COMNAP

COUNCIL OF MANAGERS OF NATIONAL ANTARCTIC PROGRAMS

Workshop: 'Advancing Antarctic Station Waste Water Management'
Christchurch, New Zealand, 28 August 2014

CONVENORS' REPORT

Version: 16 December 2014

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This document draws together key observations and lessons arising from the Council of Managers of National Antarctic Programs' workshop 'Advancing Antarctic Station Waste Water Management' held in Christchurch, New Zealand, on 28 August 2014 – an event in which some 60 representatives from more than 20 Antarctic nations participated.

The workshop presentations and discussions thereafter highlight:

- how the management of waste water is becoming an increasingly complex issue
- the wide range of technologies currently in use to treat waste water generated by stations in Antarctica
- how many of the systems employed in Antarctica are undergoing continuous improvement
- how compliance with Annex III of the Environmental Protocol to the Antarctic Treaty alone may be insufficient in protecting the Antarctic environment, and
- the value in information sharing on environment protection challenges and solutions

This document is expected to assist COMNAP in its role in providing the Antarctic Treaty System with objective and practical, technical and non-political advice drawn from the national Antarctic programs' pool of expertise. The presenters in particular, are warmly thanked for their generous contributions to this task.

While summaries of the the presentations formed Annual General Meeting Paper 9.3, and have been included in this compilation, readers are encouraged to contact their fellow national programs and speakers for further information.

Sandra Potter & Jose Retamales
Convenors
Australian Antarctic Division & Instituto Antartico Chileno
on behalf of the Council of Managers of National Antarctic Programs

Contents

Key insights and observations

List of presentations and speakers

Summary of presentations delivered at the workshop

Key insights and observations

General

- The inputs that Antarctic waste water treatment systems are expected to handle include sewage (variously described as 'grey' and 'black' water) – urine, faeces, shower and other washing water, and mascerated kitchen waste. Such water may contain chemicals including from everyday cleaning and personal care products, and pharmaceuticals.

- The amount of water use by station personnel may vary by as much as 200 L/day; there is no typical figure. The volume of waste water tends to correlate with the extent to which water is readily available, as determined by generation costs and/or storage and production capacities.

- Waste water management challenges include those arising from highly variable waste loads/flows; fluctuations may be diurnal or seasonal.

- The development of systems for Antarctic use needs to factor the potential for extreme weather conditions, significant fluctuations in personnel numbers, and high staff turnovers. At some coastal locations, corrosive atmospheres may also be an issue.

- National Antarctic programs' waste water treatment challenges and solutions are becoming increasingly complex; it is vital that maintenance and operation staff receive adequate training.

- The management of waste water treatment systems may sometimes be so complex that it is necessary for plumbers to receive as many as three weeks of on-site specialist training, in addition to training delivered pre-departure for Antarctica.

- While some successful collaborations with industry partners or other non-Antarctic agencies have occurred, such developments may be complicated by the partnering agency's differing objectives, constraints, number of technical personnel on site and/or budgets.

- Low ambient temperatures impact on the efficacy of some systems; to work optimally, some components may need to be maintained in environments heated to as high as 25°C.

- Before installing new units, Antarctic operators are well-advised to consult with other Antarctic operators running plants at comparable sites and with comparable station populations and waste streams.

- The exchange of information on best available technologies for waste water treatment in Antarctica, and operational care requirements, should continue to be promoted within COMNAP.

