Waste water treatment in Antarctica

– a feasibility study for grey water at Wasa station

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KTH Chemical Engineering and Technology

Master of Science Thesis
Stockholm 2005

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Supervisor & Examiner:
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Swedish Polar Research Secretariat
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Abstract

Today more and more of our focus in Antarctica and the rest of the world are turning towards how we, the inhabitants, leave footprints on our planet. Scientists have found trace of humans all over the world even in Antarctica's fauna and flora. To be able to do research and understand our planet's development and problems, we must try to make as small impact on Antarctica as possible today and leave a pristine continent to the coming generations. One way to manage this is to not release untreated waste water.

The aim of this thesis was to investigate different techniques for cleaning grey water for the Swedish Antarctic Summer Station Wasa. A survey on waste water treatment on almost all Antarctic research stations has been carried out in order to find a suitable treatment method for the grey water released from Wasa. The survey showed that all twenty eight member states that operate research stations was included and the survey covered 41 permanent stations, 26 summer stations and 4 field stations. The study showed that 26 permanent stations and 8 summer stations had some kind of treatment for their waste water. The most common treatment method at the permanent stations are biological treatment (8 stations) followed by secondary treatment and maceration (4 stations per method). The results are based upon analyses from the survey answers and information from COMNAP's homepage about members' stations.

One treatment system using chemical precipitate is currently under evaluation for Wasa. The system will be tested in Sweden before the planned installation at Wasa during season 2006/2007.

Acknowledgments

I would like to express my deepest thanks to the following people for their encouragement and support during the development of this thesis. This work could not been done without their help, support and knowledge.

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Ms. Sara Nilsson for helping me with translation of parts of information from other polar program in Spanish.

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Table of Contents

1. Thesis Introduction

1.1 Foreword

This thesis was carried out by Ann Thomsen student at the department of Industrial Ecology at the Royal Institute of Technology (KTH), Stockholm, Sweden. The thesis was commissioned by the Swedish Polar Research Secretariat (SPRS) and carried out under the supervision of Environmental Officer Johan Sidenmark, SPRS, Technical Officer Sven Lidström, SRPS, and associate professor Fredrik Gröndahl at the department of Industrial Ecology, KTH.

1.2 The Swedish Polar Research Secretariat

The Swedish Polar Research Secretariat is a government agency under the Swedish Ministry of Education and Science that work to promote and coordinate the Swedish research in the Polar Regions. This is carried out by organizing and supporting research expeditions to the Artic and Antarctica with Swedish scientists and companies. Another important issue for the secretariat is to inform and inspire teachers and students to do research and learn more about the Polar Regions. In Antarctica the secretariat maintains the two Swedish research stations Wasa and Svea. Both are summer only facilities and occupied a few months during the yearly expeditions to the continent.[1]

1.3 Environment

The environment on Antarctica is unique, mostly because of the extreme climate and isolation. Research in Antarctica may gain knowledge about the evolution of earth over millions of years, which is crucial in order to solve todays and tomorrows environmental problems. To protect the environment it is essential that the visitors affect the surroundings as little as possible. Waste water should be treated before it is detached into the sea or ice.

1.4 Aims and Scope

The objective of this project is to find a treatment method for the grey water from Wasa. The work is focusing on finding a method that can work in the extreme conditions and harsh climate with low temperature. Another aspect is that the station only is used during the austral summer and therefore the system must have the feature that it can be stopped and started with short notice. The system should preferably not need power or at least need very little power. Because of the location, the system should not need maintenance very often and not need surveillance by staff on the station. The aim of this report is to find a system that is optimal in terms of emissions, efficiency, cost, size, life and maintenance.

[1] SPRS homepage

The scope of the project is not to develop new methods. A survey among other nations stations about their waste water treatment has been carried out. Different water treatment methods are described.

1.5 Methodology

The study is done by collecting information from countries and organisations that have experience of engineering in Polar environment. The work is carried out by searching for existing reports and relevant literature, which have been read, evaluated and summarised in the report. Email, databases, books and phone have been used for this purpose.

By sending out a survey to all nations active in Antarctica, information about how other countries handle the waste water from their stations has been gathered. The survey was emailed out to members in Antarctic Environment Officers Network (AEON), which is a forum for the different Environment Officers to exchange information, experiences and ideas about practical environment management issues. AEON is a network in Council of Managers of National Antarctic Programs (COMNAP).[2] The COMNAP was established in 1988 to bring together those managers of national agencies responsible for the conduct of Antarctic operations in support of science. The Council comprises representatives from twenty-nine countries encompassing the Americas, Africa, Asia, Europe and Oceania. [3]

Also a list of demands has been sent out to companies providing treatment systems to see if they have something that could meet the specific demands. All this together leads to a suggestion of one system, which could be used at the Swedish Antarctic station Wasa.

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[2] COMNAP homepage AEON
[3] COMNAP, homepage overview

2. Antarctica

The Antarctica is the coldest, driest, highest and windiest continent on earth. With an average height of 2500 meters, it is the highest elevated continent and that is more than three times higher than most continents. It is also the most isolated continent, surrounded by stormy oceans. It covers an area twice the size of Australia.[4] It contains a surprising number and variety of lakes, ponds and pools. Almost every lake here has arisen as a consequence of glacial retreat, though earth movements have formed a few.[5] Since most part of the continent is situated below the 70°S, the sun shines 24 hours per day during the austral summer and it is totally dark during the winter. Since Antarctica is in the southern hemisphere their warmest period is during our winter and their coldest is during our summer. In Antarctica there is a corresponding phenomenon to our Northern Lights the Southern Lights. It is the solar wind and the earth's magnetic field that causes this phenomenon.[6]

Map 2.1. Antarctica

Roughly 98 percent of the surface is covered with ice[7] and it contains nearly 70 percent of the world's fresh water resources. The thickest ice found is in Wilkes Land near the magnetic South Pole, where it reaches a depth of 4776 meters. If all the ice dissolves it would increase the ocean level with almost 76 meters. Because ice reflects more than 80 percent of the incoming radiation, this is one of the several explanations why it is so cold on the continent. It is the two percent not covered with ice that are the most important environment for flora and fauna in Antarctica. The flora that is found on bare ground can be hundreds years old and grows extremely slow. Because of this, all contact that could harm the flora should be avoided.

[4] Lucas, Mike
[5] Bonner, W N
[6] The ozone hole - homepage about Southern Light
[7] Greenpeace

The yearly average temperature for the continent as a whole is almost –40°C. The coldest temperature on earth has been recorded on the Russian base Vostok in Antarctica, it was –89.2 °C in July 1983.[8] The Antarctic Oceans temperature varies between +2 °C and -1.8 °C. [9]

It is very windy on the continent. Sometimes the wind can reach over 50 m/s in speed. The highest wind speed that has been detected was 88 m/s on the French base Durmont d'Urville in July 1972.[10] Antarctica has been designated as a natural reserve, devoted to peace and science. Today there are more than 80 research stations on the continent[11].[12]

2.1 Historical Background to Antarctica

The conception "Terra Australis Incognita"- an unknown continent in the south- was already alive during the antiques approximately in year 500 B. C. Even the Greek antique philosophers for example Aristotle's understood that the world was spherical. They predicted that there had to be an opposite pole to Arctic. The first known expeditions to Arctic took place about 150 B.C with Ptolemaios. Many were the following attempts to discover the South Pole continent. The famous explorer James Cook crossed the Antarctic Circle in 1773, but did not come across a continent. But he did discover a rich animal life existing of seals and whales, which started a huge commercial hunt in the area. Even though three different expeditions claimed to have found Antarctica in the 1820s, the land was still a "terra incognito". [13]

The number of expeditions to the South Pole exploded in the end of the 19th century. To be part of a polar expedition was full of prestige and different geographical societies competed for the governments founding's for their expeditions. The ones that made it all the way back home were celebrated as heroes.[14]

In Sweden there is a long tradition of polar research, because of the geographical situation, the focus has been on Artic. Under command of Otto Nordenskiöld (1869-1928) the first Swedish expedition to Antarctica took place in 1901 to 1903. The expedition was only intended to last for a year. The plan was that a group of scientists should spend the winter in Antarctica. During this time samples should be taken and data collected. Otto Nordenskjöld was a geographer and geologist. It was a private expedition and part of the equipment was donated to the expedition. The *Antarctica*, owned by the Danish Carlsberg Fond, was used as the expedition ship. Captain was the Norwegian C.A. Larsen that already had paid two visits to Graham Land. He later became one of the great names in modern whaling industry. Altogether the expedition had 39 male members. The expedition left Gothenburg on the 16th of October 1901 and reached King George Island, South Shetland Islands, on the 10th of January 1902, after a stop in Buenos Aires. Trying to find a suitable site for the base station the journey proceeded. After a month of

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[8] May, John
[9] Lucas, Mike
[10] May, John
[11] COMNARP homepage stations
[12] Lucas, Mike
[13] Jacobsson, Marie
[14] Lucas, Mike

searching for the optimal place Nordensköljd decided on Snow Hill Island, where a suitable site for a building was found on a terrace above the shoreline. Snow Hill Island is situated outside the Antarctic Peninsula. The wintering group was left when *Antarctica* sailed off and was not expected back until the next year. The group consisted of six men, Nordenskjöld included. The first thing that had to be done was to build the hut, consisting of 3 bedrooms, two men in each, one kitchen and one bigger main room. Altogether the hut was 4.0 by 6.3 meters. The hut on Snow Hill is still standing, so the construction was vigorous. A magnetic and astronomical observatory was built near the main building. They made observations without interruption for 20 months. Snow Hill Station was the first Swedish station in Antarctica.

The *Antarctica* had during the year that passed since they left the men at Snow Hill made several observations on the journey back to Port Stanley, Falkland Islands and before going back to Ushuaia, Tierra del Fuego, Argentina. During the stay in Ushuaia reparations were made. Letters to the Secretary of the Swedish society of Anthropology and Geography and the Swedish-Norwegian Consul General in Buenos Aires were sent. The letters were identical and contained instructions for a help expedition. Three expedition members on board, where left in Hope Bay on the Antarctic Peninesula, with two separate missions, during the way back to Snow Hill. They were supposed to reach the Snow Hill group by sledge and together with them wait for the *Antactica*. If *Antarctica* did not arrive, they were all supposed to return to Hope Bay for evacuation. Unfortunately the group of three did not make it to Snow Hill, because they discovered that the passage they planned to use, were not all ice covered. So they returned to Hope Bay. *Antarctica* did not reach Snow Hill either, so the group prepared for a second winter. The ship came across several difficulties and the rest of the crew had to abandon the ship outside of Paulet Islands and bring the rest of equipment with them. They also had to prepare for the winter and build a hut. One young crewmember died during the following winter due to heart diseases.

The expedition were now divided in to three groups. The Hope Bay group started to prepare for a new sledge journey in the beginning of the spring. This time they made it and were reunited with Nordenskjöld and one other man, four days from the hut. The meeting was very dramatic because the men from Hope Bay were dirty and not recognized until they introduced themselves.

All men from the *Antarctica* expedition was saved and evacuated on the 8th of November 1903 by a relief expedition organized by Argentina and its commander Julian Irizar with the gunboat *Uruguay*. It was the letters sent to the Secretary of the Swedish society of Anthropology and Geography and the Swedish-Norwegian Consul General in Buenos Aires that initiated the rescue expedition.[15]

The Norwegian Roald Amundsen was the first to reach the geographical South Pole on the 14th of December 1911. The Englishman Robert F. Scott arrived a month later, only to discover the Norwegian Flag at the pole. Like many other expeditions during this time, Scott's expedition ended with death. During their way back from the South Pole they encountered a big snowstorm that forced them to camp out and they ran out of food. Fortunately, today the expeditions to Antarctica have totally different conditions and possibilities for advanced scientific research.[16]

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[15] Liljequist, Gösta H.
[16] Lucas, Mike

A large British-Norwegian-Swedish expedition took place in 1949 – 1952 to Dronning Maud Land. The modern Swedish Antarctic-research has a strong connection to these early expeditions both geographical and scientific. Now like then it is the climate studies that are in focus.[17]

2.2 Antarctic Treaty System

Behind today's good cooperation between the active nations in Antarctica lies many years of disagreement. Many nations have claimed to own parts of Antarctica, but since the 23rd of June 1961 Antarctica has been administered under the Antarctic Treaty System. It is an international agreement to preserve the continent for peaceful scientific studies and every member of the UN may join the Antarctic treaty. Currently 45 countries have signed the treaty. The members are divided into consultative and non-consultative members. Only the consultative members have the right to vote at Antarctic Treaty meetings.[18] Sweden signed the Antarctic Treaty 1984 and became a consultative member 1988. [19]

2.2.1 The Protocol on Environmental Protection

The Protocol on Environmental Protection is a part of the Antarctic treaty and covers all issues of environment and protection. It is stated that activities in the Antarctic Treaty area shall be planned and conducted with as limited effect on the Antarctic environment and dependent and associated ecosystems. The Antarctic Treaty covers everything south of 60^{o} South Latitude. [20]

2.2.2 Waste Management

Annex III to the Protocol on Environmental Protection is about waste disposal and waste management. It is stated in article 1:2 that the amount of waste produced or disposed of in the Antarctic Treaty area shall be reduced as far as practicable to minimise interference with natural values of Antarctica, with the scientific research and other users of Antarctica consistent to the Antarctic Treaty. In article 1:3 it is stated that waste storage, disposal and removal from the Antarctic Treaty area, but also recycling and source reduction shall be an essential consideration in the planning and conduct of activities here. In the fifth paragraph in article 1 it is stated that past and present waste disposal on land and abandoned work sites, should be cleaned up by the generator of such waste and the user of such sites. Exceptions are historical sites or monuments or in those cases where cleaning up will give or could give greater adverse environmental impact than leaving its existing location. In article 5:1b it is stated that sewage and domestic liquids (shower-, kitchen- and washing waste water and urine) generated in stations where the average

[17] Johansson, A-K, Floderus, S
[18] SPRS homepage
[19] Antarctic Treaty Secretariat
[20] Antarctic Treaty

weekly occupancy over the austral summer is approximately 30 individuals or more should use treatment on the water with at least maceration before it is released into sea.[21]

2.2.3 Area Protection and Management

In Annex V to the Protocol on Environmental Protection Area Protection and management is covered. Any area, including any marine area, may be designated as an Antarctic Specially Protected Area to protect outstanding environmental, scientific, historic, aesthetic or wilderness values. In article 4 the Antarctic Specially Managed Areas are described as any area, including any marine area, where activities are being conducted or may in the future be conducted. The protections are designated to assist in the planning and co-ordination of activities, to avoid possible conflicts, improve co-operation between Parties or minimise environmental impacts. Each Party shall make information available about the location of these areas. Listing them with maps, restrictions, location of historic sites and monuments and any other relevant information.[22]

2.3 Animal Life

Even though the climate in Antarctica is cold and rough, there are several animal and plant species living there. Well known species of Antarctica are penguins, other birds, krill, fish, whales and seals. Other ecosystems have different levels and mutual demand. It is the variation and the width of the level that creates the stability in the system. The ecosystem in Antarctica lacks many of those levels, despite that de mutual demand is big. The result is that any disturbance gives bigger and more serious consequences than on other places.

