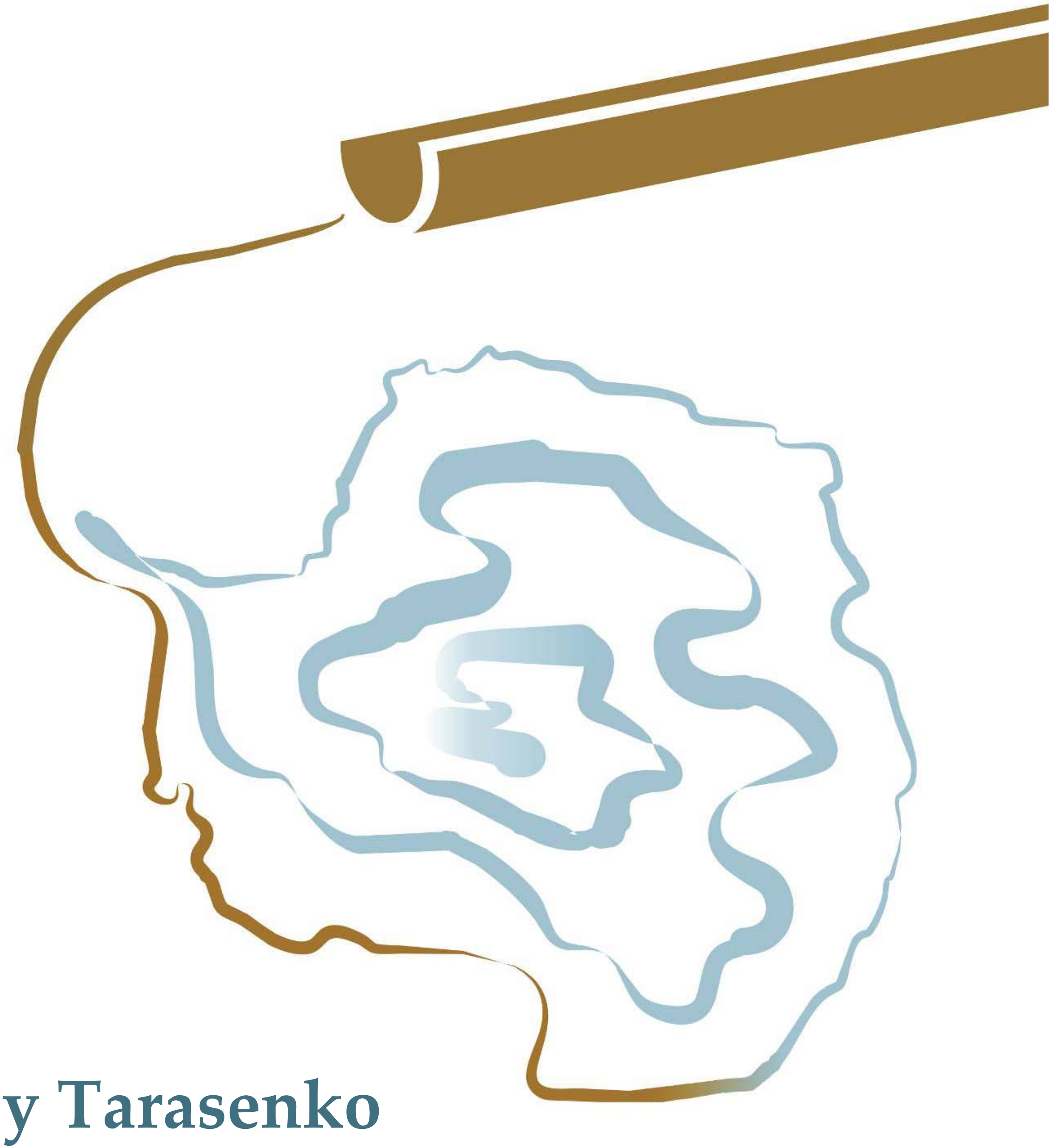
Wastewater Treatment in Antarctica



Sergey Tarasenko
Supervisor: Neil Gilbert

GCAS 2008/2009

Table of content

Acronyms

AEON	Antarctic Environmental Officers Network
BOD	Biological Oxidation Demand
COD	Chemical Oxidation Demand
COMNAP	Council of Managers of National Antarctic Programs
MARPOL	International Convention for the Prevention of Pollution from Ships
MBR	Membrane Bioreactor
PVC	Polyvinylchloride
PVDV	Polyvinyliden fluoride
RBC	Rotating Biological Contactor
SCALOP	Standing Committee on Antarctic Logistics and Operations
SCAR	Scientific Committee on Antarctic Research
SS	Suspended Solids
UV	Ultraviolet

Introduction

Human wastes production is a necessary result of research and logistic activity in Antarctica. Solid and liquid wastes disposal may lead to irreversible changes of the Antarctic environment. This problem can partly be solved by application of efficient methods of wastewater treatment.

Minimum requirements for sewage treatment and disposal are prescribed in The Protocol on Environmental Protection to the Antarctic Treaty. Transferring treatment technologies to Antarctica is not simple because of quite a number of reasons. The principles guiding the design of the water disposal systems are firstly, to minimize environmental impact; secondly, to make rational layout for minimizing land occupation; and thirdly, to operate safely and reliably and make the system easy to manage.

This project will briefly discuss main methods of domestic wastewater treatment and basic principles of sewage disposal for small objects. It also will describe problems of transferring treatment technologies to Antarctica and review treatment plants that have been installed at research stations.

1 Basic principles of wastewater treatment for small objects

1.1 Domestic wastewater characteristics

Domestic sewage consists of two main fluxes. The first one is household sewage (grey water) which includes wastewater from wash basins, kitchen sinks, baths, showers, laundry washing etc. The second one is fecal (black water) from toilets and urinals. Weight of feces per one adult person makes about 1,500 g per day (that includes about 1,250 g of urine). Amount of grey water depends on housing facilities: from 15–40 liters per day per person in premises without central water supply, to 100–200 liters per day per person in premises with central water supply or individual water supply. Composition of household and fecal sewage is very different (table 1), and sometimes it is expedient not to combine it in one flux, but treat separately. Domestic sewage contains contaminants of mineral and organic origin which can be in nonsolute, solute and colloidal state. The major part of organic contaminants is represented by proteins, fats, carbohydrates and products of its degradation. Nonorganic contaminants consist of quartz sand, clay, and salt particles which are formed in the vital processes of the human. The last ones include phosphates, hydrocarbonates, ammonium salts (product of urea hydrolysis). Organic substances make 45–58% of the total weight of contaminants in domestic sewage [1, 2].

Table 1 – *Characteristics of grey and black wastewater*

Compound	Unit	Grey water	Black water
BOD_{total}	*mg* O_2*/l*	100–400	300–600
COD_{total}	*mg* O_2*/l*	200–700	900–1500
Total nitrogen	*mg N/l*	8–30	100–300
Total phosphorus	*mg P/l*	2–7	20–40
Potassium	*mg K/l*	2–6	40–90

1.2 Characteristics of main methods of domestic wastewater treatment

Methods of sewage treatment can be divided into mechanical, physicochemical and biochemical. Treatment process leads to formation of sludge which undergoes deactivation, disinfection, dehydration and deliquification. If discharge or reutilization conditions require higher purification degree, then advanced treatment facilities can be installed after the main treatment plant. After treatment and before discharge, wastewater is disinfected with a view to destroy pathogenic microorganisms. Usually a combination of mechanical and biological treatment is used for treatment of domestic sewage. Physicochemical treatment is considerably less common.

Mechanical sewage treatment is intended for trapping of nonsolute contaminants. Mechanical treatment facilities include bar screens (to remove large waste), sand catchers (to separate mineral contaminants, mostly sand), sedimentation tanks (to remove sinking and floating contaminants (figure 1)) and filters. For treatment of sewage with specific contaminants, grease catchers, oil separators and resin retainers. Mechanical treatment facilities reduce concentration of suspended substances for 40–60%, which leads to reduction of BOD value for 20–40% [1, 2].

Figure 1 – *Sedimentation tanks (St. Petersburg, 2006)*

Biological sewage treatment methods are based on activity of microorganisms which mineralize solute organic compounds which serve as a nutrient source for such microorganisms. Biological treatment plants can be conditionally divided into two types. The first type includes plants where biological treatment process is carried out in conditions similar to natural conditions. Plants of the second type provide similar treatment in artificially created conditions, i.e. in aeration tanks and biofilters. Biological treatment method is the most cost-effective method, but it is applied only in certain conditions. There are following restrictions:

– wastewater temperature must be above 6–10°C (moreover, at temperature above 10°C the biological treatment method is certainly applied. At lower temperatures it is necessary to perform an engineering and economical comparison with systems of physicochemical wastewater treatment);

– long breaks in wastewater inflow (a week or more), because it takes some time for microorganisms to grow after a break (about one month);

– presence of high-toxic contaminants in the water.

Biological treatment plants provide reduction of BOD contamination values for 80–95% [1–4].

Physicochemical sewage treatment methods are applied very rarely. Peculiarity of physicochemical sewage treatment plants is that such plants can be put into operation very quickly. Treatment plants which apply physicochemical processes can be divided into separators and destructors. In plants of the first type, contaminants are removed from the water in the form of strong solutions, sludges and sediments. In destructors, contaminants are destroyed directly in the treated water, and destruction products also remain in the water; at that, no secondary wastes of wastewater treatment are created. Residential wastewater treatment plants apply such methods as flotation, coagulation, sorption, ozonation which are used on different stages of water treatment. Expediency of application of those methods on treatment plants must be justified by technical and economic assessment [1, 2, 5–8].

