Graduate Certificate in Antarctic Studies 2000/2001

Individual Project:

Waste Management in Antarctica: The impact of sewage and wastewater disposal and available treatment options for Scott Base.

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Executive Summary:

This report aims to describe and discuss the impacts of direct sewage and wastewater discharge in Antarctica and the available treatment options, with specific reference to Scott Base. The information required to achieve this has been obtained from a variety of resources, predominantly the reports and journals published by researchers who have studied the effects of sewage and wastewater disposal.

The impacts of sewage and wastewater disposal are shown to be localised in the areas of Antarctic stations. Research also shows that the effects on the Antarctic marine environment are similar in most regions. Although the scale of many of these effects is unknown, the potential risk they pose to the Antarctic marine environment is highly significant. The major issue is that sewage and wastewater released into these areas contain microorganisms and chemical substances that have the potential to persist and degrade the health of receiving water bodies and ecosystems. The consequences of this are adverse ecological effects on the local environment. The release of large volumes of untreated sewage into the Antarctic marine environment creates a source of persistent organic matter, bacterial and viral agents. Many of these are potential disease-causing agents for indigenous wildlife. Scientific results indicate collectively that treatment sites are necessary because of this impact and the potential for much more. Recommendations for the implementation of particular treatment options at Scott Base are made based on these results.

The available treatment options can be separated into two categories: traditional and alternative. Traditional treatment methods are divided into three treatment levels: primary, secondary and tertiary. They are designed to reduce concentrations of the major contaminants and to minimise their potential to cause damage to the receiving water body. These options are assessed with regard to their applicability to the Antarctic environment and their practicality as far as implementation at Scott Base is concerned.

The findings of this report illustrate that the amount of knowledge relating to the specific ecological effects of effluent discharges in the Antarctic marine environment is inadequate and requires more research.
Acknowledgements:

This report would not have been possible without the assistance and guidance of a number of people. Firstly I would like to thank Emma Waterhouse and Rebecca Gee for providing the interesting and challenging topic of sewage and wastewater disposal in Antarctica. Their guidance and assistance with research material has been a huge help throughout the project duration and is much appreciated.

Thanks also must go to Anatrctica New Zealand and the University of Canterbury for enabling me to visit Antarctica and among other activities see the current discharge system at both Scott Base and McMurdo Station first hand.

Thank you also to Professor John Hay for all the time and effort you put into the supervision of this report. Your advice and guidance throughout the duration of this project has been much appreciated and to the benefit of the final product.

This report has further stimulated my interest in Antarctica and enabled me to look past the boundaries of modern society. I want to acknowledge that all those who assisted me in the preparation and formation of this project had some part in this and for that, I am most grateful.
Introduction:

All areas of the ocean including estuaries, near shore and deep ocean habitats have been used for waste disposal at some time. The major issue is that sewage and wastewater\(^1\) released into these ocean areas contain microorganisms and chemical substances that have the potential to degrade the health of receiving water bodies and ecosystems. This report discusses the impacts of the sewage and wastewater discharge into the Antarctic marine environment and the possible treatment options that are available for this discharge at the New Zealand Station, Scott Base.

Since the construction of Scott Base in 1957 untreated sewage and wastewater has been discharged into the shore are directly in front of the base (Redvers, 2000). The current sewage and wastewater system at Scott Base consists of a reticulation network and three effluent storage tanks. These tanks are located near 3A ablutions, the lower base ablutions and Q-hut ablutions (see Figure 1). The effluent is discharged from the end of a heated, insulated pipe that extends from the base, to the shore directly in front of the base (Redvers, 2000). The Scott Base outfall discharges directly into the receiving water through a hole in the sea ice. As shown in Figure 2 the hole is approx 5m off shore and intersects with a seasonal tide crack, marking the boundary between fast ice, which is attached to the shore, and floating sea ice (Redvers, 2000 p. 140). Both the sewage and grey water are discharged raw, maceration being the only form of treatment. The average daily discharge during summer is approximately 8000-9000 litres (Royds, 1997). This number is taken from the Scott Base summer population mean of 50 although at peak times it can reach up to 100. During the winter season however, there are only approximately 10-12 people living at Scott Base. (Redvers, 2000). An intake line for the Scott Base drinking water is also located approximately 75m east of the sewage and wastewater outfall.

In a waste disposal report by the Scientific Committee for Antarctic Research (SCAR 1989, p. 21) it was stated “At their present scale of operations, the organic additions to the marine environment of isolated coastal stations and field bases are not

\(^{1}\) Note that throughout this report the terms sewage and effluent are used interchangeably and refer to all components of liquid waste. The terms wastewater and greywater refer to all liquid waste not containing sewage i.e. kitchen, laundry and bath discharge.
Figure 1. Plan of main base buildings and location of sewage and wastewater outfall at Scott Base. 
(Redvers, 2000)

Figure 2. Photograph of sewage and wastewater outfall location outside Scott Base.
considered by the Panel to have significant biological impact on inshore areas. Because the amount of sewage discharged is relatively low, the trace metals content of sewage sludges and domestic wastes are unlikely to be significant when mixed and dispersed inshore and ocean currents”. This report aims to discuss the topics arising from such a statement and to produce some conclusions about the outcomes and futures of sewage and wastewater disposal in Antarctica, with specific reference to Scott Base.

**Methods:**

This report is divided into three main sections. These sections reflect the process by which information gathering was achieved. Section one describes and assesses the various effects that the disposal of sewage and wastewater has on the Antarctic marine environment. This approach to the topic in this section is very general. The information in this section has been obtained from a wide variety of resources, predominantly the reports and journals published by researchers who have studied the various effects of sewage. This enables the establishment of a wider ecological picture of the effects, as although they may be localised to certain parts of Antarctica, the impacts that sewage and wastewater have on the Antarctic marine environment are the same in most regions. Section two presents a number of possible treatment options that are available. The information in this section has also been obtained from a variety of resources. These options are discussed with regard to their applicability to the Antarctic environment and their practicality as far as implementation at Scott Base is concerned. This then allows for the assessment of the best options available for Antarctica New Zealand to consider. Section three consists of a list of recommendations for the implementation of a particular treatment options. These are given based on the results from the previous sections.
Section One

Assessment of the Effects of Direct Sewage Discharge into the Marine Environments of Antarctic Bases:

The impacts of sewage discharge vary in scale and intensity according to the quality and quantity of the effluent, receiving water conditions and the use of the receiving water. The extent of the impacts are often determined by the assimilative ability of the receiving waters, for example local hydro graphic characteristics and water movement and the adaptive abilities of the organisms within the local ecosystems (Redvers, 2000). Discharge impacts are measurable in terms of their physical, chemical and biological effects observed in the water column, sediments and biota (Redvers, 2000). Sediments are of particular concern as they have a high potential adsorption capacity for trace contaminants, which may not only be adsorbed but also released back into the environment (Redvers, 2000). As the pollution in a marine environment increases, species richness, abundance and biomass decline and more pollution tolerant species dominate the benthic community (Redvers, 2000). Bioconcentration and bioaccumulation are also areas of concern as they lead to cumulative effects transferred through the food chain.