Penguins are a symbol for Antarctica. They are clumsy and inflexible on land, but really good swimmers. On land they suffer from near-sightness, but in the water they have perfect sight. They have many enemies, for example other birds, leopard-seals, sea lions and killer whales. The largest penguin is the Emperor penguin (Aptenodytes patagonica) which can be up till 1.2 m. The most common is the Adelie penguin (Pygoscelis adeliae).

Picture 2.1. A Krill.

Krill (Euphausia superba) is a generic name for a number of crustaceans that lives on plankton. Krill is Norwegian and means small fry. The most common is a half see-through shrimp look-

[21] Antarctic Treaty
[22] Antarctic Treaty

alike that is called the Antarctic Krill. It can be up to 4 cm and live for 7 years. A shoal of more than two billion has been spotted in the Antarctic region. They produce enormous red fields on the surface and in night time their organs becomes luminous. They are the main nourishment for the most part of the marine life in Antarctica. The South Oceans entire ecosystem is based on this little shrimp.

From time to time there are many whales around Antarctica. One reason is that there is a big abundance of krill. During the summer the whales migrate to the area to feed from Krill during three to four months.

Largest of the seals are the sea lion. A full-size adult can reach 4 meters and weight four tonnes. These seals were the first species to be hunted during the commercial hunting in the Antarctic region in the 1820s.

In the waters around Antarctica between 200 and 250 different species of fish live. Most of them belong to the Notothenioidea group. This group is divided into four families: Antarctic Cod, Plunder fish, Dragonfish and Ice fish. These fish have during the last 140 million years adjusted to a life in ice-cold water. Some species of Antarctic Cod can produce a compound similar to "anti freeze" in their blood. This stops their body fluids from freezing, even when temperatures drop below freezing. Their freezing point instead becomes about -2°C. [23]

2.4 Human impact on Antarctica

As mentioned earlier the extreme climate and small variety of available food makes the wildlife in Antarctica especially sensitive to environmental hazards. Today researchers are not the only visitors in Antarctica. During the last season 2003/04 approximately 27 500[24] tourists went there. Both researchers and tourists increase the risk that humans introduce infectious agents that are new to the Antarctic flora and fauna. Already micro organisms with origin from humans have been detected around Antarctic stations. Some of those were found on species and the micro organisms have potential to cause devastating effect on native fauna. Contaminated food and untreated sewage from research stations, tourist and commercial ships are the most likely factors for introduction of pathogenic bacteria and virus. In spite of the low water temperature these bacteria can survive in the marine environment during a long time, where it can be transferred to seabirds and marine mammals. Bacteria can also travel a long way from its outcome and pose potential dangerous to organism very far away[25]. There have been some reports of mass mortality in the area, suspected to be caused by infectious diseases in seal and bird population. One was at Scott Base on Ross Island in 1990-1991 were an incident with unintended pollution by sewage had consequences on marine fauna in the affected area with a high mortality of marine animal species. In 1998 on Auckland Island both Salmonella and a Campylobacter-like bacterium cause a suspected sequence of mass mortality in sea lions. [26]

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[23] Greenpeace
[24] IAATO
[25] Naturvårsverket
[26] Olsen, Björn

Investigation of penguins colonies visited by thousands of tourists annually have not shown to cause any spread of human-associated pathogenic bacteria and that may indicate that the regulations implemented on Antarctic tourism have paid off. Today Antarctic tourism is rigorously regulated and all waste is handled on board the ships. South of the Antarctic convergence sewage is not allowed to be let out. The tourists have to make all toilet visits on board the ships and they are not allowed to leave anything behind. All direct contact with wildlife is banned. Boots should be washed in between landings. In contrast, on most research stations the interaction with wildlife can be extensive and the food waste often is consumed by local birds, primarily Skuas and Sheathbills. [27]

Studies have shown that some viruses can survive for more than 180 days in 4 °C water. Also pH affects the virus. It has been shown that an acid environment makes virus live longer and a basic environment leads to quick death for the virus. During anaerobic conditions the virus lives longer. It is easier for the virus to survive in ground water than in surface water. A virus cannot propagate in the environment, it needs a host cell to multiply.[28] In lake Vostok, scientists have found living bacteria almost 4000 m down in the ice that is over 1 million years old. These bacteria could be an analogue to sub-ice Europa or subsurface Mars where conditions are similar. They believe ice is a good environment for primitive bacteria. There the bacteria need less food and its metabolism slows down.[29] Australian scientists identified that antibodies to an avian pathogen from domestic chickens has been integrated on 2 % of the Adelie penguins and up till 63 % of the Emperor penguins near Mawson station.[30]

In the Antarctic Region several different animals and plants have been introduced by humans, so called alien species. Many of the alien species today were introduced in the beginning of the 19th century such as the Norway rat (Rattus norvegicus), rabbits (Oryctolagus cuniculus) and cats (Felix catus). There has also been an invasion of an insect and two spiders from the Arthropod family to the Antarctic continent. The alarming concern and reality when introducing alien species, is that they cause structural and functional changes in the native biotic assemblages. These alien species do not have native predators. The early explorers brought down the Norway rat in the beginning of the 19th century. The rats together with rabbits and cats are responsible for local elimination of various birds on some sub Antarctic islands. [31]

It is not just local impact from humans being in the Antarctic region. There is also an impact from the other developed parts of the world. During 1960s DDT and other human-synthesised compounds began its accumulation in Antarctic ice, lakes and species. All this in the most remote and isolated part on our planet. Later emissions with CFCs from the northern hemisphere caused the ozone hole over Antarctica. Also now, in the beginning of the 21-century, carbon dioxide from combustion of organic compounds has contributed to the increasing concentration of carbon dioxide in the atmosphere and this has also been found in ice cores.[32]

[27] Olsen , Björn
[28] Stenström, Thor-Axel
[29] NASA
[30] Berkman, Paul Arthur
[31] Berkman, Paul Arthur
[32] Berkman, Paul Arthur

2.5 Human impact on Arctic Wildlife

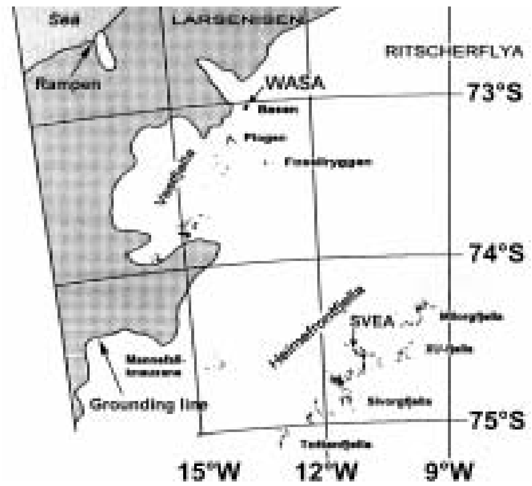
Recently scientists have warned that pollutants threaten the polar bears in the Arctic. Also global warming may be a threat for the polar bear. The extension of drift ice that the bears are dependent upon may decrease with increased temperature. Today the threat seems to be the pollutants from industries in the populated part of the world. Scientists have found high content of pollutants in the fatty tissue among the bears. They have seen that the reproduction organ on females has changed and that can affect their future possibilities to breed. PCB, bromide flame retardant and different chloride substances have been found in the polar bears fatty tissue. The substances that industry develops today are heavier and more complex than before, but still that does not prevent them from occurring in the animals in Arctic. Substances and pollutants travel by wind and water all around the world in just a couple of days.[33] In the future similar problems may cause trouble in the Antarctic ecosystem.

[33] Bratt, Anna

3. Swedish Polar Research in Antarctica

The Swedish Antarctic Research Programme (SWEDARP) started in 1987/88 and a small research station, Svea was built in Dronning Maud Land. The following season a larger station, Wasa, was constructed on a nunnatak 200 km away from Svea. Since then there has been expeditions almost yearly. [34]

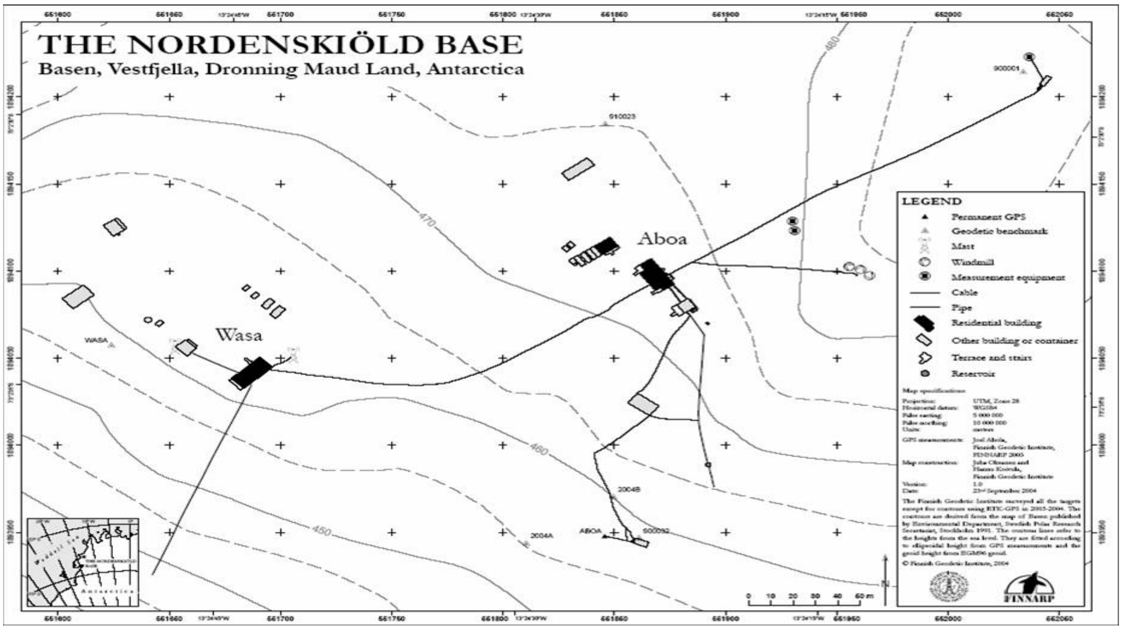
The Swedish Polar Research Secretariat was founded in 1984. The purpose of this government agency is to promote and organise Swedish polar research and activities. The secretariats task are to give access to the Artic and Antarctica for Swedish scientists and maintain the research stations Wasa and Svea in Antarctica.[35]



Map 3.1. Map over Dronning Mauds Land.

Only 200 meters from Wasa lies the finish station Aboa, together the two stations form the Nordenskiöld Base. There is a close logistic and scientific collaboration between the two countries.

[34] Johansson, A-K, Floderus, S
[35] SRPS Homepage



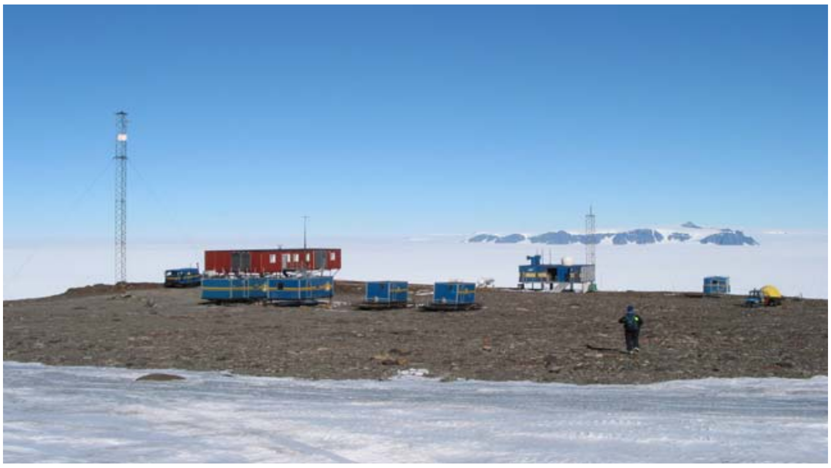
Map 3.2. The Nordenskiöld Base, the Swedish station Wasa and the Finnish station Aboa.

3.1 The Swedish Research Stations

The two Swedish stations in Antarctica are only used during the austral summer season, which is during our winter. The Swedish station Svea was built in the Heimefront Range under the duration of Antarctic Expedition 1987/88. It was the first Swedish research station since Maudheim in 1949 and Snow Hill in 1901. The location of Svea is 74°35´S, 11°13´W and is built by two joined glass fibre modules. The small station has an area of 12 m^2 with four beds and one kitchenette. The station is in use ever so often during the field period. Svea is used less than 100 persons-days a year and therefore it does not need any special arrangement for waste.

Picture 3.1. Svea.

The main Swedish research station Wasa was built during the 1988/89 Antarctic Expedition to Vestfjella, Dronning Maud Land, East Antarctica. The station is located at 73°03´S, 13°25´W at the nunatakk Basen. Basen is the westerly offshoot to Vestfjella and is situated approximately 460 meters above sea level. The station was built on snow-free basalt and regolith ground.



Picture 3.1. Wasa.

The small station consists of nine buildings. The main building, the Radio house[36], is 17.5 x 7.6 m, made out of wood and rests on 1.5 meter high poles to avoid the accumulation of blowing snow. Wood has been chosen because it is the most common material in Scandinavian traditional construction. The Radio house consists of four bedrooms, a large kitchen and a common room. There is also a sauna, showers and a laundry room. The station normally accommodates 12 to 16 persons, but can using the living modules, accommodate up to 30 people. The other buildings are four living modules, a generator house, a workshop, a garage and a laboratory module. A plan over the Radio house and a map over the station area can be found in Appendix one.

