PHYTOMINING OF GOLD FROM ELSUKARI MINE SOIL [6]

EI-Kassas, H. I.[(1)]; Abd El-Razek, Taha. A. M.[(1)] and Japer, M. H.
1) Institute of Environmental Studies and Researches, Ain Shams University
Ain Shams University

ABSTRACT

The present study aims at using phytomining technology to extract gold from ElSukari soil by Helianthus annuus L plant. This is achieved by adding three solubilizing: ammonium thiocyanate, ammonium thiosulphate and thiourea. 300 kg soil was divided into four treatments(three of these gold solubilizing agents) by 3 kg per pot and 25 pots for each treatment Harvest intervals were 15, 30 and 60 days. Then, the plant parts were subjected to analysis of the concentration of gold using AAS (Flame + graphite furnace spectrometry). The results showed that there is an increase in the absorption of gold by some plants when phytomining is applied to induce gold absorption using Helianthus annuus L. at temperatures conditions ranging from 13.6 - 29.2 ° C, Abu Rawash in Giza government, and pH 7.7of ElSukari soil and containing 1.42 mg kg -1 (ppm) of gold element. At age of 30 days, gold content in root reached up to 8.02, 4.14 and 2.8 ppm for ammonium thiosulphate, thiourea and ammonium thiocyanate treatment respectively. Leaf gold recorded 4.48, 5.65 and 0.3 ppm upon treatment with for ammonium thiosulphate, thiourea and ammonium thiocyanate treatment respectively.

Key words: Gold, Phytoremediation, Mine Soil.

INTRODUCTION

Phytomining is the use of plants and bacteria specialized in the absorption of gold from the soil and its accumulation within the biomass of plants or bacteria and thereafter treating biomass in different ways to produce gold. Phytomining is green technology alternative and more environmentally

friendly and less expensive (Anderson *et al*., 2005 and, Gavrilesc *et al.,* 2009).

Gold is a very precious metal and a chemical element that has the symbol

Au with atomic number 79 and atomic weight 197 with soft and shiny yellow color. It is used in the manufacture of jewelry and gems. Residues in nature in the form of granules inside rocks and riverbeds, or in the form of veins in the ground, and often there is gold with other metals such as copper and lead.It is also among the high density chemical elements as they reach density of 19.5 g / cm3.

Phytomining requires the use of cyanide once only, over a timeframe of minutes, where the purpose of the chemical is to promote sufficient solubility for uptake. Solubility and availability of the metal is one of the key limiting factors for gold phytomining (Piccinin *et al.,* 2007).

These gold solubilizing agents was recently used and reported for solubilization of heavy metals from gold bearing ores (Ebbs *et al.,* 2010).

During phytomining the irrigation with chemical is designed to mitigate the potential for leaching of the chemical and gold out of the root zone.

Nowack *et al.,* (2006). suggested that much discussion has been made on the environmental consequences of using the chemical EDTA during phytoextraction.

Thus, phytomining for gold solubilizing could be considered as an economically viable and environmentally sustainable technology that might operate alongside conventional technology at operating mining sites, or alone at legacy sites.

Further research is needed at the physiological and biochemical level for optimization of the process, greater understanding of how plants absorb, translocate and metabolize gold. Identification of genes responsible for gold uptake,needs further inveatigation.

The plants used for induced hyperaccumulation do not have to be exotic species.

ElSukari mine is a huge ore located in the Nubian Desert (part of the Eastern Desert), 30 km from the city of Marsa Alam .

The aim of this work is to investigate the solubilizing agents behavior of gold using Helianthus sp. with the aid of some solubilizing agents i.e ammonium thiosulphate, ammonium thiocyanate and thiourea.

MATERIAL AND METHODS

Soil used for plant growth: 300 kgm grounded rock from elsukari area (Gazelle zone) were been grinding.

