THE PERFORMANCE OF LEACHING AND BIO-LEACHING FROM SULPHIDE ORES USIING SEVOP

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ABSTRACT. The refractory or low grade copper chalcopyrite ores or galena/sphalerite domestic ores in Republic of Macedonia are investigated by conventional copper flotation and selective flotation for galena/sphalerite. In the meantime, investigations are directed to the new possibilities of leaching by microorganisms – bioleaching. The paper is result of these technologies and investigations carried out for recovery of in the mentioned ores. Using Simplex EVOP and computer programme. Multisimplex the tabular and especially graphic performaces are most acceptable and excellent way for presentation of the leaching and microorganisms – bioleaching.

Keywords: investigation, leaching, bioleaching, SEVOP, Multisimplex, Bucim

INTRODUCTION

Simplex **EVOP** was proposed as an alternative to the original Box **EVOP**. The Simplex requires much less experimentation and reaches the optimum of a process much more quickly. Instead of factorial experimentation, Simplex **EVOP** uses a succession of experimental designs in the form of a regular Simplex.

The regular Simplex is the first-order design which requires the smallest number of experimental points; for *n* factors (*n*-dimensional), (*n*+1) experimental points are required. Thus for two factors the regular Simplex design is an equilateral triangle requiring three points; for three factors the design is a regular tetrahedron requiring four points. As in other forms of **EVOP**, more than three factors can be handled but the designs cannot be shown diagrammatically. Fixing the number of measured intervals of each factor to the unit length of the Simplex side is important for all moves from the initial cycles. The regular Simplex design permits estimation of the first order effects in any number of factors. The direction of steepest ascent leading out of the Simplex is through the side or face (or hyper-plane) opposite the lowest value of response. The deletion of one old point and the introduction of one new point in this most favorable direction of movement leads to the formation of a new Simplex. At each stage regularity is maintained and each new Simplex after the first involves only one new point. The procedure can be repeated indefinitely.

1. Scales for the separate factors should be chosen so that unit change in each is of equal to the experimenter. By a suitable linear transformation of co-ordinates any Simplex can be made "regular" (where "regular" has its usual geometric meaning), so that regularity in a specified co-ordinate system is not essential to the application of the technique.
2. In any Simplex determine the point which gives the least acceptable response, then move into the next Simplex by rejecting this point and replacing it by its mirror image. The factor-value (or co-ordinate) for the new point is given by:

"*Twice the average of the co-ordinates of the common points minus the co-ordinate of the rejected point*"

$2/n\ (A_1+A_2+A_3+\ldots+A_{j-1}+A_{j+1}+\ldots+A_n+A_{n+1})-Aj$

A succession of Simplex moves.

3. When this technique is used on observations which are subject to error it is possible for the system of Simplexes to circle around a spuriously high result, accepting this result as if it were a genuine optimum. To reduce this risk the following rule is applied:

"*If in a Simplex on $_n$ factors an observations has occurred in (n+1) successive Simplexes and then is not eliminated under rule two above, do not move but discard this observation and repeat experimentation at that point*"

If the original observation represent a genuine optimum, the repeat observation also will tend to be high. However, if the original observation is high because of experimental error, it is unlikely that the repeat observation will give so high a result and the point is likely to be eliminated.

4. Spuriously low results cause less trouble as these tend to be eliminated from the system fairly rapidly. In case such results are obtained, the following rule is applied:

"Where the new point in a Simplex has the lowest response, do not return to its mirror image, but move out of the Simplex from the next lowest points".

According to the process observation, the second move made should send the Simplex back to its original position *i.e.* triangle 2 should move to triangle 1.The rules formulated for Simplex do not allow such swings, so instead of dropping the worst observation for Simplex 2, the next worst observation is dropped. This ensures that a completely new Simplex is formed. This procedure will permit the system to circle continuously around an indicated optimum rather than oscillate between very narrow limits.

Advantages of Simplex EVOP

The advantages of Simplex EVOP are:

1. in many processes the optimum tends to move with time.

Responses may indicate a moving optimum even though the true optimum does not change. It is unrealistic, and may be useless, to make process changes on the basis of out-of-date and irrelevant information; only the most recent observations should be used.

