Critical Minerals and the O&G Industry

Critical minerals are indispensable in the manufacturing of a wide range of next-generation technologies, including electronics, medical devices, renewable energy, and national security applications. As the demand for critical minerals increases, unconventional resources are coming into prominence. Produced water, a significant byproduct of oil and gas extraction, has long been considered a **challenge to manage** due to its high **salt content and potential environmental impact**. As these produced waters can also contain critical minerals, **increasing effort is being applied to transform once burdensome waste streams into valuable resources.**

This article delves into the intriguing intersection of the oil and gas industry and critical mineral production. In particular, it will introduce some of the most common critical elements found in produced water streams and the chemical processes used for their extraction and valorization.

Critical Minerals in Produced Water Streams

Oil and gas produced water streams, conventionally regarded as a challenging waste product, harbor a surprisingly diverse array of critical minerals. While Lithium is the most conventionally well-known at present, it is worth noting that many elements commonly found in produced water streams are also considered Critical elements including Magnesium, Barium, Strontium, Boron, Bromine, Iodine, and Zinc. Higher temperature and/or geothermal-produced water streams have also been found to contain an even more diverse range of ions including battery elements such as Cobalt, Manganese or Molybdenum, Rare Earth Elements such as Cesium or Scandium, Precious metals such as Gold or Silver and more exotic valuable elements such as Rubidium or Selenium [1].

Commodity	Canada (2021)	EU (2020)	South Korea (2020)	USA (2022)	Japan (2019)	Australia (2022)	South Africa (2022)	India (2016)	UK (2021)
Aluminum	x	x		x		x			
Antimony	x	x	x	x	x	x			x
Arsenic			x	x					
Barium		x	x	x	x				
Beryllium		x	x	x	x	x		x	
Bismuth	x	x	x	x	x	x			x
Boron		x	x		x				
Cadmium			x						
Cesium	x		x	x	x				
Chromium	x		x	x	x	x	x	x	
Cobalt	x	x	x	x	x	x	x		x
Coking Coal		x					x		
Copper	x						x		
Fluorspar	x	x		x	x				
Gallium	x	x	x	x	x	x			x
Germanium	x	x	x	x	x	x		x	
Graphite	x	x		x	x	x		x	x
Hafnium		x	x	x	x	x			
Helium	x					x			
Indium	x	x	x	x	x	x			x
Iridium				x					
Iron ore							x		
Lead							x		
Limestone								x	
Lithium	x	x	x	x	x	x	x		x
Magnesium	x	x	x	x	x	x			x
Manganese	x		x	x	x	x	x		
Molybdenum	x		x		x				

Commodity	Canada (2021)	EU (2020)	South Korea (2020)	USA (2022)	Japan (2019)	Australia (2022)	South Africa (2022)	India (2016)	UK (2021)
Nickel	x		x	x	x		x		
Niobium	x	x	x	x	x	x		x	x
PGM	x	x	x	x	x	x	x		x
Phosphate		x	x						
Potash	x								
Rare earth elements group	x	x	x	x	x	x	x	x	x
Rhenium			x		x	x		x	
Rubidium				x	x				
Selenium			x		x				
Silicon		x	x		x	x		x	x
Strontium		x	x		x			x	
Tantalum	x	x	x	x	x	x		x	x
Tellurium	x		x	x	x				x
Thallium			x		x				
Tin	x		x	x					x
Titanium	x	x	x	x	x	x			
Tungsten	x	x	x	x	x	x			x
Uranium	x						x		
Vanadium	x	x	x	x	x	x	x		x
Zinc	x					x	x		
Zirconium			x	x	x	x		x	

Fig 1. Comparison of federal government Critical Mineral lists [2].

Critical Mineral Extraction Processes

In general, Critical Mineral production from produced water streams involves three key steps: Pre-treatment, Extraction and Post-processing/Refinement into a saleable product. Pre-treatment typically includes degassing, removal of solid fines and de-oiling to mitigate fouling of the extraction unit operation, and may require pH adjustment, concentration and/or removal of other problematic stream components such as H_2S, if necessary [3]. Once pre-treated, one or more extraction unit operations can be used to selectively remove the element of interest from the produced water stream. Examples include ion exchange/adsorption, solvent extraction, precipitation, membranes and electrodeposition, depicted below [4]. Choice of which unit operation is most technically and economically feasible depends heavily on the element of interest, the overall chemistry of the produced water stream and particular details of the unit operation design, often provided by a technology supplier.

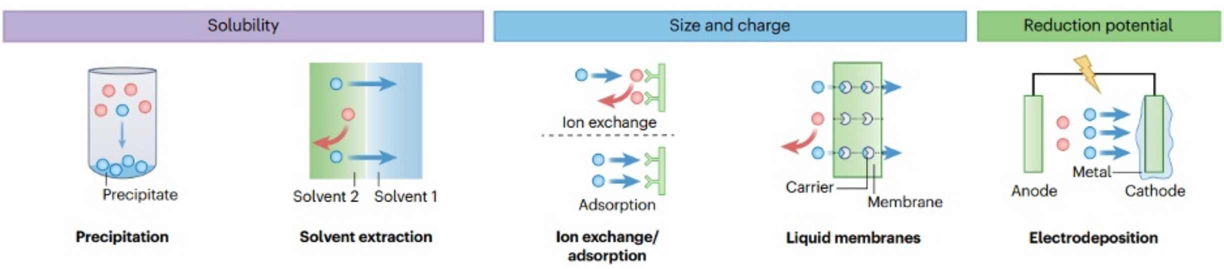

Fig 3. Unit operations used to selectively extract ions from an aqueous stream [4].