1.1 Trace Metals:

In excess, trace metals are known to interfere with a variety of biochemical functions (Johnston & Stringer, 1988). There is however, evidence that some organisms can adapt to elevated levels. Despite this, the accumulation and storage of metabolically inert forms may lead to problems in marine ecosystems such as the accumulation of relatively small elevations in trace metal levels in the environment (Bryan, 1971). This is a particular concern for benthic communities as these metals have the potential to pass through the food chain (Johnston & Stringer, 1988). This is a problem facing the Antarctic marine environment as a result of the Scott Base sewage and wastewater discharge. Trace metal contamination of marine systems can also affect the
reproductive success of a range of organisms and this has the potential to significantly disturb the structure of these ecosystems (Johnston & Stringer, 1988). Because the conditions of the Antarctic marine environment are so unique, this may alter the regular processes used by marine organisms to cope with contamination. This could result in modifications to the cycling of metals, which may be of toxicological significance (Johnston & Stringer, 1988).

The current understanding of metal behaviour in Antarctic systems is poor so their mobilisation should be viewed with concern (Johnston & Stringer, 1988). Silver for example, an extremely potent metal biologically has been found in the McMurdo sewage and wastewater discharge (McKee & Wolf, 1963). Water and sediment samples from areas close to the Scott Base and McMurdo outfalls also contained elevated levels of copper, lead and zinc (Redvers, 2000). Significant amounts of cadmium were also present in the effluents of the outfalls. Cadmium has no known biological function and excess levels have been found to interfere with the reproduction of freshwater organisms (Johnston & Stringer, 1988). This contaminant is therefore of huge potential risk to the fragile Antarctic marine environment.

Studies by Lenihan (1992) in Winter Quarters Bay, McMurdo Sound showed that metals concentrations were much higher in both this area and the area around the outfall. Concentrations of trace metals in invertebrate and fish tissues were low in general and showed no clear distribution pattern (Lenihan, 1992). The benthic community however showed a much more distinct pattern. Within this area were low numbers of opportunistic polychaete worms (Capitella spp. and Ophryotrocha claperedii). These species are common to contaminated sediments in temperate latitudes. No large bivalves were found in the bay like those in uncontaminated stations, although an accumulation of shells on the seafloor indicates that the area once supported a rich benthic community. Sediments from Winter Quarters Bay were toxic to several crustacean species and changed the burrowing behaviour and substrate preferences of crustaceans and echinoderms in laboratory and field experiments (Lenihan et al., 1990). The highly mobile infauna species amphipods and tanaids showed a clear avoidance of contaminated sediments. Uncontaminated sites contained communities with high abundance, high species numbers and a complex
trophic structure. Those areas with moderate levels of disturbance were dominated by species with intermediate opportunistic life histories (Lenihan et al., 1990).

1.2 Organic Material:

Offshore sewage release is of concern because anthropogenic organic material degradation is three times slower in −1.8°C Antarctic seawater than temperate 20°C waters (Howlington et al. 1994). The results of a study by Howington (1994) suggest that only one third of the carbon released into the Antarctic marine environment is degraded by the microorganisms present. Organic particles in sediment may concentrate before consumption however suspended particles will disperse more. Therefore, organic material released by the sewage outfall may take months or years to fully degrade and will accumulate and persist in the Antarctic marine environment particularly in the benthic communities of this area (Howlington et al. 1994). This will further degrade the health of receiving water and ecosystems.

The nutrients from organic material, in particular nitrogen (N) and phosphorus (P), can cause excessive biomass production in receiving waters resulting in depletion of dissolved oxygen and possibly eutrophication (Goldberg, 1995). Grey water discharge is likely to have a higher proportion of total P as detergents are a major source of phosphorus compounds. Sewage discharge however, is more likely to have a higher proportion of N as it is a major component of raw sewage. (Redvers, 2000).

Nutrient accumulation is evident in the nutrient storage organs of the sea star (*Odontaster validus*). These organs were significantly heavier at the McMurdo outfall site than any other. In the sea urchin (*Stereochinus neumayeri*) mean population size was greater and the nutrient storage organ significantly heavier and lipid rich. The sea urchin’s diet also differed at the outfall site and shifted from diatoms to lipid rich materials. (Conlan et al., 2000 & SCAR, 2000). This is most likely due to the breakdown products of cholesterol such as coprostanol, a substance virtually unique to human waste (New Scientist, 1998). Previous projects studying the effects of organic enrichment and heavy metals found that organics favoured annelid and
nematode worms whereas heavy metals predominantly depressed crustacean and echinoderm populations. Conlan (2000) results supported these findings and indicated that sewage selects for annelid and nematode worms while echinoderms and crustaceans can colonise copper contaminated sediments.

1.3 Disease:

In addition to organic material, human pathogenic organisms such as *Escherichia coli*, *Enterococcus faecalis*, *Salmonella typhimurium* and *Clostridium perfringens* have the capacity to increase persistence and survival times in Antarctic marine environments (Howlinton et al. 1994). Studies by Smith et al. (1994) at the McMurdo Station outfall found that percentages of *E. coli* and *S. typhimurium* significantly increased with the addition of nutrients at all temperatures tested. This indicates that it is the availability of nutrients, not temperature that limits enteric bacterial activity in this cold environment. Large nutrient inputs into low temperature marine environments may then allow for the long-term persistence of enteric bacteria in a non-recoverable state (Smith et al. 1994). The study also revealed that although recovery of all organisms examined was slower, high proportions of enteric bacteria populations in this marine environment sustained sub lethal injury, greatest in the first week of exposure. Long-term cold exposure may also promote physiological changes in these organisms, which allow growth at cold temperatures (Smith et al. 1994 & Alter, 1969). Environmental adaptation through changes in membrane lipids at low temperatures and the expression of cold shock proteins is known to occur in *E. coli* (Smith et al. 1994).

Studies by McFeters and Smith (1998) showed that bacterial strains harbouring both conjugative and antibiotic resistance plasmids not only increased survival in cold temperatures but also viable but non-culturable response and maintenance of their genetic material throughout *in situ* exposures. These, together with increased persistence indicate the potential for transfer of virulence and or antibiotic resistance genes from pathogenic microorganisms, likely to be present in untreated sewage, to indigenous micro biota. The effects of this on susceptible indigenous wildlife are
unknown. This occurrence is a form of “genetic pollution” where new genetic material has been introduced or genes transferred in the environment as a result of anthropogenic activities (Smith & McFeters, 1998, p. 56-57). This poses a huge environmental and ecological threat to Antarctica, as once the genes are introduced to the population the potential and scale for permanent change is colossal.

