Supplementary material

Life cycle environmental impact assessment of gold production in an artisanal small-scale mine in Colombia

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DETAILS OF SYSTEM BOUNDARIES

In Section "2.2.3 System Boundaries", the main stages analyzed are mentioned, namely the mine construction process, the whole-ore amalgamation process and the cyanidation one. Below each stage is detailed and supplemented by a series of photographs.

Deforestation of the selected area was the first step for the mine construction, the latter being summarised in **Figure S1**.

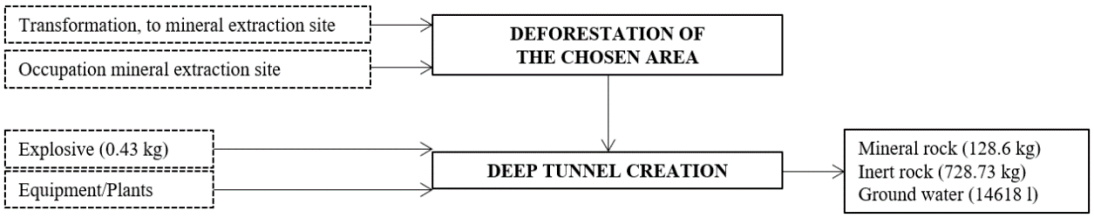


Figure S1. Flowchart showing the system boundaries limitedly to the mine construction steps, the reported quantities are referred to the functional unit.

Explosives were used to build the underground tunnel which was then held up with wooden perimeter supports. A rail and a cable [1] were used for the cart transporting the excavated rock to the surface. Electricity was installed in order to aerate the tunnel, run the rail and pump out the groundwater.

The performed interviews revealed that workers during the mineral rock blasting are exposed to large emissions of fine particulate matter into the air for long periods of time. Indeed, while the presence of fans for the ventilation of the tunnels allows the oxygen to reach many meters of depth, it does not allow the dust to settle on the ground. Moreover, no water systems, as in the case of Valdivia and Ugaya [2], are employed. This issue is deeply felt, since interviews revealed how miners are worried and bothered by dust, despite being equipped with face masks. However, in the LCA analysis this issue was not addressed in

the absence of atmospheric environmental sampling, while only a hypothetical scenario was considered in the sensitivity analysis based on literature data.

The whole-ore amalgamation process, comprising the crushing of the mineral rock and the amalgamation process, was divided up into three steps. The first and the second steps, involving the use of two bar mills (Coco A and Coco B), are summarised in **Figures S2** and **S3** respectively, while the last one, in which only Coco A bar mill is used, is outlined in **Figure S4**.

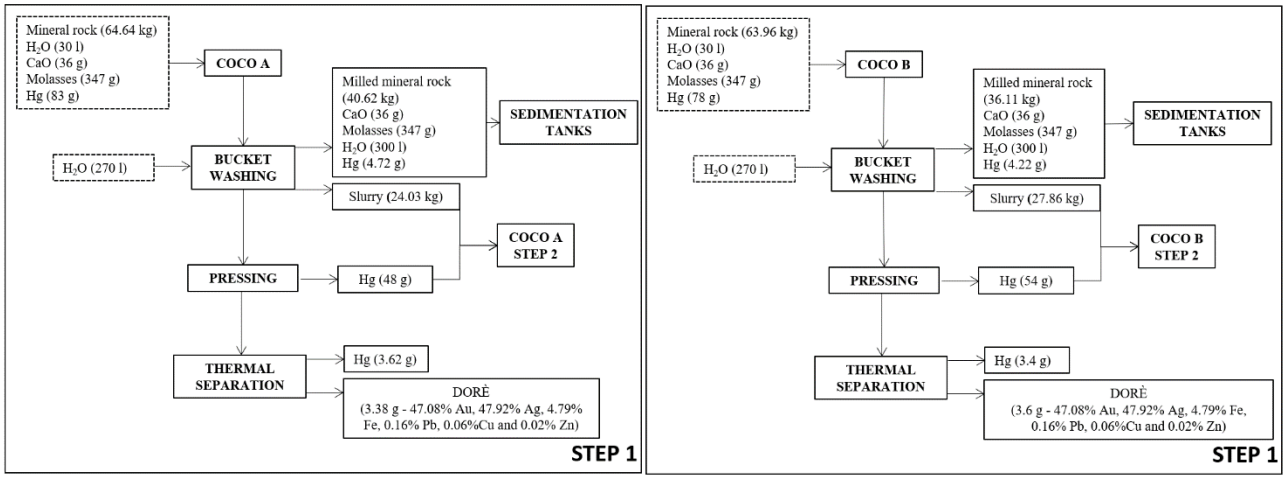


Figure S2. Flowchart showing the system boundaries limitedly to the first step of the whole-ore amalgamation process, the reported quantities are referred to the functional unit.

