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***Environmental Contamination and the Legacy of Human  
Activity: Mitigation, Remediation and Liability in the  
Antarctic***

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**Abstract:**

The impacts of pollution and contamination in Antarctica are multi-faceted and significant. Atmospheric, marine and terrestrial contaminants are having adverse effects on the Antarctic environment and pose significant management challenges. The current framework for managing human activities in the Antarctic is increasingly complex with considerable differences in the operationalisation and interpretation of both the Antarctic Treaty and the Madrid Protocol between Antarctic operators. Many current practices are incongruent with the principles outlined within the Treaty and the Protocol. Attempts to rectify these practices have so far failed to elicit unanimous positive environmental outcomes. Effective mitigation strategies are necessary to prevent further contamination and provide best practice environmental management with the increasing pressures of human activity in Antarctica. Managing legacy and liability issues is an important stage in remediating past environmental contamination. A more effective governance regime and increased political will by all is required to achieve compliance with the environmental standards set within the Protocol in order to achieve comprehensive protection of Antarctica and Antarctic values.

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## Introduction

Environmental contamination resultant from human activity has been taking place in the Antarctic environment for centuries, where 'Antarctica' can be defined as "all landmasses, ice shelves, and seas in the area south of 60°S" (Poland, Riddle & Zeeb, 2003, p. 370). Anthropogenic contamination has occurred at the local and regional scale with internal factors driving this process. In addition, contamination at a global level is also having an impact in the Antarctic through oceanic and atmospheric circulation and climatic events causing long range transfer of contaminants from lower latitudes to the polar region where external factors can be seen as driving the process.

Management and regulation of human activity in the Antarctic and externally to protect the continent have taken numerous forms, with the International Geophysical Year (IGY) 1957–58 providing a major catalyst in the lead-up to the signing of the Antarctic Treaty in 1959. Environmental considerations beyond the protection of 'wilderness and intrinsic values' are notably absent in the Treaty, unsurprisingly due to the difficult political context under which it was negotiated with the exception of the prohibition on the disposal of radioactive material in Antarctica. Article VI (f) also mentions that the treaty parties further consider the "preservation and conservation of living resources in Antarctica". The 'Question of Antarctica' was formally placed on the agenda of the United Nations in 1983 at the request of the Malaysian government. Concern over the potential environmental cost to the Antarctic of mineral exploration and exploitation eventually led to the adoption of the Convention on the Regulation of Antarctic Mineral Resource Activities (CRAMRA) in 1988. It is important to note that the Convention never became ratified and thus never entered into force due to mounting pressure from external environmental non-government organisations (NGOs) at the time of negotiation where CRAMRA sought to regulate mineral exploitation, rather than outright ban it. It was the collapse of CRAMRA that formed the basis of negotiations and led to the more comprehensive framework of the Protocol on Environmental Protection to the Antarctic Treaty (the Madrid Protocol) which came about in its place.

The signing of the Madrid Protocol in 1991 saw considerations of environmental protection really come to the forefront and was overseen by the Committee for Environmental Protection (CEP). However, despite the agreed environmental and scientific considerations, contamination continues to occur with issues of legacy and liability increasingly complex. This paper explores issues of contamination and associated facets in an Antarctic context. Human activity and impact in the Antarctic remains significant with numerous effects to the environment including exploitation of living resources and invasive species threatening biodiversity. However, these invasive species and

over-exploitation impacts from human activity in the Antarctic are beyond the scope of this paper. Furthermore, while it is acknowledged that the Commission on the Conservation of Antarctic Marine Living Resources (CCAMLR) plays an important regulatory role in the prevention of marine contamination; explicit discussions relating to CCAMLR are also outside the brief of this paper.

## Antarctic Contaminants

Antarctica is no longer the pristine and unspoilt environment that it is often portrayed as, with the effects of local activities as well as those elsewhere in the world having discernible impacts on the continent and its surrounds (Aronson et al., 2011, Bargagli, 2005, 2008, UNEP 2002). While the Madrid Protocol provides strict guidelines for environmental practice, impacts resultant from an increased human presence in the Antarctic are inevitable. Antarctica is the most remote continent on earth surrounded by natural barriers provided by atmospheric and oceanic circulations. However, despite these barriers Antarctica's vulnerability to global processes has become increasingly evident in recent decades through the appearance of the Ozone Hole as well as the rapid rate of warming experienced on the Western Antarctic Peninsula (Bargagli, 2008). Concerns over the vulnerability of the Polar Regions to contaminants from lower latitudes are increasing as contaminants are transported to these remote areas with Polar Regions acting as a sink for some contaminants (Aronson et al., 2011, UNEP, 2002).

