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(54) **DRAINAGE AID FOR METAL HEAP LEACHING**

(76) Inventor: **Paul Burgmayer**, Wayne, PA (US)

Correspondence Address:
WEGMAN, HESSLER & VANDERBURG
6055 ROCKSIDE WOODS BOULEVARD
SUITE 200
CLEVELAND, OH 44131 (US)

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(57) **ABSTRACT**

Methods for increasing drainage or percolation of a lixiviant solution through mineral ore in a heap mining operation. A drainage aid comprising ethoxylated aliphatic primary alcohols and mixtures thereof is dripped, sprayed or otherwise brought into contact with the heaped metal ore aggregate and thereby improves percolation or drainage of the lixiviant through the heaped metal ore.

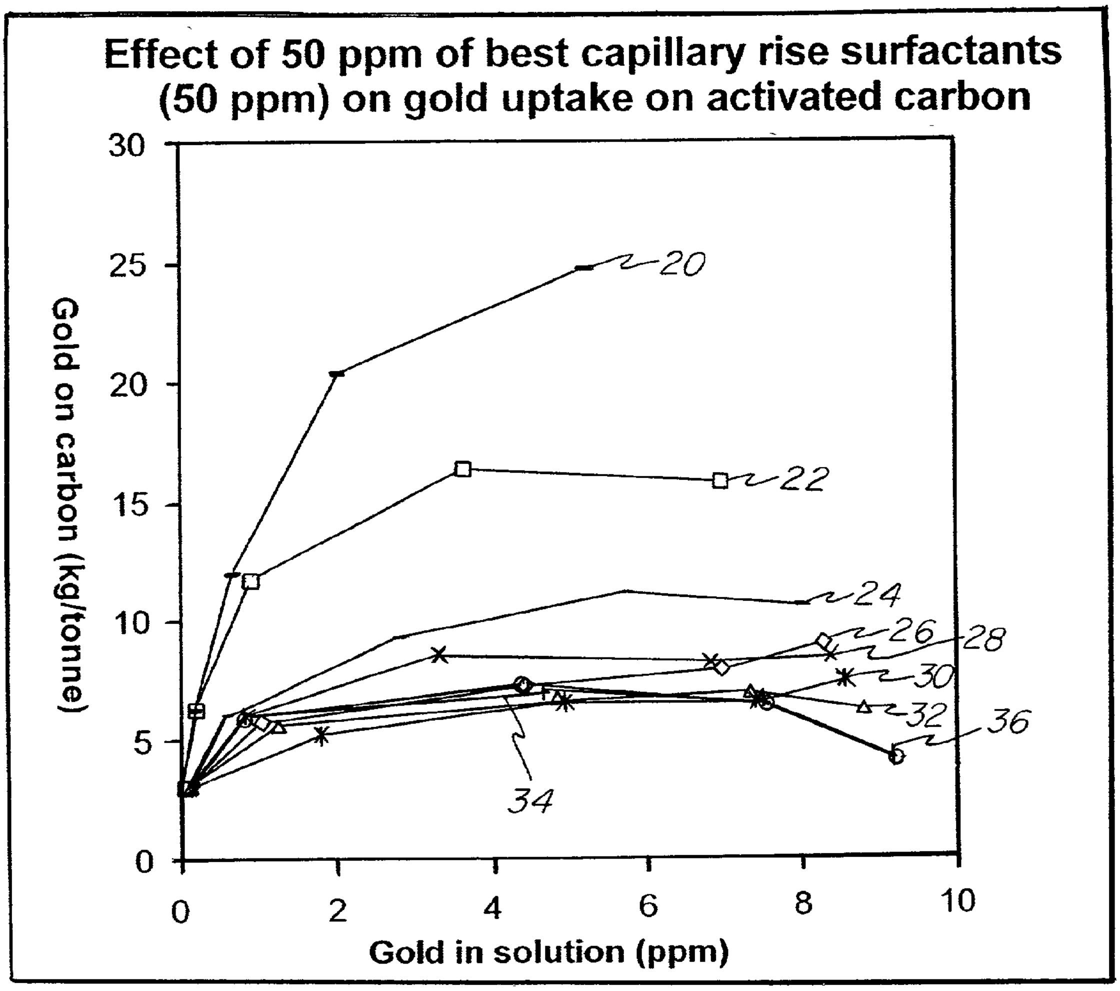


FIG-1

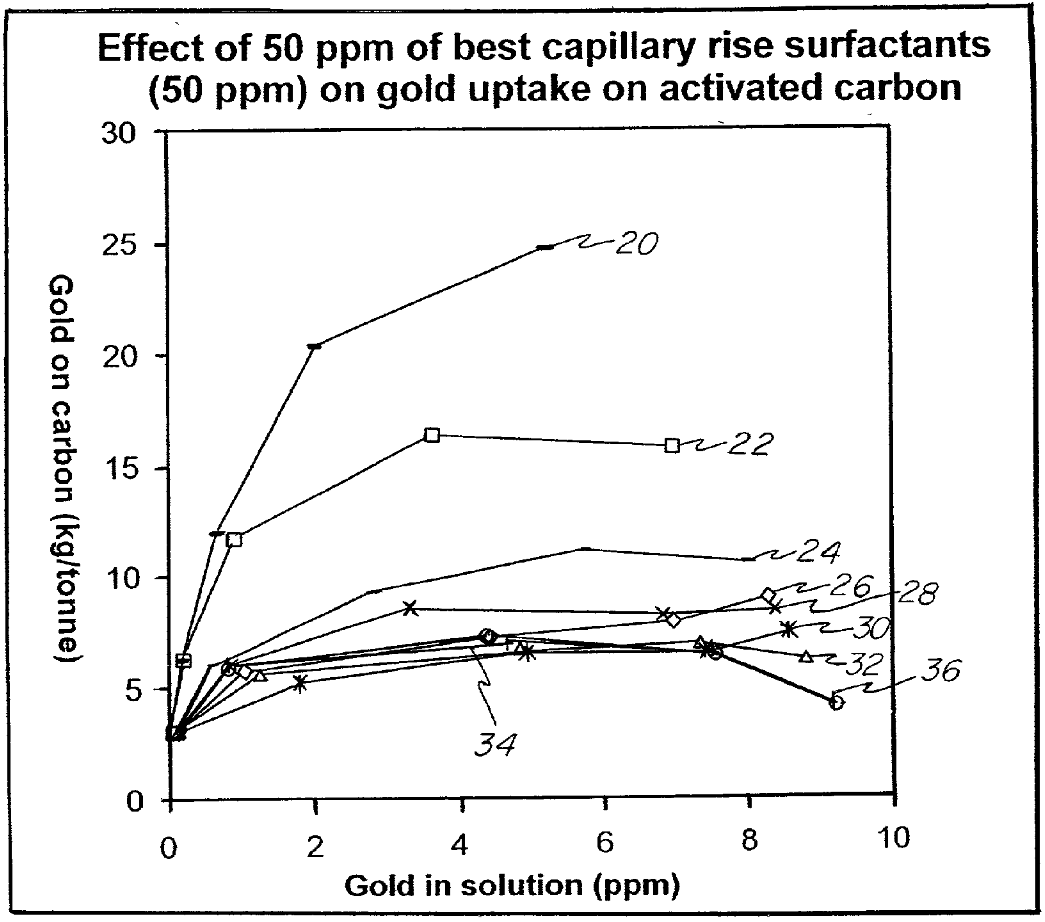
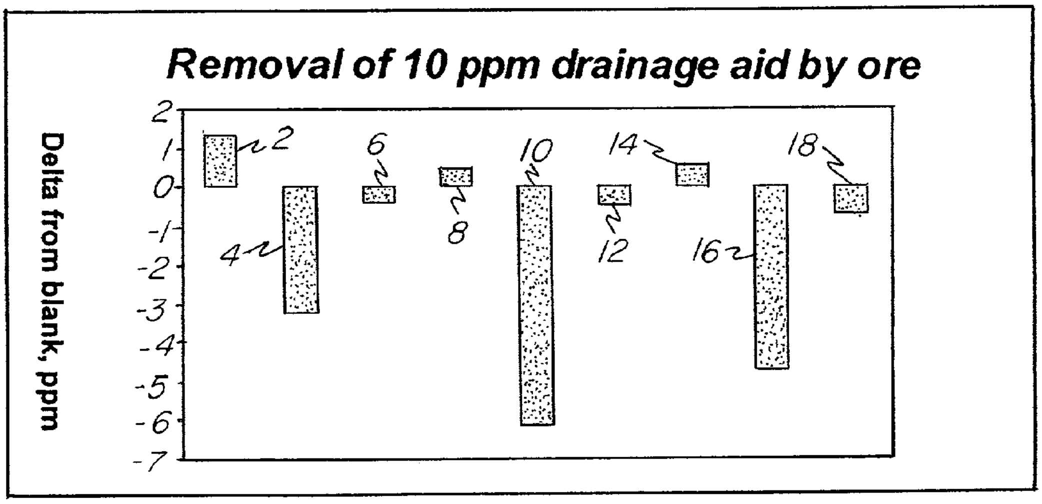

Effect of 50 ppm of best capillary rise surfactants (50 ppm) on gold uptake on activated carbon
Gold on carbon (kg/tonne)
30
25
20
15
10
5
0
0
2
4
6
8
10
Gold in solution (ppm)
20
22
24
26
28
30
32
34
36

FIG-2


Removal of 10 ppm drainage aid by ore
Delta from blank, ppm
2
1
0
-1
-2
-3
-4
-5
-6
-7
2
4
6
8
10
12
14
16
18

DRAINAGE AID FOR METAL HEAP LEACHING

FIELD OF THE INVENTION

[0001] The present application relates to an improved process for leaching of metal from ore heaps in which a lixiviant solution is brought into contact with the ore to form a "pregnant" solution, from which the metal is ultimately separated. The improvement lies in contacting the metal ore with an ethoxylated aliphatic alcohol to improve percolation of the lixiviant through the heap.

BACKGROUND OF THE INVENTION

[0002] In recent years, heap leaching has become a cost effective method for recovering precious metals such as gold or silver from low grade ores. In the process, a lixiviant system, comprising a ligant and an oxidant is used to dissolve out the desired precious metal from the ore. As used herein, the phrases "lixiviant system" and "lixiviant solution" will be used interchangeably and do not imply a true chemical solution—only a chemical combination adapted to extract the mineral value in the ore.

