GEOTHERMAL WASTE TREATMENT BIOTECHNOLOGY

Eugene T. Premuzic, Mow S. Lin, Jing-Zhen Jin, and Karlene Hamilton

Biosystems and Process Sciences Division
Brookhaven National Laboratory
Upton, New York

Key Words: Biochemical Processes, Detoxification of Sludges, Metal and Salts Recovery, Environmentally Acceptable By-products

ABSTRACT

Studies at the Brookhaven National Laboratory (BNL) have led to the development of a technically and economically feasible, as well as an environmentally acceptable, biochemical process for detoxification of geothermal residues. For this process, selected microorganisms which live in extreme environments have served as models for the new biotechnology:. Assuming a 2500 kg/h sludge production rate., the new technology is capable of a better than 80% removal of toxic metals usually in less than twenty-five hours periods of time. The process itself depends on a number of flexible parameters, allowing this technology to be tailored to specific needs of different geothermal producing regimes, such as those, for example, found in the Salton Sea and the Geysers areas of California. Thus, geothermal residual sludges and brines can be processed to remove only a few metals such as arsenic and mercury only, or many ranging from valuable metals such as chromium, gold, and silver to radionuclides, such as radium. In some cases, combined metal removal and metal recovery processes may be cost-efficient and, therefore, advantageous. The emerging biotechnology for the treatment of geothermal energy production wastes is versatile and offers a number of application options, which will be discussed in this paper.

1. INTRODUCTION

Over the past several years ongoing R&D effort at BNL in the area of renewable geothermal energy has focused on the development of economically and environmentally acceptable methods for disposal of geothermal wastes and conversion of by-products to useful forms. It is known that microorganisms can interact with metals by means of several mechanisms such as surface adsorption, oxidization. reduction, solubilization and/or precipitation. These mechanisms served as a basis for the development of a technology which allows to use biochemical processes for removal and concentration of toxic metals present in the wastes converting them into environmentally and regulatory acceptable byproducts. A flexible biochemical process has been developed which can be used in several modes of operation, such as (1) solubilization and removal of many metals, including radionuclides, from brines and sludges; (2) selective removal of a few metals; (3) concentration of metals; (4) recovery of metals; and (5) recovery of salts. The end product is a silica-type material which meets regulatory requirements, while the aqueous phase meets drinking water standards and can be reinjected and/or used for irrigation. A pilot-scale plant has been constructed and used to identify process variables and optimize processing conditions.

A number of process variables have been identified which range from reactor size and co-processing to recycling of biocatalysts (Premuzic *et al.*, 1992, 1993). Optimization of parameters which influence these variables has resulted in fast kinetics of metal removal, i.e., rates of better than 80% in 25 hours or less at a pH of 1-2, and temperatures of up to 50-55°C. Because of corrosive conditions, the temperature-acidity conditions, for example, are just one of the several process parameters that must be considered in the design of bioreactors and processing streams.

Further, different types of wastes have to be also considered. There are circumstances in which one is dealing with large quantities of sludges (such as those produced at a rate of ~2500 Kg/h) consisting of predominantly benign silica containing traces of toxic and valuable metals to waste residues containing only one or two metals, such as arsenic and mercury. Toxic and valuable metals are present in small, however regulated, quantities. Biochemical methods are particularly suitable for handling of such large quantities containing low concentrations of contaminants, On an annual basis, accumulation of such wastes can become a valuable metals resource (e.g., silver, gold, etc.) and may justify combined "detoxification" and "valuable metals recovery" processes. In addition, the brines themselves are a potential resource of commercial products such as potassium chloride.

Preliminary engineering studies of the metal and salt recovery technologies have indicated that significant cost benefits could be obtained by means of combined processing. The emerging biochemical technology also has led to several spin-off applications. Particularly promising, are the applications in the treatment of fossil fuels such as upgrading of low grade heavy crudes and the downstream processing of crude oils.

3. METHODS

Instrumentation, analytical methodology, and process design and optimization of variables have been discussed elsewhere (Premuzic *et al.*, 1992, 1993; Ulrich, 1984; Garrett, 1989; Premuzic *et al.*, 1991) and applied in the studies described in this paper.

4. RESULTS AND DISCUSSION

Biochemical technology for the treatment of geothermal sludges, brines, and wastes depends on several process variables, such as tank size, agitation, pH, temperature, recycling, production of biocatalysts, integration with the total process and scenarios dealing with the combination of several processes. These have been discussed in detail elsewhere (Premuzic *et al.*, 1992, 1993).