The effects of effluent and wastewater disposal, and the bacteria and contaminants associated with this are indicators of ecosystem health. The study of this is required in order to understand the effects of external stressors on the expression of disease that might otherwise go un-exhibited (www.up.ac). The results from a workshop on the Diseases of Antarctic Wildlife recognised the risk untreated waste disposal in Antarctica poses to wildlife and untreated sewage is no exception. It is likely to contain organisms pathogenic to humans and poses a threat that it may transmit to susceptible indigenous wildlife (www.up.ac. & Alter, 1969). Clark (1998), found that viruses, bacteria and fungi are of potential risk to Antarctic and sub-Antarctic penguin species and that untreated waste disposal is a source of such disease agents.

The threat of human caused infectious agents is increasing with the increasing human activity in Antarctica. The Antarctic wildlife has evolved in one of the most isolated ecosystems in the world with minimal exposure to infectious agents from other regions (Gallagher et al. 1998). Faecal contamination from humans for example, can contain a range of pathogenic organisms such as bacteria, viruses and protozoa. Not only can these pathogens result in damage to local biota and ecosystems but they can also cause diseases such as Cholera, Poliomyelitis and Gastroenteritis (Turner 1996). Smith and McFeters (1998) also suggest that there is potential for the transfer of virulence genes from pathogenic microorganisms likely to be present in untreated sewage, to indigenous microbiota. Stress is also a major contributor to disease outbreak and environmental contaminants are capable of inducing such a state (www.up.ac).

There is also potential risk to human health at Scott Base as shown by Antarctica New Zealand data (1999). This data indicated localised contamination close to the outfall as faecal coliform and nutrient concentrations were elevated above background levels.
Faecal coliform was also regularly found to be entering the drinking water intake area suggesting that the effluent plume extends to at least this region (Antarctica NZ 1999).

1.4 Chemicals:

Cold water temperatures less than or equal to 2°C are likely to aid in the greater persistence of chemicals discharged into that marine environment (Lenihan et al., 1990). This can have very significant ecological impacts on the receiving environment.

1.5 Bacteria:

Clive Evans, a professor at the University of Auckland stated that “the biggest threat from the sewage is the rise in microbial life, which can drive processes that can ultimately lower the amounts of oxygen in the water” (Landis, 1999). Evans also believed that the sewage effluent did not seem to harm fish as they show an adaptive approach to it by eating it (Landis, 1999). This however is not necessarily a positive reaction as it indicates that the natural physiology of the fish is changing and adapting not to a natural environmental change, but to a human induced one whose long term effects may be much more significant through bioaccumulation.

As well as trace metals, organic carbon, suspended solids, pathogenic organisms and nutrients, biochemical oxygen demand (BOD), the amount of oxygen required by aerobic microorganisms to break down organic matter, hydrocarbons and organochlorine compounds may also be present in raw effluent at potentially harmful concentrations (Redvers, 2000). The unique biological processes of Antarctica may result in slower rates of hydrocarbon degradation as a response to effluent and wastewater contamination. An example of this is bioturbation by resident polychaete worms in Winter Quarters Bay. If this process is slow and burrowing species are absent then hydrocarbon breakdown may take an extremely long time (Lenihan, 1992). This is again changing the natural behaviours and life histories of Antarctic marine organisms. Results such as these have not yet been obtained from the Scott Base outfall area however, this does not mean such circumstances do not exist, the
research simply has not been undertaken yet. This poses the question: is it worth continuing with the current system to find similar results and irreversible ecological contamination? Although McMurdo Station obviously produces a much larger discharge than Scott Base, the cumulative effects of similar processes at Scott Base are too significant to overlook. It is unnatural for human contamination to be dictating which organisms inhabit these environments. It destroys the natural diversity and communities that have survived here for centuries.

Results from the work of Conlan (2000) in the McMurdo outfall region showed that there was a "distinct sewage signature contaminating the McMurdo coastline from the sewage outfall to as far as the team sampled – 842m downstream." (Conlan, 2000). This signature may persist for a considerable time as the bacterium *Clostridium perfringens* was present in the sediment to a depth of 5cm (Edwards et al., 1998). The benthic communities affected by this bacterium are among some of the most extraordinary and important in the world. Tunicates (*Cnemidocarpa verrucosa*) and sea urchins (*Steerchinus neumayeri*) near the McMurdo Station outfall were found to have high percentages of their intestines colonised by *C. perfringens* (Edwards et al. 1998). The tunicates showed 100% colonisation and the sea urchins 83% (Edwards et al. 1998). Although the proportions of organisms positive for *C. perfringens* declined with distance from the outfall, at the 842m downstream sampling endpoint 33% of tunicates and 15% of sea urchins were still testing positive for the contaminant (Conlan et al. 2000). Starfish, sea urchins and ribbon worms also demonstrated a shift in nitrogen isotopes in their tissues. This corresponded to the sewage signature on the seabed and indicated that they had assimilated nitrogen from the sewage outfall. Suspension feeding clams, tunicates and soft corals however showed no sign of assimilation. This is probably due to the differences in the sewage concentration. This data concluded that the sewage outfall influences benthos to at least 842m downstream via organic and bacterial material.

The sea urchin, sea star and nemertean worm (*Parborlasia corrugatus*) are predominantly deposit feeders, predators and scavengers so consume settled sewage detritus or species that have preconsumed sewage-derived material (Conlan et al., 2000). Diatom communities near the McMurdo outfall were also found to differ in
relative abundance, cell counts and chlorophyll-a content when compared to control
sites (Crockett 1977). A similar study by Anderson and Chague-Goff (1996) of
benthic foraminifera assemblages close to Scott Base outfall found that they differed
in composition from samples collected at locations that are more distant from the
outfall (Redvers, 2000). These occurrences are major indicators of the extreme
biological and ecological changes that are occurring in these benthic Antarctic marine
environments as a result of sewage and wastewater discharges.

McFeters and Edwards also found some indication that seals near McMurdo Station
were also being infected by *C. perfringens* during the summer. Infection of other
marine invertebrates may also lead to the transfer of the bacteria to other marine
organisms as well (Conlan et al. 2000, p. 318).

1.6 Science:

The contaminants in the receiving water body outside Scott Base can also affect
scientific research, which utilises this water body. Scientific experiments studying the
organisms and biota in this region for example will provide data that is not necessarily
reliable as the organisms may have assimilated their behaviours such as diet and life
expectancy and adapted to the varying degrees of pollution in the area.

An analysis of Scott Base aquarium water accidentally contaminated with raw sewage
by Meyer-Rochow (1992) found that the water contained high levels of N, P and
faecal coliforms. This resulted in the death and severe suffering of all but one species
in the contaminated aquarium within 10 hours of exposure. These species were
nemertean worms; sea spiders (*Colossendeis* sp.; *Ammotheo* sp.); starfish and two
fish species (*Pagothenia borchgrevinki*; *Trematomus bernacchii*). The one species to
survive was the Antarctic Slater (*Glyptonotus Antarctic’s*) (Redvers, 2000).
1.7 Dispersion and Concentration:

A comparison between the sampling years of Redvers (2000) indicated that between 1998 and 1999 the extent of the area effected by the effluent plume had increased, with the plume extending further to the west of the outfall. This is most likely because the plume had not dispersed far between years. The currents close to shore at Scott Base are relatively weak and variable so provide little opportunity for quick dispersion of effluent away from the base or the water intake line. However, stronger currents have been recorded further offshore so could provide for more rapid effluent dispersion from the sewage outfall (Redvers, 2000).