Flotation is one of the kinds of adsorptive bubble separation which principle is to create floating agglomerates (flotation complexes) of contaminants with dispersed gas phase and its following separation in the form of concentrated froth product (flotation sludge). Flotation is used for cleaning of water from light particulate pollutants, mostly of organic origin, and also from solute surfactants. Flotation plants are used instead of sedimentation tanks or clarification tanks with suspended sediment; flotation plants can also substitute microfilters. Along with removal of mechanical impurities as well as solute and colloidal contaminants, flotation treatment methods provide reduction of BOD and COD values, and removal of volatile components. Effectiveness of flotation process varies widely: from 20 to 99% [1, 2, 5–9].

Coagulation – process of water treatment with coagulants – salts of polyvalent metals. Coagulation is understood as physicochemical agglomeration of finest colloidal and dispersed particles under the influence of molecular attraction forces. 50–60% of residential sewage consist of contaminants which can be classified as colloidal due to its physicochemical properties; such contaminants do not sediment and cannot be trapped with regular filters. Coagulation provides the following treatment efficiency: COD – 78%, BOD – 91.3%, suspended substances – 98.8% [1, 2, 5–8].

Sorption – equilibrium dynamic process of substance absorption from environment by a solid, liquid or gas. The major method used in sewage treatment is absorption process (substance absorption by the surface of a solid sorbent. Sorption methods are mostly effective for advanced cleaning of sewage from solute organic substances [1, 2, 5–8].

Ozonation is a universal method for effective purification of sewage from different kinds of contaminants. Due to high oxidizing capacity, ozone is used both for disinfection and destruction of hard oxidable organic (for example, surfactants) and nonorganic compounds. An additional effect of water ozonation is its enrichment with solute oxygen. Besides, application of ozonation as a destructive method does not lead to increase of salinity, and contaminates water with reaction products to a small extent; the whole process can be easily operated automatically [1, 2, 5–8].

Advanced cleaning of sewage from suspended substances requires application of different filters (filtration of sewage reduces content of suspended substances for 50–80%). Advanced cleaning from solute organic substances is made with the help of sorption, biosorption, ozonation and other plants. Advanced cleaning from nitrogen and phosphorus compounds can be made by physicochemical and biological methods [1, 2, 5–8].

Disinfection of sewage is the final stage of treatment before discharge. The purpose of disinfection is destruction of pathogenic microorganisms existing in wastewater.

The most common disinfection method is to treat water with chlorine (gaseous or liquid) or sodium hypochlorite, obtained through electrolysis of salt brine. Active chlorine takes germicidal effect. *Chlorine treatment* has a number of disadvantages:

– chlorine is a potent toxic substance;

– precise chlorine dosage is necessary (underdose of chlorine result in absence of the necessary germicidal effect; overdose of chlorine has a negative effect on human health (if treated water is used for drinking));

– chlorine must be thoroughly mixed with water; chlorine and water must be in contact for a sufficient (30 minutes minimum) amount of time;

– it is necessary to store massive supplies of chlorine in treatment plants.

Therefore, application of chlorine requires special safety measures and precise adherence to the operating procedure [1, 2, 10, 11].

Wastewater can be disinfected by ozone. *Ozonation* kills bacteria a thousand times faster than chlorine treatment. Ozonation also has a number of disadvantages:

– ozone toxicity makes it necessary to prevent penetration of ozone in premises;

– complex process of ozone preparation (atmospheric air must be dedusted and dry; ozonation plants are energy-consuming and requires efficient maintenance);

– necessity to provide special equipment for introduction of ozone and the required time for contact between ozone and water [1, 2, 10, 11].

Water-borne bacteria can be destroyed by means of *ultraviolet light treatment*. This process is carried out in special facilities, where relatively thin layer of water passes sources of UV-light (quartz-mercury or argon-mercury lamps). Disadvantages of such disinfection method are:

– danger of contamination by mercury used in such lamps;

– special requirements for treated water (it must be transparent and characterized by maximum permeability for UV-light) [1, 2].

Ultraviolet light disinfection has the following advantages:

– UV-treated water does not show toxic and mutagenic compounds;

– no adverse effects in case of overtreatment, which considerably simplifies process control procedures;

– disinfection time makes 1–10 second in continuous flow mode (no necessity to build contact tanks);

– UV-light disinfection plants has low operation costs in comparison with chlorination and ozonation (the reason is comparatively low electric power consumption: 3–5 times less than ozonation) [1, 2, 10–12].

Apart from the listed disinfection methods, in the present time the following disinfection methods are being studied: *disinfection in magnetic field* and *disinfection with electrochemical activation of water* [11, 13].

Treatment of sludges of different types which are formed in the process of mechanical, biological and physicochemical treatment of wastewater and contain organic and mineral components is carried out with a view to obtain an end product characterized by minimal damage to environment or suitable for industrial utilization. This goal can be achieved by implementation of the three major processes in different sequence: dehydration, stabilization, disinfection. Depending on conditions of generation and separation, sludges can be divided into the following types: primary sludges (coarse sludges; heavy sludges; floating sludges; raw sludges which have been separated from wastewater as a result of mechanical treatment), and secondary sludges (raw sludges which have been separated from wastewater as a result of biological or physicochemical treatment; digested sludges, compacted sludges with humidity 90–85%, dehydrated sludges with humidity 80–40%, dry sludges with humidity 5–40%). Heavy sludges are removed by sand catchers. Its composition includes sand and fragments of some minerals. For the purposes of design calculations, the amount of removed heavy contaminants is accepted as 0.02 l (3 g) for one person per day at humidity 60% and bulk weight 1.5 t/m^3. Amount of floating sludges removed by grease catchers or floating up in sedimentation tanks, makes 2 l at humidity 60% and bulk weight 0.6 t/m^3 for one person per year in domestic sewage systems. Raw sludges from primary sedimentation tanks are characterized by considerable non-homogeneity and represent suspended sedimentation of grey or light-brown color with sour smell. It quickly decays due to great amount of organic substances (about 70%). Average humidity of raw sludge makes 93–95%. Amount of raw sludge for one person per day is 25–40 g (0.5–0.8 l). Activated sludge represents suspended sedimentation which contains amorphous flakes, including microorganisms and protozoa with wastewater-borne contaminants adsorbed on their surface. Raw sludge quickly decays in the process of storage and compaction. Average humidity of compacted excess sludge makes 97–98%; its quantity – 20–32 g (0.7–0.11 l) for one person per day. Content of organic substances is about 75%. Sludge can be characterized by high bacterial density (by one order higher than that of wastewater) [2, 14, 15].

1.3 Designing of treatment facilities for individual sewage disposal systems

Choice of wastewater treatment methods and configuration of treatment plants depends on many factors and presents a complex engineering and economical problem. Configuration of a treatment plant should be chosen depending on properties and quantity of influent wastewater, required degree of purification, method of sludge treatment and local conditions.

Estimation of required purification degree shows the necessary effect for reduction of contaminants on a treatment plant.

Treatment plants with capacity not exceeding 25 m^3 per day can be classified as individual treatment plants. Such plants are designed for treatment of wastewater coming from detached houses or a group of buildings. Normally, facilities designed for disposal of small amounts of wastewater can be characterized by high remoteness from well-developed transportation lines, weak construction base, high construction costs and absence of skilled regular staff. Besides, difficulties in designing and construction of treatment facilities for individual sewage disposal systems are also connected with the fact that here we deal with small amounts of wastewater which can be characterized by irregular inflow and instability of contaminants' concentration. These factors drastically reduce operating efficiency of treatment facilities and demand increase of capacity of treatment facilities on the design stage [1, 16–19].

Cost-efficient treatment of small amounts of wastewater calls for application of compact treatment facilities. Such facilities should be installed on operation site as of one piece or of separate bocks delivered by auto, rail or water transport.

Compact factory-made plants can be divided into the following types according to technological process: treatment facilities with activated sludge; treatment facilities with biofilm; combined treatment facilities with activated sludge and biofilm; physicochemical treatment facilities. For treatment of wastewater from settlements with temporary residence of staff and for other objects with periodical presence of people it is recommended to use physicochemical treatment.

At the present time the industry produces a number of different types of modular treatment plants for individual sewage disposal systems. In some cases it is possible to use ship sewage treatment plants (figure 2).

Figure 2 – *UNEX BIO sewage treatment plant (Rauma-Repola, Finland) installed onboard r/v "Akademik Fedorov"*

2 Wastewater treatment in Antarctica

2.1 Problems of transferring treatment technologies to Antarctica

2.1.1 Requirements of the Protocol on Environmental Protection to the Antarctic Treaty / Wastewater quality standards

In accordance with *Article 1* of the Protocol on Environmental Protection to the Antarctic Treaty waste storage, disposal and removal from the Antarctic Treaty area, as well as recycling and source reduction, shall be essential considerations in the planning and conduct of activities in the Antarctic Treaty area.

