Harvesting of Antarctic icebergs: Melted dreams?

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Abstract

By 2040, global water demand will outstrip supply by 30%. Every 20 years global water consumption doubles. With increasing population growth in developing countries and climate change placing pressure on water resources there will be an increasing demand for the importation of water. Antarctica's icebergs have in the past been viewed as a potential source of freshwater but the feasibility is technically challenging and the cost high. With growing pressure on water resources globally, Antarctica's icebergs are likely to be viewed in the future as a feasible source of freshwater. However, there are numerous issues both legal and technical regarding the harvesting of icebergs. This study will review the ownership of Antarctic icebergs and the technical issues of towing Antarctic icebergs for harvesting.

Introduction

As the world's population increases over the next 50 years, demand for water will increase dramatically. It is predicted that by 2040 global water demand will outstrip supply by 30%. Every 20 years global water consumption doubles (Newsweek, 2010). With 90% of the 3 billion people expected to be added to the world's population by 2050 living in developing countries there will be additional stress placed on water supplies, particularly in regions where the current population does not have sustainable access to safe drinking water (UNESCO, 2009). Despite human activity using only 3,240 km^3 of water per annum out of a total annual renewable resource of 41,000 km^3, the spatial distribution of precipitation is changing with climate change, making some places drier and other places wetter (Free Drinking Water, 2010). Lack of adequate water resources is one of the leading causes of disease in the developing world. In particular, 1.4 million children die each year of diarrhoeal disease and 50% of all malnutrition is a result of unclean water and inadequate sanitation (UNESCO, 2009). In the 1970s there was discussion over the use of Antarctic icebergs as a source of freshwater (Time, 1977). Antarctica has 30 million km^3 of water, of which 1250 km^3 is locked up in icebergs per annum. This represents 3-4 times Australia's annual renewable water supply (Free Drinking Water, 2010). This paper reviews the legal aspects of harvesting Antarctic icebergs and the technical issues of towing Antarctic icebergs for harvesting.

The legal status of Antarctic icebergs

Ownership of icebergs originating from ice shelves in Antarctic is dependent on the type of regime governing Antarctica. The regimes that are most conceivable include the current Antarctic Treaty System, a Freedom of the High Seas regime, a National Approach regime and a Common Heritage regime.

Antarctic Treaty System

The legal status of ice is contentious when it is treated as a resource, as the exploitation of ice resources invokes the issue of sovereignty. Effective occupation is pivotal for defining the legal relationship between ice shelves, icebergs and the rights of appropriation (Joyner, 1991). Therefore, any claims to ice floating in the waters adjacent to Antarctica must find support in a valid claim to sovereignty. Article IV of the Antarctic Treaty however freezes claims to sovereignty in Antarctica. By withholding the recognition of sector claims, two effects are produced. First, the status of sector claims extending seaward, beyond the ice shelves, remains frozen. According to Joyner (1991), a strict interpretation of Article IV would relegate sector claims only to the Antarctic's land mass and ice shelves. Second, the assertion by claimant States to sovereign jurisdiction over icebergs drifting in "their" sector projection is open to challenge as no coastal State exists in Antarctica from which jurisdiction could be extended from (Joyner, 1991).

Freedom of the High Seas

The Antarctic Treaty implies the circumpolar Southern Ocean basin to be High Seas (Joyner, 1991). As a result, no sovereign claim can be made on icebergs, pack ice, fast ice or ice islands. In fact, the legal status of icebergs has not been formally addressed in international law, either by treaty, state practice or general principles of international law (Joyner, 1991). According to the Freedom of the High Seas doctrine, icebergs can be considered a water resource and be subject to acquisition and appropriation for private use anywhere in the Southern Ocean basin. Furthermore, legal logic may permit the extraction of ice from the ice shelf since portions float over the High Seas (Joyner, 1991).

National Approach

It is possible that in the future Antarctic claimant States declare zones of national jurisdiction over coastal waters offshore from their claimed sectors. If ice shelves are considered to be portions of the land margin, they would then become property of the coastal State (Lundquist, 1977). Because icebergs are derived from the ice shelves, claimant States could argue they have property rights over all the ice structures located within their territorial waters (Joyner, 1991). It could also be argued that icebergs floating inside the claimant States Exclusive Economic Zone (EEZ) are under their jurisdiction. Under this approach, Antarctica would be divided into independent sovereign sectors with each claimant State possessing exclusive territorial and resource rights over its own territory.