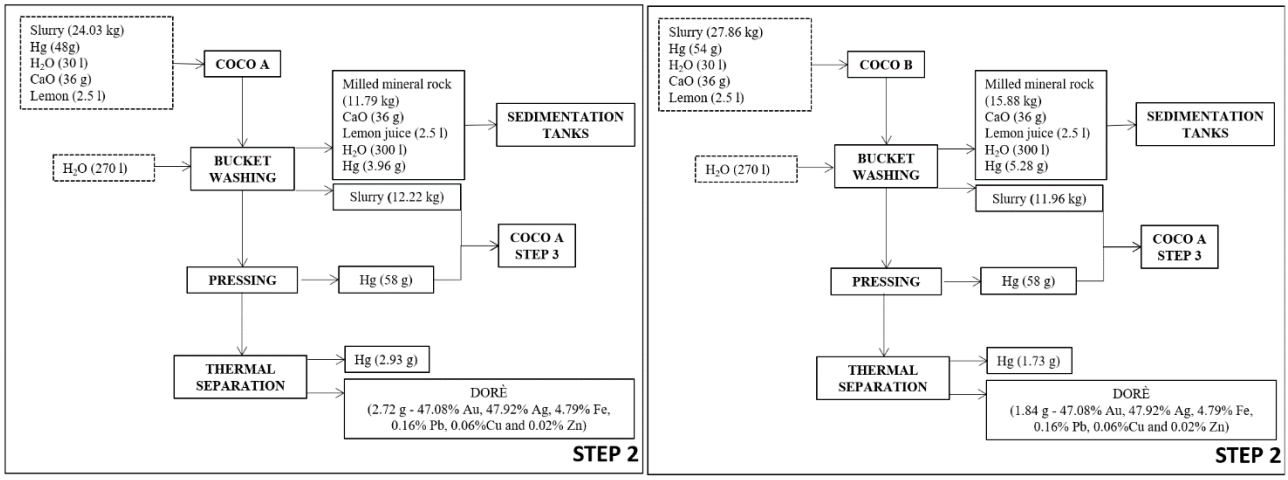


Figure S3. Flowchart showing the system boundaries limitedly to the second step of the whole-ore amalgamation process, the reported quantities are referred to the functional unit.

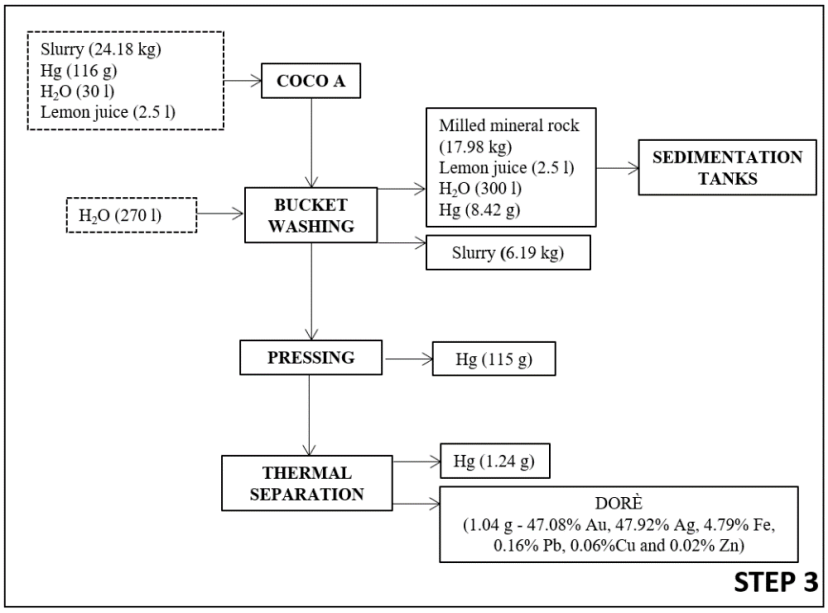


Figure S4. Flowchart showing the system boundaries limitedly to the last (i.e., third) step of the whole-ore amalgamation process, the reported quantities are referred to the functional unit.

The mineral rock was crushed for 30 minutes, in order to reduce its particle size, and subsequently sent for amalgamation. The crushed rock (128.6 kg) was divided up into two parts: 64.64 kg of rock was placed in Coco A and 63.96 kg in Coco B. Inside the two bar mills, the rocks were further reduced in size and mixed for three hours with water, mercury, CaO and molasses. The latter two were added to keep the pH around the value of 11, in order to both reduce the surface tension of mercury, thus trapping more precious metal [3], and to stop the mercury from fully breaking down, thus reducing mercury losses [4].

The as obtained amalgam was washed manually with water for ca. 15 minutes in buckets. The washed amalgam was then squeezed with a cotton fabric to eliminate excess mercury, with the latter being recovered and reinserted into the second cycle. This manual pressing allows to obtain a small sphere named amalgam, normally made up of approximately 50% mercury (later removed by thermal separation) and 50% Doré. The remaining amalgamation slurry from the buckets was returned to the bar mill for the second amalgamation cycle, which was similar to the first, except for the fact that the molasses were replaced with lemon juice which stabilized the pH at around 5 [3]. The further third cycle was similar to the second one, except for the fact that CaO was not added. Therefore, further amalgam is obtained from the second and third cycles.

