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A Review: Mining of Heavy metals from Low-grade ore usingInSitu techniques- Bioleaching and Phytomining

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ABSTRACT
Many different methods of extraction of metal from its ores have been processed using chemicals like cyanide, ammonia, acids and alkali with the drawback of depositing significant quantities of effluent or waste into the environment. To overcome these issues, two different ecological approaches have been applied viz. Bioleaching and Phytomining. Bioleaching is an effective simple technology for the extraction of metals from low-grade ores and mineral concentrates. This phenomenon has the potential to recover metals, detoxify industrial waste products, sewage sludge, and can also beused in the remediation of soil.It is a simple eco-friendly method for the extraction of minerals or heavy metals from mineral wastes and ores when compared to other conventional methods. Several minerals and heavy metals like Copper, Zinc, Gold, Mercury, Uranium, Arsenic, etc. can be mined using this approach. Another effective method for extraction of heavy metal is Phytominingwhere extraction or mining of metals using hyperaccumulators (metal crops). Metals extracted from these high biomass crops producesulphide-free 'bio-ore' and are safely disposable. This method could be applied in degraded or mined land which provides a good economical profit in the extraction of metals via cropping and also increases the level of the plantation. As these two methods have to get explored on a large scale, this review has been designed to describe the extraction of the most important heavy metals like Copper, Nickel, Uranium, and other heavy metals using bioleaching and phytomining.

Keywords: Bioleaching, Heavy metals, Hyperaccumulators, Phytomining

I. INTRODUCTION

Due to rapid growth in the world population, there is an increase in our needs which leads to anincrease in the production of several products by the industries.Although these commodities are producing many different products as a boon there is always a byproduct that accommodates along with it as a curse. For instance, the production of biodiesel with a byproduct of crude glycerol as a waste effluent. In most cases, these byproducts or effluents would be toxic, non-biodegradable, and hazardous to the environment. Upon applying conventional techniques, removal of a toxic compound is ineffective as it requires high cost, large treatment plants, and may produce secondary pollutants [1], [2]. So, to treat and reuse these effluents, many technologies have been revealed. Nowadays, ecologically-based methods have been given more importance. In that aspect, two basic methods like Bioleaching and Phytomining are used for the remediation as well as to extract metals from the waste products or effluents. Generally, the adequate concentration of high-grade ores are required for the extraction of metals by conventional methods like roasting, smelting, etc.,[3] but bioleaching and phytomining emphases on lower grade ores for the extraction ofsome heavy metals like Copper, Zinc, Nickel, Uranium, Chromium,etc.

Heavy metals occur naturally through the processes of weathering of parent materials and anthropogenic sources. Most of the heavy metals became contaminants in the soil and water bodies due to man-made activities. The source of contamination of heavy metal in the environment is through discharging of higher concentrations of waste by the industries [4]. Heavy metals such as Copper (Cu), Nickel (Ni), Uranium (U), Chromium (Cr), Cobalt (Co), Lead (Pb), etc. are useful metal and becomes harmful if its exposure exceeds. Many mining and nuclear industries use these materials as the primary source for the production of nuclear weapons and power.The effluents from these industries are discharged as spent waste

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which contains these hazardous heavy metals in a lesser concentration. To revive the metal from the waste, bioleaching and phytomining processes could be applied instead of engaging with the chemical process. This article emphasizes the recovery of heavy metals from low-grade ores or contaminations using microorganisms and plants.

