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Critical Literature Review
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Management and Disposal of Anthropogenic wastes and its Effects on the Antarctic Environment

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As Antarctica is the only continent on Earth that does not maintain a permanent resident human population it is important to gain an understanding of how humans impact upon the local environment so the best management strategies and approaches can be defined.

Throughout this review it was found that despite its vast land area and recent, comparatively low human population the necessary activities required for humans to inhabit Antarctica had a noticeable impact on Antarctic ecosystems as pathogens were found to be released from human waste products to infect local fauna and the community make up of several benthic and soil communities were altered via exposure to contaminants via fuel spills and leakage from abandoned station waste sites . Legacy waste left over from less environmentally focused periods in Antarctic history is a big problem for current managers.

A more effective range of environmental measures may be required to ensure the Environmental Protocol is implemented efficiently. Many waste water treatment installations are still relatively new and the effects on the environment are as yet unknown.

PCAS CRITICAL REVIEW

Topic

Management and Disposal of Anthropogenic wastes and its Effects on the Antarctic Environment

Introduction

Due to its isolation Antarctica has remained untouched by human interference for much of human history, leaving its unique environment pristine from human modification while the rest of the world's landmasses experienced significant change due to human occupation (Riffenburgh 2007). However from the 19th century onwards early explorers and whalers found their way on to the continent, exploiting its resources and steadily pushing into the most remote parts of the continent (Riffenburgh 2007). With the advancement of new technology allowing increasing activity on the white continent and the signing of the Antarctic Treaty following the increased Antarctic interest brought about by the international geophysical year in 1957, scientific research became one of the primary focuses of Antarctic habitation. Over the years the amount of stations present and nations involved with Antarctica has increased however this presents a challenge as pressure is placed more on the once pristine environment through the bi-products of human habitation. This is a particular challenge as processes such as waste management are difficult to practise in Antarctica as its isolation and harsh environment make it difficult to dispose of potential contaminants created from human occupation with minimal effects to the natural environment.

As Antarctica is the only continent on Earth that does not maintain a permanent resident human population it is important to gain an understanding of how humans impact upon the local environment so the best management strategies and approaches can be defined. This review will look at the present literature around waste management and disposal practices (wastes being sewage, food scraps, fuel emissions and other such bi-products associated with habitation) amongst human populations in the Antarctic and the effects these wastes have on the surrounding environment, particularly the native ecosystems present.

Discussion

Background: Early History and the implementation of policies

Antarctica is one of the most regulated places on the planet so it is unsurprising that there is now framework laid down to ensure the protection of the Antarctic environment. However this was not always the case. Early exploration and exploitation of the continent naturally paid little thought to environmental conditions as this was not indicative of the time and there was no governing body in place to manage resources and conditions within the continent (Riffenburgh 2007). With the signing of the Antarctic treaty in 1959 some form of governing body was established however the treaty paid little heed to environmental issues, primarily focusing on scientific and political considerations with the exception being a all out ban on nuclear activity occurring within the treaty zone (Hanessian, 1960). Environmental issues were likely not given much attention as at this time the continent was viewed as being so large that human impacts had little effect.

From around the 1980-90s onward parties became increasingly aware of how human activities on the continent were potentially threatening both its intrinsic wilderness and scientific values. In 1991

Protocol on Environmental Protection to the Antarctic Treaty was created and came into force in 1998. Commonly called the Environmental Protocol, it is the main environmental policy underneath the Antarctic Treaty System with its primary objective being *"The protection of the Antarctic environment and dependent and associated ecosystems and the intrinsic value of Antarctica, including its wilderness and aesthetic values and its value as an area for the conduct of scientific research essential to understanding the global environment, shall be fundamental considerations in the planning and conduct of all activities in the Antarctic Treaty Area"* (Parties 1991). It sets minimum waste disposal requirements for Antarctic signatories and requires parties to maintain environments in their areas. The requirements of the Environmental protocol have been translated into practical documents and practises amounts parties such as the New Zealand code of conduct and the Nordic environmental handbook on Antarctic operations (Gröndahl, Sidenmark, & Thomsen, 2009). In addition it also dealt with the issue of historical waste sites including the stipulation that "past and present waste sites on land and abandoned worksites of Antarctic activities shall be cleaned up by the generator of such wastes and the user of such sites" although it excluded historical sites and areas deemed too risky to clean up without causing further environmental damage (Parties 1991).

Environmental Impacts

Although the area of the Antarctic region is very large, with the continental landmass alone being roughly twice the size of Australia and the human population is very sparse with a the Council of Managers of National Antarctic Program (COMNAP) giving a total of 53 research stations existing across the continent with a maximum population of 1000 people in the winter and 4000 in the summer while tourism sees an estimated 6000 visitors per year (many of which are ship board visitors only), all numbers low numbers in comparison with the rest of the world (COMNAP 1999, IAATO 2008). Due to this it would seem that any human activity on the continent would have relatively a low impact on the Antarctic environment as a whole; however when reviewing the data this becomes apparent that it may not be the case.

