

**Microbiological Health Risk Assessment
at Gunnamatta Beach**

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for

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CONTENTS

	SUMMARY	Page 1
1	INTRODUCTION	4
	1.1 Scope of this project	4
	1.2 Methods to assess health risks	5
	1.3 Epidemiological Study Designs	5
2	LITERATURE SURVEY	8
	2.1 Survey Method	8
	2.2 Literature Survey Results	8
	2.2.1 Epidemiological Studies - Cohort Studies	8
	2.2.2 Epidemiological Studies - Randomised Trials	9
	2.2.3 Review Paper	10
3	RISK ASSESSMENT STUDIES	12
4	WATER QUALITY AT GUNNAMATTA BEACH	13
5	THE RISK OF DISEASE AT GUNNAMATTA BEACH	16
6	SPECIFIC CONSIDERATION OF SKIN AND EYE SYMPTOMS	19
7	ADDITIONAL ISSUES IDENTIFIED IN THE REVIEW	21
8	CONCLUSIONS	23
9	RECOMMENDATIONS	24
	TABLES	25
	Table 1 Cohort studies comparing swimmers and non-swimmers	
	Table 2 Cohort studies comparing swimmers with different degrees of exposure	
	Table 3 Association of indicator organisms with illness	
	APPENDIX	34
	Summary of Papers	
	REFERENCES	47

SUMMARY

Summary of conclusions

In this project brief two issues were addressed:

- The first was to assess the published literature to determine if there was evidence indicating that swimming at beaches contaminated by effluent caused more disease than swimming at beaches NOT contaminated with effluent. It should be noted that swimming in any water is associated with more disease than not swimming.
- The second was whether there was sufficient information from these studies to determine if swimmers at Gunnamatta Beach were at more risk of disease than swimmers elsewhere. This was to be achieved by correlating the water quality parameters at Gunnamatta Beach with those published in the studies.

The first stage of this consultancy was completed in late 1997 and it was concluded that the available water quality data for Gunnamatta Beach (E.coli counts) would only permit comparison to a few published studies, and that no conclusions could be drawn on this basis.

An expanded water sampling program was recommended, incorporating the two organisms most frequently reported to show a strong association with disease risks - Total Coliforms and Enterococci. It was also recommended that samples be taken further from shore in the areas where surfers most often swam. This sampling program was undertaken by Melbourne Water in January 1998.

Evaluation of the published literature shows that despite the limitations of some studies, it can be concluded that risks of illness are higher for swimming in water with substantial sewage effluent pollution than for swimming in water with little or no sewage effluent pollution.

Comparison of bacterial indicator levels for Gunnamatta Beach with those in published studies showed that the water quality at Gunnamatta was generally similar to or better than the "clean" beaches in most published studies. Therefore it is very unlikely that swimmers at Gunnamatta Beach would be at increased risk of illness due to faecal microorganisms in the treated effluent being discharged there, compared to swimmers at other ocean beaches.

Summary of literature review and water quality data

Study methods

Assessment of the risk of disease from swimming in polluted beaches can be derived from either epidemiological studies or risk assessment modelling. Both of these approaches have their limitations, and in the present context we consider epidemiological studies to be most relevant.

On the whole, epidemiological studies have shown an increased risk of disease associated with swimming in waters contaminated by effluent or storm water, although levels of statistical significance were not always reached. The diseases associated with swimming in these contaminated waters are varied and derive from direct contact with the water (eg ear, eye, and skin conditions) and from ingestion or inhalation of water (eg. gastroenteritis and respiratory disease). Most studies have concentrated on gastroenteritis due to the primary concern over enteric pathogens in effluent.

Best indicator organism

There is no general agreement on the indicator organisms that are best able to assess the likelihood of disease, although E.coli and enterococci or faecal streptococci have been most closely correlated with a increase in disease risk. The absolute levels of these indicator organisms found to be associated with disease varies in different studies.

Microbiological Water Quality at Gunnamatta Beach

The overall conclusion from comparing microbiological indicator counts at Gunnamatta Beach with beaches described in published studies is that the water quality at Gunnamatta is relatively good. Indeed, for a number of studies the microbiological indicator levels at Gunnamatta are equivalent to or lower than the "clean" beaches which have been used as a baseline to assess risks at beaches with much higher levels of indicator organisms.

Studies relevant to Gunnamatta Beach

A number of published studies could be compared to Gunnamatta Beach on the basis of microbiological water quality indicators.

E coli

Three studies using this indicator organism were available for comparison.

Total Coliforms

Four studies were able to be compared on this basis.

Enterococcus

Five studies using Enterococcus as a microbiological indicator could be compared to Gunnamatta.

Summary of other issues

Difference between EPA requirements and detectable disease risk

There is no question that the water quality data from Gunnamatta beach reach the EPA guidelines of a geometric mean titre for E.coli of less than 200 and an 80th percentile of less than 400 cfu/100ml. However, water of this quality may be associated with disease although at levels considered to be acceptable by regulating authorities (ie less than 190 episodes per 10,000 swims - see Section 6).

The issue is whether swimmers at Gunnamatta beach, which easily fulfils the EPA requirements, are becoming sick more frequently than those swimming at non-contaminated beaches. The key research question is then, at what level of indicator organisms is it possible to "see" an increase in disease risk.

Background rate of illnesses

It should be noted that many of the conditions that have been seen to occur more commonly in swimmers at highly contaminated beaches actually occur relatively commonly in the general population anyway. For example - ear, nose and throat infections normally occur in adults around once every three months, while gastroenteritis attacks occur once every 2 years or so. In children both types of illness are about twice as common. It is important to appreciate that these are "average" attack rates and some individuals will experience them more commonly than this and others less commonly.

What increases at Gunnamatta might we expect?

What increase could be expected at Gunnamatta Beach if indeed there was an increased risk?

A rough guide to this can be obtained from the Santa Monica study. In this study there was a 111% increase in the rates of gastro from about 85 for every 10,000 people who swim to about 180 for every 10,000 people who swim. In other words, on average every second attack of gastro occurring in people who swim in the polluted waters at Santa Monica could be attributed to swimming in that water. Similarly ear nose and throat infections increased by 66%. The background rate for this is 183 episodes per 10,000 people who swim. This rose to 303 episodes per 10,000 people who swim in contaminated water.

The contaminated water in the Santa Monica study that was associated with the increased rates of disease described above had 25% of samples with E coli counts above 320 cfu/100ml. In contrast Gunnamatta beach has at the worst beach site only 2% of samples with readings above this level. If there was an increased risk of disease from swimming at Gunnamatta it would be reasonable to expect that it would be very small compared to what was seen in the Santa Monica Study.

1 INTRODUCTION

This report was commissioned by the Melbourne Water Corporation in response to concerns raised by Surfriders Foundation Victoria and the Peninsula Surfrider Club/ Surfing Victoria. Based on reports by their members, these organisations felt that swimming at Gunnamatta Beach was associated with an increased risk of illness compared to swimming at other Victorian beaches.

Gunnamatta Beach is in close proximity to the outfall from the Eastern Treatment plant which discharges secondary treated effluent, and hence it is possible that this water is contaminated by microorganisms that may cause disease.

1.1 Scope of this project

The scope of the project included the following:

1. Search the medical and scientific data bases and identify and review the literature on epidemiological studies undertaken of recreational exposure to contaminated marine waters;
2. Review the literature on microbiological quantitative risk assessment (eg. Regli et al. 1991 and Ashbolt et al, 1997) and assess applicability of this approach to Gunnamatta Beach;
3. Review the data provided by Melbourne Water on *microbiological indicators* from marine water around Gunnamatta Beach. Meteorological conditions to be considered with the data set provided;
4. Indicate on the basis of the literature review and assessed data if there is:
 - a strong evidence in favour of disease occurring from swimming and surfing in the area or
 - a strong evidence against disease occurring from swimming and surfing in the area.The extent of the external bodily contact with water and water ingested when surfing should be taken into account;
5. In the event that the evidence is insufficient to make a strong conclusion, a suggestion of possible research studies that could be undertaken and their estimated costs should be recommended;.
6. Liaise with The Client Representative and others, as required, for the duration of the project;
7. Prepare a final report concluding the undertaken desktop assessment. Interpretation of collected data, findings and recommendations are to be included in the report.
8. Present findings of the final report to the Steering Committee.
9. Assist in Community Consultation Program to effectively communicate the progress and results, if required.

1.2 Methods to assess health risks

There are basically two different approaches which may be adopted to assess the health risks in this situation. The first approach utilises epidemiological studies and the second utilises risk assessment modelling.

In epidemiological studies, the risk of illness in groups with differing degrees of exposure to the presumed risk factor are compared to determine whether increasing exposure is associated with increasing risk. In this sort of study, the main outcome measures are clinical conditions such as gastroenteritis, or ear infections. It is important to appreciate that each of these clinical conditions can be caused by a number of different microorganisms. In this type of study the microorganisms responsible for the disease are not identified.

In contrast, risk assessment modeling is centred on specific microorganisms and not on clinical conditions. A number of assumptions are made about the concentration of each microorganism and the chance of the swimmers coming in contact with these organisms. For example it might be assumed that each swimmer consumes 50 ml of sea water each hour and that they swim for on average 2 hours. If the infectious dose is known then one can mathematically model how likely a person is to get the disease from that specific organism. This does not however predict how likely they are to develop the clinical condition (eg gastroenteritis) unless all the organisms that cause that condition are known. In almost all conditions associated with swimming, this information is not available. It should also be appreciated that there is often a considerable uncertainty surrounding the estimates for the various parameters (eg infectious dose) used in these models.

A second important limitation of the risk assessment approach is that the risk of infection can only be calculated for conditions associated with ingestion of microorganisms. This is because our knowledge of the “infectious dose” of specific microorganisms is essentially limited to such situations, and is based on studies of pathogens in food or drinking water. Conditions such as skin or ear infections which are caused by external contact with microorganisms, or respiratory infections caused by inhalation of microorganisms are therefore not amenable to the risk assessment approach at the present time.

We therefore have reviewed the epidemiological studies undertaken in this area in addition to the mathematical modelling approach adopted by Ashbolt et al. (1997). We have outlined briefly below the type of epidemiological studies that have been undertaken. It is considered that the studies comparing the risk of disease associated with swimming in polluted versus non polluted marine waters will be of primary interest to Melbourne Water Corporation. There have however been a considerable number of studies undertaken assessing the risk of disease for swimmers compared to non-swimmers. Some of this data is presented for information, although it is considered of lesser significance in this review.

1.3 Epidemiological Study Designs

A number of different study designs have been employed to investigate the health risks associated with swimming. The salient features of each design are outlined below, together with some of the limitations of these studies.

Retrospective Cohort Beachgoers are recruited, a questionnaire is administered at recruitment which records swimming behaviour and symptoms of illness over the preceding several days. There is no follow up. Exposure (ie swimming or not swimming) is not determined by the investigators - participants freely choose whether or not to swim.

Prospective Cohort Beachgoers are recruited, a questionnaire is administered at recruitment, with a follow up questionnaire some days later to cover the intervening period. Exposure (ie swimming or nor swimming) is not determined by the investigators - participants freely choose whether or not to swim.

Randomised Trial Beachgoers are recruited and randomly assigned by the investigator to swim or not to swim. A questionnaire is administered at recruitment, with a follow up questionnaire several days later to cover the intervening period.

The major shortcoming of the Retrospective and Prospective Cohort study designs is that there may be underlying differences between people who chose to swim and people who chose not to swim. If these differences affect the likelihood of the person developing or reporting illness, then all or part of any observed difference between the groups may be attributable to these underlying factors, rather than the difference in swimming behaviour.

Thus the results of comparisons between exposed groups (swimmers) and non-exposed groups (non-swimmers) in such studies must be regarded with considerable caution in their interpretation. However greater reliance may be placed on differences observed between subcategories of the exposed group - eg swimmers exposed to high densities of indicator organisms vs swimmers exposed to low numbers of indicator organisms.

The Randomised Trial design virtually eliminates the possibility of significant underlying differences between the two groups, and allows a much higher degree of confidence in the results of comparisons between the non-exposed and exposed categories.

Other factors influencing illness

There are a number of other factors which may influence the risk of subjects developing illness during the observation period of a study. These include pre-existing medical conditions, contact with pets and other animals, and consumption of foods which are prone to contamination by microorganisms. If these factors are not measured and they unevenly distributed among the different exposure groups, then they may account for some or all of the observed differences in illness rates.

