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Bacteriological examination of the water supply on an Antarctic base

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SUMMARY

Faraday Base represents a small isolated community producing its own domestic water by desalination of sea water. During the Antarctic winter of 1986 (April to October), regular bacteriological examination of the water supply and surrounding sea took place. Samples were collected and examined every 2 weeks by the methods described in the Department of Health and Social Security Report No. 71, on the Bacteriological Examination of Drinking Water Supplies (DHSS, 1982), for membrane filtration and colony counting. The results of these examinations are presented in this paper. The results obtained suggest that water of good bacteriological quality was produced by the desalination plant, but some samples from the distribution system contained coliforms or presumptive *Escherichia coli* in small numbers. The possible reasons for this low-level contamination are discussed. No cases of gastroenteritis occurred on the base during this time.

INTRODUCTION

The British Antarctic Survey base Faraday (latitude 65° 15′ S – longitude 64° 15′ W) is situated on an island 8 km from the western coast of the Antarctic peninsula. Geologically, the island is composed of rock of the cretaceous Antarctic peninsula volcanic group (Elliot, 1964). The base is a meteorological station and geophysical observatory. In the winter time the base is isolated and for the latter 3 months surrounded by sea-ice. Ten men, five scientists and five support staff, live on the base for periods of up to 2 years. All supplies are brought in from the UK by ship during the summer. In the summer the number of people living on the base may more than double.

The base generates its own electricity which is required in order to run the desalinator unit. Sea water is pumped into the unit and distilled under reduced pressure at a temperature of approximately 50 °C. The desalinated water is stored in a holding tank before use. Sea water is kept running continuously through the plastic intake and cast-iron sewage disposal pipes to prevent freezing; the pipes are also electrically heated. Untreated sewage is discharged into the sea. The desalinator unit was switched on for approximately 48 h each week, and this provided sufficient domestic water for the base. On two occasions the sewage pipe did require unblocking after freezing; the pipe was checked and found to be

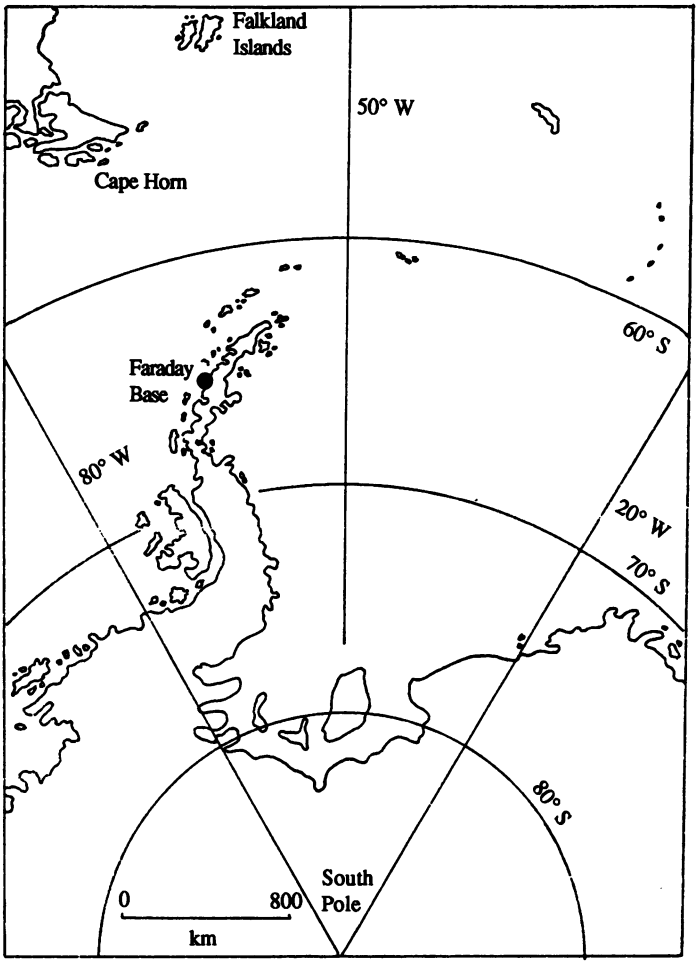

Fig. 1. Map of Antarctica showing position of Faraday base.

undamaged by these episodes. The distance between the salt-water intake pipe and sewage outlet was 54 metres in the sea. The two systems are generally separated by about 50 m, except within the base itself, and apart from in the sea, there appeared to be no point where the sewage system could have contaminated the domestic water supply.