[0003] In heap leaching, the metal bearing ore may be obtained from an open pit mine or the like and is crushed to produce an aggregate that is coarse enough to expose the desired mineral values but fine enough to allow intimate contact of the lixiviant system or solution therewith. The lixiviant solution may be distributed over the top of the metal ore heap via sprinklers, wobblers, or other similar equipment. The barren lixiviant "percolates" through the heap to perform its desired function with the metal and the resulting pregnant solution is then collected by an impervious leach pad or the like located at the bottom of the heap. The pregnant solution is then subjected to conventional mineral recovery techniques to obtain the desired precious metal.

[0004] In gold heap mining operations, a lixiviant system comprising cyanide, air and lime is commonly used under highly alkaline conditions (pH 9-11.5) to form the pregnant solution, (i.e., a complex or ligand coordinated with a gold cation). The gold cation complex or ligand leaches from the ore heap and is recovered. The gold is then separated from the lixiviant complex via conventional separation techniques such as the conventional method of adsorption on an activated carbon column or bed.

[0005] A variety of factors can contribute to poor percolation of the lixiviant through the heap. For example, high clay ores, the formation of large rock fragments and the formation of surface muds or slimes on the heap can be detrimental to the desired percolation through and contact of the ore with the lixiviant solution.

[0006] It is therefore desirable to provide a treatment that can enhance the percolation or contact of the ore with lixiviant solution so as to increase the amount of precious metal recovered per unit area of the metal ore heap.

[0007] It is especially desirable to provide such a percolation or drainage aid that does not severely impede the functioning of desired process parameters such as the ability of the lixiviant solution to react or complex with the ore, or the ability of the pregnant lixiviant solution to drain through the heap for recovery.

SUMMARY OF THE INVENTION

[0008] The present invention is directed to a drainage aid useful in heap mining operations. More preferably, the invention is directed toward precious metal heap leaching operations such as gold heap leaching. The drainage aid can be applied by itself to the heap or it can be mixed with the lixiviant solution and then sprayed or dripped onto the ore to thereby contact the ore.

[0009] The drainage aid is preferably applied in an aqueous solution via drip or spray application and is present in the aqueous solution in an amount of between about 1-1,000 ppm. The drainage aid is an ethoxylated aliphatic primary alcohol having a carbon chain length of from about C_4-C_{20} and about 2-20 moles of ethoxylation per molecule.

[0010] The invention will be further described in the following detailed description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] **FIG. 1** is a graph showing the results of activated carbon gold uptake tests reported in Example 4; and

[0012] **FIG. 2** is a bar graph illustrating the tests reported in Example 5 showing the uptake of the drainage aids by gold ore.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0013] The drainage aids in accordance with the invention are ethoxylated aliphatic alcohols having the formula

$$HO\text{-}[CH_2CH_2\text{—}O]_n\text{-}R$$

[0014] wherein R is C_4-C_{20} alkyl or C_4-C_{20} alkenyl with n being about 2 to 20. More preferably, R is C_4-C_{14} alkyl or C_4-C_{14} alkenyl and n is about 3 to 8.

[0015] Preferably, the drainage aid is applied to the metal ore in the form of an aqueous solution with the drainage aid present in an amount of about 1-1,000 preferred, about 1-500 ppm active more preferred, and 1-100 ppm most preferred.

[0016] The ethoxylated aliphatic alcohols are commercially available from a plurality of suppliers. Based upon presently available data, the following four commercially available products appear to be especially effective.

Description	McCutcheon description	Analysis results
Ethoxylated aliphatic alcohol	Isodecyl alcohol ethoxylate	A heavily branched ethoxylated aliphatic alcohol. The average carbon chain length is 7.3 C's/molecule. The average ethoxylation is 4.5 moles/molecule
Ethoxylated aliphatic alcohol	2-decylethoxy poly(ethyleneoxy) ethanol	a heavily branched ethoxylated aliphatic alcohol. The average carbon chain length is 6.7 C's/molecule. The average ethoxylation is 5.3 moles/molecule
Ethoxylated aliphatic alcohol	Ethoxylated 2-decanol	a heavily branched alcohol 1 ethoxylated aliphatic alcohol. The average carbon chain length is 10.5 C's molecule. The ethoxylation is 3.5 moles/molecule
Ethoxylated aliphatic	Ethoxylated alcohol	a straight chain ethoxylated aliphatic alcohol. The average carbon chain

-continued

Description	McCutcheon description	Analysis results
alcohol		length is 12.2 C's/molecule. The average ethoxylation is 4.0 moles/molecule

[**0017**] At present, the most preferred treatment is the 2-decylethoxy poly (ethyleneoxy) ethanol.

EXAMPLES

[**0018**] The invention will be further explained in conjunction with the following illustrative examples which should not be construed as a limitation on the inventive concepts set forth herein

[**0019**] A drainage aids for heap leaching must have certain desirable characteristics and not have some undesirable characteristics. Five tests proving these characteristics have been developed to determine the suitability of potential drainage aids for gold heap leach applications. The importance of the ability of a potential drainage aid to pass each test is described below.