Susceptibility to infection is influenced by age, with young children and the elderly generally being more prone to infections. Therefore it is usual for results to be adjusted to take into account any difference in age distribution between the exposure groups.

Bias and subjectivity of symptoms

Studies which rely on participants to report symptoms may be prone to some degree of bias if one group over-reports illness compared to another group. If participants are aware that a study is seeking to assess a relationship between swimming and illness, those who swim may report all symptoms in great detail while non-swimmers may feel less motivated to do so. This would introduce bias in favour of finding a difference in symptom rates between the groups.

The method of reporting may also introduce bias - for example Seyfried et al (1985a) found that those responding by postal questionnaire reported a much higher rate of symptoms than those followed up by telephone. This is in agreement with the general observation in medical research that people who experience illness are more highly motivated to respond to questions about health than people who are well. This tends to inflate the estimates of illness rates, and

may distort comparisons between groups if the proportion of subjects reporting by different methods varies between the exposure groups.

The experience of symptoms is by definition a subjective phenomenon, and thus all studies which rely on self reporting by participants are measuring the perception of illness rather than medically confirmed illness. It is generally not feasible for both logistical and financial reasons to carry out medical examinations on large numbers of volunteer subjects. Therefore investigators may focus on subgroups who have reported symptoms which considered to be more “objective”. For example, for gastroenteritis the range of symptoms may include vomiting, diarrhoea, nausea, abdominal cramps, chills/sweats, fever etc. Generally it is felt the reporting of vomiting and diarrhoea will vary little between subjects, whereas reporting of other symptoms such as nausea or cramps will be less reliable. Thus a number of different definitions of illness with varying stringency may be applied during analysis of results.

2 LITERATURE SURVEY

2.1 Survey Method

The initial literature survey was carried out using the Medline database (1990-August 1997) and the Current Contents database (1993 - 11 September 1997). Searches were done using combinations of keywords including:

bathing + marine /sea /water

bathing + illness /morbidity /gastroenteritis /disease /health

swimming + illness /morbidity /gastroenteritis /disease /health

marine /sea + illness /morbidity /gastroenteritis /disease /health

Over 300 references were found by these searches and assessed for relevance based on their Abstracts, and copies of selected references were obtained from the Monash University Library and Document Delivery services. Additional references were identified from citations in these articles and copies of these were also obtained. Two additional sources of data on the Santa Monica Study and the New Zealand study were supplied by Melbourne Water Corporation.

It should be noted that the conventionally accessible published literature (ie journals, monographs and books) does not represent the full body of data on research into swimming and health effects. A number of studies have been published only as reports to health authorities and are not readily obtainable at short notice. Only those studies where the full reference could be obtained in the available time frame have been included in this report.

2.2 Literature Survey Results

2.2.1 Epidemiological Studies - Cohort Studies

The information available from the published papers on cohort studies is presented in Tables 1 to 3. The individual papers are summarised in the Appendix to this report. There are three principal findings from cohort studies:

- Swimmers are at increased risk of a broad range of diseases compared to non-swimmers.
- Increased exposure (swimming) results in more disease.
- Polluted waters are associated with a greater risk of disease than non-polluted waters.

The studies were undertaken in marine waters with different degrees of pollution. There was considerable variation in the type of bacterial indicators used and in their absolute level. Definitions of “swimmers” and “non-swimmers” also varied from one study to another, as did definitions of illness categories.

The symptoms studied have been predominantly those associated with gastrointestinal illness due to the concern over enteric pathogens in effluent. Respiratory, ear, eye and skin symptoms have been included in some studies. In many studies the available information was not sufficient to relate numbers of indicator organisms to levels of risk.

Cohort studies have been subject to considerable criticism because of their design weaknesses (as outlined in Section 1.3; Jones and Kay 1989). These studies have also produced widely differing estimates of illness rates among non-bathers - suggesting that results may not be comparable from one location to another or that the protocol is subject to considerable variation in the hands of different investigators.

2.2.2 Epidemiological Studies - Randomised Trials

Four randomised trials have been conducted by the same research group. These studies were conducted over 4 summer seasons at UK beaches from 1989 to 1992 and the combined results were analysed. These prospective randomised studies have employed the most stringent methodology of bathing studies published to date, thus we consider it relevant to present a summary of the methodology below. The relevant papers are individually summarised in the Appendix (Fleisher et al 1993, Fleisher et al 1996, Kay et al 1994).

The characteristics of the first 2 study sites are described as having “adjacent effluent outfalls” but not affected by “agricultural or significant storm drainage”. The remaining sites are not described in this respect.

Healthy adult volunteers were recruited at local shopping centres, sports centres etc and asked to attend the beach test site on the study day. After arrival they were randomised to bathing or non-bathing groups and were closely supervised to ensure compliance with the exposure requirements. Bathers were required to enter the water in one of five 20 metre wide roped off areas, to remain for at least 10 minutes and immerse their heads 3 times (without protective cap or goggles). Non-bathers were required to remain in a roped off area away from the water.

Water quality samples were taken at 30 minute intervals and 3 water depths in each 20 metre bathing zone during the 3 hour period of each trial. A number of bacteriological indicators were measured - total coliforms, faecal coliforms, faecal streptococci, total staphylococci (3 of 4 sites) and *Pseudomonas aeruginosa*, and personal exposure for each bather was estimated from these figures. Information on illnesses experienced by participants was collected by interview 1 week after the exposure day and by written questionnaire 3 weeks after exposure. Data from a total of 548 bathers and 668 non-bathers was analysed after excluding 90 participants with incomplete information.

These studies are of particular importance as they address some major shortcomings of previous investigations using Cohort designs:

- participants were randomly assigned to exposed (bathing) and non-exposed (non-bathing) groups. This tends to equalise the characteristics of the two groups prior to exposure.
- the water quality sampling program was designed to take into account the variability in the density of indicator organisms over time and location.
- a measure of personal exposure was estimated for each bathing participant based on the water quality sample closest to the location and time of their exposure.
- non-water-related risk factors for gastroenteritis were also assessed. These included an existing tendency to frequent diarrhoea, unusual fatigue prior to exposure, and consumption of some take away foods.

The overall conclusions of these studies were:

- bathers showed statistically significant increased risks for gastroenteritis, ear ailments, eye ailments and acute febrile respiratory illness. No statistically significant difference was observed for skin ailments.
- faecal streptococci measured at chest depth (ie where exposure occurred) were found to show the strongest association with risk of gastroenteritis and acute febrile respiratory illness.

- faecal coliforms showed the strongest association with the risk of ear ailments.
- non-water related factors (specifically the consumption of some fast foods) were estimated to show similar risks for gastroenteritis as swimming in moderately polluted water (up to 79 faecal streptococci / 100ml).

Threshold levels for increased risk for swimming were estimated as follows:

Indicator	Illness	Threshold level
Faecal streptococci	Gastroenteritis	33 / 100ml
“	Acute febrile respiratory illness	60 / 100ml
Faecal coliforms	ear ailments	100 / 100ml

These threshold levels were derived by estimating the risks of illness associated with exposure to higher levels of microorganisms, then extrapolating downwards towards lower numbers of organisms until the risk of illness in swimmers equalled the risk of illness in non-swimmers. In other words the threshold level represents a water quality where an increase in risks of illness begins to occur.

These findings again suggest that no single indicator organism is sufficient to predict the risk of all illnesses due to swimming in polluted waters. This is not surprising given the wide range of microorganisms capable of causing the observed illnesses, and the large variation which must exist in their survival characteristics in marine waters.

These randomised trials support the evidence from less stringently designed cohort studies that swimming in polluted waters is associated with increased risks of illness. While they may be criticised for using relatively “artificial” exposure conditions (short duration swimming in a small area) and a restricted population group (healthy adults), it would be expected that both of these features would tend to reduce the chance of finding differences between exposure groups.

2.2.3 Review Paper

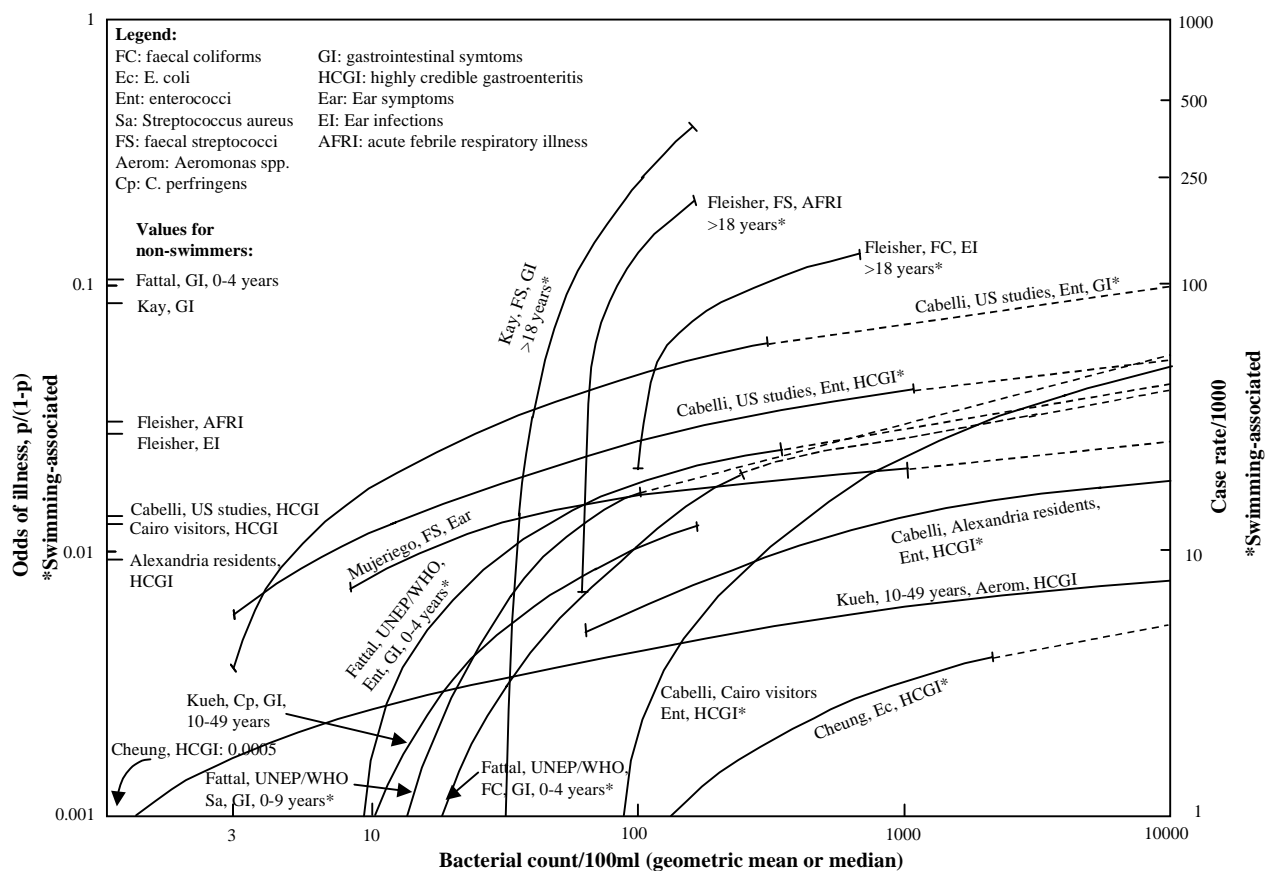
During the course of this consultancy a paper was published which reviewed epidemiological studies on this topic (Prüss 1998). The material covered by the review overlapped to a great extent with this report.

The conclusions of the author can be summarised as follows:

- the review suggests there is a causal relationship between gastrointestinal symptoms and water quality as measured by indicator bacteria.
- in most studies the rate of symptoms or symptom groups is significantly related to counts of faecal indicator bacteria. Gastrointestinal symptoms were the most frequently reported health outcomes.
- several indicator organisms were used, and these were related either to faecal pollution or pollution by other bathers.

- both freshwater and marine water studies suggest that the indicator organism thresholds where increased risk occurs are relatively low.
- the randomised trials have the most accurate data but may be applicable mainly to adults in temperate climates.
- some studies suggest that thresholds may be higher for populations where endemic levels of disease are higher. This may indicate that higher levels of immunity exist in such populations.