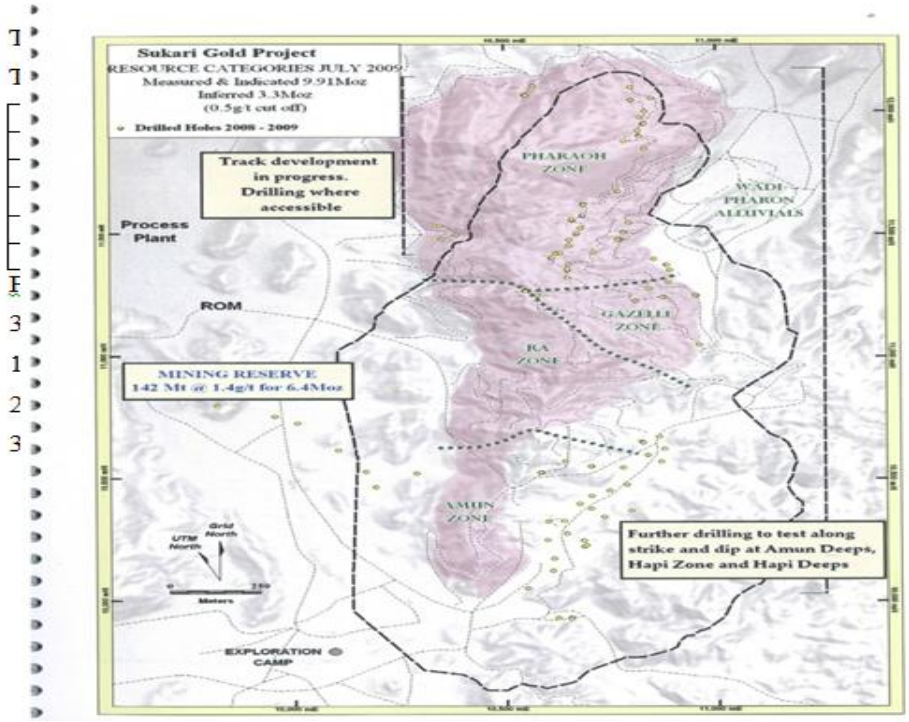

Fig.(1): Location of El Sukari mine (Resource Categories july, 2009).

The Chemical and physical characteristics of this soil are shown in table 1.

Table(1): Physico-chemical characteristics of the El Sukari soil.

Au	1.42	ppm
pH	7.70	–
CaO	4.1	%
Organic matter	1.0	%
CaCo3	6.45	%
L.O.i	3.52	%

Field trials for gold phytomining. 300 kg soil was divided to four treatment.

1 The first treatment with Ammonium thiocyanate from No. 1-26

2 The second treatment with Ammonium thiosulphate from No. 27-50

3 Third treatment with Thiourea from No. 51-74

Table(1-a): Some physical and chemical characteristics of the soil before planting.

pH	EC dS /m-1)(	CaCO3 %	CaO %	L.O.I % %	O.M %	Particle size distribution %			Textural class
						Sand	Silt	Clay	
7.7	0.97	6.45	4.1	3.52	1.0	76.8	8	15.2	Loamy sand

L.O.I = Limiting Oxygen Index.

Table (1-b): Au in soil (mg Kg -1)

Element	concentration
Au	1.42

Table (2): The values of pH and EC in soil after irrigation .

Treatment	pH	EC dS /m-1)(
Ammonium thiocyanate	7.4	0.4
Ammonium thiosulphate	7.35	0.94
Thiourea	7.39	0.66

Table (3): Effect of dryness in plant at age 15, 30 and 60 days.

Part of plants	Periods (days)	Ammonium thiocyanate			Ammonium thiosulphate			Thiourea		
		Fresh	Dry	Dec. %	Fresh	Dry	Dec. %	Fresh	Dry	Dec. %
Root	15 days	2.27	0.3	10.94	1.18	0.24	19.15	1.95	0.46	21.63
Stem		6.03	3.0	43.72	10.38	5.03	38.07	8.69	3.74	34.34
Leaves		4.27	1.36	27.58	6.42	3.05	41.08	5.46	2.08	32.63
Root	30 days	0.437	0.286	65.00	0.773	0.486	62.09	1.394	1.149	81.03
Stem		2.511	1.589	60.77	2.453	1.055	40.55	3.580	2.941	78.57
Leaves		2.875	1.182	38.23	3.907	1.939	45.72	4.715	3.579	71.19
Root	60 days	1.79	0.66	35.08	1.72	0.60	33.16	3.75	1.151	26.94
Stem		4.17	0.67	11.89	2.55	0.63	22.15	7.7	1.11	6.71
Leaves		5.49	1.24	17.09	5.33	1.07	14.74	9.96	1.95	9.61

*Dec.= Decrease% = (fresh weight - dry weight) / fresh weight x 100

Field trials for gold phytomining: 300 kg soil was divided to four treatments as follows:

1 -The first treatment : ammonium thiocyanate from No. 1-26

2 -The second treatment: ammonium thiosuphate from No. 27-50

3-Third treatment :Thiourea from No. 51-74

4-Four treatment : Control from No. 75-100

plants were harvested at intervals of 15, 30 and 60 days The pots were fertilized with chemical fertilizers (N–P–K) at a rate of 1 gram hybrid SB / liter of water. The plants were cultivated for 60 days in a greenhouse at temperature range of 14–29 o C . At the end of the 60 days growth period, each pot was assigned one of four treatments.

Treatment application rates in moles of chemical per kg of soil and grams of chemical per kg of soil are presented in Table 4.