Bargagli (2005) defines environmental pollution as an interruption to a biological system and therefore chooses to use the words 'contaminant' and 'contamination' instead, for discussions of low concentrations of atmospheric contamination, except in localised areas where "measurable damage to living organisms cannot be excluded" (Bargagli, 2005, p. 127); it is these definitions that this paper will adhere to also. Anthropogenic contamination in the Antarctic can be atmospheric, marine and terrestrial (including snow, glacial and limnological processes) with impacts on associated ecosystems, and occurs from both local and regional internal sources as well as through external global processes via long range transfer. Contaminants can be chemical, metal and organic. This paper will firstly discuss Persistent Organic Pollutants (POPs) and their presence in the Antarctic before describing the types of contamination occurring in the different Antarctic environments and the processes leading to such contamination.

## Persistent Organic Pollutants

Persistent Organic Pollutants (POPs) are “organic substances that possess toxic properties, resist degradation, bio-accumulate and are transported, through air, water and migratory species, across international boundaries and deposited far from their place of release, where they accumulate in terrestrial and aquatic ecosystems” (SCAR, 2009, p. 5). These synthetic organic compounds are fat soluble and as a result can bio-accumulate in organisms faster than the body can get rid of them. POPs bio-magnify up through food chains with negative effects on the health of wildlife, including being carcinogenic and reproductive and endocrine disruptors (Gaw, 2015). Furthermore, because POPs condense in cooler regions and in relatively high levels (Gaw, 2015), they have the potential to be particularly problematic at high latitudes.

In 2009, the SCAR Action Group on Environmental Contamination in Antarctica produced an information paper for the ATCM in Baltimore entitled *Persistent Organic Pollutants in the Antarctic* after a review was requested by the Stockholm Convention on Persistent Organic Pollutants, providing updated information building upon the United Nations Environment Programme Report in 2002: *Regionally Based Assessment of Persistent Toxic Substances*. The review outlined current information on the original 12 banned compounds of the Stockholm Convention acknowledging data deficiencies with some organochlorine compounds. POP sampling, methodologies, reporting and monitoring in the Antarctic is highly variable making comparisons between studies and across regions difficult (SCAR, 2009). Furthermore, monitoring often focused on local contamination making continental scale predictions difficult with SCAR highlighting the need for an internationally coordinated Antarctic Monitoring and Assessment Programme (AnMAP) akin to the Arctic Monitoring and Assessment Programme (AMAP) where a coordinated approach is already progressing (SCAR, 2009).

## Atmospheric

The atmosphere has inadvertently become a dumping ground for human emissions (Bargagli, 2005, UNEP, 2002, AMAP, 1997). The burning of fossil fuels during the last century has increased causing an exponential rise in the global emission of carbon dioxide and other gasses into the atmosphere. Relatively high concentrations of contaminants are now detectable in the Arctic

and Antarctic environments, areas that were previously thought of as pristine (Bargagli, 2005, AMAP, 1997). The transport of POPs, and also mercury and lead to the Antarctic and Southern Ocean regions largely takes place through atmospheric pathways (UNEP, 2002, Bargagli, 2008). POPs and other contaminants are transported to the higher polar latitudes through the process of 'global distillation' (also known as the 'grasshopper effect') whereby pollutants evaporate at temperate and tropical latitudes where they are produced and, via atmospheric circulation are transported to higher latitudes and altitudes where they condense and where less evaporation takes place, thus allowing them to settle out and accumulate in relatively high levels in these environments (Bargagli, 2005, UNEP, 2002). The burning of fossil fuels and biomass (fires), pesticides, agricultural emissions, industrial chemicals and intentional and unintentional chemical by-products all contribute to global emissions (Bargagli, 2005). Furthermore, as Poland et al. (2003) highlight, because of the lack of local contamination from industry and the prohibition on radioactive substances in the Antarctic, the continent has been used as a 'control' for monitoring background levels of global contamination. External and distant processes are the primary sources of this long range atmospheric contamination. Contaminants and contaminators are party to governance regimes outside that of the Antarctic Treaty System (ATS), such as laws of the state and international instruments, and where those releasing contaminants in other areas of the world are not necessarily signatories to the Antarctic Treaty but are nevertheless still having an impact on the Antarctic environment. Anthropogenic contaminants are also emitted into the atmosphere locally in the Antarctic, in areas of scientific and logistical operations as well as during tourism and fishing operations. There is greater scope to remediate local sources of contamination generated through human activity compared with contamination via long rang transfer which can only be controlled at their source, outside of the Antarctic area (Poland et al., 2003).