Common heritage: owned by no one, owned by everyone

Under the approach 'owned by no one, owned by everyone', icebergs are part of the common heritage of humanity. The legal theory underpinning this concept is all claims to Antarctica are invalid and unrecognised under international law. As there is no rightful owner of Antarctica, the continent could be declared *res communis*, common space belonging to all mankind (Lundquist, 1977). The result would be all benefits from ice resources distributed internationally with the preference of proceeds going to least-developed nations. If the common heritage approach was made legitimate, icebergs would become immune from national appropriation and private gain. Joyner (1991) suggests the exploitation of water resources from Antarctic icebergs could be conducted through an international programme hosted by the United Nations.

Technical feasibility

The Ross Ice Shelf is seen as the most optimal region for obtaining icebergs in the Pacific region. If single icebergs were harvested, acquisitions in this region could be made year-round between the latitudes 60° and 65°. However, a collection of large quantities of icebergs are required in order to benefit from economies of scale. Therefore, ice trains will need to be created (Hult and Ostrander, 1973).

Identifying icebergs

To improve efficiency of identifying individual small icebergs for an iceberg train, satellite pictures could identify clusters of icebergs most suitable for the train based on size and shape. The Iceberg Water Harvesting Group (IWHG) has developed software that optimises routing of individual icebergs and includes rough melting kinetics (Smakhtin et al, 2001). The software allows each possible iceberg route to be simulated, subject to minimisation of energy input for tugboats, travelling time and the maximisation of ice mass at the destination site. To steer the iceberg train, each iceberg needs to be a ship shape to reduce friction. On size, each individual iceberg must survive natural melting during the voyage of up to six months through progressively warmer waters, while being exposed to strong winds that enhance sublimation from the iceberg's surface (Smakhtin et al, 2001). It has been estimated that in 18°C waters, the predicted melt rate for icebergs is one metre per day (Russell-Head, 1980). For the iceberg train to be economically viable, Hult and Ostrander (1973) estimate icebergs need to measure at least 250-300m in height. As there needs to be a certain volume of water that satisfies the requirements at the end destination, the volume must be calculated to include all loses during the transportation process- resulting in the need of wrapping each individual iceberg (Hult and Ostrander, 1973).

Large-scale wrapping of icebergs has never been conducted before, however, the German Antarctic RV Polarstern, an icebreaker, conducted a small-scale experiment in which it wrapped up a small 3,000 tonne iceberg using plastic rolls 2m wide, covering the tip of the iceberg (Free Drinking Water, 2010). To protect the underside of the iceberg, the plastic wrap was allowed to sink under its own weight and be carried under the iceberg by the current. If the current was not strong enough, the plastic wrap was drawn under the iceberg using cables. Once the underside of the iceberg was covered, air sacks inside the plastic wrap were inflated causing the iceberg to rise, limiting the area surface exposed to sea water. The experiment involved attaching cables from a floating platform across the top of the iceberg. Air-filled rollers were used to overcome friction. Once the iceberg was fully wrapped up, the plastic wraps were welded together, sealing the entire mass (Free Drinking Water, 2010).

Towing resistance

When designing ships in general, the limit to achievable speed is wave-making resistance. When operating at speeds below the wave-making barrier, the principal resistance for conventional ships is skin friction, which generally makes up 80% of total resistance. The remaining 20% being form drag (eddy-making resistance). Form drag can be designed to only comprise a small percentage of total resistance. An iceberg's resistance can be approximated by:

$$D = \frac{1}{2} p V^2 [AF.CD + AW.FS],$$

D – drag (newtons), p – density of seawater (kg/m^3), V – free stream velocity (m/s), AF – max frontal area for determining form drag (m^2), CD – form drag coefficient, AW – wetted surface area for determining skin friction drag (m^2), and FS – skin drag coefficient (Hult and Ostrander, 1973).