Bioleaching is an eco-friendly technique that overcomes environmental issues aroused during mining. This method is mostly based on the microorganism's ability in breaking down complex minerals into extractable elements [3], [5]. Bioleaching is a renowned chemical process in which ferric iron and protons are responsible for carrying out the leaching reactions. In this process, the microorganisms generate the leaching chemicals and create a space for the reaction to occur. Typically, when microbes adhere to the surface of minerals or metals, they form an exopolysaccharide (EPS) layer. The production of EPS will be more only when it grows as biofilm not as planktonic cells and within this EPS layer, the bio-oxidation reaction takes place most efficientlywhich leads to leach metals[6]. Microorganisms leach the metals or minerals using three principles such as acidolysis (decomposition of a molecule under the influence of an acid), complexolysis (microbes excretes biogenic agents which solubilizes metal ions through ligand formation), and redoxolysis (oxidation and reduction reaction occurs when setting metals free from minerals) [7], [8]. The efficiency of leaching depends on the chemical composition of the ore and the microorganism that has been chosen. Effectual bacteria provide maximum yield in the extraction of metals. The other basic factors that influence bioleaching are nutrients, oxygen, carbon dioxide, pH, temperature, mineral substrate, heavy metals, and surfactants [9], [10]. Krzanovic states that in modern society, many mining industries have initiated to apply bioleaching technology for accomplishing more profit with fewer investments [11]. Nowadays, e-waste, slag, flyash, and metal sludge are the major pollutants that contain many metals like Mo, V, Ni, Cu, Co, Pb, etc. Among these, some metals are toxic to humans which need to be treated. Direct disposal will lead to the leaching of land or water bodies [12]**.** Currently, hydrometallurgy and pyrometallurgy are being in process to solve this issue but on continuing, these process makes a pavement to a secondary pollutant as these methods have a drawback of releasing acid waste and harmful gas respectively. In contrast, bioleaching spurns the use of acid or base, as it employs only naturally available microbes. Being economic and ecological, bioleaching has been given a major priority among scientific researchers [13].

Phytomining paves the linkage between plants and metals, where high biomass plants are grown for the accumulation of metals from the soil [14]. The process of accumulating defined concentrations of heavy metals by a plant crop is termed hyperaccumulation and a plant that actively participates in this action is termed as hyperaccumulators. Hyperaccumulators can accumulate metals 100 times greater than that of a normal plant [15]. Hyperaccumulators extract metal from the metal-rich soil via root and translocate it to the ground tissues. After growth, the plant is harvested and dried which is reduced to ash with or without energy recovery. It is further treated by roasting or smelting methods, which allow the metals in ash or ore to be recovered by conventional metal refining [16]. Hyperaccumulation occurs in two different ways viz. Natural and Induced. In the natural process, hyperaccumulators normally absorb metal without any other influencing parameters but in the case of an induced process, chelates have been used to induce the mechanism. On the contrary, there is a drawback that excess induction leads to root damage which affects the efficiency of the process. Various chelates such as EDTA (Ethylenediaminetetraacetic acid), HEIDA (Hydroxyethyl iminodiacetic acid), NTA (Nitrolenetriaceticacid), CA (Citric acid), DTPA (Diethylenetriaminepentaacetic acid), EDDS (Ethylenediaminedisuccinicacid), and thiocyanates could be used as an inducer. The usage of EDTA causes ill-effects to plant biomass on growth [2] hence proper practice and handling are needed to incorporate induced hyperaccumulation [17]. For an efficient phytomining process, several parameters have to be optimized which majorly depend on sufficient yield of plant biomass i.e.,hyperaccumulators, soil pH, fertilizers, and chelate [17]. The steps involved in phytomining are as follows: Solubilization of metal from the soil matrix, root absorption and transportation to shoot, and finally involves distribution, detoxification, and sequestration of metal ions. Thus, Bioleaching and Phytomining are the alternative economic in situ process by which the metals could be extracted from the ore or metal-contaminated sites using microorganisms and plants respectively. In this review, the process of recovering heavy metals by the mechanism of bioleaching and phytomining will be described in detail.

II. COPPER (CU)

Copper is a naturallyoccurring metallic

ductile element that occurs in the soil at an average concentration of about 50 parts per million (ppm). The main sources of copper released into the environment include the excavation, smelting and refining, production of various copper-based products such as wire, metal sheets, pipes, and fossil fuel combustion [18]. Since it has good electrical and thermal conductivity it is widely used in the production of electrical and electronic devices. Mostly, after its usage, it is considered as e-waste and discharged as it is to the surrounding but it needs to be disposed of or should be treated for reuse. On looking into this platform, e-wasteisconsidered as a predominant source of producinga higher amount of copper [18], [19], [20]**.** Moreover, it is reported thatoverexposure of copper will leads to chronic liver and kidney problems in humans. So, it needs to be treated before dumping into the atmosphere.To achieve this with better efficiency, bioleaching (Bacteria and Fungi) and phytomining would be the most preferable technology as it executed with less investment.

