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Green Gold—Dirty Gold, Tadó, Dept. Chocó, Colombia

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Abstract

In place of mercury, small-scale alluvial gold miners in Tadó, Dept. Chocó, Colombia produce "green gold" (*oroverde*) using locally available plant extracts. The leaves of Balso (*Ochroma pyramidale*) and Malva (*Hibiscus furcellatus*) are crushed by hand and are mixed with water to make a foamy liquid that is added to the gold pan (*batea*) instead of mercury. After the plant extract is added, the gold, magnetite, and other heavy minerals sink and the lighter minerals are floated out of the gold pan. For final clean-up, a combination of other methods may be used. However, ICP (Inductively Coupled Plasma) analyses indicate that even green gold contains 208 - 4530 ppm Hg—this mercury may have been released from *dragas* or other small-scale gold mining operations that continue to use mercury; coal burning; volcanism; or native mercury released from cinnabar occurrences. ICP also indicates 308 - 106,000 ppm Ag and 452 - 585 ppm Pt.

Keywords

Green Gold, Mercury, Geochemistry, Plants, Colombia

1. Introduction

Gold has been mined from alluvial sources since ancient time using gravity methods in combination with mercury to amalgamate the gold [1] [2]; however, since the 1880s cyanide has also been used to leach gold from disseminated gold-silver-copper ores [3] and gold-bearing pyrite. Even though mercury and the mercury vapors that result from smelting the amalgam are toxic, mercury is widely used in Perú [4], Colombia [5], and elsewhere in South America for small scale gold mining. Colombia is considered to be one of the top three users of mercury in the world [6] and mercury is openly sold and used in Remedios, Dept. Antioquia for small-scale gold

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mining [5]; however, cyanide is used on gold-silver bearing pyrite ores at Marmato, Dept. Caldas. Because of the environmental issues and human health problems caused by the use of toxic chemicals, specifically mercury, the United Nations awarded alluvial miners in Dept. Chocó, Colombia, the Seed Award for their exemplary production of green gold, their aggressive efforts to reduce the use of mercury in the region, attention to conservation, and the elimination of mining practices such as the use of backhoes and dredges that pollute and destroy the streams [7].

2. Small-Scale Gold Mining in Chocó

Since the 17th century, people of African origin (*afrodescendientes*) have lived in Dept. Chocó in western Colombia. Choco's inhabitants were originally brought to the region as slaves to work the alluvial gold mines [8] [9]; however, in the 1980s the Colombian government began a number of social programs to improve conditions in the remote area [10] and now the government backs eco-friendly gold production [11]. The Amichocó (Friends of Chocó) Foundation and Corporación Oro Verde developed the Certified Green Gold Program (GGP) in Chocó and are expanding to other regions. These programs provide a sustainable alternative to the use of mercury in underprivileged communities and guarantees socially and environmentally responsible small-scale gold mining. The gold and platinum (platinum group metals, or PGMs, include platinum, palladium, rhodium, ruthenium, osmium, and iridium) mined in the region are sold to local and international fair trade markets and the miners receive a bonus on the market value of the gold [12]. The green gold programs also minimize the miner's exposure to the toxic mercury vapors released during alluvial gold mining and amalgam burning [5] [13].

3. The Green Gold Process in the Field

In Tadó, Dept. Chocó, Colombia, alluvial gold (*oroverde*) is produced using plant extracts in place of mercury. The panned, alluvial gold concentrate, which also contains silver combined with the gold as electrum, may also include mm-sized platinum nuggets with PGMs, is treated with the extract from readily available local plants such as Balso (*Ochroma pyramidale*), Malva (*Hibiscus furcellatus*), *Guácimo blanco* (*Goethalsia meiantha*) and Yarumo (*Cecropia virgusa*) or other plants (**Figure 1**). These may include *Cedro playero* and Yarumo (Colombia) [14] and Murmuncho and Cuiguyum (Perú) [15]. In other regions, *Cedro playero* (*Pseudosamanea guachapele*)

Figure 1. Plants used to separate alluvial gold from the waste material, Tadó, Dept. Chocó, Colombia: (A) and (B) *Hibiscus furcellatus* (common name, Malva); (A) leaves and bud; (B) flower; (C) and (F) *Cecropia virgusa* (common name, Yarumo), (C) underside; (F) in flower; (D) *Ochroma pyramidale* (common name, Balso); (E) Goethalsia meiantha (common name, *Guácimo blanco*).

may also be known as Iguá, Tobaco, or Cedro amarillo [16]. The green gold process is a traditional African technique that was handed down to Chocó's modern small-scale miners by their ancestors and allows the use of plant extracts in place of mercury amalgamation to recover alluvial gold [11].