The figure below is taken from the Prüss review paper and illustrates how the risks of illness vary according to bacterial counts in the various individual studies in marine waters.



Predicted risks of illness in swimmers against bacterial count in marine water

(Figure 4 from Prüss 1998, reproduced by permission of the International Epidemiological Association and Oxford University Press. We thank Dr Annette Prüss for supplying the figure)

It can be seen that there is great variation in the bacterial indicators used, and in the estimated degree of risk for a given indicator level.

3 RISK ASSESSMENT STUDIES

Quantitative risk assessment is an alternative approach to epidemiological studies. This method uses mathematical modelling to estimate the risks of illness from specific pathogens in the water. It requires knowledge of the levels of specific pathogens in the particular body of water, the infectious dose for the pathogen, and the degree of exposure to the polluted water.

In these models a large number of assumptions must be made about factors that have not and cannot be directly measured. For example, in the study by Ashbolt et al (1997) the concentration of each pathogen was determined by taking its measured concentration in primary effluent and making many assumptions about how it mixes in the marine waters. Also of concern is the use of dose response curves based on very limited data. In almost all human studies the uncertainty surrounding these point estimates is enormous and subject to wide confidence intervals.

This approach has been applied to assessing the risk of gastroenteritis from ingestion of drinking water or seawater. However the applicability of this method is limited by lack of empirical data on the relevant parameters and the consequent large error factors in estimates of risk. While direct measurement of individual pathogens is possible, it is generally impractical and highly expensive. Use of indicator organisms introduces another level of uncertainty as there is insufficient data to correlate pathogen numbers with indicator organisms under the wide range of natural environmental conditions.

A second important limitation of the risk assessment approach is that the risk of infection can only be calculated for conditions associated with ingestion of microorganisms. This is because our knowledge of the “infectious dose” of specific microorganisms is essentially limited to such situations, and is based on studies of pathogens in food or drinking water. Conditions such as skin or ear infections which are caused by external contact with microorganisms, or respiratory infections caused by inhalation of microorganisms are therefore not amenable to the risk assessment approach at the present time.

For these reasons we consider the use of this method to be of limited value in assessing the risk of disease among swimmers.

4 WATER QUALITY AT GUNNAMATTA BEACH

To relate the findings from the studies to the situation at Gunnamatta beach it is necessary to examine the water quality there.

The initial phase of this review was undertaken in late 1997. At that time the only water quality measurements available for Gunnamatta beach were E.coli counts for the period January 1992 to July 1997. These water samples were taken close to the shoreline at several sites along the beach. Therefore it was only possible to assess the health risks of swimming at Gunnamatta relative to a few published studies which used this indicator organism.

It was then recommended by this consultancy that the water sampling program be expanded to include tests for Total Coliforms and Enterococci as well as E.coli, and that the sampling should be carried out in areas offshore where surfers commonly swam.

Sample size calculations for the program are summarised below. The table presents the 95% confidence intervals which would apply for different numbers of samples where the indicated percentage of samples are positive. Given the low E.coli numbers present in shoreline samples collected from 1992 to 1997, and the anticipated dilution factor for offshore samples it was expected that 2% or less of samples would be positive.

Sample number	50	100	250
2% positive	0-20	0-7	1-5
5% positive	1-26	2-11	3-9
10% positive	3-21	5-17	7-14

Melbourne Water undertook an expanded water sampling program in line with these recommendations during January 1998, with the aim of collecting at least 100 samples. Water samples were collected with the assistance of the Surf Lifesaving Club.

However opportunities for sampling were limited by unfavourable weather conditions. Water samples were collected from 1m below the surface on 4 occasions from 7 locations where surfing occurs. Three replicate samples were collected from each location, giving 84 samples in total.

4.1 Shoreline samples - January 1992 to July 1997

Sites	Mean Ecoli cfu/100ml	Median E.coli cfu/100 ml (75th percentile)	Geometric mean titre (GMT)	Number of Readings \geq 320 fu/100ml for E.coli	% of Readings \geq 320 cfu/100ml for E.coli (95% CI)
Beach No 1	38	2 (13)	4.95	7/296	2% (1-5%)
Beach No 2	92	2 (3)	2.62	2/296	1% (0-3%)
Beach No 3	98	2 (2)	2.62	5/296	2% (1-4%)
Beach No 4	11	2 (4)	2.50	3/296	1% (0-3%)
Beach No 5	35	5 (14)	6.30	4/295	1% (0-4%)
Beach No 6	10	2 (2)	2.18	2/292	1% (1-3%)

95 % CI = 95% confidence intervals

A cutoff level of 320 cfu /100 ml for E.coli has been selected as representing significant pollution in accordance with the results of the Santa Monica study. There was considerable variation in E.coli readings between the different sampling sites. The worst sites had 2% of samples with E.coli levels over 320 cfu/100ml while the best site had only 2 of 296 samples exceeding this level (refer to map on page 17 for location of sampling sites).

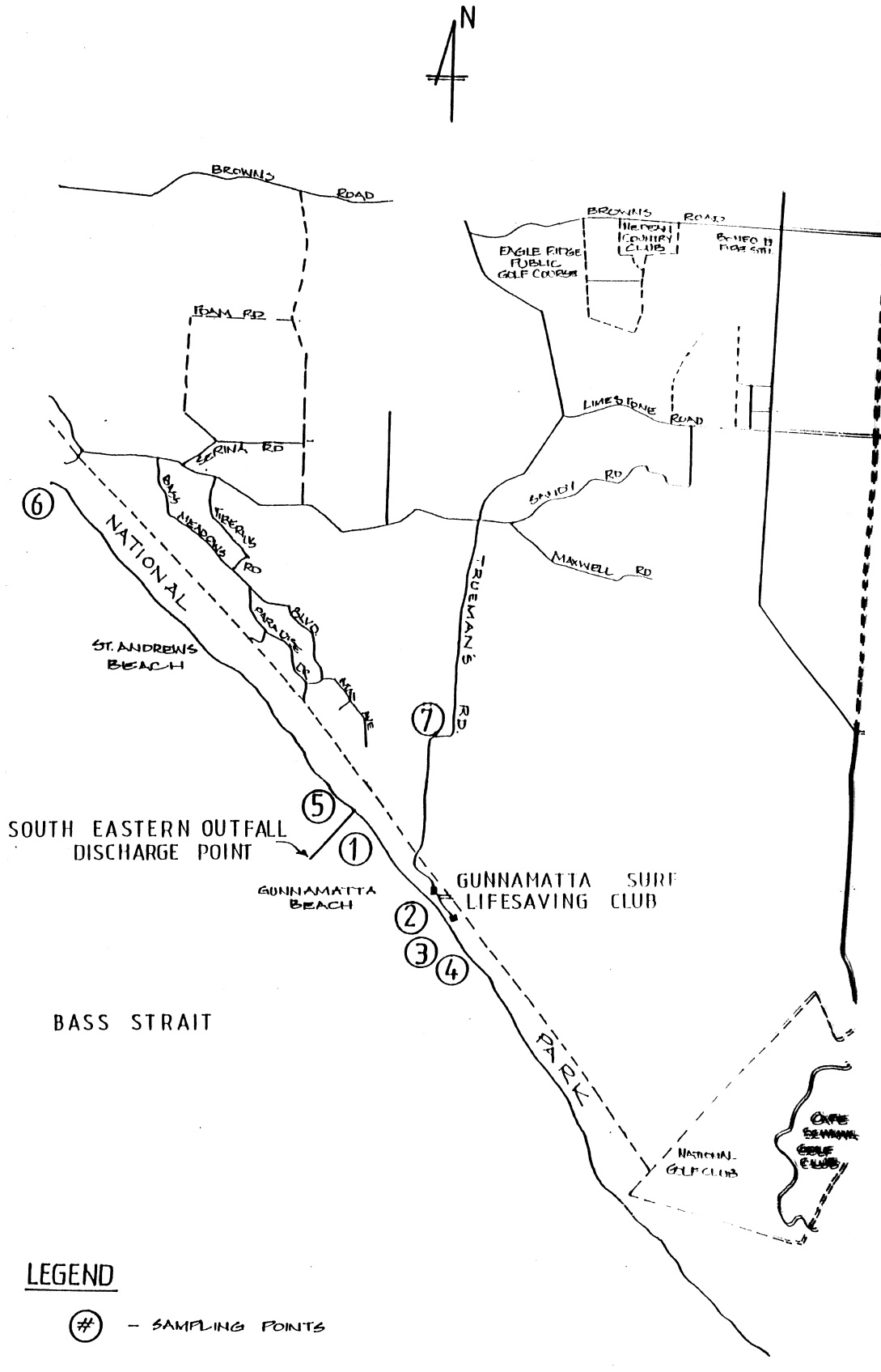
4.2 Offshore samples - January 1998

	Total coliforms	Enterococci
Number of samples	84	84
Number of positive samples	54	7
Range (cfu /100ml)	0 - 76	0 - 3
Arithmetic mean	5.01	0.13
Geometric mean *	1.84	0.54
Median	2	0

* Adjusted geometric means were calculated by assuming samples with 0 organisms detected had 0.5 organisms.

Map of Gunnamatta Beach area showing location of shoreline sampling sites

(supplied by Melbourne Water Corporation)



5 THE RISK OF DISEASE AT GUNNAMATTA BEACH

An increase in the risk of disease associated with marine water effluent pollution has been observed in the majority of cohort studies, and has been confirmed by randomised trials. The type and level of indicator organisms used to compare the “polluted” water to the “clean” water varied in different studies.

For Gunnamatta beach comparisons can be made with published studies which used E coli, Total Coliforms or Enterococci.

Comparisons using E.coli counts

Six of the published studies measured E.coli levels:

Fattal, et al. 1986, Holmes 1989

In these studies the water quality was far worse than Gunnamatta beach so that the water quality at Gunnamatta beach was more similar to the “control” beach or “clean” beaches than it was to the “polluted” beaches. Therefore no comparisons can be made to Gunnamatta.

Von Schirnding et al. 1993

In this study the E.coli counts at the clean and polluted beaches were not significantly different, so this study is not helpful.

There were however three studies with E.coli counts similar to Gunnamatta Beach.:

Santa Monica Study, 1996, Bandaranayake et al. 1995

These two studies reported no excess disease risk among individuals swimming in water quality similar to that seen at the beach sites at Gunnamatta.

Cabelli et al. 1983

In this study insufficient data was presented in the report to determine a threshold level of E.coli that was associated with an increased risk of disease. It should be noted however that there was a relationship between disease and E.coli levels below a mean of 100 cfu/100ml which may correspond to the water quality at beach site 3.

Comparison using Total Coliform counts

Four of the published studies used Total Coliform counts to assess water quality.

Alexander et al 1992

The geometric mean Total Coliform counts in this study were vastly in excess of those observed at Gunnamatta, with values of 1896 and 2141 per 100ml at the 2 sites sampled. Therefore no comparisons can be made with Gunnamatta beach.

Cabelli et al 1982

Total Coliforms were measured at only 2 of the 5 beaches reported in this paper, and this parameter is not used in analysis.

Ferley et al 1989

The least polluted beach assessed in this study had Total Coliform counts greatly above the levels observed at Gunnamatta - with a geometric mean of 786 per 100ml. Therefore no meaningful comparison can be made.

Santa Monica Study 1996

This study does not provide actual counts for indicator organisms but rather presents information on the percentage of samples exceeding a cutoff level. For Total Coliforms this cut off was 10,000 cfu /100ml. The percentage of samples exceeding this level for different areas on the coast were:

at storm water drain	8.6%	exceeded	10,000	cfu /ml
100 yards upcoast	0.4%	"	"	"
100 yards down coast	0.9%	"	"	"
400 yards downcoast	0.0%	"	"	"

The location 400 yards downcoast of the storm water drain was considered to represent "clean" water. In the absence of actual colony counts or sample numbers this information cannot be directly compared to the water quality at Gunnamatta. At Gunnamatta the maximum Total Coliform count recorded was 76 organisms per 100ml, well below the 10,000 per 100ml cutoff level used in this study.

Comparison using Enterococcus counts

Five studies used Enterococcus as an indicator organism to assess water quality.

