Coliforms and *Escherichia coli* as Indicators of Pollution - A Brief Review

*Final Report to the Department of the Environment*

DWI 3935
MAY 1995
COLIFORMS AND *ESCHERICHIA COLI* AS INDICATORS OF POLLUTION -
A BRIEF REVIEW

Final Report to the Department of Environment

Report No: DWI 3935
May 1995
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Contract No: 09008-1
DoE Reference No: PECD 7/7/360

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EXECUTIVE SUMMARY

This brief review has been produced as a result of a request from the Department of the Environment for references dealing with the use of coliform organisms and Escherichia coli as indicators of faecal pollution.

A great deal of literature exists on this subject, and it is difficult to identify key reports which give a satisfactory overview. This report provides a selection of suggested references, mostly review articles where the authors have assembled a body of information in a comprehensive but accessible form. It does not claim to be all-embracing, but the papers cited, plus additional references which they provide, should give an adequate overview of the subject.

A bibliography of 22 references is included.
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1. INTRODUCTION

This brief review has been produced as a result of a request for authoritative references on bacterial indicators of water pollution, with particular reference to coliform organisms and *Escherichia coli*.

Much has been published on this subject over the years, and the vast size of the literature makes it difficult to identify key reports which give a satisfactory overview. Individual research papers have their value, but a better insight into the subject can be gained from review articles, especially if these are well-written, and the authors have comprehensive knowledge and understanding of their subject matter. Reviews of this quality are scarce, however.

The following section gives some suggested literature. This is a personal selection by the present writer, and does not claim to be fully comprehensive. Most of the papers are reviews, but some supplementary references are given. Many more references can be identified from the bibliographies in the review articles.

The use of surrogates to indicate the potential presence of pathogenic organisms has become so well-established over the years that the concept is seldom questioned. For this reason detailed reviews of indicator systems do not often appear. The fact that many of the references in the following section are relatively old, and often from the United States, should not be taken to mean that they are irrelevant to modern debate on indicator organisms.
2. INDICATORS OF POLLUTION

2.1 Background

Long before the germ theory of disease was propounded, ancient civilisations realised the need to protect the quality of water to be used for human consumption. Much later, it became understood how the major waterborne diseases such as typhoid fever and cholera were spread, and faecal contamination of drinking water was seen to be a major factor. Early attempts to isolate and monitor pathogenic micro-organisms in water were generally unproductive, and more effort was put into finding surrogate organisms which would indicate the potential presence of faecal contamination, and hence the possible presence of pathogens.

From early work, the coliform group emerged as the most useful indicators. The characteristics desirable in pollution indicators have been described by a number of workers (e.g. Cabelli 1977, Kott 1977, Olivieri 1987). Some such as Cabelli (1977) have concluded that there is no ideal indicator available at present, and implied that coliforms must serve the purpose until something better emerges.

In time efforts were made to refine the test so that those strains most associated with faecal pollution could be measured. Different definitions of coliform organisms, and the criteria used for the definitions, have confused the situation. Where an organism or group of organisms is defined in terms of the method used for its enumeration, then that group may be diverse, and organisms which are not significant from a sanitary point of view may be included. On the other hand, if the indicator consists of a single species, such as E. coli, then a reliable analytical test may be complicated and infeasible. It therefore becomes necessary to use a simplified working definition of the species to allow the use of a test which is straightforward and easy-to-use. In its turn this test is unlikely to be completely selective, and again organisms other than the target one may be enumerated. For example, reliable identification of E. coli to species level can involve a complex series of tests, such as described by Edwards and Ewing (1972), and this would be infeasible in a routine water microbiology laboratory. A working definition of E. coli based on fermentation of lactose and production of indole from tryptophan at an elevated incubation temperature, can result in some species of Klebsiella effectively being classified as E. coli, even though their sanitary significance may be doubtful. Also some genuine strains of E. coli may be missed if they are unable to grow at the elevated temperature of the indole test.

2.2 Applicability of indicator organisms to different water types

Ultimately the choice of indicator depends on the material being tested, and the kind of information which is required. Where it is important to know that any detected pollution is definitely of a faecal nature, such as when monitoring the quality of recreational waters, then a test for E. coli is the most appropriate, since this organism is the only coliform which is an undoubted inhabitant of the gastro-intestinal tract. However, when testing
treated, disinfected drinking water, a much less selective test may be appropriate, since any kind of contamination, faecal or otherwise, is undesirable (Bonde 1978). This view is supported by various authors (e.g. Mack 1977, WHO 1992). Therefore a test for total coliforms, or some similarly defined group, may be suitable. However, it must be accepted that the less rigorous the test, the greater will be the occurrence of false positive results, and the importance of this aspect must be considered.