2. Simplex provides a rigorous definition of the frequency and extent of the changes to be made. Each move is from one Simplex to the adjacent Simplex. The least acceptable set of operating condition and is replaced by its mirror image in the plane (hyper-plane) of the remaining points.
3. When the real effects are small compared with the observational errors they may be obscured and a false move may be made. As long as the change made is small compared with the changes in the basic design, no great harm will result. In any case, since any decision taken is reviewed and corrected continuously, the greater any adverse effect may be then the more rapidly will it be detected and eliminated.
4. The use of such a precise pattern of experimentation eliminates the need for statistical analysis of the data. The arithmetic involved is trivial and at no stage is it necessary to calculate the direction of steepest ascent. Although this procedure is ideal for control by means of a digital computer, plant supervisors optimizing a process with Simplex **EVOP** are under no disadvantage without a digital computer, an appropriate worksheet can be made.
5. The direction of advance depends only on the ranking of the responses and not on their scalar values. Thus Simplex **EVOP** may be used when a response can be arranged in order of preference for a combination of responses, and the least preferable combination dropped every time.

Disadvantages of Simplex EVOP

The disadvantages of Simplex EVOP are:

1. All factors must be quantitative.
2. In order to minimize wrongful elimination of points due to imprecise measurement of response, either the measurement techniques must be precise, or the Simplex points chosen must be far enough apart to outweigh the imprecision of measurement.

Future techniques development and recoveries of metal bearing ores

Future sustainable development requires measures to reduce the dependence on nonrenewable raw materials and the demand for primary resources. New resources for metals must be developed with the aid of novel technologies, in addition, improvement of already existing mining techniques can result in metal recovery from sources that have not been of economic interest until today. Metal-winning processes based on the activity of microorganisms offer a possibility to obtain metals from mineral resources not accessible by conventional mining. Microbes such as bacteria and fungi convert metal compounds into their water-soluble forms and are biocatalysts of these leaching processes. Additionally, applying microbiological solubilization processes, it is possible to recover metal values from industrial wastes which can serve as secondary raw material.

Generally speaking, bioleaching is a process described as being “the dissolution of metals from their mineral sources by certain naturally occurring microorganisms” or “the use of microorganisms to transform elements so that the elements can be extracted from a material when water is filtered through it”. Worldwide reserves of high-grade ores are diminishing at an alarming rate due to the rapid increase in the demand for metals. However there exist large stockpiles of low and lean grade ores yet to be mined. The problem is that the recovery of metals from low and lean grade ores using conventional techniques is very expensive due to high energy and capital inputs required. Another major problem is environmental costs due to the high level of pollution from these techniques. Environmental standards continue to stiffen, particularly regarding toxic wastes, so costs for ensuring environmental protection will continue

Biotechnology is regarded as one of the most promising and certainly the most solution to these problems, compared to pyro metallurgy or chemical metallurgy. It holds the promise of dramatically reducing the capital costs. It also offers the opportunity to reduce environmental pollution. Biological processes are carried out under mild conditions, usually without addition of toxic chemicals. The products of biological processes end up in aqueous solution which is more amenable to containment and treatment then gaseous waste.

Bacterial leaching is a revolutionary technique used to extract various metals from their ores. Traditional methods of extraction such as roasting and smelting are very energy intensive and require high concentration of elements in ores. Bacterial leaching is possible with low concentrations and requires little energy inputs. The process is environment friendly even while giving extraction yields of over 85-90%.

Occurrence of copper in sulphide and oxide-silicate ores

Chalcopyrite dissolves in ferric chloride solution and the reactions, depending on the ferric concentration, may be simplified as:

$CuFeS_2$+ 4Fe+^{3}= Cu+^{2}+ 5Fe+^{2}+ 2S
$CuFeS_2$+ 3Fe+^{3}= Cu+ + 4Fe+^{2}+ 2S

In the case of pyrite dissolution, the reaction can be expresses as:

$4FeS_2$+ 4Fe+^{3}+ O2 + 2H2O = 8Fe+^{2}+ 4 OH$^-$+ 8S

Elemental sulfur, which is the predominant solid product of the reactions, can account for more than 50% by weight of the leaching residue. An economically successful recovery of sulfur will be a great asset to chloride-based hydrometallurgical processes.