The climate on the continent is characterised by low temperature, sparse precipitation and low humidity. During the off season, winter-time, between May to September the average temperature is –20 °C with wind speeds up to 50m/s. During austral summer the temperature varies from –20 °C to 0 °C and the wind speed varies from 2 m/s to 70 m/s[37]. The snow melts on the station area throughout the warm summer months. The main wind direction is north easterly.[38,39]

3.1.1 Waste water management and waste minimization at Wasa

When operating in Antarctica waste minimization is a key consideration. It starts from purchasing and continue to packing waste and cargo for departure from Antarctica. For material brought to and used on Wasa the key words is reduce, reuse, recycle and return.

[36] Plan shown in Appendix 1
[37] Weather date from Aboa station
[38] SPRS Homepage
[39] Hagum, Dag

There is only running water in the Radio house. The water comes from a nearby blue-ice area, approximately 1.5 km from the station, where ice in the summertime melts to water. When the expedition starts a hole is drilled in the ice and water is pumped up with a small electrical pump. The transportation back to the station is made either by skidoos (300 litres total) or by tracked vehicles (1600 litres tank). This water collecting system requires less than 1 litre of petrol to produce 300 litres of water. If it is early in the season and melt water is not available, water can be gained by melting snow. There are specially designed tanks for this purpose on the tracked vehicles, which also can be used during fieldtrips to supply the group with drinking water. There is also a snow and ice melting equipment at Wasa.

Water consumption at Wasa averages at 100 litres a person per day, compared with Australian stations that have an average of 94.5 litres per person and day in the summer and 135 litres per person and day in the winter.[40] Different water saving equipment has been installed at the station including water savings taps at all wash sinks, two standard thermostatic showers with water saving showerheads, a dishwasher machine with low water consumption and a washing machine with low water consumption.[41]

Grey water from Wasa is today transported out via a 100-metre long insulated and heated pipe downhill and discharged to an ice covered area below the station where it drains into the surrounding ice and ultimately to the sea. BOD and TSS are monitored by an irregular basis. A waste water treatment system was installed in 1991/92 but decommissioned in 1996, since it did not function properly.[42,43]

Table 3.1 Analyses on Wasa output water 1st of December 2003

pH	**BOD_7 [mg/l]**	**COD_{CR} [mg/l]**	**N_{tot} [mg/l]**	**P_{tot} [mg/l]**	**NH_4N [mg/l]**	**Solid fabric [mg/l]**	**COD_{MN} [mg/l]**
8.9	3800	5800	73	84.6	2.3	1100	1400

To minimize the environmental impact on the receiving waters, a system with dry toilets are used at the station. The system consists of a simple long-drop into a 200-litre fuel drum. When the drum is filled a lid is placed loosely on the drum and the drum is left for two or three seasons for primary treatment in Antarctica. The primary treatment is evaporation of the liquids and freeze-drying. The rest is transported by ship for disposal in South Africa.

Because the Swedish operations in Antarctica are during short periods this system has many environmental benefits. The only discharge into the local environment is untreated grey water that is released to the ice and the liquid in the drums that slowly evaporates into the atmosphere during a relatively long time period. The impact on the local environment is considered to be minor and transitory, and the energy cost for this system is minimal.[44,45]

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[40] Australian Antartic homepage
[41] Australien Antarctic committee
[42] SWEDARP
[43] Swartling, Anne
[44] Swartling, Anne

3.1.2 Power generation at Wasa

All walls and floors are well insulated and all windows are triple glazed placed on the northern, eastern and western walls to maximise the heat gain from the summer sun. There is also a heat-exchange system that continuously circulates heat from one part of the house to the other. The activities inside the house like cooking, taking a shower, using the sauna and even the people contributes to the whole house getting an even temperature. Sometimes during the summer it is even necessary to let some heat out. Two Liquid Petroleum Gas (LPG) heaters are in use at the station when heating is need, for example during long time blizzards.

The electricity at Wasa is generated by 48 solar panels (total area 20.6 m^2). The total output varies between 1.76 kW (12V) during daytime and 0.88 kW (12V) during night time. The solar panels charges Ni/Cd-batteries, which are stored under the radio house. Approximately 95 % of the energy used for electrical equipment, such as computers, communication equipment, lighting, dishwasher, washing machine, heat exchanger and water pumps, is covered by the solar panels.

Two diesel generators can provide back-up power during cloudy conditions. Under the last seasons the solar panels has been working very satisfying and the diesel generators has hardly been used. Every season they have been function tested in case of power problems with the solar panels or days of blizzard.[46]

[45] SWEDARP
[46] SWEDARP

4. Grey water

All waste water produced on a station except toilet waste (urine and faeces) is called grey water. The largest part of residential grey water comes from laundry, showers, sinks and washing dishes. The amount of grey water produced per day and person varies from 20- 30 litres in poor regions and up till several hundred litres in rich parts of the world. To get the grasps of the figures an ordinary bathtub contains approximately 300 litres.

Characteristic ingredients in grey water are fat, oil and other organic substances from cooking, residues from soap and tensides (tensid = surfactant) from detergents. This all reflects the lifestyle in the household and the choice of chemicals used during washing-up, laundry and in the shower.

The content of pathogens in grey water is generally low, because pathogens are primarily added to waste water through faeces. Still grey water can be seen as a health hazard and that is mainly because of all the indicator bacteria that are found in grey water. This could be explained by very little amount of bacteria in grey water increase due to its contents of easily degradable organic compounds.[47] It has been shown that grey water can contain pathogens especially bath/shower and laundry water can have low content of pathogens, bacteria and virus. Particularly laundry and bath/shower water from infants and sick older people.[48]

Metals in grey water come from different leaching sources in dishes and laundry, such articles are cutlery and pots in the dishes and metal buttons, zips and textile colours in laundry. It could also come from leaching from pipes, wires, machines and similar products.[49]

The levels of nutrients in grey water are normally low compared with normal waste water (grey water and toilet waste) from water-borne systems. In some grey water high concentration of Phosphorous are found. This originates from washing and dishwashing powder, where it is used for softening the water. There are products with out Phosphorous on the market, which works as good as the one with Phosphorous.

One way to get cleaner and less dangerous grey water starts with investigating what is put in to the system. This can be done by looking over all chemicals used in the system, seeing if they could be changed to more environmental friendly ones.[50]

Today more and more of our efforts are focused on green electricity, environment friendly food, renewable fuel and sorting garbage. But at the same time the number of cosmetics are increasing and we use more than before. It has been shown that this cosmetics and indeed hair products contains dangerous and environment hazards. Many substances that are forbidden in other consistencies exist in hair products. In one investigation carried out in Stockholm they found that in 73 examined products they found 438 different compounds and 21 of them were considered or classified as dangerous for the environment. Further 41 could be harmful for the environment and

[47] Naturvårdsverket 1990
[48] Stenström, Thor-Axel
[49] Naturvårdsverket 1995
[50] Riddarstolpe, Peter

then pigment was not included. Many of the products in the investigation contained several substances with the same qualities but with different toxicity for the environment. [51]

Triclosan is a chemical used for its antibacterial properties in many detergents, dish-washing liquids, soaps, deodorants, cosmetics, lotions, anti-microbial creams, various toothpastes, and an additive in various plastics and textiles. It has been showed that it does not break down in purification plants and becomes bio accumulated in fish. It is classified as a toxic substance that immediate kills water living organisms and can give difficult long time harm in the water environment. It can also transform into dioxins by combustion. If Triclosan is added in chemico-technical products it must to have a warning text, but it is not needed for cosmetics. Even though two tones a year is let out only in Sweden.[52]

4.1 Treatment Methods

There are several different treatment methods for grey water. The first thing to consider when trying to find a treatment method is to know the characteristics of the water that should be treated. If the toxic substances in the grey water are identified, the next step is to see where they originate. Sometimes it can be a derivate from a reaction that started after the actual reaction. There is always a possibility to replace the raw material that contains the toxic substances. If it is not possible to replace the raw material then it is time to find a treatment method.

When all the background data is complete, that process starts. There are at least two main water treatment methods. The most common is external treatment and it is used outside the production spot. Another frequent title for the external treatment is the end of pipe solution. The second method is internal treatment and that it is supposed to be treatment on the source directly. Both these techniques are common in industrial use. Today the development goes towards having more internal treatment, though it is easier to deal with one pollutant at a time. Together with the external technique you will get a complete treatment for various pollutions and to a reasonable cost. It is also good to have different techniques in a plant to get better cleaning, but also to get a more fail safe system. Because if something happens when there is only one treatment method it is common that the water passes by without treatment and that can be devastating for the surroundings of the outflow. [53]

4.2 Different Methods

Since this treatment process will be placed in Antarctica, the process should be preferably placed inside the building and be small. Therefore the focus will be on internal treatment methods. Internal methods are those used on every different process part's water and the cleaning is done where the different parts end and on that specific composition. External methods are used when several parts of a process water is collected and treated. Of course, the different methods can be used in the opposite field, but it is mainly used as they where intended. The main internal

[51] Johansson, Kristina
[52] SNF
[53] Nilsson, L, Persson, P-O

treatment methods are adsorption, ion-exchange, membranes, extraction and vaporization. But also three external methods; mechanical treatment, biological treatment and chemical precipitate, will be in focus because they are often used in compact cleaning plants.

4.2.1 Adsorption

With adsorption unwanted molecules can be separated from a liquid by getting caught on a surface of a solid material, the adsorption-material. In figure 4.1 the getting caught process for the unwanted molecules can be seen. All material used as an adsorption-material has a big inner surface. Activated Carbon is the most common one. It has a big specific surface, 500 to 1500 m^2/g, which explains the good adsorption quality. It can remove organic substances from water and is best used on substances with low solubility in water, high molecular weight and low polarity. The concentration of substances to be adsorbed should not exceed 1 %. This process is also favoured by low temperature. It is also possible to use polymeric adsorption-material and can be tailor-made to fit the substances with different solubility and polarity. It is a suitable method to remove biological, hard to break down, organic substances from waste water, especially when other methods cannot be used. Often used as a polish method before the treated water is let out to get really clean water.

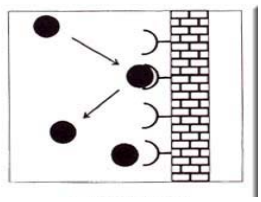


Figure 4.1. Description on Adsorption.

4.2.2 Ion-Exchange

Ion-exchange catches substances in ion-form. In the Ion-exchanger good ions is placed and when the bad ones passes through they get replaced (figure 4.2.). The ion-exchanger rather bonds with the bad ones than the good ones, because the ionic bond between the ion-exchanger and the bad ions is more favourable. This method is mostly used when there are toxic or highly valuable ions in a fluid. It is easy to reuse the Ion-exchange since all you need to do is to wash it with an acid or a base and then it is ready to use again. It can only be used on either anions or cations in a fluid. This method can also be used as a polish method in the end of treatment and gives really clean water. There are two reasons for this, the first is that used like this there is no need to clean the ion-exchange very often. The second is that the treated water becomes truly clean, because the method works fine even if there is only a low content of pollution.

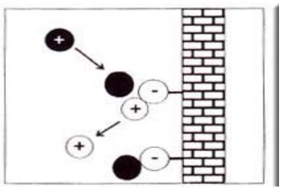


Figure 4.2. Descriptions on Ion-Exchange.

4.2.3 Membrane methods

Membrane methods are being used more and more. There are some different methods of membrane processes. There are micro-filtration, ultra-filtration, nano-filtration and reverse osmosis that all are driven by pressure. Then there is electro-dialyse, which is driven by difference in electrical potential and dialyses, which is driven by difference in concentration. All membrane methods are built on the same principle. If a liquid of a certain concentration is in contact by a half penetrable membrane with another liquid with another concentration nature struggle to level out the differences. This is carried out by water from the lower concentrated fluid moving to the higher. It is called osmosis (1. in figure 4.3.) and by putting a bigger pressure on the high concentrated fluid it reverses the process, reverse osmosis (2. in figure 4.3.). The smallest substances are separated by reverse osmosis, then comes nano-filtration, ultra-filtration and micro-filtration, which separates the biggest substances of these four. After some time on the membrane surface there will be a gathering of different substances. Eventually these will lead to a block and a cleaning has to be made. Sometimes it is enough to clean with water at a high speed through the membrane, but often there is a need for stronger fluids as acids, bases or special washing chemicals. In the end the membrane has to be changed to a new one. It has wide range of area for usage and can be used for water treatment.

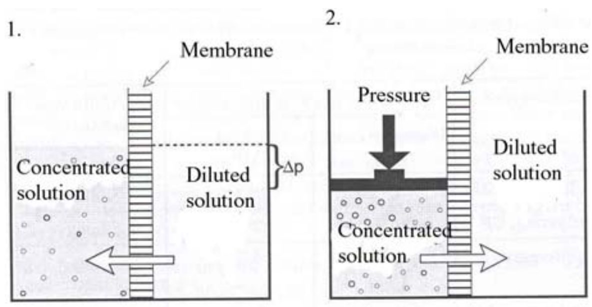


Figure 4.3. The principle for Osmosis (1) and Reverse Osmosis (2). ΔP is the osmotic pressure when equilibrium is achieved.

4.2.4 Extraction

Extraction is a rather old method and is developed from the concept that a substance has different solubility in water and organic solvent. If a substance in water comes in contact with an organic solvent. The solubility for the substances is higher in the organic solvent, and then the substance will be concentrated in the organic solvent. The concentrated substances can than be reused or scraped. In figure 4.4 a principle for industrial use for this method is shown.

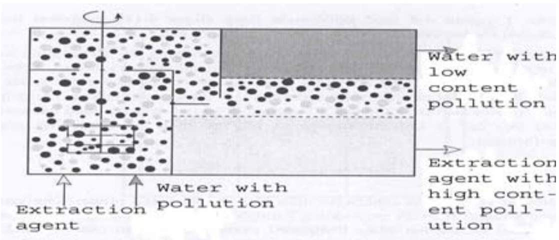


Figure 4.4. Principle for industrial extraction.

4.2.5 Vaporization

Vaporization is already in use at many companies. It is mainly used with easily vaporized substances and sometimes it is not planned for the vaporization to take place. It is often utilized with adsorption to get a better result.

4.2.6 Mechanical treatment

Mechanical treatment could also be an option even though it is mostly used as an external treatment. In this method particles are detached from the solution with fences, strainers or filters. The pollution is removed from the solution and captured in the ooze. To remove the pollution either flotation or sedimentation (figure 4.5.) is used and it works because the solution and the particles have different density.

