Survey of waste water disposal practices at Antarctic research stations

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Abstract

To inform the future practices to be employed for handling waste water and grey water at the Swedish Antarctic station, Wasa, in Dronning Maud Land, the Swedish Polar Research Secretariat took the initiative to survey the practices of the 28 nations with stations in Antarctica. A questionnaire was sent out to all members of the Antarctic Environment Officers Network during the autumn of 2005. Questions were asked about the handling of waste water and grey water, the type of sewage treatment, and installation and operational costs. The response to the questionnaire was very good (79%), and the results showed that 37% of the permanent stations and 69% of the summer stations lack any form of treatment facility. When waste water and grey water containing microorganisms are released, these microorganisms can remain viable in low-temperature Antarctic conditions for prolonged periods. Microorganisms may also have the potential to infect and cause disease, or become part of the gut flora of local bird and mammal populations, and fish and marine invertebrates. The results from 71 stations show that much can still be done by the 28 nations operating the 82 research stations in Antarctica. The technology exists for effective waste water treatment in the challenging Antarctic conditions. The use of efficient technology at all permanent Antarctic research stations would greatly reduce the human impact on the pristine Antarctic environment. In order to protect the Antarctic environment from infectious agents introduced by humans, consideration should also be given to preventing the release of untreated waste water and grey water from the smaller summer stations.

Antarctica is the most pristine continent on Earth, as its remoteness, enormous size and extreme climate have left Antarctica with little or no evidence of human impact over vast regions. However, increased accessibility has led to an increase in the activities and numbers of visitors to the Antarctic region (International Association of Antarctica Tour Operators [IAATO] 2008). The increased human presence is also leading to increased pressure on the surrounding environment, and one challenge for Antarctic operations is waste management and waste disposal in these untouched areas (e.g., Hughes 2003, 2004; Hughes & Blenkharn 2003).

Scientific research is a major activity in Antarctica. In recent years there has been a continued growth in the number and size of stations and semi-permanent field camps. In the summer season, approximately 4000 scientists and technicians carry out research and monitoring, and in the winter the scientific community in Antarctica is estimated to comprise around 1000 people (CIA 2008). Most of the scientific stations, semi-permanent bases and field stations are situated in coastal areas or on ice-free terrain. These areas make up only 2% of the Antarctic surface (CIA 2008), and are areas that are prone to disturbance and/or where the environment is slow to revert to the undisturbed state.

Tourism is another prominent activity, with 37 550 tourists visiting Antarctica during the austral summer 2006/07, according to IAATO. In addition to the tourists, approximately 22 500 tourism industry staff and crew also visited the area (IAATO 2008). Tourist activities are also concentrated on coastal areas, mainly on the Antarctic Peninsula, and take place during the austral summer, which is the most biologically sensitive period for terrestrial biota.

Both research and tourism increase the risk of humans introducing infectious agents that are new to the Antarctic flora and fauna. One output from both of these activities that poses a threat to the Antarctic environment is waste generation. Studies in the region have already detected well-known pathogens that may have been introduced by humans, such as *Salmonella enteritidis*, *Salmonella typhimurium*, *Campylobacter jejuni* and *Pasteurella multocida*, in both seal and bird populations (De Lisle et al. 1990; Olsen et al. 1996; Broman et al. 2000: Palmgren et al. 2000). The first findings of the enteropathogenic *Escherichia coli* in Antarctic wildlife have recently been reported in Antarctic fur seals (*Arctocephalus gazella*) (Hernandez et al. 2007).

All waste water produced at a research station excepting toilet waste (urine and faeces) is called grey water. Most of the grey water comes from laundry, showers, sinks and washing dishes. Grey water may contain fat, oil and other organic substances from cooking, residues from soap and tensides from detergents. The content of pathogens in grey water is low in comparison with toilet waste (black water). However, grey water, especially from bath/shower and laundry, may contain pathogens such as bacteria and viruses (Stenström 1996).