## Marine

Contamination of the marine environment around Antarctica originates mostly from old dump sites, oil spills, sewage, leachates and exhaust emissions (Aronson et al., 2011, Bargagli, 2005, 2008). The legacy of historic and inferior waste disposal practices is evident with high levels of heavy metals, hydrocarbons and POP contaminants present in waters proximal to currently used and abandoned research stations (Aronson et al., 2011, Bargagli, 2005, UNEP, 2002). Winter Quarters Bay, Ross Island, boasts the title "most polluted marine site in Antarctica" with "one of the highest toxic concentrations of any body of water on earth" (Aronson et al., 2011, p. 90). However, impacts on benthic communities from this contamination tend to remain localised and although some

recovery has been observed, many contaminants are likely to persist for years to come (Aronson et al., 2011). Contamination from vessels in the Southern Ocean, whether resupply ships, tourist or fishing vessels, is a further area for concern with fuel spills and other accidents causing significant hydrocarbon contamination and pollution. The worst example to date is the Argentine vessel *Bahia Paraiso* which ran aground off Anvers Island in West Antarctica in 1989 releasing vast quantities of diesel fuel into the surrounding environment with devastating impacts on local wildlife (Bargagli, 2008). Whilst the Southern Ocean is not along a trade route with large amounts of shipping traffic, re-supply ships carrying vast quantities of oil regularly frequent Antarctic waters with the risks of an oil spill enhanced by the presence of both sea ice and ice bergs (Poland et al., 2003).

Significantly, Bargagli (2008, p. 214) states: "Pesticides have neither been produced nor applied in Antarctica, but Dichlorodiphenyltrichloroethane (DDT) and its congeners were detected in Antarctic marine biota in the 1960s". This discovery highlighted how pervasive anthropogenic contaminants are and the finding was well publicised coinciding with a time when concern over Antarctica's future was growing (UNEP, 2002). Biological adaptations to colder climates demand greater levels of fatty tissues in the animals that inhabit them resulting in the transfer of larger quantities of fat soluble compounds up the food chain (Poland et al., 2003) and thus the potential for low contaminant concentrations to accumulate becomes greater.

## Terrestrial

The environmental impacts of land-based research activities in the Antarctic are twofold; the potential environmental damage and displacement of wildlife during construction of a given base or facility as well as the contamination and emission into the surrounding marine and terrestrial environments during its lifespan and beyond (Aronson et al., 2011). "The combustion of fuel, waste incineration, sewage and accidental oil spills are among the main sources of contaminants in Antarctic air, snow, soil and biota" (Bargagli, 2008, p. 213). Metals with high toxicity, namely lead, copper, arsenic, zinc and mercury have been widely used in building materials, plant, vehicles, machinery and scientific equipment, which bind to sediments and soils and do not degrade (Gaw, 2015). A wide range of synthetic organic compounds have been used on buildings in the Antarctic including, paints, flame retardants and corrosion inhibitors with various environmental fates (Gaw, 2015). "Pollution levels depend upon the duration of the station's presence, its source of electrical power and waste management practices, and the capacity of the local environment to degrade or remove contaminants" (Aronson et al., 2011, p. 90). Antarctic soils have low moisture content,

limited organic matter and microbial activity and as a result degradation rates are reduced (Gaw, 2015). Terrestrial contamination due to waste management is significant and will be addressed in greater detail in subsequent sections.

## Governance

The Madrid Protocol ratified in 1998, provided a commitment by parties to the Antarctic Treaty of protection for the Antarctic environment and dependent and associated ecosystems, designating Antarctica as a natural reserve, devoted to peace and science and prohibiting activities associated with mineral extraction. In addition, the Protocol has six Annexes:

1. Annex I: Environmental Impact Assessments
2. Annex II: Conservation of Antarctic Flora and Fauna
3. Annex III: Waste Disposal and Waste Management
4. Annex IV: Prevention of Marine Pollution
5. Annex V: Area Protection and Management
6. Annex VI: Liability arising from Environmental Emergencies.

Annexes I, II, III and IV were adopted along with the Protocol in 1991, entering into force in 1998. Annex V was adopted at the ATCM in 1991, entering into force in 2002. All Treaty instruments have been developed by consensus and once agreed upon, are “given legal effect by the domestic legislation of each party” (Poland et al., 2003). Annex VI: Liability Arising from Environmental Emergencies was adopted in 2005, however it has yet to enter into force with all consultative parties still to ratify the Annex, with this process likely to take several more years due to the slow progress of the consensus decision making process within the Antarctic Treaty System (ATS). (Secretariat to the Antarctic Treaty, 2016). Despite these numerous and comprehensive forms of environmental protection agreed upon in the Treaty and in the Madrid Protocol, which should collectively ensure standards across all activities, many current practices remain incongruent with the outlined principles with little consequences for non-compliance. In addition, whilst the Madrid Protocol does provide a framework for environmental management in the Antarctic, environmental quality standards have never been established however, the CEP as well as the Australian Antarctic Division (AAD) have produced guidelines for remediation, working towards the establishment of clean-up protocols.