The Protocol requirements for waste (wastewater) disposal are as fallows:

– sewage and domestic liquid wastes, shall, to the maximum extent practicable, be removed from the Antarctic Treaty area by the generator of such wastes (*Article 2*);

– wastes not removed or disposed of shall not be disposed of onto ice-free areas or into fresh water systems (*Article 4*);

– sewage, domestic liquid wastes and other liquid wastes not removed from the Antarctic Treaty area in accordance with *Article 2*, shall, to the maximum extent practicable, not be disposed of onto sea ice, ice shelves or the grounded ice-sheet, provided that such wastes which are generated by stations located inland on ice shelves or on the grounded ice-sheet may be disposed of in deep ice pits where such disposal is the only practicable option; such pits shall not be located on known ice-flow lines which terminate at ice-free areas or in areas of high ablation (*Article 4*);

– sewage and domestic liquid wastes may be discharged directly into the sea, taking into account the assimilative capacity of the receiving marine environment and provided that:

(a) such discharge is located, wherever practicable, where conditions exist for initial dilution and rapid dispersal; and

(b) large quantities of such wastes (generated in a station where the average weekly occupancy over the austral summer is approximately 30 individuals or more) shall be treated at least by maceration;

– the by-product of sewage treatment by the Rotary Biological Contactor process or similar processes may be disposed of into the sea provided that such disposal does not adversely affect the local environment, and provided also that any such disposal at sea shall be in accordance with Annex IV to the Protocol (*Article 5*) [20].

At the same time the Protocol does not make specific demands on treated wastewater quality. For the reason that it is difficult to define a precise standard of effluent that would be acceptable for discharge to the Antarctic environment it becomes necessary to consider nominal standards for a wastewater treatment plant to achieve. On the other hand treated water might also be in compliance with national or international standards (it is clear that while disposal system meets the requirements of the Protocol it may not comply with national standards). It is obvious that there are significant differences between countries (table 2).

Table 2 – *Nominal designed wastewater quality standards [21–28]*

Country	Designed effluent quality			
	COD, *mg/l*	BOD_5, *mg/l*	SS, *mg/l*	Fecal colon bacillus, *cfu/100 ml*
China (Zhong Shan)	≤20	≤5	0	≤3
China (Dome A)	≤4	≤3	≤2	–
Germany	–	50	100	200
India	–	<20	<20	<200
Korea	–	<50	<50	<250
New Zealand	–	<30	<30	<200
Norway	<30	<20	–	–
USA	–	30	30	200

2.1.2 Geographical situation

2.1.2.1 Climatic conditions

Climatic conditions in Antarctica are extreme. Severe low temperatures vary with latitude, elevation, and distance from the ocean: East Antarctica is colder than West Antarctica because of its higher elevation, Antarctic Peninsula has the most moderate climate; higher temperatures occur in January along the coast and average slightly below freezing (table 3). Heavy winds (highest recorded wind velocity – 327 km/h) and blizzards are not infrequent and can develop very quickly.

Table 3 – *Mean temperatures in different areas of Antarctica*[1]

Area	Mean summer temperatures, °C	Mean winter temperatures, °C
Coast	0	-18… -29
Plateau	-40	-68
Antarctic Peninsula	–	-9

In consideration of weather conditions treatment plants are to be enclosed in heated buildings designed to protect equipment and wastewater flow from freezing temperatures (figure 3).

Figure 3 – *Wastewater treatment plant building at McMurdo station (2008)*

Freezing of pipes connecting plant components can be a serious problem. As a rule wastewater pipelines need to be heated (figure 4). It also means that treated effluent discharge is usually best done intermittently so as to minimise the chance of outfall pipes freezing up. This in turn implies that plants need to include a buffer tank in which treated effluent can be stored until the next discharge.

[1] SCAR official website (http://www.scar.org)

Figure 4 – *Heated wastewater pipeline at Progress station (2006)*

Extreme conditions together with prolonged period of darkness during winter mean that there are just several weeks in summer when conditions are good for outdoor construction work. This time is needed for shipping of plant components to the selected site, installation, and connection of pipes and utilities.

2.1.2.2 Remote location

Remote location of Antarctic station makes transportation and construction of plants (especially in aggregate, but in some cases (for large plants) aggregate is needed) very expensive and inconvenient. For convenience of transport and handling, and to protect plant components during the rough weather characteristic of the southern ocean, it is preferably to build plants inside containers (for instance New Zealanders opted to construct wastewater treatment plants for Scott Base within ISO-20 containers; plants for Novolazarevskaya station were also placed in containers (figure 5)). Modular, prefabricated plants that can be easily disassembled for shipping and readily reassembled on site are therefore virtually a necessity. Such plants can also be commissioned and modified prior to shipping, further alleviating demands on the limited staff available on-site at research stations. Compactness is necessary if plants are to fit into containers.

The remoteness and isolation of plants means that spare parts may be unavailable for long periods and therefore plants must incorporate a high level of redundancy for all items of equipment not readily repairable on site.

Figure 5 – *Wastewater treatment plants at Novolazarevskaya station (2008)*

2.1.2.3 Absence of qualified personnel

Absence of qualified personnel must also be considered. Particularly during winter, plant operation is usually handled by staff who usually has numerous other responsibilities and lacks a detailed understanding of wastewater treatment fundamentals (for example the station's doctor monitored treatment process at Chilean Frei station during 2001 season [29]). This implies that a highly automated control system is desirable, yet it must still be possible to run the plant on manual control in the event of a control system breakdown.

2.1.3 Station facilities

2.1.3.1 Power generation

Alternative energy systems (solar energy or wind generators) seem to be useful in conditions of Antarctica. However, power is generally provided by diesel generators and energy is expensive in Antarctica, being derived from hydrocarbon fuels shipped in at high cost and stored in heated storage tanks. Therefore wastewater treatment plants need to have low energy consumption.

2.1.3.2 Water supply

Water supply in the majority of cases s is provided by melting of snow (waste heat from diesel generators can be used to melt snow). Water supply systems may also be based on pumping fresh water from aqueous deposits below ice or lakes. Desalting of seawater is another way of fresh water production.

There are substantial differences in the consumption of water among stations. The average daily fresh water consumption ranges from 25 to 200 litres per person. This is at least partly explained by differences in the sanitation and washing facilities among stations. Stations may have lower water consumption if vacuum free-of-flushing or incinerator toilets are installed. Water production may also be supplemented by recycling of grey water.

2.1.4 Wastewater characteristics

The amount of wastewater is the result of water consumption. Per capita wastewater output is similar to specific fresh water consumption.

Quantity of sewage in the first place depends on the stations' staff number and it should be noted that the number of people overwintering on bases can be as few as 10% of the peak number present during the summer resupply period (figure 6). So, a key design consideration at all plants is the marked seasonal variation in hydraulic loading rates.

Most people at bases have similar work schedules so diurnal load fluctuations are pronounced and have to be allowed for. Another aspect of importance is that numbers on stations tend to alter stepwise, for example when the resupply vessel arrives. This means that plants have to be able to adjust rapidly to the load changes. This problem is the most acute for seasonal stations.

There are quite limited data for wastewater composition at Antarctic bases, but it is recognised that content of organic contaminants tends to be high (table 4). This can be attributed to the fact that people working in Antarctica are well fed and have a high calorific value food input rich in fats; there is also a predominance of males, who produce more wastes than females. It is also possible that the higher organic contaminants content at research stations might be caused by a more concentrated waste stream. In addition to human waste, municipal wastewater in a typical city also contains grey water from washing activities and in some cases wastewater may also be diluted with ground water infiltrating into sewer lines. The addition of grey water and in some cases infiltrating ground water to the waste coming from human contribution would result in a lower BOD level measured in the influent at a wastewater treatment facility. It would be expected that the wastewater stream in most research stations in Antarctica is concentrated with little dilution from washwater since water use is restricted [24, 27–31].

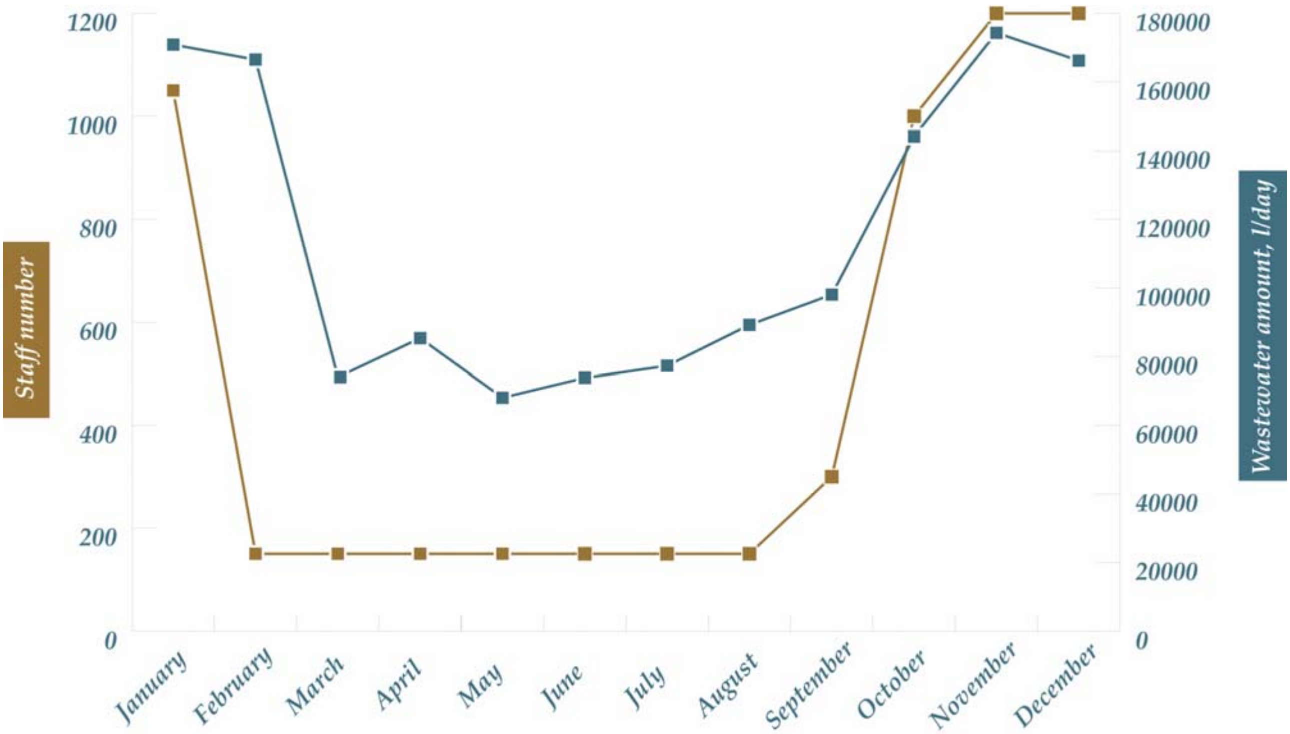


Figure 6 – *Seasonal variations in wastewater amount and station staff number (McMurdo station, USA)*