Bandaranake et al. 1995

In this study the Enterococcus counts at the "clean" beaches were higher than the counts at Gunnamatta (Arithmetic means 19.2 and 1.9, Geometric means 2.8 and 1.2 respectively). Swimmers at these beaches were not at increased risk for gastrointestinal illness or respiratory illness than non-swimmers. When data for all beaches was analysed according to enterococcus counts (regardless of whether the beach was expected to be "clean" or "polluted") there was no evidence of increased risks for water quality in the lowest quartile of enterococcus density (arithmetic mean 0-1.5).

Cabelli et al 1982

This study found that Enterococcus numbers showed the strongest correlation with total and highly credible gastrointestinal illness. It was estimated that significant excess risks began at a threshold level of about 10 Enterococci per 100ml. At this level the risk of total gastro for swimmers was estimated at 1.5 times the rate for non-swimmers, and the risk for highly credible gastro was estimated to be about 2 times the rate for non-swimmers.

The Enterococcus numbers at Gunnamatta are about 10 fold lower than this level, therefore the risks would be much lower.

Fattal et al 1986

In this study the "clean" beaches had Enterococcus counts of 0 - 24 per 100ml with a median of 7 per 100ml. Thus their water quality was on average worse than that at Gunnamatta.

There was no significant difference in the rates of illness between swimmers and non-swimmers at these beaches.

Holmes 1989

The geometric means of Enterococcus counts for "relatively unpolluted" beaches ranged from 0 to 39 /100ml - much higher than the counts at Gunnamatta. Therefore no comparisons can be made with this study.

Santa Monica study 1996

Bacteriological water quality was presented as the percentage of samples exceeding a cutoff level. For Enterococci this cut off was 106 cfu /100ml. The percentage of samples exceeding this level for different areas on the coast were:

at storm water drain	28.7%	exceeded	106	cfu /ml
100 yards upcoast	6.0%	"	"	"
100 yards down coast	9.6%	"	"	"
400 yards downcoast	1.3%	"	"	"

The location 400 yards upcoast was considered to be "clean" water in this study and was used as the reference point to estimate excess disease risks for people swimming closer to the drain outlet. Clearly the water offshore at Gunnamatta has much lower numbers Enterococcus than this, with the maximum count being only 3 organisms per 100ml.

Von Schirnding 1993

In this study the "clean" beach had water quality worse than Gunnamatta with a mean Enterococcus count of 8.6 per 100ml . Therefore no inferences can be drawn.

6 SPECIFIC CONSIDERATION OF SKIN AND EYE SYMPTOMS

Surfers at Gunnamatta have raised concerns specifically about skin and eye irritations which they believe occur more frequently after surfing at Gunnamatta than other beaches. These types of disease have been studied infrequently in epidemiological studies of bathing, with most attention being directed to gastrointestinal disease. Details of those studies which have examined skin and eye ailments are presented below.

Alexander et al 1992

This study examined the reported rates of various symptoms in children before and after visiting sewage polluted beaches (with much higher indicator organism levels than Gunnamatta). Children were classified as having "no contact" with water or having "contact" (swimming, paddling or playing by the water). There was a significant increase in the rate of "itchy skin" or "rash + itchy skin" among children in the contact group. There was no significant increase in "red eyes" or "sore or itchy eyes".

Balaranjan et al 1991

The rate of "eye symptoms" was not significantly different between bathers and nonbathers, but was significantly higher for surfers and divers. The levels of indicator organisms were not clearly stated, just that the water failed the EC mandatory thermotolerant coliform level on 12% of tests.

Bandaranayake et al 1995

Data was collected under the category "OSPRI" - other significant people related illness, (comprising ear, eye, throat and skin infections). However the risk of such illness was found to show no relationship with any indicator organism, and was not further analysed.

Corbett et al 1993

"Eye symptoms" were significantly increased in swimmers as compared to non swimmers, however there was no consistent dose-response effect. People who swam only once had a higher risk than people who swam more than once, and the risk did not increase with longer time spent swimming.

Fattal et al 1986

Swimmers at beaches with low pollution levels (but still more highly polluted than Gunnamatta) did not have increased risk of skin symptoms compared to non swimmers.

Ferley et al 1989

The reported rate of skin disease increased with increasing pollution however levels of indicator organisms even at "clean" beaches were well above those found at Gunnamatta.

Fleisher et al 1996

Eye and skin ailments were examined in the UK randomised trials. Bathers had a significantly increased rate of eye ailments (red or sore eyes) compared to non bathers. However those who bathed in water with the highest levels of indicator bacteria did not have increased risk compared to those who bathed in the least polluted water. The risk of eye ailments did not increase with duration of swimming.

Skin ailments (rash, sores, ulcers or itching) were not significantly increased in bathers relative to non bathers. Again there was no significant difference in rates between those who bathed in the most polluted water and those bathing in the least polluted water.

Holmes 1989

Swimmers had significantly higher rates of skin complaints and eye/ear complaints than non swimmers. When swimmers at "barely acceptable" beaches were compared with those at "relatively unpolluted" beaches using different indicator organisms to define the cutoff between beaches, eye/ear complaints showed an inverse relationship with lower illness rates at the worst beaches. The rate of skin complaints was generally higher at the more polluted beaches regardless of the indicator used.

However the levels of indicator organisms at even the "relatively unpolluted" beaches in this study were much higher than those at Gunnamatta.

Santa Monica Study 1996

Limited data on skin rashes are presented in this study. It was estimated that swimming in water with >10,000 Total coliforms /100ml or >400 Faecal coliforms/100ml was associated with twice the risk of skin rash than swimming in clean water. From consideration of the data on indicator organisms it is evident that the water quality at Gunnamatta is similar to or better than the "clean" water at Santa Monica.

Seyfried et al 1985

Rates of eye and skin symptoms were higher in swimmers than non swimmers, but statistical significance was not reported. Only total staphylococci numbers were found to be significantly associated with skin and eye symptoms. Staphylococci are not faecal organisms - they are believed to originate from swimmers themselves.

Von Schirnding et al 1993

The "clean" beach in this study had water quality worse than at Gunnamatta, and the rates of skin symptoms was not different between swimmers and non swimmers.

Summary

There is a fairly general observation of increased rates of skin or eye ailments among swimmers vs non swimmers although in most studies the indicator bacteria levels were much higher than at Gunnamatta.

It is notable that a number of studies which were able to look for a dose-response relationship (ie increasing risk with increasing exposure) did not find such an effect. This is not consistent with an infectious agent or agents being responsible for these symptoms.

7 ADDITIONAL ISSUES IDENTIFIED IN THE REVIEW

There are a number of relevant issues in addition to an excess disease risk that are evident from the review of the available literature.

What is an acceptable level of illness?.

In this review we are concerned with determining if there is ANY increased risk of disease associated with swimming in a polluted beach compared to a non-polluted beach. It should be noted however that the concept of “acceptable risk” has been adopted in setting recreational water quality guidelines in many countries.

Work by Cabelli and co-workers in the US led to an initial proposal that a risk of 60 illnesses per 10,000 swims be adopted as acceptable. This was estimated to correspond to a geometric mean of 3 enterococci /100ml of water. However after public consultation, this level was raised to 190 illnesses per 10,000 swims which corresponded to about 35 enterococci /100ml sample. Ashbolt’s risk assessment of Sydney ocean beaches estimated that the risk of Giardia infection may be up to 74 illness per 10,000 swims (Ashbolt et al 1997).

Randomised trials conducted by Fleisher and coworkers also assessed the risk of gastroenteritis for non-swimming risk factors and found that consumption of some fast foods was associated with a similar risk of gastroenteritis as swimming in moderately polluted water (containing up to 79 faecal streptococci /100ml).

It is beyond the scope of this review to identify if such risk levels are acceptable or not to the public who swim at Gunnamatta beach.

Choice of indicator organism

A large number of different indicators have been used in different studies. The use of total coliforms, and E.coli or thermotolerant coliforms is fairly universal. Other frequently used indicators are faecal streptococci or enterococci, staphylococci, and Pseudomonas aeruginosa. Measurement of enteric viruses has been used occasionally.

No single indicator stood out in the literature as being sufficiently superior that other indicators do not have a place in measuring water quality in the setting of an epidemiological study.

The reported relationships of individual indicator organisms to illness risks are variable. There appears to be growing support for using enterococci or faecal streptococci in combination with total coliforms and E.coli or thermotolerant coliforms. The lack of a single “ideal” indicator organism is not surprising - many different pathogens are potentially present in effluent, and these will have differing survival characteristics relative to time, temperature, salinity, UV exposure etc. Therefore it is probably unrealistic to expect one microorganism to always be a good indicator of risk under all environmental conditions.

Water sampling program

Water sampling for epidemiological studies has generally been on basis of one or two samples per day at only one position on the beach. This probably reflect budgetary constraints rather than a sampling program planned to take account of variations in indicator levels over time

and distance. Some authors are strongly of the opinion that such infrequent sampling is inadequate to permit accurate exposure assessment. Measurement at the time and place of swimming for each individual would be optimal, but to date this protocol has been adopted only in a few studies including the UK randomised trials.

Nature of exposure

The type of exposure is also important. Most studies were undertaken of swimmers and not surfers. If surfers swim for longer than a swimmers in the epidemiological studies then their chance of acquiring an illness may be expected to be greater. Conversely if surfers tend to swim further away from the shoreline than regular swimmers, the dilution factor for pollution would be higher and the level of potential pathogens (and indicator bacteria) would be lower. This would be expected to lower the risk of illness.

8 CONCLUSIONS

A number of epidemiological cohort studies have found increased risks of disease are associated with swimming in waters polluted by effluent, as compared to swimming in unpolluted waters. While these studies have some methodological weaknesses, their conclusions have been supported by a series of randomised trials recently conducted in the UK. It should also be noted that swimming even in unpolluted water carries an increased risk of illness compared to not swimming.

The majority of epidemiological studies have concentrated on gastroenteritis symptoms with a lesser emphasis on other types of illness such as eye, ear and respiratory diseases and skin symptoms. Generally gastroenteritis symptoms are the most frequently reported to be associated with swimming.

Considering the sample sizes required (several thousand people) for epidemiological studies with adequate statistical power to assess health risks associated with swimming, it would appear to be not feasible to undertake such a study at Gunnamatta Beach.

The quantitative risk assessment approach is also considered not appropriate for assessing possible health risks at Gunnamatta Beach, as no data are available on specific pathogens in effluent and there are many uncertainties with this approach.

Attempts to correlate measurements of indicator organisms with health risks have given conflicting results, and no single indicator has been demonstrated to be adequate for predicting the risk for wide range of symptoms which may occur. Enterococcus and total coliforms provide the most consistent relationship but it should be remembered that all are surrogates for the large number of different organisms that cause disease.

The available information on bacterial indicator organisms for Gunnamatta Beach comprises E.coli counts taken close to shore and Total Coliforms and Enterococci taken offshore in areas where surfers generally swim. Comparison of these data to published papers shows that the water quality at Gunnamatta is similar to or better than the "clean" beaches in published studies. Therefore it is very unlikely that swimmers at Gunnamatta Beach would be at increased risk of illness due to faecal microorganisms in the treated effluent being discharged there, compared to swimmers at other ocean beaches.

9 RECOMMENDATIONS

It is recommended that:

- the expanded microbiological monitoring program be continued next summer to provide a larger water quality data set.
- that the medical literature be periodically reviewed to assess any new information on the risks associated with swimming in waters receiving sewage effluent.

To clarify the cause of the reported skin symptoms among surfers at Gunnamatta Beach it may be helpful if affected people seek microbiological investigation of apparently infected wounds via their medical practitioner.