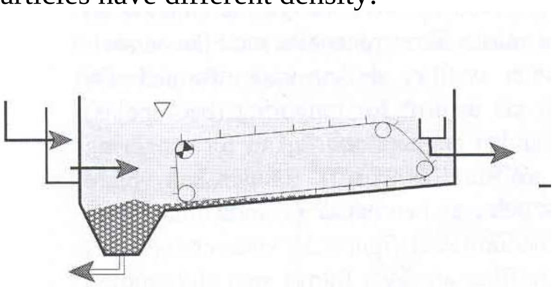


Figure 4.5. A Sedimentation tank.

4.2.7 Biological methods

Biological treatment can transform different compounds into less hazardous. The most important of these is aerobic break down (figure 4.6.), the small micro organisms needs oxygen during the break down of organic carbon compounds to carbon dioxide, water and cell-pulp. Anaerobic break down (figure 4.6.), occur without oxygen, of organic carbon to carbon dioxide, methane, water and cell-pulp. Most used for treatment of water with high content of organic material and also to stabilize organic ooze. The aerobic process demand and can handle a low content of organic material. Anaerobic process is sensitive to toxic substances and demands long treatment time. The anaerobic process demands and can handle higher temperatures than the aerobic process. It does not need energy for aeration and the main part of the organic material becomes biogas and it produces less mud.

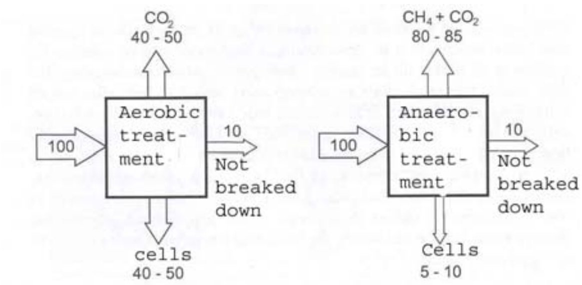


Figure 4.6. Comparison between the turnover in an aerobic and an anaerobic biological breaking down process.

4.2.8 Chemical precipitate

Chemical precipitate is when a suitable chemical is added to the water and it transfers the pollution from soluble from to insoluble form (shown in picture 4.7.). The insoluble particles can then be separated by particle separation methods, sedimentation is the most common. It is often used for separation of phosphors in form of phosphate in municipal treatment methods. It is often used to reduce the content of metals in industrial sewage water.

Picture 4.7. Chemical precipitate in small scale

4.3 Package solution

The methods described above in the text can be put together to small treatment plants that can be used in one household or an apartment block. The challenge in this small context is that these methods often need supervising and attendance to run. Often a solution contains a mechanical, biological or chemical precipitate and maybe one of the other as a polish method. Technically anything is possible, but as already mentioned it is the care and attendance that is the limiting factor. Especially the chemical step is easy to work with and get good results from, even if the plant is small. It is because the chemical additive dosed in addiction to the load and the results is therefore not as dependent by variation in load. The biggest production in a package treatment plant is mud and to get it dried and removed there need to be a solution for the mud production. This solution is often put together with a mud separation step if it is placed in a remote area as in this case.

All of the described methods in chapter 4.2 can be combined in different shapes and settings. The decision, which one to choose is often made from the pollution, its shape and solubility in the water, money, space, and accessibility. For example are membrane techniques still more expensive than the methods that have been used for a long time, such as mechanical treatment and biological treatment. If the treatment in the beginning have one method it is often easy to expand and get more steps and different systems. But when there need to be an increase, it is important to understand that it is often easier to use one method several times instead of having different methods in a line. Though there is a big advantage with having a plant with different systems if there is an error in one step then the other still works. But it can be solved by having emergency back up system or by just having a backup tank. If the treatment is not working properly and then the water can be stored in the backup tank and cleaned after the problem is fixed, so that no untreated water will be released. [54]

[54] Nilsson, L, Persson, P-O

5. Results

In this chapter the results from the before mentioned survey will be presented. All questions can be found in appendix three and was written to try to find out more about how different countries treat their waste water, cost for plants, all season stations and so on. The answer from the 24 countries that answered can be found in Appendix 3 and also which 31 countries this survey was sent to.

In table 5.1 below there is a compilation on stations, treatment and cost. The column with Number on Map is the station that is shown on the map 5.1 and 5.2 further below. The table covers all countries with stations, if they have treatment, type of treatment and cost for treatment. The answers are taken from the survey, which can be found in appendix 3 and the countries that did not answer, the facts are taken from COMNAP's homepage.

*Table 5.1. Statistics on survey, * information from COMNAP homepage.*

Country	**Number* on Map 5.1 and 5.2 on page 27, 28**	**Stations**	**Treatment**	**Type of treatment**	**Cost[55]**
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 toilettes, black water treated in septic tank. Or all water treated in biological treatment plant.	Last machine US$ 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 bio filters.	The new plant will probably cost 2.2 million US$
Belgium	-	One will be opened in the season 2007/08	The station will have a plant	Not considered yet.	Not relevant yet
Brazil*[56]	20	1 permanent station	Yes	Primary and Secondary Treatment	Not answered
Bulgaria*[57]	21	1 summer station	No	-	-
Chile*[58]	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	Not answered
China	12, 57	2 permanent stations	Yes	Sewage treatment, biological treatment	Not answered
Czech Republic	Not listed	1 summer station	No	-	-

55 Money change rate from 15 of April 2005
56 COMNAP Brazil
57 COMNAP Bulgaria
58 COMNAP Chile

Ecuador*[59]	79	1 summer station	No information	-	-
Finland	35	1 Summer station	Yes	Biological waste water treatment plant that treats grey water.	Not answered
France	6, 31, 51, 63, 72	2 Permanent stations	One of them, the other will in the future	Recycling of grey water, Grey water treatment: 4 stages of membrane filtration (Ultra filtration, Nano filtration and 2 steps of reverse osmosis). Black water: anaerobic and aerobic digestion and nitrification.	846 000 US$ installation and machine
Germany	18, 37, 81	1 Permanent station, 1 Summer station	The permanent has treatment	Biological plant	Not answered
India*[60]	41	1 Permanent station	Yes	Biodigestor (liquid waste) & incineration (human waste)	Not answered
Italy*[61]	64, 69	1 Permanent station is Concordia ran together with France, 1 Summer station	Yes Summer station, Permanent station will get treatment in two years	Sewage treatment plant	Not answered
Japan	46,47,48,49	2 Permanent 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 US$ for installation and 9 500 US$ per year.
Norway	39, 40	1 Permanent station, 1Field station	Yes, Faeces is collected and transported out of Antarctica	Waste water is treated and released to the ground. Incinerator toilettes are used and therefore no black water.	To soon to say because it opened this season (2004/05)
Peru	22	1 Permanent station	No, but is getting similar like 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, 2 Summer stations	One of them, but they are planning to get it for the others.	Destruction of micro biota by electric field and disinfections before outlet to sea. The other directly outlet to sea except Vostok that discharge to an ice pit.	Unit cost 60000 US$ and 3000 US$ yearly.
South Africa	36, 38, 42, 43	1 Permanent station	Yes	Bio filter: Rotating Biological Contactors Purification plant.	Cost for plant 231 000 US$ and 800 US$ annual.

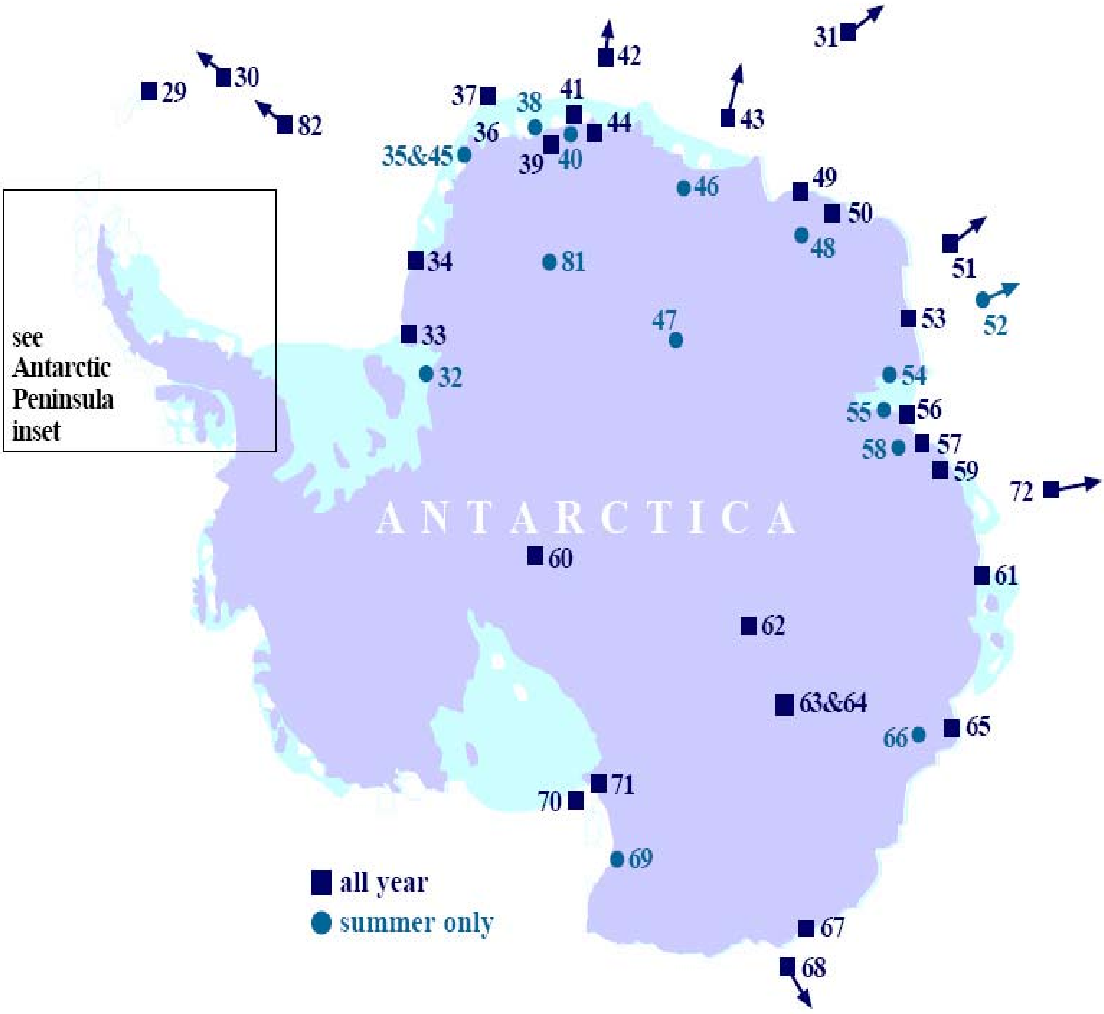
[59] COMNAP Ecuador
[60] COMNAP India
[61] COMNAP Italy

Spain	9, 80	2 Summer stations	Yes	Treated in septic tank. Get operative in one to two days.	Not answered
Sweden	45	1 Summer station, 1 Field station	No, but a new treatment for grey water at the summer stations is coming.	There are dry toilettes	To 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 has incinerated toilettes of the permanent.	Primary treatment (screening and settling), secondary (biological aeration) and tertiary (UV sterilization).	Plant 147 000 US$ in 1999, but shipping, construction and running is not included.
United States	2, 70, 60	3 Permanent staitons	Yes, two of them. Consideration for all in the future.	Sewage treatment plant and the other one have maceration before disposal into ocean.	To build a waste water treatment plant cost 1.2 million US$ and running with one operator with minimal training cost 125 000 US$ annual.
Uruguay	15	1 Permanent station, 1 Summer station	Yes	Treated in septic chambers, and after that stored in drums for removal out of Antarctica. Primary treatments take place in the septic tank.	Machine cost 600 US$ and running cost 900 US$.
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		

Map 5.1 and 5.2 shows that most stations are situated along the coastline, where the accessibility is better. There is also an aggregation of stations on the Antarctic Peninsula. Most stations are situated near the Sea or at least Ice on Sea and therefore water travels a short distance before it reaches the Sea. Many stations are built on bare ground and some is built on glaciers. The variation is big between different countries concerning environment policy and resources, there is also a big difference between how many persons that lives on the stations in summer and winter. In Table 5.2 below numbers with station name and country from Map 5.1 and 5.2 can be seen.

