Modeling and optimization of bioleaching process to recover heavy metals from spent catalyst

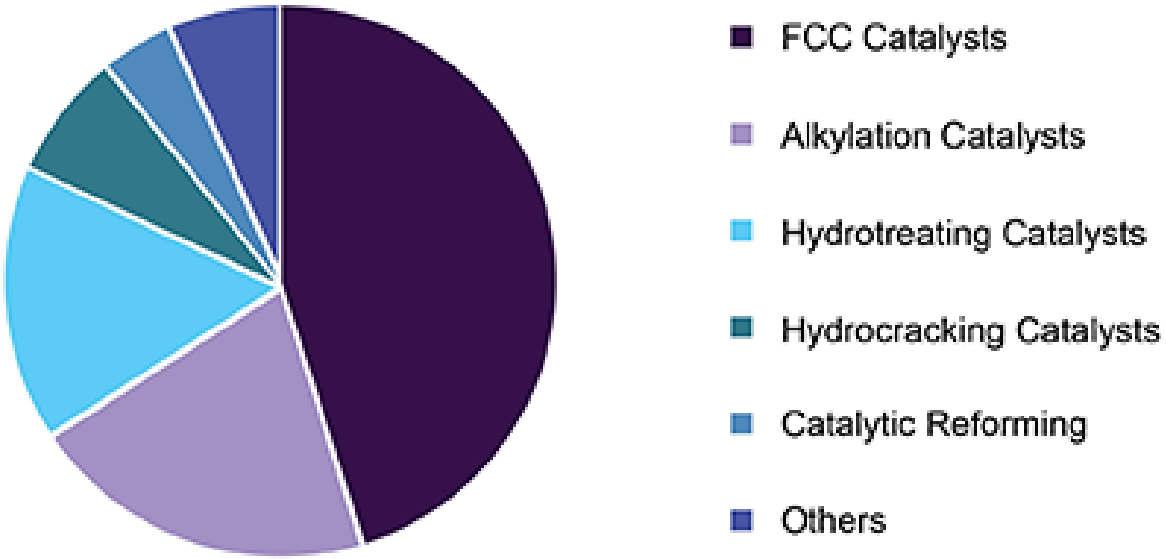
Dr.R.Satish Babu

Associate Professor

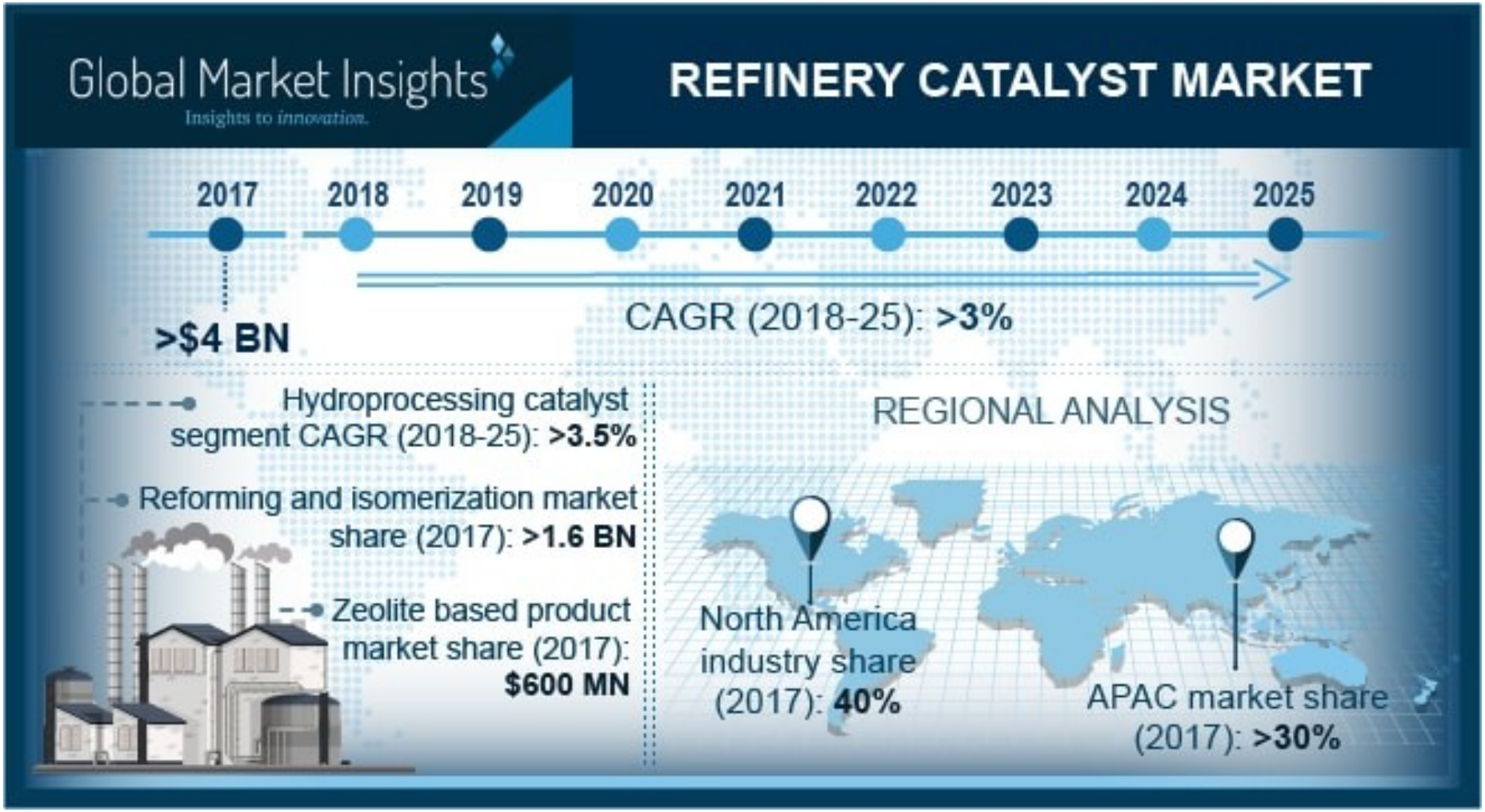
Contents

- Introduction
- Need for the study
- Objective of the research
- Experimental Design
- Results
- Discussion