Elemental sulfur produced by hydrometallurgical processes usually contains 50-2000 parts per million of selenium and a lesser amount of tellurium; hence, it is not suitable for many industrial or agricultural uses. If the hydrometallurgical sulfur is to be marketable, selenium and tellurium may have to be removed. Otherwise, the sulfur may be considered as an industrial waste rather than a by-product. Dissolution of the sulfur with solvents such as carbon disulfide, xylenes, and tetrachloro-ethylene followed by evaporation fails to remove selenium and tellurium from the sulfur.

In recent studies, a process to remove selenium and tellurium from sulfur has been developed. In the process, the Se- and Te-containing sulfur was dissolved in an organic solvent such as xylene or tetrachloro-ethylene followed by mixing the solvent with an aqueous solution of a high redox potential. The mixing can be effectively conducted in a mixer-settler unit for a typical solvent extraction operation. Both selenium and tellurium were oxidized in the mixing and thus became very hydrophilic. After the separation of the organic phase from the aqueous phase, sulfur remained in the organic phase and selenium and tellurium in the aqueous phase. A sulfur product with high purity was obtained by crystallization from the organic phase.

Lead sulfate ($PbSO_4$) as an important chemical product can be widely used in white pigment, lead storage battery and so on. [1-2] Fire metallurgy is the process which produce $PbSO_4$ from lead concentrates and electrolysis of the crude lead to produce electrolytic lead, then chemical synthesis [3-5]. Thus, there is serious pollution due to the emission of SO_2 and lead vapor as well as filled dust during processes of the lead metallurgy and electrolysis. These emissions of pollutants not only do harm to the health of operators, but also result in local atmosphere and water pollution. Under the current pressures of strict environmental regulations, seeking much efficient ways to produce $PbSO_4$ is very necessary. Many researches have done extensive work on hydrometallurgical lead production process. The ferric chloride leaching of galena has received considerable attention over the last 20 years or so [6-10]. This process is based on the rapidly of the reaction between $FeCl_3$ and PbS on the predominant formation of elemental sulphur, and on the elevated solubility of $PbCl_2$ in hot concentrated chloride media. It can be found that the methods of hydrometallurgical lead production process mainly involve lead sulfide concentrates leaching in some medium, followed by fused-salt electrolysis to produce electrolytic lead. All mentioned methods lead to the conversion of lead sulfide concentrates to lead sulfate, and to demonstrate the feasibility of realizing a green route to prepare lead sulphate.

On account of the lowest valence state of sulphur in PbS, the insoluble PbS can be transformed into soluble lead salts by strong oxidation of ferric chloride with rapid reaction and the moderate solubility of lead chloride in concentrated chloride media. During this leaching process chloride ion plays an important role, especially in saturated NaCl solution system. Ferric attack of mineral:

$PbS + 2\,Fe^{3+} + 2Cl^- = PbCl_2 + 2Fe^{2+} + S^o$
$PbCl_2 + 2Cl^- = PbCl_4^{2-}$
$PbS + 2\,H^+ + 2Cl^- = PbCl_2 + H_2S$
$2FeCl_3 + H_2S = 2\,FeCl_2 + 2\,H^+ + 2Cl^- + S^o$

The reaction mechanism to prepare $PbSO_4$ with $PbCl_2$ is as follows.

$PbCl_2 + H_2SO_4 = PbSO_4 + 2\,HCl$

The are several factors, affecting the leaching processes, which involve stirring speed, reaction time, and reaction temperature and lixiviant concentration. The maximum leaching rate of $PbCl_2$ from galena concentrate is 98%. The optimum leaching conditions are 250 gr/L NaCl, 75 gr/L $FeCl_3x6H_2O$, o,1 mol/L HCl, 40 min, L/S= 20, pH<2, 1600 r/min.