> [**0020**] capillary rise in gold ore—the basic desired outcome for application of a drainage aid is that it reduce the extent of capillary rise in a gold ore. Reduction of capillary rise especially in smaller ore particles is important to promote uniform movement of lixiviant through the heap. Excessive capillary rise will lead to so-called "blinding" so that movement of cyanide and oxygen into and gold cyanide complex out of that portion of the heap is greatly reduced. A successful drainage aid will have the maximum possible reduction in capillary rise at a given concentration.
>
> [**0021**] goldfilm dissolution inhibition—While it is important that a drainage aid reduce heap blinding, it is equally important that the drainage aid not impede gold dissolution from the ore. Gold is generally present in ore as particles of metallic gold in the rock matrix. Any coating of the gold metal by the drainage aid could slow the dissolution process leading to slower recovery of the gold value, an undesirable outcome. The use of a surface-active agent to modify capillary rise could reasonably be expected to have an impact on gold dissolution as any surface film formed by the surfactant could interfere with the gold dissolution reaction. Given equal drainage properties, the drainage aid with the least effect on gold dissolution would be the most successful.
>
> [**0022**] clear solution cyanide reactivity—Another important property that a potential drainage aid must possess is an inertness to cyanide under leaching conditions (pH9-11.5, 7-9 ppm oxygen). Cyanide concentration is one of the two important parameters (the other is oxygen concentration) which affect gold dissolution rates. A drainage aid that reacts with cyanide to reduce cyanide concentration in the heap will also lead to a slower recovery of the gold value. Given equal drainage properties, the drainage aid with the least effect on cyanide concentrations would be the most successful.
>
> [**0023**] activated carbon gold uptake—After gold is leached from a heap, it is passed through a column of activated carbon to strip the gold cyanide from the lixiviant (so-called carbon-in-column (CIC) gold recovery). Any drainage aid which prevents the uptake of gold by the activated carbon would not be desired unless it could be shown that in actual practice the drainage aid does not reach the activated carbon column. Again as surface-active agents are being used, it is a reasonable expectation that gold uptake would be affected by the film-forming properties of the agent on the activated carbon.
>
> [**0024**] uptake of the drainage aid by gold ore—If the drainage aid had a detrimental effect on activated carbon gold uptake, it is still possible that a drainage aid could be successfully applied if it were adsorbed onto the ore in the process of improving drainage. As is stated in U.S. Pat. No. 5,827,348, proper wetting of the ore is an important factor in optimizing precious metal recovery.

[**0025**] A large number of potential drainage aids were initially tested using a capillary rise experiment to determine if they had any effect on drainage. Potential drainage aids were selected on the basis of their stability in high pH (pH 10.5) solutions and a stated ability (in McCutheon's Emulsifiers and Detergents 1999: North American Edition, Vol. 1) to impact wetting. Those tested included fatty acid derivatives (such as those described in AU application 07/011, 659), ethylene oxide/propylene oxide block copolymers (such as those described by Smith and Craft in Chapter 5 of Heap and Dump Leaching Practice), sulfosuccinate derivates (such as those described in U.S. Pat. No. 5,827,348), ethoxylated alkylphenols, betaine derivatives, various phosphate esters, caprylic and imidazoline amphoterics, sulfonated aromatics, silicones, 2-ethyl hexyl sulfate, various ethoxylated aromatic alcohols, branced- and straight-chain aliphatic alcohols, and some proprietary mixtures of surfactants provided by manufacturers.

Example 1

[**0026**] Benchtop Capillary Rise Experiments.

[**0027**] Capillary rise screening tests were performed using an 18×30 mesh sieved ore from a mine in Northern Nevada (Marigold Mine). The ore was prepared by first sieving to this size fraction. The 18×30 fraction was washed extensively with tap water to remove embedded clays. Material was dried overnight at 105° C. and then stored in an environmental chamber at 50% humidity and 25 C.

[**0028**] A 1 cm×30 cm plastic tube was prepared with a fine stainless steel mesh pushed to the bottom of the tube to hold the ore in place. The tube was filled about ⅔ full with the sieved, washed, and dried ore and suspended from the bottom weighing hook of a Mettler analytical balance. A petri dish was filled with a solution of the surfactant at the desired concentration prepared in buffer solution. The buffer solution was prepared by dissolving 0.1 gram of calcium oxide per liter of solution along with 400 ppm of sodium sulfate (expressed as sulfate) adjusted to a pH of 10.5 with sulfuric acid. The sulfate was added to more closely approximate the high ionic strength of a typical lixiviant solution. Some surfactants show reduced activity at his ionic strength, therefore it was important that test solutions match a typical lixiviant.

[0029] The petri dish was placed under the suspended plastic tube and raised with a lab jack until the solution just touched the bottom of the tube and solution began to rise in the tube due to capillary action. Capillary rise was monitored by the rise in the liquid level in the tube (easily see as a darkening of the tube interior) and by the weight gain of the tube.

[0030] The liquid was allowed to enter the tube for seven minutes after which the petri dish was lowered, the gain in weight of the tube was measured and then the tube was removed from the hook to measure the height. In general, weight gain and the rise of liquid were highly correlated for a given ore so that the two measurements were used as checks on each other. Height of the wetted column after seven minutes is reported below.

[0031] Surfactants were run at 5, 20 and 100 ppm. Below the surfactants are described as one of three classes, those that no effect or does response (>95% of blank, approximate noise level of experiment), those that slightly decreased capillary rise with increasing dose (75% to 95%), and those that had a significant impact (<75% of blank).