In the event of the system failing, domestic water is produced from melting snow. Snow is cut into blocks after removing the top surface where contamination from the wildlife may have occurred. The blocks are then melted electrically in a large steel tank inside the building. As discussed later, this method has been associated with outbreaks of gastroenteritis in the past.

MATERIALS AND METHODS

Materials used and methods followed are as described in Report No. 71. Samples were collected fortnightly for 7 months, from the cold water tap in the base eating area and from the water storage tank. Depending on sea/ice conditions samples were taken at the same time from the sea or through a hole cut in the ice, at the following two sites on the shore:

(1) In a line perpendicular to a fixed point six feet from the waste outlet pipe.

(2) In a line perpendicular to the salt-water intake pipe.

Sea-water samples were always taken in a morning at approximately 10.00 h local time. This follows the heaviest output of sewage between 08.00 and 09.00 h into the sea.

The two sampling sites on the shore were 54 metres apart and both affected by varying tides, sea temperatures, wind direction and sea-ice conditions. 300 ml sterile glass bottles as used by the Public Health section of the Regional Laboratory, City Hospital, Aberdeen were used for collection. All samples were analysed within 1 h of collection. Sodium lauryl sulphate broth (PHLS/SCA, 1980) was the medium used in the membrane filtration method, and yeast extract agar (Report No. 71) for colony counts. When filtering samples, 100 ml volumes were used. In total, 206 results were obtained.

RESULTS

Table 1 shows the results for presumptive coliform, presumptive *Escherichia coli* and colony counts at the two recommended incubation times and temperatures (Report No. 71) for water samples from the holding tank and domestic water tap. The majority of tap water results show zero counts for presumptive *E. coli* and coliforms. Sample 3 had a presumptive coliform count of 1 per 100 ml, samples 11 and 13 produced presumptive coliform counts of 9 and 5 respectively. Whilst taking sample 11 it was noted that parts of the tank surface were peeling. The colony counts for the tank and drinking water also showed an increase at this time. These results suggest an overall decline in the bacterial quality of the water in the system at this time.

Samples 1, 7, 13, showed low presumptive *E. coli* counts in the absence of coliforms from the tank samples. If these represent *E. coli* then contamination of the tank from the desalinated water or sewage (human or wildlife) had taken place. Contaminated water from the desalinator seems unlikely, given the results for samples 4, 12, 14 discussed below. The tank, although uncovered, was housed in a room inside the base. The room also contained the desalinating and central heating units and was regularly visited by base personnel; it is not unreasonable to suppose that air-borne contamination of the tank may have taken place. The 'presumptive *E. coli*' could represent environmental organisms and not faecal *E. coli*.

On three occasions (samples No. 4, 12, 14), the water tank sample was taken directly from the inlet pipe to the tank, thus sampling water as it was leaving the desalinator unit and before storage in the holding tank. All three samples showed total absence of coliforms and very low colony counts per ml (although two similar counts can be found in samples taken from the tank as shown in Table 1). Research on water produced by desalination (Rakhmanin, 1980) suggests that this process may lead to a reduction in microbes, but that the vacuum inside the