Plume size determines the extent of impacts due to sewage and wastewater discharge. Antarctica New Zealand monitoring identified a plume zone using elevated nutrient and faecal coliform levels near the outfall. The results show that the zone extends approximately 40-50m offshore and approximately 150-175m long shore. It was also recorded that at times this plume extends up to approximately 100m offshore and 300m west of the outfall. (Redvers, 2000, p. 138). Therefore, in general, the effects are not widespread but local and intense.

Flow direction, as shown by measurements taken at two depths was generally in an easterly direction. Average current direction varied between depths, generally flowing off shore at 1m and on shore at 6.5m depth. (Redvers, 2000, p. 135). Figure 3 illustrates the current patterns of the Ross Sea region.

The variation in dilution depends mostly on tidal current speed. Dilution of wastewater with brine will only result in small reductions of effluent concentrations (Railsback, 1992). Surface discharge as oppose to subsurface discharge will allow for less mixing before the effluent spreads under the sea ice and tidal cracks. This allows solids to settle over a wider area whereas submerged discharge is expected to confine settleable solids from the discharge to a benthic area near the outfall (Railsback, 1992).
Figure 3. Map of the Ross Sea Region showing the large scale current patterns. (Barry, 1995)
The results from Redvers (2000) also showed that the concentrations and spatial extent of faecal coliform bacteria were greater on an outgoing tide than incoming, with no significant difference in the dispersion direction between tidal conditions. There was no significant difference in the dispersion patterns of nutrient concentrations either however sites closest to the outfall demonstrated the highest nutrient concentrations. (Redvers, 2000). Both the maximum concentrations and the area of the effluent plume as shown by nutrient levels, were greater in the 1999 samples than the 1998 samples. This correlates with the plume data. The highest faecal coliform, nutrient and total organic carbon concentrations were consistently found near the surface indicating that the effluent plume is a buoyant. These concentrations were also elevated above background levels throughout the water column that indicates some degree of vertical mixing (Redvers, 2000).

It was also found that the degree of vertical mixing at McMurdo Station was much greater than that at Scott Base. Highest faecal coliform levels for Scott Base were found near the surface but levels in the McMurdo water column were relatively uniform. (McFeters et al., 1993). The McMurdo outfall is also an example of a much larger plume approx 1km long-shore and 200-300m off shore. The human bacterium *Escherichia coli* has been detected in these waters as far as 300m offshore of the sewage outfall with altered community structure, significantly lower diversity and biomass and the dominance of disturbance associated animals (Antarctic, 2000). This is most likely due to the greater volume of effluent and wastewater discharged from McMurdo Station.

The location of the effluent discharge has changed over the years from a old foreshore site, offshore sea ice location to the existing tide crack location. This means that although these areas may not be far apart the localised effects from the sewage and wastewater discharge has impacted upon a much wider area than if the discharge location had remained in the one area. This has however, significantly lowered the faecal coliform levels in the reverse osmosis intake location (Redvers, 2000).
1.8 Heat:

The heat content of a discharge plume is likely to melt the sea ice with which it comes into contact. The effluent is then likely to be buoyant because its temperature is higher than the receiving water body (Railsback, 1992). The effluent temperature was determined by Royds (1997) to be 18.8°C, markedly higher than the 1.8°C water temperature. This change in temperature as the discharge is released into the receiving water body is also highly probable that this will have significant ecological effects on the local biota and organisms because the area is constantly undergoing significant heating followed by cooling.

Section Two

Possible Treatment Options for the Sewage and Wastewater Discharge at Scott Base:

The treatment systems available for sewage and wastewater are designed to reduce concentrations of major contaminants and to minimise their potential to cause damage to the receiving water body.

Almost all wastewater and sewage treatment processes are affected by temperature and climate. There are a number of waste treatment options that could be implemented at Scott Base, many however pose serious engineering difficulties as well as excessive construction and operation costs. Temperate practices can be implemented if warm sewage is expected and the whole system is to be heated. If cold sewage is expected or variable temperature changes likely within the system adaptations in the unit design are necessary (Env Canada, 1986). It is also important that any system be tested and analysed during the design stages and well before implementation.

The waste being discharged from any disposal system is likely to contain a combination of human excreta, food wastes, bath, kitchen and laundry water and industrial waste (Atler, 1969). They may be in a variety of forms and each needs to be
classified and considered individually as to the most effective form of disposal and required treatment system. Table 1 is an example of this classification.

**Table 1.** Characterising waste products at Scott Base in order to determine the most effective treatment system (from Scar, 1989).

<table>
<thead>
<tr>
<th>WASTES</th>
<th>CHARACTERISTICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sewage</td>
<td>Highly organic, high BOD, odour</td>
</tr>
<tr>
<td>Kitchen and Laundry Effluent</td>
<td>High BOD, high level of dissolved organic solids,</td>
</tr>
<tr>
<td></td>
<td>nitrogen, grease, detergents, high level of</td>
</tr>
<tr>
<td></td>
<td>dissolved and emulsified oils, suspended organic</td>
</tr>
<tr>
<td></td>
<td>matter, high turbidity and alkalinity</td>
</tr>
<tr>
<td>Expired Foods</td>
<td>High BOD, high level of dissolved organic solids,</td>
</tr>
<tr>
<td></td>
<td>nitrogen, grease, suspended organic matter, high</td>
</tr>
<tr>
<td></td>
<td>turbidity and alkalinity</td>
</tr>
<tr>
<td>Domestic Detergents</td>
<td>High BOD, saponified soaps and high total solids</td>
</tr>
<tr>
<td>Laboratory and Industrial</td>
<td>Various toxic dissolved elements and compounds,</td>
</tr>
<tr>
<td></td>
<td>chemicals including heavy metals</td>
</tr>
</tbody>
</table>
The treatment options to be discussed in this report can be separated into two categories: traditional treatment methods and alternative treatment methods. Traditional treatment methods are divided into three treatment levels: primary, secondary and tertiary.

1) Primary treatment - The process of passing sewage through screen filters, strainers or macerators and or primary sedimentation processes for grit removal and solid separation.

2) Secondary treatment - Involves further sedimentation the activated sludge process and varying degrees of aeration.

3) Tertiary treatment - Requires disinfection of the remaining product after primary and secondary treatment for example by ultraviolet or ozone treatment.