Table(4): Treatment rates applied to Helianthus annuus L growing in El Sukari Soil.

Chemical	Treatment rate (mol kg -1)	Treatment rate (g kg -1)
NH4SCN	0.0140	1.24
(NH4)2S2O3	0.0312	2.00
SC(NH)2	0.0002	0.03

Note: all treatments were applied to pots as 150 mL of solution.

A dose of 2 g kg -1 of (NH4)2S2O3 was reported in a greenhouse study (Msuya et al., 2000). Finally, the dose of SC (NH2)2 used in this study is equivalent to double the dose used and reported by Rodriguez et al. (2006).

After harvesting, plant samples were dried at 70o C par 12 h and then milled.

Chemical Analysis: Gold analysis was conducted in the Ministry of Petroleum and Mineral Resources (the central laboratories sector) as follows. The following steps were performed on each of the root, stem or leaves

1 -The root was dried in the dryer for 12 hours at a temperature of 70 ° C.

2 - The root was weighted after drying

3 - The sample was dissolved in 100 ml (aqua ragia) mixture of nitric acid and hydrochloric acid (3:1).

4 - The sample was left on the heater for 15 minutes until brown fumes

5 - The sample was transferred in 100 ml Flask then shaked well.

6 - The sample was measured by the atomic absorption device Flame Atomic Absorption Spectrophotometer using this device to perform quantitative analysis of element percentages or as parts of a million (p p m) for gold

7 - A standard solutions curve was applied according to the following law : (ɤ × V) / W

Where V = volume of Flask

Where ɤ = read the device

Where W = sample weight

Johnr et al.(1999).

RESULTS AND DISCUSSION

Pots experiment: The gold concentration in Helianthus annuusL harvested plant i.e. the leaves, stems, and roots of control and chemically treated soils are presented in Tables (5,6,7,and 8).

Table(5): Gold concentration (ppm) in H.annusL plants after 15,30 and 60 days with Ammonium thiocyanate treatment.

Plant growth period	Ammonium thiocyanate		
	Root	Stem	Leaves
15 day	0.01	0.01	0.006
30 day	2.8	0.3	5.77
60 day	N.D	N.D	N.D

*N.D = Not detected

Table(6): Gold concentration (ppm) in H.annusL plants after 15, 30 and 60 days with Ammonium thiosulphate treatment

Plant growth period	Ammonium thiosulphate		
	Root	Stem	Leaves
15 day	0.01	0.006	0.006
30 day	8.02	4.48	5.92
60 day	N.D	N.D	N.D

*N.D = Not detected

Table(7): Gold concentration (ppm) in H.annusL plants after 15 ,30 and 60 days with thiourea treatment.

Plant growth period	Thiourea		
	Root	**Stem**	**Leaves**
15 day	N.D	0.008	0.01
30 day	4.14	2.65	3.27
60 day	N.D	N.D	N.D

*N.D = Not detected

Table(8): Gold concentration in soil after 30 and 60 days.

Detection time	Gold concentration (ppm)
30 day	1
60 day	0.54

Ammonium thiosulphate increased the gold concentration in plant parts, however the results were very variable.

This may reflect a non homogenous distribution of gold in the soil, and uneven distribution of the soluble gold Ammonium thiosulphate throughout the root zone of the plants. The maximum gold concentration recorded was 8.2 mg/kg for the roots, 4.48 mg kg -1 for stem, and 5.92 mg kg -1 for leaves after 30 days.

The maximum gold values recorded for this pots experiment were slightly lower than those recorded by Anderson et al. (2005), during their field experiment in Brazil where the plant species Brassica junica and Zea mays were tested for their ability to absorb mobilized gold after cyanide and thiocyanate treatment. Brassica juncea showed the best ability to concentrate gold giving an average of 39 mg kg -1 after sodium cyanide treatment.

The amount of gold adsorption, qt (mg Au/g) was computed according to the following equation: $qt = \frac{(Ci - Ct)\ W}{W}$

Where Ci and Ct are the concentrations of gold in solution (mg/L) at initial time and at time t, respectively; V, the volume of solution (mL) and W, the dosage of sorbent used (mg).

The influence of microbial activity on the gold solubilization depends on the ability of the microorganisms to promote gold oxidation and to excrete ligands capable of stabilizing the resulting gold ions by forming complexes or colloids (Reith and Mo phail., 2007).

While half the helianthus annuus L plnats were dead a 40 days after treatment: it is important to note that dead plants, as live plants provided no biomass is lost. In the case of gold phytomining this may even be advantageous as it would be known that maximum gold uptake had occurred and would eliminate the need to dry the tissue prior to recovery of the gold.