Table 1 Cohort studies comparing swimmers and non-swimmers

Reference and location	Design and number of subjects	Method	Type of pollution	Clinical disease end point	Illness associated with swimming
Alexander et al 1992 UK	prospective cohort at 1 beach over 7 weekends 1406 children aged 6 to 11 years	beach interview and telephone or postal follow up 10-14 days later	raw effluent	gastroenteritis respiratory disease ear disease skin disease	vomiting diarrhoea fever itchy skin lack of appetite lack of energy
Balarajan et al 1991 UK	prospective cohort at 1 beach over 3 weeks 2010 subjects 5 - 64 years	beach interview and telephone follow up 1 week later	effluent treatment not stated	gastroenteritis respiratory disease ear disease eye disease	gastroenteritis diarrhoea
Bandaranayake et al 1995 NZ	prospective cohort at 7 beaches over 2 months 3,884 people aged 5 years and over	beach interview and telephone or postal follow up 3 days later	treated effluent or rural runoff	gastroenteritis respiratory disease eye /ear /throat or skin disease	gastroenteritis skin diseases
Brown et al 1987 UK	retrospective cohort study at 2 beaches 1903 people	beach interview	effluent discharge at 1 beach	gastroenteritis respiratory disease eye disease ear disease skin disease	gastroenteritis headache

Table 1 Cohort studies comparing swimmers and non-swimmers (continued)

Reference and location	Design and number of subjects	Method	Type of pollution	Clinical disease end point	Illness associated with swimming
US Cabelli et al 1982	prospective cohort study at 6 US beaches 26,686 people	beach interview with telephone follow up 8-10 days later	effluent (domestic wastewater)	gastroenteritis respiratory disease other illness (headache, fever, skin condition, backache) disability (staying home due to illness, medical care)	gastroenteritis
Australia Corbett et al 1993	prospective cohort study at 12 beaches 2839 people	beach interview with telephone follow up 7 to 10 days later	effluent and storm water	gastroenteritis respiratory disease eye disease ear disease fever	cough ear symptoms
Israel Fattal et al 1986	prospective cohort study at 3 beaches 2,231 people	beach interview with telephone follow up 3 to 4 days later	effluent at 2 beaches	gastroenteritis respiratory disease general (skin, ear, conditions, fever)	gastroenteritis skin disease
France NB fresh water Ferley et al 1989	retrospective cohort at 5 beaches over 2 months 5737 tourists from 8 holiday camps	interview at camp covering up to 8 days prior	untreated effluent	gastroenteritis respiratory disease ear/nose/throat disease eye disease skin disease	gastroenteritis skin disease

Table 1 Cohort studies comparing swimmers and non-swimmers (continued)

Reference and location	Design and number of subjects	Method	Type of pollution	Clinical disease end point	Illness associated with swimming
Fleisher et al 1996 UK	randomised trial at 4 beaches 1216 people over 18 years of age	beach interview with telephone follow up at 7 days and 3 weeks	effluent	acute febrile respiratory illness ear ailments eye ailments skin ailments	acute febrile respiratory illness ear ailments eye ailments
Harrington et al 1993 Australia	prospective cohort study following swimmers over 3 months 2003 people	diary returned by post every month	effluent and storm water	not specifically listed but included: gastroenteritis respiratory disease ear disease eye disease	any symptom respiratory illness
Holmes et al 1989 Hong Kong	prospective cohort study at 9 beaches 18,986 people	beach interview with telephone follow up		gastroenteritis respiratory disease ear and eye disease skin disease	gastroenteritis respiratory disease ear and eye disease skin disease
Kay et al 1994 UK	randomised trial at 4 beaches 1216 people over 18 years of age	beach interview with telephone follow up at 7 days and 3 weeks	effluent	gastroenteritis	gastroenteritis

Table 1 Cohort studies comparing swimmers and non-swimmers (continued)

Reference and location	Design and number of subjects	Method	Type of pollution	Clinical disease end point	Illness associated with swimming
Seyfried et al 1985a, b Canada NB fresh water	prospective cohort at 10 beaches over 3 months 4537 people wide age range	beach interview and telephone or postal follow up 7 to 10 days later	not stated	gastroenteritis respiratory disease ear disease eye disease skin disease	increased rates for all symptoms but statistical significance not stated
Von Schirnding et al 1993 South Africa	prospective cohort at 2 beaches 5,551 people wide age range	beach interview with telephone follow up 3-4 days later	effluent and stormwater	gastroenteritis respiratory disease skin disease	gastroenteritis at "worst" beach respiratory disease at "better" beach

Table 2 Cohort studies comparing swimmers with different degrees of exposure

Reference and location of study	High exposure group	Medium exposure group	Low exposure group	Clinical disease end point	Illness associated with increasing exposure (does not include swimmer vs non-swimmer comparisons)
Balarajan et al 1991 UK	surfers/divers	other swimmers	waders	gastroenteritis respiratory disease ear disease eye disease	all symptoms surfers/divers had increased risk of eye and respiratory symptoms
Bandaranayake et al 1995 NZ	swimmers who swam for > 30 mins and immersed their head	swimmers who swam for less than 30 min and immersed their head	paddlers who entered the water but did not immerse their heads	gastroenteritis respiratory disease eye /ear /throat or skin disease	increased risks of gastroenteritis and respiratory symptoms were seen in long duration swimmers
Brown et al 1987 UK	swimmers who immersed their head	-	swimmers who did not immerse their head	gastroenteritis respiratory disease eye disease ear disease skin disease	increased rates for gastroenteritis and headache for high exposure group
Corbett et al 1993 Australia	swimming more than once between interview and follow up	-	swimming once between interview and follow up	gastroenteritis respiratory disease eye disease ear disease fever	“high” exposure group had decreased rates of gastroenteritis, fever, eye, ear and cough symptoms

Table 2 Cohort studies comparing swimmers with different degrees of exposure (continued)

Reference and location of study	High exposure group	Medium exposure group	Low exposure group	Clinical disease end point	Illness associated with increasing exposure (does not include swimmer vs non-swimmer comparisons)
Ferley et al 1989 France NB fresh water	swimmers at 2 most polluted beaches	swimmers at 2 intermediate polluted beaches	swimmers at least polluted beach	gastroenteritis respiratory disease ear/nose/throat disease eye disease skin disease	higher rates of gastroenteritis and skin disease at intermediate and most polluted beaches, compared to least polluted beach
Harrington et al 1993 Australia	high frequency swimmers (>once per month)	-	low frequency swimmers (< once per month)	not specifically listed but included: gastroenteritis respiratory disease ear disease eye disease	no statistically significant increases in risk
Seyfried et al 1985a, b Canada NB freshwater	swimmers who immersed head	-	swimmers who did not immerse head	gastroenteritis respiratory disease ear disease eye disease skin disease	rate of ear illness greater in swimmers who immersed their head
“	swimmers at 3 beaches with treated effluent pollution	swimmers at 2 beaches with rural runoff pollution	swimmers at 2 beaches with minimal pollution		increased risks of gastroenteritis and respiratory symptoms were seen at effluent polluted and rural polluted beaches relative to unpolluted beaches

Table 3 Association of indicator organisms with illness

Reference and location	Type of pollution	Water sampling program	Indicator organisms	Indicator levels	Comment
Alexander et al 1992 UK	raw effluent	2 samples x 2 locations (both ends of 1 beach) per day	total coliforms faecal coliforms faecal streptococci enteroviruses	Geometric means Location A / B 1896 / 2141 895 / 826 290 / 139 4 / 2	insufficient data to correlate indicator levels with risk of illness
Balarajan et al 1991 UK	effluent treatment not stated	daily, number of sites not stated	total coliforms thermotolerant coliforms faecal streptococci	12% of samples failed mandatory EC standard for thermotolerant coliforms	insufficient data to correlate indicator levels with risk of illness
Bandaranayake et al 1995 NZ	rural run off and effluent	3 times a day	faecal coliforms enterococci E. coli Staph. aureus RNA bacteriophages	E coli cfu per 100 ml. in percentile from 0, 25,50,75,100 were 0, 3, 6, 28.3, 552	There was no consistent trend between E coli counts and disease risk although the correct analysis to fully interpret this was not undertaken. There was a suggestion that disease risk increased with enterococci levels although again the correct analysis was not presented.
Brown 1987 UK	Effluent	NA	faecal coliforms	GMT Faecal coliforms 440cfu vs 10 cfu/100ml	Gastroenteritis was more common in polluted beach.
Cabelli 1983 US	treated effluent	daily, at 3-4 sites	total coliforms faecal coliforms enterococci E. coli Klebsiella Enterobacter P aeruginosa A. hydrophilia	Median enterococcus about 100, median faecal coliform about 500	Very clear relationship between disease and enterococci and E.coli. Threshold level of about 10cfu/100ml for both indicators.
Corbett 1993 Sydney	effluent	daily	Faecal coliforms Faecal streptococci	FC GMT 389-591 FS GMT 43-66cfu	linear relationship with faecal coliforms. 50% increase in disease 10-300 cfu versus 300-1,000

Table 3 Association of indicator organisms with illness (continued)

Reference and location	Type of pollution	Water sampling program	Indicator organisms	Indicator levels	Comment
Fattal 1986 Israel	effluent	twice daily	Faecal coliforms faecal streptococci enterococci E.coli Staph aureus Pseudomonas aeruginosa	Means Faecal coliforms (38-117), faecal streptococci (19-67), enterococci (10-41), E.coli (5-30),	Enteric disease was more common among swimmers in beaches with higher levels of enterococci (GMT of 0-24 cfu/100ml vs >24 cfu), and of E.coli (GMT of 0-24 cfu/100ml vs >24 cfu) compared to beaches with low levels
Ferley et al 1989 France NB fresh water	untreated effluent		total coliforms faecal coliforms faecal streptococci Aeromonas P. aeruginosa		
Holmes 1989 Hong Kong		Every 3 hours at 2 sites	faecal coliforms E.coli Klebsiella faecal streptococci enterococci staphylococci, Pseudomonas fungi	GMT Ecoli of 249	A higher rate of illness was seen for Faecal coliforms (0-410 vs 410-3200 cfu/100ml), E.coli (0-180 vs 180-1,800 cfu/100ml), Klebsiella (0-100 vs 101-1,000 cfu/100ml) faecal streptococci (0-55 vs 26-290cfu/100ml) enterococcus (0-39 vs 40-250) and staphylococci (0-1,000 vs 1001-3000 cfu/100ml).
Santa Monica Bay USA	storm water	daily 4 sites	Ecoli (>320 cfu) Enterococcus (>106cfu) Total coliforms (>10,000) Faecal coliforms (>400)	Ecoli (>320 cfu) 1-25% Enterococcus (>106cfu) 1-29% Total coliforms (>10,000) 0-9% Faecal coliforms (>400) 1-30%	Levels associated with disease Ecoli (>320 cfu) Enterococcus (>106cfu) Total coliforms (>10,000) Faecal coliforms (>400)

Table 3 Association of indicator organisms with illness (continued)

Reference and location	Type of pollution	Water sampling program	Indicator organisms	Indicator levels	Comment
Seyfried et al 1985a, b Canada	not stated		faecal coliforms faecal streptococci heterotrophic bacteria P aeruginosa staphylococci		
Von Schirnding et al. 1993. South Africa	effluent	daily at 3 sites	Enterococci faecal coliforms E.coli	Faecal coliforms GMT (32-54) Enterococci (8-17) E.coli (42-47)	Gastrointestinal illness was less at the clean beach (median FC of 8 cfu, 34 Ecoli, 3 enterococci) compared to the polluted beach (median FC of 20 cfu/100ml, 43 Ecoli, 9 enterococci). These are relatively low levels of indicators.

APPENDIX Summary of Papers

Alexander, L. M., A. Heaven, et al. (1992).

“Symptomatology of children in contact with sea water contamination with sewage.” *J Epidemiol Community Health* 46: 340-3.

Parents or guardians of children aged 6-11 years were recruited on a 2 km stretch of Blackpool beach over 7 weekends in the summer holiday period from July to Sept 1990. One child per family was included in the study. An interview was conducted on the beach covering demographics, water exposure, foods and health status for the 2 days prior plus the interview day. Participants were told the study related to leisure activities and general health of children. The beach was contaminated with raw sewage and failed to meet prevailing EC standards for recreational waters in more than 90% of samples.

Beach interviews were completed for 939 children, and 857 (91.9%) parents /guardians agreed to complete a follow up interview. Of these, 719 (83.9% of the 857) were contacted again by phone or letter 10 to 14 days later and similar questions were asked covering the interval since the beach visit. Water sampling was done once each day during the study period at the each end of the 2 km study area. Samples were collected at waist depth on the incoming or high tide, and analysed for total and faecal coliforms, faecal streptococci, salmonella and enteroviruses.