Global refinery catalysts market share, by application, 2018 (%)



Source: www.grandviewresearch.com



Source. https://www.hydrocarbonprocessing.com/news/2018/07/global-refinery-catalyst-market-worth-over-58b-by-2025

Spent Catalyst

Roasting

Waste Gas Treatment

Leaching of Metals

Solvent Extraction

Waste water treatment

Ni Product

V Finishing

V Product

Mo Finishing

Mo Product

Leaching of spent catalyst

Introduction

- Demand for catalyst : fertilizers, petroleum refinery and other related industries
- The catalysts are composed of various metals like Ni, Co, Cu etc
- Recycling of such waste is an important subject not only from the point of waste treatment but also from the recovery of valuable materials

Need for the study

- To develop an economically feasible, technically viable and environmental friendly bioleaching process for metals recovery from the spent catalyst.
- To develop mixed culture of two strains of Fe/S oxidizing bacteria *A. ferrooxidans*, and *Aspergillus niger* in leaching metals from spent catalyst

Objectives

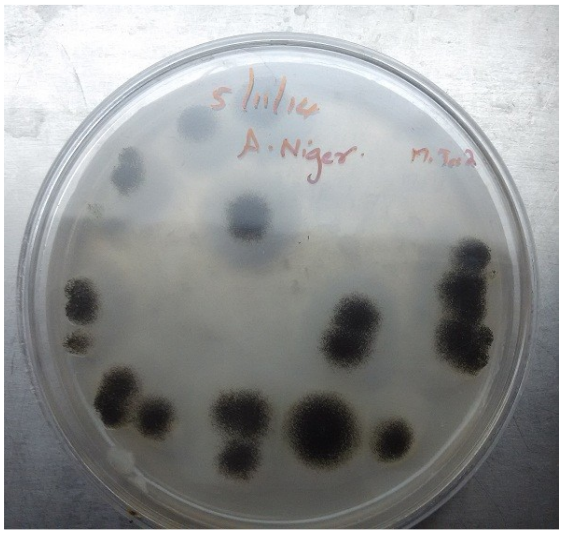
- Identifying a group of microbes for the effective metal recovery from spent catalyst using bioleaching process.
- Leaching process parameters in bioleaching route which will ultimately help in design of industrial scale leaching process.
- Determination of optimum values of metals extraction.

Experimental Design

- Collection of *Aspergillus niger* and *Acidithiobacillus ferrooxidans* from National Collection Of Industrial Microorganisms (NCIM), Pune, India.
- Fresh and spent catalyst was provided by petroleum industry (BPCL). The spent catalyst was pre-treated by heating in a furnace at 600°C for two hours.
- Then the pre-treated spent catalyst was gently and sieved to separate fraction of desired particle size.
- The sieved material was used for bioleaching purpose and composition of spent catalyst consists of 12% Mo, 5.8% Ni, 3% Cd, and 2.5% Cu.

