

Original Article

## Features of the Bioleaching Process under Controlled Mixing of a Solid - Liquid Mixture

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### Abstract

One of the most often used methods in the bioremediation processes of the contaminated soils is the bioleaching. This technology is specific for the land in the neighborhood or within any area of the country run steel companies. Bioleaching as a bacterial leaching/bioextraction is a process in which microorganisms are used to reduce heavy metals: lead, copper, zinc, cadmium, etc. by transforming toxic pollutants in soils in non-toxic compounds, without affecting the environment and/or human health.

**Keywords:** *Acidithiobacillus ferrooxidans*, *Acidithiobacillus thiooxidans*, polluted soils, heavy metals, bioleaching.

### 1. Introduction

The processes of the biological decontamination of the soils rely on the ability of some microorganisms to degrade inorganic matter and to allow the acceleration of the natural decomposition of the inorganic pollutants. Decontamination in a biological, respectively bioleaching, consists in the stimulation of a natural development of microorganisms, in order to accelerate the metabolism of pollutants. To achieve these goals has been developed, designed and built a facility in accordance with principles that define biolixiviere technologies designed in a new vision adequate for the structure, actioning, orders and its kinematics [5].

### 2. Material and Method

Aqueous suspension made for treatment, is composed of soil taken from inside the enclosure SC Romplumb SA Baia-Mare, at a depth of 0 - 10 cm and developed 9K nutrient medium. Aqueous suspension thus formed is in a solid/liquid report 1 : 3. The soil's treatment was performed in the facility designed, performed and described in fig. 1 [5, 6]. The used strain of microorganism is *Acidithiobacillus*. It was taken from Central Flotation Baia Mare and developed in a nutrient medium 9K [2, 3, 4, 5, 6]. The characteristics of the environment 9K used for aqueous suspension are as follows: pH = 1.81, electrical conductivity 281 mV;  $\text{Fe}^{3+} = 5.58 \text{ [mg/L]}$ ,  $240 \cdot 10^6$  microorganisms [5].

#### 2.1. The design and the design structure of the facility

The facility was designed and carried out while finalizing the experiments of the thesis

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entitled "*Contributions to an optimized extraction of heavy metals from polluted soils by bioleaching ex situ*" [5]. From structural point of view, were taken in to account some principles that define bioleaching technologies designed in a new vision. Among them:

- a cylindrical container in which occur "reactions" or "treatments" of bioleaching to be made of other materials than metal;
- the container must have a capacity which can allow the treatment of various amounts of mixture;
- the introduction and the removal of the mixture to be achieved easily, as well as the ways of cleaning the container;
- sampling must be carried out promptly and respecting their homogeneity;
- obtaining a forced oscillatory motion of the exciter (the rocking of a rectangle mechanism) a movement defined in the paper as a swing motion;
- obtaining an oscillatory movement of the excited mixture motions with different parameters from the oscillation of the exciter;
- creating a continuous aeration of the treaty's suspension;
- monitoring the temperature from the container with suspension and the temperature of the heat source which provides the temperature from the container (water tank and the heating resistance), [5, 6, 7] according to mechatronic vision.

**The facility's structure.** From structural point of view, the system has the following three

elements and components: 1 engine, 2 engine support, 3 coupling rod crank, 4 rod coupling beam, 5 rod, 6 rocking rod, 7 water tank, 8 heating tank, 9 motor brackets.

Cylinder-tank is equipped with two holes. The first hole allows the introduction of soil mixture + 9K medium; this whole also allows the access of the interior for introducing the measurement instruments: pH, electrical conductivity and temperature [5, 6].