The Committee for Environmental Protection (CEP) was a new institutional body established under the Madrid Protocol in 1991 to “provide advice and formulate recommendations to the Parties in connection with the implementation of this Protocol, including the operation of its Annexes, for consideration at Antarctic Treaty Consultative Meetings” (Madrid Protocol, 1991, Article 12) with the first meeting taking place in 1998 (Secretariat of the Antarctic Treaty, 2016). The workload of the CEP has increased exponentially since its inception and become increasingly complex with the Antarctic environment subject to additional new pressures such as tourism where the CEP has to adapt accordingly to ensure the most pressing environmental issues are prioritised (Orheim, Press & Gilbert, 2011). The CEP has a significant involvement in the Environmental Impact Assessment (EIA) process under Annex I to the Protocol especially regarding advice on Comprehensive Environmental Evaluations (CEEs) forming an Intercessional Contract Group in 2009 to specifically address CEES and other matters related to EIA (Orheim et al., 2011). The primary policy making body within the ATS is the ATCM with the CEP in an advisory role with the ATCM. The CEP in addition, has working relationships with the Scientific Committee on Antarctic Research (SCAR), CCAMLR, UNEP, the International Association of Antarctic Tour Operators (IAATO), as well as the Antarctic and Southern Ocean Coalition (ASOC) amongst others (Orheim et al., 2011).

The United Nations’ ‘Question of Antarctica?’ placed on the agenda in 1983 by the Malaysian Government was drawn to a close in 2005 with the topic officially taken off the agenda and although the UN would “remain seized of the Question of Antarctica”, the topic would not be discussed henceforth (Beck, 2006). The regulatory framework for protecting the Antarctic environment changed considerably between 1983 and 2005 with important milestones along the way namely the signing of the Madrid Protocol and its associated annexes and the establishment of numerous institutional bodies including the Secretariat to the Antarctic Treaty, providing an important platform for information sharing and increased access to the Antarctic (Beck, 2006). Members were in agreement on the “ability of the Antarctic Treaty Consultative Parties (ATCPs) to manage Antarctica in a democratic, transparent and accountable manner without attracting criticism from the broader international community” (Beck, 2006, p.217).

## Waste

Solid and liquid waste disposal practices in Antarctica have left a legacy of contaminated sites at both occupied and abandoned research stations as well as in the marine environment, with attitudes towards such sites dependent upon the era from which they were created (Poland et al., 2003). Waste management practices in the Antarctic reflected those elsewhere in the world until the

1980s before the ratification of the Madrid Protocol, with dump sites created, open burning of rubbish as well as common practices of disposing of waste onto the sea ice (Stark et al., 2006). Ever since the establishment of research stations and sites in the Antarctic, the question of what to do with waste has arisen and, “their solution has become our problem: what to do about abandoned waste disposal sites” (Stark et al., 2006, p. 21). Annex III to the Madrid Protocol, Waste Disposal and Waste Management, entering into force in 1998, stipulates that any wastes produced or disposed of by activities undertaken in the Antarctic Treaty area be reduced as far as practicable to “minimise any impact to the Antarctic environment and minimize interference with the natural values of Antarctica” (Annex III). In addition, it states that existing waste disposal sites be “cleaned-up by the generator of such wastes and user of such sites” with the exception of historic sites and areas where removal of waste would cause greater environmental impact than leaving the waste or structure in situ.

As a result of past waste management policies, legacy issues in the Antarctic are significant. Snape et al. (2001) highlight that terrestrially speaking, such sites tend to be on the same habitat; that is, ice free, rocky and coastal areas, and as a result amount to a large proportion of this type of habitat on the Antarctic continent. How States have responded to the Protocol and its associated Annexes varies, depending as much on political will as financial and technical capabilities (Snape et al., 2001). Waste disposal sites in the Antarctic largely remain undocumented with some disposal sites resultant from numerous States’ activities (Stark et al., 2006). Dealing with contamination and its various facets requires recognition that there is an issue to be addressed, then ownership of the issue needs to be acknowledged, and finally steps need to be enacted to redress sites through remediation. “While the requirement to remediate these sites may be widely accepted socially and culturally, it is economically unpalatable and creates competition for resources with traditional scientific disciplines with interests in Antarctica” (Stark et al., 2006, p. 22).

Annex IV to the Madrid Protocol, Prevention of Marine Pollution regulates ships’ discharge including ballast, oil, rubbish and disposal of sewage and adopts practices similar to those outlined in the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) (AAD, 2016).

## Mitigation

Mitigation measures for anthropogenic impacts on the environment take place in various forms at different political levels throughout the world, where prevention of environmental damage

is always preferable. Environmental Impact Assessments are to be carried out for all activities in Antarctica in order to mitigate and prevent damage to the environment at a local and regional scale. Globally, mitigation takes on a much broader scope relying on global reform regarding the use of certain persistent chemical compounds and operations that lead to contamination.