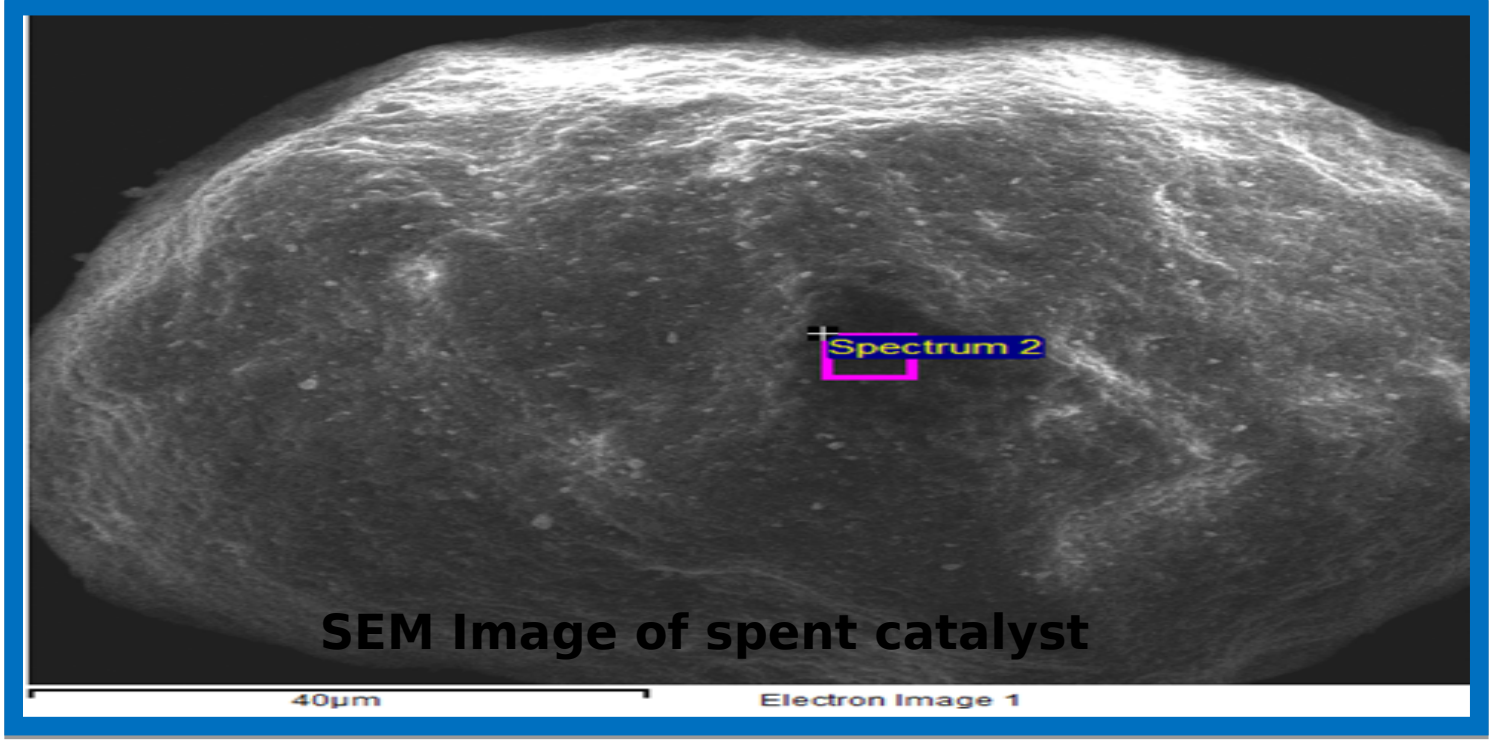
Bioleaching feasibility study

Work flow of bioleaching

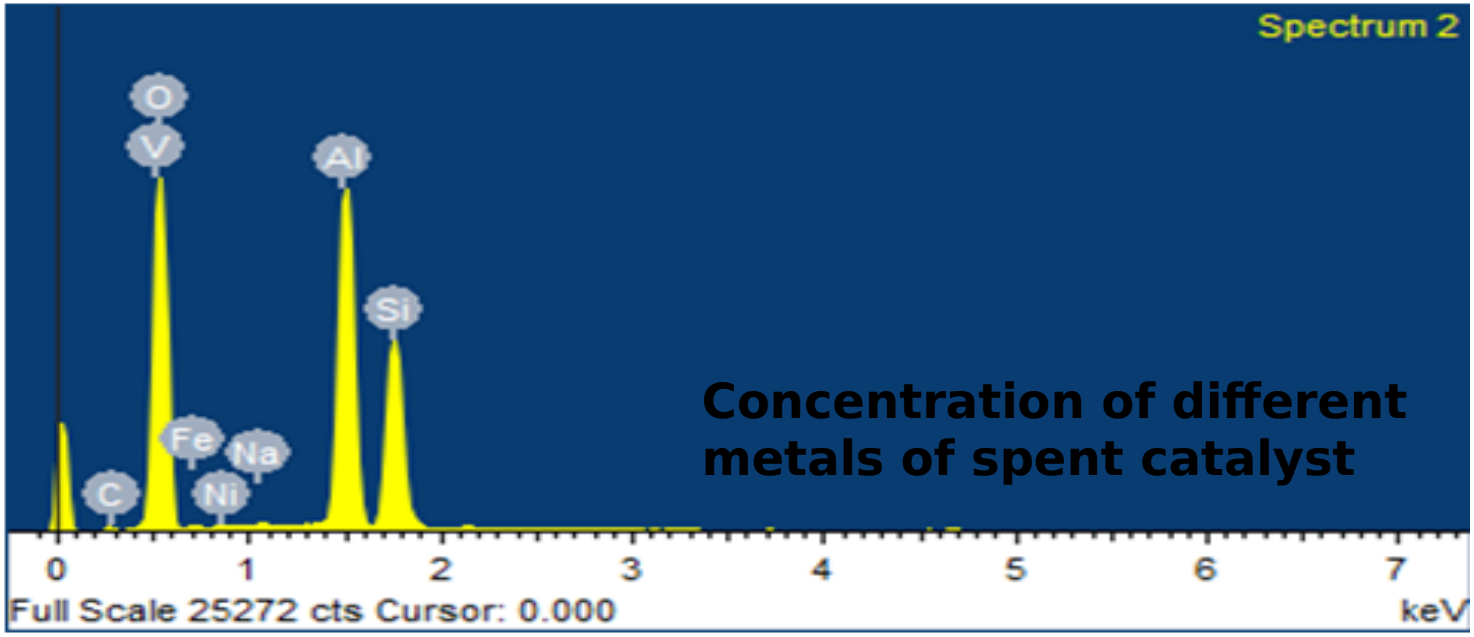


Sub-Culture of *Aspergillus niger* a) before subculture b) aft

Sub-Culture of *Acidithiobacillus ferrooxidans* a) before subculture b) after subculture



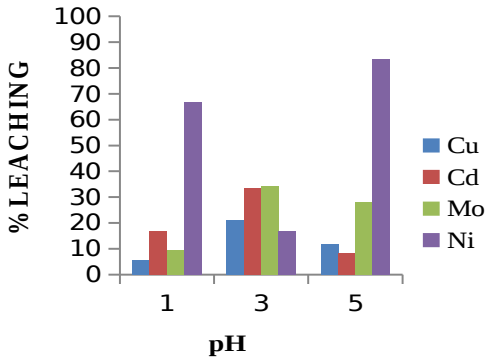
12% Mo
5.8% Ni
3% Cd
2.5% Cu



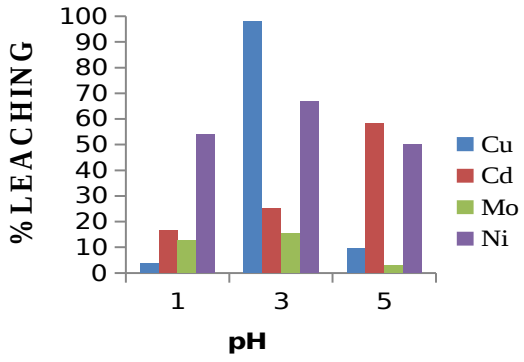
Batch Studies

- The range of variables taken on the basis of batch experiments.
- pH (1-5), Temperature (10-40°C), Contact time (1-10 days) as test variables and metal removal percentages as the response are considered in the optimization process.