These unit operations produce a fluid enriched in the element of interest, known as Concentrate. Typically, this concentrate is not 100% pure and often contains many of the elements most abundant in the produced water stream, such as Sodium, Calcium or Magnesium. These contaminant elements must be selectively removed from the concentrate stream with the same unit operations used for initial extraction, such as neutralization/precipitation and ion exchange. Once purified, the concentrate must be dried to produce a saleable salt or metal product suitable for shipping. The depleted water stream can then be further treated or directly reinjected downhole via a disposal well.

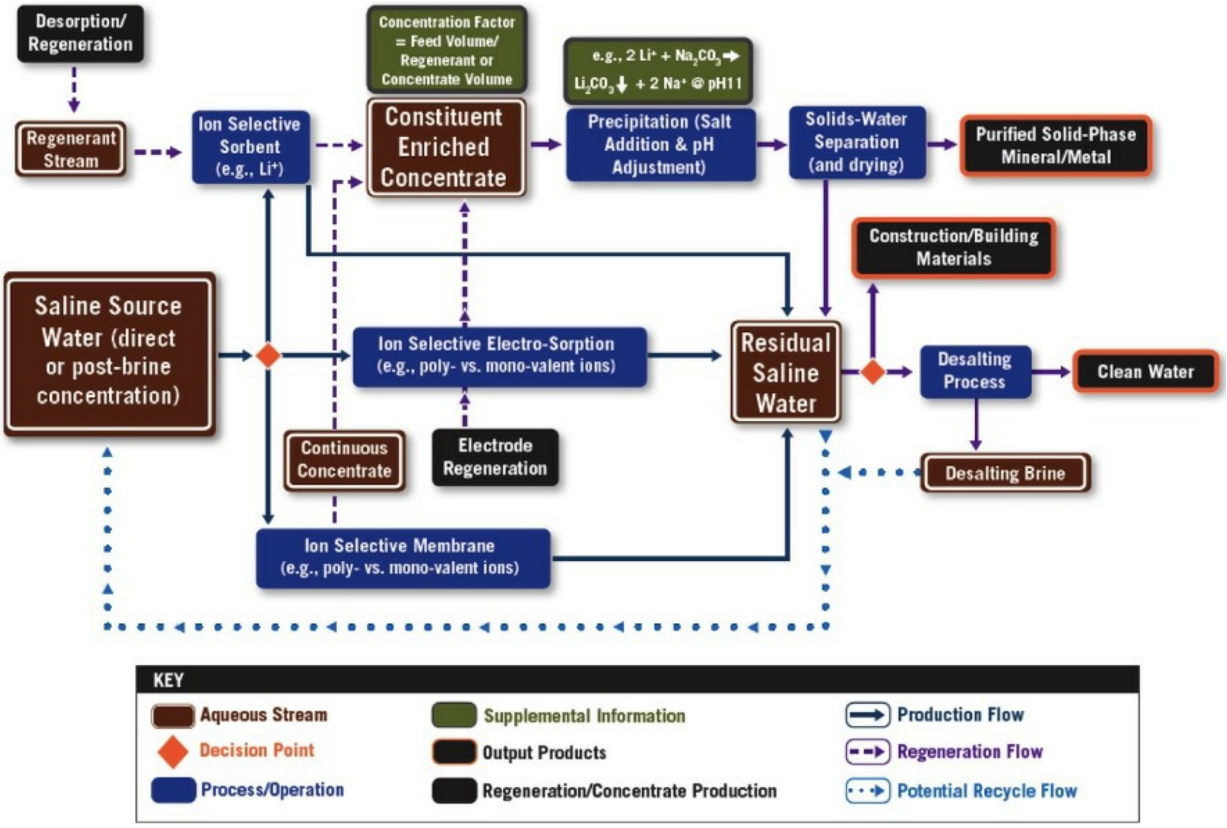

Fig 4. Process flowsheets for critical mineral extraction from aqueous streams [5].

While challenges of technical feasibility, environmental impact, and regulatory frameworks persist, the potential benefits of tapping these unconventional resources are too compelling to ignore. By harnessing the latent value within these often-overlooked streams, we not only address the pressing demand for critical minerals but also shift the paradigm of waste management. The same water treatment technologies used to treat or remediate produced water streams are necessary to extract and valorize their critical element constituents. Therefore, this emerging field not only reshapes the conventional narratives of resource extraction but also underscores the potential for harmonizing disparate industries in service of a more sustainable and technologically vibrant future.

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Source Attribution:

[1] Maimoni, A. "Minerals recovery from Salton Sea geothermal brines: A literature review and proposed cementation process." *Geothermics* 11.4 (1982): 239-258.

[2] *The Canadian Critical Minerals Strategy*, 9 Dec. 2022. https://www.canada.ca/content/dam/nrcan-rncan/site/critical-minerals/Critical-minerals-strategyDec09.pdf. Accessed 29 Aug. 2023.

[3] Miranda, Michael Angelo, et al. "Treatment and recovery of high-value elements from produced water." *Water* 14.6 (2022): 880.

[4] DuChanois, Ryan M., et al. "Prospects of metal recovery from wastewater and brine." *Nature Water* 1.1 (2023): 37-46.

[5] Can Sener, Serife E., et al. "Recovery of critical metals from aqueous sources." *ACS sustainable chemistry & engineering* 9.35 (2021): 11616-11634.