The amalgam produced was subjected to a thermal treatment in a system called retort, whereby heating at a temperature of approximately 700 °C for 20 minutes was performed to ensure evaporation of the mercury. The mercury vapours released by the combustion process passed through a heat exchanger, employing water as a closed cooling fluid circuit, thus the as condensed mercury was then recovered, therefore it was modelled as an avoided product in the LCA since it could be reused in further amalgamation cycles. Thermal separation of mercury from the amalgam produces Doré (12.58 g), the typical composition of which is 47.08% gold, 47.92% silver, 4.76% iron, 0.16% lead, 0.06% copper, and 0.02% zinc, as reported in **Table S1**, referred to the functional unit of the study.

Table S1. Composition of 12.58 g of Dorè.

Metal	Value	Unit
Gold (Au)	5.92E-03	kg
Silver (Ag)	6.03E-03	kg
Iron (Fe)	5.99E-04	kg
Lead (Pb)	2.01E-05	kg
Copper (Cu)	7.55E-06	kg
Zinc (Zn)	2.52E-06	kg

The gold grade in the mineral rock extracted was of 80.3 mg/kg. Thus, the Doré obtained allowed the extraction of 57.31% (i.e., 5.92 g) of the gold contained in the mineral rock.

As a consequence, 4.41 g of Au could be potentially yet extracted from the subsequent cyanidation phase, without accounting the unavoidable losses. Water deriving from washing of the amalgam and tailings not sent to subsequent amalgamation cycles were sent to sedimentation tanks, through canals. Since the cyanidation process is activated with 6000 kg of tailings coming out of amalgamation and directed to cyanidation by recovery from the sedimentation tanks, it was not possible to sample the amount related to the functional unit of the system. However, the gold grade of cyanidation tailings, which is 65.93 mgAu/kg, was sampled.

Therefore, the amount of tailings relative to the functional unit, was calculated by means of a gold mass balance having available the gold grade of the mineral rock (80.3 mgAu/kg) and in the cyanidation tailings (65.93 mgAu/kg), the mass and the percentage of gold present of the Doré (47.08%) and in the CyG (33.47%).

In order to recover the remaining gold originally contained in the mineral rock, it was estimated that 30% of the solid fraction and 1.55% of the liquid fraction are recovered from the sedimentation tanks and sent to cyanidation process (**Figure S5**), together with the amalgamation slurry remaining inside the buckets for the third cycle.

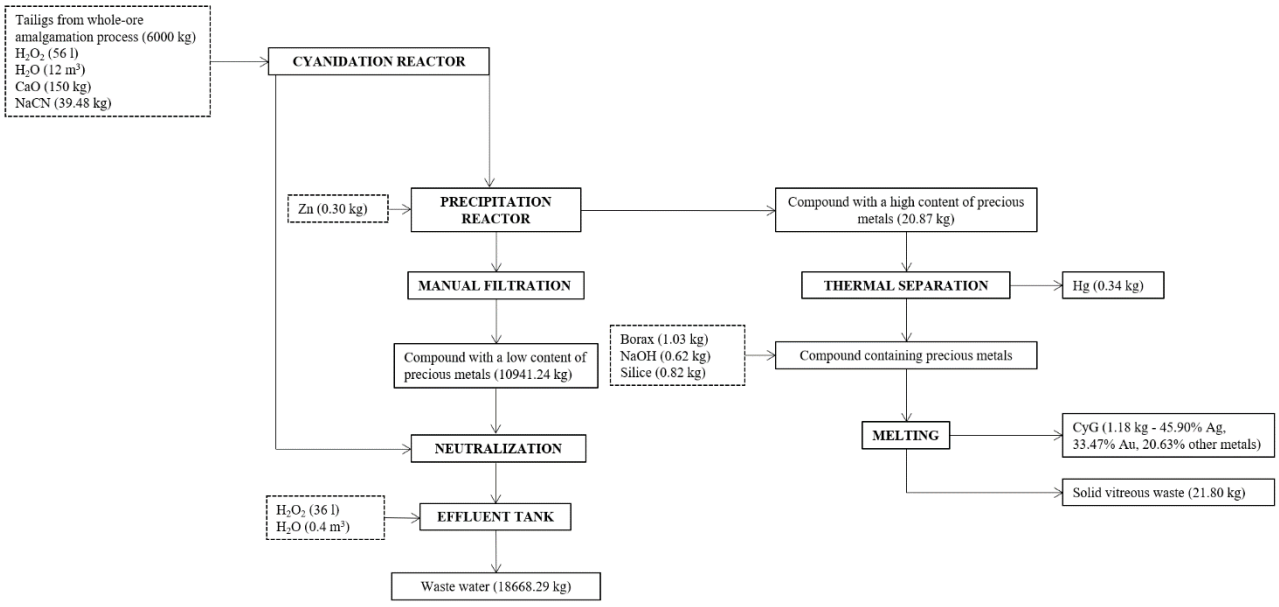


Figure S5. Flowchart showing the system boundaries limitedly to one cyanidation cycle, for 6000 kg of tailings from whole-ore amalgamation process.

