

Instructions of Eco-Goldex Agent Application in Gold/Silver/PGM Leaching

by Eco-Goldex

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Applications of Eco-Goldex Agent

Eco-goldex agent is a specially formulated and produced for precious metal extraction from various materials.

Eco-Goldex agent is the first type of such chemical that fits a wide spectrum in precious metal extraction covering various materials processing for precious metal extractions in the current global market and yet with extremely high extraction kinetics (efficiency).

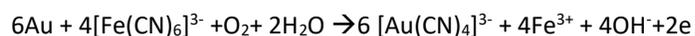
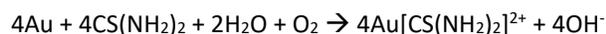
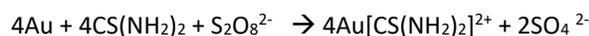
Eco-goldex agent can be used in:

- **Rock ores** materials leaching (oxide **gold ore**, sulphide gold ores, **silver ores**, **PGM enriched ores**)
- **E-waste materials** recycling (for **Au, Ag, Pd** recovery)
- **Automobile catalyst converter** recycling (for **Pd, Pt, Rh** recovery)
- **Solar panel recycling** (for **Ag** recovery)
- Its leaching kinetics is **1.5-2x faster than any other chemicals** even including sodium cyanide that commonly used in rock ore materials leaching.

Eco-Goldex agent is the first one that one agent fits for all types of precious metal bearing material extraction in the industrial market.

Precious Metal Leaching Mechanism

One of the reasons that eco-goldex agent has much strong leaching power than other chemicals is that the Eco-Goldex agent is a chemical compound. This compound is a mixture of several ordinary chemicals that fused under high temperature (650-750°C) in reactor. There are several anions participate in precious metal dissolving in solution and convert solid metal into soluble ions. These anions are organic complexing agents, and react with metal ions to form complexes anions. Possible chemical reactions may include the following (use Au as an example):



Product (Agent) Appearance

Light grey or light brownish color in solid granular or powder form. The actual color may differ from batch to batch. Product with weak ammonia odor.

Favorable Leaching Temperature

Favorable rock ore leaching ambient temperature should be $>15^{\circ}\text{C}$. For E-waste alike, the ambient temperature of the solution should be $35\text{-}45^{\circ}\text{C}$ for optimum stripping performance.

Applicable Leaching Method

When used in rock ore leaching, Eco-Goldex agent can be applied in **Heap leaching, VAT- leaching, agitation tank leaching** (CIP / CIL) method. Its flowsheet/equipment configuration is compatible with existing sodium cyanidation process. Any existing cyanidation process can be smoothly switched to eco-goldex agent leaching without any modification in flowsheet or equipment configuration.

When applied in E-waste recycling, a specially designed stripping system is used for effective surface Au/Ag stripping;

When applied in Automobile catalyst converter, Solar panel and pulverized IC chips leaching, a specially designed agitating tank leaching circuit is used.

Leaching Solution pH Control

Eco-goldex agent water solution is alkane with a pH value >9.5 . in general, there is no pH adjust in E-waste, catalyst converter and solar panel recycling leaching. But it is generally required in most gold/silver ore materials leaching due to sulfide minerals in these materials react with the leaching solution and release acidic solution that reduces leaching solution pH.

In Rock ore leaching, Solution pH can be adjusted with lime (CaO) or caustic sodium (NaOH). Water solution should be adjusted /maintained in the range of 11.0-11.5 during leaching process. If lime (CaO) is used in pH adjust, pH number should not be over 12 as overdosed lime will form lime scales on materials surface which will hinder leaching result.

It is recommended lime/Caustic soda be pre-mixed during ore grinding/loading stage to maximise leaching result. Eco-goldex leaching solution be pre-conditioned to 11.0-11.5 for 3-4 hours before agent is added in the alkaline water solution to make the leaching solution.

It is recommended the digital pH tester is used for precise solution pH control, though pH paper strip also does the work.

Leaching time

Attributing to its exceptional leaching kinetics, leaching time of materials with Eco-goldex agent solution is very short. Below is the typical leaching time for various materials processing:

- For rock ores leaching:
 - 3-4 days for VAT leaching per batch;
 - 12-25 hours Retention time for agitating tank leaching;
 - 2-3 weeks for Heap leaching;

These leaching times are significantly much shorter (1.5 – 2x) compared with similar agents in the market even sodium cyanide. This significantly reduced leaching time is of very importance for existing operators as with the same facilities in operation, their production will be increased 1.5-2x without any equipment investment!