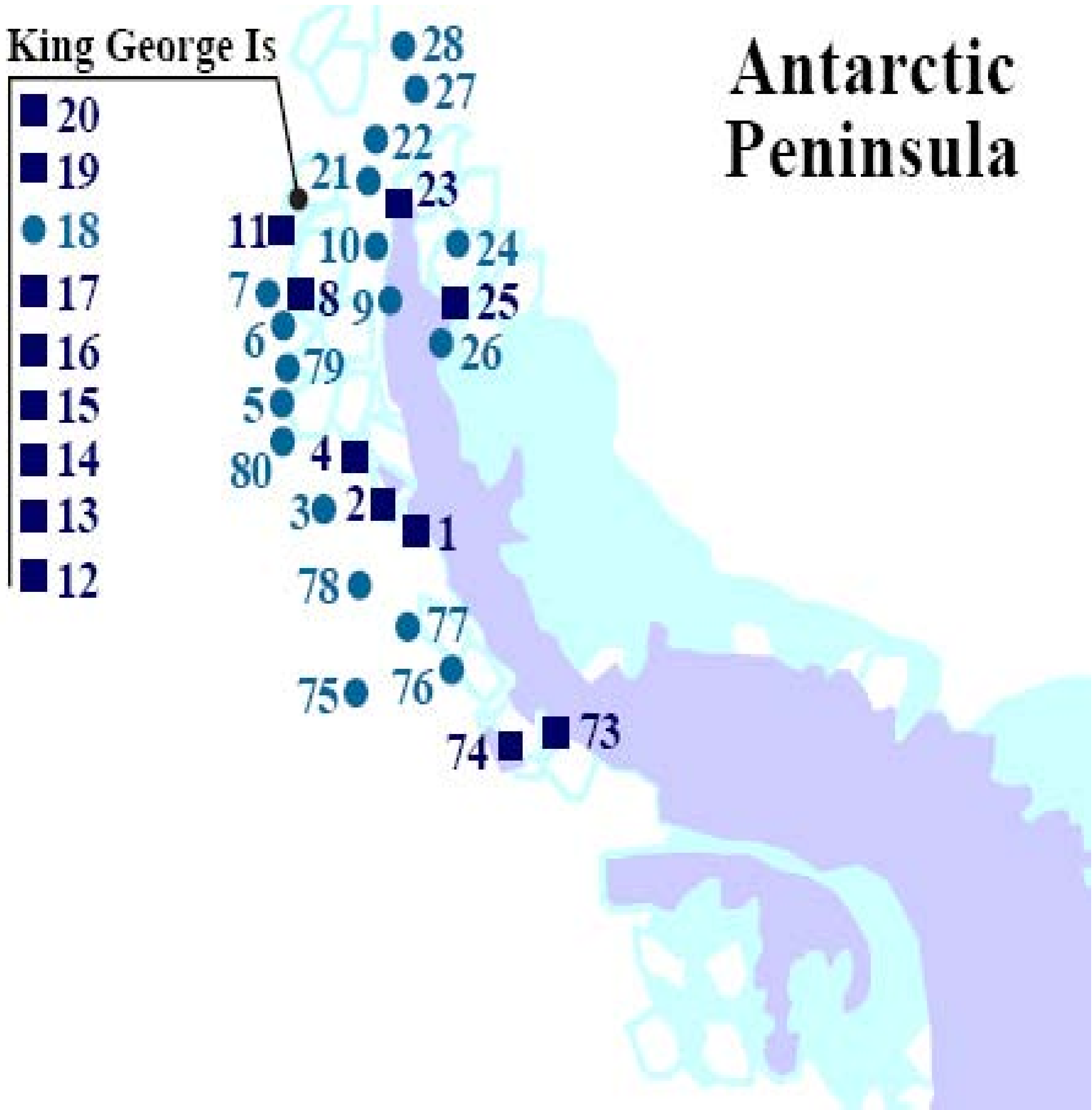
Table 5.2 Stations by number from Map 5.1 and 5.2.

1	Vernadasky	Ukraine	42	Gough Is	South Africa
2	Palmer	United States	43	Marion Is	South Africa
3	Brown	Argentina	44	Novo	Russia
4	Escudero	Chile	45	Wasa	Sweden
5	Decepción	Argentina	46	Asuka	Japan
6	Cámara	Argentina	47	Dome Fuji	Japan
7	Risopatron	Chile	48	Miznho	Japan
8	Prat	Chile	49	Syowa	Japan
9	Juan Carlos I	Spain	50	Molo	Russia
10	Ripamonti	Chile	51	PAF	France
11	O'Higgins	Chile	52	Heard Is	Australia
12	Great Wall	China	53	Mawson	Australia
13	Bellinghausen	Russia	54	Soyuz	Russia
14	Frei	Chile	55	Druzhnaya 4	Russia
15	Artigas	Uruguay	56	Progress	Russia
16	King Sejong	Korea	57	Zhongshan	China
17	Jubany	Argentina	58	Law Base	Australia
18	Dallman	Germany	59	Davis	Australia
19	Arctowski	Poland	60	South Pole	United States
20	Ferraz	Brazil	61	Mirny	Russia
21	Ochridiski	Bulgaria	62	Vostok	Russia
22	Macchu Picchu	Peru	63	Concordia	France
23	Esperanza	Argentina	64	Concordia	Italy
24	GGV	Chile	65	Casey	Australia
25	Marambio	Argentina	66	Law Dome	Australia
26	Primavera	Argentina	67	DDU	France
27	Signy	United Kingdom	68	Macquarie Is	Australia
28	Petrel	Argentina	69	Mario Zucchelli	Italy
29	Orcadas	Argentina	70	McMurdo	United States
30	Bird Is	United Kingdom	71	Scott	New Zealand
31	Alfred-Faure	France	72	Martin-de-Viviès	France
32	Sobral	Argentina	73	San Martin	Argentina
33	Begrano II	Argentina	74	Rothera	United Kingdom
34	Halley	United Kingdom	75	Carvajal	Chile
35	Aboa	Finland	76	Matienzo	Argentina
36	SANAE IV	South Africa	77	Melchior	Argentina
37	Neumayer	Germany	78	Yelcho	Chile
38	E-Base	South Africa	79	Vicente	Ecuador
39	Troll	Norway	80	Gabriel de Castilla	Spain
40	Tor	Norway	81	Kohnen	Germany
41	Maitri	India	82	King Edward Point	United Kingdom



Map 5.1. Stations on Antarctic[62].

62 From COMNAP homepage



Map 5.2. Stations on Antarctic Peninsula[63].

[63] From COMNAP Homepage

From the answers in the survey, the figures below are developed, separated on the different types of stations and finally for all stations. Almost two thirds of the permanent stations have some kind of treatment, which can be seen in figure 1 below. When it comes to summer stations only one in three has treatment (figure 5.2) and none of the field stations (figure 5.3). All together this gives that nearly half the stations have some sort of treatment (figure 5.4).

Figure 5.1.The treatment situation for the permanent stations

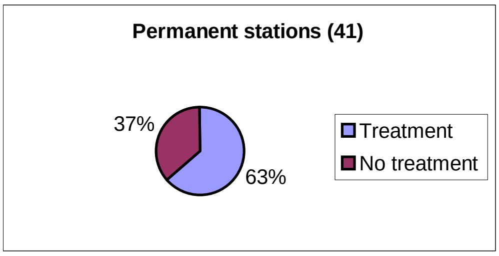


Figure 5.3.The treatment situation for the field stations

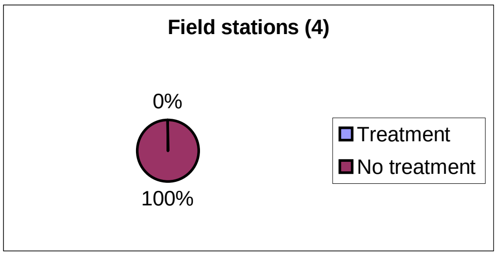


Figure 5.2. Treatment situation for the summer stations

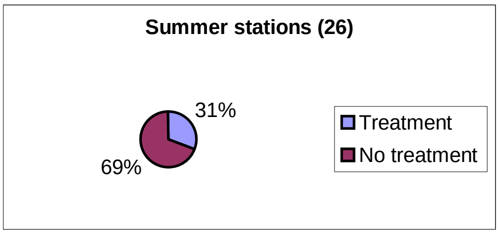
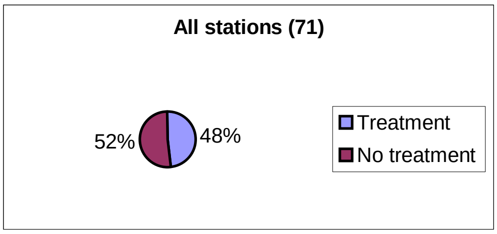


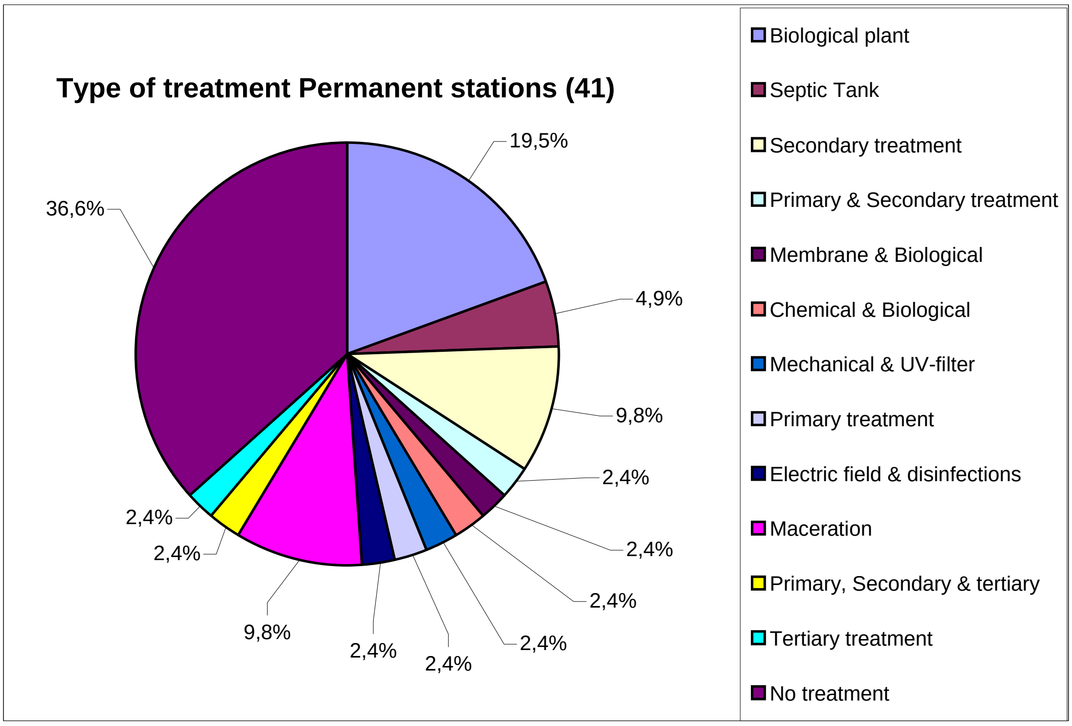
Figure 5.4.The treatment situation for all stations, includes permanent, summer and field stations.



Most of the countries with permanent stations have biological treatment in their plants. Because Wasa is only used during the summer season biological treatment with micro-organism might not be working. To survive they need food, in form of organic material, and that can only be supplied during summertime visits. One of the questions in the survey was; does it take long time to start the process? That could not be answered for those countries with permanent stations. Even though most of the countries with summer stations said that it takes one to two days to get it going, it is more likely that it take much longer time. Often the time that is given, is the time it takes under perfect circumstances. It is especially difficult if the winter has been hard and long and with a plant placed outside. If this is the case there is a risk of getting frozen pipes and tanks and before they can be used again they need to be thawed.

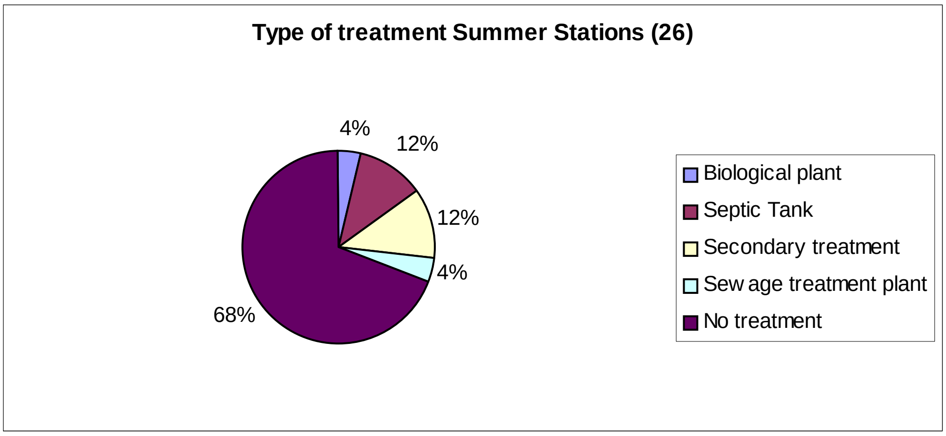
The different types used at the stations can be seen in figure 5.5 and 5.6 below. In the figure for permanent stations the slice with no treatment is the largest section with 38% and then there is the biological treatment that is most common for permanent stations with 21 %. Maceration and secondary treatment has equal selections (10 %). Two stations have septic tanks as treatment and the other methods are used on one station each.

Figure 5.5. Type of treatment Permanent Stations



For the summer stations septic tanks and secondary treatment has the same selection (12%). Biological plant and Sewage treatment is only used at one station each.

Figure 5.6. Type of treatment Summer Stations



6. Products

To find out what kind of small treatment systems that exists on the market, companies in the water cleaning industry were contacted. In appendix 3 there is a product specification that was sent to the companies suggested in “Small treatment plants for households”[64]. Companies that had other treatment than biological were contacted. They were also asked to give suggestions on products that they have or is going to have in the near future. All together eight companies where interesting at this stage, three immediately answer that they had no interesting products for Wasa.

The company Ecotreat suggested a chemical precipitate for phosphor, a mud separator and a biological treatment step. Because it is a biological treatment it is important to use environmental friendly chemicals, so the ecosystem does not get eliminated. But they have not been able to be reached for price, size and time frames. A biological solution is probably not the most suitable solution.

Other companies did not have a ready solution nor time to development one. Time limit was the most common answer received from the companies. Not one said that the location was a problem it only required special arrangements.

The company Emendo AB has a chemical precipitate plant, which fulfil all demands on a plant that where in the production specification (Appendix 2). One similar plant, but for more persons, was delivered to the Swedish UN-force in Liberia in 2004. This plant cost 275 000 Swedish crones (37 300 US$)[65] without transports and work on site. The advantages with this type of plant are many. It is in one big part and has few moving parts, this means that it has better durability. It is also easy to transport. It starts when water is put in and can be left for a long time before new water is added and then work again. Reinhold Skoglund[66] at Emendo AB describes two different types of chemical precipitation and separation of mud. They are based on the same principle that is carried out in two different ways.

The first one is a three chamber well. In the first chamber sedimentation take place. This is important, because grey water contains a lot of different fat. In the second chemical substances are added and starts to brake down and catch the pollution in the water. In the third chamber the flocculation substances is added and has to be used to bind the parts that the chemicals has created together. All this happens simultaneously and is a continuous method.

The other method is a system that starts when enough water is added to the waste water tank. It has the same reaction and steps. But it all takes place in one tank and no water is added during the reaction and it takes approximately three to four hours. The problem with this method is that the need for an equalization tank and its size depends on the water use and occupation. If every one in the station showers directly after each other this system needs a tank that can store all that water.

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[64] Taken from the suggested in *Petersens*
[65]Money change rate from 13 of May 2005
[66] Contact info in References

The water that comes from these two plants needs to be separated from the generated mud. The percentage of mud is not very high, which means that it needs to be stabilised more. A very low percentage of mud gives that the storing area needs to be large. Today there are a lot of different options for mud separation and the most common way when using small treatment plants is to have a truck to come and remove the mud from the system when it is needed. This cannot be done in Antarctica. The challenge here is to find a method that works and demands as little effort from the visitors as possible. One solution can be using a filter similar to that in coffee machines where the mud is detached and the water get separated. The mud will by this action get dryer and the separated water will go back to the cleaning tank. The separated mud will then be freeze-dried in drums. The drums with the freeze-dried mud will then be removed from Antarctica by boat. One other solution is to have a sand filter that separates and detaches the mud. It is important to have this process running in an environment where the temperature does not drop below zero. If this happens it will freeze and the added water and mud will not be able to pass through the filtration and probably cause an overflow.