Type	chemical name	height cm	height % of blank	Classification
Ethoxylated aliphatic alcohol	Ethoxylated 2-decanol	6.8	66%	Good effect
Proprietary		7.0	68%	Good effect
fatty acid + amphoteric	sodium laureth(2) sulfate	7.0	68%	Good effect
Ethoxylated aliphatic alcohol	isodecyl alcohol ethoxylate	7.0	68%	Good effect
Ethoxylated aliphatic alcohol	Ethoxylated alcohol	7.1	69%	Good effect
sulfonate aliphatic	sodium dioctyl-sulfosuccinate	7.3	71%	Good effect
fatty acid + amphoteric	ammonium lauryl sulfate/ ammonium laureth sulfate/ cocoamidopropyl betaine/ cocamide dea	7.3	71%	Good effect
fatty acid + amphoteric	sodium laureth(3) sulfate	7.5	73%	Good effect
fatty acid + amphoteric	ammonium laureth(3) sulfate	7.5	73%	Good effect
mixed	fatty acid sulfo salt	7.6	74%	Good effect
Ethoxylated aliphatic alcohol	Ethoxylated 2-decanol	7.7	75%	Good effect
Sulfonate aromatic	sodium dodecyl diphenyloxide disulfonate	7.8	76%	Some effect
sulfonate aliphatic	dihexyl sodium sulfosuccinate	7.9	77%	Some effect
Ethoxylated aliphatic alcohol	Alkoxylated isopropanolamide	8.2	80%	Some effect
acrylic acid		8.7	85%	Some effect
Proprietary	Modified ethoxylate	8.7	85%	Some effect
sulfonate aliphatic	tetrasodium N-(1,2 dicarboxyethyl)-octadecyl sulfosuccinate	8.7	85%	Some effect
fatty acit + amphoteric	sodium laureth(1) sulfate	8.8	86%	Some effect
fatty acid	ammonium lauryl sulfate	8.8	86%	Some effect
Ethoxylated aliphatic alcohol	Lauryl alcohol alkoxylate	9.0	88%	Some effect
sulfonate aliphatic	di-tridecyl sodium sulfosuccinate	9.2	90%	Some effect
sulfonate aromatic	sodium di-isopropyl naphalene sulfonate	9.2	90%	Some effect
Proprietary		9.3	91%	Some effect
Ethoxylated aliphatic alcohol	C-12 to C-14 secondary alcohol ethoxylate	9.5	93%	Some effect
Ethoxylated aromatic alcohol	ethoxylated nonylphenol	9.5	93%	Some effect
Ethoxylated alphatic alcohol	C-12 to C-14 secondary alcohol ethoxylate	9.6	94%	Some effect
phosphate ester	aromatic based organic phosphate ester	9.7	95%	No effect
sulfonate aliphatic	dibutyl sodium sulfosuccinate	9.7	95%	No effect
Silicone	Silicone glycol copolymers	9.7	95%	No effect
Ethoxylated aromatic alcohol	ethoxylated nonylphenol	9.8	96%	No effect
Proprietary		9.9	97%	No effect
Proprietary		9.9	97%	No effect
block copolymer	EO/PO copolymer	10.0	98%	No effect
amphoteric betaine	Alkylether hydroxysultaine	10.0	98%	No effect
Ethoxylated aliphatic alcohol	C-12 to C-14 secondary alcohol ethoxylate	10.0	98%	No effect
amphoteric caprylic	caprylic amphoteric	10.1	99%	No effect
amphoteric imidazoline	imidazoline sodium salt	10.1	99%	No effect
sulfonate aliphatic	disodium alkoxy sulfosuccinate	10.1	99%	No effect
amphoteric imidazoline	sodium salt of 2-caprylic-1 (ethyl beta oxypropanoic acid)	10.2	100%	No effect
amphoteric	cocoamidopropyl betaine	10.3	100%	No effect
block copolymer	EO/PO copolymer	10.4	101%	No effect
amphoteric betaine	cocoamidopropyl sulfobetaine	10.4	101%	No effect
sulfate	2-ethyl hexyl sulfate	10.6	103%	No effect
Proprietary		10.7	104%	No effect
Ethoxylated aromatic alcohol	Ethoxylated alkylphenol	10.9	106%	No effect

[0032] Of the surfactants showing a maximum reduction in capillary rise ("good effect"), it was found that these were of four types, a sulfosuccinate, ethoxylated aliphatic alcohols, mixtures of fatty acids and amphoterics, and a sulfo salt of a fatty acid. A fifth material is described by its manufacturer as a mixture of anionic and nonionic surfactants. The fatty acid/**1** mixtures were found to be too expensive and were not tested further.

[0033] It is interesting to note that the longer chain ethoxylated aliphatic secondary alcohols did not show any effect; neither did the ethoxylated aromatic alcohols. With regard to the sulfosuccinates, only sodium dioctyl-sulfosuccinate and possibly dihexyl sodium sulfosuccinate showed an appreciable impact on capillary rise.

Example 2

[0034] Goldfilm Dissolution Inhibition

[0035] Gold dissolution rates were monitored in the presence and absence of the candidate drainage aids. The technique used was similar to that described in U.S. Pat. No. 5,484,470. Gold metal films sputtered onto ¼" cm×2" plastic film backings were prepared. The gold film was stripped from the film in the presence of cyanide at pH 10.5 in a magnetically stirred UV-Vis cuvette. Gold dissolution was monitored during the stripping using a $Au(CN)^-_2$ absorption peak at 240 nm. The absorbance at this wavelength is linearly related to $Au(CN)^-_2$ for concentrations up to 20 ppm.

