Sea Water Mining June 2013

Mining Desalination Brine Residues

This think piece sets out to assess the prospects for obtaining minerals from desalination brines and to assess the quantities of minerals that could be obtained.

Figure 1: A reverse osmosis desalination plant. Most new desalination plants are of this type. (photo: James Grellier)

The oceans contain vast quantities of dissolved metal ions which in principal could be extracted. Seawater brine mining has long been carried out for obtaining common salt, and currently four metal ions are extracted from brine: sodium, magnesium, calcium and potassium. Recently the rise in commodity prices has spurred interest in brine mining as a possible source of other raw materials and as a means of solving resource security issues. Japan, for example, has carried out research to assess whether uranium can be affordably extracted from seawater[1]. In addition to mining seawater brines, a further suggestion has been to mine the brine residues from desalination plants.

Mining desalination residue

Desalination residues are currently regarded as a waste that must be disposed of. They are highly saline and so can have a negative environmental impact if returned to the sea. The residues could be mined for sodium, magnesium, calcium and potassium but interest has also been expressed in using these brines to obtain the next four elements with the largest oceanic concentrations: lithium, barium, molybdenum and nickel. If we were to mine these elements from brine residues, what quantities could we obtain and would it be economically viable?

As an example, Saudi Arabia is planning to build the largest desalination plant in the world[2]. This will have a capacity of 600,000 m^3 of drinking water per day. Assuming that three tonnes of seawater are required for every tonne of drinking water

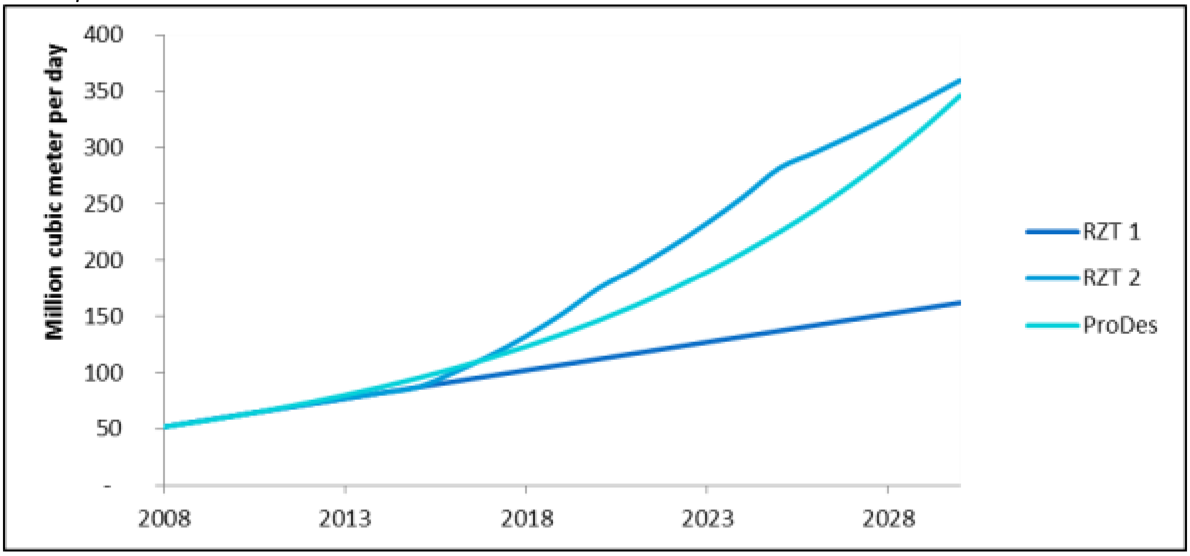
[1] *Extracting Minerals from Seawater: An Energy Analysis, U. Bardi, Sustainability 2010, 2, 980-992.*
[2] *Saudi Press Agency. http://www.spa.gov.sa/details.php?id=1077365*

produced, this amounts to around 657 million m^3 per year of water passing through the desalination plant. If lithium were extracted from this water at 80% efficiency, the amount obtained would be around 90 tonnes per year. This compares with global production of around 37,000 tonnes[3]. If the value of lithium is around $1500 per tonne, then 90 tonnes would give $135,500 per year. This is relatively small sum in comparison to the additional costs that would be incurred.

In total, Saudi Arabia produces around 3.3 million cubic meters of drinking water per day from desalination. Using the same assumptions outlined above, a total of around 500 tonnes of lithium could be extracted worth $750,000.

Looking at the global picture, some estimates suggest that by 2030 as much as 345 million cubic metres of desalinated water could be produced per day, though more conservative estimates suggest around 155 million cubic metres (seeFigure 2). Using this conservative figure a total of around 23,000 tonnes of lithium could be extracted per year worth around $34 million.

Figure 2 Extrapolation of desalination capacity to 2030 based on three different growth assumptions



Source: Critical Metals in Low-Carbon Energy Technologies, EC, 2013

Figure 3 illustrates the possible quantities of lithium to be extracted from brine compared with total current global production. The quantity that could be produced from brine mining only approaches current production levels when all the desalination plants in the world (using the 2030 projected value) are used to extract lithium.

For the above analysis, none of the figures take account of extraction or transportation costs, or the cost of the additional equipment required. Unless lithium extraction systems become an inexpensive addition to desalination plant equipment, it is unlikely that desalination brines will be used to mine this metal. Also, lithium supply from other more cost-effective sources is likely to increase and could even lead to oversupply, so resource security is less likely to be an issue for this element[4]. More cost effective methods for obtaining lithium include conventional mining and extraction from continental brines where lithium has leached from volcanic rocks and so is present in relatively large concentrations.