For example, in the design of a total biochemical process, the cost of the production of the biocatalysts has to be factored in. The treatment of geothermal brines requires two types of biocatalysts: one whose rate of production is fast, designated as Biocatalyst 1, and another whose rate of production is slow, designated as Biocatalyst 2. Significant cost variations are associated with the production of biocatalysts at rates required by the processing conditions. There are several factors that influence the costs. These include: (1) Slow rate of production which requires large volume reactors and holding tanks. For fast rates of production, the opposite holds; (2) Cost estimates have to factor in whether plant space and utilities (e.g., power, water, etc.) are in place; and (3) Relative concentration of biocatalysts. Further optimization of other key variables such as construction materials, biocatalyst ratios, recycling of the biomass, metal and salt recovery offset the processing costs. The metal and salt recovery option becomes very attractive under the circumstances in which the end-product, i.e., the aqueous phase, can be reinjected into the reservoir without upsetting its chemistry. Such processing scenarios for geothermal brines and sludges are systematically studied in this laboratory. Some of the recent results will be discussed briefly. Thus, a total biochemical process for the treatment of a highly saline geothermal sludge produced by a *50* MW plant at a rate of 1000-2500 kg/h is shown in Figures 1-3. All of the data presented describing process block diagram and cost calculations were produced by a computer program developed at Brookhaven National Laboratory and published data. Tons in all calculations are metric. In highly saline reservoirs a salt and minerals recovery is an attractive option as shown in Figures 4 and 5. In this mode of operation, a waste mandated to be cleaned becomes a commercial resource. The example deals with the recovery of potassium chloride, 3 feedstock to the fertilizer industry. Recovery of trace metals is another attractive option.

There are many valuable metals in such highly saline brines (Maimoni, 1982), such as silver, zinc, vanadium, nickel, chromium, gold and others. Biochemical methods for detoxification and metal recovery are particularly suitable for handling large quantities of materials containing trace concentrations of contaminants and/or recoverable materials. In the recovery mode, both chemical and biochemical processes (Premuzic *et al.*, 1991) can be used. Biosorption, for example, compares well with a chemical precipitation process: as shown in Table 1.

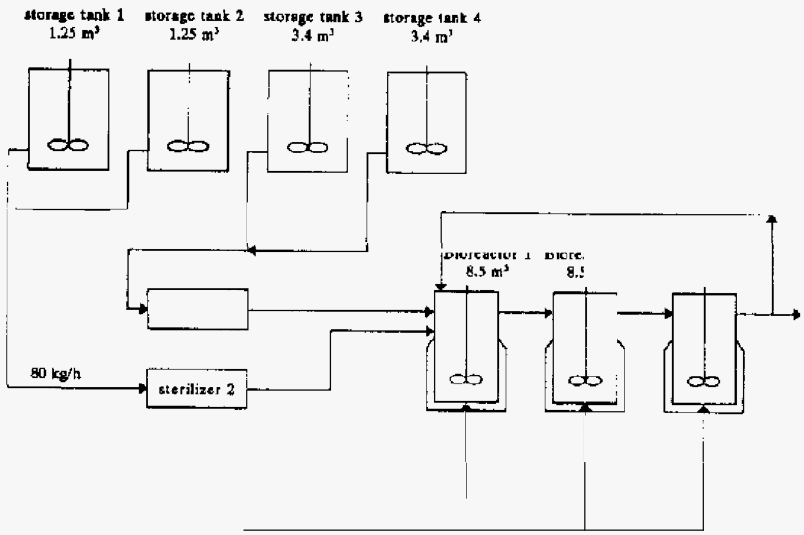


Figure 1. Process diagram for the production of Biocatalyst 1 for the triple recycle process. Biocatalyst 1 production capacity 4RZ Kg/h.