System choices

- From an engineering/operational perspective, desirable unit features may include:
    - compact design
    - low energy consumption
    - operational reliability in sub-zero temperatures
    - combined treatment of black and grey water
    - system location where waste water streams can be gravity collected

  - ease/simplicity of maintenance, including cleaning
  - a system that is closed, to reduce smells
  - provision for the reuse of treated water for toilet flushing, vehicle washing etc,
  - minimal need for spare parts
  - limited human interventions or opportunity for human error through, for example, using the wrong chemicals or not giving adequate attention to system cleaning
  - ease of start-up at stations that are not occupied year-round
  - ability to be 'scaled down' during periods of low demand, e.g. winter

- Bespoke waste water management solutions may need to be developed to deliver outputs that satisfy both Annex II as well as Annex III requirements. Processes they may need to be incorporated to achieve microorganism-free outputs include:

  - ozone disinfection/destruction
  - ceramic micro-filtration
  - biologically-activated carbon
  - reverse osmosis
  - ultra violet disinfection
  - chlorine disinfection

- There are fewer risks associated with using industrial standard sources as the research and development have already been done, and as system parts and expertise are more readily available. (Conversely, 'turn-key' solutions may not work; adaptation, development and imagination may be needed.)

- Secondary treatment plants may cost US $500 000 or more, without factoring installation costs.

- A back-up arrangement is desirable where sophisticated, automated systems are in place.

- No one system is likely to adequately manage grey and black waste water at inland sites.

- The by-products of some systems may need to be incinerated and/or retrograded.

- The re-use of treated water may offer energy savings at stations needing to use water desalination processes for water supply. (At some sites, the installation of more advanced systems has however resulted in an increase in energy requirements.)

- Micro-pollutants are not readily removed by conventional waste water treatment plants; the treatment plants mostly in use are designed to remove nutrients and organic matter.

Day to day operations

- Some units require the attendance of qualified personnel year-round.

- Maintenance is best done in winter when there are usually fewer demands on systems. (This timing may however raise logistical problems, e.g. access issues.)

- Attempts to integrate new waste streams into treatment plants (for example, from remote facilities and field camps) may generate strong concentration ratios and create shock impacts on the biological communities in treatment plants.

- The volume of fats, oils and grease generated by kitchen operations can overwhelm waste water treatment plants. Similarly, food waste may shock load units and create conditions for unstable reaction, sludging, blockage and the like.

- The installation of kitchen grease trap will likely help but can not be expected to solve all of the problems associated with large volumes of fats, oils and greases entering waste water treatment plants.

- High volumes of fat, oil and grease may seriously compromise the operation of waste water treatment plants. These substances should be repatriated and station kitchen staff briefed accordingly.

- Bones, mussel shells, stones from fruit and the like need to be removed/screened from systems purporting to handle food waste. Large volumes of expired food may also need to repatriated or incinerated.

- Waste water treatment plants are liable to fail when wash cloths, paper-towels and new products such as ‘flushable wipes’ are allowed to enter the waste stream.

Monitoring and waste water treatment plant outputs

- Effluent monitoring is of critical importance.

- It is not sufficient to conduct monitoring and recording of system outputs; the results need to be scrutinised for their significance.

- BOD (Biological Oxygen Demand), TSS (Total Suspended Solids), TN (Total Nitrogen) and *E. coli* are the outfall parameters that are most often measured by national programs.

- Measurement of coliform contamination is especially important.

- Monitoring regimes need to consider the technical aspects of a system’s functioning (e.g. flow running through the system and pressure on membranes) as well as the nature of the discharges to the environment.

- Monitoring may need to be undertaken on a daily basis to allow remedial action to be taken before larger problems occur.

- Samples of outputs from waste water treatment plants may need both on and off-site analysis.

- As well as meeting Environmental Protocol obligations, some programs are bound by or seek to meet other ‘non-Antarctic’ effluent standards or guidelines, for example those of the International Maritime Organisation, or national drinking or hygiene water requirements.

- As analytical technology/capabilities have improved, the number and nature of waste water contaminants that are able to be identified have increased. Discoverable micro-pollutants include steroid hormones, pharmaceuticals, personal care products and flame retardants.