[0036] The experiment was run for 15 minutes. Initially, no surfactant was added to the cuvette. After 1 minute, monitoring of the rise in the $AU(CN)^-_2$ absorbance peak began at one minute intervals until 6 minutes. At 7 minutes, 100 ppm of surfactant was added to the solution using a microliter pipette. Monitoring the $Au(CN)^-_2$ continued until 15 minutes. The slope of the increase in absorbance taken from 7 to 10 minutes was expressed as a percentage of the slope for 1 to 6 minutes. Typically, the slope for a blank (no surfactant solution) was slightly (10%) lower than that at the start of the experiment. A suppression of the gold dissolution by a surfactant was seen as a further decrease in the ratio (or percentage) of the slopes after and before surfactant addition.

[0037] Examples of the four top classes of surfactants from the capillary rise experiments were compared to blank (no surfactant) solution. The materials included ethoxylated 2-decanol, fatty acid sulfo salt; LD-450 (Stephan-Proprietary); and sodium dioctyl sulfosuccinate. Because of claims made in U.S. Pat. No. 4,929,274 about the hydrolyzability of the sodium dioctyl sulfosuccinate, tests were done using both hydrolyzed (prepared by allowing an alkaline solution to sit overnight) and unhydrolyzed (freshly prepared) solutions. The results are shown in the table below:

	Blank	X-1	C-1	C-2	C-3 (fresh)	C-4 (aged)
Average % of slopes (8 to 15 minutes)/ (1 to 6 minutes)	89%	81%	9%	9%	45%	44%
Standard deviation of of ave %	11%	5%			20%	21%
% decrease in dissolution rate from blank {Ave $\%_{sample}$ − Ave $\%_{blank}$}/Ave $\%_{blank}$	0%	9%	90%	90%	50%	51%

[0038] Of the tested materials only X-1 showed acceptable performance. Both C-1 and C-2 had a dramatic inhibitory effect on dissolution, reducing the dissolution rate by 90% compared to the blanks. C-3 reduced the gold dissolution by about 50%. Aged (hydrolyzed) C-4 had the same effect as fresh C-3. X-1 had no statistically significant impact on the gold dissolution rate.

[0039] X-1=ethoxylated 2-decanol

[0040] C-1=LD450—Stepan-proprietary

[0041] C-2=fatty acid sulfo salt

[0042] C-3=sodium dioctyl sulfosuccinate

[0043] C-4=hydrolyzed sodium dioctyl sulfosuccinate

Example 3

[0044] Clear Solution Cyanide Reactivity

[0045] Experiments were completed evaluating the effect of the same four surfactants on cyanide consumption after 1 and 24 hours. Testing was conducted at 50 and 100 ppm of these surfactants (as actives) in the presence of 25 ppm cyanide (much higher surfactant/cyanide ratios than expected in an actual application). The experiments were done in stock solutions of 1 g/L Ca with 400 ppm of sulfate added, adjusted to pH 10.5.

[0046] Analysis of free CN was done using a LACHAT Flow Injection Analyzer and an analysis method which converts CN in an alkaline media to cyanogen chloride, CNCl, by reaction with chloramine-T at pH<8. The CNCl then forms a red-blue dye by reacting with a pyridine-barbituric acid reagent. The resulting color is read at 570 nm. The results are shown below:

	Exposure time, hrs			
	1		24	
	surfactant concentration, ppm			
	50	100	50	100
C-3	96%	96%	95%	96%
C-1	100%	96%	96%	98%
C-2	96%	96%	95%	96%
X-1	98%	94%	96%	91%

[0047] Within the error of the cyanide analysis methodology (±10%), none of the surfactants had a negative effect on cyanide consumption.

Example 4

[0048] Activated Carbon Gold Uptake

[0049] Similar types of experiments have been reported in U.S. Pat. No. 5,827,348.

[0050] Stock solutions of gold cyanide were prepared by dissolving 0.900 g of $KAu(CN)_2$ and 12.6 g. of NaCN (95%) in DI water to 55 liters. The solution pH was adjusted to pH 10.5. After gold analysis, the stock solutions were diluted further with DI water to adjust the gold concentration to 10.25 mL. This gives a test solution concentration of 10 ppm and approximately 200 ppm NaCN. Stock solutions of the reagents were prepared to contain 2000 ppm of active surfactant in a 500 mL solution. The pH was adjusted to pH 10.5 with lime before final dilution. Surfactants prepared using this procedure included C-3, X-2, C-5, C-1, X-3, X-1, C-6, C-2, X-4, C-7, C-8.

[**0051**] For a test, the specified volume of 10.25 ppm gold stock solution is placed in a 2.5 liter bottle along with the required amount of surfactant stock solution to obtain the desired surfactant concentration (0 ppm, 10 ppm, 50 ppm). Additional DI water was added to adjust the gold concentration to 10 ppm. The required amount of preattrited (+20 mesh) Calgon GRC-22 carbon was added. For each surfactant concentration, five solution to carbon ratios were tested as shown in the table below. The ratio of gold solution volume to weight of carbon ("carbon loading") is an important factor in representing what might happen in a carbon stripping column. As gold is progressively loaded onto a carbon column, a profile of loading values is created across the column. It is important to know if an inhibitor of the gold adsorption process affects the process at both low and high solution to carbon ratios.

