1]. These rivers contain rainwater that change the salinity; drowned animals and litter that add biological contaminants; soil with naturally occurring toxic metals and trees with a wide variety of alien material. The sea has coped with this load since creation. However, today there are an unknown number of pipelines in use for water disposal along the South African coastline. The majority of these pipelines dispose their effluents into the surf-zone or above the high-water mark onto the beaches. It is a well-established fact that urban development creates many potential pollution sources, both point and non-point/diffuse sources [2,3,4]. It is,
therefore, understandable that all waters (surface water runoff, stormwater, waste water, etc.) may carry high concentrations of many substances including high bacterial numbers. These waters eventually contaminate the marine surf-zone where it enters the marine environment. Any effluent, treated or untreated, legal or illegal, that is disposed of into the marine surf-zone are polluting the surf-zone, and are therefore posing a health hazard.

It is obvious that the microbiological water quality along our coastlines must be monitored and managed in order to ultimately assure tourists and local bathers that the beaches are suitable and safe from a health point of view. This is done at great costs and it is important that the “right” bacterial indicator is used to monitor the microbiological water quality.

Faecal coliforms, *Escherichia coli* and *Enterococci* are some of the commonly used indicators worldwide. However, all over the world by almost all authorities that manage marine water quality, a shift towards *Escherichia coli* as preferred indicator is taking place.

This paper discusses the relevant water quality guidelines and compares the different indicator organisms with each other in relation to the water quality criteria.

2 Water quality guidelines

In South Africa, the first edition of water quality guidelines for the South African coastal zone was published by SANCOR in 1984 [5]. A second edition followed in 1992 and a third edition in 1995 the Department of Water Affairs and Forestry (DWAF) [6,7]. Faecal coliforms (including *E.coli*) are used to evaluate the microbiological water quality for full contact and intermediate contact recreation and the collection of filter feeders for food use. The target range specification is the following:

*Full and intermediate contact recreation:*

- Maximum acceptable count /100 mL
  - 100 in 80% of the samples
  - 2000 in 95% of the samples

*Filter feeders for food use:*

- Maximum acceptable count/100 mL
  - 20 in 80% of the samples
  - 60 in 95% of the samples

In South Africa, it is generally assumed that the maximum acceptable count for *Escherichia coli* is the same as for faecal coliforms. In the second edition, DWAF, 1992, it was stated that: “*If the marine water quality does not comply with the faecal coliform guidelines, then testing for Escherichia coli should be conducted.*”

Comparing the above with the European Economic Community (EEC) council directive concerning the quality of bathing waters [8], it is clear that the DWAF guidelines were influenced by existing “world guidelines” and not necessarily on the results of epidemiological studies.
The EEC 1976 [8] directive is presented here for comparison:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>G value (%)</th>
<th>I value (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total coliform /100 mL</td>
<td>500 (80)</td>
<td>10 000 (95)</td>
</tr>
<tr>
<td>Faecal coliform /100 mL</td>
<td>100 (80)</td>
<td>2 000 (95)</td>
</tr>
<tr>
<td>Faecal streptococci /100 mL</td>
<td>100 (80)</td>
<td>-</td>
</tr>
</tbody>
</table>

(G value = guide; I value = mandatory)

Although, initiatives of the EEC to revise the Bathing Water Directive already started during 1994, their new proposed directive (24/10/2003) is now under consideration. Based on World Health Organisation epidemiological study (WHO 1989 to 1992) results on intestinal Enterococci and Escherichia coli the Commission of the European Communities propose the following guidelines for EU bathing water (coastal and fresh) quality:

**Intestinal Enterococci** -
- Excellent quality (guide) / 100 mL
  - 100 in 95% of the samples

- Good quality (obligatory) / 100 mL
  - 200 in 95% of the samples

**Escherichia coli** -
- Excellent quality (guide) / 100 mL
  - 250 in 95% of the samples

- Good quality (obligatory) / 100 mL
  - 500 in 95% of the samples

This is more stringent than their 1976 directive. It is also in line with the South African Water Quality Guidelines (fresh water) for Recreational Water Use (1996, volume 2) of DWAF which specify a target water quality guideline for faecal coliforms of not exceeding 130 counts per 100 ml, with a second tier guideline value of 600 counts per 100 ml. It would seem that much stricter risk limits were adhered to in setting the fresh water recreational indicator organism guidelines in 1996 than with the marine water quality guidelines in SA.