Environmental Impact Assessment (EIA) instruments have existed within the Treaty System for a number of years before coming into effect under Annex I to the Madrid Protocol in 1998. Under Annex I, EIAs address the level of impact a given activity will have on the environment and assess whether that impact is “less than minor or transitory” which in turn determines the level of EIA to be carried out. There are three levels of EIA: Preliminary Assessment, Initial Environmental Evaluation and Comprehensive Environmental Evaluation; the latter is required when an impact is likely to be “more than minor or transitory”. All activities taking place within the Antarctic Treaty Area whether governmental or nongovernmental are subject to EIA provisions under the Madrid Protocol, with the exceptions of emergency situations, fishing, sealing and whaling activities (Bastmeijer & Roura, 2008). There have been significant differences in the way that Annex I has been transposed into national laws with further differences noted between Antarctic EIA procedures and those within domestic EIA systems (Bastmeijer & Roura, 2008). Furthermore, an exercise in ground-truthing of the EIA process in 2006 on Fildes Peninsula, King George Island noted “inconsistencies in the way the required level of EIA is determined. In almost all instances the interpretation of the level of EIA required had been pushed downwards” (Bastmeijer & Roura, 2008, p. 16).

Mitigation and monitoring measures are also part of the EIA process, however there is no follow up through the process and as a result, compliance with EIA procedures can be indirectly monitored through the ‘Provision to Inspect’ (Article VII Antarctic Treaty & Article 14 Madrid Protocol) via official inspection reports (Bastmeijer & Roura, 2008). However, the inspections provision largely serves to maintain an overview of Antarctic operations, observing behaviour and establishing procedures without mandatory guidelines for the way in which inspections are carried out, their frequency, no mandatory right of response to the reports produced nor a requirement to act on any discrepancies (Jabour, 2013).

Environmental risk management processes and the creation of best practice guidelines and implementation advice are important steps in mitigating and avoiding environmental damage. For example, the Council of Managers of National Antarctic Program (COMNAP) produced a document addressing best practice Fuel System Design (New Zealand, 2013) and deals with containment of spills and leaks, contingency planning and oil spill response plans (COMNAP, 2008). “For the most

part, local and regional contamination can be reduced through legislation and with adequate financial and technological resources” (Poland et al., 2003, p. 382).

Mitigation at a global scale to address the long range transfer of contaminants from lower latitudes to the Polar Regions requires global reform from international institutions and instruments. Recognising the need to protect human health and the environment, international initiatives aimed at reducing and/or eliminating persistent toxic substances and the transport of them globally have taken place (SCAR, 2009). The uses of POPs for example have been controlled and eliminated firstly through the United Nations Economic Commission for Europe (UNECE) protocol of POPs, signed in 1998 and entering into force in 2003 followed in 2001 by the signing of the Stockholm Convention on POPs (SCAR, 2009), both documents enabling compounds to be added, an important consideration with the pervasive nature of emerging contaminants and their spread yet to be fully realised.

## Remediation

Remediation is costly and therefore having an idea of the likely successes or failures of a given remediation program is highly advantageous. Environmental remediation “deals particularly with the removal, in situ treatment or containment of pollution or contaminants from / within environmental media such as soil, groundwater, sediment, or surface water for the general protection of human health and the environment” (New Zealand, 2013 p.5). There have been numerous attempts at remediation in an Antarctic context with different strategies and with varying degrees of successes and failures.

Remediation strategies in the past have largely consisted of excavations of waste disposal sites and/or the removal of surface material with little assessment of risk, ecological impacts and with little or no monitoring undertaken (Stark et al., 2006). One example that has been well documented is that of the clean-up of the past waste disposal site in the Thala Valley at Casey Station taking place over two consecutive summers in 2002/3 and 2003/4. Terrestrial contamination at the waste disposal site at Casey Station began to be measured in 1993 finding high levels of metals and hydrocarbons in the sediments (Stark et al., 2006, Snape et al., 2001). A clean-up in the summer of 1995/6 saw roughly 150 tonnes of rubbish removed from the site, with aesthetic concerns being the primary driver and with, according to Stark et al. (2006, p. 22): “little thought given to the real environmental consequences of contaminants or of disturbance associated with site remediation. No monitoring was undertaken and few records were kept”. Stark et al. (2006)

highlight that although this initial attempt of clean-up did not produce outcomes in line with the objectives of the Madrid Protocol, it did lead the Australian Antarctic Division (AAD) to commence a program of monitoring to determine the extent of contamination in Australia's Antarctic territory. As a result, significant planning and scientific assessment took place prior to the remediation project in the Thala Valley, with science underpinning operational decisions (Stark et al., 2006). The waste disposal site clean-up highlights the importance of multi-disciplinary research between chemistry and ecology through ongoing recolonization experiments and measuring recruitment as well as studying "cause and effect of the relationship between pollutants and biota" as a means of monitoring ongoing environmental impacts (Stark et al., 2006, p. 29). The remediation project at Casey Station had short, medium and long term monitoring processes in order to provide key information on the environmental performance of the remediation (Stark et al., 2006).