2.1 Bacterial bioleaching

To leach copper from contaminated sites or their desired ore, chemolithoautotrophs bacteria are commonly used viz. Acidithiobacillus ferrooxidans, Leptospririllium ferrooxidans, Acidithiobacillus thiooxidans,etc.[19] uses carbon dioxide and inorganic compounds as a carbon and energy source respectively. With these energy sources, the dissolution of metals could be facilitated usingbio-oxidants and bioleaching reactions. Generally, bioleaching is done by two different mechanisms(i)Direct bio-oxidation (ii)Indirect bio-oxidation. Most of the researchers prefer indirect bio-oxidation which includes two mechanisms, one is a contact mechanism and another one is a non-contact mechanism. In the view ofthe contact mechanism, the bacteria get to adhere to ore and forms a biofilm in which the oxidation of Fe^{2+} to Fe^{3+} takes place as expressed in equation (1)and the ore is dissolved by Fe^{3+}either by electrolysis or by ion displacement method [21] that can be expressed as equation (2). Biofilm formation is an important step in this mechanism as it produces EPS which acts as a carrier for the leaching mechanism to take place. In a non-contact mechanism, the process of adhesion of bacteria is not necessary as oxidation of ions occurs without any agents, and the oxidized $Fe^{3+}$was used to dissolve the ore.

Indirect copper bioleaching mechanism is presented in the following reaction[22]

$$2Fe^{2+} + 1/2O_2 + 2H^+ \longrightarrow 2Fe^{3+} + H_2O \qquad \ldots\ldots(1)$$

$$2Fe^{3+} + Cu \longrightarrow 2Fe^{2+} + Cu^{2+} \qquad \ldots\ldots(2)$$

In general, the copper dissolution from thee-waste is divided into two phases. In the first phase, bacteria oxidize the ferrous ions to ferric ions and in the second phase, copper is mobilized from the e-waste by ferric ions and is reduced to ferrous ions. Although the process of treating the copper from e-waste has some hitches due to the toxicity it provides a better efficiency when some metal concentrates are blended [23]. Highly oxidizing bacteria and microbial consortia were screened to deplete this e-waste [24], [25]**.**To design the microbial consortia and other factors, statistical tools like response surface methodology have been used for achieving better efficiency [26].

The components of metal present in the e-wastes like printed circuit boards (PCBs) were analyzed by cutting into small pieces and pulverized to make it as a fine particle and it was sieved finally. These particles were subjected to hydraulic sorting for the removal of non-metallic components. The leftover concentrates were dried, digested with aqua regia, cooled, and then finally diluted using deionizing water. The obtained solution or leachate is subjected to ICP-OES for the determination of metallic compounds.

Microorganisms that are used to leach copper from e-waste/ore are listed in table 1. [23],[26], [27], [28].

Name of microbe	Type of microbe	Recovery of copper (%)	Duration required (Day)	Pulp density (g/L)
Mixed culture of Acidophilic bacteria	Mesophiles	96	2	12

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Sulfobacillus thermosulfdooxidans and Thermoplasma acidophilum	Moderately Thermophile	85	165	100
Acidithiobacillus ferrivorans and Acidithiobacillus thiooxidans	Mesophiles	98	7	10
Acidithiobacillus ferrooxidans	Mesophiles	100	20	8.5

Table 1: List of Microbes that extracts copper

For an effective growth of culture, a medium termed 9K was used which contains ammonium sulfate, potassium chloride, magnesium sulfate, ferrous sulfate, and calcium nitrate [19] as chief chemical components at definite concentration. This medium acts as a nutrient or bio-oxidant source by which the microbes oxidize the ferrous ions to ferric ions. Later, the precipitates were removed by filtration to produce a bacteria-free- culture supernatant. To this supernatant, the e-waste or the pulp of 5g/L was added for leaching, as a result, 100% of copper has been dissolved in this solution and was finally extracted by the electrolysis process. But on the contrary, an increase in the concentration of pulp density reduces the yield as the copper affects the bacteria with its toxicity [19]. From this, it could be depicted that the major factor that needs to be taken into account in the bioleaching of copper is the concentration of waste or the pulp density and the type of microorganisms.

2.2 Fungal bioleaching

Bioleaching of copper from black shale ore was performed by using Penicillium notatum with the supplement of organic waste as a substrate. Black shales are thin dark-colored laminated mudstones containing substantial organic matter, silt, iron sulfides, and detrital particles [29], [30]. When compared with other shales, black shales mostlycontain sulfide-forming metals such as Cu, Cr, Mo, U, Ni, Pb, etc., and also some rare earth elements [31]. Various substrates like cane molasses, mango peel, rice bran, and seed cakes are pretreated and used as a nutrient source for the growth of microbe. During its growth, the substrate gets oxidized utilizing microorganism that results in the production of citric, malic, tartaric and other acids. These organic acids play a vital role in the leaching of metals. In the case of copper, glucose as a substrate played a worthy role in leaching the metal on its 33rd day of incubation with an efficiency of 50% [5]. Finally, electrolysis was done with the leachate for the recovery of pure metal.