Notes: these leaching times are variable in different ore types. These time slots are based on either our pilot test results or at designated gold/silver mines from our clients. New clients are encouraged to do their metallurgical leaching test to define the optimum leaching time!

- For e-waste, catalyst converter and solar panel materials recycling
 - 6-9 minutes per batch with eco-goldex stripping machine for typical PCB, connectors;
 - 15-20 minutes for IC Chip, catalyst converter and solar panel powder in agitating conditions.

Eco-Goldex Agent Concentration in Leaching Solution

The most frequently asked question from eco-goldex agent users is probably this “Sir, how much eco-goldex agent should I use/add in water to start my leaching?”. Our standard answer is “it depends”. In commercial operations, the agent concentration in leaching solution is always defined through series metallurgical leaching tests.

- Too high agent concentration (Too much agent was added) in solution will cause unnecessary waste of agent and costs of agent, and extra agent in solution will also consume extra free oxygen in solution hence jeopardize leaching process.
- Too low agent concentration (too little agent added) in leaching solution will cause elongated leaching time or incomplete leaching process that result in gold/silver are sent to tailing pond site.

Any serious mining operations should conduct series metallurgical tests to define the following leaching parameters:

- Optimum agent concentration for the specific rock ore leaching(how many kg eco-goldex agent should be added per ton of water);
- Optimum leaching time of the specific ore materials (how many hours the ore materials should be processed in the leaching solution);

- Optimum ore material (grain) size for optimized gold leaching (how fine the ore materials should be ground so that most gold grains are exposed to the leaching solution);
- Optimum leaching rate. Leaching rate is a key parameter used to evaluate a project is economically viable or not. Many users without industry experience/knowledge asked us “ **we want 100% recovery of Au, Ag, Pd, Cu from my ores**”, **our answer is “ technically it may be doable, but it may not be doable economically”**. We need to look for a leaching rate that is maximize your investment return with reasonable operation time and operation costs. A typical leaching rate of various rock ores (gold) with different leaching methods are as following:
 - Heap Leaching: 75-85%;
 - VAT Leaching: 85-90%;
 - Agitating tank leaching: 90-99%

Notes:

leaching rate ≠ **recovery rate**. **Leaching rate** is a parameter to evaluate how much gold is leached (leachable) from the original rock ores; some part of gold (grains) are so fine that are enclosed in minerals that they can't be leached and hence loss in to tailing pond. While **recovery rate** is a parameter to evaluate the overall gold recovered from the whole process from leaching to gold recovery that include gold precipitation, refinery. There is always minor gold loss in all steps.

Eco-goldex Inc. recognize also that not all artisanal/small scale gold miners have access to metallurgical test lab nor the financial capacity to do that. For this, we provide an empirical agent concentrations as reference to deal with in various gold grade rock ores:

- For most **common gold ores** (oxide, semi-oxide, quartz vein type and easy leaching ores...) with **gold grade ranging 3-8 g/t, the eco-goldex agent to be added in water solution is about 0.5 kg - 1.5 kg per ton of water**. If the ore contain multiple elements (i.e. Au, Ag), then the concentration should also be adjusted accordingly, example, double the agent in water solution.
- For **sulfide dominant gold ores**, there are multiple metallic metals that may be involve leaching reactions and hence much higher agent consumption in solution. **Eco-goldex agent added** in solution is recommended in the range of **2-5 KG/tonne water**.
- For existing gold mining facilities with cyanide leaching operations, Cyanide concentration data can be used as a reference for eco-goldex agent to be used in water solution (use the same amount as cyanide to replace). In existing cyanidation facilities, eco-goldex leaching solution can be applied directly without draining the cyanidation solution.

For E-waste materials recycling, a separate instruction is provided as of how to prepare the stripping solution and the agent concentration in solution.

Gold Recovery methods from leaching Pregnant Solution

Gold/Silver/PGM (Pd, Pt, Rh) recovery from eco-goldex agent derived pregnant solution can be achieved through the conventional Activated carbon (Resin) absorption or Zinc cementation method. For

gold/silver high grade ore concentrate, direct electrowinning method can be used to recover gold/silver from gold cons extensive leaching solution.

About Leaching Solution Color Variations

Eco-Goldex still provides its various product agents to meet clients' satisfaction. Though the Eco-Goldex agent (with booster) is the newest product, other regular agents (the regular O series and E series) are still available for clients' selection. In general, the **regular O series agent water solution shows grey color** or no color in water solution, while the **E series and the agent with booster show orange or brownish color** in water solution.

As eco-goldex is fussed in high temperature (650-750 °C), there are some minor ferric materials are formed when it is cooled down, these **minor black ferric materials are not dissolvable in water solution**. They don't interference with solution leaching capacity. You don't need to filter them out.

