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Intelligent optimization of bioleaching process for waste lithium-ion batteries: An application of support vector regression approach

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Introduction:

- Lithium-ion batteries (LIBs) have gained the importance and are being used in high volumes due to their known high power and energy density, high potential, long storage life, and low self-discharge rates.
- The growth in usage of LIBs has gone up so much, that by 2017, the sales of electric vehicles alone exceeded one million units per year.
- Considering an average of 250kg battery pack in each vehicle, the electric vehicles (EVs) alone could contribute 250,000 tons of unprocessed waste.
- Recovery of toxic and vital metal from spent Li-ion batteries is a vital problem in the recycling industry. Though there are diaspora of commercial recycling methods used for this cause, but all these methods are energy intensive and hazardous.
- The recycling processes such as bioleaching are much simpler and environment friendly but lack the required efficiency for metal recovery to prove the commercial feasibility of the model. This work focuses on increasing the efficiency of the bioleaching process.

Figure 1. *Categorization of recycling processes.*

Literature:

- From figure 1 it can be seen biological process majorly includes bio-leaching. It is a growing field which involves the concepts of chemistry, biology and metallurgy. Lately, this potential avenue is being discovered at a great depth. It is used to obtain metabolites like sulfuric acid and ferric ions using chemolithotrophic and acidophilic bacteria.
- These metabolites excreted by microbial activity help in subsequent recovery of required metals from spent LIBs.
- It is observed that both bacteria and fungi have an ability to bio-leach on heavy metals. But fungi are found to be functional in a wide range of pH values, with faster activity rate and better pH tolerance.
- Aspergillus niger is one such fungus which is predominantly used in bioleaching processes. It is a haploid filamentous fungus which is mainly found in decayed vegetation and other mesophilic environments.

Methods:

- This study focuses on the bioleaching method. Compared to other methods of recycling, bioleaching involves usage of organic acids which are easier to dispose of and environment-friendly. These acids have less toxic effects on many biological communities and also are capable of reducing toxic metal concentrations [9].
- In this work, the main parameters that have a dominant effect in providing the environment for incubation are considered. Factors like Sucrose concentration, Inoculum size, Initial pH along with responses like Malic acid, Gluconic acid, Citric acid, Oxalic acid and finally the pH condition are considered for the study.
- For modelling of experimental design, the SVR (Support Vector Regression) algorithm is used. This technique is known for its precision with generalized and fewer data set problems over other techniques like ANN (Artificial Neural Network).

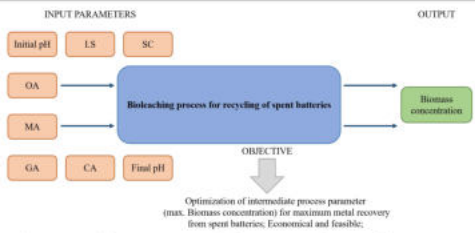

Figure 2. *Illustration of the research problem statement.*

Analysis:

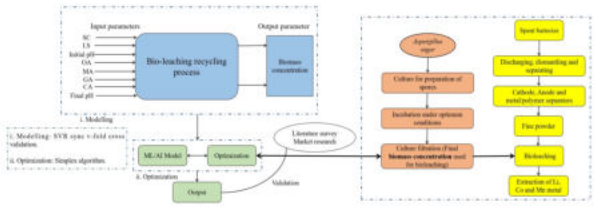

Figure 3. *Illustration of methodology and flow of the process.*

Results:

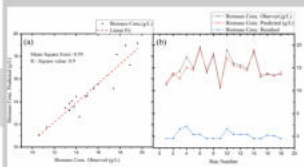

Figure 4.*Statistical fit validation of SVR model.*

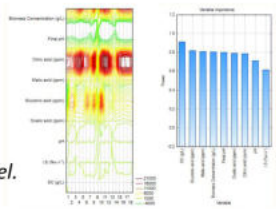

Figure 5.*Global Sensitivity Analysis.*

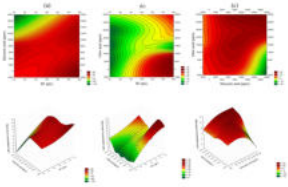

Figure 6.*Contour and 3D plots for interaction analysis.*

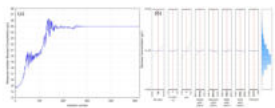

Figure 7.*Maximization of biomass concentration yield*

Conclusions:

- This study focused on the optimization of recycling process conditions for waste batteries. The aim was to achieve a commercially viable recycling model.
- There were eight input parameters and one output parameter biomass concentration.
- This model was optimized using the Simplex algorithm. The formulated SVR model showcased good fit and stability, where R2 = 0.9 and RMSE = 0.59. The stable target was attained under 300 iterations.
- The results of global sensitivity analysis were beneficial in carrying out interaction analysis. The intelligent optimization of bioleaching process shows the maximum value of biomass concentration as 25 g/L for optimized input values.

Important References:

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