Most tabular icebergs have rectangular shapes and blunt ends. As a result, form drag is likely to dominate skin friction if the icebergs length, L, is only a few times the width, W. If L/W = 30 the two resistances are equal, but if L/W = 300 the skin friction will dominate form drag. If an iceberg train is rectangular except for the rounding of the ends and with a fixed depth, the optimal value of L/W to minimise the combined form drag and skin resistance is approximately CD/(2FS) (Hult and Ostrander, 1973). However, the width must be wide enough compared to the thickness of the iceberg to prevent rolling during transit. This could be an issue as there may not be an adequate amount of icebergs available with suitable width and thickness values. There are also technical difficulties arising from the use of suitable cables required to tow the iceberg trains. If the cable is wire rope with a safety factor of five, the 1000 ton pull for Antarctic tabular icebergs is beyond the capacity of standard wire ropes. For instance, the six inch wire rope only has a safe working load of 200 tons (Mellor, 1980).

Coriolis force

The optimum transport speed for towing icebergs is <1m/sec, however, at low speeds the effects of Coriolis forces are likely to dominate design considerations and the costs of moving icebergs at high latitudes. The Coriolis force on a mass moving on the Earth's surface is:

$$Fc = 2\ M\ Ve\ \Omega \sin \varphi,$$

Fc – Coriolis force (newtons), M – mass (kg), Ve – velocity relative to the Earth's surface (m/sec), Ω - angular velocity of the Earth (radians/sec) and φ – Earth's latitude at the mass position (Hult and Ostrander, 1973).

For moving Antarctic icebergs, the Coriolis force is at right angles. There is a great amount of uncertainty though regarding the effects of the Coriolis forces as the iceberg is floating in moving seawater, which itself is under the influence of Coriolis forces. According to Hult and Ostrander (1973), a more important Coriolis factor of even greater uncertainty is the counteracting effects of displaced water. If an iceberg is moving in water, it is continuously displacing water from the front to the rear. Therefore, the momentum of the displaced water is equal and opposite of the iceberg momentum. The fraction of how much water is displaced by an iceberg, with rectangular faces in water undisturbed by propulsion, is h/W where h = submerged depth and W = width with $W > h$. If the bow and stern are wedged-shaped, a large amount of displaced water should move around the sides. If the shaping is selected to increase flow of displaced water around the side, more of the Coriolis forces is likely to be cancelled. The net Coriolis effects should be $< (W – h)/W$ times the direct Coriolis force on the iceberg (Hult and Ostrander, 1973).

Potential costs

Attempts at evaluating the costs of iceberg transportation are speculative because the technology associated with iceberg harvesting has not been developed. The required infrastructure at the destination site for processing the iceberg is also not known precisely. Components of the cost calculation are generally known and are the costs of iceberg detection, towing, route tracking, transportation, operation and maintenance at the destination port, minimisation of pollution loss, sublimation and the construction of suitable storage facilities for the melt-water (Smakhtin et al, 2001). A preliminary calculation made by the IWHG, using an expected cost analysis approach, suggests if iceberg water was to be sold to consumers at US$0.50/$m^3$ to satisfy an annual demand of 2,000 Mm^3, the total investment, made over five years would be approximately US$500 million (Smakhtin et al, 2001).

Discussion

Because all claims to sovereignty are frozen under Article IV of the Antarctic Treaty, no claimant State can claim any jurisdiction over icebergs floating in waters adjacent to the coastline. This is due to no coastal state existing in the Antarctic from which sovereignty could be extended from. Only if the Antarctic Treaty collapsed could claimant States assert their rights over icebergs floating inside their territorial waters and EEZ's. However, it is unlikely that the Treaty will collapse. Therefore, it can be assumed that as the Antarctic Treaty implies all seas adjacent to the Antarctic coastline to be High Seas, icebergs are freely available for commercial harvesting.