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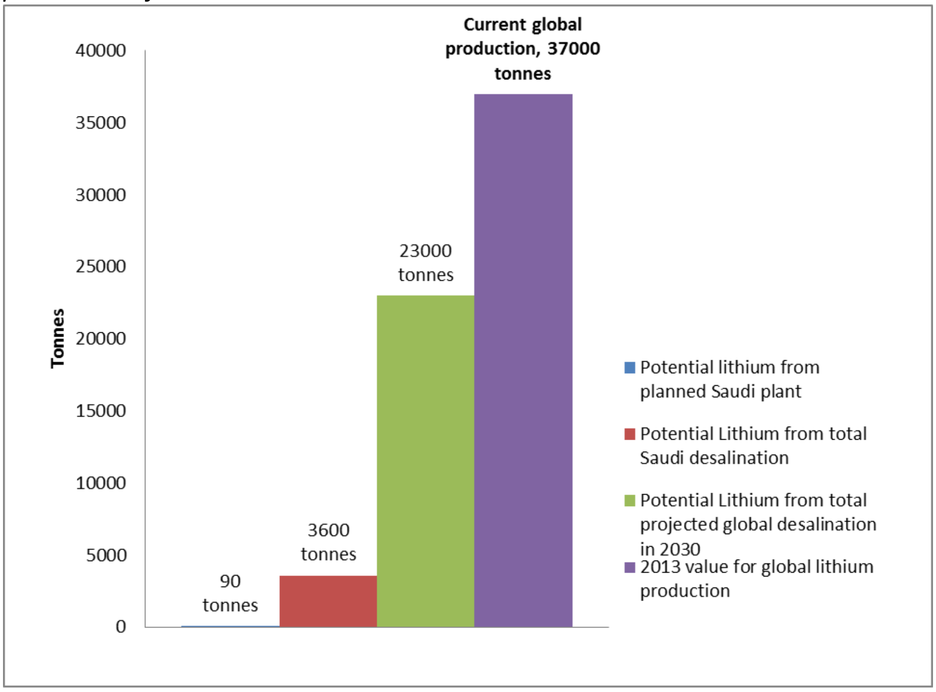
3 http://minerals.usgs.gov/minerals/pubs/commodity/lithium/mcs-2013-lithi.pdf
4 Critical Metals in Low-Carbon Energy Technologies, EC, 2013

Despite the lack of a compelling economic argument for mining lithium from brine, reports state that South Korea plans to extract lithium from seawater and intends to produce around 30 tonnes annually by 2015[5]. This is part of a programme to increase self-sufficiency of raw materials critical to the Korean economy and is not part of a desalination plant but a stand-alone offshore facility. Although Japanese researchers concluded that the technology was five times too expensive to be economically viable, South Korean scientists claim to have improved the efficiency of extraction by 30 percent. Despite this improved efficiency, the full costs are still likely to be higher than for conventional mining.

For Barium, Molybdenum and Nickel the abundance of their metal ions in seawater is an eighth to a thirtieth that of lithium and so the quantities that could be obtained from desalination brines are even smaller than for lithium. However, values per tonne for molybdenum and nickel are much higher than for lithium. If by 2030 desalination has reached 155 million tonnes per year, this could be used to extract around 1700 tonnes of molybdenum. At current values this is worth around $60 million, still too small a figure to warrant the costs of extraction.

Figure 3 Possible values for lithium extraction from brine compared with the total 2013 global production of lithium



Nanotechnology, desalination and brine mining

If the cost of implementing and operating desalination and brine mining systems were to substantially fall, then the economic picture may change. Technological developments, particular in the area of nanotechnology, are likely to improve the efficiency of filter membranes. Scientists at MIT, for example, have shown theoretically that graphene could be used as a water filter. Because graphene is only a single atom thick, the amount of energy required to filter the water would be much lower. Such technological developments may increase the efficiency and reduce the cost of desalination, leading to an increase in its adoption.

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5 http://www.reuters.com/article/2011/01/20/korea-lithium-idAFTOE70J02H20110120

Similar developments in nanotechnology are also occurring for brine mining. Researchers have patented a process for extracting lithium ion from brine that uses electrodes made of a form of nanoscale crystalline manganese dioxide[6]. These and other developments will improve the efficiency of brine mining and will lead to lower costs.

Conclusions

In the near future it is unlikely that mining of desalination brines will become a cost effective means of obtaining lithium, barium, molybdenum or nickel. Conventional mining methods are much more attractive and in the near term these elements will not become sufficiently scarce to make brine mining more economically attractive. The potential for desalination brine mining may lie in the future with advancements in technology. The cost of desalination and mineral extraction would have to decrease and the efficiency of extraction would need to increase. However, brine mining for raw materials may be carried out for reasons of resource security, though this will have to be balanced against higher production costs.

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- *the mainstreaming of sustainability and resource efficiency into business operations*
- *researching and designing interventions throughout the product life cycle from raw material supply and product manufacture to use and end-of-first-life strategies*
- *enabling successful product and service innovation.*

The company has developed substantial global expertise in resource management and economics. We have a growing involvement in business models that enable a more circular economy and we operate Europe's only centre that focuses on remanufacturing and reuse (see www.remanufacturing.org.uk).

Much of our work requires problem-solving abilities and a confidence to identify insights that can be presented to busy managers.

Oakdene Hollins aims to contribute to sustainable development not only through our advice and research, but also in the way we conduct our own business. We seek substantial improvements in resource- and carbon-intensity that mean a long term transformation in the ways in which we work.

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6 http://www.geotimes.org/june06/feature_NanoTech.html