Table 1. *Results of bacteriological examination within the distribution system*

Sample number	Site	Presumptive coliforms /100 ml	Presumptive *E. coli* /100 ml	Colony count /ml 72 h/20 °C	Colony count /ml 48 h/37 °C
1	Tank	0	1	> 300 × 10	7
	Drinking	0	0	10	11
2	Tank	0	0	1140	0
	Drinking	0	0	10	1
3	Tank	2	0	27	0
	Drinking	1	0	39	0
4	Tank	0	0	1	0
	Drinking	0	0	3	0
5	Tank	0	0	19	30
	Drinking	0	0	28	17
6	Tank	2	0	43	0
	Drinking	0	0	44	0
7	Tank	0	1	2	4
	Drinking	0	0	2	0
8	Tank	0	0	5	2
	Drinking	0	0	0	5
9	Tank	0	0	224	128
	Drinking	0	0	47	10
10	Tank	0	0	4	0
	Drinking	0	0	1	0
11	Tank	21	0	276	NT
	Drinking	9	0	252	NT
12	Tank	0	0	1	0
	Drinking	0	0	3	0
13	Tank	0	2	1	7
	Drinking	5	0	19	2
14	Tank	0	0	5	5
	Drinking	0	0	8	8

NT, Not tested.

system and the presence of water vapour can lead to contamination. Water of excellent quality may well have been entering the tank but then underwent some deterioration during storage. The importance of this source of contamination is also illustrated in a study of the sanitation in a rural drinking water supply (El Attar *et al.* 1982).

Table 2 shows the results of analysis from the two sea-water sampling sites. The results of coliform and *E. coli* counts in marine and recreational water are not easy to interpret (Bonde, 1977; Agg & Stanfield 1979); however, some trends can be seen in the results. The influence of the waste pipe was noted in higher presumptive coliform/*E. coli* counts near the waste pipe, compared to the water near the intake pipe on all but one occasion (sample No. 8).

Figure 2 also shows the possible influence of the local bird population on the presumptive *E. coli* count. The trend of results for this faecal indicator shows an increase at both sites after sample No. 5 was taken. This corresponds to late June and the formation of sea-ice. Dominican gull's (*Larus dominicanus*) and sheath-bills (*Chionis alta*) were noted to be feeding around the waste pipe discharge at this time. The discharge of water into the sea always ensured a small area of open water; this and the practice of throwing waste food from the base into the same

Table 2. *Results of bacteriological examination of two sea-water sites*

Sample number	Site	Presumptive coliform/100 ml	Presumptive *E. coli*/100 ml
1	Waste	5	3
	Intake	2	0
2	Waste	40	0
	Intake	0	0
3	Waste	44	3
	Intake	9	1
4	Waste	86	0
	Intake	1	0
5	Waste	52	0
	Intake	20	0
6	Waste	80	50
	Intake	20	7
7	Waste	39	80
	Intake	30	53
8	Waste	33	4
	Intake	2	25
9	Waste	32	29
	Intake	NT	NT
10	Waste	50	1
	Intake	NT	NT
11	Waste	NT	NT
	Intake	NT	NT
12	Waste	30	18
	Intake	25	1
13	Waste	50	31
	Intake	10	1
14	Waste	0	0
	Intake	6	6

NT, Not tested.

area produced a feeding point for the birds, because they were unable to feed through the surrounding sea-ice. The birds would normally have migrated north if it were not for the food they received from the base. The relative proximity of the intake pipe meant that birds were also found on the ice or in the water at this site.

Another explanation for this rise in the faecal indicator count could be the physical effect of the sea-ice, reducing the dilution effect on the sewage as it enters the sea. The sewage and food tended to remain longer in this area of water that was surrounded by sea-ice. This relative increase around the waste pipe could then have been transmitted to the intake pipe area. Moore (1959) found a seasonal variation in coliform counts, namely lower counts during the summer months on UK shore samples and suggests changes in stratification of the sewage in the sea, caused by changing sea-water temperatures. Over the period of time testing took place at Faraday the sea-water temperatures at the sampling sites varied by only a small amount, 2·3 °C (maximum +0·5 °C, min −1·8 °C) and is less likely to have had an effect on the sewage than the presence or absence of sea-ice. Comparable analysis during the summer months may clarify the effect of the sea-birds and sea-ice on the coliform counts.