This topic has been examined in detail by Waite (1985), who proposed some redefinitions of indicator bacteria for various purposes. This kind of reasoning has been continued through in modified form to the latest edition of Report 71 (1994), which now defines coliform organisms in terms of the possession of a gene coding for production of the enzyme β-galactosidase. It also removes parts of the earlier definition which were irrelevant in practical terms to the tests which are carried out by testing laboratories. These included the description of coliforms as “Gram-negative non-spore producing rod-shaped bacteria”, whereas in practice tests to prove these characteristics were almost never carried out. The working definition of E. coli is also made less restrictive, and now states that organisms satisfying the definition of coliforms and producing indole from tryptophan at 44°C can be considered as E. coli. As mentioned above, this will result in some strains of organisms such as Klebsiella oxytoca being classified as E. coli. The revised Report 71 (1994) gives more detail about the rationale for water testing and suitable indicator organisms.

2.3 References on the development of the indicator concept

The historical aspects of the use of coliforms and E. coli as pollution indicators are covered in a number of early research reports, many of which are difficult to obtain. It is interesting to read reports such as MacConkey and Hill (1901) on the development of bile salt media and sugar fermentation tests, but an overview is perhaps more generally useful. The subject is covered in detail in Elements of Water Bacteriology (Prescott and Winslow 1931, or earlier editions). The history of the nomenclature and classification of coliforms and related organisms has been reviewed by Agg et al. (1978).

A good general review of bacterial indicators of pollution is that by Olivieri (1982). It gives a brief historical perspective, followed by a description of the characteristics required of an indicator, and a detailed treatment of a variety of indicator groups.

An American perspective on the subject, with particular reference to the concept of faecal coliforms as indicators of pollution, can be gained from Geldreich et al. (1962) and Geldreich (1966, 1967).

One of the most comprehensive and useful single volumes on the subject of pollution indicators is that edited by Hoadley and Dutka (1977). This consists of 25 papers given at a conference held in Chicago in 1976, and many of the articles are of direct relevance and interest.

E. coli is discussed by Dufour (1977), and total coliform bacteria are considered by Mack (1977). Other useful papers included in the volume are Kott (1977) on the then current
concepts of indicator bacteria, Ptak and Ginsburg (1977) on bacterial indicators of drinking water quality, and Cabelli (1977) on indicators of recreational water quality. Other papers cover alternative indicators to coliforms and E. coli, and water quality standards are considered by Müller (1977), Suess (1977) and Barrow (1977).


2.4 Coliforms as indicators of bacterial and non-bacterial pathogens

Prescott and Winslow (1931) noted that water may be grossly polluted without any specific disease-causing organisms being present. However, since all sewage-polluted water was considered potentially dangerous, the need for an indicator of faecal pollution was therefore necessary. This has been considered in the previous sections. A particular concern which has been expressed is that the indicators currently in use may be inadequate in warning of the presence of some pathogens which are very resistant to inactivation.

Olivieri (1982) gives graphs of die-off rates for indicator organisms and *Salmonella* in trickling filter effluents, and concludes that the survival of the indicators and pathogens is comparable. However, he notes that viruses and protozoan cysts may survive considerably longer than bacterial indicators in the environment, and can be particularly more resistant to disinfection.

Mack (1977) describes reports on incidents where viruses were isolated from water supplies, when coliforms were not detected by the standard tests. However, it must be pointed out that reports of this nature do not represent truly comparable sampling for pathogens and indicators. The respective volumes of sample analysed need to be taken into account. It is customary to concentrate volumes of up to hundreds of litres for viral analysis, but results for indicator bacteria are almost always based on testing around 100 ml. Mack (1977) comments on two outbreaks of gastro-enteritis where coliforms were not demonstrated by the standard methods, but viruses were found to be present when large volumes of water were tested. He noted that coliforms were in fact found in concentrates of the samples, and concludes that the perceived shortcomings of coliforms as indicators in such situations could be corrected to some extent by analysing much larger volumes of sample than is the current practice.

Another approach would be to select alternative indicator organisms which survive environmental stress and disinfection processes in a way more comparable to the harder pathogens. This has been considered by Engelbrecht *et al.* (1974) and Bitton (1980). These publications consider the perceived shortcomings of coliforms and *E. coli* as indicators of viruses, and suggest that coliphages, yeasts and acid-fast bacilli may be potentially useful as indicator organisms. Part 1 of the volume edited by Berg (1978) also gives a comprehensive overview of indicators of viruses in water.
REFERENCES


Bonde, G.J. (1978) Importance of non-faecal coliforms and germ counts as quality criteria for potable water. *Aqua*, 1, 6-12.