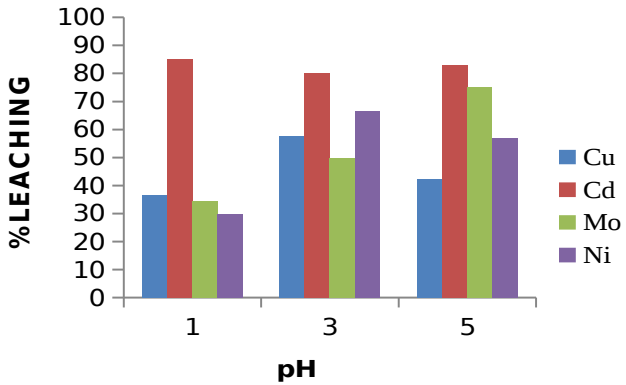
Batch studies



day-1
temp_25

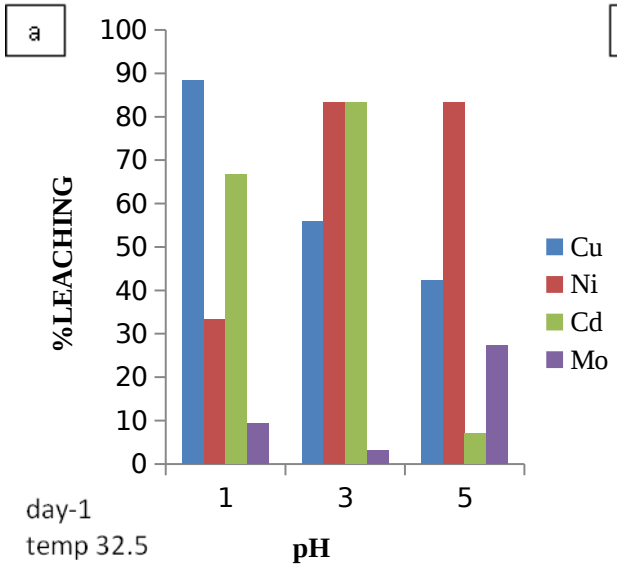


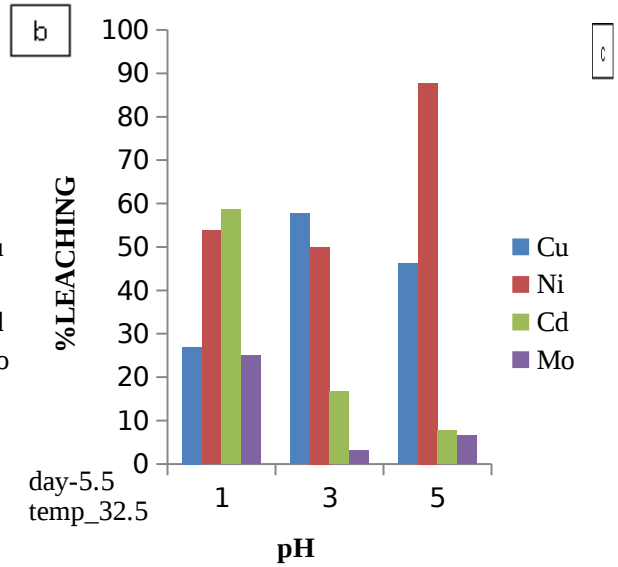
day-5.5
temp_25

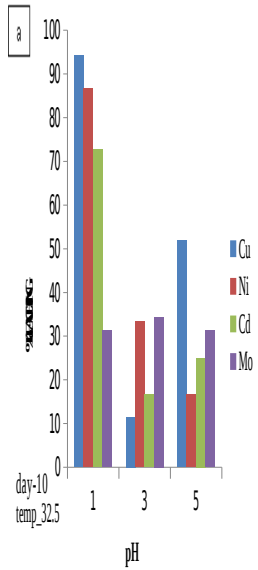


day-10
temp_25

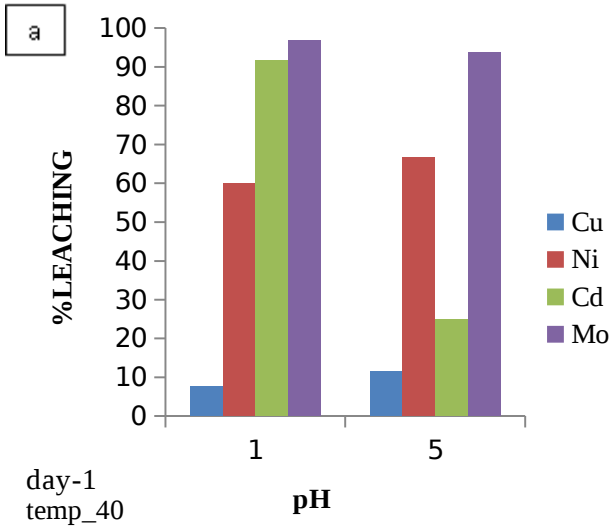
Leaching of different metals at Temperature 25°C and 170 rpm at different days (a) 1 day (b) 5.5 days (c) 10 days ,