Indeed, both the amalgamation slurry and tailings still contain a significant amount of gold [5]. In fact, the goal of cyanidation phase is to process amalgamation waste (amalgamation slurry and tailings) precisely to recover the gold still present in them.

The remaining 70% of solid material and 98.45% of the liquid fraction from the sedimentation tanks were released into the environment.

Environmental sampling revealed also a concentration of mercury in tailings coming out of the whole-ore amalgamation of: 112 mg/kg from the first cycle, 323.5 mg/kg from the second cycle, and 461 mg/kg from the third cycle. The analysis also covered the water generally exiting from the whole-ore amalgamation process, which was found to have an average mercury concentration of 422 mg/l.

Before cyanidation the amalgamation slurry from the third cycle of amalgamation and tailings were washed for two hours with CaO, H_2O_2 and H_2O inside a cyanidation reactor. Subsequently, NaCN was added to the reactor at the ratio of 6.58 g of NaCN/kg of slurry and the mixture was mechanically stirred for eight hours. During cyanidation, the precious metals are dissolved by NaCN at a high pH value of ca. 11 [6-8].

It was assumed that the following chemical reactions (**eq. S1-S3**) took place simultaneously, according to Rivera et al. [7]:

$$NaCN+H_2O_2 \rightarrow NaOCN+H_2O \quad (\textbf{eq. S1})$$

$$NaCN+CaO \rightarrow NaOCN+Ca \quad (\textbf{eq. S2})$$

$$NaCN+H_2O \rightarrow HCN+NaOH \quad (\textbf{eq. S3})$$

When the pH value is lower than 10, NaCN potentially reacts with H_2O (**3**) forming hydrogen cyanide which is a hazardous substance for human health [31] and which tends to evaporate at Colombian ambient temperature, due to its boiling point equal to ca. 26°C [9]. The performed interviews revealed that workers usually handle NaCN without any protection and that the lowering of the pH is typically associated with the insurgence of some HCN poisoning symptoms like headache, nausea and dizziness [10], thus confirming the need for specific skills for cyanidation process [11].

Furthermore, it was assumed that the chemical reaction between the NaCN and part of the mercury contained in the slurry also took place in the cyanidation reactor, giving rise to mercury-cyanide complexes [4,12], in accordance with the following reaction (**eq. S4**).

$$4Hg+8NaCN+O_2+2H_2O \rightarrow 4NaHg(CN)_2+4NaOH \quad (\textbf{eq. S4})$$

The amount of mercury in the slurry was measured by on-site sampling and analyzed. In addition to precious metals and mercury, NaCN can also cause leaching of lead, and other heavy metals present in the amalgam slurry [3]. However, only mercury was considered in this study, since primary data for further metals were not available. After 12 hours of sedimentation, the liquid fraction contained $NaAu(CN)_2$ and $NaAg(CN)_2$, which floated on the surface [6], while the solid fraction settled at the bottom of the reactor. The latter contained the earthy slurry and products formed by chemical reactions and it was released from the bottom of the reactor by opening a valve into an underground effluent

tank. The liquid fraction, which was rich in precious metals, was pumped out from the above and transferred to the precipitation reactor with Zn powder where it was subjected to the Merrill-Crowe process [4]. The amount of Zn used was calculated stoichiometrically, in accordance with the following balanced chemical reactions (**eq. S5-S6**) [6,8]:

$$4NaAu(CN)_2+2Zn \rightarrow 4Au+2Na_2Zn(CN)_4 \quad (\textbf{eq. S5})$$

$$4NaAg(CN)_2+2Zn \rightarrow 4Ag+2Na_2Zn(CN)_4 \quad (\textbf{eq. S6})$$

An additional 30 wt% of Zn powder with respect to the stoichiometric amount was added for precautionary reasons.

The use of the reagents was not fixed but varied in accordance with the availability and characteristics of the slurry to be treated, as determined through analyses and titrations.

Zinc can also precipitate other metals in the compound sent to the precipitation reactor [3], however this was not evaluated in the absence of primary data. Similarly, the chemical reaction potentially occurring between Zn and H_2O was not considered as well.

In order to obtain a homogeneous and complete reaction (**eq. S5**) (**eq. S6**), a slow mixing lasting two hours was used in the precipitation reactor. Subsequently the compound contained in the precipitation reactor was sent to filtration. Filtration was performed manually with denim fabric. The fraction of compound that was passed through the fabric did not contain gold or silver, or at least in negligible amounts. It mostly consisted of water that was sent to a further effluent tank. On the opposite, the retained fraction contained Au, Ag, $Na_2Zn(CN)_4$, unreacted Zn, a fraction of slurry and a fraction of unreacted Hg.

The retained material was sent to thermal separation, where the mercury was vaporized and recovered by means of a retort. Therefore, in the gold production process at Mina Nueva, there are two retorts (or thermal separation systems) to evaporate and subsequently condense the mercury present in the amalgam or in the sediments resulting from cyanidation.

Nevertheless, the mass balance of mercury shows that a small fraction of mercury was released into the atmosphere. The entire mining process produces an air emission of mercury equal to1.62E-3 kg per 1 kg of gold.