Geometric means for each organism were as follows:

Organism	Site A (15 samples)	Site B (16 samples)
Total coliforms	1896	2141
Faecal coliforms	895	826
Faecal streptococci	290	139
Enteroviruses	4	2
Salmonella (presence /absence only)	present in 67% of samples	present in 50% of samples

NB the volume upon which these figures are based is not stated in the paper - it is likely to be 100ml as is standard practice for environmental water samples.

“Contact” was defined as “swimming, paddling or playing by the water”. Data analysis was done on 703 matched data sets (455 children from the contact group and 248 from the no contact group who had complete data for both interviews). Both groups showed an overall increase in reported symptoms between interview 1 and interview 2. A statistically significant increase in 7 individual symptoms (vomiting, diarrhoea, itchy skin, sunburn, fever lack of energy, lack of appetite) was found in the contact group but not in the no contact group. One symptom (blocked nose) increased significantly in the no contact group but not in the contact group. Symptoms showing a statistically significant increase in both groups were sore throat, nausea /feeling sick, and stomach pains /cramps.

The increased rate of symptoms in the contact group was not associated with age, sex, prior illness, food consumption, acute symptoms in other household members, or water related activity between the two interviews. It was not possible to determine any association between illness and water quality parameters on particular days due to high variability in the number of interviews carried out each day, and the relatively infrequent water sampling program.

The authors conclude that there is strong evidence that children in contact with sea water which fails to meet recreational water standards are at significantly increased risk of experiencing symptoms. These symptoms (vomiting, diarrhoea, itchy skin, fever, lack of energy and loss of appetite) are consistent with sewage contaminated water.

Ashbolt, N. J., C. Riedy, Haas C.N. (1997).

Microbial Health Risk at Sydney's Coastal Bathing Beaches. 17th Federal Convention, Australian Water and Waste Water Association, Melbourne, AWWA Inc.

Prior to the commissioning of deep outfalls, Sydney sewage was discharged at the low water line causing pollution of nearby beaches. During heavy rains, storm water overflows were also a source of contamination. This paper describes risk assessment modelling for infection of swimmers by Salmonella, Shigella, Giardia and Cryptosporidium in addition to two viruses (hepatitis A and rotavirus). This modelling was undertaken because the authors considered there was confusing results from epidemiological studies. In particular there it was considered that there was considerable uncertainty surrounding which indicator organism should be used. The authors also highlight the disparity between the acceptable level of disease associated with drinking water (less than a 1 in 10,000 annual risk of illness) compared to the 190 illness per 10,000 swims suggested by Cabelli's work in the US.

Estimated numbers of Giardia, Cryptosporidium and enteric viruses. Assumed dilutions based on index bacteria and that this did not vary temporally. Assumed ingestion of 50mls seawater per hour and 2 hour swims. Assumed dose response data from small published studies.

The exposure was estimated to be consumption of water containing these organisms. A number of assumptions were made about the concentration of the organisms in the sea water. It was assumed that swimming resulted in ingestion of 50ml of seawater per hour. Previously published dose response curves were used to estimate the number of organisms need to cause disease.

The data was expressed in illnesses per 10,000 bathers. Giardia and enteric viruses were estimated to account for up to 74 or 37 illnesses per 10,000 bathers. Risk estimates for Salmonella, Shigella and Cryptosporidium were low (<1/10,000). Installation of deep ocean outfalls have effectively increased the dilution factor for discharged sewage from 20-100 fold dilution to a 600 to 1,000 fold dilution, and disease risks would have been reduced accordingly.

The assumptions for exposure and dose response curves are poorly validated. While the authors state that they identified similar levels to those by epidemiological studies these calculations were carried out with knowledge of the epidemiological studies.

Balarajan, R., V. Soni Raleigh, et al. (1991).

"Health risks associated with bathing in sea water." BMJ 303(Dec 7): 1444-5.

A survey of 2010 subjects aged 5-64 years was carried out on Ramsgate beach, Kent over 3 weeks in August 1990. Recruitment was based on a quota sampling technique where specified numbers of participants were sought according to age, sex, and bathing /non-bathing status. Follow up phone calls were made to 94% (1883) subjects to determine whether a range of symptoms occurred within 1 week after leaving the area.

24.2% of participants reported one or more symptoms and the relative risk was significantly increased in bathers relative to non-bathers (RR=1.3, age and sex adjusted). A dose response relationship was seen when bathers were classified as waders (RR=1.25), swimmers (RR=1.31) or surfers /divers (RR=1.81).

When individual symptoms were examined, bathers were found to have a significantly increased risk for gastrointestinal illness (nausea, vomiting diarrhoea or stomach cramps, RR=1.47) and for diarrhoea (RR=1.88) compared to non-bathers. Surfers and divers also had significantly increased risks for eye conditions (RR=2.65) and respiratory symptoms (RR=2.85). There were insufficient data to assess the association between water quality measures and risk of illness. 12% of water samples failed to comply with the EC standard for thermotolerant coliforms.

Bandaranayake, D. R., C. E. Salmond, et al. (1995).

Health Effects of Bathing at Selected New Zealand Marine Beaches.

Studies were carried out at 7 beaches during January and February 1995. The beaches were chosen to represent a range of faecal contamination levels - “control” (2 beaches with minimal contamination), “rural” (2 beaches with pollution mainly from animal sources) and “oxidation pond” (3 beaches with pollution mainly from treated sewage). People at the beaches were recruited by interviewers and questioned about their activities on the interview day and for 3 days prior. Information collected included swimming, food consumption and demographics. Children under 5 years were excluded from the study.

Follow up telephone interviews were carried out 3 days later, and postal questionnaires were sent to those who could not be contacted by phone. The follow up included questions on a range of symptoms, food consumption, contact with animals other than household pets, and recreational water activities in the intervening period.

Subsurface (0.1m below surface) water samples were taken twice each day from 3 sites and 2 water depths (0.3m and 1.0m) on each beach. The 3 samples from each sampling time and depth were pooled for analysis - giving 4 measurements per beach per day. The organisms tested were faecal coliforms, E.coli and enterococci.

Of 5533 people interviewed, the data for 3,884 were able to be analysed. The majority of exclusions were due to people having swum in the intervening period between interviews. In terms of water activities the characteristics of the 3,884 individuals were as follows:

2,307 non-exposed (did not enter water)

1,577 exposed - consisting of:

377 paddlers (entered water but did not immerse their heads)

626 who swam for less than 30 mins, immersing their heads

574 who swam for more than 30 mins, immersing their heads

Illnesses reported by participants were classified as:

HCGI highly credible gastro-intestinal illness

POSSGI possible gastro-intestinal illness

ANYGI either HCGI or POSSGI

RESPI respiratory illness

OSPRI eye or ear infections, sore throat, skin rash

When crude risks for these disease categories were compared between the exposed groups and non-exposed group, elevated risks were noted for ANYGI in all swimmers, HCGI and RESPI in those who swam more than 30 mins, and RESPI in paddlers.

Mathematical modelling of relative risks for exposure at different quartiles of indicator bacteria with adjustment for age and other variables did not produce consistent patterns as would be expected for a dose-response relationship. Further analysis using deciles or actual numbers of enterococci failed to produce a clearer relationship. Analysis of the risk of illness according to the type of beach did not demonstrate any difference between “rural” and “oxidation pond” beaches, but both of these types had significantly higher risks of illness than “control” beaches.

The authors conclude that there was no basis for separating polluted beaches according to the type of pollution (ie animal waste vs treated sewage). Measurement of enterococci appeared to be the most appropriate indicator of health risks. The strongest association between enterococci numbers and risk was observed for RESPI in paddlers and long duration swimmers. A weaker association between ANYGI and enterococcal density was found for long duration swimmers.

The authors note that overall numbers of indicator bacteria were lower than expected (judging from preliminary studies the previous year) and this may have reduced their ability to detect a significant relationship with risks of illness. A number of recommendations are made for future revisions of recreational water guidelines:

- consideration should be given to including respiratory illness in the range of health effects in addition to gastrointestinal symptoms.
- enterococci should be the preferred indicator organism.
- the results of this study tend to support the prevailing median limit of 35 enterococci per 100ml which was derived from previous US studies. This is estimated to correspond to an excess risk of 19 cases of illness per 1,000 swimmers relative to non-swimmers.
- guideline limits should make provision for variability of single sample readings.
- consideration should be given to standardising sampling conditions (eg depth and timing of samples) based on empirical data on microbial survival.

Brown, J. M., E. A. Campbell, et al. (1987). “Sewage Pollution of Bathing Water.” Lancet (Nov 21): 1208-9.

This paper describes a cohort study undertaken at 2 UK beaches during July and August 1987. Water at Resort A was polluted by sewage discharge and had a geometric mean faecal coliform level of 440 /100ml during this period. Resort B was unpolluted, with a geometric mean faecal coliform count of less than 10 /100ml. 1402 people were interviewed at Resort A and 501 people at Resort B, and information was collected on swimming behaviour, health and knowledge of pollution.

People who swam at resort A had a higher rate of reported symptoms than those at Resort B, and both groups of swimmers had higher rates than non-swimmers. Highly statistically significant differences were found between Resort A swimmers who immersed their heads and non-swimmers for “generally felt ill”, stomach upset, diarrhoea and nausea. Swimmers at

Resort A who immersed their heads also had statistically increased risks of stomach upset and nausea than swimmers at the same resort who did not immerse their heads.

The authors also report on the result of intensive water quality monitoring at 27 beaches over a 10 day period. Prevailing European regulations required that 95% of samples have faecal coliform levels of less than 2000 /100 ml. 55% of the tested beaches passed this criterion in routine sampling in 1986, but only 37% met the standard during the brief intensive monitoring program. The comment is made that infrequent monitoring fails to provide adequate information on pollution levels.

Cabelli, V. J., A. P. Dufour, et al. (1982).

“Swimming associated gastroenteritis and water quality.” Am J Epidemiology 115(4): 606-616.

Prospective cohort studies of 26,686 swimmers were carried out at 6 US beaches from 1973 to 1978. Participants were recruited at the beaches and follow up questionnaires were completed by telephone 8-10 days later. A wide range of indicator organisms were measured during the initial 3 year period at New York beaches (enterococci, E.coli, Klebsiella, Enterobacter/Citrobacter, total coliforms, Clostridium perfringens, Pseudomonas aeruginosa, faecal coliforms and Aeromonas hydrophila). Subsequently, testing for most organisms except enterococci and E.coli was discontinued based on the early results.

Swimming was defined as “exposure of the upper body orifices (ie mouth and nose) to the water “- therefore corresponding to immersion of the head. Participants were questioned on the occurrence of gastrointestinal symptoms (vomiting, diarrhoea, stomachache, nausea) and whether such symptoms resulted in staying at home, remaining in bed or consulting a doctor. Highly credible gastrointestinal (HCGI) symptoms were defined as (i)vomiting, (ii)diarrhoea with fever or diarrhoea with staying home/staying in bed/seeing a doctor, or (iii) stomachache with fever or nausea with fever.

Swimmers has increased rates of gastrointestinal symptoms and HCGI. Illness rates were higher for swimming near known sewage pollution sources, but even relatively low levels of pollution were estimated to be associated with increased risk of illness. Of the indicators tested, enterococci showed the greatest degree of correlation with gastrointestinal symptoms and HCGI A threshold level for risk of about 10 enterococci /100ml was estimated

Cabelli, V. J., A. P. Dufour, et al. (1983).

“A marine recreational water quality criterion consistent with indicator concepts and risk analysis.” Journal WPCF 55(10): 1306-14.

This paper summarises a series of studies sponsored by the US EPA with the aim of developing recreational water quality criteria based on estimates of acceptable risk. These studies have served as models on which most subsequent cohort studies have been based.

The authors begin by reviewing the deficiencies of previous procedures for setting guideline levels and the scarcity of epidemiological data, then describe the design of their studies and repeat some of the data from previous publications.

The initial 3 year study at 2 New York beaches showed that enterococci numbers had the best correlation with total gastrointestinal symptoms (correlation coefficient 0.81) or HCGI

(correlation coefficient 0.96). E.coli numbers showed a weaker correlation with risks. Combined analysis of all the studies produced lower correlation coefficients but still showed enterococci to be a better indicator of risk than E.coli. The authors conclude that the relationship of health risk and enterococcal numbers is sufficiently strong to allow quantification of the risks and derivation of guideline levels once the degree of “acceptable risk” is defined.

Corbett, S. J., G. L. Rubin, et al. (1993).