2.1 Primary Treatment:

Primary treatment of sewage and wastewater allows solid separation and the removal of a large proportion of suspended particles (Horan, 1990). It screens the large floating material and collects solid particles in sedimentation tanks removing a proportion of the BOD and viruses. Sludge degritting for example via screening through coarse and fine screens and grinding (cutting and shearing large sludge solids into smaller particles) are important secondary treatment processes (WEF manual, 1992). These processes result in a sludge and liquid effluent suitable for biological treatment downstream. Primary sedimentation enhances the effectiveness of biological treatment. The possibility of using screens and grinders to collect and separate particles is a valid option for a primary treatment system at Scott Base. These could be implemented into a specifically designed system for the Antarctic environment.
2.1.1. Sedimentation Tanks:

Sedimentation tanks are another part of the primary treatment process. A well-designed sedimentation tank can remove up to 40% of the BOD in the form of settleable solids (WEF manual, 1992). The advantages of this are that the BOD load to the next treatment stage will be reduced thus resulting in a lowered power consumption as a reduced surplus sludge production. This in turn allows for the use of smaller secondary sedimentation tanks (Horan, 1990). In addition, it is important that sewage velocity be self cleansing during distribution as this prevents solids accumulating within the distribution system (Horan, 1990). These sedimentation tanks seem good in theory for collecting fluid and sludge however the land and materials required for such an option are expensive and perhaps not logistically possible for Scott Base. They could however be implemented on a small scale with specially designed equipment or coordinated with a larger scheme at McMurdo Station where land availability and storage facilities are already prevalent.

2.1.2. Filters:

Filtering is another commonly applied primary treatment practice (see Figure 4). Trickling filters, also known as bio filters, bacteria beds or percolating filters allow a film growth to detach from the surrounding media also known as ‘sloughing off’ as the resulting sludge is carried away with the filter effluent (Horan, 1990, p. 55). It is for this reason that a sedimentation tank is required as it settles out and removes solids from the filter effluents (Horan, 1990). Trickling tanks are proven to be relatively simple in operation and have very low running costs. However, their land requirements are very high and their treatment efficiency limited (Horan, 1990). These are very important factors to consider when selecting a treatment system for Scott Base as available land is a very significant limiting factor. The fact that this particular option has significant land requirements makes it an unrealistic option for Scott Base.
2.1.3. Rotating Biological Contactors (RBCs):

Maceration is the current primary treatment process at Scott Base. This is a relatively inexpensive mechanical process that reduces sewage particle size, improves its reaction rate in the sea, makes it easier to pump and can reduce visual impact (SCAR, 1989). However, as use of the base increases and as quantities of sewage discharge increase, using Rotating Biological Contactors (RBC) may be more advantageous as a first step to an improved treatment system (SCAR, 1989). RBCs operate on a similar principle to the trickling filter but have a rotating bed of attached bacteria immersed in a tank of wastewater (Horan, 1990). The rotation exposes the disk surface to the atmosphere, which allows aeration. The disk is then re-submerged into the wastewater (Horan, 1990). A film of microbial composition develops on the disk and it is this disk that removes BOD. As this film accumulates, sloughing off then occurs in a similar way to the trickling filters. The disks can be made from wood or metal. The advantages of RBC treatment as listed by Honlan (1990, p. 56-57) are as follows:

- Ease of operation
- Low land requirement
- Reduced power and maintenance costs
- Capability of achieving a high degree of carbonaceous and nitrogenous BOD removal
- Ponding of the bed and clogging of filter nozzles is eliminated

It is for these reasons that RBCs are a possible secondary treatment for Scott Base. They are effective at coastal sites because of their ability to take seasonal loads of sewage and domestic wastes. They can also operate at lower temperatures than other biological treatment systems.

The disadvantages to this process are that it lacks operational control as well as having the risk of disc cracking and breakage (Horan, 1990). Such engineering difficulties could be overcome if design and implementation requirements were specific to Scott Base.
2.2 Secondary Treatment:

Secondary treatment is usually biological for example activated sludge or trickle filters. They remove most of the remaining dissolved organic matter and further reduce BOD as well as viruses. This is achieved by aerating the sewage promoting microorganism growth and the microorganisms oxidise dissolved organic matter. Remaining sludge from this process requires further treatment usually in a digester, which degrades organic solids to soluble substances and gas.

Biological methods for separation or stabilisation of sewage solids in solution are stabilisation ponds and activated sludge processes (Alter, 1969). Each however would require modification for use in Antarctica. Sedimentation is also a commonly applied secondary treatment practice (Alter, 1969). The viscosity of sewage increases with lower temperatures and settling velocity decreases. Settling tanks for cold regions should therefore have minimum settling rates (Alter, 1969). This can be done through different types, or series of types of sedimentation ponds. Biological treatment in controlled conditions is possible because much of the waste is almost entirely aqueous with a high concentration of organic and biodegradable material (SCAR, 1989). At coastal stations, waste heat from electrical power generation can provide an artificial environment for the biological treatment of sewage and wastewater (SCAR, 1989).

2.2.1. Sedimentation Ponds:

Aerobic ponds are relatively shallow with depths ranging between 0.3m and 0.6m. Algae supply oxygen during photosynthesis and wind-aided surface aeration (WEF manual, 1992). They are usually mixed by recirculation to maintain dissolved oxygen at all depths and are usually limited to warm, sunny climates (WEF manual, 1992).

Facultative ponds, also known as oxidation ponds are usually between 1.5 and 2.5m in depth with detention times of 25 to 180 days (WEF manual, 1992). Pre treatment before these ponds is usually limited to screening therefore a series of up to three ponds is recommended so that solid and grit are collected in the first ponds. The
ponds surface layers are aerobic with an anaerobic layer near the pond bottom. Oxygen is supplied by photosynthetic algae and surface aeration. A problem with these ponds is that algae production often remains in the effluent and so effluent suspended solids may exceed discharge requirements (WEF manual, 1992).

Aerated ponds are either partially or completely mixed. Oxygen is supplied by mechanical floating aerators and sometimes diffused aeration. They are usually 3m to 6m in depth with detention times between 7 and 20 days. These ponds accept higher BOD loadings than facultative ponds, are less susceptible to odours and require less land. Aerated ponds are usually followed by a facultative or settling pond to reduce suspended solids before discharge (WEF manual, 1992).