One or two leaves from the plant, for example, Balso, Malva, Cedro playero or other, are crushed by hand and mixed with water to make a foamy, sticky liquid (**Figures 2-7**). Mainly the liquid is added to the gold concentrate in the gold pan (*batea*) in place of mercury, the coarse gold and heavy minerals (*jagua*), such as magnetite, sink, and the remaining sedimentary material that may include quartz, feldspars, and lighter minerals remains suspended and are poured out of the *batea* (**Figure 6**, **Figure 7**) leaving a gold concentrate [14] [16] [17]. The green gold process is effective because: 1) it produces a soapy mixture that traps and floats lighter minerals effectively separating them from the denser gold [11] (**Table 1**); and 2) at the same time, the plant juice-water mixture breaks the surface tension of the water and allows precipitation of the very fine-grained gold (**Figure 6**) that would normally float away; and therefore, the green gold process increases gold production. The process is analogous to minerals separation by the use of heavy liquids, that is, the soapy plant juice allows the high specific gravity minerals such as gold, platinum, and magnetite to sink while the low specific gravity minerals (quartz, feldspars, and micas) remain suspended and can be poured out of the gold pan leaving a gold concentrate.

Figure 2. Malva leaf before crushing.

Figure 3. Crushing the Malva leaf by hand with water makes a foamy liquid.

Figure 4. Crushed Malva leaf.

Figure 5. The liquid that results from hand crushing the plant with water is added to the *batea* in place of mercury.

Figure 6. Gold pan with green gold and magnetite (*jagua*) [16].

The gold concentrate may then be further cleaned of magnetite by the use of a hand magnet to remove the black magnetite-rich sand (*jagua*) from the panned, dried gold concentrate. The *aventadero* method is another cleaning method in which the dried gold concentrate is tossed into the air allowing waste mineral material to be removed by the wind leaving a more pure gold concentrate [18] or the concentrate may be placed on an inclined pan that is gently tapped and the more rounded waste material tumbles away leaving the gold. The use of borax as a substitute for mercury, mainly in hard-rock small-scale gold mining in Bolivia, the Philippines, and Indonesia, is a relatively new method that has also increased gold recovery [19].

Typically, the alluvial gold produced by non-mercury methods can be easily recognized—the grains are individual, mm-sized, flattened, and may be very shiny [5]. Green gold samples analyzed for this study (**Table 2**) were obtained from gold shops in the respective areas and not in the field because of the presence of armed groups (**Figure 8**) [20].

Figure 7. Green gold concentrate, see **Table 2**. Small amounts of gold, palladium, and silver may be used in memory cards.

Figure 8. Security in the gold mining areas is a serious concern. The graffiti on the backhoe indicates the presence of ELN (Ejercito de Liberación Nacional/National Liberation Army), an armed paramilitary group, in the mining area [5] [20].

Table 1. Specific gravity of common minerals.

Quartz (2.65)
Feldspars (2.62 - 2.76)
Magnetite (4.9 - 5.2)
Platinum (14 - 19)
Gold (15.6 - 19.3)

Table 2. Inductively Coupled Plasma (ICP) analyses of three alluvial green gold concentrates from Colombia.