Table 4 – *Untreated wastewater analysis data*

Country	Compound			
	COD, *mg/l*	BOD_5, *mg/l*	SS, *mg/l*	N ammonium, *mg/l*
McMurdo	–	159–382	43–187	–
Molodezhnaya	–	1200–2300	3500	–
Scott Base	–	700	700	–
Wasa	5800	3800	1100	2,3

Nominal input levels used in designing treatment facilities differ between stations as well (table 5).

Table 5 – *Designed wastewater input levels [21, 22, 32]*

Country	Design input levels			
	COD, *mg/l*	BOD_5, *mg/l*	SS, *mg/l*	N ammonium, *mg/l*
Czech Republic	300	400	367	–
China (Zhong Shan)	≤450	≤250	≤200	≤25
China (Dome A)	80–120	30–50	40–60	5

An additional complication at coastal stations using seawater for toilet flushing is the high salt content of the wastewater (at Scott base up to 28% of the sewage is seawater [24]).

2.1.5 Wastewater quality monitoring

Wastewater quality monitoring is necessary to ensure the normal functioning of treatment facilities. According to COMNAP/SCAR recommendations wastewater quality is the one of parameters that should be included in environmental monitoring programmes [33].

Permanent monitoring of influent and effluent quality is unrealizable in most cases in the absence of qualified personnel or required facilities. Many countries carry out occasional monitoring.

2.2 Review of used technologies

There are about 60 permanent and seasonal stations in the Antarctic Treaty area with population from 10 to 1000 persons (figure 7).

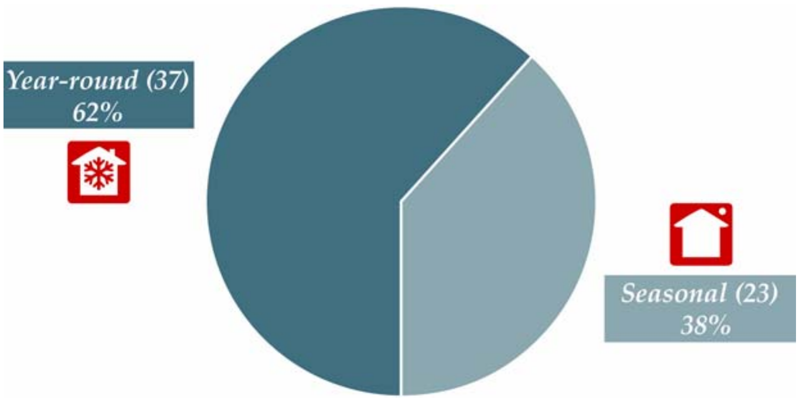


Figure 7 – *Year-round / seasonal stations ratio (2009)*

Review of wastewater disposal methods and used sewage treatment technologies are listed below (table 6).

Table 6 – *Sewage treatment technologies used at Antarctic stations*

Name & status of station	Country	Method of treatment	Description of used technology
Aboa	Filnland	Biological	*Grey water from washing machine, kitchen, dish washer and shower is treated in biological wastewater treatment plant. Urine is collected to barrels and brought away from Antarctica. There is no black water at the base [31].*
Amundsen-Scott	USA	No treatment	*Sewage is disposed untreated into deep ice pits [31].*
Arctowski	Poland	Mechanical	*There are two sewage treatment facilities at the station. The facility at the main building is limited primarily to treating non-solid waste. Grey water from this facility is filtered, heated and bio-enzyme treated. The liquid is then discharged via the beach sand and gravel to the bay. One of the outbuildings housed the main toilet facilities, showers and laundry. Sewage and grey water from this building entered a buried septic tank. The liquid was discharged via a leach field through the sand and gravel beach to the bay without monitoring. The solids are periodically removed from the septic tank and shipped to Poland [29].*
Artigas	Uruguay	Mechanical	*The waste water is discharged to septic chambers for treatment, and afterwards stored in 200 l drums for removal from Antarctica. The sewage treatment is running the whole year [29, 31].*
Arturo Prat	Chile	–	*No information*
Belgrano	Argentina	Mechanical	*Grey water is recycled for use in toilettes; black water is treated in septic tank. Effluent and sludge released onto ice [31].*
Bellingshausen	Russia	Biological+ UV-sterilisation	*The wastewater treatment plant EOS-15 was used at the station. A new biological plant "Astra-20" and a UV-steriliser for the station are under construction (in 2009/2010 season).*
Casey	Australia	Mechanical+ Biological+ UV-sterilisation	*The plant used at Casey is a Rotating Biological Contactor type which is housed in a heated building to provide the environment necessary for the plant to function effectively. The design flow capacity of the RBC systems is 5,000 l/day with a maximum flow rate of 6,000 l/day.* *The sewage is first collected in a storage tank where it is retained for a period of approximately 24 hours to allow settlement and digestion to take place. The settled waste then flows through a Bio-rotor unit comprising polypropylene disc banks which are partially immersed in the effluent. The discs are slowly rotated through the air and waste water alternately, causing a biccnass to gradually form on the disc surfaces which assimilate nutrients from the wastewater and oxygen from the air. This process results in a staged reduction of the organic impurities in the waste water as it travels past each disc. During 1999/2000 summer a UV-steriliser was installed at Casey to sterilise the effluent before discharge into the sea. The effluent is monitored on a regular basis by the station doctor to ensure that it is within the standards set by Australian authorities. Sediment from the waste treatment plants is removed during regular maintenance and stored in 200 l drums [35].*
Comandante Ferraz	Brazil	Mechanical+ Biological	*The sewage treatment plant has been in operation since the austral summer of 1995/96 and is designed to serve a population of 50.* *The black water, after a primary treatment, is directed to anaerobic filters, where it undergoes a secondary treatment. At the anaerobic filters the water is purified again, and then it passes through filtration drains. The treatment system for grey water collects wastewater from showers and directs them to a box that retains solid materials. From this box, the grey water passes through anaerobic filters and filtration drains that are not connected to the black water system. The black and grey waters final effluent is piped to the low tide line on beach. The system has four septic cesspools, two anaerobic filters, two grease boxes and two intercepting boxes. To avoid the system and cesspool freezing, a thermal girdle was installed along the system and the septic cesspool [36].*

Concordia	France Italy	Physicochemical	*The study and the development of water treatment systems for Concordia have been placed under the leadership of the European Space Agency. All wastewater streams, including grey water from washing, and black water consisting of organic waste (food scraps from the kitchen and refectory) and excrements, are collected by two respective networks under vacuum and transferred to two treatment systems. Grey water undergoes a 4-step treatment process – ultrafiltration, nanofiltration and two stages of reverse osmosis; black water is treated by an anaerobic fermentation unit.* *In order to minimize waste production, the sludge from the grey water unit is retreated by the black water system and the water produced from the black water system is taken up by the grey water treatment unit.The sludge issuing from the black water fermenteur, is frozen and shipped back to the coast to be dried and incinerated [37].*
Davis	Australia	Mechanical+ Biological	*All human waste and waste water from the new station complex passes through the Waste Treatment Building, where it receives primary and secondary treatment in a two-stage rotating biological contactor (RBC) before discharge of the effluent through an outfall into the sea [35, 38].*
Dome A	China	Physicochemical	*Upon the consideration of small amount of water consumption, environmental protection, easy management and simplification of treatment facilities, a negative pressure free-of-flushing system will be used in the toilet to reduce the capacity of black water. The human excrements (including night soil and urine) will be packed automatically and shipped back to Zhong Shan Station for treatment. The lower contaminated waste water through super-filtration can be turned as intermediate water for cleaning, and then through further treatment by a reverse osmosis system, the treated water will be recycled for simple cleaning of clothes in the station. The residual water after filtration is roughly about 70 l/day will be discharged into the ice pits.* *The Dome A Station will build an integrated container-type of sewage treatment system. The system mainly consists of sewage tank, reactor tank, out-tank pump valve and filters. Without special attendee, it will operate continuously or intermittently then stops at night. One person might be appointed to make routine inspection and maintenance. Residual black water comes from super-filtering unit and reverse osmosis unit will flow into a combined rector, there water will precipitate and flocculate under the function of a chemical, the upper clear water in this combined reactor will flow back to low pollutant water tank. The filtering core will be changed when the effectiveness drops [22].*
Dome Fuji	Japan	No treatment	–
Druzhnaya 4	Russia	No treatment	–
Dumont d'Urville	France	No treatment	*Untreated sewage has been released from Dumont d'Urville permanent station into Southern Ocean for more than 40 years. The outfall discharged the sewage directly at the base of a deep shelf cliff at approximately 50 m of the seashore. In winter-time the frozen sewage accumulated between the outfall and the land fast ice [39].*
Escudero	Chile	Mechanical+ Biological+ Chlorine sterilisation	*Domestic sewage from each building is macerated, then passed through an anaerobic chamber and a settlement chamber. The remaining liquid is first chlorinated and then de-chlorinated before being piped to the sea. The solids are returned to Chile [40].*
Esperanza	Argentina	Biological+ Chlorine sterilisation	*The base operates a biological based sewage treatment plant. The plant is in operation on Mondays, Wednesday, Friday and Saturdays. The effluent water is treated with chlorine before being discharged into the marine environment. Every three months, the sewage sludge is removed and placed in drums for storage until it is removed from the Antarctic Treaty Area. On average, three drums of sludge are produced every three months [31, 41, 42].*