Leaching of copper minerals (chalcopyrite)

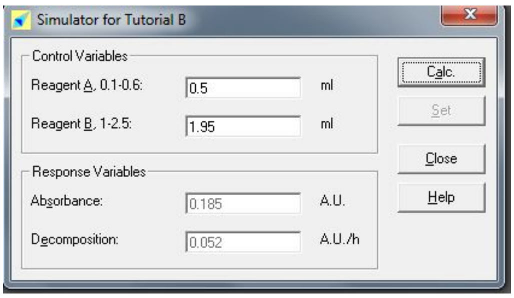


Fig.1 Input parameters

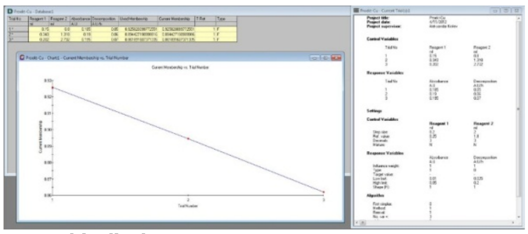


Fig.2 Graphic display

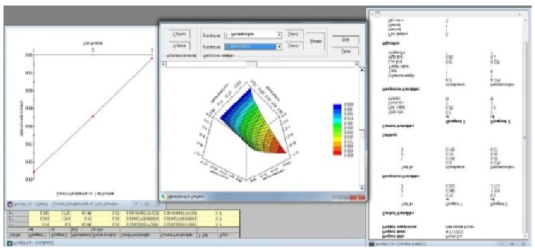
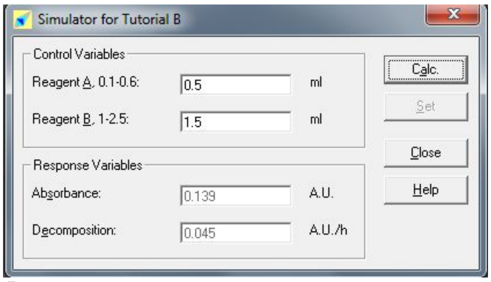


Fig. 3 Graphic display

Bacterial leaching of copper minerals (chalcopyrite)



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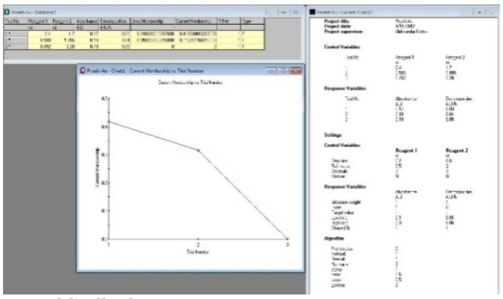

Fig.5 Graphic display

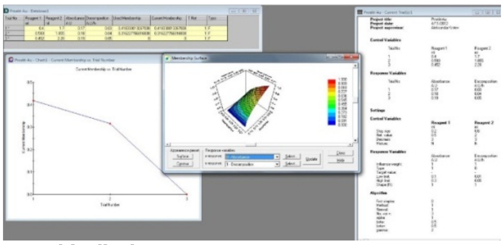

Fig.6 Graphic display

Leaching of lead minerals

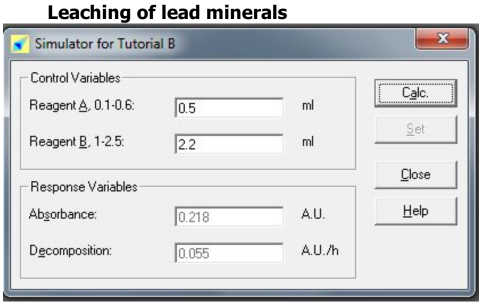

Fig. 7 Input parameters

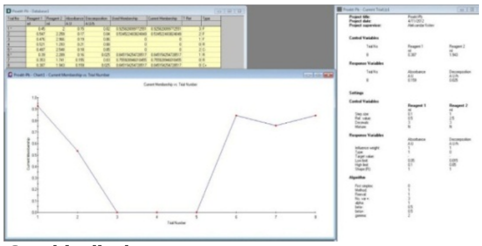

Fig. 8 Graphic display

CONCLUSION

Simplex EVOP was proposed as an alternative to the original Box EVOP. The Simplex requires much less experimentation and reaches the optimum of a process much more quickly. Instead of factorial experimentation, Simplex EVOP uses a succession of experimental designs in the form of a regular Simplex.

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