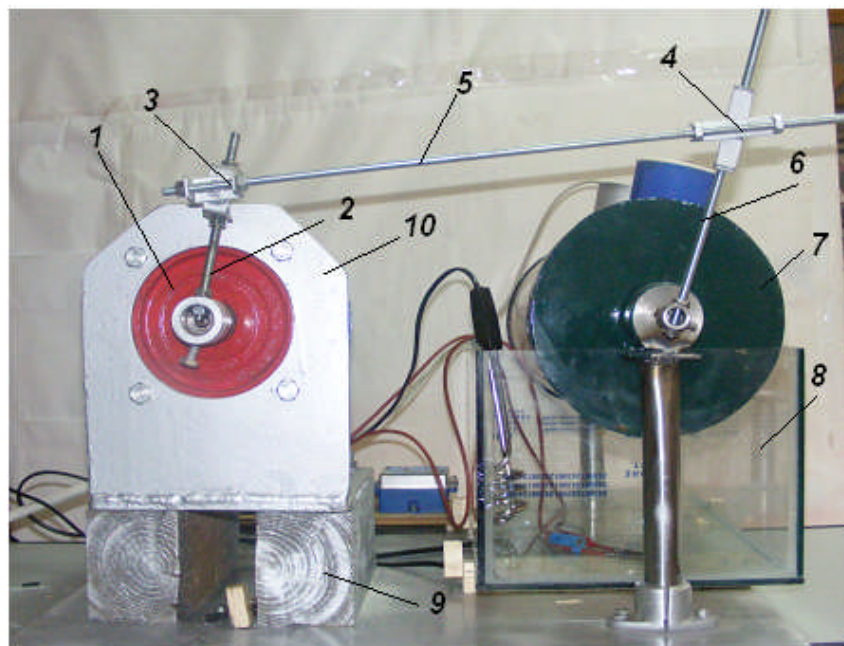
The second hole serves for sampling of the aqueous suspension, and also for the ventilation of the inside space of the cylinder [5, 6].

The cylinder is driven in a rotational movement of "*balance*" through a crank-type mechanism of a rectangular beam. It was considered that the shaking movement by "*balancing*" is better than shaking movement through vibration [5, 6].

To ensure a disruption of the soil and a homogenization of the mixed aqueous solution formed in less time, were introduced two elements of blending/mixing/aeration. Their shape is cubic, and the centers of the faces were mounted protrusions of equal length [5].

The used couplings of the quadrilateral mechanism, [1] allow the amplitude adjustment of the oscillations in the movement of balance. Its structure belongs to the helical couplings class, screw-nut type.

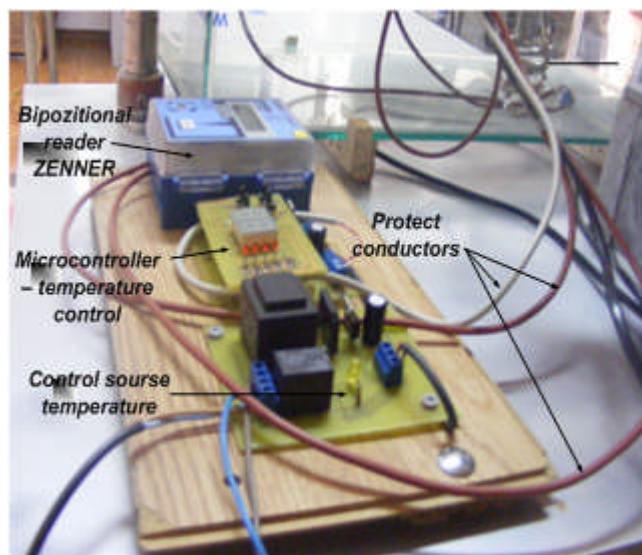
Change of the crank's lengths are possible, the rod, or beam, independently of each other or simultaneously, of all three elements.



**Figure 1.** The image of the created installation [5]

To obtain a rocking movement, the quadrilateral rocking mechanism and its handle should be positioned flush, and the axes of rotation of the gear, and also of the container must also be positioned flush-horizontal [1, 5, 6].

The gear motor is mounted on the support plate through two prisms 9. This alternative design was turned to in order to achieve the above coplanar conditions. In fig. 1, there can be seen these above mentioned details.



**Figure 2.** The structure and the monitoring system of the temperature [5]

In fig. 2 are shown details of the structure the monitoring system of the temperature. Implementation and continuous control of these temperatures are provided by the second unit of the facility's structure [5, 6].

This unit is designed in a variant in which the measuring information, the temperature, is taken through two sensors which are connected to a ZENNER reader multi data S1 with microprocessor, an indicated area of temperature between 0 - 180 °C and the variation  $\Delta t$  between 3 - 150K. The two sensors indicate simultaneously the temperature of the water tank and the temperature of the aqueous suspension in the cylinder tank. This is possible by using a type of by positional ZENNER reader [5, 6].

### 3. Results and Discussions

The variant of ex-situ treatment was conducted over 14 days, with the help of the bacterial strain *Acidithiobacillus* 9K developed in the nutrient medium [2, 3, 4, 5, 7].