The compound resulting from thermal separation was subsequently placed inside a refractory container and sent to fusion. Before melting, borax, NaOH and silica were added to the compound, in order to eliminate the oxides and lower its melting point and viscosity [4,13]. During melting, zinc steam was released into the surrounding environment [3].

Two outputs resulted from fusion: the CyG, which sank in the refractory container, and a lighter vitreous silicate [13] which settled on top of the CyG and was modelled with an ad hoc created substance, named 'Solid vitreous waste'.

CyG was made up mainly of silver (45.90%) and gold (33.47%), while the remaining 20.63% was made up of further metals which were not analyzed, as detailed in **Table S2** and referred to the functional unit.

Table S2. Composition of 13.18 g of CyG.

Metal	Value	Unit
Gold (Au)	4.41E-03	kg
Silver (Ag)	6.05E-03	kg
Other metals	2.72E-03	kg

The substance in the two effluent tanks was subjected to a neutralization treatment with H_2O_2 and H_2O. This treatment was performed in order to make eventually unreacted NaCN, reacting with H_2O_2 according to equation **(1)**. The mercuric-cyanide complexes in the solution contained in the effluent tanks were dispersed into the environment [3], as water emission.

A series of photographs taken in the field are shown below (**Figures S6-S29**).



Figure S6. Deforestation of the area chosen for the creation of the mine (ACVC - Asociación Campesina del Valle del Rio Cimitarra, Peasant Association of the Cimitarra River Valley).



Figure S7. View of the mine, 60.000 m^2 of extension (ACVC).



Figure S8. Photographs of the external and internal part of the tunnel (ACVC).



Figure S9. Undercuts area (Tunnel with fan and inlet ventilation pipe and subway mine water outlet, electric cables inlet) (ACVC).



Figure S10. Mechanical extraction of material from the mine by "Elevator" and support structure and compressed air inlet and water outlet to the undercut, wagon and rails for transport of extracted material (ACVC).



Figure S11. Mechanical control "Elevator" system (ACVC).



Figure S12. Storage area for material extracted from the mine (ACVC).



Figure S13. Mechanical crusher for material size reduction (ACVC).



Figure S14. Sinkhole waste unloading area and recycling area (managed by women from the community) (ACVC).



Figure S15. Mine water outlet piping, water accumulation and pumping zone for production process requirements (ACVC).



Figure S16. Photograph of the Whole-ore amalgamation process (ACVC).



Figure S17. Bar mills (Cocos) (ACVC).



Figure S18. Dorè before and after thermal separation (ACVC).



Figure S19. Thermal separation and retort in the whole-ore amalgamation process (ACVC).



Figure S20. Sedimentation tanks downstream of the Whole-ore amalgamation process (ACVC).



Figure S21. Sediments accumulated before being transported to the Cyanidation area (ACVC).



Figure S22. Cyanidation area (ACVC).



Figure S23. Cyanidation agitator tanks (ACVC).



Figure S24. Cyanidation tanks, water for reprocessing and deactivation (ACVC).



Figure S25. Discharge area with solid and liquid waste from the cyanidation process (ACVC).



Figure S26. Thermal separation and retort in the cyanidation process (ACVC).



Figure S27. Compound coming out of the thermal separation and the fusion process (ACVC).



Figure S28. Outputs coming out of the fusion and the CyG (ACVC).



Figure S29. Electric generators area (ACVC).

DETAILED LIFE CYCLE INVENTORY (LCI)

Table S3. Inventory data related to the extraction of 2.58E-02 kg of the Dorè and CyG deriving from 128.6 kg of mineral rock from the Mina Nueva mine.

Mine construction phase		
Input	**Value**	**Unit**
Inputs from nature		
Land transformation (into industrial area)[1]	1.70E-01	m^2
Land occupation (industrial area)[2]	5.10E+00	m^2 yr
Land transformation (into mineral extraction site)[3]	1.95E-01	m^2
Land occupation (mineral extraction site)[4]	5.76 E+00	m^2 yr
Land transformation (into artificial water bodies)[5]	4.57E-03	m^2
Land occupation (water bodies, artificial)[6]	1.37E-01	m^2 yr
Gangue (gold-bearing rock)[7]	1.29E+02	kg
Materials		
Ammonium nitrate explosives[8]	4.3E-01	kg
Energy		
Electricity from diesel generator[9]	4.33E+02	MJ
Transport		
Road[10]	2.93E-01	t km
Whole-ore amalgamation phase		
Input	**Value**	**Unit**
Inputs from nature		
Gold, in raw[11]	5.92E-03	kg
Silver, in raw[12]	6.03E-03	kg
Iron (Fe), in raw[13]	5.99E-04	kg
Lead (Pb)[14]	2.01E-05	kg
Copper (Cu)[15]	7.55E-06	kg
Zinc (Zn)[16]	2.52E-06	kg
Water, wells[17]	2.22E+03	l
Materials		
Mercury[18]	1.61E-01	kg
Calcium oxide[19]	1.44E-01	kg
Molasses[20]	6.94E-01	kg
Lemon[21]	1.49E+01	kg
Cotton fabrics[22]	10E+00	kg
Natural gas[23]	1.47E-04	m^3
Energy		
Electricity from diesel generator[24]	8.24E+02	MJ
Transport		
Road[25]	1.88E+01	t km
Output	**Value**	**Unit**
Co-products		
Amalgamation slurry[26]	8.23E+01	kg
Tailings[27]	6.69E+01	
Mercury[28]	2.18E-01	kg
Avoided products		
Mercury[29]	1.28E-01	kg