“The Health Effects of Swimming at Sydney Beaches.” Am J Pub Hlth 83(12): 1701-6.

A prospective cohort study was conducted on 12 Sydney beaches over a total of 41 sampling days. Consenting volunteers were included if they were 15 years or older, had not swum in the previous 5 days and had no illness on the interview day that would have prevented them from swimming. Follow up telephone interviews were carried out 7 to 10 days later. Symptoms studied comprised vomiting, diarrhoea, cough, cold, fever, flu, eye or ear infections.

Swimming was defined as immersion of the head or face in the water, and subjects were also asked to estimate the amount of time spent in the water. Water samples were taken twice each day at a depth of 0.3 to 0.45 metres, and analysed for faecal coliforms and faecal streptococci. Low contamination levels were defined as a geometric mean for faecal coliform count of <300 CFU /100ml, and no single sample exceeding 2,000 cfu /100ml.

Of 9650 people approached to take part, 8413 agreed to participate but only 2839 were able to be included in the analysis due to exclusion for illness, swimming during 5 days prior, failure to contact for follow up or incomplete data. 915 (32.2%) were classified as non-swimmers, and only 303 (10.7%) had swum on days where contamination levels were high.

Swimmers were significantly more likely to report symptoms than non-swimmers, however those who swam between the interview day and the follow up day had a lower rate of symptoms than those who swam only on the interview day. The authors suggest two possible explanations for this - frequent swimmers may have a higher degree of immunity to waterborne pathogens, or those experiencing illness following their first swim may have been prevented from subsequent swimming because of this.

As pollution levels increased, the reported rate of symptoms also rose except for gastrointestinal conditions. When only subjects who did not swim between interviews were considered, increased risks for gastrointestinal symptoms were seen with increasing duration of swimming. Faecal coliform counts were better predictors of illness risk than faecal streptococci. For single day long duration swimmers the odds of illness (any symptom) relative to non-swimmers rose from 2.9 at 10-300 cfu/100ml to 5.9 at levels >3,000 cfu/100ml

The authors suggest that differences in the association of indicator organism with disease risks seen in different studies may reflect survival characteristics in chlorinated vs unchlorinated sewage, or in waters of different temperature.

Fattal, B., E. Peleg-Olevsky, et al. (1986).

“The Association between Morbidity among Bathers and Microbial Quality of seawater.” Wat Sci Tech 18(11): 59-69.

A prospective cohort study was carried out on 3 beaches in Israel during 1983. 2 of the 3 beaches were located within 5km of the main sewage outfall from the city of Tel Aviv, the

third was 15km distant and considered to have low pollution levels. 2,231 individuals were recruited from 615 families. A questionnaire was administered on the beach, with a telephone follow up 3 to 4 days later. Information was collected on enteric symptoms (vomiting, diarrhoea, abdominal pain, nausea), respiratory symptoms (throat infections, heavy cough, cold) and general symptoms (skin lesions, ear infections, fever). Reported morbidity (illness) was considered to be highly credible if associated with fever, or absence from work/school, or seeing a nurse/doctor or having lab test performed.

All people on the beach were classified as “bathers” while those who had immersed their head, had swallowed seawater or had their face splashed were defined as “swimmers”. Faecal coliforms, faecal streptococci, enterococci, E.coli, Staph aureus and Pseudomonas aeruginosa were measured twice daily in water samples from the most crowded swimming area of each beach. As expected the densities of bacteria of faecal origin (faecal coliforms, E.coli, faecal streptococci, enterococci) were higher at the 2 beaches closer to the sewage outfall. Numbers of P.aeruginosa and S.aureus did not vary significantly between the 3 beaches. The authors note that data on faecal streptococci was omitted from further analysis when it was found that many of the colonies growing on supposedly selective media could not be confirmed as genuine streptococci.

Enteric disease was more common among swimmers in beaches with higher levels of enterococci (0-24 cfu/100ml vs >24 cfu), and of E.coli (0-24 cfu/100ml vs >24 cfu) compared to beaches with low levels. Swimmers were also more at risk than non swimmers, and higher rates of illness were seen in young children below 5 years of age. The rates of respiratory illness were higher in swimmers than non swimmers but this did not correlate with bacterial densities in the water. The incidence of ear infections was significantly higher in swimmers compared to non-swimmers at high levels of faecal coliforms, E.coli or enterococci.

Ferley, J. P., D. Zmirou, et al. (1989).

“Epidemiological Significance of Microbiological Pollution Criteria for River Recreational Waters.” Internat J Epidemiol 18(1): 198-205.

NB Fresh water

5737 tourists were recruited from 8 summer holiday camps in the Ardeche river basin in France in July and August 1986. Untreated urban sewage was being discharged into the river at several points. 5 beaches were included in the study, but participants may also have bathed at other beaches along the river. Families were questioned about the 8 days prior to the interview with information being recorded on day and location of swimming activity, illnesses /symptoms experienced, type of meals eaten and drinking water. If swimming had occurred at non-study beaches, the following 3 days were excluded from analysis.

Water samples were taken every Monday and Thursday at each beach and tested for total and faecal coliforms, faecal streptococci, Aeromonas and Pseudomonas aeruginosa. The Monday sample was taken as representing exposure on Sun /Mon /Tues, and the Thursday sample as representing Wed /Thurs /Fri. Swimming on Saturday was excluded from analysis. Classification of the water exposure relative to each reported illness event was complex, and a maximum latency of 3 days was assumed. A total of 47,699 person-days of data was collected but only 9011 non-exposed person-days and 18,945 exposed person-days could be analysed due to the method of exposure classification.

Significantly elevated rates of acute gastrointestinal disease (AGID, rate ratio 2.4), objective AGID (involving diarrhoea or vomiting, rate ratio 2.3) and skin disease (rate ratio 3.7) were seen in bathers versus non-bathers. Beaches were classified into 3 groups based on total and faecal coliform levels and risks of illness relative to non-bathers were calculated.

	most polluted	intermediate	least polluted
all illnesses	2.3	2.1	1.5
AGID	2.4	2.6	1.2
objective AGID	2.4	2.7	0.7
skin disease	4.9	3.4	2.9

When correlation between each indicator organism and illness was examined, it was found that faecal streptococci showed a stronger association with AGID than did total or faecal coliforms. However faecal coliforms were better indicators for skin disease. Thresholds for excess risks were estimated at 7 faecal streptococci per 100ml for AGID, and 20 /100ml for objective AGID. The corresponding figures for faecal coliforms were 270 /100ml for AGID and 800/ 100ml for objective AGID, but the error margins were greater. For skin diseases a threshold of 120 faecal coliforms /100ml was estimated.

The authors also mention another publication (in French) where an alternative logistic regression analysis was applied to these results. This analysis also found faecal streptococci to be the best predictors of AGID risk. The risk threshold for objective AGID was estimated at 20-60 faecal streptococci /100ml.

Fleisher, J. M., F. Jones, et al. (1993).

“Water and Non-Water-Related Risk Factors for Gastroenteritis among Bathers Exposed to Sewage-Contaminated Marine Waters.” Internat J Epidemiol 22(4): 698-708.

The results of the first 2 of 4 randomised studies are reported in relation to gastroenteritis symptoms and measures of faecal coliforms and faecal streptococci. It was found that the only water quality parameter showing a statistically significant association with gastroenteritis among bathers versus non-bathers was the number of faecal streptococci in water samples taken at chest depth. This measure was used in subsequent analyses. Rates of gastroenteritis symptoms did not differ between non-bathers and bathers exposed to densities of less than 40 faecal streptococci per 100ml water sample. Excess risk for bathers began at exposure levels of 40 - 59 faecal streptococci per 100ml.

Geometric means and ranges of indicator organisms were as follows:

	Site 1		Site 2	
Faecal coliforms	31 /100ml	(0-1310)	145 /100ml	(0-556)
Faecal streptococci	42 /100ml	(0-196)	29 /100ml	(0-159)

Examination of non-water-related risk factors (eg consumption of certain foodstuffs known to be common vectors of gastroenteritis) showed these to be confounders in some circumstances. It was estimated that the risk of gastroenteritis associated with exposure to low levels of faecal streptococci (up to 79 organisms per 100ml) was similar to that for eating these foodstuffs (purchased sandwiches, hamburgers or cold meat pies).

Fleisher, J. M., D. Kay, et al. (1996).

“Marine Waters Contaminated with Domestic Sewage: Nonenteric Illnesses Associated with Bather Exposure in the United Kingdom.” Am J Public Health 86(9): 1228-34.

This paper deals with non-enteric symptoms experienced by participants in 4 randomised studies - acute febrile respiratory illness, ear, eye and skin ailments. Bathers showed increased rates of acute febrile respiratory illness, ear ailments, and eye ailments compared to non-bathers. No difference was seen between the two groups for rates of skin ailments.

The concentration of faecal streptococci was predictive of the risk of acute febrile respiratory illness, while levels of faecal coliforms were predictive of the risk for ear ailments. The threshold levels for excess risks for bathing versus not bathing were estimated at 60 faecal streptococci per 100ml water for acute febrile respiratory illness, and 100 faecal coliforms per 100 ml for ear ailments.

The authors suggest these results indicate that no single parameter (type of illness or specific microorganism) is adequate for monitoring recreational water quality. The different dose-response relationships seen for two illnesses may be due to the differences in characteristics of individual pathogens.

Harrington, J. F., D. N. Wilcox, et al. (1993).

“The Health of Sydney Surfers: An Epidemiological Study.” Wat Sci Tech 27(3-4): 175-81.

A prospective cohort study was carried out at 6 Sydney beaches. The study design was different to most other studies - people who swam frequently (at least once per month) and infrequently (less than once per month) were recruited using a quota system to give approximately equal numbers in each group. These people were then asked to fill in questionnaires covering swimming behaviour and symptoms over a 3 month period.

Water samples were collected once daily at 3 sites on each beach and analysed for faecal coliforms, faecal streptococci and *Clostridium perfringens*. From a total of 2003 initial participants (994 high frequency swimmers, 1009 low frequency swimmers), 4011 monthly diaries were returned which recorded 43,175 swimming events. Illness was classified as possibly related to swimming if it occurred within 2 days (for gastroenteritis and headaches) or 6 days (all other symptoms) of a swim. A total of 2059 illness events were reported and 78% of these began within the specified lag period after a swim. Of the 43,175 swims recorded, only 14% (5,879) were possibly associated with subsequent illness.

Overall, swimmers were 1.63 times more likely to report illness than non-swimmers. The risk of illness after swimming at a given beach was generally consistent with bacteriological water quality - ie higher risks were seen at beaches with higher numbers of faecal coliforms, faecal streptococci or *C.perfringens*. Risk of illness was less in beaches with 0-1% of water samples with faecal coliforms >300 cfu/100ml vs 27% of samples. For faecal streptococci the disease risk was less if 1-2% of water samples had >33 cfu vs. 38% of samples. For *Clostridium* the risk was less with if 1-3% of samples were >20 cfu vs. 38% of samples.

An attempt was made to estimate threshold levels of indicator bacteria associated with increased risk by analysing “pure” swims. These were swimming events where no other swims took place in the following 7 day interval. About 12% of such swims were followed by

illness. However, no threshold was evident for total, respiratory or gastrointestinal illness for any of the 3 indicators.

Holmes, P. R. (1989).

“Research into Health Risks at Bathing Beaches in Hong Kong.” J IWEM(3 Oct): 488-95.

Beachgoers at 9 Hong Kong beaches were surveyed over 6 weekends in 1987. The study protocol was based on US studies by Cabelli et al. Of 24,308 people surveyed, usable data was collected on 18,986, and 78% of these were swimmers

Water samples were taken every 2 hours at three points and tested for faecal coliforms, E.coli, Klebsiella, faecal streptococci, enterococci, staphylococci, Pseudomonas, and fungi. Rates of illness observed in swimmers at relatively unpolluted beaches and those classified as “barely acceptable” were compared.

Statistically significant increases in rates of illness were seen for Faecal coliforms (0-410 vs 410-3200 cfu/100ml), E.coli (0-180 vs 180-1,800 cfu/100ml), Klebsiella (0-100 vs 101-1,000 cfu/100ml) faecal streptococci (0-55 vs 26-290cfu/100ml) enterococcus (0-39 vs 40-250) and staphylococci (0-1,000 vs 1001-3000 cfu/100ml).