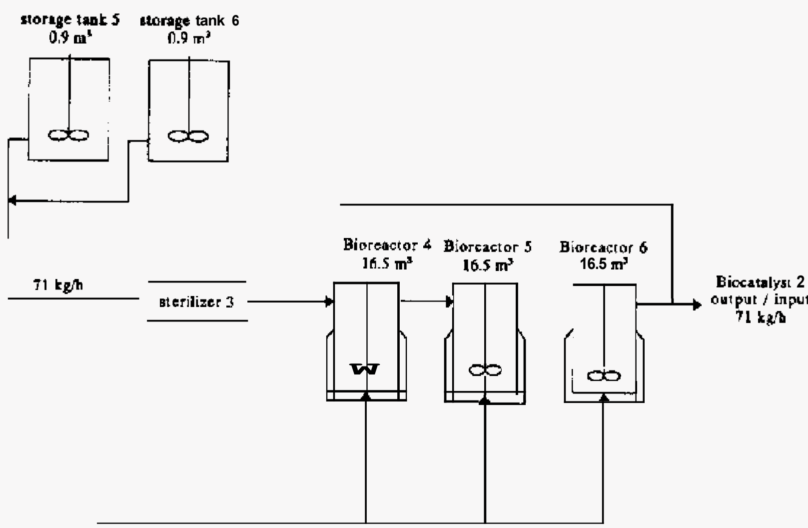


Figure **2.** Process diagram for the production of Biocatalyst 2 for the triple recycle process. Biocatalyst 2 production capacity 71 Kg/h.

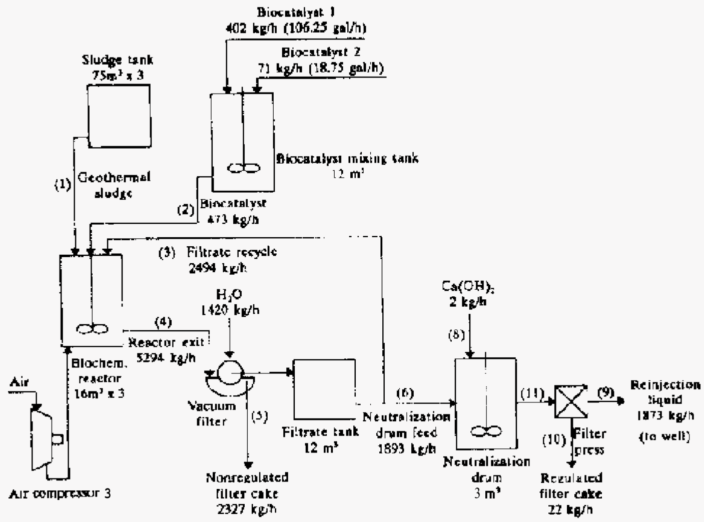
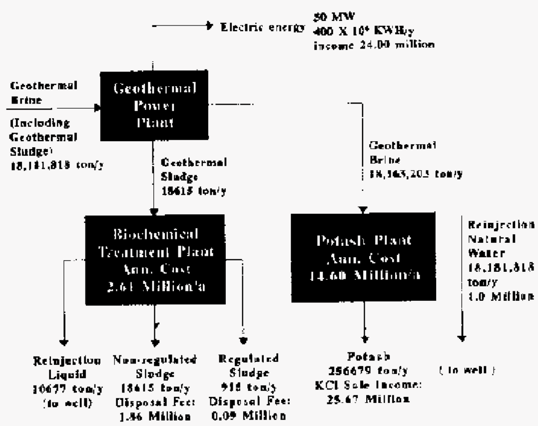


Figure 3. Total biochemical process for geothermal sludge (2500 Kg/h). Treatment: Biocatalyst 1 (85%):Biocatalyst 2 (15%) triple recycling process.



KCl Sale Income: 25.67 Million/y

Expenses:	Biochemical Treatment Fee	2.61 Million
	Nonregulated Sludge Disposal Fee	1.86
	Regulated Sludge Disposal Fee	0.09
	Potash Production Fee	14.60
	Natural Water for Reinjection	1.00
	Total Expenses	2016 /y

Banlance: 25.67 - 20.16 = 5.51 Million/y Gain

Figure 4. Total biochemical process **cost estimates** including potash plant option **under** optimized condition.

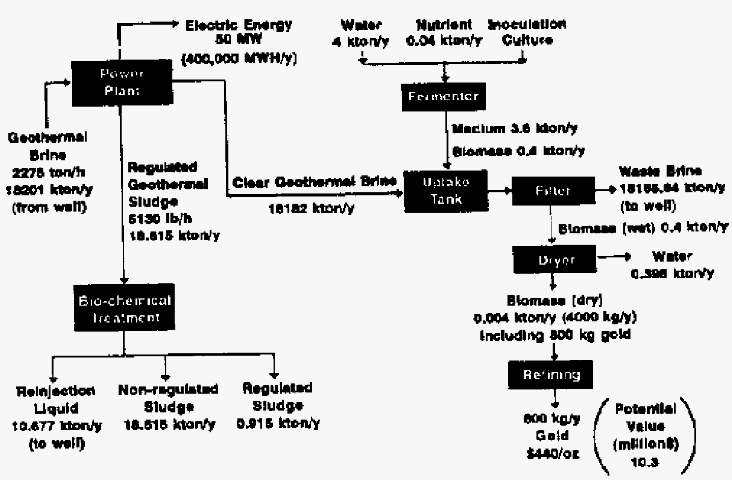


Figure 5. Biochemical processing of geothermal sludge **and** brine. Gold recovery option.