In aerobic treatment the range of microorganisms are contained in tanks, ponds or beds. The required air for this is supplied naturally by wind and surface currents as well as the growth and life processes of photosynthetic organisms. Air can also be supplied mechanically by: the diffusion of air through the fluid sewage mass; injection through porous plates within the mass in a tank; bulbing air into the mass from perforated headers or tubing, or by stirring the surface of the fluid mass. Horizontally turning vaned rotors and vertically rotating brush mechanisms are examples of such surface stirring devices (Alter, 1969). If the air is heated there is much less chance of the waste freezing. The most desirable method of heating sewage is to raise the water supply temperature and indirectly raise sewage temperature (Alter, 1969). This is possible using part of the waste heat from power generation. The sewage can be heated by immersion heaters, heat exchangers and by a mixture with warm water or steam. In a digestion chamber sludge is heated by circulating hot water through pipe coils in the tank wall (Alter, 1969). To avoid operation and maintenance problems of such methods regular cleaning is required. The material and land requirements of this scheme are the major obstacle preventing its implementation at Scott Base. Utilisation of waste heat from power generation, or utilising alternative energy such as solar power may be adequate to prevent the sewage from freezing and allow it to be stored in tanks with microorganisms. The logistics of such a process may not seem suitable to the current Scott Base scheme however they are worth consideration.
Anaerobic ponds do not have an aerobic zone and are heavily loaded with organics. They are between 2.5m and 5m deep with retention times between 20 to 50 days. Biological activity is predominantly low and these ponds are usually used before facultative or aerobic ponds. They are not widely used as a treatment system around the world (WEF manual, 1992).

The generic utility of these three pond treatment options is reasonable, however their applicability to Antarctica is low as the facilities and materials required for such a venture seem beyond the current capacity of Antarctica New Zealand or Scott Base.

2.2.2. Sewage Sludge:

The activated sludge process is comprised of a mass of microorganisms predominantly heterotrophic bacteria and saprobic protozoa constantly being supplied with organic matter and oxygen. The microorganisms grow in flocs and they transform the organic material into new bacteria, carbon dioxide and water. The flocs are constantly being washed out of the reactor into sedimentary sedimentation tanks by the incoming flow of sewage. It is here that they can settle. A factor of the activated sludge process is that a small part of the settled sludge is recycled back to the aeration tank in order to provide sufficient biomass to achieve efficient BOD removal (Horan, 1990). The principle of activated sludge processes is that a mass of activated sludge is kept moving by stirring or aeration, suspended solids are recycled and those that settle are removed via the excess sludge (Henze et al. 1995). Figure 5 shows an example of this type of treatment system.

Sewage sludge is the mainly organic residue that remains after sewage treatment and should be treated before final disposal. Possible treatment options for this sludge at Scott Base are as follows:

- Anaerobic digestion to reduce the overall sludge solid weight and reduce smell and pathogen levels
Figure 4. Diagram of a controlled filtration process. (Alter, 1969).

Figure 5. Example of an activated sludge system. (Alter, 1969).
• Drying by heat treatment producing a granular or pelleted product that is odourless and pasteurised to control bacteria levels

(Hester & Harrison, 1995, p. 24)

2.2.3. Biological Treatment:

Under adequate environmental conditions, bacteria and microorganisms utilise organic waste as food and convert it into simpler, non-polluting compounds. The rate of this biological activity depends on the temperature of the surroundings and decreases with decreasing temperature (Miholits, 1961). The heat required for an efficient biological treatment system is very large. This problem can however be overcome by carrying out the process in a heated building, utilising heated sewer lines or heated collection transport vehicles for waste transport (Miholits, 1961). This heating process is what makes these treatment options less applicable to Scott Base. As previously mentioned, heat for this process could be obtained from power generation waste heat, or an alternative source such as solar power. This would prevent the sewage freezing and allow it to be held in tanks with microorganisms. The insulated sewage and wastewater piping system currently at Scott Base may provide enough insulation so as to contain the water at an optimum temperature, however it would only be applicable for the summer season when sunlight is available.

Secondary biological treatment systems will take up phosphorus from solution for biomass synthesis during BOD oxidation (WEF manual, 1992). The sequence of anaerobic treatment followed by aerobic treatment selects for organisms capable of taking up significant proportions of phosphorus and nitrogen (WEF manual, 1992). Specialised bacteria for example enable the microbiological process of nitrification, converting ammonium to nitrite and eventually nitrites to nitrates (Henze et al. 1995).
The organisms in biological treatment are:

- Bacteria: in large numbers in biofilters and activated sludge processes. They transform and degrade dissolved organic matter.
- Fungi in biofilters and activated sludge processes. Compete with bacteria for food, bacteria usually win.
- Algae on surface of biofilters
- Protozoa in biofilters and varying numbers in activated sludge plants. They graze on bacteria, fungi, algae and suspended organic matter.
- Metazoa in biofilters and activated sludge processes

(Henze et al. 1995, p. 56)

There is also the electrochemical process of mixing sea water with screened sewage, this mixture is then passed through an electrolytic cell. It is then flocculated and settled, becoming disinfected in the process. Magnesium hydroxide from seawater serves as the flocculent and the chlorine as the disinfectant. The effluent is clear and the sludge may be dried out with further processing. This process is relatively quick and requires little space but requires seawater and electricity (Alter, 1969). This option is a possible option for Scott Base as it could be applied on a small scale and utilises the seawater components and prepares the sludge for treatment elsewhere, for example for shipment back to New Zealand.

Section 2.3. Tertiary Treatment:

At the end of primary and secondary treatment processes, the effluent still contains some BOD, approximately 50% of the original N and 70% of the original P (Totara et al. 1995). It is for this reason that tertiary treatment is necessary. Tertiary treatment aims to remove all the remaining contaminants using mainly physical and chemical processes to kill any remaining microorganisms (Redvers, 2000)
2.3.1. Photolytic Processes:

Light can be used under certain conditions to promote the breakdown of pollutants to harmless byproducts (Rajeshwar, 1996). It can be used directly to break bonds photolytically within the pollutant molecule. Photolytic processes usually use ultraviolet (UV) light. Variants of this process are also available for example a dissolved inorganic complex in an aqueous medium can photoionise to produce hydrated electrons. These have a very effective reducing power and can either react with dioxygen to produce oxygen or electrochemically reduces the pollutant directly. Mixtures of Iron (III) and hydrogen dioxide when irradiated with light of suitable wavelength generate hydroxide, which can destroy the pollutant. Hydroxide can decompose a pollutant chemically into harmless end-products (Rajeshwar, 1996).

Solar treatment is another option for bacteria-laden water. It is particularly effective for remote areas where electricity and the means for generating anti-bacterial agents are not readily available. Portable UV lamps are efficient in this process. UV radiation-based water disinfection is a far more environmentally accepted form of treatment as there are many health concerns associated with other disinfection by-products for example chlorination. The UV process is also being increasingly recognised as a potential candidate for the destruction of pollutant structure and concentrations in certain environments (Rajeshwar, 1996).

2.3.2 Disinfection Processes:

Ultraviolet disinfection is a physical process by which ultraviolet energy is absorbed in the DNA of microorganisms causing structural changes to their DNA. This prevents them from propagating (WEF manual, 1992). Low-pressure lamps, which emit approx 85% of their output energy at 253.7 nm are most effective and efficient for this process (WEF manual, 1992).

Ozone disinfection is another option for tertiary treatment. Ozone disinfection can also be applied for suspended solid removal, oxidation of organic materials, odour control and sludge processing. Ozone is generated on site and for full-scale treatment
by passing a filtered, dry oxygen-bearing gas through a gap between two electrodes, across which a high-voltage electrical current is maintained (WEF manual, 1992).