Environmental aspects

- Monitoring has shown that:
  - contaminants may accumulate in sediments some 1.5 km from outfall points
  - histopathological deformities found in fish may be linked to exposure to waste water that has only been treated by maceration
  - sewage and associated contaminants are making their way into the food chain of higher predators
  - untreated waste water introduces non-native genetic material to Antarctic microbial communities

- Emerging research suggests that the presence of micro-pollutants may lead to the development of antibiotic resistance in species, behavioural effects (e.g. through exposure to estrogenic compounds), endocrine disruption in fish and have impacts on fish growth and development.

- Summer melts and the presence of sea ice at waste water outfall points can result in pulses of or the pooling of contaminants, that is, they can impact on the initial dilution and dispersal rates of contaminants.

- Compliance with Annex III alone of the Environmental Protocol will not ensure that the local environment is protected from the impacts of waste water discharge.

Human health considerations
(recommendations contributed by the SCAR and COMNAP Joint Expert Group Human Biology and Medicine)

- Sampling and activities around potentially contaminated sites in Antarctica, including sewage outfalls, should be undertaken with appropriate consideration of potential and unknown risks, and include the use of appropriate personal protective equipment and occupational medicine measures.

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Workshop: 'Advancing Antarctic Station Waste Water Management'
Christchurch, New Zealand, 28 August 2014

PRESENTATION TITLES AND SPEAKERS

Introductory remarks on the impetus for COMNAP holding a waste water management workshop Sandra Potter
Waste water treatment at Comandante Ferraz Antarctic station Cdr Bueno, Secretariat of the Inter-ministerial Commission for the Resources of the Sea
A new waste-water treatment system at Syowa station Kenji Ishizawa, National Institute of Polar Research
Waste water treatment approaches and challenges in the United States Antarctic Program Nature McGinn, National Science Foundation
Waste water treatment system in Indian Antarctic stations Anoop Tiwari, National Centre for Oceanographic Research
Waste water treatment practices at Korean Antarctic stations Hyoung Chul Shin, Korea Polar Research Institute
Experience with ultrafiltration membrane technology for waste water treatment on Neumayer Station III Eberhard Kohlberg, Alfred Wegener Institute for Polar and Marine Research
Waste water management at Concordia station Claire le Clavez, Institut Polaire Francais
Waste water treatment plants monitoring at nine Antarctic stations Jose Retamales, Instituto Antartico Chileno
Antarctic research station effluents as a source of organic micro-pollutants in coastal waters Sally Gaw, University of Canterbury
Advancing waste water management at Australia's Antarctic stations Rob Wooding, Australian Antarctic Division

summary of presentations delivered at the
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Introductory remarks on the impetus for COMNAP holding a waste water management workshop
Sandra Potter, Australian Antarctic Division

One of the drivers for having a session devoted to waste water management was a Chilean working paper submitted to the Antarctic Treaty System's Committee for Environmental Protection in 2012. The paper (WP 55 'New Records of the Presence of Human Associated Microorganisms in the Antarctic Marine Environment') describes new records of human-associated microorganisms found in water samples taken from the Antarctic Peninsula region. Amongst other things the paper raised questions around how actively countries are undertaking monitoring to understand whether or not their treatment plants are working to specification.

Another driver for holding the workshop was the expectation that COMNAP will review the outcomes of the broader waste management workshop that the Antarctic Environment Officers Network held in Hobart, Australia, in 2006. One of the points well made at the workshop was the value of information sharing.

While the minimum standards for waste water management are set out in Articles 4 and 5 of Annex III of the Madrid Protocol, a growing body of evidence suggests that even strict compliance with Annex III will not necessarily result in a good environment protection outcome.

In addition to Annex III, there is also the important but difficult practical application of Annex II to consider, namely the requirement to take precautions to prevent the introduction of microorganisms not present in the fauna and flora. These precautions are required without the need to demonstrate that non-native microorganisms are pathogenic or likely to cause detrimental impacts to the ecosystem beyond their presence.