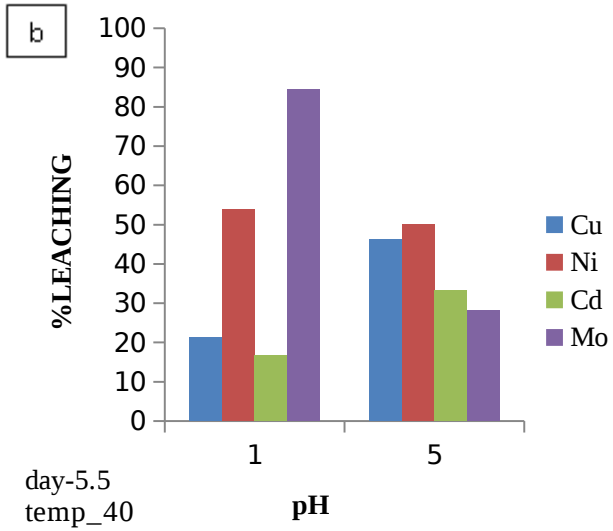


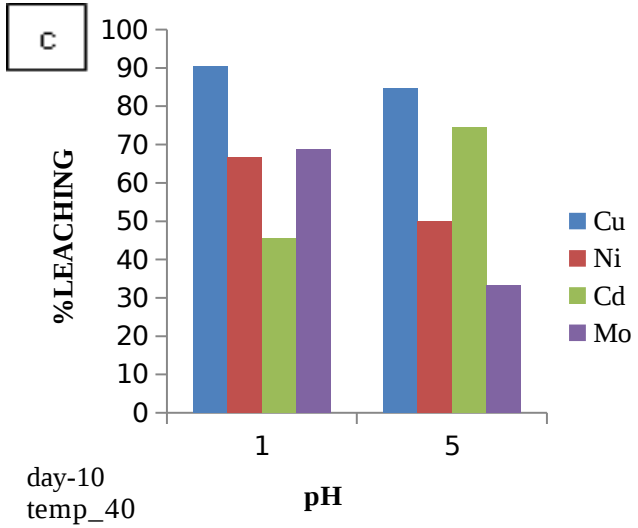




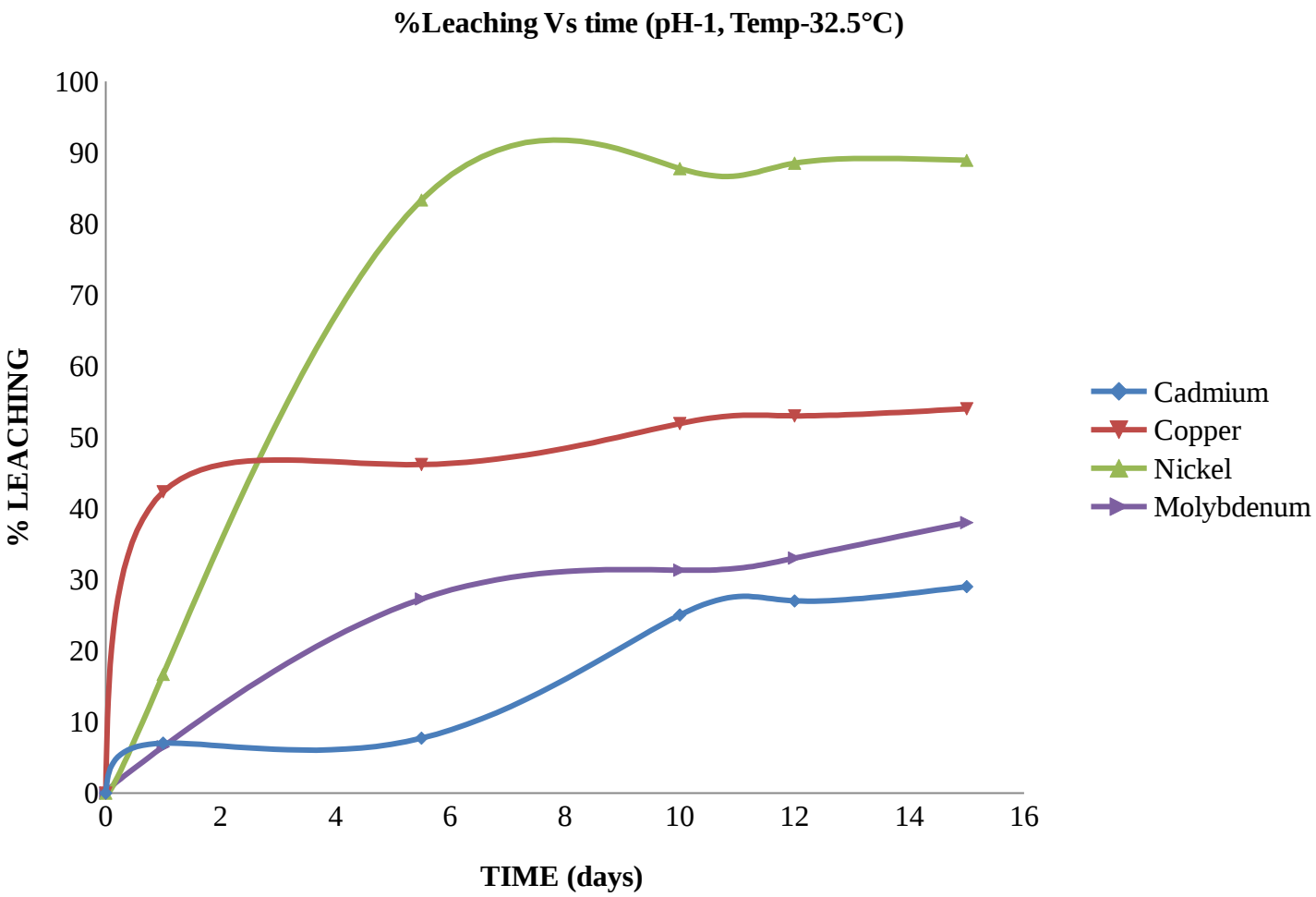
Leaching of different metals at Temperature 32.5°C and at different days (a) 1 day (b) 5.5 days (c) 10 days , shaking speed 170 rpm