Frei	Chile	Mechanical+ Biological+ Chlorine sterilisation	*Sewage and grey water are treated in a two-chambered anaerobic digestion sewage treatment plant. The treated effluent is chlorinated and then de-chlorinated prior to its discharge into the sea. The sludge is cleaned out once a year, placed in a metal or plastic drum and taken for disposal in Chile [29, 40].*
Gabriel de Castilla	Spain	Mechanical	*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 the additional mud, goes an exit tub that pours the treated water to land. Each 2–3 years the tank must be opened to extract the mud. [40, 41,]*
Great Wall	China	Biological	*The station's sewage and grey water are processed through a biological treatment plant. Sludge from the treatment plant is incinerated and the water is discharged untreated into the tidal basin [21, 43].*
Halley	UK	Mechanical/ *Biological*	*At Halley V grey water is treated by maceration. During the 2005/06 season at the station a further 850 m³ of grey water was discharged to a deep ice pit.* *At Halley VI, a Microbac bioreactor sewage treatment plant will be used for the main platform. The biological sewage plant will provide an excellent growth environment for bacteria, as the tank is fitted with a rigid PVC matrix with an internal surface area 150 times larger than any traditional active sludge plant or tank. The tank will introduce some modified bacteria that will reduce the amount of sludge produced. De-sludging the tank will be required only once a year. Treated wastewater will be discharged to the ice. Treated sludge will be incinerated and ash will be removed from Antarctica [44, 45].*
Johann Gregor Mendel	Czech Republic	Mechanical	*The waste water is only sewage water from the hygienic facilities and from food preparation. Therefore, it is common municipal waste water. The process of maceration was rejected because the station has a seasonal character and a smaller personnel than the stated material presumes. The amount of liquid wastes would be significantly lower. The liquid wastes would be discharged directly into the sea [32].*
Juan Carlos I	Spain	Biological+ Physicochemical	*The working principle of the sewage system used on the Spanish Antarctic station Juan Carlos I is the biological digestion of the organic matter realized by the bacteria already found in the residual water.* *At the end of the season 1999/2000, the system consisted, for all waste waters, of two consecutive septic tanks and an active carbon filter. The first tank is separated in three digestion and sedimentation chambers. Leaving the first tank, the effluents are directed to the second one that consists of two digestion chambers and after that to a third one, equipped with a biological filter. Finally, before being discharged to the sea, the water passes an active carbon filter that reduces significantly the emission of organic matter in the effluent.* *During the long history of the station the sewage system had to stand some anomalies. The increasing number of the station's crew members during the last few seasons produced a raising amount of waste waters, which resulted in an insufficient bacteria digestion of the organic matter. Because the station is only occupied during the austral summer the biological processes are decreased at the beginning of the season by the months of inactivity, making it difficult to start the biological digestion.* *A series of improvements in the sewage system have been introduced destined not only to improve its performance but also to reduce the time necessary for the bacterial activation.* *The obtained measurements show the evolution of the system for the last six campaigns which clearly demonstrates the reduction of the total suspended solids (90%), the COD (80%) and the nutrients (e.g. nitrates 93%) in the waste water discharged to the sea [29, 41, 46].*
Jubany	Argentina	Biological+ UV-sterilisation	*Grey and black waters are treated in biological treatment plant; effluent is treated with ultraviolet sterilization before release into the sea. Sludge is dehydrated and then removed from Antarctica. The sewage treatment plant is an AQUAMAR System (Germany) [28, 29].*

King Sejong	Korea	Biological+ Physicochemical	*The station is equipped with UNEX Simultan-40 sewage treatment system (Rauma-Repola). Volume of wastewater is no more than 10 m³ per day. Type of treatment: aeration, settling down, chemical & biological (38% $FeCl_3$, 10% $NaOCl$). Treated water is discharged into pebble zone in tidal area. The sludge is shipped out of Antarctica. Seawater and benthic environment are annually monitored around the sewage trap [47].*
Kohnen	Germany	No treatment	–
Law-Racovita	Australia Romania	No treatment	–
Leningradskaya	Russia	No treatment	–
Macchu Picchu	Peru	No treatment	*All wastes are removed offsite the area of the Antarctic Treaty [48]*
Maitri	India	Mechanical+ Biological	*The station is equipped with incinerator toilet facilities. Two modules (four toilets) are located in the summer station area, and five single modules are located in the main station building. The incineration temperature is 600°C. Solid human waste is incinerated once a day. The ashes are collected in drums and transported out of the Antarctic Treaty area once a year.* *The grey water is fed into a rotational biological contractor. The treatment involves three stages: a primary settling basin, followed by a bio-digester and a final settlement basin. The settled waste material is incinerated. The treated effluent is temporarily stored in a pond close to the station building. The treated effluent is sporadically pumped from the settling pond into a tank and subsequently discharged into an ice-free area approximately 1 km from the station. There is no regular analysis of the treated effluent during winter (although it is analysed during the summer season by the environmental team) and no monitoring of potential impacts is conducted at the discharge point [49].*
Maldonado	Ecuador	–	*No information.*
Marambio	Argentina	Mechanical+ Biological+ Chlorine sterilisation	*Sewage and domestic liquid waste is treated in a multi-stage sewage treatment plant. This is sited adjacent to the main complex. The plant macerates and settles out solids, then aerates and chlorinates the effluent before it is discharged just over the edge of the plateau onto ice-free ground. Solid residue is drummed and removed from the Treaty Area [41].*
Mario Zucchelli	Italy	Biological+ Physicochemical	*A sewage treatment plant of the biological type was installed at Mario Zucchelli (Terra Nova) station during the construction of the base in the 1986/87 season. The plant was designed for 40–50 people. The body of water where the treated effluent is discharged has been under constant monitoring from the third campaign onwards: the first monitoring was that for the BOD-biochemical oxygen demand, later broadened to include BOD, COD, nitrites, surfactants, oils, etc. The monitoring was used to verify the effectiveness of the treatment and to adjust the process. At the end of the eighties it was clear that the plant was becoming insufficient for the increasing load due to the enlargement of the programme and the larger number of people. A new plant was added in parallel with the old. The new plant is of a physicochemical type and after a few years it was connected in series with the old one. In 1995/98 a completely new plant was installed. The experience with sewage treatment at Terra Nova Station has been positive. Pollution in the receiving body of water is low, is kept under constant surveillance and the plant is adjusted to the needs in a simple way. The sludge resulting from the treatment is retrograded to Italy [50–52].*

Mawson	Australia	Biological	*Rotating Biological Contactor (RBC) sewage treatment plant has been installed and commissioned at Mawson station [35].*
McMurdo	USA	Mechanical+ Biological+ Disinfection	*Prior to 2002, wastewater generated from McMurdo was only treated with maceration prior to direct discharge in the Ross Sea. The United States Antarctic Program began processing wastewater produced from McMurdo Station in 2003. The Wastewater Treatment Plant uses conventional methods of solids removal (clarification) and microbial digestion. The system is capable of treating 495,900 litres per day of domestic wastewater. The four major treatment components are an anoxic zone, an aerobic zone, clarification, and disinfection. These four components comprise a single treatment train at the plant.* *Wastewater is supplied to the plant from the station by gravity feed and is pumped from lower laying areas by two lift stations. There are two by-products of treatment. Clear and disinfected effluent released to McMurdo Sound and settled, de-watered sludge is packaged and removed from the continent [27, 53–57].*
Mirny	Russia	No treatment	*Untreated wastewater is discharged into the sea.*
Molodezhnaya	Russia	*Physicochemical/* No treatment	*The wastewater treatment plant EOS-15 was mounted and started up at Molodezhnaya base in 1988. EOS-15 conducted the electrochemical treatment of sewage water by means of electrolysis of liquid masses running trough the special electrodes after mechanical treatment. As a result of commissioning the optimal operational regime EOS-15 was chosen to provide for the maintenance of treated sewage parameters in accordance with the International Convention for the Prevention of Marine Pollution from Ships MARPOL 1973/78. The content of suspended matter remained at a level of 77 mg/1 in comparison with the normal value equal to 100 mg/1, coli index did not exceed 900 bodies of colibacillus in 1 ml against the normal value 1000 bodies/ml. Sludge forming after sewage treatment was incinerated [30].*
Neumayer	Germany	Biological+ UV-sterilisation	*During the season 1995/96 a sewage treatment plant was installed at Neumayer Station. This plant was designed in a way that it only requires electric energy and heat energy of the station to be able to clarify the waste water. The entire system of waste water and sludge treatment is installed in a 20 ft container. The waste heat of the diesel generators is used to keep the container at a temperature of +15°C and to dry the sludge. The sewage is collected in a level regulated tank. This tank is situated under the container for water generation. It is used for mixing the different waste waters and to even out peak times of waste water inflow. From that tank water is turned out by a screw-spindle pump through a pipe to the sewage treatment plant over a distance of about 60 m. There the sewage is purified in a biological process. Then the clarified water is sterilized by UV-rays and pumped through a pipe to the dump in the shelf ice which is located approximately 100 m away from the station.* *The dewatering system for the sludge consists of the reaction tank and a filter module equipped with two separate inlets. Arising surplus sludge with a dry substance of about 2% is drawn off periodically and pumped into the reaction tank where it is sterilised by adding hydrated lime. After admixing of a flocculation powder the surplus sludge is thickened and then dewatered in semipermeable drainbags. The draining water is collected and led to the inlet of the sewage treatment plant. During the dewatering of the sludge vitiated air is arising. It is led directly out of the container by a fan. After the drainbags have dewatered for about 24 hours they have a dry substance of approximately 18%. They are dried in a drying chamber that is heated to +35°C by using the waste heat of the diesel generators. Resulting from this step of treatment the sludge has a dry substance of 40%. Now it is inodorous and has storage stability. The sludge containing the solid residues of the purification process is removed from Antarctica [58–60].*