	Tau	Rau	Qau
Ag	106,000	308	415
Al	968	33,300	1710
As	9	1	680
Au	665,000	552,000	819,000
B	0	4	3
Ba	25	8	7
Be	0	nr	nr
Bi	0	3	0
Ca	656	34	30
Cd	0	0	1
Ce	0	1350	10
Co	<1	2	1
Cr	21	15	16
Cu	377	180	227
Dy	0	0	0
Er	0	0	0
Eu	0	0	0
Fe	3430	1680	1080
Ga	0	2	2
Gd	0	0	0
Ge	0	nr	nr
Hf	0	nr	nr
Hg	4530	208	575
Ho	0	0	0
In	0	0	1
Ir	0	2	2
K	242	10	0
La	0	0	0
Li	0	nr	nr
Lu	0	0	0
Mg	183	12	17
Mn	15	2130	3
Mo	3	0	2
Na	856	82	49
Nb	0	2	0

Continued

Nd	6	0	0
Ni	8	4	5
Os	0	0	1
P	29	4	22
Pb	124	28	9
Pd	0	2	24
Pr	0	0	0
Pt	0	452	585
Rb	0	0	0
Re	0	0	0
Rh	0	8	3
Ru	0	0	1
S	5630	7	67
Sb	0	10	49
Sc	0	0	0
Se	5	0	4
Si	1430	nr	nr
Sm	0	0	0
Sn	0	1300	340
Sr	1	1	0
Ta	0	0	0
Tb	0	0	0
Te	0	9	2
Th	0	0	2
Ti	39	49,300	2590
Tl	0	0	1
Tm	0	0	0
U	0	0	4
V	7	6	11
W	4	7	1
Y	0	0	0
Yb	0	0	0
Zn	21	6	3
Zr	0	32,500	3240

Tau—alluvial green gold concentrate, platinum removed, from gold shop in Tadó, Dept Chocó, Colombia; Rau—alluvial green gold concentrate from gold shop in Remedios, Dept. Antioquia, Colombia [5]; Qau—alluvial green gold concentrate from gold shop in Quibdó, Dept. Chocó, Colombia [5]; Inductively Coupled Plasma (ICP) analyses, in parts per million (ppm), by American Assay Laboratories, Sparks, NV. nr-not reported.

4. Dirty Gold

However, despite the use of this sustainable, environmentally-friendly plant-based method, Inductively Coupled Plasma analyses (ICP) indicate that even green gold produced without any mercury may still contain 208 - 4530 ppm Hg (**Table 2**). This mercury is interpreted to be mercury released from small-scale gold mines in the region that used or continue to use mercury. For example, even as the market moves toward green gold, the jungle in Chocó is already pock-marked with craters where gold-bearing sediments were extracted and treated with mercury [21]. Gold dredges, or *dragas* [5] used in the waterways in Dept. Chocó use a copper plate smeared with mercury over which the gold-bearing sediments were washed and this process also released mercury to the environment. Mercury may also be released during volcanic eruptions, from coal-burning, from epithermal mineral occurrences, and some hot springs. Cinnabar occurrences in the region [5] [22] may also provide some native mercury that would readily amalgamate with the alluvial gold.

The ICP analyses also indicated 308 - 106,000 ppm Ag and 452 - 585 ppm Pt (**Table 2**).

5. Discussion

The use of plant extracts in Tadó for alluvial gold production is a relatively new, environmentally sound, and sustainable method for small-scale gold mining in Colombia with applications to small-scale gold mining in the region. However, the properties of the liquid extracted from these plants may not be unique to the species described herein. Therefore, it is necessary to consider other species of the Malvaceae family (ex. genus Malachra, Matisa or others) as well as other plants that may have similar properties. These include Clausiaceae (Chrysochlamys, Clusia), Euphorbiaceae (Acalypha, Alchornea, Croton, Hyeronima), and Moraceae (Ficus).

6. Conclusion

The green gold method is inexpensive, sustainable, eliminates the use of mercury, and helps recover fine-grained gold that can only be trapped by mercury. However, because of several geologic and environmental factors, the green gold still contains contaminant mercury that must be retorted and removed at the smelter—this recovered mercury may then be recycled or sold. In addition to the mercury, the gold from the Chocó region also contains silver and platinum (PGMs) that must be parted at the smelter before sale. But most importantly, the advent and use of green gold methods is sustainable; inexpensive; reduces the exposure of the small-scale miner to toxic mercury and mercury fumes during amalgam burning; and reduces anthropogenic mercury releases related to small-scale gold mining to the environment.

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