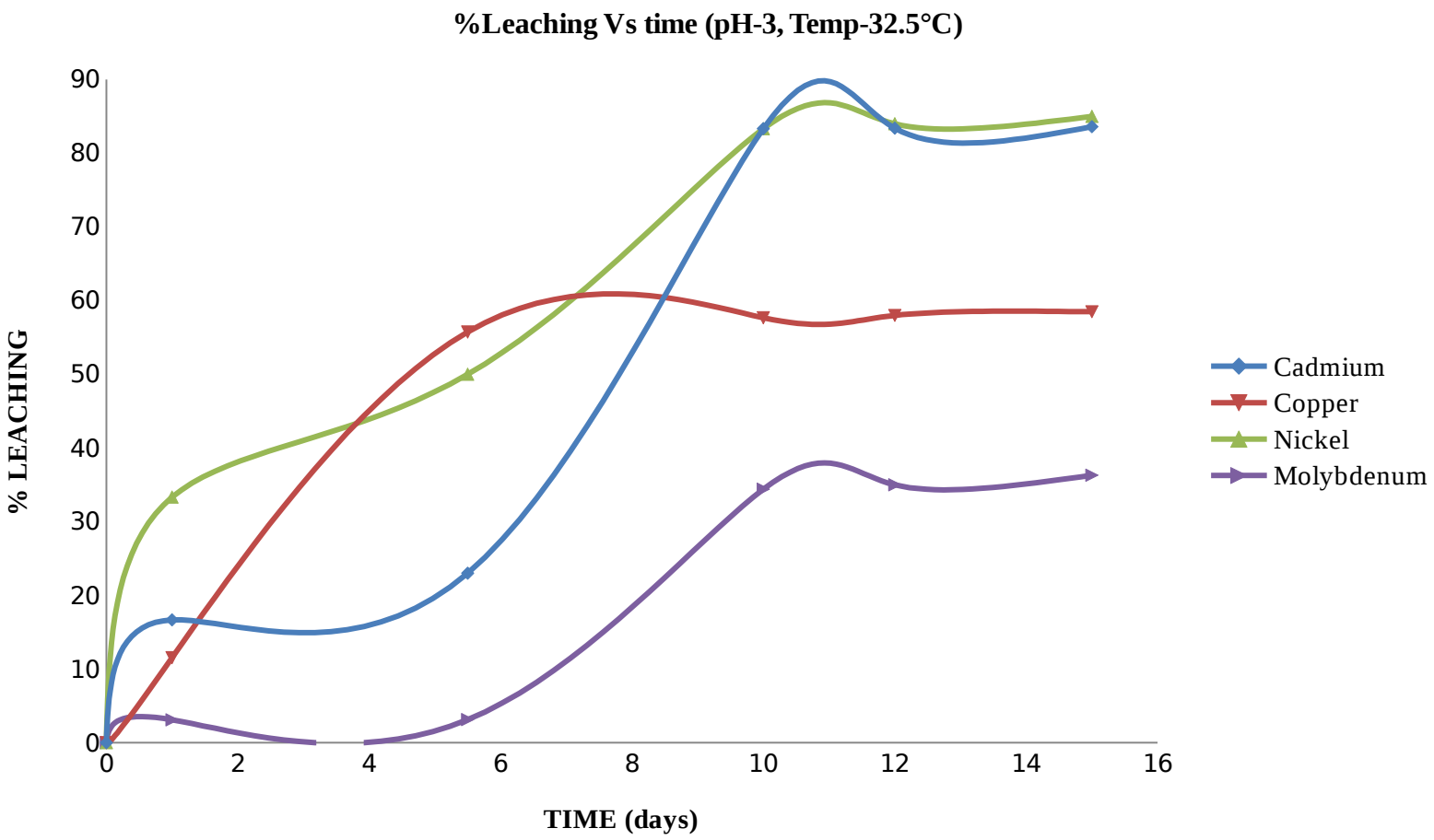




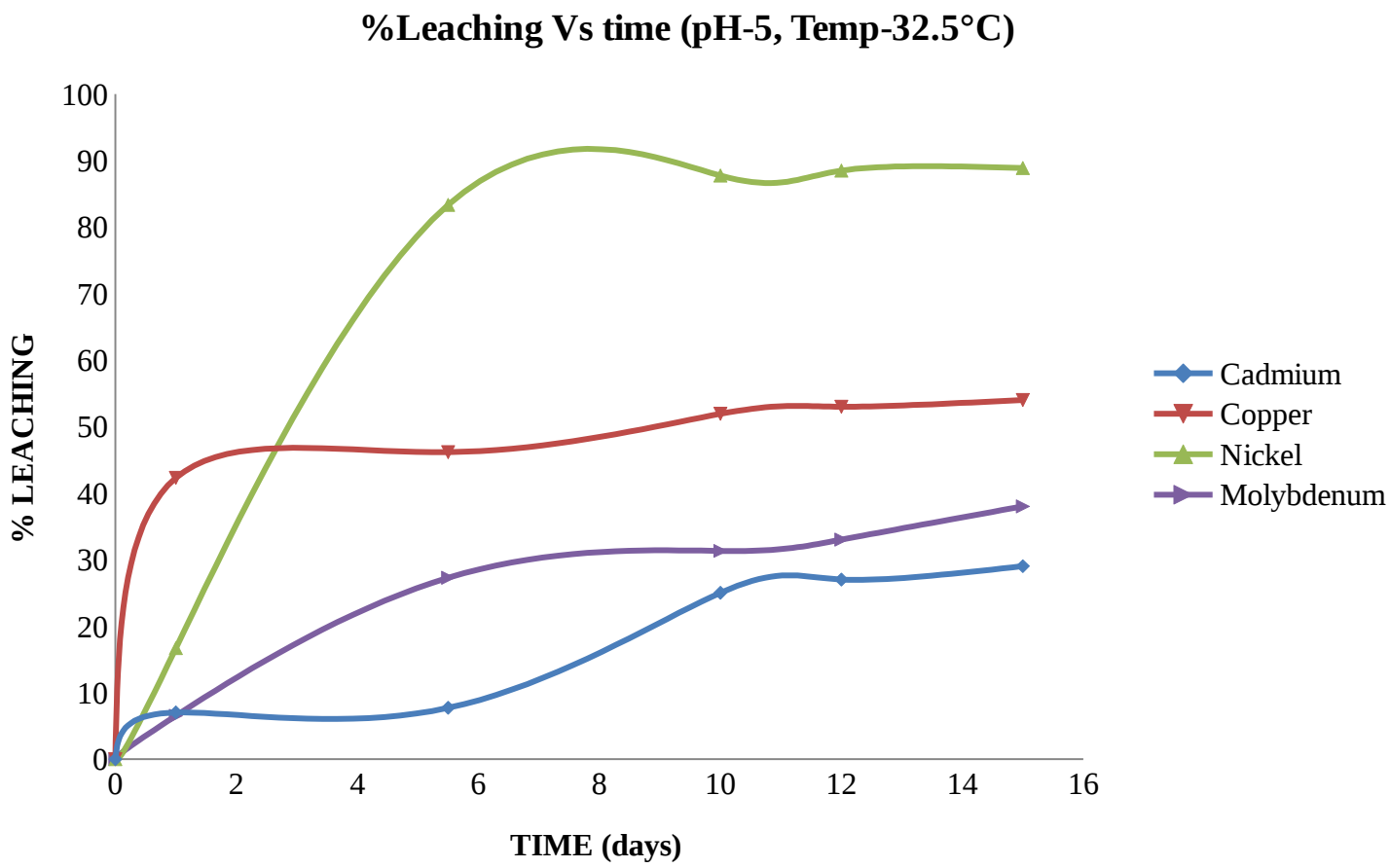
Leaching of different metals at Temperature 40°C and at different days (a) 1 day (b) 5.5 days (c) 10 days, shaking speed 170 rpm