Waste water treatment is the process of removing physical, chemical and biological contaminants from waste water, and as a result it involves physical, chemical and biological processes. External and internal treatments are the two main methods available. External treatment is the most common method, and is usually performed away from the production site (e.g., a sewage treatment plant). Internal methods are generally located where the waste water is produced; examples include septic tanks, biofilters and anaerobic treatment systems. The main methods used for internal water treatment are adsorption, ion exchange, membranes, extraction and vaporization (Persson 2005).

Waste water treatment can involve three stages: primary, secondary and tertiary treatment. The primary stage removes solids such as waste, fats, oils and grease from the waste water stream. The methods used are mechanical, maceration and sedimentation. In the secondary stage, dissolved biological matter is progressively converted into a solid mass using waterborne microorganisms, and the biological solids are either disposed of or are reused (e.g., activated sludge, fluidized bed reactors, filter beds, biological aerated filters or membrane biological reactors). In the tertiary treatment, the treated water may be disinfected chemically or physically (e.g., by microfiltration, nutrient removal with biological processes or chemical precipitation, chlorine, UV light or ozone). The final effluent can then be discharged to the natural environment (Persson 2005).

The *Protocol on environmental protection to the Antarctic Treaty* (hereafter referred to as the Protocol) states that the protection of the Antarctic environment, and the dependent and associated ecosystems, is in the interest of mankind as a whole (Antarctic Treaty Secretariat 1998a). The Protocol is based on the principle that protection of the Antarctic environment, and the dependent and associated ecosystems, and consequently the intrinsic value of Antarctica, shall be fundamental considerations in the planning and conduct of all activities in the Antarctic Treaty area (Article 3.1).

Annex III to the Protocol (Antarctic Treaty Secretariat 1998b) applies to waste disposal and waste management, and obliges all countries to apply responsible waste management principles and to develop waste management plans. Article 1.2 states that "The amount of wastes produced or disposed of in the Antarctic Treaty area shall be reduced as far as practicable so as to minimise impact on the Antarctic environment and to minimise interference with the natural values of Antarctica, with scientific research and with other uses of Antarctica which are consistent with the Antarctic Treaty".

Built during the austral summer 1988/89, Wasa is the main Swedish station in Antarctica. The station is located at 73°03′S, 13°25′W at the nunatak Basen. Basen is the westerly offshoot of the Vestfjella mountain range, Dronning Maud Land, and is situated 460 m a.s.l. and 120-km inland. The Finnish station Aboa is located 200 m from Wasa. The station is only used during the austral summer seasons. The station consists of nine buildings, and normally accommodates 12–16 people, but can accommodate up to 30 people. Sweden also has a small field station, Svea, located at 74°35′S, 11°13′W.

Water consumption at Wasa is on average 100 litres per person per day. Grey water from Wasa is transported downhill via a 100-m-long insulated and heated pipe, and is discharged to an ice-covered area below the station, where it drains into the surrounding ice and finally to the sea. A waste water treatment system was initially installed, but was decommissioned in 1996 because it did not function properly.

The legal obligations from the Protocol have been interpreted into practical guidelines, and can be found in the *Nordic environmental handbook on Antarctic operations*. Expeditions follow specific guidelines when handling waste on the Swedish station Wasa and in the field. Waste is recycled, separated and retrograded for appropriate disposal outside Antarctica. As Wasa is a small summer-only station, releasing untreated waste water and grey water into a crevasse still fulfils the obligations under the Protocol. The ambition for the Swedish Antarctic Research Programme and the Swedish Polar Research Secretariat is to investigate the possibility of installing waste water