Emissions to air		
Mercury[30]	1.29E-05	kg
Emissions to water		
Mercury[31]	1.39E-2	kg
Emissions to soil		
Mercury[32]	1.39E-2	kg
Cyanidation phase		
Input	**Value**	**Unit**
Inputs from nature		
Gold, in raw[33]	4.36E-03	kg
Silver, in raw[34]	5.98E-03	kg
Other metals ore, in raw[35]	2.68E-03	kg
Water, wells[36]	1.38E+02	l
Materials		
Tailings[37]	6.69E+01	kg
Calcium oxide[38]	1.65E+00	kg
Hydrogen peroxide[39]	1.02E+00	l
Sodium cyanide[40]	4.36E-01	kg
Zinc[41]	3.31E-03	kg
Borax[42]	1.14E-02	kg
Sodium hydroxide[43]	6.84E-03	kg
Sand[44]	9.04E-03	kg
Natural gas[45]	9.77E-03	m^3
Energy		
Energy from diesel generator[46]	9.35E+00	MJ
Transport		
Road[47]	3.25E-01	t km
Output	**Value**	**Unit**
Avoided products		
Mercury[48]	3.75E-03	kg
Emissions to air		
Particulates < 2.5 μm[49]	1.39E-03	kg
Particulates > 2.5 μm, and < 10 μm[50]	2.55E-03	kg
Particulates > 10 μm[51]	6.94E-04	kg
Hydrogen cyanide[52]	2.38E-03	kg
Mercury[53]	3.63E-06	kg
Emissions to water		
Cyanide compounds[54]	2.84E-01	kg
Mercury compounds[55]	6.90E-03	kg
Hydrogen peroxide[56]	6.39E-01	kg
Emissions to soil		
Cyanide compounds[57]	2.84E-01	kg
Mercury compounds[58]	4.83E-03	kg
Hydrogen peroxide[59]	6.39E-01	kg
Zinc compounds[60]	4.89E-06	kg

[1] Ecoinvent process used was: Transformation, to industrial area. It represents the transformation of the soil from the natural condition (forest) to an area used for mechanical and manual processing, storage, power plant, mercury grinding and washing, dry crushing, sediment accumulation for cyanidation, cyanidation community houses. The parameter was calculated knowing that the industrial area is 7000 m^2, the life time of the mine is estimated to be 30 years, and that 1200 tons of rock (sum of mining rock 15% and inert rock 85% of the total) are processed per year. Therefore, the potential mass of Doré and CyG produced during the life of the mine was calculated and found to be 1611 kg. Consequently, through a linear proportion, the share of area allocated to U.F. was calculated.

[2] Ecoinvent process used was: Occupation, industrial area. It represents land occupancy. The parameter was calculated by multiplying the value of transformation, to industrial area by the number of years the area has been in use, which is 30 years.

[3] Ecoinvent process used was: Transformation, to mineral extraction site. It represents the transformation of the area in which tunnels are created for gold rock mining. The parameter was calculated in the same way as *Transformation, to industrial area* knowing that the mining area is 8000 m^2.

[4] Ecoinvent process used was: Occupation, mineral extraction area. It represents land occupancy. The parameter was calculated as the process *Occupation, industrial area*.