Test	Gold Stock Sol. mL	Carbon g	Reagent Test Conc. mg/L	Total Solution Volume mL	Solution to Carbon Ratio
1	1500	0.3	10	1538	5125
2	1000	0.4	10	1025	2563
3	500	0.4	10	513	1281
4	500	0.8	10	513	641
5	450	1.5	10	461	308

[**0052**] Each bottle was rolled for 48 hours then a sample of the solution was filtered and analyzed for gold expressed as ppm of gold in solution. The carbon with loaded gold was fire-assayed for its gold content expressed as kilograms of gold per metric ton of carbon. A plot of results (carbon loading vs. solution gold concentration) is shown in **FIG. 1**.

[**0053**] Reference numerals used in **FIG. 1** are as follows:

[**0054**] **20**—control

[**0055**] **22**—C-8; di-tridecyl sodium sulfosuccinate

[**0056**] **24**—C-6; dihexyl sodium sulfosuccinate

[**0057**] **26**—C-2; fatty acid sulfo salt

[**0058**] **28**—C-3; sodium dioctyl sulfosuccinate

[**0059**] **30**—C-1; LD 450 Stepan proprietary

[**0060**] **32**—C-5; ammonium lauryl sulfate/ammonium laureth sulfate/cocoamido propyl betaine/cocamide dea

[**0061**] **34**—X-1; ethoxylated 2-decanol

[**0062**] **36**—X-3; isodecyl alcohol ethoxylate

[**0063**] The results clearly show that all surfactants (with the possible exception of C-8, di-tridecyl sodium sulfosuccinate) have a detrimental effect on carbon loading at 50 ppm. Running the same experiments at 10 ppm show a decreased but still significant impact of surfactant on recovery.

Example 5

[**0064**] Uptake of the Drainage Paid by Gold Ore

[**0065**] As mentioned above, if the drainage aid had a detrimental effect on activated carbon gold uptake, it is still possible that a drainage aid could be successfully applied if it were adsorbed onto the ore in the process of improving drainage. Tests were conducted with the four most cost-effective drainage aids to determine their retention on a representative oxide gold ore from Northern Nevada.

[**0066**] As with the capillary rise experiments, the uptake experiments were done using an 18×30 mesh sieved ore. The ore was prepared by first sieving to this size fraction. The 18×30 fraction was washed extensively with tap water to remove any embedded clays. Material was dried overnight at 105° C. and then stored in environmental chamber at 50% humidity and 25 C.

[**0067**] A 1 cm×30 cm plastic tube was prepared with a fine stainless steel mesh pushed to the bottom of the tube to hold the ore in place. Ore was filed to a height of 10 cm in the tube and 10 ppm surfactant solutions were dripped onto the ore at a pumping rate (3.24 ml/min) corresponding to a typical heap leach application rate of 0.005 gpm/ft^2. Buffer solution was the same as the capillary rise experiments, 0.1 gL Ca with 400 ppm sulfate added, adjusted to pH 10.5 with sulfuric acid.

[**0068**] The experiments were run over 66 hours during which a composite sample of the effluent solution was collected.

[**0069**] Uptake of surfactant by the ore was measured using total carbon after acidification with a Shimadzu Model TOC-5000 Carbon Analyzer calibrated using potassium hydrogen pthalate standards. Recovery was calculated by the following equation:

$$(\text{Effluent Total Carbons}_{\text{surfactant}}-\text{Influent Total Carbon})_{\text{surfactant}}-(\text{Effluent Total Carbon}_{\text{blank}}-\text{Influent Total Carbon})_{\text{blank}}$$

[**0070**] Results are shown in the graph shown in **FIG. 2**.

[**0071**] Reference numerals used in **FIG. 2** are as follows:

2	C-3	
4	X-2	2-decylethoxy Poly (ethyleneoxy) ethanol
6	C-5	
8	C-1	
10	X-1	
12	C-6	
14	C-2	
16	X-4	ethoxylated alcohol
18	C-7	sodium dodecyl diphenyl oxide disulfonate

[**0072**] Combining the results of all five of the above examples, one class of compounds successfully meets the desired criteria for a gold heap leach application. Specific commercial products of this class (CAS # 61827-42-7) which demonstrated efficacy include the following:

Description	McCutcheon description	Analysis results
Ethoxylated aliphatic alcohol	Isodecyl alcohol ethoxylate	A heavily branched ethoxylated aliphatic alcohol. The average carbon chain length is 7.3 C's/molecule. The average ethoxylation is 4.5 moles/molecule (X-3)

-continued

Description	McCutcheon description	Analysis results
Ethoxylated aliphatic alcohol	2-decylethoxy poly(ethyleneoxy) ethanol	a heavily branched ethoxylated aliphatic alcohol. The average carbon chain length is 6.7 C's/molecule. The average ethoxylation is 5.3 moles/molecule (X-1)
Ethoxylated aliphatic alcohol	Ethoxylated 2-decanol	a heavily branched alcohol ethoxylated aliphatic alcohol. The average carbon chain length is 10.5 C's molecule. The ethoxylation is 3.5 moles/molecule (X-2)
Ethoxylated aliphatic alcohol	Ethoxylated alcohol	a straight chain ethoxylated alcohol aliphatic alcohol. The average carbon chain length is 12.2 C's/molecule. The average ethoxylation is 4.0 moles/ molecule (X-4)

[0073] The invention is therefore applicable to enhance drainage or percolation of lixiviant solutions such as the cyanide based lixiviant solutions through a heap of mineral ore. The invention performs particularly well in the leaching of gold from gold ore with a cyanide/oxygen/lime lixiviation system operated at a pH of from about 9-11.5 but is also applicable to other heap mining environments such as precious metal heap mining in general and copper heap mining.