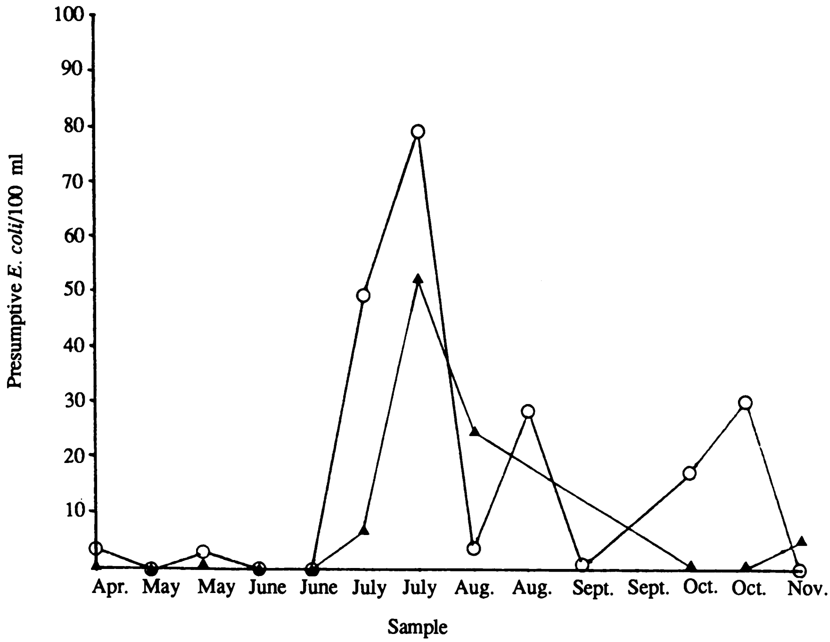

Fig. 2. Seasonal variation of faecal indicators in samples of sea water. ○, Waste; ▲, intake.

In general the number of coliforms found was very low; the median presumptive *E. coli* count was 1/100 ml. These are especially low compared to Moore (1959) and to the standards set by the EEC (*Commission of the European Communities*, 1975) for surface water intended for the abstraction of drinking water.

DISCUSSION

Living and working in the Antarctic poses many problems, not least is the provision of a safe drinking water supply. Most modern Antarctic bases offer a comfortable and pleasant environment in which to live and work. It is important in such closed and isolated communities to maintain good health as outbreaks of disease such as gastroenteritis can have a devastating effect on base life.

Information from previous British Antarctic Survey medical reports (unpublished) confirm that this can occur. For instance, during September and October of 1981, four to six people per week on Faraday base suffered from gastroenteritis. At this time water was being produced by melting snow. Boiling all water abolished the diarrhoea, re-introducing unboiled water resulted in a re-occurrence. Again on the same base in 1982, 11 cases of diarrhoea presented over 3 days. The week previous to this the desalinator had broken down and snow was being melted for use.

This study shows that during the period of investigation, drinking water of good quality was normally produced by the desalination of sea water. In order to maintain and improve the quality of the water consumed, it was suggested that a cover was made for the water storage tank, and that it should always be kept in a good state of repair in order to reduce contamination. The water tank is made of mild steel and was lined with an epoxy resin coat. In several areas rust was on the surface; this was removed and replaced with a non-toxic protective coating recommended for use in drinking water storage tanks.

As demonstrated by Fleisher (1985) coliform enumeration in recreational water can be imprecise, and the same applies to sea-water samples at Faraday. Neither of these results or results from the distribution system should lessen care taken in the production of water. The effect of faecal contamination, especially in the event of the desalinator breaking down, has been significant in the past and could well be in the future. Thought must always go into the correct siting of sewage pipes. Food disposal should not be in areas where water is to be extracted, and snow for melting should always be taken from areas most likely to be free from contamination. Materials should be available for chlorination of the water supply if necessary.

It is not envisaged that examination of the drinking water supply, requiring full laboratory facilities, will continue in the future. However, regular examination could continue using a system such as the 'Millipore' portable unit used in the Malawi study (Young & Briscoe, 1987). This would enable examination to take place in more remote field camps, as well as continuing surveillance on the base.

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