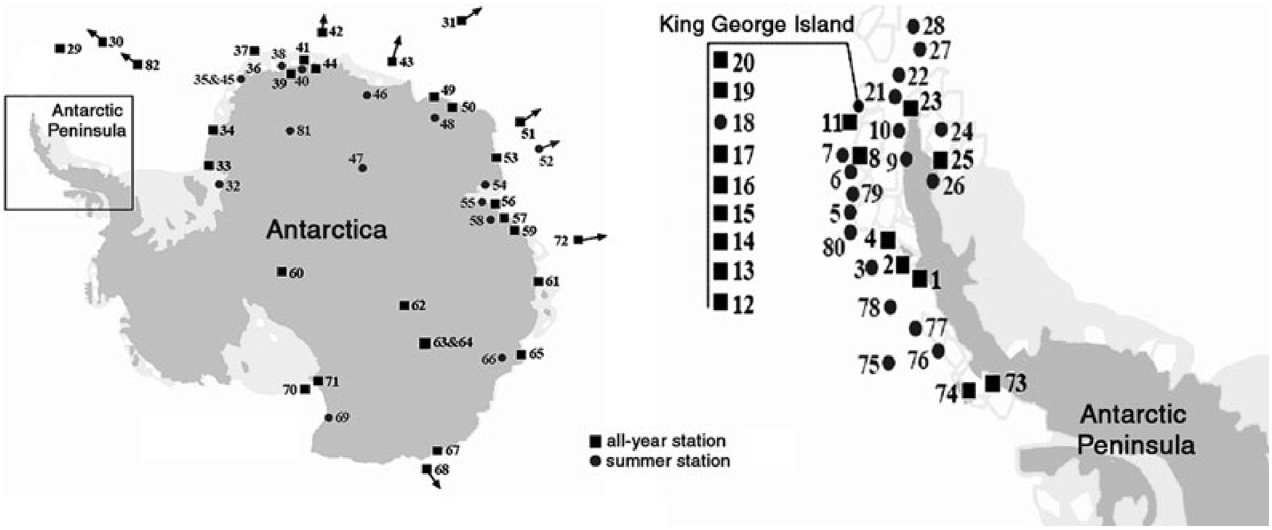

Fig. 1 The location of research stations in Antarctica. Arrows on the map indicate stations on sub-Antarctic islands. The nationality of the stations is indicated in Table 1. (Map modified from COMNAP 2005, and used with permission.)

treatment at Wasa in the coming years. In order to learn from other nations and stations, the Swedish Polar Research Secretariat took the initiative for the present study.

This paper investigates waste water disposal in Antarctica, and presents an inventory of the existing practices at 71 Antarctic research stations.

Materials and methods

Study area

Most Antarctic stations are situated along the coastline, where accessibility is better (Fig. 1). Most stations are built on bare ground (e.g., McMurdo Station). Some have been constructed on the permanent ice cap (e.g., Amundsen-Scott Base, South Pole) or on ice shelves (Halley Research Station, Brunt Ice Shelf). The Swedish station Wasa (no. 45 in Fig. 1) and the Finnish station Aboa (no. 35 in Fig. 1) are examples of stations located on snow-free basalt ground.

By sending out a questionnaire to all 28 nations active in Antarctica, information was obtained on how these other countries handle the waste water from their stations. The questionnaire was emailed to members of the Antarctic Environment Officers Network (AEON) during the autumn of 2005. The questions asked were as follows:

(1) How many stations are used by your country?
(2) How is waste water handled by the station/s?
(3) Is there a sewage treatment system in operation? If not, is such treatment being planned?
(4) What type of sewage treatment system is in use?
(5) How does the sewage treatment system work, and what kind of process is used?
(6) Does the sewage treatment system run all year around or only during expeditions?
(7) Does it take a long time to get the system working when an expedition arrives at the station?
(8) Does the sewage treatment system need a power source?
(9) What are the running costs, and how much has been invested in sewage treatment?
(10) Is the system working satisfactorily?

The information collected, together with some additional information from the Council of Managers of National Antarctic Programs (COMNAP 2005), was used to draw conclusions and to provide a better picture of waste water management at Antarctic research stations.

Results

There was a good response to the survey, with 22 out of 28 countries completing the questionnaire (Tables 1, 2). Almost two-thirds (63%) of the permanent stations have some kind of treatment system (Table 2). When it comes to summer stations, however, less than one-third (31%) have a treatment system (Table 2), whereas none of the field stations has any such system (Table 2). Altogether, the results show that less than half (48%) of all 71 stations have some sort of waste water treatment (Table 2).