Table 1. Typical Recovery of Metals from the Aqueous Phase Generated by the Biochemical Processing of Geothermal Sludges.

Metal	% Metal Recovery	
	Chemical	Biochemical
Al	96	98
Ni	99	82
Cu	99	92
Ag	99	98
Pb	93	95

In another type of geothermal resource such as that dominated by *steam*, the power production process leads to a waste which contains only a few regulated, for example, arsenic, mercury and sulfur. A modified version of the process described in Figures 1-3, has led to a prototype process (Premuzic, 1994) in which the metals are removed and concentrated with concurrent high yield recovery of chemically pure sulfur. The modified process can he applied in area such as those of Northern California and purification of fluids used in Hot Dry Rock Processes. Additional spin-offs derived from the development of the emerging biotechnology have *led* to the applications in fossil fuel processing (Premuzic *et al.*, 1993), such as enhanced oil recovery, the upgrading of heavy crude oils (Premuzic and Lin, 1994) and the extension of catalyst operating efficiencies.

5. CONCLUSIONS

1. Biochemical technology for geothermal sludges is cost efficient and environmentally acceptable.

2. Biochemical processing is flexible and adaptable to various feedstocks.

3. Biochemical processing can he integrated with other technologies.

4. The combination of technologies enables the conversion of geothermal waste streams into usable resources.

6. ACKNOWLEDGMENTS

This work has been supported by the U.S. Department of Energy: Renewable Energy and Conservation, Division of Geothermal Technology, Contract No. AM-35-10. K. Hamilton was a participant in the Geothermal Division's, Minority Student Program.

7. REFERENCES

1. Premuzic, E.T., Lin, M.S., and Jin, J.-Z. (1992). *Geothermal Waste Treatment Biotechnology: Progress and Advantages to the Utilities.* Proceedings Geothermal Program Review X, San Francisco. CA, pp. 111-116.

2. Premuzic, E.T., Lin, MS., and Jin, J.-Z. (1992). Developments in Geothermal Waste Treatment Biotechnology. *Geothermics*. Vol. 21(5/6), pp. 891-899.

3. Premuzic, E.T., Lin, M.S., and Jin, J.-Z. (1993). *Geothermal Waste Treatment Biotechnology.* Proceedings Geothermal Program Review XI, Geothermal Energy–The Environmentally Responsible Energy Technology fnr the Nineties, Berkeley, CA.

4. Premuzic, E.T., Lin, M.S., atid Jin, J.-Z. (1993). *Recent Developments in Geothermal Waste Treatment Biotechnology.* Proceedings Heavy Metals in the Environment. R.J. Allan and J.O. Nriagu, Eds., Toronto, Vol. 1, pp. 356-363.

5. Ulrich, G.D. (1984). *A Guide to Chemical Engineering Process Design and Economics.* John Wiley & Suns, New York.

6. Garrett, D.E. (1989). *Chemical Engineering Economics*, Van Nostrand Reinhold, New York.

7. Maimoni, A. (1982). *A Cementation Process for Minerals Recovery from Salton Sea Geothermal Brines*, Lawrence Livermore National Laboratory, UCRL-53252.

8. Premuzic, E.T., Lin, M.S., Zhu, H.L., and Gremme, A.M. (1991). Selectivity in Metal Uptake by Stationary Phase Microbial Populations, *Arch. Environ. Contam. Toxicol.* Val. 20, pp. 234-240.

9. Premuzic, E.T., Lin, M.S., Racaniello, L.K., and Manowitz, B. (1993). Chemical Markers of Induced Microbial Transformations in Crude Oils. In: *Microbial Enhancement of Oil Recovery--Recent Advances*, Elsevier, Amsterdam, pp. 37-54.

10. Premuzic, E.T. and Lin, M S. *(1994)* Biochemically Enhanced Oil Recovery and Oil Treatment, U.S. Patent No. 5,297,625,

11. Premuzic, E.T. and Lin, M.S., AUI has title to the inventions developed under this research program, and has filed a U.S. Patent applicatinn on these inventions which are pending before the U.S. Patent Trade Office, and has initiated an act of licensing programs aimed at commercializing these technologies.

12. Premuzic, E.T. (1994). Advanced Biochemical Processes for Geothermal Brines. BNL Report 60291.