[0074] While the present invention has been described with respect to particular embodiments thereof, it is apparent that other forms and modifications of the invention will be obvious to those skilled in the art. The appended claims and this invention generally should be construed to cover all such obvious forms and modifications which are within the true spirit and scope of the present invention.

What is claimed is:

1. In a method of leaching metals from metal ore in which a lixiviant solution is placed in contact with said metal ore to extract said metal therefrom, the improvement comprising contacting said metal ore with an effective amount of a drainage aid comprising an ethoxylated aliphatic alcohol.

2. Method as recited in claim 1 wherein said ethoxylated aliphatic alcohol has the formula

$$HO\!\left[CH_2CH_2-O\right]_nR$$

wherein R is C_4-C_{20} alkyl or C_4-C_{20} alkenyl and n is from about 2 to about 20.

3. Method as recited in claim 2 wherein R is C_4-C_{14} alkyl or C_4-C_{14} alkenyl and n is about 3 to about 8.

4. Method of recited in claim 2 wherein said step of contacting said metal ore comprises contacting said metal ore with an aqueous solution containing said drainage aid, said drainage aid being present in said aqueous solution in an amount of about 1-1,000 ppm.

5. Method as recited in claim 4 wherein said drainage aid is present in an amount of about 1-500 ppm.

6. Method as recited in claim 4 wherein said drainage aid is present in an amount of about 1-100 ppm.

7. Method as recited in claim 3 wherein said drainage aid comprises a mixture of ethoxylated aliphatic alcohols and wherein, in said mixture, R is about 7.3 alkyl and n is about 4.5.

8. Method as recited in claim 3 wherein said drainage aid comprises a mixture of ethoxylated aliphatic alcohols and wherein, in said mixture, R is about 6.7 alkyl and n is about 5.3.

9. Method as recited in claim 3 wherein said drainage aid comprises a mixture of ethoxylated aliphatic alcohols and wherein, in said mixture, R is about 10.5 alkyl and n is about 3.5.

10. Method as recited in claim 3 wherein said drainage aid comprises a mixture of ethoxylated aliphatic alcohols and wherein, in said mixture, R is about 12.2 alkyl or alkenyl and n is about 4.

11. In a method of leaching gold from a heap of gold metal ore in a heap leaching operation wherein a cyanide based lixiviant system is used to contact and remove gold from said gold metal ore, the improvement comprising contacting said gold metal ore with a drainage aid comprising an ethoxylated aliphatic alcohol or mixtures of said ethoxylated aliphatic alcohol.

12. Method as recited in claim 11 wherein said lixiviant system has a pH of about 9 to about 11.5 and wherein said ethoxylated aliphatic alcohol is a primary alcohol having a carbon chain length of about 4 to about 20 carbon atoms and average ethoxylation of about 2-20 moles of EtO (ethylene oxide) per molecule.

13. Method as recited in claim 12 wherein said ethoxylated aliphatic primary alcohol is present in an aqueous solution in an amount of about 1—about 1,000 ppm.

14. Method as recited in claim 13 wherein said ethoxylated aliphatic primary alcohol is present in an amount of about 1-500 ppm.

15. Method as recited in claim 13 wherein said ethoxylated aliphatic primary alcohol is present in an amount of about 1-100 ppm.

16. Method as recited in claim 12 wherein said carbon chain length is from about 4-14 and said average ethoxylation is about 3 to about 8 moles of EtO per molecule.

17. Method as recited in claim 13 wherein said drainage aid comprises a mixture of ethoxylated aliphatic primary alcohols.

18. Method as recited in claim 17 wherein said mixture has an average carbon chain length of about 7.3 and an average of about 4.5 moles of EtO per molecule.

19. Method as recited in claim 17 wherein said mixture has an average carbon chain length of about 6.7 and an average of about 5.3 moles of EtO per molecule.

20. Method as recited in claim 17 wherein said mixture has an average carbon chain length of about 10.5 and an average of about 3.5 moles of EtO per molecule.

21. Method as recited in claim 17 wherein said mixture has an average carbon chain length of about 12.2 and an average of about 4 moles of EtO per molecule.

22. Method as recited in claim 11 wherein said drainage aid comprises isodecyl alcohol ethoxylate.

23. Method as recited in claim 17 wherein said drainage aid comprises 2-decylethoxy poly(ethyleneoxy) ethanol.

24. Method as recited in claim 11 wherein said drainage aid comprises ethoxylated 2-decanol.

25. Method as recited in claim 11 wherein said drainage aid comprises ethoxylated aliphatic alcohol having a chain length of about 12.2.

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