The plant will approximately be 1.5 meter wide and 2 meter high (the drum for mud separation and filled drums will take up some space). It does not smell in the plant, but the mud can smell if it gets too warm, kept at a low temperature smelling is minimised. The plant should be built up in Sweden and tested before shipped to Antarctica.[67]

To get more information about Emendo and their previously products, the Swedish Armed Forces where contacted. They are using the plant in Liberia. They answered that the plant are corresponding to the expectation they had before ordering it. The airborne transportation was not a problem and it only took one day for two men to make all the adjustment on the location. They check the plants chemical system every morning and evening, in all it takes two minutes. During this time they have never come across any problems, disadvantages or something that could be better. They would like to recommend it to other field work sites. Today they have locals to take care of the management.[68]

Picture 6.1 The Swedish UN-forces treatment plant in Liberia, this plant is for 230 persons.

[67] Skoglund, Reinhold
[68] Sundberg, Patrik

7. Discussion

It seems like many countries goes around the requirements of the Environmental Protocol by having stations occupied by less than 30 individuals per week during the austral summer. By this standard, even a permanent occupied station fulfils the Antarctic Treaty without having any water treatment. Even if there is an article[69] in the protocol saying that if there are less than 30 persons a week during the austral summer you do not need to have treatment, every country should or at least could act to prevent releases of sewage that can cause danger for the surrounding environment. Also, there seems to be a big difference between how tourists and stations are treated. According to Olsens[70] investigation it seems like the tourists manage to look after them self's. On the other hand the personnel at the stations stay in Antarctica for much longer time and has at least until now not been so considerate about the surrounding environment. But the personnel at the stations have been in Antarctica for longer than tourists and that gives longer time to build up the damages. In the earlier days the effect that humans can give on the flora and fauna was not know and researched. Today we know much more than before and can take more responsibility for our actions.

Much seems to be changing, but perhaps it is time to force all permanent stations to use some kind of water treatment and stop the leak of potential hazards to the marine life. For example if you have a permanent station with an average of 25 people their individual water use is 100 litres per day and in a year that will give a total water use of 9,125,000 litres leaking right out in the ocean. If there is a summer station open for 3 months, and the same water use and same occupation, it gives 225,000 litres that leaks out. The permanent stations water leak is over 40 times bigger and during a whole year. The big differences for the environment when it comes to water leak and disturbance is that for a summer station there is almost 3 times more time to recover from the visit, but with a permanent station there is never time for the environment to recover.

All countries with stations doing research in Antarctic need to have the environment as pristine as possible. Then, not to have a working treatment of waste water seems really bizarre. It would probably be better if there were no trace of humans in the environment and in that way easier to get good results or better predictions of the future. Antarctica is the last unexplored part of earth and our use of it should not be devastating for the next generations' research.

Also, the expression "station" is used for both places like Wasa and for McMurdo, the American base that can occupy more than 1000 persons during summertime. It seems like there should be different rules for small stations and really big stations, looking more like small villages. It would be a better rule, if it were more concrete and separate summer stations from permanent stations, but still consider how many residents the stations have. It would be preferable that if a station uses more than say 3 m^3 water a day it must have a treatment system.

Most of the stations got their treatment plants during the last decade and before that all waste water was let out directly to the ice or sea. As an example McMurdo, the big American base, got

[69] Annex III to the protocol for environment protection. Art. 5
[70] Olsen, Björn

their treatment plant 2003 and had prior to that no treatment of their waste water. In this case it follows that waste water from at least 1000 persons has been released right out to the ocean during earlier summer seasons. It could have devastating effects on the marine life in McMurdo Sound. Untreated water has been released during a long time and probably the consequences of this will come throughout a long period of time. Since the affects are not really investigated, it is better to prevent damages than to wait and see what happens.

One way to prevent damages from untreated waste water is to find out what is put in to the system. All products used with water ends up in the outgoing water. If the products used at stations are too checked and selected after environmental friendliness, some of the harm can be prevented. An example can be that the station's owner makes a list of products that are approved for use in Antarctica. Products that contain triclosan, for example toothpaste and soap, should not be used at all and especially not in Antarctica. The already sensitive ecosystem in Antarctica should be treated carefully and not be exposed to unnecessary potential danger. As Johansson's[71] study showed cosmetics and hair products contains dangerous and environmental hazards. The second best way to prevent the flora and fauna in Antarctica from potential hazards is to choose good products to bring. This must be the easiest way for all countries to be more environmental friendly in Antarctica, because all the products are brought there.

Researchers today find more and more indication that impacts from human activities affects the flora and fauna. Our knowledge also change our preferences when it comes to see what products are dangerous both for us but also for the environment. The development provided that something that was not considered dangerous 30 years back is that today. This shows that it is not only the products used at the moment that are a problem but also those we used 50-60 years back that cause problems today. The environment suffers a great longer time from our mistakes than we do, because the trace can be seen during so long time.

Conducting the survey was much easier then to get information from potential companies about their small treatment plants. Even though the companies were contacted several times they did not answer. A few answers were received, but one of the companies had a really good solution. The Emendo solution may not be the absolute best, but with their staff, the overall achievement is the best. It is important to have both good technical solutions and also have employees that are pushing to do better and willing to develop during the process.

The method in the plant that is recommended is one with chemical precipitation and sedimentation of organic material. It is an easy process that works the same way all the time and the chemicals are added after a flow measurement has translated the flow into how much chemicals are needed. This gives that the flow can change without affecting the process, since the flow gives what is added in the process. This is better than having a biological plant that needs to defrost which leads to the problem that the bacteria and micro organism will not survive another winter without food, in form of organic material. It is easy to run the plant and it does not need a lot of efforts from the visitors and researchers.

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[71] Johansson, Kristina

It is important that SPRS gets a treatment plant for Wasas grey water and prevent the surroundings of Wasa from getting more contaminated with human bacteria and dirt. Since Antarctica is such a big resource for research about our planet and development it should be kept untouched for the coming generations. Soon the Antarctic Treaties articles can be more adjusted to today's techniques, development and possibilities.

During the last couples of years Antarctica is more accessible than before and the yearly visitors are increasing. Both the number of researchers and tourist are increasing. The tourists are an important key to getting more done when it comes to maintenance and keep the content clean. The tourist that visits stations may not have the same picture on how it looks as the returning researchers and stations staff. Maybe the new comers did not think that abandoned trash would lie on the ground and that before the trash was sunken outside in the ocean. All this gives new input to the active countries on what needs to be done at their station. In the end all the tourist visits will give more publicity to what happens and can occur in Antarctica.

Efforts that help the Antarctic Treaty to maintain this unspoiled continent have to be done. If problems are discovered the action has to come immediately after options has been looked into and measured. New techniques that work in this environment needs to be developed and used by all possible clients. To preserve Antarctica is not a one mans mission, to get good results everyone has to contribute with their special knowledge.

8. Conclusion

Of all station in Antarctica 48 % of them have some kind of treatment. The permanent stations have a higher number of treatment, 63 %, and only 31 % of the summer stations have some kind of treatment. This means that a lot of countries should get treatment if they want to live up to the Antarctic Treaties articles. Sweden is soon going to join and increase today's 48 % with treatment.

One treatment method for grey water is found and it is the company Emendo AB that have the final product. The product will use chemical precipitation and sedimentation to clean the water before it will be released to the ice outside Wasa. This will minimise the environmental impact from SPRS in Antarctica further.

9. Recommendations for further work

The recommendation for further work is that the plant is to be ordered and built. So it can be tested in Sweden before it is shipped of to Antarctica. It would be best if it was tested during a winter at Tarfala station near Kebnekaise in the north of Sweden. This would nearly correspond to the climate in Antarctica. The testing will be useful both for the technical appearance and for education of personnel. During this full-scale test potential problems will be discovered and solutions found. After final adjustments of the system it is ready to be shipped to Antarctica.

Another recommendation is to do a survey among potential companies too see if they could build it cheaper or better. Now when it is stated that there is 17 other summer station that in the future will need a similar treatment plant. If the plant that Sweden decides to use works well. It can be recommended for other stations and the company might find several potential clients.

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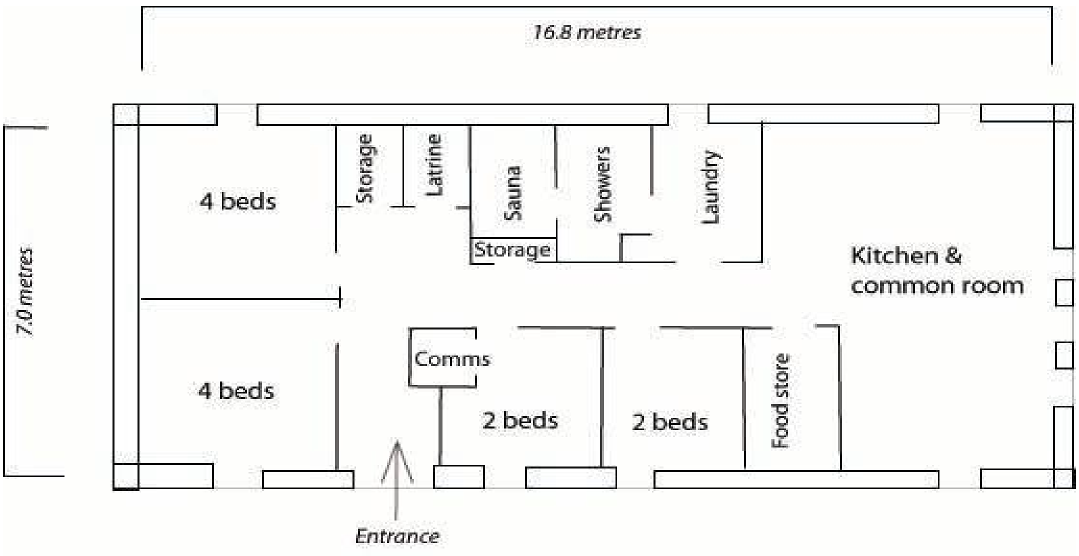
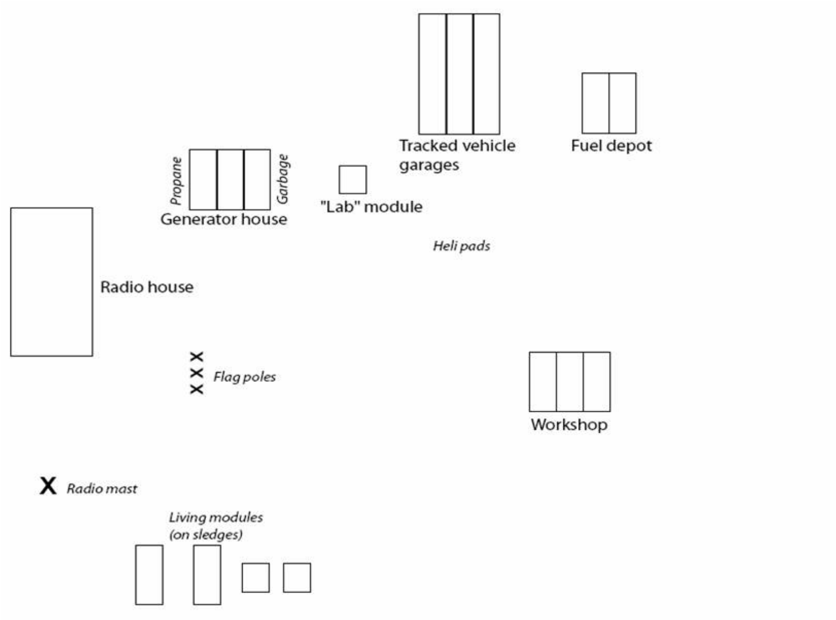
12. Appendix

12.1 Plan Radio House and Map over Station Area



Plan 12.1. Radio House



Map 12.1. Station Area

12.2 Product specification

The Swedish polar research secretariat is seeking new technology/product to test/use in Antarctica.

The Swedish polar research secretariat is looking for an installation that can clean grey water in Antarctica. Sweden has since 1988/89 a summer station Wasa in Antarctica. The climate on the continent is characterised by low temperature, sparse precipitation and low humidity. During the off season, winter-time, between May to September the average temperature is –20 °C and wind speeds up to 50m/s are measured. During austral summer the temperature varies from –20 °C to 0 °C and the wind speed varies from 2 m/s to 30 m/s. The snow melts on the station area throughout the warmer summer months. The main wind direction is northeasterly. During the summer no heating is necessary because of that the windows is turn towards east, west and north to gain the heat from the summer sun. There is also a heat-exchange system that continuously circulates heat from one occupied part of the house to the others. In Antarctica there is also a corresponding phenomenal to our Northern Lights the Southern Lights.

Some kind of treatment is needed to the Swedish summer station Wasa. It should be for grey water from maximum 30 people at the same time and during maximum two months. The amount of water used is estimated to 100 litre/person and day. The water comes from showers, sinks, washing machine and dishwasher. Grey water from Wasa is today transported out via a 100-metre long insulated and heated pipe downhill and discharged to an ice covered area below the station where it drains into the surrounding ice and ultimately to the sea. Dry toilets are used at the station. The system consists of a simple long-drop into a 200-litre fuel drum. Both faeces and urine are collected in the drum. When the drum is filled a lid is placed loosely on the drum and is left for two or three seasons for primary treatment in Antarctica. The primary treatment is evaporation of the liquids and freeze-drying. The rest is transported by ship for disposal in South Africa.
The construction needs to be place inside because otherwise it will freeze and break down. The cost is too high for warming up an outdoor facility. The use of hygiene products is the same as in any home in Sweden. All visitors bring their own products, and the Polar Secretariat supply washing powder, washing up liquid and other cleaning chemicals.

The Antarctic Treaty regulates all activity in the region. The grey water does not need to be treated to fulfil the regulation and laws. Sweden will as an environment concerned country work to get minimal influence in the region and guarantee that the human activity doesn’t destroy the research resource in Antarctica.