Novolazarevskaya	Russia	Mechanical+ Physicochemical+ Ozonation	*Grey water is treated in sand filters, carbon filters, sterilised by ozone and discharged into ice-free area near the station.*
O'Higgins	Chile	Biological	*The base employs a state-of-the-art sewage treatment system and treats all sewage and grey water with the effluent being discharged into the marine environment [42].*
Ohridski	Bulgaria	No treatment	*Sewage and domestic liquid wastes are discharged through a flexible pipe directly into a snow-covered gully some 20 m to the side of the main building. From here, it flows beneath the snow to the beach and percolates through the rocks into the foreshore [29, 41].*
Orcadas	Argentina	Biological	*Grey water is recycled for use in toilettes. Black water is treated with biological treatment plant. Effluent and sludge are released into sea [31].*
Palmer	USA	Mechanical	*Maceration is the only treatment step [31].*
Princess Elisabeth	Belgium	Biological + Disinfection	*It is planned that all grey water is to be treated with the bio-membrane reactor, ozonation, peroxide and chlorine treatment [61].*
Progress	Russia	Physicochemical	*Electric-chemical treatment plant was in use at Progress. It is planned to install a new physicochemical plant for the station.*
Rothera	UK	Biological + UV-sterilisation	*Untreated sewage has been released into the sea since the base opened in 1976. In February 2003 a submerged aerated biological filter sewage treatment plant (Hodge Separators Ltd) was commissioned at Rothera. The produced sludge is pressed, dewatered and bagged for shipment to UK for disposal. The effluent water is treated under ultraviolet light and discharged into the bay [41, 42, 44, 62, 63].*
Russkaya	Russia	No treatment	–
San Martin	Argentina	No treatment	*Grey water passes via a separate discharge pipe directly to a small cove behind the station [41].*
SANAE IV	South Africa	Biological + Physicochemical UV-sterilisation	*A biological sewage treatment plant (Rotating Biological Contactor) has been installed at SANAE IV. Sludge is separated out and is transported out of Antarctica. Effluents and grey water are treated by bio-filters and filtered through a carbon filter, a sand filter and a UV-filter before being discharged over the Vesleskarvet cliff. All detergents used at the station are biodegradable to avoid damaging the bio-filter. Effluents must meet South African standards for discharge into freshwater, and regular analysis of effluents is conducted to ensure compliance. No problems had been experienced in achieving these standards, although discoloration of the effluent was sometimes a problem in the summer season due to the limited load capacity of the system [49, 64].*
Scott Base	New Zealand	Biological	*A wastewater treatment plant for Scott Base has been installed and became operational in October 2002. The plant uses contact aeration process. The wastewater is treated in a chamber containing plastic mesh on which grows a bacterial biofilm. Aeration is provided by air blown into the bottom of the chamber through fine holes. Waste solids are settled out as sludge and dewatered for disposal. Disinfection is provided by ultraviolet light [23, 24, 65, 66].*
Signy	UK	No treatment	*Sewage and grey water are discharged unmacerated into the sea [44].*
Soyuz	Russia	No treatment	–

Syowa	Japan	Biological	*There are presently 49 buildings at Syowa Station. Passageways connect the central building, generation house and two sleeping lodges to each other. Other station buildings are located apart to minimize problems of snowdrift and vulnerability in the event of fire. Sewage and grey water from main buildings are treated by the biological treatment plant (contact aeration process) before released into the ocean. Other buildings are not connected to the sewage system yet. The treatment has started to operate for a part of facilities since April 1999. Therefore, three kinds of simple toilets are installed in some buildings where people work.* *Two of the toilets are combustion-type, one using an electric heater and the other a kerosene burner. The third, and newest, is a biological-processing toilet. The toilets collect human wastes in a small tank (98 liter) containing wooden chips. The tank's contents are stirred by a blade at regular intervals. The temperature of the waste and chips in the tank is controlled between 30–45°C by an electric heater. The intestinal bacteria are nourished by the waste and multiply in the tank. Finally the bacteria facilitate the decomposition of the waste into water and carbon dioxide. The gas bye-products are discharged from the tank to the outside atmosphere. The wooden chips need to be replaced every half a year based on a maximum frequency of use for 150 times per week. The toilet system has been proved to be effective because it is compact, does not use an open fire and is environmentally sound, as it does not require the introduction of special bacteria to Antarctica [67, 68].*
Tor	Norway	No treatment	–
Troll	Norway	Mechanical	*A compost toilet has been installed at Troll. It was tasted during several seasons. At present electrical incinerator toilets are in use. There is no black water at the station.* *Prior to 2005, grey water generated at the station ran through a three chamber mechanical filtering system. After the grey water was treated in the filtering system and went through the ultraviolet filter before discharging into the soil. Treated wastewater was expected to reach near drinking water quality and could in principle be reused for cleaning purposes and such.* *A new and improved wastewater treatment system delivered by Haco AS was installed in February 2005. The new system ensures simple handling and monitoring of discharge and has sufficient capacity to handle the normal personnel load during summer season. The treated water can in principle be reused for non-consumption purposes, and in this manner it is possible to reduce water production, thus saving both energy and labor associated with the melting procedures. Wastewater is discharged through a heated piping system in an ice-free area behind the station [25, 69].*
Vernadsky	Ukraine	No treatment	*Sewage and grey water at Faraday station were discharged unmacerated directly into the sea [44]. Waste water at Vernadsky is discharged by constantly circulating sea water [29, 31].*
Vicente	Ecuador	–	*No information*
Vostok	Russia	No treatment	*Untreated water is discharged to a deep ice pit.*
Wasa	Sweden	No treatment *Physicochemical*	*A wastewater treatment system was installed in 1991/92 but decommissioned in 1996, as it did not function properly. In 2005 the Swedish Polar Research Secretariat investigated different techniques for cleaning grey water for the station. Three systems using chemical precipitate or membrane were under evaluation for Wasa.* *At present time the grey-water is not treated by any means but discharged through a pipeline to an ice-cover area in the vicinity of the station from where it ultimately drains to the sea [31, 64, 70].*

Zhongshan	China	Biological	*Chinese Antarctic Research Expedition has decided to upgrade the wastewater treatment plant at Zhong Shan Station. The new sewage treatment pant will divide waste into black water (faces, urine, kitchen wastewater) which will be treated such that there will be no disposal to the ocean and grey water which will be sterilized and discharged to the ocean by a submarine pipe.* *The selected treatment technology involves new membrane separation and intermediate water circulating technology. This technology has been very successful in China and has become a popular method of treatment. The technology has many advantages including energy savings and operating at room temperature. The new treatment system will significantly improve ocean water quality in the near shore and ocean waters in the vicinity of the station.* *The Membrane bioreactor is a recent but increasingly utilized technology for treating municipal and high organic industrial wastewater by combining the highly efficient separation technology of hollow fiber membranes within a compact activated sludge process. Flat plat PVDF based membrane is the optimum choice for system designers and end users alike for continuous immersion in activated sludge. The liquid-solid separation by membrane replaces the conventional settling process and effectively removes suspended and organic solids producing bacteria tree water. MBR allows for the activated sludge to be maintained at much higher levels of mixed liquor suspended solids than conventional systems and because of the membrane interface, bacteria are retained longer within the activated sludge enhancing the decomposition of the organic matter. The Membrane bioreactor is a modern, highly effective water treatment system that can deal with the ever increasing demands of municipal wastewater quality and increasing treatment volumes. The Membrane bioreactor is easy to operate, automatic, modular based treatment process.* *It was proposed to ship the treatment plant to the station in December 2005 and commission the plant in 2006 [21].*

Current practices range from use of sewage treatment plants at larger stations and bases, storage in containers for disposal at home countries or at coastal stations, and incineration. Containment, storage, and retrograde of grey and black water is the method used by the majority of programs for field and small stations [71].

The general situation can be summarized as follows: wastewater from 32% of all stations is discharged untreated, 63% of all stations are provided with some kind of treatment (figure 8).