### 3 Methodology

Water samples were collected aseptically in sterile containers twice a month at twelve positions along a coastline. Samples were collected in the surf-zone, ~two metres seawards from the lip of a newly broken wave, between the surface and ~0.2 metre depth. Water samples were held in closed, insulated containers and were analysed within six hours after sampling. Appropriate volumes of water samples were analysed for faecal coliforms and Escherichia coli according to standard methods [9].

Membrane filtration methods were used to culture faecal coliform bacteria. Three volumes of 100 mL or appropriated dilutions in normal saline (0.85%) from a one litre, thoroughly mixed water sample, were filtered through a 47 mm,
0.45 µm membrane (Whatman®), using a heat sterilised multi-funnel membrane filter system. The membranes were transferred to 60 mm diameter sterile, disposable petri dishes containing sufficient sterile, prepared mFC Agar (Difco® Laboratories, No. 0677) and incubated at 44.5 °C (± 0.5 °C) for 18 to 24 hours. All the blue colonies were counted using a magnifying colony counter. The results were calculated as colony forming units per 100 mL sample. The faecal coliforms membranes were then used to culture *Escherichia coli*. These membranes were then transferred onto a 60 mm diameter disposable petri dish containing Tryptone Soy Agar (Biolab®) with Oxoid® No. X4521A BR071E MUG supplement. The plates were incubated for four hours at 37 °C (± 0.5 °C). All the bright light blue fluorescent colonies were then counted using a cabinet with a long-wave ultra-violet light source. The results were calculated as a percentage of the counted blue colonies (faecal coliforms) and reported as colony forming units per 100 mL sample.

4 Results and discussion

It was found, as illustrated in fig.1, that many indicators could be used to evaluate the microbiological quality of marine surf-zone water. It is clear that the water quality, as indicated by the organism numbers, is evaluated the same by all the microorganisms used.

![Figure 1: Occurrence of microorganisms in the marine surf-zone.](image)

However, the results indicate that if *Escherichia coli* is used as faecal indicator with the faecal coliform bacteria limit, then the human health risk will increase. A different limit must be set for each indicator used. The results indicate that if *Escherichia coli* is used as indicator a lower bacteria limit must be set. It was found in this study that a 100 faecal coliform count represents a 60 *Escherichia coli* count, while 2000 faecal coliforms represent 1200 *Escherichia coli* [10]. This proposed change to the 1995 DWAF [7] is in agreement with the results of Genthe et al., [11]. They carried out a process of exploring different levels of indicator organisms to compare swimming associated health risks with
different bacterial levels of water quality. Their results showed that different health risks were found for different levels of water quality, with swimming exposure to higher counts showing an increased risk. The faecal coliform level that best predicted a health risk is, as stipulated in 1995 DWAF [7], 100 cfu in 100 mL, whereas for *Escherichia coli*, it was 65 cfu in 100 mL.

To illustrate the above, the results from three areas are presented as xy-plots with the faecal coliform bacteria on the X-axis and *Escherichia coli* on the Y-axis. The dotted vertical lines on the xy-plots represent the existing 1995 DWAF [7] maximum allowable faecal coliform count per 100 mL for full and intermediate contact recreation (100 in 80% of samples and 2000 in 95% of samples). The dotted horizontal lines on the xy-plots represent the proposed *Escherichia coli* counts. It is added to illustrate the proposed change in the guidelines that 100 faecal coliform bacteria represent 60 *Escherichia coli* while 2000 faecal coliform bacteria represent 1200 *Escherichia coli*.

The first area represents a period with pollution followed with a period after the pollution source was terminated. Area 2 represents an area without pollution while area 3 represents an area with pollution.

In fig. 2, the correlation between faecal coliforms and *Escherichia coli* from area 1 with and without pollution is shown. The data clearly indicates a high correlation between faecal coliform and *Escherichia coli* numbers. It indirectly indicates that when a faecal pollution source is present, most of the faecal coliform bacteria are *Escherichia coli*. Except for the move to the lower end of the chart without pollution, no difference between the faecal coliform and *Escherichia coli* correlation is observed.