Each of these tertiary treatment options in particular the UV system, are possibilities for Scott Base providing there is some set up of primary and or secondary treatment processes beforehand. The requirements are substantial but achievable and the potential for success is evident.

2.4. Alternative Treatment Options:

Alternative treatment options are those that are somewhat more innovative and have more flexibility to be adapted to varying circumstances. The options that are possible for Scott Base are discussed in this section.

2.4.1 Thermal Treatment:

One alternative treatment option is to separate sewage and wastewater at Scott Base, filtering the wastewater for discharge outside the base while freezing and storing the remaining sludge products for return to New Zealand for thermal treatment. If thermally treated at 175°C for one hour the filtration resistance of the sludge is reduced. This heat treated sludge is then dehydrated to 50% water content and the dehydrated cake can be used as energy for heat treatment. The dehydrated liquid can then be anaerobically fermented in a fixed bed reactor for carbon oxygen demand (COD) removal and biogas recovery (Nishio et al. 1988). The first part of this option is a perfectly viable one for Scott Base and returning the sludge back to New Zealand means that it can be treated in a temperate environment and exceptions for the Antarctic climate do not need consideration.

2.4.2 Intermittent Biological Sand Filters (IBSF):

IBSFs are another alternative treatment option for sewage and wastewater at Scott Base. The IBSF can produce effective reductions in BOD, suspended solids and
bacteria. Such a system has been implemented at the Treble Cone ski field in the Southern Alps within which limitations were similar to those at Scott Base:

- Limited availability of space
- High quality effluent required
- High altitude, cold climate
- Raw effluent varying in quality and flow
- No permanent power source
- Few personnel available and trained for such technologies

(McNeill & Bradley, 1988, p. 245-246).

This type of system would consist of a septic tank, adequately sized and compartmentalised for maximum flows with a simple mechanical dosing chamber, intermittent sand filter consisting of two alternating beds and effluent underdrain and collection (McNeill & Bradley, 1988). Specific to Antarctica and Scott Base, the ultimate disposal may be discharge into the marine environment and the sludge collected and perhaps treated as in the above example. The septic tanks are insulated while the dosing chamber is insulated and heat traced. The power source is an on-site generator. This helps retain the residual heat of the raw effluent and provides heat for the proper functioning of the sand filter (McNeill & Bradley, 1988). The filter is covered with removable lightweight coated steel covers as well as more specialised coverings for protection against freezing and snow accumulation on the bed. Snow on the covers of the filter bed also provides additional insulation (McNeill & Bradley, 1988).

2.4.3 Vermicomposting:

If the sewage or sludge was to be sent back to New Zealand a vermicomposting farm could be set up for its treatment using earthworms to convert the waste into organic fertiliser as they mineralise nitrogen making it more readily available to plants. (Madan et al. 1988). Figure 6 shows an illustration of how this process may work.
2.4.4 Non-Waterborne Systems:

There is also the possibility of putting non-waterborne systems in place for the treatment of human wastes. This includes composting humus toilets, which make use of specially formulated starters promoting the natural decay of wastes and chemical toilets, which use formaldehyde (SCAR, 1989). The output from formaldehyde toilets, if diluted and discharged into an area of the sea with efficient circulation will have little environmental damage (SCAR, 1989). The Greenpeace World Park Base for example used a multi chambered rotating biological toilet, consisting of composting dry toilets. The humus created by this process was then returned to New Zealand (Szabo & Dalziell, 1993). This option has therefore been proven to work in Antarctica and is of specific enough design to be successfully implemented at Scott Base given its relative size.

2.4.5 Energy Systems:

During the summer months the installation of solar panels could assist in the heating of the sewage treatment systems mentioned in the above section, as well as having storage tanks with solar panels to prevent the sewage from freezing. The utilisation of wind energy is also an option worthy of more consideration. The Greenpeace World Park base used a simple system of solar and wind energy for 40% of their time at the base (Szabo & Dalziell, 1993).

2.4.6 The RUCK Treatment System:

The RUCK treatment system, as shown in Figure 7, is another alternative option for the wastewater from Scott Base. This involves separating the wastewater from effluent and the separation of kitchen, bathing and laundry wastewater, which are treated in a separate septic tank and a layered sand filter (Laak, 1988). The sand drain, which has in-drains and vents, aerates the wastewater, converting nitrogen compounds to nitrates, oxidises organic carbon compounds and removes volatile compounds. This biochemical reaction utilises inorganic carbon, which acidifies the water to a pH of 4, which enables the filter to remove excreted phosphorus (Laak, 1988). This acid state
Figure 6. The recycling of organic waste through earthworms. (Madan et al., 1988).

Figure 7. The RUCK System. (Laak, 1988).
also increases virus adsorption and accelerates the death rate of excreted bacteria. Another tank mixes the kitchen, laundry and bath wastes with the sand filter effluent. The anoxic conditions of this denitrify nitrates to nitrogen gas (Laak, 1988). At the same time, the acid filter causes coagulation and flocculation in the mix, assisting in the removal of phosphorus. During this denitrification, bicarbonate is produced and the acid water is converted back to its original pH level (Laak, 1988).

2.4.7 Flow Separation:

Possibly a simpler option for wastewater treatment is the collection and storage of grey water in a collection tank. A screen below the catchment drain would catch any larger particles for example 10 micron mesh as it is accessible and cleanable (Greenpeace, 1991). This could then be recirculated or pumped out to the sea discharge area. The residues from the holding tank and water from the cleaning of the filtering system could then be returned to New Zealand. Further separation of the kitchen, laundry and bath waters would make this system more effective as would a regulation on the detergents and cleaning product types used at Scott Base. For example using only organic or biodegradable products resulting in the least amount of environmental damage possible would also help regulate and minimise the amount of harmful contaminants being discharged via the outfall (Alter, 1969).

2.4.8 Reclaim and Re-use:

There is also the option of reclaiming and reusing wastewater for other purposes for example flushing via a recirculating type toilet system, the transport of wastes and for cooling mechanical equipment. A collection and storage tank could receive these wastes and hold them for later use. Such uses however would require tertiary treatment (Alter, 1969). Achieving aesthetically acceptable regenerated water may be facilitated by the separation of wastes according to type for example kitchen and laundry water. This would also require the separation of this wastewater from sewage.
Each of these alternative options are possible at Scott Base, or any Antarctic Base because they involve relatively simple changes to the existing systems and offer more design flexibility to be able to fit into the extreme environmental requirements of Antarctica.

Other possible treatment options are:

- Retro treating – where all sewage and wastewater is collected, stored and sent back to New Zealand as a liquid for treatment there.
- Storing and freeze drying all sewage and wastewater to be taken back to New Zealand for treatment.
- Pumping sewage and wastewater into holding tanks on ships for disposal out at sea or brought back to New Zealand for treatment.
- Reduce the volume of discharge via reverse osmosis, which leaves sludge. The sludge can then be brought back to New Zealand for treatment.
- Incorporate Scott Base waste with that of McMurdo, pump the Scott Base waste to them and have it treated there.
- There is also the option of doing nothing and leaving the current system as it is. It complies with current environmental regulations and changing the system to be one of more intense treatment may cause more environmental damage and degradation than is currently occurs. This includes the consideration of the long term and cumulative effects of keeping the remaining system or implementing another.