Leaching of different metals at pH 1, Temperature 32.5°C



Leaching of different metals at pH 3, Temperature 32.5°C

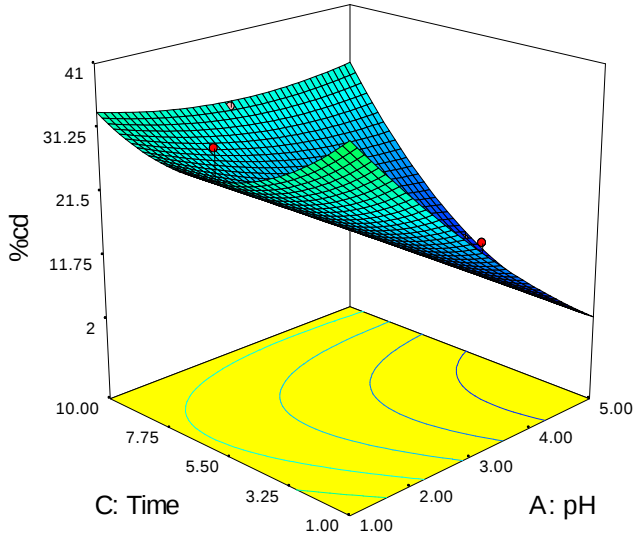


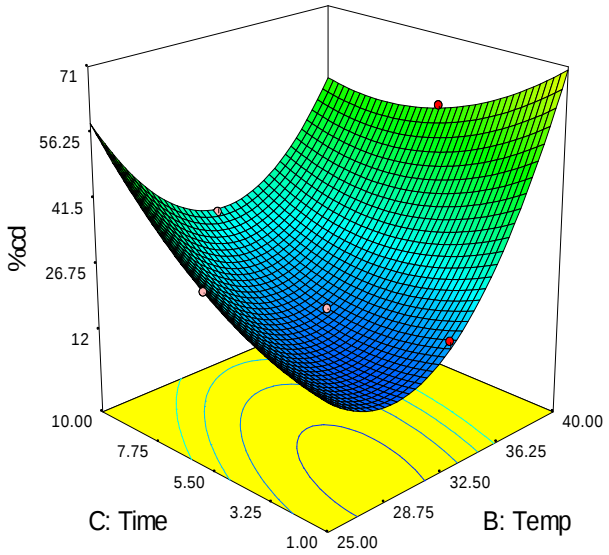
Leaching of different metals at pH-5, Temperature -32.5°C

Optimization by Response Surface (RSM) Optimization

Optimization of process for Cadmium removal using RSM

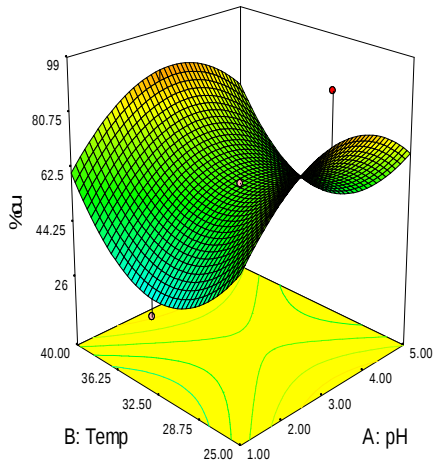
Cd removal (%) =+16.92-10.23*A+11.32*B+5.52*C+9.08*AC-13.84 *BC +2.39 *A^2+ 25.87 *B^2+7.85*C^2

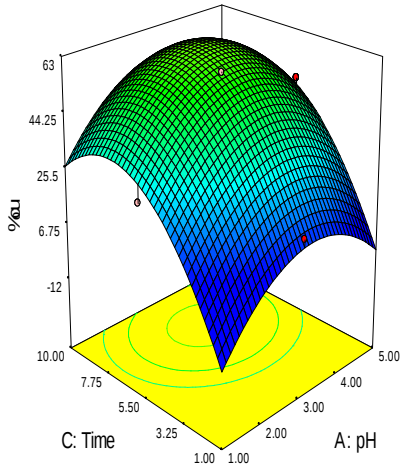


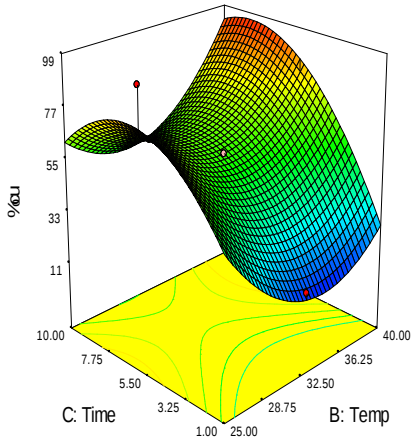


Optimization of process for Copper removal using RSM

Cu removal (%) = 57.96+5.57*A+2.34*B+19.89*C-0.81*AB+0.60*AC+12.84*BC-19.50* A^2+25.38*B^2-25.47*C^2