2.3 Phytomining

Many different varieties of plants have been used as hyperaccumulators but on corresponding to copper, Haumaniastrum, Katangense, and Ipomea alpine are extensively targeted. These plants accumulate around 8356 milligrams of copper for each kilogram of dry matter [32]. Generally, phytoextraction of copper is possible only when the hyperaccumulating plants absorb copper through their roots by natural means as the plants mentioned above. In some cases, to increase the accumulating process, chemicals or chelates were added. For instance, a Helianthus annuus and Kalanchoe serrata has been used as a hyperaccumulator for the extraction of copper. Decisively, the metal uptakingefficiency of plantswas checked by treating them with a combination of chemicals like sodium cyanide, ammonium thiocyanates, ammonium thiosulphate, and thiourea. As a result, H. annuus doubled the extraction efficiency of metals from soil whereas K. serrata does not have any effect on these chemicals [33]. Sequentially, after the accumulation of copper by the root of a plant, they were transported to shoot and these metals are stored in vacuoles by binding with the proteins or acids present in it. After the plant attains perfect growth, it is harvested, dried, and burned. These burnt ashescontain metal soluble compounds which are then dissolved in sulphuric acid to form copper sulfate. From this sulfate, copper is extracted by electrolysis or by displacement with scrap ion by the following equation (3)

$$\text{Iron + Copper Sulphate} \longrightarrow \text{Iron Sulphate + Copper} \quad \ldots\ldots (3)$$

Nickel is a silvery-white strategic metal with dynamic importance in many metallurgical and industrial applications. As nickel has a high thermal resistance and electrical resistance, it is widely used in both ferrous and non-ferrous alloys. Nickel generally occurs in two forms viz. sulfide and oxides where sulfide are high graded ores and oxides are low graded ores. Due to the depletion of high-graded sulfide ores, nowadays more attention has been given to low-graded ores [34]. On account of this, new technologies have to be implemented for the mining of Ni. As bioleaching and phytomining majorly deal with low graded ore, it could be used to achieve the goal with less energy utilization and with an eco-friendly process.

III. BACTERIAL BIOLEACHING

Microorganisms like Acidithiobacillus thiooxidans, Acidithiobacillus ferrooxidans, Sulpholobus spp. Leptospirillum ferrooxidansand thermophilic bacteria including Sulpholobushermosulphidoxidans and Sulpholobusbrierleyi are used for bioleaching the sulfide ores of nickel but nowadays low graded ores of nickel i.e., oxides or laterites are more available than sulfide ores. Upon implementing one of the above-mentioned bacteria, Acidithiobacillus ferrooxidans in leaching oxide ore, it produces better results based on the parameters of incubation time and pulp density. As mentioned earlier this organism was grown in a 9K medium which acts as a bio-oxidant source and facilitates redox reactions with the process following. In this case, the percentage of nickel extraction increases with residence time but does not have any effect with respect to pulp density and it has been stated that the maximum amount of nickel was extracted from the oxide ore when the pulp density is 2% and the residence time is 15 days [34]. Moreover, it is clear from the reports that maintaining the pulp density constant and increasing the residence time exponentially will have a predominant effect on nickel bioleaching.

3.2 Fungal bioleaching

Mostly Aspergillus spp. (Aspergillus niger and Aspergillus humicolaSKP102) are used for the bioleaching of nickel from the chromite mining overburden ore. The former Aspergillus nigerleaches the nickel employingthe culture filtrate method [35]. This method involves the production of organic acids that facilitates the dissolution of the metal. For the growth of the Aspergillus niger, a media has been formulated using Sucrose, yeast extract, Potassium dihydrogen phosphate, and magnesium sulfate and the fungus was allowed to grow. During its growth, the sugar molecules get oxidized and form oxalic acid. Later, it was filtered and the filtrate was taken for future purposes. The roasted chromite ore was added to the filtrate and the acid present dissolute or leaches the metal. As a result, 67% of Ni has been extracted by using 2% of pulp density with a residence time of 21 days. The obtained concentrate is subjected to metal displacement processes to recover the desired metal [36]. Latter one, Aspergillus humicola maintained in Czapek dox medium leaches the metal by three different aspects viz. direct one-step leaching, direct two-step leaching, and indirect leaching. All these processes were incubated for 30 days with a pulp density of 2%. The direct leaching method is operated in batch mode whereas indirect leaching was accomplished by the fungal cell-free supernatant method [37]. Upon analysis of the leachate using atomic absorption spectrophotometer, direct one-step mode operation extracts around 53% of nickel whereas direct two-step and indirect leaching extract 53% and 69 % of nickel respectively which confirms that around 50- 60% of nickel that could be leached using Aspergillus spp.