[5] Ecoinvent process used was: Transformation, to water bodies, artificial. It represents the transformation of land to create a collection area for water extracted from the underground aquifer. The extracted water in part is used for mining. The parameter was calculated in the same way as *Transformation, to industrial area* knowing that the area dedicated to water collection is 192 m^2.
[6] Ecoinvent process used was: Occupation, to water bodies, artificial. It represents land occupancy. The parameter was calculated as the process *Occupation, industrial area*.
[7] Ecoinvent process used was: Gangue. It represents the mining rock required for the extraction of U.F. It equals the average rock processed per day by CocoA and CocoB, which is 128.6 kg, accounting for 15% of the total rock mined.
[8] Ecoinvent process used was: Blasting {RoW}| processing | APOS, U. It represents the explosive used to open mine shafts. As a primary figure, 0.5 kg of explosive is used for every 1 ton of rock mined. Therefore, through a linear proportion, the amount of explosive referred to the U.F., i.e. mining rock equal to 128.6 kg and inert rock equal to 728.7 kg.
[9] Ecoinvent process used was: Machine operation, diesel, < 18.64 kW, generators {GLO}| machine operation, diesel, < 18.64 kW, generators | APOS, U. Represents the consumption of generator energy for ventilation of the tunnels, extraction of water from the aquifer, and handling of the extracted rock by a trolley. Indicated in energy consumption of a typical working day.
[10] Ecoivent process used was: Transport, freight, lorry 16-32 metric ton, EURO5 {RoW}| transport, freight, lorry 16-32 metric ton, EURO6 | APOS, U. It represents the transport of the entire mine creation equipment, assuming a transport of 100 km.
[11] Ecoinvent process used was: Gold. It represents the gold content present in the doré, which is 47.08%.
[12] Ecoinvent process used was: Silver. It represents the silver content present in doré, which is 47.92%.
[13] Ecoinvent process used was: Iron (Fe). It represents the Fe content in doré, which is 4.76%.
[14] Ecoinvent process used was: Lead (Pb). It represents the Pb content present in the doré, which is 0.16%.
[15] Ecoinvent process used was: Copper ore. It represents the Cu content in doré, which is 0.06%.
[16] Ecoinvent process used was: Zinc ore. It represents the Zn content present in the doré, which is 0.02%.
[17] Ecoinvent process used was: Water, wells. It represents the water extracted from the aquifer and used for the entire amalgamation process, i.e., 30 l are placed in each coco together with the mining rock, 270 l for manual washing of the amalgam, and 143 l for condensation of mercury vapors. These quantities are the same for each amalgamation cycle.
[18] Ecoinvent process used was: Mercury {GLO}| production | APOS, U. It represents the mercury used for the entire amalgamation process.
[19] Ecoinvent process used was: Lime {RoW}| production, milled, loose | APOS, U. It represents the lime oxide that is inserted into the first and second cycle cocoas used to adjust the pH of the pulp.
[20] Ecoinvent process used was: Molasses, from sugar beet {RoW}| beet sugar production | APOS, U. It represents the molasses that is inserted into the cocoas of the former to adjust the pH of the pulp.
[21] Ecoinvent process used was: Lemon {RoW}| lemon production | APOS, U. It represents the lemons used for the production of lemon juice employed of the second and in the third cycle to adjust the pH of the pulp.
[22] Ecoinvent process used was: Finishing, textile, woven cotton {GLO}| finishing, textile, woven cotton | APOS, U. It represents the cloth used by miners to manually squeeze amalgam in order to remove excess mercury. It was assumed to use 10 cloths weighing 0.2 kg each for each amalgamation cycle.
[23] Ecoinvent process used was: Natural gas, low pressure {RoW}| natural gas pressure reduction from high to low pressure | APOS, U. It represents the methane gas used in the thermal separation stage of amalgam for obtaining Doré and for mercury vapor recovery.
[24] Ecoinvent process used was: Machine operation, diesel, < 18.64 kW, generators {GLO}| machine operation, diesel, < 18.64 kW, generators | APOS, U. It represents the use of electricity produced by the generator and used for the crushing stage upstream of amalgamation and for the pump connected to the thermal separation condenser.
[25] Ecoinvent process used was: Transport, freight, lorry 16-32 metric ton, EURO5 {RoW}| transport, freight, lorry 16-32 metric ton, EURO6 | APOS, U. It represents the transport of the entire equipment and raw materials used for the entire amalgamation stage, considering a hypothetical transport of 100 km.
[26] Co-product created by the authors to represent the amalgamation slurries exiting from the various amalgamation cycles that re-enter the subsequent amalgamation cycles.
[27] Co-product created by the authors to represent tailings exiting the various amalgamation cycles sent to cyanidation. They represent 30% of the solid fraction and 1.55%of the liquid fraction coming out of the amalgamation, stored in the sedimentation tanks and processed in the cyanidation.
[28] Co-product created by the working group to represent mercury recovered from the manual amalgam squeezing process and reintegrated into the amalgamation process.
[29] Ecoinvent process used was: Mercury {GLO}| production | APOS, U. Represents mercury recovered after thermal separation by condenser and mercury recovered from manual squeezing in the third cycle. It represents an avoided product because it is not used for the case study, but for a future amalgamation cycle.
[30] Ecoinvent process used was: Mercury. It represents the mercury emission to air generated during thermal separation. A plant mercury recovery efficiency of 99.9% was assumed.
[31]Ecoinvent process used was: Mercury. It represents the emission of mercury to water as a result of the release of 70% of the solid fraction and 98.45% of the liquid fraction present in the sedimentation tanks and not recovered by cyanidation into the environment. Environmental analyses showed an average mercury concentration of: 112 mg/kg for sludge leaving the first amalgamation cycle, 323.5 mg/kg for sludge leaving the second amalgamation cycle, and 461 mg/kg for sludge leaving the third amalgamation cycle. It was assumed to consider half emission as emission to water and half as emission to soil.