The highest average and maximum concentration was achieved using thiosulphate, followed by thiocyanate. The average gold concentration of the plants treated with cyanide was the same as for the control. This is due to the relevant gold complexes being stable under different geochemical conditions (Anderson,*etal*, 2005).

Thiocyanate, however, was the first chemical used to induce gold uptake in plants. But in later years, researchers have focused on cyanide, as this chemical is actually less toxic to plants.

Gold phytomining can be improved by the discovery of fast growing plants with high biomass and ability to accumulate high concentration of gold

in the harvestable parts. The cheap methodology of recovery of gold from plant biomass is also an area of research.

The true potential of the phytomining is yet to be established, it requires integrated multidisciplinary research efforts that combine plant biology, genetic engineering, soil chemistry and soil microbiology, as well as agricultural and environmental engineering. Phytomining of gold is a 'green' approach to the environmentally sensitive and energy intensive practice of mining, involving the use of selective plants to extract valuable metals from both solid and liquid substrates.

It is a viable alternative or supplementary to conventional mining methods of low grade gold ore bodies' soil.

Typical feedstocks for a phytomine are metalliferous sites with low metal content that cannot be economically mined using conventional technology or sites with high metal content that possess significant risk to the environment due to anthropogenic activities.

The process improves the quality of the soil for postmining applications over the duration of phytomining. Removal of metals and the increased fertility of the land that results from improved management practices are the two key benefits of phytomining.

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التعدين النباتي للذهب من تربة منجم السكري

[٦]

هشام إبراهيم القصاص[١]– طه عبد العظيم محمد عبد الرازق[١]– محمد حسن جابر

١) معهد الدراسات والبحوث البيئية، جامعة عين شمس

المستخلص

تهدف هذه الدراسة إلى استخدام تقنية التعدين النباتي في استخلاص الذهب من تربة منجم السكري بواسطة نبات دوار الشمس بإضافة ثلاث مواد عامل إذابة هي (ثيوسيانات الامونيوم – ثيو سلفات الامونيوم – ثيويوريا) .

أوضحت النتائج أن هناك زيادة في امتصاص الذهب بواسطة دوار الشمس عندما يتم تطبيق تقنية التعدين بالنبات للحث على امتصاص الذهب حيث تم استخدام نبات دوار الشمس في ظروف درجات حرارة تتراوح بين ١٣،٦ – ٢٩،٢ درجة مئوية بمنطقة أبو رواش التابعة لمحافظة الجيزة ودرجة حموضة ٧,٧ لتربة المنجم والتي تحتوى على ١،٤٢ مليجرام / كجم (جزء في المليون) من عنصر الذهب حيث تم توزيع كمية تربة المنجم المتحصل عليها ٣٠٠ كجم / تربة على ٤ معاملات بواقع ٣ كجم / تربة لكل أصيص والمعاملة الواحدة تحتوى على ٢٥ كيس على النحو الاتى . على فترات حصاد ١٥، ٣٠ ،٦٠ يوم وتم إجراء التحليل لتركيز الذهب في المعامل المركزية لوزارة البترول والثروة المعدنية باستخدام التحليل الناري لتقدير الذهب باستخدام جهاز الامتصاص الذرى أ.أ (لهبي+ فرن احتراق جرافيتي).

أظهرت النتائج في معظم الحالات أن تركيزات الذهب كانت أعلى في الجذور مما كانت عليه في باقي أجزاء النبات كما وجد ان تركيز الذهب عن المعاملة بثيوسيانات الامونيوم وثيوسلفات الامونيوم والثيويوريا هى :

١ – الجذور:٠,٠١ جزء في المليون ، ٠,٠١ جزء في المليون، صفر على الترتيب عند عمر١٥ يوم. ٢,٨ جزء فى المليون، ٨,٠٢ جزء فى المليون ،٤,١٤ جزء فى المليون على الترتيب عند عمر ٣٠ يوم.

٢ – الأوراق: ٠,٠٠٦ جزء في المليون ،٠,٠٠٦ جزء في المليون ،٠١. ٠ جزء في المليون على الترتيب عند عمر ١٥ يوم . ٥,٧٧ جزء في المليون،٥,٩٢ جزء في المليون،٣,٢٧ جزء في المليون على الترتيب عند عمر ٣٠ يوم.

٣ – السيقان : ٠,٠١ جزء في المليون ، ٠,٠٠٦ جزء في المليون ، ٠,٠٠٨ جزء في المليون على الترتيب عند عمر ١٥ يوم .

٠,٣جزء في المليون ، ٤,٤٨ جزء في المليون ، ٢,٦٥ جزء في المليون على الترتيب عند عمر٣٠ يوم – عمر ٦٠ يوم في الثلاث معاملات صفر .