The Antarctic continent is primarily covered by an ice sheet with only 0.34% of the land area being ice free (BAS 2004). This land itself does not consist of a large homogenous exposed area, with much of it being scattered across iced over areas as islands of exposed ground where climatic or topographic conditions have prevented the forming of ice (BAS 2004). This leaves considerably smaller, more unique habitats in which organisms live, which creates a problem when the number of human settlements currently existing/that have existed on these zones.

Chemical contamination

The impacts of waste introduced into the Antarctic environment through sewage disposal, spills, landfills and abandoned sites, chemical spills and other activities that create unwanted residues in the environment have been cited as being particularly problematic in numerous studies. Bargagli (2008) argues that the most widespread human related environmental impact is chemical contamination (particularly through fuel spills). Tin *et al* (2008) discusses the problems caused by the slow break down of substances in the Antarctic environment, due to factors such as the cold temperatures, dry climate and long dark winters which do not provide the energy required for physical breakdown processes biological activity such as decomposition, although Hughes (2005) found that the depletion of the ozone layer above Antarctica in the summer can aid in break down

and sterilization of waste products in the environment. However ozone related breakdown was found to be seasonal and also rather inconsistent in nature. Seasonal variability is common amongst contaminated sites as ice melts during the summer and freezes back up again during the winter (George, 2002). Wilkes station is an abandoned station located on Cark Peninsula in East Antarctica in which very little clean up was performed when it was left (Fryirs, Snape, & Babicka, 2013). Although during cooler conditions very little in the way of contamination recorded, with the station being predominantly buried in snow, during warmer weather when high levels of melting occur fuel plumes several kilometres long have been observed originating from the station and spilling into the marine environment (Fryirs et al., 2013)

Chemical contamination though legacy wastes is generally agreed in most papers to be harmful to native ecosystems. However there are some studies that argue that in particular areas of the continent heavy chemical contamination makes little difference. Santos *et al* (2005)state that although there is evidence of human related heavy metal contamination in soils around the Brazilian Antarctic Station on King George Island due to the low levels of biological activity in this region it makes little difference to the actual environment.

For the most part foreign contaminants being introduced into the Antarctic environment can have detrimental effects on local ecosystems. Bargagli (2008) found that chemical contamination from oil spills caused a decrease in diversity within the microbial soil community as microbes that specialise in degrading hydrocarbon products like fuel increase in population. This was a pattern commonly seen in multiple studies of Antarctic contamination. Organisms that were sensitive to the increased toxicity were found to die off in areas directly exposed to contaminants while either opportunistic or resistant species quickly underwent a population boom as competition was removed and new nutrients were introduced into the system(Bargagli, 2008; Conlan *et al* 2004; Webster *et al* 2003(Stark, Riddle, & Simpson, 2003).

An example of an Antarctic environment that has suffered from severe degradation is McMurdo station (located on Ross island). The largest and longest running settlement on the Antarctic continent, it has traditionally dumped its sewage and grey water (waste water containing oils, fats and detergents used for cleaning and cooking purposes) into the ocean with little in the way of prior treatment. As a results studies have found that its surrounding environment is as heavily polluted as urban areas of the U.S.A. with Quarters Bay (McMurdo's dumpsite until the 1980s) being the most heavily contaminated environment anywhere (Tin et al., 2008). Areas such as this show a significant reduction in fauna with few species surviving the heavily polluted areas (Lenihan, Oliver, Oakden, & Stephenson, 1990) Detergents used for cleaning present in grey water may also cause environmental degradation however a study by George (2002) found sodium dodecyl sulphate (SDS), the most commonly used ingredient occurs reasonably well when microorganisms are present.

Invasive Organisms

Introducing species into the environment through food scraps and human wastes being released into the environment has also been found to be an issue for management activities. Pathogens have been known to infect native fauna potentially impacting on populations(Hernandez et al., 2007; K. A. Hughes, 2003; Stark et al., 2003). In 1995 infectious bursal disease virus (IBDV) was found in wild Emperor and Adelie penguin populations near the Australian Mawson Station (located in Holme Bay) (Gardner, Kerry, & Riddle, 1997). This disease is found in domestic poultry across the planet and

therefore it was thought to have likely been introduced through inappropriate disposal of chicken giving an opportunity for scavengers such as the south polar skua to access the food scraps, thus spreading the pathogen throughout the environment to the detriment of avian populations exposed to the infection(Gardner et al., 1997; Sánchez & Rodriguez, 1999). Sewage and grey water can also contain microorganisms that can be released into the environment when water is left untreated (Gröndahl et al., 2009). Several studies have found that micro-organisms can remain viable even in Antarctic conditions for prolonged periods of time (Gröndahl et al., 2009). Smith *et al* (1994) found that *E. coli* exposed to polar conditions survived for over 54 days of treatment whole Hughes and Nobbs (2004) finding viable microorganisms in human faeces left at a waste dump for 30-40yrs. There is evidence to show that not all pathogens are brought over to Antarctica via humans as Hernandez *et al* (2007) argues that many migratory birds and mammals introduce organisms into the Antarctic environment naturally, particularly from South America to the Antarctic Peninsula and there has been little research to separate all human introductions from natural ones. However humans appear to be drastically increasing the likelihood of invasion via micro-organisms in waste products therefore there is an important area to be managed.