3.3 Phytomining

The availability of nickel in the soil varies across the region and a very good amount of nickel is available in Ultramafic or serpentine soils where the concentration of Ni ranges from 1000-7000mg/Kg. Extraction of Nickel from these sources has more benefits than acquiring it from ores [14],[38]. Hyperaccumulators such as Alyssum species,Hybanthusfloribundus, Streptanthuspolygaloides, and Berkheyacodii are mostly used for Ni harvest [1], [39]. The very first trial for phytomining was done with the source of ring strain of S. polygaloides which is a species recognized to hyperaccumulate nickel [38], [40], [41]. This strain was grown in the serpentine soil contained a normal range of about 3500 mg/kg Ni. For the total dry biomass of 10,000 kg/ha, about 10,000 mg/kg Ni was obtained. Another variety of hyperaccumulators, Alyssumbertolonii was also used to extract nickel with the provision of some fertilizers for 2 years [16]. It was reported that 8000mg/Kg Ni was obtained with the dry biomass of 9000kg/ha. B. codii was another strain studied for effective extraction of nickel which mines or extract around 121 kg/ha Ni with the biomass of 22000kg/ha and it was reported that B. codii was the most efficient candidate in phytomining of nickel as it has increased biomass [17], [42].

IV. URANIUM (U)

Uranium is the most predominant natural resource used for the generation of nuclear energy and acts as the raw material for the production of uranium [43]. The conventional method of extracting U has some drawbacksof creating secondary pollutants and with the conventional methods, extracting U from low graded ore is a challenging task [10].Hence it is mandatory to switch over our thoughts in an alternative path for recovering the metal with better efficiency and economics. Bioleaching is one of the best methods to extract lower graded ore by using the phenomenon of growing thermophiles in a heavy metal-rich medium. [44]. Moreover,the processing of uranium in the nuclear industry generates more uranium-contaminated waste which has the capability of contaminating the environment [45] as it is left as sludge. These kinds of waste or contaminants could also be treated or remediated by the phenomenon of bioleaching and phytomining.

4.1 Bacterial bioleaching

Although many different bacteria play a major role in the bioleaching of Uranium, Acidithiobacillus spp. namely Acidithiobacillus ferrooxidans, Acidithiobacillus thiooxidansgive a promising efficiency in uranium extraction where these organisms grow with ferrous ion as a sole substrate. Since Acidithiobacillus ferrooxidans was isolated from acid coal drainage, it can sustain in lower grade uranium ore of 1000ppm at a very high temperature. This species differs from other Acidithiobacillus by the fact that even in the absence of oxygen, it can grow on reduced inorganic sulfur compounds with the help of ferric ions as an electron acceptor. Uranium oxidation drags rapidly when the medium is devoid of ferric ions [46]. During the oxidation, U^{+4} ions are converted to U^{+6} ions which were readily soluble in water and the leachate was subjected to precipitation for the recovery of U [47], [48].

4.2 Fungal Bioleaching

Fungal leaching mostly deals with the production of organic acids that acts as a chelating agent for the solubilization of metal ions. So far, many different heavy metals were extracted by two major fungal species viz. Aspergillus and Penicillium[49], [50]. It has been reported that around 80% of uranium was recovered using Aspergillus terreus and Penicillium spinulosum. Many other fungal strains like Cladosporium oxysporum, Aspergillus flavus andCurvulariaclavata recover about 71%, 59%, and 50% ofU from its ore respectively [51].