While not a driver for this workshop as such, countries' waste water management practices rate mention in a paper (WP-2 'Key Thematic Recommendations from 10 years of Antarctic Treaty Inspection Reports') submitted to the ATCM XXXVII. The paper had nine co-proponents and identified themes arising out of ten years of Treaty inspection reports. One of the recommendations was that the ATCM should ask 'COMNAP to review its 2002 guidelines on waste water management'. The 2002 guidelines presented at ATCM XXV ('Information Paper on Best Practice to Avoid Waste Water Disposal onto Ice-free Ground at Inland Sites') are not so much guidelines as a brief summary of the approaches employed at that time. They nonetheless establish the ongoing and useful agenda, i.e. that 'COMNAP will continue to maintain its focus on waste water treatment technologies, so that the capability of emerging technologies can be considered as and when the CEP conducts its review of the waste water management annex of the Protocol.'

Waste water treatment at Comandante Ferraz Antarctic station

Secretariat of the Inter-ministerial Commission for the Resources of the Sea (SECIRM), Brazil

Since the beginning of the Brazilian Antarctic operations, back in 1982, waste water treatment has always been a concern, either because of the effluents of the participating vessels or due to the way the sewage is treated in the Comandante Ferraz Antarctic Station (EACF). The old EACF had a biological sewage treatment system, which was not affected by the unfortunate accident occurred in the main body of the EACF. The biological sewage treatment allowed the continued effluent treatment during the dismantling operation and the removing of wreckage of the destroyed EACF. With the installation and operation of the Antarctic Emergency Modules (MAE) in 2013, a new treatment plant was put into use, operating with a chemical system.

Although the MAE have their own sewage treatment system (STS), the old STS was incorporated into the system as a solution to facilitate the maintenance of the main STS. The biological STS is also used as a stand-by of the main STS.

The implementation of a waste water treatment system is being planned for the new Brazilian Antarctic station. It will manage black and grey water inputs. These lines will be led to the Sewage Treatment Station (biological way of treatment) and to the Grey Water Treatment Station (biological/chemical way of treatment).

A new waste-water treatment system at Syowa station

Kenji Ishizawa and Yutaka Katsuta – National Institute of Polar Research, Japan
Nobuaki Kadota – SANKI Engineering Co. Ltd

The current waste-water treatment system had been successfully operated since 1999 at Syowa station however the treatment building contains septic tanks and all the instruments produced huge snowdrifts after blizzards.

Therefore, a new plant was planned at a place separate from the centre of the station. An activated sludge treatment coupled with a membrane separation process was installed in a building. The system will be operated from 2015 and the treated water of 5 parts per million biological oxygen demand will be discharged into the sea. The system could accept the waste of 50 persons in a day. The maximum electric power consumption containing heaters is 13.9 kW.

Waste water treatment approaches and challenges in the United States Antarctic Program

Nature McGinn – National Science Foundation, USA

In 2003, a waste water treatment plant (WWTP) was installed at McMurdo Station to improve effluent waste water quality. Monitoring of WWTP effluent and receiving waters has shown that waste water impacts from McMurdo Station have been significantly diminished as a result of WWTP installation.

Currently, waste water at Palmer Station is treated by maceration, as required by the Antarctic Treaty. A feasibility study for installation of waste water treatment was completed in 2009. Based on the success of extended aeration at McMurdo Station, this is the recommended option for Palmer Station. The Palmer Station Long Range Plan includes the addition of a WWTP, but the timeline and priority for construction has not yet been developed.

Waste water treatment system in Indian Antarctic stations

A. Tiwari, S. Rajan and M.J. Beg – National Centre for Oceanographic and Antarctic Research, India

Rotating biological contactors are popular treatment systems owing to their simple design, maintenance and operation, as well as high effluent standards; during normal operation they are designed to produce effluent quality with 20 mg/L biological oxygen demand and 30 mg/L suspended solids. Two such plants of different water handling capacity were installed at Maitri station in 1989. During the last few years the desired results could not be obtained. Sludge generated from the system is repatriated for proper disposal. A new containerised treatment system based on an aerated submerged fixed-film concept is being installed.