During treatment, the aqueous suspension was maintained at a temperature of 35 °C, through the temperature control system, which is part of the

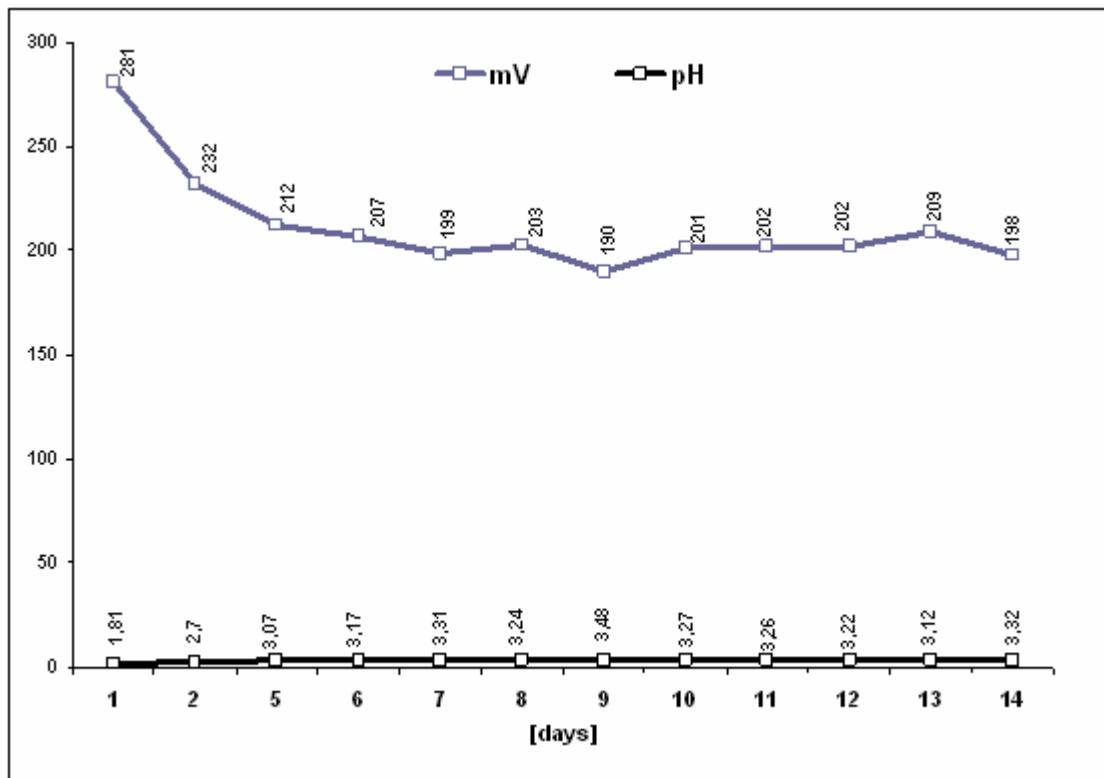
performed and described installation. The first information that has been continuously measured was the pH.

In fig. 3 is presented the variation of pH and electrical conductivity (mV) versus time [5].

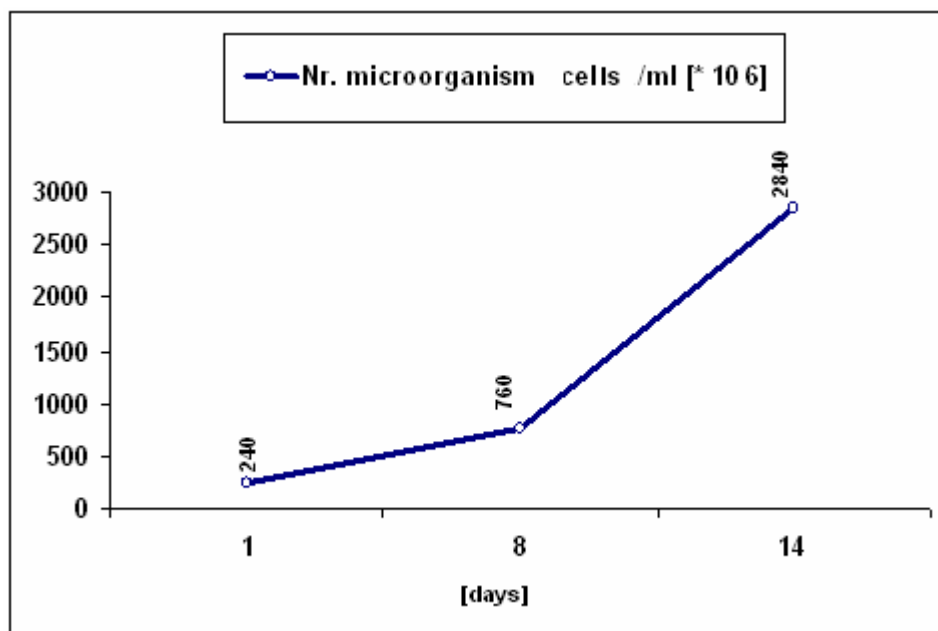
The developed 9K medium, before being introduced into the facility had a pH of 1.81 and electrical conductivity of 281 mV. After being in contact with the soil, the next day it began to increase proportional with time during one week from the beginning treatment.