Apart from the selection of microorganisms, there is also another factor that needs to be optimized is the type or methods of the bioleaching process. There are many types of bioleaching methods which are tabulated as follows:

Methods	Microbes	Type of mechanism	Recovery of metal (%)	References
Bacfox process	Bacteria from Uranium mines (Isolated)	Bacterial film oxidation	50	[52]
Shake flask	Acidithiobacillus spp.	Shaking and Percolation	88-90	[53]
Column bioleaching	Acidithiobacillus spp.	Oxidation, Percolation, Two ore system	84	[53]
Heap bioleaching	Acidithiobacillus ferrooxidans and Acidithiobacillus thiooxidans	Formation of sludge	31.6	[47]

Table 2: Methods of Bioleaching

4.3 Phytomining

Contamination of the environment by U is because of reactor operations, weapon research, waste reprocessing, and some nuclear power plant accidents. These get accumulated in large quantity and exposure to humans causes deadly diseases and renal failure. It is occupied in the land in an enormous amount, remediating or extracting the metal is quite tedious but this could be possible by Phytomining where plants act as hyperaccumulators and take over the metals from the soil by roots and stored in ground tissues. Later on,it could be extracted by converting it into ashes. Initially, it was reported that phytomining could not

be an apt phenomenon for the recovery of Uranium but later some unusual plant species such as Uncinialeptostachya and Coprosma arborea are used as U accumulators which recovered around 3mg/Kg U [54], [55]. For increasing the efficiency of phytoextraction, various tools like genetic engineering, fertilizers, the addition of chelates, and microbial activities were applied [55]. It was revealed that the addition of chelates especially citric acid will escalate the efficiency of the extraction. Apart from the above-mentioned plants, many different hyperaccumulators were also used viz. Indian mustard (Brassica juncea), edible rape (Brassica chinensis), sunflower (Helianthus annuus), andcanola (Brassica napus). Deprived of treatment with chelates these plants showed less extraction whereas the plants treated with citric acid (30mM) showed an increased level of U extraction. Generally, hyperaccumulators can absorb uranyl ions through active or passive transportation as it possesses membrane proteins or cytoplasmic enzymes. Plants having dense roots absorb a high amount of uranium. For instance, terrestrial plants with denser and longer roots are preferred for this process [56].
Other heavy metals that could also be extracted by Bioleaching and Phytomining are tabulated.

Method	Microbes	Metal	Recovery	Reference
BIOLEACHING	Leptospirillum ferrooxidans (Iron-oxidizing bacterium) Acidithiobacillus albertis, Sulfobacillus thermosulfidoxidans, Acetobacter, Acidophilum, Arthrobactor, Pseudomonas, Trichoderma, Penicillium, Aspergillus and Fusarium.	Zinc	84-90% [A]	[57]
			94 % [B]	[26]
		Chromium	19-41% [A]	[58]
			8% [B]	[59]
		Cadmium	80-85% [A]	[57]
			93% [B]	[55]
		Manganese	81-89% [A]	[60]
			78% [B]	[61]
		Lead	55% [A]	[62]
			2.89% [B]	[63]
PHYTOMINING	Thlaspicalaminare	Zinc	10000 mg/Kg	[32]
	Thlaspicaerulescens	Cadmium	3000 mg/kg	
	Macadamia neurophylla	Manganese	55000 mg/Kg	
	Thlaspirotundifolium	Lead	8200 mg/Kg	
	Haumaniastrumroberti Berkheyacoddii	Cobalt	10000 mg/Kg	

Table 3: List of other heavy metals which are extracted by Bioleaching and Phytomining.

Note: 'A' denotes Batch mode and 'B' denotes Continuous mode. The values in phytomining are for 1 kg of biomass.

V. BIOLEACHING VERSUS PHYTOMINING

Although both bioleaching and phytomining are cost-saving, ecological, and deals with low-graded ores it has some advantages and limitations one over the other, where bioleaching needs less time but phytomining needs extended time. Secondary pollutants or harmful gases are produced during phytomining but in the case of bioleaching, there are no gas emissions. Bioleaching does not require a grinding process and it is non-seasonal. Grinding of Plants is necessary for phytomining and is seasonal. Extraction of metals by bioleaching necessitates a lab setup or large area whereas phytomining requires very little space.

VI. CONCLUSION

Bioleaching and Phytomining have numerous benefits over the conventional process as they will not generate any kind of disaster for mankind. The viability of these approaches mainly depends on the category of metal and pulp density. On thinking about the price of an individual metal, every microgram has its definite standard in the market. So, looking keen into this aspect, extracting a small amount of metal from a low graded ore would be beneficial and that too with a simple ecological investment would add a topping to it. This article paves an end to the conventional method of leaching or remediating the metal and concludes that bioleaching and phytomining would be the best tactic to diminish the hazards present in the environment.

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