The faecal coliform bacteria and *Escherichia coli* data from area 2 are presented as xy-plots in fig. 3. For illustration purposes, the data is split to compare with the two periods of fig. 2. It represents a scenario without pollution and compare favourably with fig. 2 without pollution.

![Area 2 - without pollution - same period as Area 1 with pollution](image1.png)

![Area 2 - without pollution - same period as Area 1 without pollution](image2.png)

Figure 2: Correlation between faecal coliform and *Escherichia coli*. 

Figure 3: Correlation between faecal coliform and *Escherichia coli*

Figure 4: Correlation between faecal coliform and *Escherichia coli*

The faecal coliform bacteria and *Escherichia coli* data from area 3 are presented as xy-plots in fig. 4. For illustration purposes, the data is split to compare with the periods of fig. 2. It represents a scenario with pollution and compare favourably with fig. 2 with pollution.

The faecal coliform bacteria and *Escherichia coli* data from all the areas are presented as xy-plots in fig. 5 to illustrate that all the results are in comparison with the above. The results are arrived from the analyses of 2276 samples [10].

As shown in all the figures, the correlation between faecal coliform bacteria and *Escherichia coli*, occurring in the marine surf-zone water, is very high. This is an indication that both can be used to indicate the microbiological quality of marine bathing water.
5 Conclusions

It has been proved that the Faecal coliform / Escherichia coli ratio do not vary significantly in the marine surf-zone water whether the water is polluted or not. This also proves that when both faecal coliform bacteria and Escherichia coli are used together as indicators for marine pollution an extra safety control is added. If any change in the high correlation between faecal coliform bacteria and Escherichia coli occurs during a single sampling and analysis run, it may be the first indication that something is wrong and a follow-up sample may be needed to confirm the change in order to start an investigation to rectify the possible problem.

It is proposed that both faecal coliform bacteria and Escherichia coli be used to evaluate the marine water quality during monitoring programmes to detect any change in correlation ratios.

All the epidemiological studies found during literature searches, relating to human health and water quality, eventually concluded that either faecal coliform bacteria or enterococci (faecal streptococci) be used as indicator organism for the microbiological quality of marine bathing waters. Although the DWAF (1995) stipulated that a 100 faecal coliform bacteria per 100 mL is the maximum allowable count in 80% of samples analysed, it was not evaluated in terms of the prediction of human health risk. However, as discussed previously, in South Africa, Genthe et al. [11] during their study on the health risks associated with polluted marine water, concluded that a faecal coliform count of 100 cfu / 100 mL best predicted a health risk whereas for Escherichia coli it was 65 cfu / 100.
During this study it was proved by the substantial data available, that a count of 60 and 1200 *Escherichia coli* must replace the counts of 100 and 2000 faecal coliform bacteria as stipulated in DWAF (1995) if *Escherichia coli* is used as bacterial indicator. This will incorporate a safety precaution against a possible health risk associated with the 65 cfu per 100 mL.

The 1995 DWAF should be replaced with the following to increase health safety for bathers [10]:

**Faecal coliform as indicator**

**Full and intermediate contact recreation:**

<table>
<thead>
<tr>
<th>Maximum acceptable count /100 mL</th>
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<tbody>
<tr>
<td>100 in 80% of the samples</td>
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<td>2000 in 95% of the samples</td>
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**Filter feeders for food use:**

<table>
<thead>
<tr>
<th>Maximum acceptable count /100 mL</th>
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<tbody>
<tr>
<td>20 in 80% of the samples</td>
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<tr>
<td>60 in 95% of the samples</td>
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</table>

**Escherichia coli as indicator**

**Full and intermediate contact recreation:**

<table>
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<th>Maximum acceptable count /100 mL</th>
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<tr>
<td>60 in 80% of the samples</td>
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<tr>
<td>1200 in 95% of the samples</td>
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</tbody>
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**Filter feeders for food use:**

<table>
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<th>Maximum acceptable count /100 mL</th>
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<tr>
<td>12 in 80% of the samples</td>
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<tr>
<td>36 in 95% of the samples</td>
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**References**