The different waste water treatment systems used at the stations are shown in Table 3. Of the 63% of permanent stations that have some form of treatment system, the most common type is biological treatment, which is used by 20% of the stations. 10% of stations use macerations and another 10% use secondary treatment. Two stations (5%) have septic tanks as treatment, and the

Table 1 Waste water treatment at the Antarctic research stations used by the 28 countries with activities on the continent. The answers are taken from the 22 responses to the survey, whereas for the six countries that did not respond, the relevant data were drawn from the COMNAP website (COMNAP 2005), as indicated in column 6. Some of the field stations, e.g., Sweden, UK and Uruguay, are not located in Fig. 1.

Country	Station[a]	Stations in the survey	Treatment system	Type of treatment	Cost
Argentina	3, 5, 6, 17, 23, 25, 26, 28, 29, 32, 33, 73, 76,77	6 permanent stations, 7 summer stations	Four of the permanent stations.	Grey water recycled to be used in toilets, black water treated in septic tank, or all water treated in biological treatment plant.	Last equipment $9000.
Australia	23, 52, 58, 59, 65, 66, 68	3 permanent stations	Yes, though one has failed and is going to be replaced.	Secondary treatment with rotating biofilters.	The new plant will probably cost $2.2m.
Belgium	–	One will be opened in the season 2007/08	The station will have a plant.	Not considered yet.	Not relevant yet.
Brazil	20	1 permanent station	Yes.	Primary and secondary treatment.	Data from COMNAP.
Bulgaria	21	1 summer station	No.	–	Data from COMNAP.
Chile	4, 7, 8, 10, 11, 14, 24, 75, 78	3 permanent stations, 6 summer station	3 summer stations and 1 permanent station.	Has secondary treatment.	Data from COMNAP.
China	12, 57	2 permanent stations	Yes.	Sewage treatment, biological treatment.	Not answered.
Czech Republic	Not listed	1 summer station	No.	–	–
Ecuador	79	1 summer station	No information.	–	Data from COMNAP.
Finland	35	1 summer station	Yes.	Biological waste water treatment plant that treats grey water.	Not answered.
France	6, 31, 51, 63, 72	4 permanent stations, 1 summer station	One of them, the other will in the future.	Recycling of grey water, grey water treatment: four stages of membrane filtration (ultrafiltration, nanofiltration and two steps of reverse osmosis). Black water: anaerobic and aerobic digestion and nitrification.	$846 000 installation and equipment.
Germany	18, 37, 81	1 permanent station, 2 summer stations	The permanent station has treatment.	Biological plant.	Not answered.
India	41	1 permanent station	Yes.	Biodigestor (liquid waste) and incineration (human waste).	Data from COMNAP.
Italy	64, 69	1 permanent station (Concordia) run together with France, 1 summer station	Yes, summer station, permanent station will get treatment in two years.	Sewage treatment plant.	Data from COMNAP.
Japan	46, 47, 48, 49	2 permanent stations, 2 summer stations	One of them.	Biological sewage treatment in tanks before disposal to the sea.	Not answered.
Korea	16	1 permanent station	Yes.	Aeration, chemical, biological treatment and then discharge to sea.	Not answered.
New Zealand	71	1 permanent station	Yes.	Biological treatment.	$242 000 for installation and $9500 per year.