A state-of-the-art treatment system installed at the new coastal Bharati station is producing desired results of satisfactory effluent standards. This system has also been designed to produce effluent of bathing water quality as per EU norms. The effluent from it is discharged into the sea.

Waste water treatment practices at Korean Antarctic stations

Hyoung Geun Lee, Ji Hee Kim and Hyoung Chul Shin – Korea Polar Research Institute, Republic of Korea

The first Korean Antarctic station, King Sejong has maintained waste water treatment facilities since its opening in 1988, and a new IC/SBR (Internal Circulation Sequence Batch Reactor) was installed in 2008 when the station went through a major refit. This system resorts to microbiological retreatment of sewage water. The winter maintenance personnel determines the BOD (biological oxygen demand) and COD (chemical oxygen demand) of the water on a regular basis in order to reach a target level, and the monitoring parameters include suspended solids, total nitrogen, total phosphorus and the count of *E. coli.*

The recently inaugurated Jang Bogo Station adopts a more advanced waste water treatment and re-use system. IC/SBR alone was considered to be insufficient to meet the highest standard of waste water treatment currently applied to the public facilities in Korea. Thus a membrane bio reactor was additionally mounted. Treated water is doubly sanitized via an ozone oxidizer before final release from an outlet near the station pier. Recycled water for re-use is carbon-filtered to remove residual organics, color and odor before storage in a tank, which supplies water for toilet-flushing and other types of washing. The quality of recycled water and final effluent is checked once every week.

Activated sludge process adopted by IC/SBR decomposes organics microbiologically and is designed to effectively remove BOD, COD and other nutrients. But it requires long treatment time and a large reactor space. This may explain its frequent failure at King Sejong to reach the target level of water quality. As the Jang Bogo design was even more restrictive concerning reactor space, further installations with an MBR as a key addition were made with a regular check-up schedule. IC/SBR is still a useful and comparatively safe mechanism applicable to Antarctic stations with a reasonable level of investment. However, alterations and supplementation to make it more effective embracing a water quality monitoring protocol remain as a future task.

Experience with ultrafiltration membrane technology for waste water treatment on Neumayer Station III

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Alfred-Wegener-Institute has experience in the operation of sewage plants on German wintering stations since 1996. It started on the former Neumayer Station II with a fully biological system, which was working until shut down of the base. With starting up the new Neumayer Station III a new generation of sewage plant was installed. The system is designed to treat black and grey water from 60 people at most living on the station during the summer season.

The complete installation of the plant fits into a 20’ standard container. In contrast to the former sewage plant, the new system consists of two different working units: the biological treatment part and the ultrafiltration membrane. Both parts are combined within one installation.

The ultrafiltration membrane constitutes an absolute barrier for bacteria. According to Regulation 75/160/EEC (European Economic Community) of the Council of the European Union, the treated water meets the high quality standards required for bath water.

A substantial advantage of the ultrafiltration membrane technology is the recycling of the cleaned water to flush the station’s toilet system. Additionally the treated water will be disinfected by ultraviolet light. The surplus of treated and disinfected water is drained off into an ice cavern outside the station. The cleaning process of the system is permanently monitored by a central building control system and monthly analysis. Excess sludge of the biological unit is pumped out of the plant, drained and dried by a centrifuge. According to regulations the final product is stored in sealed plastic containers, which are disposed in South Africa or Germany.

This type of sewage plant has proven to be a reliable system from the very beginning. By installation of the new technology we achieved an essential reduction of fresh water consumption and in connection with this fact, less energy consumption for melting snow.

Waste water management at Concordia station

Claire le Clavez, IPEV – French Polar Institute, France

Concordia is a permanent French/Italian inland station with an average of 55 persons in summer (3 months from November to the beginning of February) and 15 persons during winter.