Leaching Solution Recycling, Degradation and Waste Material Treatment

In rock ore leaching operations, regardless of the leaching method used (Heap leaching, VAT and stirring tank leaching), eco-goldex leaching solution is always in a closed recycling mode. In another word, eco-goldex leaching solution is always recycled from the leaching site to the tailing pond collection point. Theoretically, there is no leaching solution is released from the system.

In case leaching operation stopped, the unused leaching solution can be degraded using **bleach powder (Calcium hypochlorite)** ($\text{Ca}(\text{OCl})_2$) to neutralize the solution before release in to draining system. In general, waste solution in the tailing pond can be self-degraded. Both the tailing materials and waste solution in the tailing pond are self degraded without special method to take for the agent itself. But local wastewater and tailing material management rules should be followed such as proper tailing pond site construction, waste water management policy.

Product storage:

The product has no special storage requirement and can be stored as ordinary chemical. It is recommended product stored in storage space with low humidity and well ventilation. Keep away from acid and food. In general, we recommend Eco-Goldex agent a max 2 years storage lifetime. After that, its chemical strength may be not as good as it supposes to be.

Product handling and personal protection

When handling eco-goldex product in lab or at mine site, it is recommended dustproof mask, clothing, glass and gloves should be used.

Eco-Goldex Agent Ecotoxicity Test

Eco-goldex has passed several toxicity and ecotoxicity tests. It is low toxic chemical compound. The table below shows a compiled ecotoxicity and toxicity test results of eco-goldex product series together with other chemicals.

Chemical name	LC 50 (ug/l) with rainbow trout	LD50 (mg/kg) at Rat
Cyanide	28 [1]	4.3-15 [2, 3]
CuSO4.2H2O	750 ^[4]	482
ZnCl2	550 ^[5]	329
Eco-Goldex O series agent	793 ^[6]	584
HgCl2	84.5 [48 hr]	

1. KOVACS, T. e., AND 6. LEDUC. 1982. Acute Toxicity of Cyanide to Rainbow Trout Acclimated at Different Temperatures. *Can. J. Fish. Aquat. Sci.* 1982
2. NTP Technical Report on Toxicity Studies of Sodium Cyanide. Charles D. Hébert, Ph.D., Study Scientist National Toxicology Program Post Office Box 12233 Research Triangle Park, NC 27709. NIH Publication 94-3386 November 1993.
3. SMYTH, H. F., JR., WEIL, C. S., WEST, J. S., AND CARPENTER, C. P. (1969). An exploration of joint toxic action: Twenty-seven industrial chemicals intubated in rats in all possible pairs. *Toxicol. Appl. Pharmacol.* 14, 340-347.
4. Brown, V.M., Dalton, R. A., (1970) . The acute lethal toxicity to rainbow trout of mixtures of copper, phenol, zinc and nickel, *Journal of Fish Biology*, 2: 211-16.
5. EPA-600/3-78-094, Oct. 1978. The Acute Toxicity of Zinc to Rainbow and Brook Trout.
6. Eco-Goldex Inc. ecotoxicity test of eco-goldex agent on rainbow trout. Conducted by AGAT lab. Quebec, Canada, Oct. 4, 2019

Toxicity Classes: Hodge and Sterner Scale				
Toxicity Rating	Commonly Used Term	Oral LD ₅₀	LC ₅₀	Dermal LD ₅₀
1	Extremely Toxic	(single dose to rats) mg/kg	(exposure of rats for 4 hours) ug/l	(single application to skin of rabbits) mg/kg
2	Highly Toxic	1 or less	10 or less	5 or less
3	Moderately Toxic	1-50	10-100	5-43
4	Slightly Toxic	50-500	100-1000	44-340
5	Practically Non-toxic	500-5000	1000-10,000	350-2810
6	Relatively Harmless	5000-15,000	10,000-100,000	2820-22,590

according to the Hodge and Sterner toxicity scale

Eco-Goldex agent can be classified as either slightly toxic or practically non-toxic.

Notes:

*Though eco-goldex agent can be classified as slightly toxic or practically non-toxic, this doesn't warrant the user can abuse it without any precautions. Remember any chemical has certain amount of toxicity. Even our table salt can kill your chicken, or you cat if they take it mistakenly. Always **fence** your operation site to prevent animal intrusion and drinking operation site water, prevent children playing on operation site to prevent possible drowning accident in VAT leaching or any other possible incidents.*

Appendix I:

How to measure and control eco-goldex agent concentration in leaching solution

The conventional titration method is used to determine eco-goldex agent concentration in water solution.