Each of these options is also valid as although the logistics of returning waste to New Zealand seem like an immense task, the options for treatment be it traditional or alternative are far more numerous in a temperate climate and there are better options for waste re-use in New Zealand also.
2.5 Dispersal and Dilution Considerations:

The fact that currents further offshore are much stronger than those close to Scott Base relates to the possible treatment option of having a sea pipe which pumps the sewage out far into the sea ice where it will eventually melt and disperse. The recordings of the water intake faecal coliform concentrations when effluent was discharged from the sea ice outfall, further off shore, were significantly lower. This suggests that the effluent was being dispersed to a greater extent and possibly entering stronger regional currents further offshore. This would transport the effluent further from the base (Redvers, 2000). This supports the idea of having the discharge further offshore as it reduces local effects and disperses effluent further.

Dilution is greater at higher current speeds therefore, outfall location where tidal currents are high is most beneficial. Seasonal changes in effluent flow rates should also be carefully considered when designing an outfall also as when effluent flows are increased dilution is greatly reduced (Railsback, 1992). Disposal of sewage at the sea ice surface could result in a wider dispersion of sewage to sedimentary surfaces than when discharged through submerged pipelines (Venkatsean & Mirdadeghi, 1992).

A submerged outfall appears to be better than the surface discharge as it allows for rapid mixing vertically rather than the horizontal dispersion of surface discharge, which spreads effluent and wastewater over a much wider area. A submerged outfall is also expected to affect tidal cracks less frequently and at much lower concentrations than the surface discharge (Railsback, 1992). A submerged outfall, offshore from Scott Base would be likely to achieve higher levels of dilution than the present surface discharge (Redvers, 2000).

Although the present outfall location allows for little dispersion or dilution of effluent moving it away from Scott Base may simply cause the same amount of damage just further from Scott Base. This option is merely removing the problem from Scott Bases’ ‘backyard’. This does not help resolve the waste disposal issue at all.
Section 3. Recommendations:

These recommendations are put forward in order to emphasize each of the factors that require consideration before any treatment system is put in place at Scott Base and to summarise the most valid ideas and suggestions specified in this report.

- Construction and operation of any treatment facility must be compatible with the physical and biological constraints of the environment as well as amenable to the attitudes of the people who work there (Alter, 1969).
- Monitoring of effluent quality before and after treatment should be undertaken on a regular basis in order to assess the efficiency of the treatment process. This monitoring should also be done in conjunction with monitoring of changes, which may occur in the Antarctic marine environment as a result of this treatment.
- Construction and operation of the treatment facility should not degrade the quality of the natural environment.
- The treatment facility should utilise energy in nature and materials available at the site.
- Materials used should provide adequate weather protection and guard against freezing.
- That the selected treatment facility be economically and environmentally feasible in the long and short term.
- That the selected treatment facility be of relatively simple building design and operation.
- When considering the significant ecological effects and human health risks associated with the sewage and wastewater disposal at Scott Base along with other research findings from elsewhere, it is recommended that the sewage from this location undergo at least secondary treatment before discharge into the Antarctic marine environment (Redvers, 2000).
- That the selected treatment facility be fully tested and analysed during the design stages and well before implementation.
• Alternative treatment options should be given adequate consideration and any
design obstacles attempted to be overcome.
• The treatment facility should be an effective barrier against disease
transmission.
• The treatment facility should be acceptable aesthetically, with safety and have
psychological acceptability of users.

**Conclusion:**

The current level of interest in Antarctica is from variety of perspectives. This
suggests that the issues associated with sewage and wastewater disposal are in need of
more recognition in order to minimise the impact of the increasing human presence in
this extreme and fragile polar ecosystem. The results obtained by various scientists
indicate collectively that sewage and wastewater treatment sites are necessary because
of both the impact they have had already and their potential for much more. The
Antarctica New Zealand environmental strategy for the Ross Sea region also
recognises this through its identification of threats to the region, which includes
‘degradation of the Ross Sea marine ecosystems through pollution from oil spills,
rubbish disposal and coastal discharge’ (Antarctic, 2000). Recognition however is not
enough, recognition is ineffective without action.

The release of large volumes of untreated sewage into the Antarctic marine
environment represents a significant source of persistent organic matter, bacterial and
viral agents. Many of these are potential disease-causing agents for indigenous
wildlife (Smith & McFeters, 1998). These issues and their associated effects are still
relatively unknown. The likelihood of pathogen transfer to wild populations for
example is largely unknown and studying the susceptibility of Antarctic wildlife to
common disease causing agents has not been studied and for ethical reasons would be
difficult to study except during naturally occurring events (www.up.ac.za). It is for
this reason however that such a major risk of ecological detriment should not be taken
and that precautionary action such as sewage and wastewater treatment and separation is undertaken.

It is vital that further research into the effects of sewage and wastewater disposal on receiving water bodies is undertaken as there is clear evidence that the ecological disturbance to Antarctic marine environment discharge sites is highly significant and primarily due to sewage and wastewater disposal. As stated by Howington et al. (1992, p. 326) ‘The impact of sewage contamination from the ever increasing presence in Antarctica must be understood in order to minimise its negative influence on this pristine environment’. The limited amount of knowledge relating to the specific ecological effects of effluent discharges in the Antarctic marine environment is inadequate and requires much more research.

In comparison to the wastewater and sewage flows from other bases in Antarctica Scott Base has the least. This is primarily because it is the smallest base and it is in no way a reason for the impacts of discharges to be overlooked or treatment possibilities prevented from further development. As a smaller base, it has the opportunity to implement treatment programs which larger bases may not be able to do. New Zealand should continue the pattern that it has begun in leading the way for Antarctic environmental protection policies and governmental status.

There is perhaps a perception that because Antarctica is such an extreme, harsh and cold environment pathogens will not survive there. This report disproves this and in fact, presents evidence contrary to such a statement. The characteristics of the Antarctic marine environment enable micro organisms and sewage organic matter to persist in receiving waters. Therefore, adverse ecological effects in the vicinity if the Scott Base outfall are inevitable. This report has discussed these effects with reference to the Scott Base region and other discharge sites in Antarctica. Although the scale of many of these effects is unknown, the potential risk they pose to the Antarctic marine environment is highly significant. (Redvers, 2000). This is a vital consideration when assessing whether or not to treat the Scott Base sewage and wastewater discharge. It may be decided that it is better to remain using the current system rather than change the whole scheme and risk more environmental damage. This decision must be made
soon as the future of the Scott Base Ross Sea Region and the Antarctic marine environment are determined by it.
References:


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