The Swedish Polar Research Secretariat is a government authority under the Ministry of Education, Research and Culture and its task is to promote Swedish Polar research by organising and leading research expeditions to Antarctica and the Arctic, primarily as part of international efforts.

The Secretariat actively works to improve environmental protection in the Polar Regions and since 1994, the Secretariat is the authority that dispenses permits and overseas activities related to the Act on Antarctica.

The product must

- Demand little space because it needs to be inside.
- Be easy to switch on and off, and not demand several days to get started again.
- To be as much as possible be going without interference.
- Work in extreme cold and harsh climate.
- Not demand much service, because it is not so easy to get to the station except during expeditions.
- Capacities to clean grey water from 30 people that maximum use 100 liters/day.

The Product should

- Be environment friendly, not use too much chemicals or energy.
- Be easy installed and transported to Antarctica.
- Work direct when an expedition arrives and turns it on.

12.3 Survey about waste water from stations in Antarctica

This email contains a survey about how your station/country takes care of waste water during expeditions to Antarctica. This survey will give the Swedish Polar Research Secretariat an overview how the other countries active in Antarctica deals with their waste water and what cleaning systems that already is in use.

1. Country?

2. Number of stations that are used in Antarctica?

3. What is done to the waste water at the station today?

4. Is there a sewage treatment in work? If not, are you planning to get one?

5. What type of sewage treatment is in use?

6. How does the sewage treatment work, with which process?

7. Is it running all year or only during expeditions?

8. Does it take long time to get it started when an expedition are arriving?

9. Does the sewage treatment need a power source?

10. What is the running cost and what was the cost for the machine?

11. Is the system working satisfying?

Thank you for your time and cooperation

Countries in the survey and in the statistics
Argentina
Australia
Belgium
Brazil
Bulgaria
Canada (Do not have any station in Antarctica)
Chile
China
Czech Republic
Ecuador
Estonia (Is planning to open one, but have not decided yet on treatment)
Finland
France
Germany
India
Italy
Japan
Korea
Netherlands (Do not have any station in Antarctica)
New Zealand
Norway
Peru
Poland
Russia
South Africa
Spain
Sweden (Not sent but included in the statistics)
Ukraine
United Kingdom
United States
Uruguay

The occupation in Summer Resident, Winter Resident and place on type of ground is taken from COMNAP homepage Member and Stations, so that is not answered by the countries.

Argentina
1. Argentina

2. Six Permanent Stations: Jubany(100 Summer residents, 20 Winter residents, rock surface), Esperanza (90 Summer residents, 55 Winter residents, solid rock surface), Belgrano II (21 Summer residents, 21 Winter residents, not noted), Orcadas (45 Summer residents, 14 Winter residents, rock surface), San Martín (25 Summer residents, solid rock surface) and Marambio (150 Summer residents, 50 Winter residents, Permafrost surface). Summer Stations: Melchior (36 Summer residents, rock surface), Primavera (18 Summer residents, solid rock surface), Cámara (36 Summer residents, rock surface), Decepción (65 Summer residents, rock surface), Matienzo

(15 Summer residents, Volcanic rock surface), Petrel (55 Summer residents, Volcanic rock surface) and Brown (18 Summer residents, solid rock surface). Only used during summer, and just if each year some are required for scientific purposes.

3. Belgrano II; Grey water recycled for use in toilettes, black water treated in septic tank, effluent and sludge released onto ice. Marambio; Grey water treated with biological treatment plant, black water treated in biological treatment plant, effluent released onto ice-free land and sludge transported to other continent for disposal. Jubany; Grey water treated in biological treatment plant, black water treated in biological treatment plant, effluent treated with ultraviolet sterilization before release into the sea and sludge dehydrated then returned to another continent to disposal. Orcadas; Grey water recycled for use in toilettes, black water treated with biological treatment plant, effluent released into sea and sludge released into sea.

Summer stations, waste water released into the sea. The number of personnel at summer stations is always less than 30 people.

4. All the plants at permanent stations are at work. For now, there are no plans to get treatment plants for summer stations.

5. See SCALOP questionnaire.

6. Basically, there are two types of plants used, the one at Jubany Station, which is more complex and uses UV radiation to disinfect the output water, and the other plants, that uses chlorine to do so.

The treatment plant at Jubany Station is an aerobic biological compact cleaning plant. The cleaning of waste water (kitchen, toilet, showers, washing machine and elaboration) is carried out by microorganism and bacterial in an oxygen environment.

The plant consists of 4 tanks. The sewage water is lead through a pipe system of PVC with diameter 4 inch to a 2 sq chamber, where a pump smash and sends the water on to the first tank. In the two first tanks is the oxygen contributed by tourniquet and bacterial attack. The upper part of the second tank where most of the mud concentrates is connected with the third tank, which works as a decantery. The mud that is decanted is brought back to the first tank where the cycle starts over. The remaining liquid is exposed with ultra violet radiation to eliminate remains of bacteria. Than it is taken to the fourth tank, where a muddy test is carried out. The cleaned liquid is released in the bay.

The decanted mud in tank 1 and 2 accumulate to a concentration of 800- 900 ml mud per litre water. Where parts of the mud is extracted to a reactor where it is treated with a water and calcium oxide solution with pH 12,5 and flock detergent 5 % P/V. The product is brought to drainage bags, which is placed in an drying oven in 35 C° (it looses about 50 % of its volume because of water lost). Finally it is placed in plastic bags and brought to Argentina territorial.

The treatment plant works totally automatically. Only the controls and extraction of the decanted mud is made manually. The whole plant has automatic safety system that controls the level in the inflow, tank 1 and 2. The last two has sound alarm.

The maximal capacity for the treatment plant is estimated to 150 litre a day and individual for up to 50 individuals. The plant can handle water with a mud concentration on 300- 600 ml/l water. After treatment the mud concentration is 2-3 ml/l water.

Plants at other stations,
Example 1, Marambio Station.
The plant consists of one treatment module, two pumps for the raw liquid, one disinfections tank on 1 sq. m, a system for disinfections, pipe system that combined the different equipment and a control panel. It has a capacity to take care of sewage from 50 individuals with 125 litres a day and individual.

It is all controlled with a programmable control panel. In this way the plant works totally automatic. The method is activated mud with aeration. The reverse circulation of the mud takes place with compressed air. Finally the outgoing water is disinfected with sodiumhypochloride. The circulation equipment is in a cylindrical tank with diameter 1,5 m and height 2,5 m. When the plant is installed it takes up an area of 5 sq. m.

Example 2, Esperanza Station
The treatment plant consists of one module of model LAP-50 that built on the method with modified mud that has been activated with aeration. The character on the capacity for the process and the flow that is let out in to the ocean is summarized below:

Volume flow per unit	150 l/(pers day)
Volume flow per day	12,75 m^3/day
DBO5 in flow	220 mg/L
DBO5 out flow	<15 mg/L
Sedimentary solider	only trace
Suspender solider	only trace
Colour	crystal
Smell	do not smell
Intermission time	25 days
Process	aeration in redundancy
Volume aeration chamber	6,25 m^3

The system is totally automatic and do not demand any specially trained staff either for installation or later control. All electro mechanical equipment is doubled and used ever second month, the exchange occurs totally automatic.

The reverse circulation of the mud take place with compressed air where help pumping is not used. The treatment equipment is in a cylindrical tank of none oxidize steel with diameter 2,0 m and height 2,5 m plus the cover. The tank demands no manual cleaning on the inside because the process is automatic and continual, but it has an in port and upper cover is possible to dismantle.

Disinfections of the treated flow occur with small doses of sodiumhypochloride. The average temperature during this need to be between + 15 °C to +18 °C, which is obtained by electrical radiators. Finally the mud, which is produced in the plant, is dried and packed appropriate for evacuation from the Antarctic Treaty area.

7. The plants run all year.

8. The treatment plants run all year.

9. Yes. All treatment plants utilize electrical energy, generated using Gas Oil by Caterpillar generators.

10. The running cost of the plans is insignificant in terms of power consumption, but you should take into account the cost of heating the building. For example, at Jubany Station, the heating system needs 20 liters (gas oil) per day. Moreover, the treatment plant needs maintenance and the replacement of many parts each year, for example, the UV lamp, 2 filters, 2 air injectors, and 96 Kg of quicklime.

The prices of the machines are variable. The last machines acquired (for Marambio Station, in 2004) had a cost of US$ 9000. The plant at Jubany Station was donated by Holland, so I can not precise the cost.

11. Yes.

Australia
1. Australia.

2. 3 continental stations. Casey (70 Summer residents, 20 W, Ice free solid rock and frozen moraine surface), Mawson (60 Summer residents, 20 Winter residents, Ice free rock surface) and Davis (70 Summer residents, 22 Winter residents, Ice free, mainly frozen moraine surface).

3. The stations have secondary treatment sewage facilities. Two of the stations (Casey and Mawson) are operating effectively and having optimal quality effluent. The other station (Davis) sewage treatment plant has failed and is on permanent by-pass (a recent development late last year) though waste is still being macerated.

4. We are planning to replace the Davis Waste Water Treatment Plant within three years dependant upon funding. We hope to replace it with a tertiary treatment plant.

5. Secondary treatment only.

6. The sewage plants have rotating biofilters.

7. They run all year.

8. N/A
9. Yes - we generate power from diesel generators. At Mawson this is supplemented by wind turbines.

10. I am unable to answer this question. Though we estimate it is about 3 million AUS $ to replace the Davis Sewage Treatment Plant.

11. Two of the stations (Casey and Mawson) are operating effectively and having optimal quality effluent. The other station (Davis) sewage treatment plant has failed and is on permanent by-pass (a recent development late last year) though waste is still being macerated.

Belgium
1. Belgium

2. None for the moment – construction of a new station in the season 2007-2008.

3. Not relevant – cfr comment 2.

4. Normally we will get a sewage treatment plant in the new station, but no details of type available yet.

5. Not relevant – cfr comment 2.

6. Not relevant – cfr comment 2.

7. Normally it will work only during the opened period of the station: the summer season.

8. to 11. Not relevant – cfr comment 2.

Brazil
1 Permanent station Ferraz (40 Summer residents, 12 Winter residents, ice free unsolid rocky ground surface).

Chile
6 Summer stations and 4 Permanent. Escudero (20 Summer residents, solid rock surface), Frei (150 Summer residents, 80 Winter residents, solid rock surface), O'Higgins (70 Summer residents, 23 Winter residents, solid rock surface), Prat (no information) are the permanent

stations. None of the summer station has treatment or other information did not give more than 12 people during summertime.

China
1. People's Republic of China

2. Two: Great Wall (40 Summer residents, 14 Winter residents, Ice free solid rock surface) and Zhongshan (no information available).

3. The waste water has been treated in the sewage treatment at the station

4. Yes

5. Bio-Chemistry sewage treatment is in use

6. The treatment used double grades bio-chemistry process

7. All year running

8. Need not

9. Yes

10. The treatment is a lump-sum investment and the running cost is only the power supplying from station. No more other costs.

11. Yes. But after many year running, they will be replaced by new ones in the future.

Czech Republic
1. Czech Republic

2. One station with a capacity for 15 persons and summer-only operation is going to be established this year.

3. Not yet relevant question.

4. So far it is projected that sewage and domestic liquid wastes will be discharged into the sea as their volume, corresponding to the maximum of
15 persons at the station, and the setting of the station comply with the requirements of the Madrid Protocol (Annex II, Article 5, § 1). However, I suppose that later on with ongoing operation of the station a sewage treatment will be applied. A technology of the treatment in the future I am not able presently to specify.

5. to 11. No answer.

Finland
1. Finland

2. One, Aboa (20 Summer residents, stony soil, partly snow covered surface).

3. Biological waste water treatment plant. Only grey water from washing machine, kitchen, dish washer and shower. Urine is collected to barrels and brought away from Antarctica, no black water.

4. No, no, all sewage is brought away from Antarctica.

5. Nil

6. to 11. No answer

France
1. France

2. 2 Permanent stations Dumont d'Urville (100 Summer residents, 26 Winter residents, Ice free solid rock surface) and Concordia (45 Summer residents, 15 Winter residents, snow covered ice cap surface).

3. DDU; all sewages (toilets, showers, washing machine, kitchen) are rejected to the sea. In the kitchen there is a grinder that separate waste food. Concordia; winter station: recycle of the grey water (shower, washing machines...), urine throw in a pit, use of electric burners (no black water treatment for now), food wastes are taken back to DDU and throw in the sea. In 2 years, a whole treatment of the black and grey waters will be operational.

4. No treatment at DDU however this is foreseen for the following years. For Concordia, see above.

5. Sea above: For GW: 4 stages of membranes filtration (ultra filtration, nano filtration and 2 stages of reverse osmosis) For BW: anaerobic and aerobic digestion, nitrification

6. See above

7. At Concordia: GW will run all year

8. Not concerned, station opened full year

9. Yes: GWTU, 14 kW in average (should be the same for the BWTU)

10. Running cost: need to be converted in fuel consumption. Cost of the machine: development and materials of GWTU: 300 000 euros (not considering the spare parts and chemicals: 75 000 euros) For the BWTU: development and equipments: 300 000 euros.

11. In use for the first time this year ... need to wait to see...

Germany
1. Germany

2. 2, Permanent station Neumayer (50 Summer residents, 9 Winter residents, Ice shelf surface), summer station Kohnen (28 Summer residents, snow/ice surface)

3. –

4. Yes

5. Full biological waste water treatment plant works at Neumayer Station.

6. Two tanks with air ventilation (blower), the third tank is for sedimentation.

7. All year.

8. –

9. Yes, for blower, pump and control.

10. –

11. Yes, optimal.

India
1 permanent station Maitri (65 Summer residents, 25 Winter residents, Ice free rocky terrain surface).

Italy
1 Permanent station together with France Concordia(see above) and one summer station Mario Zucchelli (90 Summer residents, Ice free solid rock surface).

Japan
1. Japan.

2. There are two Stations, Permanent Showa Station (110 Summer residents, 40 Winter residents, Ice free solid rock surface) and summer Dome Fuji(no information, Ice sheet surface).

3. We have a biological treatment system for Showa Station, and nothing for Dome Fuji Station.

4. There are the sewage treatment systems in work.

5. It is contact aeration method.

6. We set up three tanks to deal with biological treatment for sewage, and it reduces sewage to SS70ppm and BOD20ppm, and then the treatment water is discharged into sea.