Table 1 *Continued*

Country	Station[a]	Stations in the survey	Treatment system	Type of treatment	Cost
Norway	39, 40	1 permanent station, 1 field station	Yes, faeces are collected and transported out of Antarctica.	Waste water is treated and released to the ground. Incinerator toilets are used and therefore no black water.	Too soon to say because it opened this season (2004/05).
Peru	22	1 permanent station	No, but is getting similar system to New Zealand.	Biological treatment.	–
Poland	19	1 permanent station	Collected in tank.	Not answered.	Not answered.
Russia	13, 44, 50, 54, 55, 56, 61, 62	5 permanent stations, 3 summer stations	One of them, but they are planning to get it for the others.	Destruction of microbiota by electric field and disinfection before release to sea. The other discharges directly to sea except Vostok, which discharges to an ice pit.	Unit cost $60 000 plus $3000 yearly.
South Africa	36, 38, 42, 43	1 permanent station, 3 summer stations	Yes.	Bio filter: rotating biological contactors purification plant.	Cost for plant $231 000 plus $800 yearly.
Spain	9, 80	2 summer stations	Yes.	Treated in septic tank; operative in 1–2 days.	Not answered.
Sweden	45	1 summer station, 1 field station	No, but a new treatment system for grey water at the summer stations is coming.	There are dry toilets.	Too soon to say.
Ukraine	1	1 permanent station	No.	Discharge by constantly circulating sea water.	Electric power only.
United Kingdom	27, 30, 34, 74, 82	4 permanent stations, 1 summer station, 2 field stations	One has a treatment plant, one has maceration and one permanent has incineration toilets.	Primary treatment (screening and settling), secondary (biological aeration) and tertiary (UV sterilization).	Equipment $147 000 in 1999, but shipping, construction and running not included.
United States	2, 70, 60	3 permanent stations	Yes, two of them. Consideration for all in the future.	Sewage treatment plant and the others have maceration before disposal into ocean.	To build a waste water treatment plant costs $1.2m and running with one operator with minimal training costs $125 000 yearly.
Uruguay	15	1 permanent station, 1 field station	Yes.	Treated in septic chambers, and then stored in drums for removal out of Antarctica. Primary treatments take place in the septic tank.	Machine costs $600 and running costs $900.
Total for all 28 countries		41 permanent stations, 26 summer stations and 4 field stations	26 of 41 permanent stations, 8 of 26 summer stations, 0 field station.		

[a] The station number corresponds to the numbers shown in Fig. 1.

Table 2 The waste water treatment for different types of research stations in Antarctica

	No. of stations	Sewage treatment (%)
Permanent stations	41	63
Summer stations	26	31
Field stations	4	0
All stations	71	48

Table 3 Type of waste water treatment systems used at permanent and summer stations in Antarctica

Type of treatment	Permanent stations	Summer stations
Primary	1	
Secondary	4	3
Tertiary	1	
Primary & secondary	1	
Primary, secondary, tertiary	1	
Biological plant	8	1
Septic tank	2	3
Membrane & biological	1	
Chemical & biological	1	
Mechanical & UV filter	1	
Electric field & disinfection	1	
Maceration	4	
Sewage treatment plant		1
No treatment	15	18
Total number of stations	41	26

other methods are used at one station each. Of the 31% of summer stations that have some form of treatment system, septic tanks and secondary treatment are used by 23% of the stations. Biological treatment and sewage treatment are only used by two stations (5%).

Some of the responses to the questionnaire are not shown in Table 1, for example the important question 10: is the system working satisfactorily? Ten countries responded affirmatively (Argentina, Germany, Korea, Poland, Ukraine, Uruguay, China, the UK, the US and Spain). Three countries (France, Russia and Norway) stated that their system was too new for any conclusions to be drawn about its functionality. Four countries reported problems (Australia, Japan, New Zealand and South Africa). Australia has two stations where the treatment works well, but the station Davis is having problems. Both South Africa and New Zealand reported that it is difficult to get a high quality of effluent during periods of high influx of people to the stations during the summer season. A more detailed description of the answers to the questionnaire is given by Thomsen (2005).

Some information about the cost of waste water treatment installations in Antarctica can be extracted from Table 1, although most countries did not answer question 9. The results show that the cost varies between $9000 for Argentina (with some equipment being a donation from the Netherlands) to $2.2m for replacing the non-functional treatment system at the Australian Davis station. For stations serving about 100 people, such as those run by New Zealand and South Africa, the cost is approximately $240 000 for a system with biological treatment. The running costs vary between $800 (South Africa) and $9500 (New Zealand) per annum.

Discussion

This study shows that despite the fact that Antarctica is the largest pristine wilderness on the planet, and is very sensitive to environmental disturbance, 52% of the 71 stations located there lack any kind of waste water treatment system (Table 2). Moreover, 37% of the 41 permanent stations with year-round occupancy lack a treatment system (Table 2). It is also important to note that most of the stations that have a treatment system installed it during the past decade. For example, the American McMurdo Station, the largest human settlement in Antarctica, with more than 1000 people during the summer, installed its sewage remediation plant in 2003, and prior to that had no waste water treatment at all (Conlan et al. 2004). The organic enrichment by the sewage water from McMurdo Station has had a significant negative impact on the benthic community structure of McMurdo Sound (Conlan et al. 2004). High densities of coliform bacteria were found as far back as 1992 along the 1-km shoreline outside the base, and the plume extended 200–300 m seaward (Howington et al. 1992).