Figure 9 shows different treatment types ratio. Some countries active in Antarctica have still made no move to take wastewater treatment beyond the minimum standards: sewages at two permanent and one seasonal stations are treated only by maceration. The Italians and the French opted to use complex physicochemical plants for Concordia station. The Chinese made a similar choice for their seasonal Dome A station. In the majority of cases (26 stations) biological wastewater treatment plants are used.

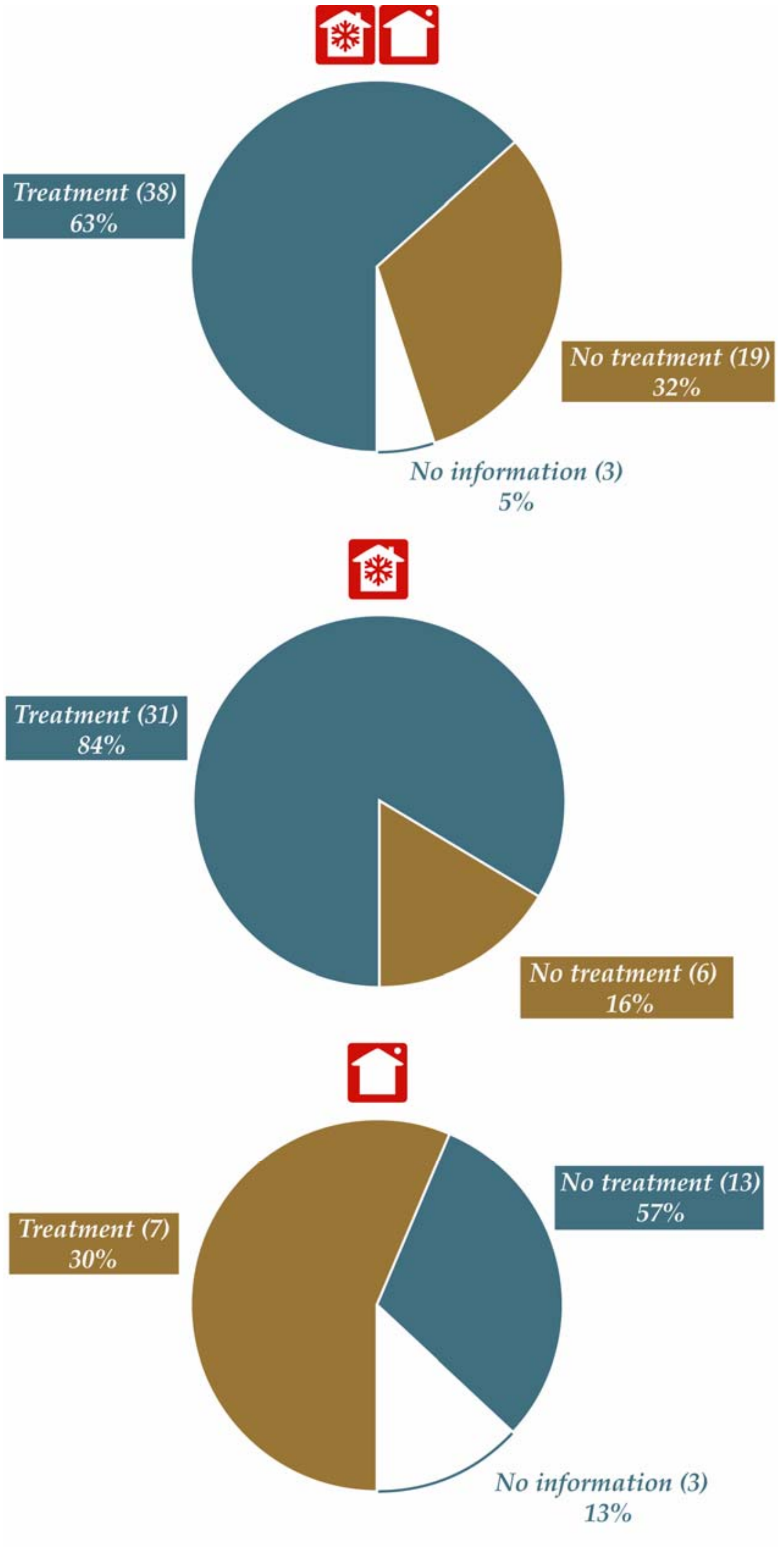


Figure 8 – *Current treatment situation for all, permanent and seasonal stations*

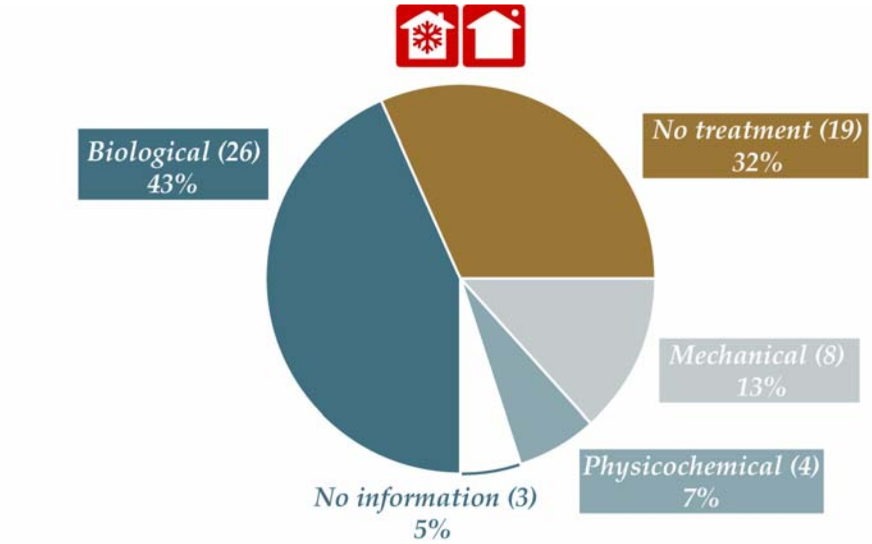


Figure 9 – *Different treatment types ratio*

It is rather interesting that percentage of stations discharging untreated sewages changed since 1990 [31, 58] (figure 10). But these changes are not characterized by any tendency. It probably may be explained by changes in total operated stations number or stations quantity in the statistics.

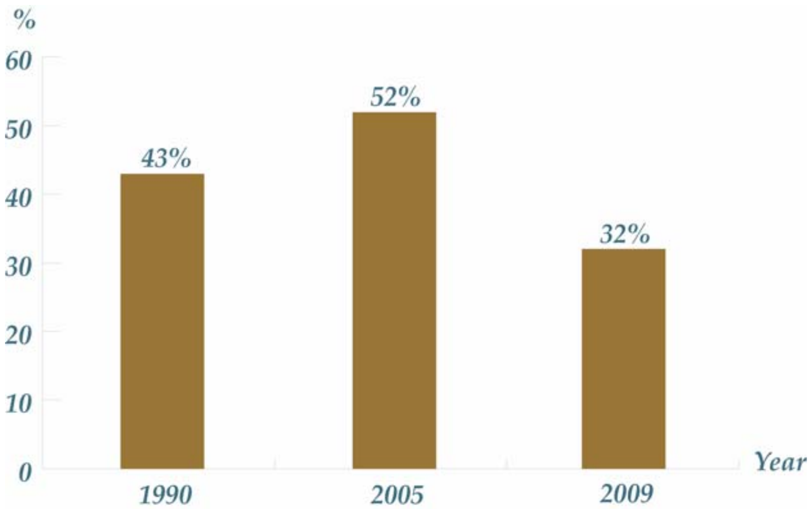


Figure 10 – *Percentage of stations discharging untreated sewages (1990, 2005 and 2009)*

Conclusion

Analysis of sources revealed a lack of information about used technologies in official reports submitted by the Parties within the scope of Antarctic Treaty Information Exchange and Annual reports pursuant to Article 17 of the Protocol on Environmental Protection to the Antarctic Treaty. As a rule these reports merely contain information on absence or presence of treatment facilities. Some information can be found in reports of the Antarctic inspections in accordance with Article VII of the Antarctic Treaty and Article 14 of the Protocol on Environmental Protection to the Antarctic Treaty. But it should be noted that this information is often rather discrepant. Initial and Comprehensive Environmental Evaluations, SCALOP proceedings or AEON Workshop reports provide more detailed information about wastewater treatment.

In spite of all previous attempts to generalize experience of wastewater treatment in Antarctica available data, unfortunately, is spotty.

Broad spectrum of used technologies (from maceration to membrane filtration) indicates that there is no any unified approach to treatment type selection. In this connection development of water quality standards in addition to requirements of the Protocol on Environmental Protection to the Antarctic Treaty is exceptionally important. Compiling of an accessible handbook on wastewater treatment in Antarctica would probably be of practical importance and helpful in decision-making.

References

1 Яковлев С. В., Воронов Ю. В., 2002. *Водоотведение и очистка сточных вод*.

2 Паль Л. Л., 1994. *Справочник по очистке природных и сточных вод*.

3 Николаев А.Н., Нилова И. В., 2002. *Основы микробиологии и биотехнологии*.

4 Карелин Я. А., 1973. *Очистка сточных вод в аэротенках*.

5 Жуков А. И., 1977. *Методы очистки производственных сточных вод: Справочное пособие*.

6 Яковлев С. В., 1979. *Очистка производственных сточных вод*.

7 Проскуряков В. А., Шмидт Л. И., 1977. *Очистка сточных вод в химической промышленности*.

8 Когановский А. М., 1983. *Очистка и использование сточных вод в промышленном водоснабжении*.

