Solid and hazardous waste production during geothermal lithium extraction

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Geothermal energy production is becoming an important source of alternative energy as efforts to reduce greenhouse gas emissions mature and new power plants are being commissioned globally. Many geothermal brines contain relatively high concentration of lithium and there are several commercial start-up projects that propose using so-called direct lithium extraction (DLE) to recover lithium from geothermal brines. All of the proposed project intend to locate their facilities adjacent to geothermal power plants and use the steam-extracted brine from the power plant as a feedstock. Since DLE has never been previously applied to geothermal brines, there is concern that development of this new industry will have unintended environmental consequences, including the generation of legacy wastes that will have long-term, negative impacts. In addition, there is very little published information concerning solid and hazardous waste generation by the geothermal power industry generally.

In this study, we document current solid and hazardous waste production by operating geothermal power plants and investigate the potential for the proposed geothermal lithium extraction facilities to generate solid and hazardous waste. We determined that geothermal power plants produce a significant amount of solid wastes and that DLE facilities have the potential to produce multiple amounts of solid wastes compared to geothermal power plants. The amounts and types of wastes produced are predicted by the process flow and the chemistry of the geothermal brine feedstock. We identify opportunities for diversion of by-product solids from landfills, which would have both economic and societal benefits.

Background

Lithium is used to produce lithium-ion batteries for electric vehicles and energy storage. Demand for lithium is growing at a rate of about 30% per year and most lithium production and refining involves complex supply chains that are subject to disruption from natural phenomena and political conflict. Nations that are transitioning to lower-carbon economies are increasingly seeking to develop “domestic” lithium resources and battery supply chains. In the USA and Europe, geothermal brines are now recognized as major domestic lithium resources and there are concerted efforts to develop technology and methods to extract lithium from this novel resource.

DLE is a chemical process that includes the pretreatment of geothermal brine to remove silica and metals prior to collection of lithium with adsorbent media. In the DLE process, sorption of lithium is followed by elution of a concentrated lithium solution that is further treated to remove impurities. Both pre-treatment and post-treatment are chemical processes that generate significant quantities of solid “by-products” that must be managed as industrial wastes. Solid waste production during geothermal lithium extraction is not analogous to lithium mining and geothermal lithium solid wastes are not mining wastes, but rather must be managed as industrial solid wastes and hazardous wastes and interred in lined landfills or otherwise properly disposed.

Methods

This study took place in the Salton Sea Known Geothermal Resource Area located in Imperial County California, USA. This area is one of the most developed geothermal resources in the world and includes 11 power plants generating over 2,000 megawatts of electricity per year. Currently, four additional power plants are under development. The Salton Sea geothermal resource has recently been identified as containing over 3 million metric tons of lithium with the potential to produce up to 13% of the current world lithium demand if currently proposed DLE projects are developed.

State (California, USA) and federal (USA) records of hazardous and industrial waste disposal, collected under various regulations governing the generation, shipment and disposal of hazardous and industrial wastes were compiled and used to determine the amounts and types of solid wastes generated by existing geothermal power plants. We used published brine chemistry data to determined how brine chemistry predicted power plant solid waste production. We then used the known brine chemistry and the proposed DLE process to predict the qualities and types of industrial and hazardous wastes that could be produced as by-products of lithium carbonate manufacture from geothermal brines. Our analysis was used to evaluate potential environmental impacts from the nascent industry and to evaluate the potential to divert solid by-products from landfills to other uses.

Results

Solid wastes are produced at geothermal power plants in the Salton Sea region from the crystallizer-clarifier processes and from waste holding ponds called brine ponds (Figure 1). The crystallizer-clarifier process removes silica from the geothermal brine, thereby preventing scale formation in the power plant. The crystallizer-clarified solids are predominantly iron-silicate and non-hazardous. The brine pond solids include various metal complexes that may be toxic. On average, approximately 80,000 metric tonnes of solid waste per year are produced by power plants in this region (Table 1). Approximately 53% of the wastes are non-hazardous by both state and federal criteria and are disposed of in regional industrial or municipal landfills. Other wastes are hazardous by California criteria and are shipped to industrial landfills in other states. Approximately 15% of solid wastes hazardous materials by both state and federal standards and are sent to hazardous waste landfills.

Figure 1. Aerial view of a representative geothermal power plant from the region showing clarifier tanks and the brine pond which contains precipitated solids that will be collected and disposed of as solid wastes.

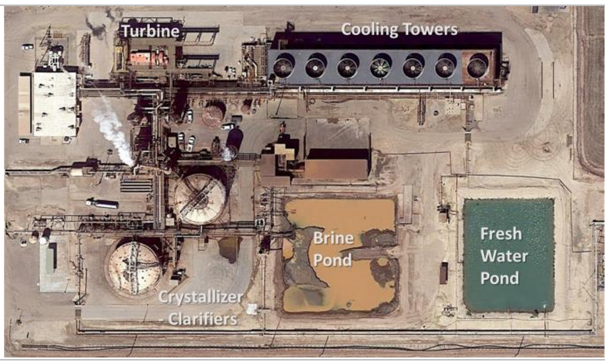

Table 1. Types and amounts of solid wastes produced by geothermal power plants in the Salton Sea region between 2015 and 2021.

Waste Description	California Hazardous Waste Code	Average Metric Tons per Year (2015-2021)	% of Total Solid Waste
Filter cake	non-hazardous	42,000	53%
Inorganic	181	35,000	45%
Organic	352	1,500	2%

The proposed DLE facilities include pre-treatment of brine to remove silica and metals and post-treatment of lithium solutions to remove calcium and magnesium. An analysis of the proposed DLE process trains in the context of the brine chemistry, suggests that for every kilogram of lithium carbonate produced, up to six kilograms of metal hydroxide solids could be produced (Table 2). It is possible that this metal hydroxide by-product may have value, rather than being a waste needing landfill. The analysis in Table 2 suggests that the formation of calcium hydroxide as a by-product of lithium carbonate manufacture could result in significant solid waste production. Reports issued by DLE project developers indicate that the new DLE projects could produce over 600,000 metric tonnes of solids from their pre-treatment and post-treatment processes. Although it is not yet known how much of the by-product solids will have salable value, if the geothermal DLE industry is successfully developed it will result in an increase in regional production of hazardous and industrial solid waste.

Table 2. Projected maximum potential solids production per metric tonne of geothermal brine processed for the extraction of lithium

Solid type	Potential kg/tonne brine
Lithium carbonate	1.1
Silica	0.3
Metal hydroxides	6.5
Calcium hydroxide	47

Conclusions

Geothermal power plants produce both hazardous and non-hazardous solid wastes that are disposed of in secure landfills. The production of lithium by DLE will result in production of a large amount of “by-product” solids. The economic value of the by-product solids will determine if solids are disposed of as waste or sold as products. Maximizing the economic value of by-products & diverting wastes from landfills would have multiple benefits.