To inform future waste water management decisions, it is important to know how effective the treatment methods reported in Table 3 are in preventing the release of human-derived microbial agents to the Antarctic environment. Only four stations have tertiary treatment, or use UV sterilization (e.g., the UK) or electric fields and disinfection (e.g., Russia), to handle the problem of microbial agents. Other treatment methods, such as maceration (used by four stations), do not reduce the likelihood of spreading human-derived microbial agents to the Antarctic environment. Maceration may, in fact, increase microbial levels if not performed properly. Hughes & Blenkharn (2003) showed that conditions favouring microbial growth were created in the sewage water tanks of the UK's Rothera Station with the addition of warm water from, e.g., showers and macerated food waste from the kitchens. The results from the present study also show that two stations with biological treatment (New Zealand and South Africa) have problems with treatment during the summer seasons, when there are many visitors to the stations.

Australia has had major problems at one of its stations (Davis), and several countries (France, Norway and Russia) do not know if their treatment systems are efficient. The US reported operational problems at McMurdo Station well into the second year of operation of the waste water plant (Antarctic Treaty Secretariat 2006). Thus, it is likely that even the stations that have some kind of waste water treatment are not treating their waste water and grey water effectively.

When waste water and grey water containing microorganisms are released, microorganisms can remain viable at low-temperature Antarctic conditions for prolonged periods (Smith et al. 1994; Statham & McMeekin 1994; Hughes 2003, 2005). Hughes (2005) showed that during the austral summer, in which intensive sunlight in combination with ozone depletion increases harmful UV-B radiation, solar radiation may reduce the number of viable waste water derived microorganisms released to the Antarctic environment. However, Hughes (2005) also stresses that this effect is not reliable, and that every effort should be made to treat waste water to eliminate human-derived microbial agents.

Microorganisms may also have the potential to infect and cause disease, or become part of the gut flora of local bird and mammal populations, as well as fish and marine invertebrates (De Lisle et al. 1990; Olsen et al. 1996; Broman et al. 2000; Palmgren et al. 2000; Hughes 2003; Stark et al. 2003; Hernandez et al. 2007). Human pathogens may also be introduced to Antarctica by natural means, such as individual seabirds and fur seals that can wander to lower latitudes near South America, where they could pick up potential pathogens such as *E. coli* (Hernandez et al. 2007).

In addition to microorganisms, grey water may also contain residues from personal hygiene products and detergents with surfactants that may be environmentally harmful. George (2002) has shown that biodegradation may occur in Antarctic coastal waters of the commonly used anionic surfactant sodium dodecyl sulphate (SDS). However, not all detergent products are as readily degradable as SDS.

The Antarctic Treaty regulates the treatment of human waste and sewage, but requires sewage treatment by at least maceration only for human populations of more than 30 persons (Antarctic Treaty Secretariat 1998b). Even if the output from waste water disposal is sometimes negligible for small operations, it is most probably cumulative in terms of the environmental impact resulting fromslow decomposition rates in the cold environment. During the summer season, a small station such as Wasa may use relatively large volumes of water—the average water consumption is 100 litres per person per day. Australian stations have reported similar water consumption during the summer, and higher rates (135 litres per person per day) in winter (Thomsen 2005).

This study shows that nearly 20% of the permanent stations have biological treatment plants (Table 3). However, biological treatment with microorganisms may not be appropriate for summer season stations such as the Swedish Wasa station. To survive, microorganisms (predominantly bacteria) need food in the form of organic material, and that can only be supplied during summertime visits. One of the questions in the survey concerned the length of time taken to start the sewage treatment process. That could not be answered for those countries with permanent stations (Table 1). Even though most of the countries with summer stations reported that it takes 1–2 days to get the system going, depending upon the type of system used (Table 1), it is more likely to take a much longer time. Often, the time stated is the time taken under optimal conditions, but start-up can be especially difficult if the winter has been hard and long, and if the treatment plant is located outdoors. If this is the case there is a risk of frozen pipes and tanks, and before these can be used again they need to be thawed.