Overall rates of gastrointestinal illness in this study were less than those reported for comparable US studies despite the presence of higher levels of pollution in Hong Kong waters. The authors suggest that a high degree of immunity to water borne pathogens may exist in the population due to frequent consumption of contaminated seafood from the same waters.

Jones, F. and D. Kay (1989).

“Bathing Waters and Health Studies.” Water Services 93: 87-9.

This paper discusses the background to efforts to develop UK guidelines for recreational water use, and the responsibilities of various government authorities. The studies conducted by Cabelli et al are described and their methodological difficulties discussed. Subsequent studies using similar protocols are also evaluated. The authors conclude that more stringent protocols are needed to overcome some of the problems inherent in previous studies.

Kay, D., J. M. Fleisher, et al. (1994).

“Predicting likelihood of gastroenteritis from sea bathing: results from randomised exposure.” Lancet 344(Oct 1): 905-9.

This paper reports on the association between reported gastroenteritis symptoms and bacteriological water quality indicators for the combined results of 4 randomised trials. A significant association was found for exposure to faecal streptococci and gastroenteritis symptoms, and a marked dose-response relationship was evident with increasing concentrations of faecal streptococci. Once again the parameter showing the most consistent association was the concentration of faecal streptococci in chest depth water. The threshold for increased risk was estimated to be 33 faecal streptococci per 100ml water.

In this combined analysis of data from the 4 studies, non-water-related factors did not confound the relationship between bathing exposure and gastroenteritis symptoms. The non-

water-related factors were independent contributors to the risk of gastroenteritis but their effect was less than that of bathing.

The authors stress that faecal streptococci are not postulated as the causative agents of the observed illnesses but these organisms appear to be better indicators of risk than the other bacteria measured here. They comment that the results obtained in these studies with healthy adults may not apply to children or to special interest groups such as surfers.

Regli, S., J. B. Rose, et al. (1991).

“Modeling the Risk From Giardia and Viruses in Drinking Water.” J AWWA 83(11): 76-84.

This is a review article dealing with risk assessment in drinking water in terms of the US EPA rules for drinking water which are not applicable to the Australian situation. It also adopts the prevailing view at the time (now being questioned) that an annual risk of 10^{-4} is reasonable. This would put for example the life time risk of infection with Giardia from drinking water at 1/142 (assuming 70 year life span). As the risk of infection from other sources is probably as much as 10% per year (or nearly 100% for a life time) it would appear that the application of such a limit to drinking water is extremely stringent.

The article discusses in detail the use of models, infectious doses, the need for monitoring and the mathematical approach used to derive a point estimate. This approach can be used for risk assessment for swimming for those organisms that cause disease via ingestion if one assumes that swimmers accidentally consume seawater. It is not however useful for diseases that arise from contact and not ingestion of the water. For example skin rashes, respiratory infections and ear infections are likely to be acquired by contact rather than ingestion. This method does also not deal with conditions where the causative organism is not known.

Santa Monica Study (1996).

“A health effects study of swimmers in Santa Monica Bay”, Santa Monica Bay Restoration Project Report, California USA.

This was a large epidemiological study conducted from June to September 1995. The Santa Monica beach receives run off from storm drains in Los Angeles, and water testing has shown the presence of human pathogens in the runoff despite the sewage and storm drains being completely separate. The source of this pollution is uncertain but it may include deliberate or accidental discharge of sewage into storm drains.

15,492 beachgoers who swam at the beach and submersed their heads were recruited. Follow up telephone interviews were carried out between day 9 and 14 after the study day. Follow up was completed for 13,278 people. Those who had swam at the study beaches within 7 days before or after the study day were excluded from analysis. Water samples were taken once per day in ankle deep water at 0, 100 and 400 yards from the storm water outlet and tested for total and faecal coliforms, enterococci and E.coli.

The following symptoms were significantly associated with the proximity to the storm water outlet (comparing swimming at 0 yards to >400 yards); fever, chills, ear discharge, vomiting, coughing with phlegm, any of the above symptoms, highly credible gastroenteritis or significant respiratory disease. The following symptoms were not associated with proximity

to the storm water outlet; eye discharge, ear ache, skin rash, infected cuts, nausea, diarrhoea, stomach pain, nasal congestion, sore throat.

A number of associations were seen between the different indicators and symptoms:

- E.coli was associated with earache and nasal congestion (cutoff level >320 cfu/100ml)
- enterococcus was associated with diarrhoea with blood and highly credible gastroenteritis (cutoff >106 cfu/100ml)
- total coliform and faecal coliform counts were associated with skin rash (cutoff levels >10,000 cfu/100ml and >400 cfu/100ml respectively)

Seyfried, P. L., R. S. Tobin, et al. (1985a).

“A Prospective Study of Swimming-Related Illness I. Swimming-Associated Health Risk.” Am J Public Health 75(9): 1068-70.

This paper is the first of two reporting the results of a series of surveys were carried out at 10 popular freshwater beaches in Ontario, Canada between June and August 1980. The beaches were chosen to represent a wide range of water quality based on sampling conducted in the previous summer. 8,402 people were interviewed at the beach and details of demographics, illness and swimming behaviour over the previous 4 days and the interview day were collected. Follow up contacts (telephone interview or postal questionnaire) 7 to 10 days later were completed by 6,166 people. Response rates for postal questionnaires were much lower than for telephone interviews but the rate of symptom reporting was much higher - indicating a heavy selection bias. Therefore incidence rates were calculated only from telephone interview data.

Crude symptom rates for respiratory, gastrointestinal, eye, ear, skin and allergy illnesses were higher among swimmers than non-swimmers. Swimmers aged 20 years or less had higher rates of symptoms than older swimmers. Swimmers who immersed their head had higher rates of ear symptoms than those who did not. Of 2,743 swimmers, 191 (7.0%) reported illness compared to 53 (3.0%) of 1,794 non-swimmers. Adjustment for age, sex, and other factors resulted in only minor changes in symptom rates.

Seyfried, P. L., R. S. Tobin, et al. (1985b).

“A Prospective Study of Swimming-Related Illness II. Morbidity and the Microbiological Quality of Water.” Am J Public Health 75(9): 1071-5.

Further details of the above studies are presented. Water and sediment samples were taken up to 3 times per day and analysed for faecal coliforms, faecal streptococci, coagulase-positive and coagulase-negative staphylococci, *Pseudomonas aeruginosa*, and heterotrophic bacteria. Samples were collected at a depth of at least 0.5 metres in places with a high density of swimmers.

The geometric mean for faecal coliforms was less than the Ontario guideline of 100 per 100ml, but levels of all organisms in sediment were at least 10 fold higher than the corresponding levels in water.

Geometric means over all sampling days were as follows:

Organism	Geometric mean	Number of samples
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faecal coliforms (water)	75.86	122
faecal coliforms (sediment)	816.16	111
faecal streptococci(water)	42.82	124
faecal streptococci (sediment)	456.44	109
heterotrophic bacteria (water)	4.05 x 10 ⁴	114
heterotrophic bacteria (sediment)	6.70 x 10 ⁵	111
Pseudomonas aeruginosa (water)	2.51	125
Pseudomonas aeruginosa (sediment)	62.04	52
total staphylococci	150.70	123

Examination of the relationship between reported illness and microorganisms showed significant associations between total illness and total staphylococci, faecal coliforms and faecal streptococci. A significant relationship was also found for total staphylococci and eye and skin illnesses. The numbers of total staphylococci showed the strongest relationship with illness. The authors suggest this parameter in combination with faecal coliform or E.coli monitoring should be considered for monitoring recreational water quality.

Von Schirnding, Y. E. R., N. Strauss, et al. (1993).

“Bather Morbidity from Recreational Exposure to Sea Water.” Wat Sci Tech 27(3-4): 183-6.

A prospective cohort study based on the Cabelli protocol was carried out at 2 South African beaches during the summer of 1990/91. Data from 5,551 people were analysed. One beach was considered to be “clean” while the other was moderately polluted. Composite water samples were collected from 3 sites on each beach on each day of the trial. Enterococci, E.coli, faecal coliforms, Staphylococci and coliphages were measured.

Swimmers had higher rates of gastrointestinal and respiratory symptoms than non-swimmers at both beaches. For skin symptoms a difference was seen only at the polluted beach. However these differences did not reach statistical significance. Levels of indicator bacteria were relatively low at both beaches compared to other studies.

REFERENCES

- Alexander, L. M., A. Heaven, et al. (1992). "Symptomatology of children in contact with sea water contamination with sewage." J Epidemiol Community Health **46**: 340-3.
- Ashbolt, N. J., C. Riedy, et al. (1997). "Microbial Health Risk at Sydney's Coastal Bathing Beaches." 17th Federal Convention, Australian Water and Waste Water Association, Melbourne, AWWA Inc.
- Balarajan, R., V. Soni Raleigh, et al. (1991). "Health risks associated with bathing in sea water." BMJ **303**(Dec 7): 1444-5.
- Bandaranayake, D. R., C. E. Salmond, et al. (1995). Health Effects of Bathing at Selected New Zealand Marine Beaches.
- Brown, J. M., E. A. Campbell, et al. (1987). "Sewage Pollution of Bathing Water." Lancet(Nov 21): 1208-9.
- Cabelli, V. J., A. P. Dufour, et al. (1982). "Swimming associated gastroenteritis and water quality." Am J Epidemiology **115**(4): 606-616.
- Cabelli, V. J., A. P. Dufour, et al. (1983). "A marine recreational water quality criterion consistent with indicator concepts and risk analysis." Journal WPCF **55**(10): 1306-14.
- Corbett, S. J., G. L. Rubin, et al. (1993). "The Health Effects of Swimming at Sydney Beaches." Am J Pub Hlth **83**(12): 1701-6.
- Fattal, B., E. Peleg-Olevsky, et al. (1986). "The Association between Morbidity among Bathers and Microbial Quality of seawater." Wat Sci Tech **18**(11): 59-69.
- Ferley, J. P., D. Zmirou, et al. (1989). "Epidemiological Significance of Microbiological Pollution Criteria for River Recreational Waters." Internat J Epidemiol **18**(1): 198-205.
- Fleisher, J. M., F. Jones, et al. (1993). "Water and Non-Water-Related Risk Factors for Gastroenteritis among Bathers Exposed to Sewage-Contaminated Marine Waters." Internat J Epidemiol **22**(4): 698-708.
- Fleisher, J. M., D. Kay, et al. (1996). "Marine Waters Contaminated with Domestic Sewage: Nonenteric Illnesses Associated with Bather Exposure in the United Kingdom." Am J Public Health **86**(9): 1228-34.
- Harrington, J. F., D. N. Wilcox, et al. (1993). "The Health of Sydney Surfers: An Epidemiological Study." Wat Sci Tech **27**(3-4): 175-81.
- Holmes, P. R. (1989). "Research into Health Risks at Bathing Beaches in Hong Kong." J IWEM(3 Oct): 488-95.
- Jones, F. and D. Kay (1989). "Bathing Waters and Health Studies." Water Services **93**: 87-9.
- Kay, D., J. M. Fleisher, et al. (1994). "Predicting likelihood of gastroenteritis from sea bathing: results from randomised exposure." Lancet **344**(Oct 1): 905-9.
- Prüss A. (1998). "Review of epidemiological studies on health effects from exposure to recreational water." International Journal of Epidemiology **27**:1-9.
- Regli, S., J. B. Rose, et al. (1991). "Modeling the Risk From Giardia and Viruses in Drinking Water." JAWWA **83**(11): 76-84.
- Santa Monica Study (1996). "A health effects study of swimmers in Santa Monica Bay", Santa Monica Bay Restoration Project Report, California USA.

Seyfried, P. L., R. S. Tobin, et al. (1985a). "A Prospective Study of Swimming-Related Illness I. Swimming-Associated Health Risk." Am J Public Health **75**(9): 1068-70.

Seyfried, P. L., R. S. Tobin, et al. (1985b). "A Prospective Study of Swimming-Related Illness II. Morbidity and the Microbiological Quality of Water." Am J Public Health **75**(9): 1071-5.

Von Schirnding, Y. E. R., N. Strauss, et al. (1993). "Bather Morbidity from Recreational Exposure to Sea Water." Wat Sci Tech **27**(3-4): 183-6.