Throughout the period of treatment, pH values showed insignificant variations, fitting within the optimum interval, development, growth of microorganisms, and in terms of extracting heavy metals from aqueous suspension content. Eh varied depending on pH values during treatment, being inversely to pH. The pH values indicating a less acid character, by increasing its value, the Eh [5] dropped.

Figure 4 shows the variation of other information, the number of microorganisms according to time, which may indicate that the bioreactor, the microbial activity during treatment represented by the number of microorganisms is continuously increasing [5, 6].



**Figure 3.** The variation of pH and electrical conductivity (mV) versus time [5]



**Figure 4.** The variation of microbial activity during soil treatment [5]

Counting the microorganisms during the 14 days as shown in fig. 4, shows a spectacular increase in number, similar to a growth registered on the known facilities over a time period of at least 45 days.

So, from this point of view the designed facility is more efficient [5, 6].

The results regarding the concentration of heavy metals solubilized presented as percentage, fig. 5, over the period of the soil treatment, after 7 days and 14 days in the designed facility are more suggestive when there is a necessary to formulate views about a bigger amount of contaminated or treated soil respectively biodrawn metals [5, 6].

From the analysis of fig. 5, you can specify that the results are significant, with a trend of growth from 7 to 14 days. At the end of treatment, 14 days, the results were approximately double from the values obtained from tests carried out after 7

days of treatment. Analyzing the values after the 14 days, there is an increase of their concentration in the used solution, similar to values recorded after a period of 30 -35 days through the using of known facilities [5, 6].

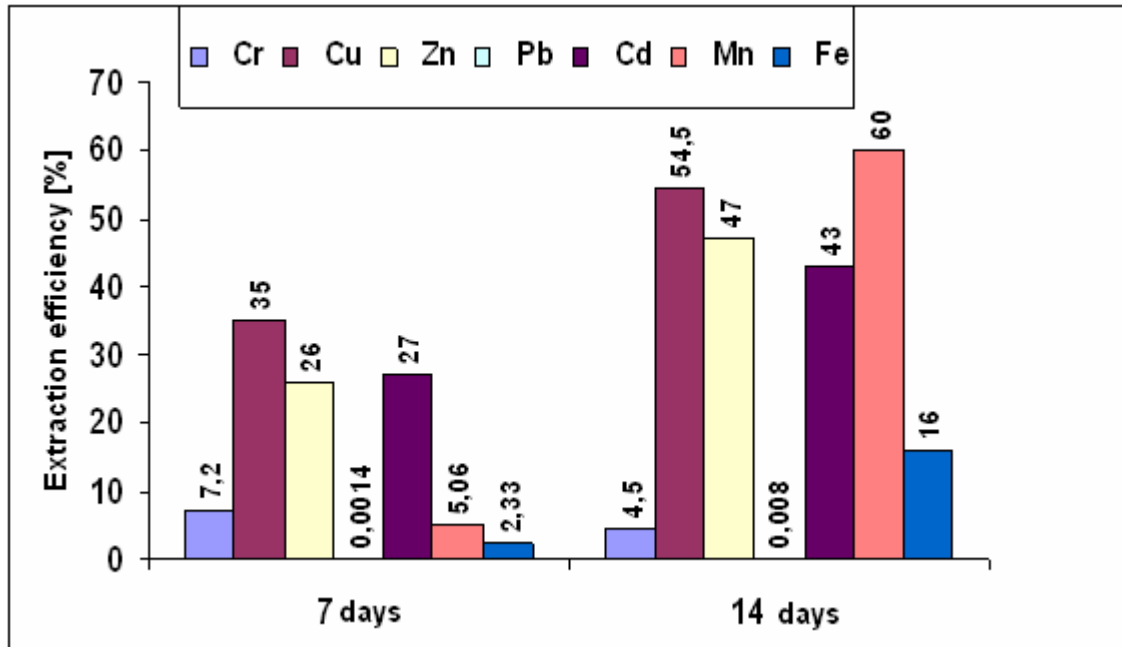


Figure 5. The extraction's efficiency of heavy metals [5]