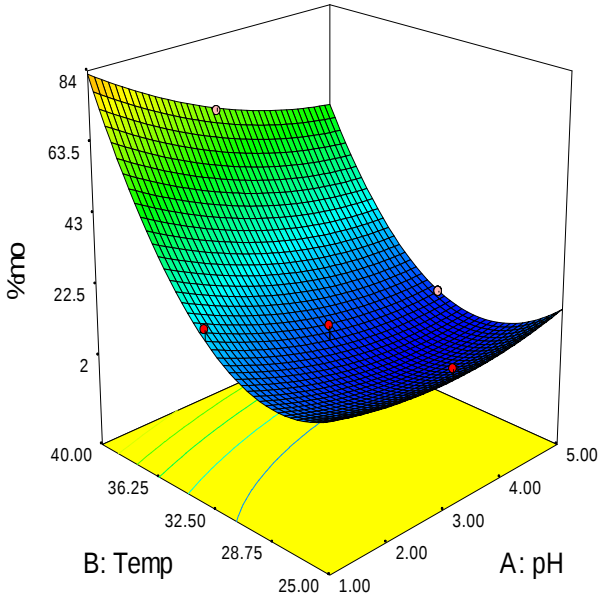


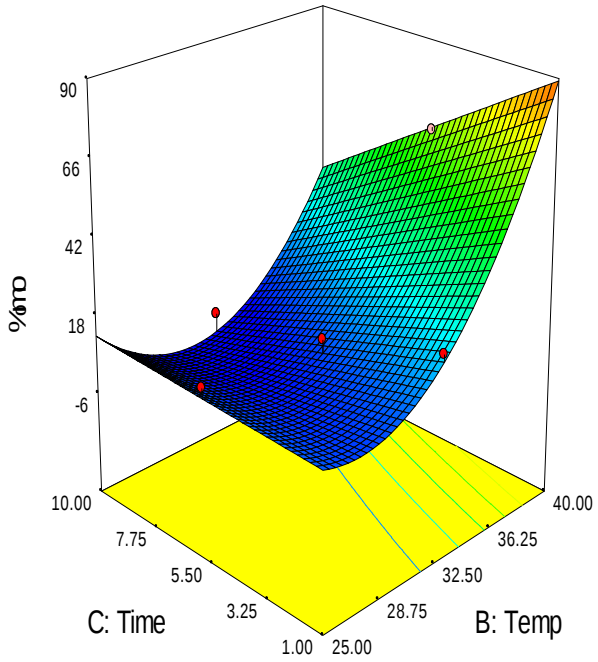




Optimization of process for Molybdenum removal using RSM

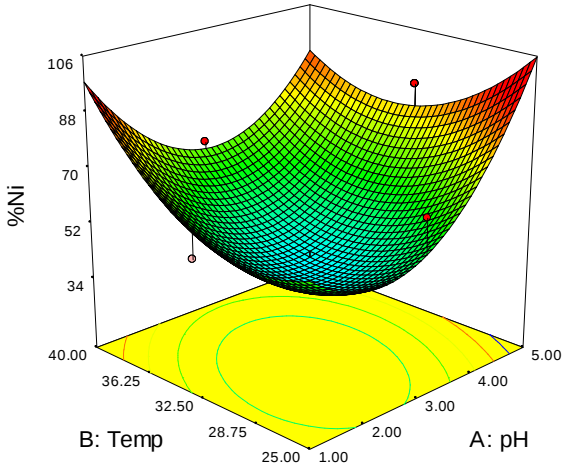
Mo removal (%) = +8.72-7.56* A+25.90* B-12.75* C-7.33* AB-13.05* AC-13.80* BC+4.86* A^2+26.87* B^2+1.98* C^2

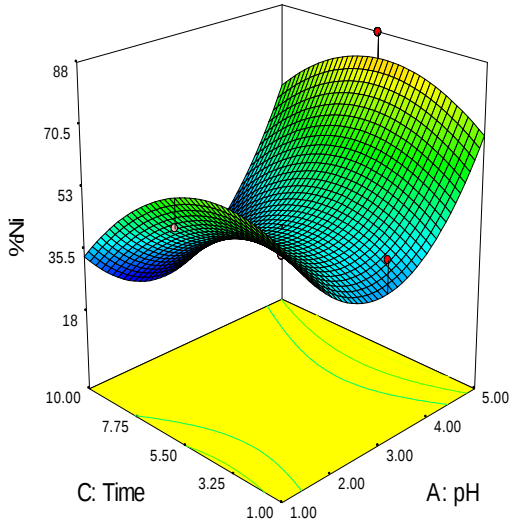


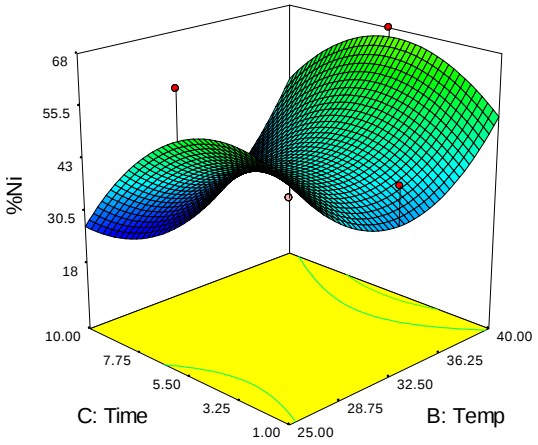


Optimization of process for Nickel removal using RSM

Ni removal (%) = +43.04+9.22*A+5.30*B-7.85*C-13.11*A*B +5.62*A*C+ 5.64*B*C+ 28.18*A²+ 17.51*B²-14.67*C²







Optimum values of different parameters predicted by RSM

Solution No	pH	Temp (°C)	Time (days)	%Cd removal	%Cu removal	%Mo removal	%Ni removal
1	3.0	40.00	4.50	55.59	79.99	66.89	65.84
2	3.0	40.00	5.40	55.48	80.39	66.62	65.86
3	3.0	40.00	6.54	36.38	81.26	11.18	51.34

CONCLUSIONS

- At pH 3, contact time of 5.4 days and at temperature 40°C it is found that optimum leaching of metals i.e Cadmium 55.48%, Copper 80.39%, Molybdenum 66.62% and Nickel 65.86%.
- These results suggest that optimizing the bioleaching method using *Acidithiobacillus ferrooxidans* and *Aspergillus niger* could facilitate the creation of an alternative to conventional waste treatment methods.


Thank
you!!