9 Мельников В. Н., 2003. *Локальная система очистки сточных вод методом напорной флотации*. Экология и промышленность России 8.

10 Николадзе Г. И., 1987. *Технология очистки природных вод*.

11 Иванов В. Г., Хямяляйнен М. М., 2000. *Обеззараживание. Альтернатива традиционным методам*. Вода иэкология: Проблемы и решения 1.

12 Ахмадеев В. В., 2000. *Применение метода УФ облучения для обеззараживания сточных вод*. Вода и экология: Проблемы и решения 2.

13 Лукерченко В. Н., Никифорова Л. О., 2000. *Обеззараживание питьевой воды*. Вода и экология: Проблемы и решения 2.

14 Яковлев С. В., 1990. *Совместна обработка осадков сточных вод и осадков, образующихся на водопроводных станциях*.

15 Делалио А., 2003. *Утилизация осадков городских сточных вод*. Химия и технология воды 25 (5).

16 Разумовский Э. С., 1978. *Очистка и обеззараживание сточных вод малых населенных пунктов*.

17 Грулер И., 1980. *Очистные сооружения малой канализации*.

18 Rezaee, A., A. Khavanin, 2008. *Treatment of work camp wastewater using a sequencing batch reactor followed by a sand filter*. American Journal of Environmental Sciences 4.4: 342(5).

19 Rodgers, M., 2006. *Small-scale domestic wastewater treatment using an alternating pumped sequencing batch biofilm reactor system*. Bioprocess Biosyst Eng 28: 323–330.

20 *Protocol on Environmental Protection to the Antarctic Treaty*.

21 Cong Kai, Wu Jun, 2004. *New Chinese Antarctic station wastewater treatment plant*. Proceedings of the XI SCALOP Symposium.

22 *Proposed Construction and Operation of the new Chinese Dome A Station, Dome A, Antarctica*, 2008. Draft Comprehensive Environmental Evaluation.

23 *Initial Environmental Evaluation (IEE) for Scott Base Wastewater treatment*, 2001.

24 *A New Waste Water Treatment System for New Zealand's Scott Base – Rationale, Selection Process and Outcome*. 2002. XXV ATCM Information paper IP-32 submitted by New Zealand.

25 *Final Comprehensive Environmental Evaluation (CEE) for the upgrading of the Norwegian summer station Troll in Dronning Maud Land, Antarctica, to permanent station*. 2004.

26 *Draft Comprehensive Environmental Evaluation of New Indian Research Base at Larsemann Hills, Antarctica*. 2006.

27 Law, K. P., Kulchawik, R. J., 2006. *Overview of the Design, Construction, and Operation of the McMurdo Wastewater Treatment Facility in Antarctica*.

28 Connor, M. A., 2008. *Wastewater treatment in Antarctica*. Polar Record 44 (229): 165–171.

29 *Report of the United States Antarctic Inspection.* 2001.

30 Klopov, V. P., 1990. *The experience of waste removal and treatment at the Soviet Antarctic Expedition.* Proceedings of the Fourth Symposium on Antarctic Logistics and Operations.

31 Thomsen, A., 2005. *Waste water treatment in Antarctica – a feasibility study for grey water at Wasa station.* Industrial Ecology, Department of Chemical Engineering and Technology.

32 *The Czech Antarctic Station of Johann Gregor Mendel – from project to realization*. 2006.

33 *Antarctic Environmental Monitoring Handbook*. 2000.

34 *Report of the Antarctic Treaty inspections undertaken jointly by Sweden, France and New Zealand in accordance with Article VII of the Antarctic Treaty and Article 14 of the Protocol on Environmental Protection to the Antarctic Treaty*. 2007.

35 Sayers J. C. A., 1990. *Environmental management of Australia's Antarctic Program*. Proceedings of the Fourth Symposium on Antarctic Logistics and Operations.

36 *Permanent information on the Brazilian Antarctic Programme*. 2003. XXVI ATCM Information paper IP-25 submitted by Brazil.

37 Lasseur C., Godon P., 2004. *Concordia water treatment and recycling systems*. Proceedings of the XI SCALOP Symposium.

38 *Davis station management plan*. 1992.

39 Delille, D., E. Delille., 2000. *Distribution of enteric bacteria in Antarctic seawater surrounding the Dumont d'Urville permanent station (Adelie Land)*. Marine Pollution Bulletin 40(10): 869–872.

40 *Report of Joint Inspection under Article VII of the Antarctic Treaty by United Kingdom and German Observers*. 1999.

41 *Report of Antarctic Treaty Inspection undertaken by United Kingdom, Australia and Peru in accordance with Article VII of the Antarctic Treaty and Article 14 of the Environmental Protocol.* 2005.

42 *Report of Inspections under Article VII of the Antarctic Treaty and Article 14 of the Protocol on Environmental Protection*. 2006.

43 *Annual Report of China Pursuant to Article 17 of the Protocol on Environmental Protection to the Antarctic Treaty*. 2008. XXXI ATCM Information paper IP-68 submitted by China.

44 Shears, J. R., 1993. *British Antarctic Survey Waste Management Handbook.*

45 *Proposed Construction and Operation of Halley VI Research Station, and Demolition and Removal of Halley V Research Station, Brunt Ice Shelf, Antarctica.* 2007. Final Comprehensive Environmental Evaluation.

46 Alcoverro, D., Sorribas, J., 2005. *Evolution of the sewage system of the Spanish Antarctic station Juan Carlos I since the season 2000-2001 to 2005-2006*. Proceedings of the XII Symposium on Antarctic Logistics and Operations.

47 *Antarctic Treaty Exchange of Information – Republic of Korea. Permanent Information*. 2003.

48 *Annual Report Pursuant to Article 17 of the Protocol on Environmental Protection to the Antarctic Treaty*. 2008. XXXI ATCM Information paper IP-96 submitted by Peru.

49 *Report of the Norwegian Antarctic inspection under Article VII of the Antarctic Treaty and Article 14 of the protocol on Environmental protection to the Antarctic Treaty*. 2001.

50 Cervellati, R., 1990. *Current developments in environmental protection at Terra Nova Bay station*. Proceedings of the Fourth Symposium on Antarctic Logistics and Operations.

51 Lori A., 1992. *Study of a new waste water treatment plant for the Italian Antarctic Station*. Proceedings of the Fifth Symposium on Antarctic Logistics and Operations.

52 *Waste Management at the Italian Terra Nova Bay Station*. 1998. XXII ATCM Information paper IP-35 submitted by Italy.

53 Crockett, A. B., 1997. *Water and wastewater quality monitoring, McMurdo Station, Antarctica*. Environmental Monitoring and Assessment 47: 39–57.

54 Mackie A., 2003. *Getting waste water treatment down cold.* Pollution Engineering 35 (9): 38–39.

55 *McMurdo Station Wastewater Treatment Plant*. 2003. Water Environment & Technology 15 (10): 59.

56 Kulchawik, R. J., Bouchard, A. B., Morris, C. E., 2001. *Taking treatment to the extremes*. Civil Engineering 71 (10): 52–57

57 *Wastewater treatment in Antarctica: Challenges and Process Improvements*. 2006. XXIX ATCM Information paper IP-60 submitted by United States.

58 Stephan, B., 1990. *Recycling and optimized utilization of materials at Antarctic research stations*. Proceedings of the Fourth Symposium on Antarctic Logistics and Operations.

59 S. el Naggar, 1994. *Waste management concept at the German winter station Neumayer*. Proceedings of the Sixth Symposium on Antarctic Logistics and Operations.

60 *Final Comprehensive Environmental Evaluation of the Proposed Activities: Construction of the Neumayer III Station, Operation of the Neumayer III Station, Dismantling of the Existing Neumayer II Station*. 2005.

61 *Construction and operation of the new Belgian Research Station, Dronning Maud Land, Antarctica*. Draft Comprehensive Environmental Evaluation. 2006.

62 Hughes, K. A., Blenkharn, N., 2003. *A simple method to reduce discharge of sewage microorganisms from an Antarctic research station*. Marine Pollution Bulletin 46: 353–357.

63 Hughes, K. A., 2004. *Reducing sewage pollution in the Antarctic marine environment using a sewage treatment plant*. Marine Pollution Bulletin 49: 850–853.

64 *Report of the Antarctic Inspection Team of Finland*. 2004.

65 Geddes, D., 1990. *New Zealand Antarctic Programme Waste Management Procedures*. Proceedings of the Fourth Symposium on Antarctic Logistics and Operations.

66 Brookman, P., 2003. *Scott Base wastewater treatment plant*. Proceedings of the Tenth Symposium on Antarctic Logistics and Operations (Shanghai, China, 2002).

67 *Waste Management at Syowa Station*. 1999. XXIII ATCM Information paper IP-60 submitted by Japan.

68 Kenji, I., 2003. *Simple biological toilets used in the isolated buildings at Syowa Station*. Proceedings of the Tenth Symposium on Antarctic Logistics and Operations (Shanghai, China, 2002).

69 *Multi-year Initial Environmental Evaluation for the operational aspects of Norwegian Antarctic Research Expedition 2000-2010*. 2000.

70 Watier, C., 2008. *Environmental Monitoring at Swedish Research Stations in Antarctica*. Master of Science Thesis Royal Institute of Technology, Sweden Department of Industrial Ecology.

71 *Best Practice to Avoid Waste Water Disposal onto Ice-free Ground at Inland Stations*. 2002. XXV ATCM Information paper IP-51 submitted by COMNAP.