Greenpeace's World Park Base, located at Cape Evans on Ross Island was operated for five years from 1987 to 1991 and was removed in 1991/2. The concept of Greenpeace putting a World Park Base in Antarctica was arguably in itself an exercise in environmental mitigation and remediation. The Greenpeace base operated in Antarctica at a time when concerns about the continent's future and protection were being negotiated with increasing pressure to have Antarctica declared a 'World Park' free from mining and mineral exploration. The base also attempted to highlight best practice operational procedures for Antarctic operators at the time, attempting to minimise the environmental damage to the site at Cape Evans and its surroundings. Low levels of hydrocarbon contamination from fuel spills have been documented and monitored at the site of the World Park Base (Roura, 2004). Hydrocarbons are persistent pollutants that once they have entered the Antarctic environment are very difficult to remove with permafrost and aeolian processes likely to spread further contamination (Roura, 2004). Whilst mean hydrocarbon levels decreased significantly post remediation, Roura goes on to argue that "the difficulties of dealing with hydrocarbon contamination underscore clear legal (under the Protocol) and ethical obligations to avoid their release and dispersal into the Antarctic ecosystem, to manage contaminated sites – both old and new – in the best possible way, and at the very least to accept full responsibility for contaminated sites" (Roura, 2004, p. 65).

Remediation processes in Antarctica face significant challenges concerning cost, logistics, health and safety and not least of all scientific understandings of likely outcomes as well as clear environment quality standards. Presently, although much research is being undertaken regarding remediation in the Antarctic, the latter two have yet to be fully developed with no guidelines available for best practice remediation of chemical contamination, nor clear remediation targets in place for Antarctica. "The need for objective risk assessment information that is specifically relevant

to the Antarctic environment is well illustrated by the difficulties encountered when designing remediation programmes with an absence of clean-up criteria” (Tin et al., 2009, p. 8). Moreover, Underwood discusses the need for an ‘ecological framework for investigating pollution’ (Underwood & Peterson 1988) and detecting human impacts on the environment emphasising the need for ongoing monitoring as well as the use of manipulative experiments in order to control for given contaminants (Underwood, 1992).

“Objectives for repair or remediation should reflect the objectives and provisions of the Environmental Protocol, and be appropriate to Antarctic conditions” (New Zealand, 2013, p.7). A commitment to effective and ongoing monitoring at sites of remediation provides information about the recovery potential and becomes an important tool in managing human impacts and contamination as well as understanding the likelihood of successes and failures of remediation activities (Stark et al., 2006, Snape et al., 2001). The setting of environmental quality standards for remediation targets in an Antarctic context has been proposed several times. A “weight of evidence” approach would monitor levels of chemical contamination, triggering a remediation response if values reach unacceptable levels and setting targets for soil contamination in Antarctica (Tin et al., 2009). The guidelines and theory of environmental quality standards elsewhere in the world are applicable to the Antarctic; however, the levels will differ due to the unique characteristics of polar environments and biota, with the CEP acknowledging “that further research is needed to establish appropriate environmental quality standards for Antarctica” (New Zealand, 2013, p. 8). “A no-action approach might in some cases be the best option available to deal with contaminants ... but is unacceptable unless it is preceded by the thoughtful consideration of all other alternatives” (Roura, 2004, p. 65). Remediation attempts in Antarctica have taken numerous forms with important lessons learned moving towards the creation of a framework for remediating environmental damages and setting environmental quality standards specific to the Antarctic.

## Liability

Exclusion of specific provisions on liability for environmental damage in international law instruments is commonplace (Francioni, 1996). Assigning liability for environmental contamination in the Antarctic is difficult, where there are no universally accepted standard operating procedures for mitigation or remediation nor a binding process for any environmental damage that might take place or indeed have already taken place (Snape et al., 2001). Obstacles in the way of an agreement on environmental responsibility in the Antarctic are as much political as they are technical (Francioni,

1996). Friedrich argues that “nonbinding instruments play a significant role in the development of international law ... [where] nonbinding instruments allow flexible learning processes in situations of uncertainty about the scientific bases of a problem and/or the appropriate solutions for the problem” (Friedrich, 2013, p. 213), which is particularly relevant in environmental matters. However, in the case of responsibility and accountability for environmental damages in an Antarctic context, Jabour argues that without penalties for non-compliance, best environmental outcomes will not be achieved as political will would remain lacking (Jabour, 2013).