There are numerous challenges to overcome before icebergs can be converted to freshwater. For instance, if iceberg harvesting is to be commercially viable, a large number of icebergs need to be towed. This requires iceberg trains to be created from small individual icebergs floating in the sea. In order to identify suitable icebergs, satellite imagery is required to detect ideal shapes and sizes most suitable for the train. Determining which iceberg is the most optimal for the iceberg train is critical in reducing form drag and skin friction. The shape of each iceberg in the train is important as it determines how much water is displaced. For instance, wedge-shaped icebergs will disperse a greater amount of water to the sides of the icebergs, limiting the amount of Coriolis force. However, it is likely to be difficult and time consuming to identify individual icebergs most suitable for iceberg trains, as they are unlikely to be located in close proximity to one another. It will take additional resources to round up these icebergs and tow them towards the location of the iceberg train. This is difficult when no cable has a high enough safety factor to ensure safe towing of the iceberg towards the iceberg train. It is also difficult to determine from satellite photos which icebergs have suitable widths and thicknesses as there is a high risk of icebergs rolling during transport, potentially damaging equipment and causing injury to crew members.

The investment of US$500 million is likely to be out of reach for countries most needy of freshwater as they are mostly developing nations. The result could be freshwater from icebergs bottled and sold in wealthy countries. Even if the icebergs were processed in New Zealand and bottled on site, the transportation cost of shipping the bottled water to Africa for instance will far outweigh the cost of providing wells. In addition, the environmental costs of using petroleum-based bottles would far outweigh the benefits of providing freshwater from Antarctic icebergs. It is doubtful that Antarctic Treaty members, especially developed countries possessing the technology for harvesting icebergs would approve of a common heritage regime due to the enormous financial costs associated with harvesting icebergs. Instead, it is better to make an investment of US$500 million in drilling water wells and providing potable water to water-stressed developing nations.

Conclusion

Because no coastal state exists in Antarctica from which sovereignty could be extended from, all seas adjacent to the Antarctic coastline could be considered High Seas. This would enable icebergs to be freely harvested for commercial gain. There are numerous challenges to overcome before icebergs can be converted to freshwater. For instance, if iceberg harvesting is to be commercially viable, a large number of icebergs need to be towed in the form of an iceberg train. This requires satellite imagery to detect ideal shapes and sizes that limit form drag and skin friction. The icebergs also need to be of a specific width and thickness to prevent rolling during transportation. However, it is unlikely suitable icebergs will be in close proximity to one another. An additional issue is the fact that wire cables have very low safety factors making it almost impossible to tow iceberg trains safely. It is estimated that an initial investment of US$500 million is required to harvest icebergs. This is likely to be out of reach for countries most needy of freshwater as they are mostly developing states. It is likely to be more cost effective and environmentally friendly to invest in wells to provide safe, potable water in developing countries than to provide water from icebergs in the near and long-term future.

References

Free Drinking Water (2010). Could icebergs be used as a source for drinking water? http://www.freedrinkingwater.com/water_quality/quality1/13-08-icebergs-for-drinking-water.html. Accessed 30 November 2010.

Hult, J. and Ostrander, N. (1973). Antarctic icebergs as a global freshwater resource. Rand, Santa Monica, California.

Joyner, C. (1991). Ice-covered regions in international law. *Natural Resources Journal*, 31, 213-242.

Lundquist, T. (1977). The iceberg cometh? International law relating to Antarctic iceberg exploitation. *Natural resources journal*, 17, 1-41.

Mellor, M. (1980). High force towing. *Cold Regions Sciences and Technology*, 1, 231-240.

Newsweek (2010). The new oil. http://www.newsweek.com/2010/10/08/the-race-to-buy-up-the-world-s-water.html. Accessed 1 December 2010.

Russell-Head, D. (1980). The melting of free-drifting icebergs. *Annuals of Glaciology*, 1, 119-122.

Smakhtin, V., Ashton, P., Batchelor, A., Meyer, R., Murray, R., Barta, B., Bauer, N., Naidoo, D., Olivier, J. and Terblanche, D. (2001). Unconventional water supply options in South Africa. *Water International*, 26 (3), 314-333.

Time (1977). Science: Towing icebergs. http://www.time.com/time/magazine/article/0,9171,915637,00.html. Accessed 30 November 2010.

UNESCO (2009). Water in a changing world. http://www.unesco.org/water/wwap/wwdr/wwdr3/. Accessed 1 December 2010.