1. Agent and lab instruments used in the test:

- 1) 50 ml conical flask (1)
- 2) 1000 ml brown volumetric flask (1), 100 ml brown volumetric flask (1)
- 3) 20 ml burette (1)
- 4) 10 ml pipette (1)
- 5) Rubber head dropper (1)
- 6) Complexing agent A (**1.7332 gram lab grade AgNO₃ agent**)
- 7) Indicator B (**0.1 grams Rhodanine**)

2. Titration solution preparation

- a. Carefully open the pipette capsule that contains the Complexing agent A as mentioned in item 6) in step 1, drop all the agent in the capsule into the 1000 ml volumetric flask. Use the 100 ml volumetric flask measuring distilled water and fill in to the 1000 ml flask. Make sure the agent A is dissolved well before put too much distilled water in. once the agent A is completely dissolved, use the 100 ml flask transfer distilled water slowly into the 100 ml flask till the 1000 ml mark. Put the cap back to cover the flask from leaking solution. Shacking the 1000 ml flask gently with two hands to ensure complete dissolving of agent A in the 1000 ml flash. Store the 1000 ml brown flash under shade (without direct sunlight) for usage later on.
- b. Carefully open the pipette capsule that contains the color indicator B powder as described in item 7) in step 1, and slowly pour the powder in a 100 ml volumetric flask. Slowly add Acetone (purity>98%) or 95% Alcohol, till the mark at 100 ml. cap the flask tight and store in shade cabin for usage later on. This is called Indicator B solution.

3. Titration method

- 1) Using a 10 ml pipette carefully transfer about 10 ml of eco-goldex leaching solution into a conical flask.
- 2) Using a rubber head dropper taking small amount of the indicator solution B and add 2-4 drops in the conical flask. Swirl the flask gently to mix the indicator color with the to-be-determined solution homogenously.
- 3) Carefully Filling a 10 ml burette with the Complexing agent A solution. Adjust the solution level in Burette to 0 scale mark. Make sure there is no air in the nozzle in the burette. Attach the burette in a dedicated burette frame and set it on a titration table.
- 4) Record the Complexing Agent A solution level reading in the Burette (the starting reading scale mark), Slowly and gently rotate the burette knob to release the Complexing agent A solution. The solution should be very slowly drop into the conical flask in which the colored TBD solution is in. watch the color solution change while the Complexing agent A solution drops are added. When the solution color start changes from Yellow to light pink. Stop dropping the Complexing agent A solution. And swirl the conical flask, if the Pink color disappears, continue to slowly add Complexing Agent A solution, until the Pink color

- become stable after swirl the flask. Top dropping Complexing agent A solution. Read the ending point scale number. The difference between the end point reading – the starting point reading = the ml Complexing agent A solution consumed.
- 5) The effective eco-goldex agent concentration in the leaching solution = consumed Complexing Agent A solution (in ml) / 2. Example, if the Complexing Agent A consumption volume is 4.8 ml, then eco-goldex Agent concentration in solution = $4.8/2=2.4\%$

4. How to calculate eco-goldex agent mass weight to be added in leaching solution to maintain concentration

There is a simple formula for this calculation:

TBD Agent Mass weight (KG) = [original (optimum) eco-goldex agent concentration in solution – determined (current) agent concentration with titration]* pool total water solution volume (in M³).

Example:

A VAT leaching facility with total leaching solution volume is 100 M³; original eco-goldex agent concentration was 1.2‰ (means 1.2 kg eco-goldex agent in 1 cubic meter water solution) when leaching started; after 12 hours leaching, titration result indicate the eco-goldex agent concentration in the VAT pool is dropped to 0.7‰. To maintain the effective leaching efficiency (which is 1.2‰), you need to add new agent to the VAT leaching solution.