In the years following World War II and the IGY an infrastructure boom took place in the Antarctic in an effort to bolster territorial claims. However, these now abandoned structures are deemed an environmental liability by some and an issue of cultural heritage by others (Poland et al., 2003). In 2005, after years of negotiations, Annex VI to the Madrid Protocol: Liability Arising from Environmental Emergencies was adopted at the ATCM in Stockholm, but as mentioned earlier has yet to come into force with all Parties yet to ratify it (ASOC, 2016). Annex VI opens by stating that the Parties recognise “the importance of preventing, minimising and containing the impact of environmental emergencies on the Antarctic environment and dependent and associated ecosystems” (Annex VI). The liability annex sets a framework of environmental responsibility in the Antarctic, requiring operators to take preventative measures and have contingency plans in place for potential environmental damages and, should an environmental emergency take place, enact prompt response actions.

## Discussion

The Madrid Protocol was landmark in its scope and ambition ensuring comprehensive protection of the Antarctic environment and its wilderness and intrinsic values. “In spite of the remoteness of Antarctica, its atmosphere and the Southern Ocean are inextricably linked to atmospheric and oceanic circulation at lower latitudes, and the large equator – pole temperature gradient drives the poleward transport of chemicals” (Bargagli, 2005, p. 128). In addition, as Tin et al. (2009) point out human activity in the Antarctic necessitates the production of wastes and the use of fuels, with anthropogenic contamination resultant from local processes and where the legitimacy of all Antarctic activities becomes scrutinised. How to best manage contamination and contaminated sites in Antarctica is a difficult issue. Dealing with contamination and its various facets has yielded significant successes for the Antarctic environment as well as highlighting limitations to current operations both environmentally and politically.

## Successes

Waste management practices have dramatically improved since the Madrid Protocol came into force in 1998. Numerous working papers, information papers and background papers have been submitted to the ATCM and are held by the Secretariat to the Antarctic Treaty on their website, contributing to the breadth of knowledge about the issues surrounding contamination in Antarctica and how to manage and remediate for them. Preliminary guidelines now exist for Antarctic operators involved in repair or remediation, in addition to standard operating procedures for Antarctic activities to mitigate contamination. Comprehensive response plans for environmental emergencies such as oil spills are in place for both incidents on land and at sea. The ability to quantify and measure anthropogenic impacts in Antarctica is developing with science underpinning many operational decisions.

## Limitations

Tolerance of Antarctic species to contaminants remains largely unknown with Gaw (2015) arguing that currently there is insufficient information available for risk assessments. Many abandoned and current stations in the Antarctic are significantly contaminated sites, with a coordinated approach and a means to prioritise remediation lacking. The focus of remediation has tended to be limited to terrestrial ecosystems with further logistical obstacles associated with polar marine environments; however there are significant contamination issues in many near shore marine environments. Environmental quality standards for the Antarctic are yet to be set which could provide a trigger for clean-ups of non-allowable levels of contamination. The ownership of the process of dealing with contamination is uneven with for example, Australia leading the way in research and remediation programmes. The liability annex to the Madrid Protocol is yet to be ratified and would provide a level of accountability for environmental emergencies not seen before within the ATS. The consensus decision making process of the ATCM is slow to bring about meaningful change for more comprehensive forms of protection, and responsibility and accountability for legacy issues.

## Conclusions

Contamination issues in Antarctica are multi-faceted with atmospheric, marine and terrestrial environments all experiencing varying degrees of contamination from both local and distant sources. Operating in the Antarctic comes with a certain level of environmental risk with



numerous institutions providing guidance on how to best manage this risk however, a more coordinated approach is required. Avoidance of contamination remains the best environmental outcome where it is important to continue to consider limiting the use of contaminants in the Antarctic through the use of renewable energy sources, efficient logistics operations and through practices that do not impinge on the environment. Remediation is an expensive exercise with surmountable logistical and environmental risk requiring further guidance. Ensuring remediation outcomes are in line with the objectives outlined within the Madrid Protocol, and that the highest likelihood of success of environmental performance post-remediation is achieved is an important next step for environmental clean-ups in Antarctica. Without penalties for noncompliance, the Antarctic continent and associated ecosystems will continue to suffer the effects of anthropogenic contamination while political will is lacking. Continued research and review into the effects of long range transfer around the world will conceivably inform global reforms of environmentally harmful practices and compounds ensuring greater environmental outcomes for Antarctica. The increased pressure of human activity in the Antarctic, in addition to the influences of climate change will test the ability of the current governing regimes to continue to effectively manage and protect Antarctica and Antarctic values.