Waste water treatment projects were developed in collaboration with the European Space Agency – ESA during the building of the station. Waste water is divided between grey and black water: grey water coming from showers, washing machines, laundry; and black water with high organic matter from kitchen grinder, waste food and toilets. These two types of waste waters are collected by two different networks. The project was to recycle them at around 90%.

The station has been now in operation for 10 years. Although the grey water treatment unit has been running since the opening of the station and has been improved over the years, the initial target has not been reached. Lots of work and development are still needed, mainly on the black water treatment. Trialing different solutions and technologies is helping to improve the existing installation.

Waste water treatment plants monitoring at nine Antarctic stations
Jose Retamales – Instituto Antartico Chileno, Chile / University of Magallanes, Chile

The University of Magallanes, supported by the Instituto Antartico Chileno, has for two years monitored nine Antarctic stations' waste water discharges in King George Island (7), and at Cape Legoupil, Antarctic Peninsula (2).

Most stations are equipped with activated sludge biological systems but electrolysis treatment, biofilters with worms, and activated sludge with ultrafiltration membranes are also in use. All of the processes involve the discharge of effluents to the sea in front of the stations. None of them has a specialized spilled system to facilitate pollutant dispersion.

Faecal coliforms turned out to be the best environmental quality control parameter of the effluent and its impact on the environment. Other physicochemical parameters, as nitrogen and phosphorous compounds, COD, suspended solids, DO, turbidity and temperature, have also been measured.

Monitoring indicated that all treatment plants have operational problems of some kind due to: varying number of scientists at the stations in summertime; measurement of parameters not suitable for microbiological quality control; lack of maintenance; insufficient knowledge of how systems work; and staff turnover. Both stations at Cape Legoupil managed to improve the quality of discharges. Staff training, proper maintenance of both treatment systems and regular effluents and environment monitoring were implemented.

Antarctic research station effluents as a source of organic micropollutants in coastal waters
Sally Gaw – University of Canterbury / New Zealand Antarctic Program, New Zealand

Stations' sewage discharges are a potential source of organic micropollutants entering the environment. Organic micropollutants likely or known to be present in Antarctic research base effluents include active ingredients in personal care and domestic cleaning products, pharmaceuticals and steroid hormones excreted by humans. Many of these compounds are not fully removed by conventional waste water treatment processes as they tend to be water soluble. Potential removal pathways for organic micropollutants include photodegradation, biodegradation and sorption to sediments. These removal pathways are likely to be impacted by the extreme cold, semi-permanent ocean ice cover, and the changing light conditions present in Antarctica. While many of these contaminants have short half lives in the environment, ongoing discharges can result in environmental concentrations and exposure of aquatic organisms remaining relatively constant.

Advancing waste water management at Australia's Antarctic stations
Michel Packer, Tony Foy and Rob Wooding – Australian Antarctic Division, Australia

The Australian Antarctic Division is replacing Davis station's rotating biological contactor with a membrane bio-reactor (MBR) that has been engineered to handle organic matter (i.e. food scraps, and sewage and other waste water) generated by stations populations of between 12 and 120.

Concurrent to the above project and in collaboration with industry and academic partners we have fully developed, manufactured and are trialling in Hobart an advanced level treatment system to further process the effluent to meet Australian drinking water standards. This final stage utilises a suite of technologies – ozone, ultra filtration, carbon filtering, reverse osmosis, ultra violet light and chlorination – to achieve a higher level of filtration. This additional treatment is intended to mitigate the risk of introducing non-native microorganisms and genetic material into the coastal marine environment and, once proven, will be retro-fitted to the Davis MBR.

While Annex III of the Environmental Protocol does not mention the impacts of introducing non-native micro-organisms in sewage wastes, Annex II recognises the threat, and requires that precautions should be taken to prevent the introduction of micro-organisms not present in the native fauna and flora. These precautions are required without the need to demonstrate that non-native microorganisms are pathogenic or likely to cause further detrimental impacts to the ecosystem beyond their presence.