7. It's running all year around.

8. No, because we use it consecutively.

9. Yes, it needs the power source.

10. -

11. We have slight dissatisfaction.

Korea

1. Republic of Korea

2. One permanent station, named King Sejong station (60 Summer residents, 15 Winter residents, Ice free bare ground surface).

3. Waste water is purified by sewage treatment system before discharge

4. Our station operates sewage treatment equipment all over the year

5. UNEX simulation-40 (Rauma-Repola)

6. Sewage treatment process is as follows;
1. Aeration 2. Settling down 3. Chemical & Biological treatment 4. Discharge into se

7. The same as Ans. 4

8. N/A

9. It is operated by electricity

10. N/A

11. Our system’s treatment capacity exceed the volume of waste water, so it manage well.

New Zealand

1. New Zealand

2. One permanent Scott (85 Summer residents, 10 Winter residents, Ice free solid rock and frozen moraine surface).

3. Discharge to sea.

4. Treatment in place

5. Biological treatment

6. Aerated fixed media sized for 122 persons maximum.

7. All year – we have a year round operation

8. Yes

10. Capital cost including insulated building approximately NZ$350,000
Operating costs approximately NZ$20,000 per annum.

11. Consistent, high quality effluent has not been achieved during periods of high loading due primarily, we believe, to inadequate aeration. Action is under way to appropriately control dissolved oxygen levels.

Norway
1. Norway

2. 1 permanent all year station Troll (40 Summer residents, 7 Winter residents, solid rock surface) and 1 field station Tor (no information).

3. Troll; waste water (which is only domestic grey water –all sewage is treated separately) is treated and released to the ground. Incinerator toilets installed at the station, and thus no black water production (only ash). Tor: Waste water (both grey and black) is collected in empty fuel drums and taken out of Antarctica for disposal.

4. Troll; a new and improved waste water treatment system delivered by Haco (www.haco.no) was installed in February 2005, and upgrading of the former simpler filter system. The treatment capability of the Haco treatment system is provided in the table below. Tor; all waste water is collected for disposal, without further treatment.

Table 7: Treatment capability for biological treatment system for wastewater[7]

	Suggested min. treatment efficiency (%)	Suggested max. discharge concentrations	Measured average concentrations in HACO system
BOD_5	>90	<20 mg/l	3.7 mg/l
COD	60-90	<30 mg/l	---
Total nitrogene	>25	<10 mg/l	5.5 mg/l
Ammonium nitrogene	>50	-	-
Total phosphorus	>75	<0.5 mg/l	0.3 mg/l
E. coli	>99	>1000 E.coli/100ml	
Thermo tolerant bacteria			280 TKB/100 ml

5. See above.

6. Troll; Sludge filter, mechanical filters and uv-filter.

7. Troll; presently all year occupation, and system is to function at all times.

8. See above.

9. Troll; yes.

10. Troll; newly installed system (February 2005), and unfortunately we do not have any cost estimates at this point in time.

11. Troll; newly installed system, and to soon to consider the functionality of the system.

Peru
Did not answer the survey but told in an email that they are getting a similar plant (biological) as the one at base Scott (New Zealand) for their summer station Macchu Picchu (28 Summer residents, no information).

Poland
1. Poland

2. One Arctowski (40 Summer residents, 12 Winter residents, no further information).

3. Collected in tank

4. -

5. Little electrically warming

6. Very nice

7. All year

8. N/A

9. Yes

10. It is part of total budget.

11. Yes

Russia
1. Russia

2. 5 - Permenant Bellingshausen (38 Summer residents, 25 Winter residents, Ice free coarse glacial till surface), Novolazarevskaya (70 Summer residents, 30 Winter residents, Ice free rocky terrain surface), Progress (77 Summer residents, 20 Winter residents, Ice free solid rock surface), Mirny (169 Summer residents, 60 Winter residents, Ice rock outcrops surface), Vostok(25 Summer residents, 13 Winter residents, snow covered ice plateau surface).
2 -Summer Molodezhnaya (no information), Druzhnaya (50 Summer residents, solid rock outcrop surface).

3. Progress - treatment – sea, Vostok - no treatment - ice pit and others - no treatment – sea.

4. In work - Progress
Novolaz. - 2005-2006
Bellingsh - 2006
Mirny - 2007
Vostok, Molodezhnaya, Druzhnaya - 2007 -2010

5. Progress - electric-chemical

6. Destruction of microbiota by electricity field and disinfection before outlet.

7. All year running

8. 1 day

9. Yes, up to 3 KW (including heater)

10. Approximately - USD 3000 (r.c. incl. salary) - USD 60000 (unit cost)

11. Due it was erected late 2004 season we have no results on how effective the treatment is.

South Africa
1. South Africa

2. One permanent Sanae IV(80 Summer residents, 10 Winter residents, Solid rock surface).

3. Waste-water is treated

4. Sewage Water Plant

5. Bio-filter RBC (Rotating Biological Contactors) Purification plant

6. The Bio Filter plant comprises of a primary septic tank, Bio Filter RBC rotor units, a humus tank and chlorine contact tank.

The effluent from standard septic tanks or primary sedimentation tanks receiving waste and soil water from domestic sources, passes through semicircular troughs in which the Bio Filter RBC disc filters rotate at slow speed.

Biological films form on the discs similar to those found on standard trickling filters and absorb the organic pollutants present in the effluent and convert these to readily settleable solids, which are removed by sedimentation in the humus tank.

The biological film acts aerobically as oxygen is absorbed form the atmosphere by diffusion into the wet film surface on the discs during rotation, and no offensive odours are therefore produced.

As a result of the large amount of active organisms present on the discs, the process can absorb large organic shock loads or high hydraulic overloads.

Under the above adverse conditions, the biomass cannot be washed out of the system, and the Bio Filter unit will thus continue to remove a fixed amount of waste material from the effluent.

7. Sewage Treatment plant runs all year

8. N/A

9. It does require a power source

10. The plant has capacity to service 100+ people. Annual cost in South African rand, R5 000 per year. Original cost of plant is about 1,5 million rand.

11. The operation works well during the over-wintering season, but with the sudden influx of the summer personnel the system it does take strain for the first two to three weeks.

Spain
1. Spain

2. Two summer stations Juan Carlos I station (14 Summer residents) and Gabriel de Castilla station (14 Summer residents).

3. In both stations the waste water is treated in a septic tank

4. Yes

5. A septic tank

6. Juan Carlos I station: The sewage goes to a 6 m^3 septic tank with 3 digestion chambers. To accelerate the organic metabolic process, the septic tank is heated with an electrical resistance. Thanks to this simple installation the DBO is reduced in a 62% at the end of the process. The second tank, prefabricated and buried at 20 cm from the first, has two digestion chambers and a third filled with a biological filter. Finally the water obtained from this second tank is channelled to sea.

Gabriel de Castilla station: The sewage is treated in a septic tank buried at 0.5 m, it has two chambers, the first, where the sewage goes directly from the station, is for sedimentation, digestion and to store mud, it has a foam baffle and at the top a tub to remove the gas outside. From the second chamber, to sedimentation of de additional mud, goes an exit tub that pour the treated water to land. Each 2-3 years the tank must be opened to extract the mud.

7. Only when the station is open in summer

8. The Base starts operations every season with a reduced team. When operative all systems starts receiving the researchers groups. The system become operative in one to two days

9. In the Juan Carlos I station the septic tank has an electrical resistance connected to the power supply but in this moment is in disuse.

10. No answer

11. Yes

Ukraine
1. Ukraine

2. One – all year-round station Vernadsky (former BAS Faraday base, till 1996) (24 Summer residents, 12 Winter residents, Ice free solid rock surface).

3. The untreated sewage is discharged in surround seawater.

4. Station isn't equipped a special sewage treatment plant, and the seawater in discharged by circulation regime is used in the sewer system (up to 4 cubic meters per hour).

5. Discharging by constantly circulating sea water.

6. See question 5.

7. All year.

8. See item 5.

9. Yes

10. Running cost: electric power supply for pumping

11. Yes

United Kingdom
1. United Kingdom

2. 2 Stations on Antarctic mainland: Rothera (130 Summer residents, 22 Winter residents, Rock and raised beach surface), Halley V (Brunt Ice Shelf) (65 Summer residents, 15 Winter residents, Ice shelf surface), Fossil Bluff (field camp) and Sky-Blue (field camp). 3 Stations on Antarctic islands: Bird Island (South Georgia Islands)(8 Summer residents, 4 Winter residents, Shelving shingle beach backed by luxuriant tussock grass surface), King Edward Point (South Georgia Islands)(18 Summer residents, 8 Winter residents) and Signy (South Orkney Islands)(10 Summer residents, rocky coastline surface).

3. Rothera – Sewage liquids are subjected to Primary (screening and settling), secondary (biological aeration) and tertiary (UV sterilization) treatment by Typepak 3 Sewage treatment plant. Includes kitchen waste and grey water. Treated waste water is discharged at high water.

Halley V – Sewage and grey water are macerated and then discharged into an ice pit. Food waste is bagged and buried in a surface ice pit.

Fossil Bluff – Incinerating toilet (powered by propane gas) for sewage disposal, and grey water and food waste discharged untreated into an ice pit. The incinerating toilet leaves a sterile ash residue behind, which is returned by air to Rothera for onward disposal.

Sky-Blue – Incinerating toilet removed due to operating constraints (too cold to operate efficiently), so currently all sewage, grey water and food waste are discharged untreated into an ice pit.

Bird Island – Sewage and food scraps are discharged unmacerated directly into the sea. Grey water is discharged unmacerated into the sea via a stream that runs out past the jetty. Bones and large quantities of grease and fat are burnt before discharge so that they are sterilized.

Signy – Sewage and grey water are discharged directly into the sea. Wet food and kitchen wastes are macerated before discharge. Large bones, grease and fat are burnt before discharge so that they are sterilized.

4. Rothera - Yes, one plant currently working.
Halley V - It is planned to install a sewage treatment plant at the new station Halley VI, which will replace Halley V. Type as yet undecided.
Sky-Blue – Field trailing AVTUR burning incinerating toilets at Rothera this season, and if successful will install one at Sky-Blue. AVTUR is aviation turbine fuel (essentially paraffin with extra additives which make the fuel more suitable for use in aircraft engines).

5. Rothera – Hodge Seperators Typepak 3 Sewage treatment plant.

6. Rothera - Sewage liquids are subjected to Primary (screening and settling), secondary (biological aeration) and tertiary (UV sterilization) treatment.

7. Rothera – Is run all year, as the station is operational all year.

8. Rothera – N/A, operational continuously.

9. Rothera – Yes, powered by diesel generators at station. Electricity supply is 415 Volts, 50 Hz, 3 phase.

10. Rothera – we do not have the detail for running costs easily available, but I can get it for you if necessary. The cost of the Typepak 3 plant in 1999 was £80,400.00 (but this does not include the shipping, construction or operation costs).

11. Rothera – Yes, however you should be aware that the plant is designed to cater for about 100 people and would be too big for the operation at Wasa.

United States
1. United States

2. 3 permanent stations that operate all year McMurdo Station (1100 Summer residents, 200 Winter residents, volcanic rock), Palmer Station (44 Summer residents, 20 Winter residents, solid rock) and South Pole (220 Summer residents, 60 Winter residents, Ice)

3. McMurdo Station – sewage treatment plant.
Palmer Station - maceration and disposal into ocean.
South Pole Station - disposal into deep ice pits.

4. McMurdo Station – yes, in operation as of 2003
Palmer Station –under consideration for the future
South Pole Station – options are being evaluated for a sewage treatment plant

5. McMurdo Station – sewage treatment plant (tertiary treatment)
Palmer Station – maceration, dilution, and disposal into ocean
South Pole Station – no treatment

Laboratory and hazardous wastes from all stations are collected separately from other wastes, removed from Antarctica, and disposed of appropriately.

6. Sewage entering the McMurdo plant is macerated, aerated, and then transferred to clarifiers where the solids settle out, and UV sterilization before being released into McMurdo Sound.

7. Human waste processing is the same all year at all stations, though volume treated varies among seasons.

8. Not applicable; the stations operate all year.

9. McMurdo Station – yes
Palmer Station – yes

10. It cost approximately $US 7.2 million to build the Waste Water Treatment Plant, and approx. $US 125,000 to operate it for per year (includes one operator with minimal training, and some supplies).

11. Yes, the plant is operating to specifications, and researchers in McMurdo Sound have noticed improved water quality.

Uruguay
1. Uruguay

2. 2 stations. One Permanent station: Antarctic Scientific Base Artigas (BCAA, spanish acronym) (60 Summer residents, 9 Winter residents, Ice free surface). One Summer station: Antarctic Scientific Station T/N Ruperto Elichiribehety (ECARE, spanish acronym)(7 Summer residents).

3. In BCAA the waste water is discharged to septic chambers for treatment, and afterwards stored in 200 lts drums for removal from the Antarctic Treaty Area. In ECARE the waste water is discharged to septic chambers, and afterwards stored in 200 lts drums for removal from the Antarctic Treaty Area. Take in account that the maximum occupancy is 7 individuals.

4. Even if the Protocol on Environmental Protection allows to directly discharge sewage and domestic liquid wastes into the sea, taking in account that the average weekly occupancy over the austral summer is below 30 individuals in our BCAA base, a sewage treatment is in use.

5. A primary treatment with biological activators in septic chambers, and removal of the dirty mud produced.

6. All sewage and domestic liquid wastes of Group 1 are discharged through piping to septic chambers distributed in the following locations:
(1).- radio room
(2).- scientific laboratory and base leader accommodation
(3).- dinning room
(4).- sick-bay and crew accommodation
(5).- hangar
(6).- power generators room

Once in the chambers the wastes are treated by biological activators (K-ion) with a weekly frequency during the summer, when the base occupancy is maximum almost 30 people, and with a 15 days frequency in the winter when the crew is 8 people.

At the time, dirty muds are emptied once a year. This manoeuvre is done by means of hoses and pumps that transfer the preheated sewage to 200 liters drums. The drums are stored in the waste area to be removed from the Antarctic Treaty Area on board our supply ship ROU 26 "Vanguardia".

7. BCAA sewage treatment is running the whole year.

8. It runs continuously.

9. Yes. The heaters inside the chambers and the pumps are provided with 220 V current produced by the base generators.

10. Running costs: U$S 900 (per year). Cost for the machine: U$S 300 (pumps) U$S 300 (heaters, 6 x U$S 50)

11. Yes, since it exceeds our requirements.

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