## References

- AAD, 2016. Australian Antarctic Division. <http://www.antarctica.gov.au/environment/human-impacts-in-antarctica> Accessed 03/02/16.
- AMAP, 1997. Arctic Pollution Issues: A State of the Arctic Environment Report. Arctic monitoring and Assessment Programme (AMAP), Oslo, Norway.
- Aronson, R. B., Thatje, S., McClintock, J. B., & Hughes, K. A., 2011. Anthropogenic impacts on marine ecosystems in Antarctica. *Annals of the New York Academy of Sciences*, 1223(1), 82-107.
- ASOC, 2016. Liability for Environmental Damage. <http://www.asoc.org/advocacy/antarctic-environmental-protection/liability-for-environmental-damage>. Accessed 13/02/16.
- Bargagli, R. 2005. *Antarctic ecosystems: environmental contamination, climate change, and human impact* (Vol. 175). Springer Science & Business Media.
- Bargagli, R. 2008. Environmental contamination in Antarctic ecosystems. *Science of the total environment*, 400(1), 212-226.
- Bastmeijer, K., & Roura, R. 2008. Environmental impact assessment in Antarctica. *Theory and practice of transboundary environmental impact assessment*, 175-219.
- Beck, P. J. 2006. The United Nations and Antarctica, 2005: the end of the 'Question of Antarctica'?. *Polar Record*, 42(03), 217-227.
- COMNAP, 2008. Fuel Manual Version 1.0. [https://www.env.go.jp/nature/nankyoku/kankyohogo/database/visit/pdf/fuel-manual-v1\\_en.pdf](https://www.env.go.jp/nature/nankyoku/kankyohogo/database/visit/pdf/fuel-manual-v1_en.pdf). Accessed 13/02/16.
- Francioni, F. 1996. Liability for damage to the Antarctic environment, in *International Law for Antarctica*. 2<sup>nd</sup> Edition, edited by Francesco Francioni and Tullio Scovazzi. The Hague: Kluwer Law International: 581-602.
- Friedrich, J. 2013. International Environmental "soft law": The Functions and Limits of Nonbinding Instruments in International Environmental Governance and Law. *Springer Science & Business Media*, (247).
- Gaw, S., 2015. Contaminants in the Antarctic. Lecture 07/12/15. Department of Chemistry, University of Canterbury.

- Jabour, J. 2013. The Utility of Official Antarctic Inspections: Symbolism without Sanction?, in *Exploring Antarctic Values*, edited by Daniela Liggett and Alan Hemmings. Gateway Antarctica Special Publication: 90-106.
- New Zealand, 2013. Repair or Remediation of Environmental Damage: Report of the CEP intersessional contact group, *Working Paper 27 for XXXVI Antarctic Treaty Consultative Meeting, Brussels, 19-29 May 2013*. 20 pp.
- Orheim, O., Press, A., & Gilbert, N. 2011. Managing the Antarctic environment: The evolving role of the committee for environmental protection. *Science diplomacy: science, Antarctica, and the governance of international spaces*, 209-221.
- Poland, J. S., Riddle, M. J., & Zeeb, B. A. 2003. Contaminants in the Arctic and the Antarctic: a comparison of sources, impacts, and remediation options. *Polar Record*, 39(04), 369-383.
- Protocol on Environmental Protection to the Antarctic Treaty, 1991.
- Roura, R. 2004. Monitoring and remediation of hydrocarbon contamination at the former site of Greenpeace's World Park Base, Cape Evans, Ross Island, Antarctica. *Polar Record*, 40(01), 51-67.
- SCAR (Scientific Committee on Antarctic Research), 2009. Persistent Organic Pollutants in the Antarctic. *Information Paper 69 for XXXII Antarctic Treaty Consultative Meeting, Baltimore, 6-17 April 2009*, 19 pp.
- Secretariat to the Antarctic Treaty, 2016. [http://www.ats.aq/index\\_e.htm](http://www.ats.aq/index_e.htm) Accessed 14/02/16.
- Snape, I., Riddle, M. J., Stark, J. S., Cole, C. M., King, C. K., Duquesne, S., & Gore, D. B. 2001. Management and remediation of contaminated sites at Casey Station, Antarctica. *Polar record*, 37(202), 199-214.
- Stark, J. S., Snape, I., & Riddle, M. J. 2006. Abandoned Antarctic waste disposal sites: monitoring remediation outcomes and limitations at Casey Station. *Ecological Management & Restoration*, 7(1), 21-31.
- The Antarctic Treaty, 1959.
- Tin, T., Fleming, Z. L., Hughes, K. A., Ainley, D. G., Convey, P., Moreno, C. A., Pfeiffer, S., Scott, J. & Snape, I. 2009. Impacts of local human activities on the Antarctic environment. *Antarctic Science*, 21(01), 3-33.

Underwood, A. J., & Peterson, C. H. 1988. Towards an ecological framework for investigating pollution. *Mar. Ecol. Prog. Ser.*, 46(1), 227-234.

Underwood, A. J. 1992. Beyond BACI: the detection of environmental impacts on populations in the real, but variable, world. *Journal of experimental marine biology and ecology*, 161(2), 145-178.

UNEP, 2002. Antarctica Regional Report. Regionally Based Assessment of Persistent Toxic Substances. Geneva: United Nations Environment Programme. Chemicals.