It may indicate that the most significant extraction yields were obtained by manganese, 60% and 54.5% copper. These are followed by zinc extraction with an efficiency of 47% and cadmium 43%, [5, 6].

The lead presented insignificant extraction efficiency, this being found in a first and very early stage. For example, unlike blend, where zinc is solubilized, the lead from galena is converted to lead sulfate which is insoluble in sulfuric acid solutions, so that the extraction was not possible this way.

Both blend and galena have a balance of sulfuric acid equal to zero, so, as much acid is consumed in the process, the same is issued [5].

#### 4. Conclusions

The conception, design and the development of the biolixiviere facility used as a bioextraction facility, takes into account the interaction between microorganisms from the leaching solution and the existing pollutants from the contaminated soils under various forms and different concentrations

The facility was structured in accordance with the bioextraction mechanisms processes.

In the same time, in the structuring bioextraction facility they took into account a so called development methodology of a system/microclimate of cultivation and development of microorganisms. Such a methodology arose as a consequence of the multiple special research on the diversity of existing and used microorganisms and the diversity of other typostructures of bioleaching facilities.

In order to make a bioleaching facility used like a bioextraction facility has been decided to use a mechanical mobile system, a bar articulated type mechanisms.

In the command and control of the operation of the factors that favors the breeding and growth of microorganisms, was used as a structuring principle, the mechatronic vision in automatique equipment variant.

By changing the vibratory motion of the swing movement, more favorable conditions were created for breeding and numerical development of microorganisms.

In the same time, their ability to "attack" on heavy metals improved.

By introducing a single stimulus element, were substantially improved aeration conditions, so as the mixing ones.

The mechatronic monitoring of the temperature of the mixture had noticeable impact on the conditions that favor accommodation, reproduction and growth of microorganisms.

The most significant extraction yields were achieved by 60% manganese and copper 54.5%. These are followed by zinc extraction efficiency of 47% and cadmium 43%.

The optiomization technique of bioleaching/bioextraction was achieved by changing the type of movement of the mixture homogenization, change which involved introducing a *swing motion* instead of a *traditional vibratory motion*.

## References

- [1] Ardelean I., V.Handraluca, 2000, Sinteza mecanismelor utilajelor tehnologice, Ed. Mediamira, Cluj-Napoca
- [2] Cociorhan Camelia, V. Oros, V. Micle, Ioana Berar (Sur), 2010, Experimental research to optimize parameters the extraction method of heavy metals on bioleaching, Proceedings of the 16<sup>th</sup> International Conference "Building Services, Mechanical and Building Industry Days", Debrecen, Hungary vol. III, 253 – 258
- [3] Cociorhan Camelia, V. Oros, V. Micle, Berar (Sur), Ioana, Coman, Mirela, Taro, G. 2011. Techniques on research aspect of sampling soil contaminated with heavy metals for bioleaching technologies, Ed. Abel Klado, vol. I, 380 – 384, ISSN 1842 – 9815, Cluj-Napoca
- [4] Cociorhan Camelia, V. Micle, V. Oros, Ioana Berar (Sur), 2011, Biosolubilization of Heavy Metals Present in Soils Polluted from Area Romplumb, Baia-Mare, ProEnvironment / ProMediu, Vol. 4, Nr. 7, p 80 – 86, ISSN 2066 – 1363, Cluj-Napoca, [www.proenvironment.ro]
- [5] Cociorhan Camelia, 2011, Contribuții la optimizarea procesului de extracție a metalelor grele din solurile poluate prin biolixiviere ex situ, Teză de doctorat, Universitatea Tehnică, Cluj-Napoca
- [6] Cociorhan C.S., V. Micle, I. Ardelean, 2011, Instalație cu agitare prin balansare pentru bioextracția metalelor grele din solurile poluate, Propunere Brevet de Invenție, Nr. A 00912