Management strategies

Although there are a wide variety of environmental impacts brought about by human occupation in Antarctica, many of these are legacy problems from before the implementation of the Environmental Protocol (Fryirs et al., 2013). Since its implementation most National Antartic Programs (NAPS) have attempted in some way to comply with standards set, with the installation of new sewage systems and changes in National Codes of Conduct occurring. However implementation of new management strategies takes a long time as installing new equipment is costly and time consuming. Additionally values between various party signatories can differ in regards to the importance of environmental protection, with some ranking it a higher priority than others. Therefore how current waste management strategies are being effectively implemented into the remains debatable.

In a review of the level of implementation of the Environmental Protocol complaints was found to be low amongst parties with it occurring ate rates of 65% amongst consultive parties and 50% amongst non-consultative ones (UNEP 2011) With a report on the SCAR/COMNAP guidelines showing that almost no countries implemented them into their national guidelines (Cameron, Columbus, Nielsen, & Wilson, 2012). However it should be noted that even though the guidelines themselves are not being implemented, there are countries that include the principles of the Environmental Code in their code of conduct (Gröndahl, Sidenmark, & Thomsen, 2009).

A survey on waste water disposal practises at Antarctic research stations conducted by the Swedish Polar Research secretariat while searching for the best treatment system to implement into their own station found that a significant proportion of summer stations and even a large proportion of winter stations completely lack even the most basic form of treatment facility (Gröndahl et al., 2009). Of the summer stations covered in the survey, 69% of them had no treatment facility. This is possibly unsurprising as the Environmental Protocol stipulates that populations of less than 30 individuals do not have to treat their waste before they dispose of it and summer camps tend to only maintain small populations. However due to the naturally slow rate of biodegradation that occurs within the Antarctic environment and the potential for wastes and associated pathogens to

accumulate over time, it is concerning that so few summer facilities still have no way of disposing of waste products in a relatively environmentally friendly manner(Tin et al., 2008). Perhaps more concerning is that 37% of the over wintering stations surveyed at that time had little or no treatment facility. These stations tend to be larger and maintain a more sustained population, amplifying the risk for detrimental environmental impacts such as contamination or the release of pathogens into the environment to occur.

Within the winter stations that did contain some form of waste water treatment 10% only used maceration, the method of removing solids from the system via macerating them into smaller pieces. Maceration is a minimum requirement needed to comply with the Environmental Protocol and is counted as a primary treatment method (Gröndahl et al., 2009, Parties 1991). A further 10% of stations used some sort of secondary sewage treatment on top of the maceration to remove dissolved biological material via converting it into solid mass. By far the most common practise amongst stations was to use biological treatment (the use of microorganisms to break down waste) with 20% of stations practicing this(Gröndahl et al., 2009).

Many of the programs and stations have experimented with various different treatment methods to reduce water usage and produce the best results with techniques such as recycling grey water into toilets being utilised to reduce water use(Gröndahl et al., 2009). Equipment malfunction was a common problem amongst stations, particularly in the summer when many of the stations surveyed (including New Zealand, Australia, Japan and South Africa) struggled to keep up with the influx of population over the summer. Yet more stations were only recently installed and could say little on the effectiveness of their systems (Gröndahl et al., 2009). According to (Tin et al., 2008) many of these strategies have yet been insufficient in preventing contamination in their locality, at least in the coastal stations. However they also acknowledge that there has been yet no apparent introduction of potentially invasive species through this method (Tin et al., 2008). However due to the fact that many waste water treatment areas were installed relatively recently it is difficult to attain just what impact , whether positive or negative, will be had on their local environment.

Conclusion

Despite its vast land area and recent, comparatively low human population the necessary activities required for humans to inhabit Antarctica whether temporarily or long term do have a noticeable impact on Antarctic ecosystems, particularly as materials were found to take a much longer time to breakdown than in more temperate climates. Legacy waste left over from less environmentally focused periods in Antarctic history is a big problem for current managers, particularly as contamination has shown to occur in some sites. More work will likely have to occur in the future to mitigate some of these issues. Human introduced pathogens are a threat to local fauna and care must be taken to ensure that food scraps and other wastes are disposed of effectively to reduce the threat of viral infection. Several benthic and soil communities have shown a change in community make up due to contamination by human waste products and fuel spills.

A more effective range of environmental measures may be required to ensure the Environmental Protocol is implemented efficiently. Many waste water treatment installations are still relatively new and the effects on the environment are as yet unknown therefore these issues need to be further researched if we are to ensure a Antarctica can remain as a relatively pristine environment as much as possible.

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