Another aspect is that waste water disposal methods have, to a large extent, been developed in temperate areas, but some technologies commonly used elsewhere do not function in the Antarctic. To be effective in the Antarctic, practices need to be adapted to local conditions, and an installation at the Swedish research station Wasa, back in 1988/89, proved to be so inefficient that it was removed a few years later. Thus, for Antarctic conditions, it is important to choose the most suitable sewage treatment methods, and to be aware of problems that may be related to the technology in the harsh environment. The climatic conditions in Antarctica, at least in areas such as the Antarctic Peninsula or the sub-Antarctic islands, are no more extreme than conditions in, for example, Scandinavia, Greenland, Alaska and Canada, which have large populations and efficient waste water treatment. Although the treatment technology may cope with the harsh climate, the experience at stations like McMurdo is that the process control often does not work as originally designed (Antarctic Treaty Secretariat 2006). These challenges are especially problematic in Antarctica because of the lack of nearby technical support that is readily available in most other parts of the world.

There are very few published reports on the efficiency of sewage treatment methods in Antarctica. Bruni et al. (1997) studied the outfall from the sewage disposal plant of the Italian base stations in Terra Nova Bay. The results showed that when the station population was high, the plant was unable to cope with the high sewage input level, and did not work satisfactorily. This is in accordance with results from the present study, which showed that both South Africa and New Zealand have difficulties in achieving high-quality effluent during periods of a high influx of people to the stations during the summer period. Hughes (2004) studied the submerged aerated biological filter sewage treatment plant (Hodge Separators Ltd., Penryn, Cornwall, UK) installed in 2003 at the permanently occupied British Rothera Research Station, located on Adelaide Island, Antarctic Peninsula. The one-year study showed that the treatment plant was efficient in reducing the concentration of faecal coliforms in waste water released from the station (Hughes 2004). Similar technology to that used at Rothera Research Station has also been installed at both the American McMurdo Station and the New Zealand Scott Base.

This study found that New Zealand has problems with sewage treatment, at least during the summer season, as have Australia, Japan and South Africa. For three countries (France, Russia and Norway), the systems were too new for any conclusions to be drawn about functionality. Of the 10 countries that reported satisfaction with their treatment system in response to our survey, at least the US has subsequently reported problems at the McMurdo station (Antarctic Treaty Secretariat 2006). More studies on the efficiency and functionality of waste water treatment systems in Antarctica are needed in the future.

The use of efficient technology at all permanent Antarctic research stations would greatly reduce the human impact on the pristine Antarctic environment. To protect the Antarctic environment from human-derived microbial agents, waste water and grey water released from the smaller summer stations should also be subjected to treatment. Sweden is looking at different treatment systems that can be used at the Wasa station. Thomsen (2005) has looked at the demands of treatment systems for grey water, and has investigated alternative products on the market. The results shown in Table 1 show that the costs for installation and operation of waste water treatment systems in Antarctica are reasonable in comparison with the overall cost of Antarctic research.

Conclusions

Although there is a legal system in place that is designed to protect the Antarctic environment, releasing untreated waste water is still in accordance with the legal obligations as long as there are not more than 30 people on the station. This study shows that 37% of the permanent Antarctic stations, and 69% of the summer stations, are lacking any form of waste and grey water treatment system. The study also shows that the treatment methods used at many stations are not efficient enough to reduce the release of microorganisms. Stations with existing treatment systems have reported operational problems and malfunctions. There is also a need for more environmental monitoring, including monitoring of human-derived microbial agents around the stations. The environmental impact of the waste water released should be analysed and appropriate treatment plants should be installed on a case-by-case basis, as the introduction of treatment plants at all stations may not be possible or even necessary. Apparently there is still much to be done by the 28 nations running the more than 80 research stations in Antarctica. The technology exists for effective waste water treatment in Antarctica. The use of efficient technology at all permanent (and most summer) Antarctic research stations would greatly reduce human impact, such as introduced human-derived microbial agents, on the Antarctic environment.

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