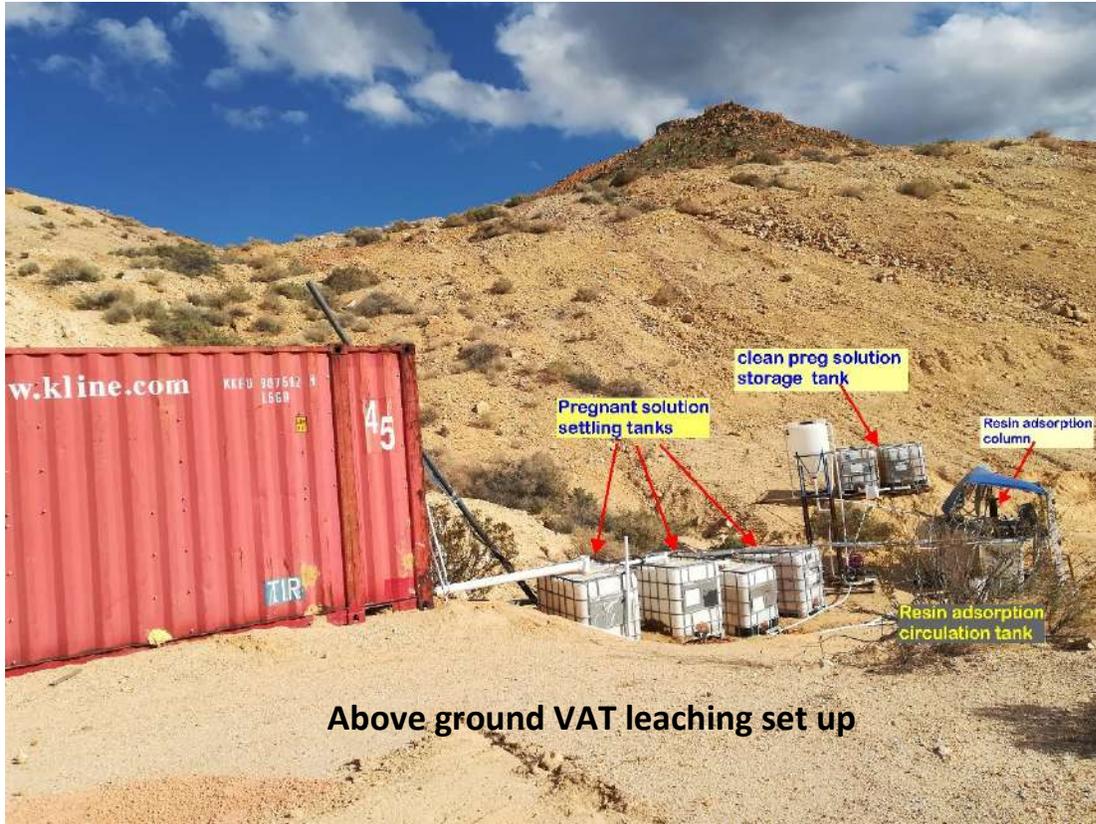
Since total water solution volume in VAY system is 100 M³ (100 tons of water solution) (assuming no water evaporation and no leaking) . based on the formula, then Eco-Goldex agent to be added to the VAT will be:

$$(1.2-0.7) * 100 = 50\text{kg}$$

this 50 KG will be the amount of Eco-Goldex agent to be added in the VAT pool to boost the agent concentration back to the optimum agent concentration (1.2‰).

Appendix II Leaching Solution preparation steps (procedures)

1. Fill a leaching solution pool with fresh water, measuring the volume while fill the water pool (tank/container). Assume the water volume measured is 1500 liters (1500 kg in weight).
2. Use Lime (CaO) to adjust the water pH up to 11-11.5 range. Stirring the water solution while lime is casted in water solution, frequently using pH test strips or pH meter to monitor pH change. When water pH around to 11.0, stop add lime.
3. Based on gold grade of the ore materials to be processed, define eco-goldex agent concentration in the water solution. Assume gold grade is about 5g/t in ore, the optimum eco-goldex agent concentration in solution is 0.65 kg per ton of water. Which means 1 ton of water dissolve 650 grams of eco-goldex agent. For the 1.5 tons water in the pool, eco-goldex agent to be used will be $0.65 * 1.5 = 0.975$ KG Eco-goldex agent.
4. Slowly and widely cast the eco-goldex agent into the water pool, make sure the agent is completely dissolved, wait 3-4 hours.
5. Pump the leaching solution in the leaching facility:
 - ✓ If heap leaching method is used, then just pump the leaching solution on top of the heap pod through the leaching spraying system to start the leaching;
 - ✓ If VAT leaching method is use, pump the leaching solution to the VAT, and make sure the solution level is about 10-15 cm above the material surface. Let the leaching process on going for the pre-defined days (i.e. 2 days) before draining the solution from the leaching VAT;
 - ✓ If agitating tank leaching method is used, then pump the leaching solution to the leaching tank and make the right leaching slurry to start the leaching process.
6. During the leaching process, using the titration method described in Appendix I to monitor eco-goldex agent in leaching solution, add new agent to maintain effective agent concentration if necessary.
7. Continue leaching till the desired leaching rate or expected gold grade in residual (tailing) materials reached, then stop the leaching process.
8. Transfer the tailing materials to the tailing pond site for storage. Gold is recovered from pregnant solution through either active carbon absorption method or zinc cementation method.
9. Recycle the diluted solution back to the dilution pool to start the new batch leaching.



Above ground VAT leaching set up





Inground VAT Leaching