[32] Ecoinvent process used was: Mercury. It represents the emission of mercury to soil as a result of the release of 70% of the solid fraction and 98.45% of the liquid fraction present in the sedimentation tanks and not recovered by cyanidation into the environment. Environmental analyses showed an average mercury concentration of: 112 mg/kg for sludge leaving the first amalgamation cycle, 323.5 mg/kg for sludge leaving the second amalgamation cycle, and 461 mg/kg for sludge leaving the third amalgamation cycle, to which were added 3.63 g of miscellaneous losses during processing closing the mass balance. It was assumed to consider half emission as emission to water and half as emission to soil.
[33] Ecoinvent process used was: Gold. It represents the gold content in CyG, which is 33.47%.
[34] Ecoinvent process used was: Silver. It represents the silver content in CyG, which is 45.90%.
[35] Ecoinvent process used was: Other metal ore. It represents the content of other metals in CyG, which is 20.63%.
[36] Ecoinvent process used was: Water, well. Water extracted from the aquifer and used for the cyanidation process. A total of 62 m3 of water is needed, to be included in the pulp and for the effluent neutralization step, for the 5 cyanidation reactors, each with a capacity of 6000 kg of sludge, so a linear proportion was performed to obtain the cyanidation water referred to the U.F.
[37] Co-product created by the authors to represent tailings coming out of the various amalgamation cycles sent to the cyanidation. They represent 30% of the solid fraction and 1.55% of the liquid fraction coming out of the amalgamation, stored in the sedimentation tanks and processed in the cyanidation along with 6.19 kg of slurry amalgamation coming out of the third amalgamation cycle.
[38] Ecoinvent process used was: Lime, hydrated, packed {RoW}| production | APOS, U. It represents the lime oxide that is fed into the cyanidation reactor to adjust the pH of the pulp. A linear proportion was made knowing that 150 kg of CaO is needed to produce 1.18 kg of CyG.
[39] Ecoinvent process used was: Hydrogen peroxide, without water, in 50% solution state {RoW}| hydrogen peroxide production, product in 50% solution state | APOS, U. Representation hydrogen peroxide used for pulp oxygenation and effluent neutralization step. To process 6000 kg of sludge, 92 l of hydrogen peroxide is required.
[40] Ecoinvent process used was: Sodium cyanide {RoW}| production | APOS, U. Represents sodium cyanide needed to cyanide tailings. 6.58 g of NaCN/kg of tailings are needed.
[41] Ecoinvent process used was: Zinc {RoW}| primary production from concentrate | APOS, U. Represents zinc used for precipitation of compounds containing precious metals. The amount of Zn used was calculated stoichiometrically. An additional 30 wt% of Zn powder with respect to the stoichiometric amount was added for precautionary reasons.
[42] Ecoinvent process used was: Borax, anhydrous, powder {RoW}| production | APOS, U. Represents borax used to regulate temperature during melting. 50 g of borax is needed for every 1 kg of precipitate.
[43] Ecoinvent process used was: Sodium hydroxide, without water, in 50% solution state {RoW}| chlor-alkali electrolysis, membrane cell | APOS, U. Represents Sodium hydroxide used to regulate temperature during melting. It requires 30 g of NaOH per 1 kg of precipitate.
[44] Ecoinvent process used was: Sand {RoW}| sand quarry operation, extraction from river bed | APOS, U. Represents Sand used to regulate temperature during melting. 40 g of sand is needed for every 1 kg of precipitate.
[45] Ecoinvent process used was: Natural gas, low pressure {RoW}| natural gas pressure reduction from high to low pressure | APOS, U. It represents the methane gas used in the thermal separation and melting stage for obtaining CyG and for mercury vapor recovery.
[46] Ecoinvent process used was: Machine operation, diesel, < 18.64 kW, generators {GLO}| machine operation, diesel, < 18.64 kW, generators | APOS, U. It represents the use of electricity produced by the generator used for the cyanidation stage.
[47] Ecoinvent process used was: Transport, freight, lorry 16-32 metric ton, EURO5 {RoW}| transport, freight, lorry 16-32 metric ton, EURO6 | APOS, U. It represents the transport of the entire equipment and raw materials used for the entire cyanidation stage, considering a hypothetical transport of 100 km.
[48] Ecoinvent process used was: Mercury {GLO}| production | APOS, U. Represents mercury recovered after thermal separation by condenser. Represents an avoided product because it is not used for the case study, but for a future cyanidation cycle.
[49] Ecoivent process used was: Particulates, < 2.5 um. It represents the emission of fine particulate matter with particle size <2.5 um emitted into the air during cyanidation. It has been assumed that 1% of the powder materials used are released into the atmosphere. This amount was distributed for different particle sizes (< 2.5 um, >2.5 um and < 10 um) according EPA. APPENDIX B.2. GENERALIZED PARTICLE SIZE DISTRIBUTIONS. https://www3.epa.gov/ttn/chief/ap42/appendix/appb-2.pdf (accessed 15.7.24).
[50] Ecoivent process used was: Particulates, > 2.5 um and <10 um. It represents the emission of fine particulate matter with particle size > 2.5 um and <10 um emitted to the air during cyanidation. It has been assumed that 1% of the powder materials used are released into the atmosphere. This amount was distributed for different particle sizes (< 2.5 um, >2.5 um and < 10 um) according EPA. APPENDIX B.2. GENERALIZED PARTICLE SIZE DISTRIBUTIONS. https://www3.epa.gov/ttn/chief/ap42/appendix/appb-2.pdf (accessed 15.7.24).

[51] Ecoivent process used was: Particulates, > 10 um. It represents the emission of fine particulate matter with particle size > 10 um emitted into the air during cyanidation. It has been assumed that 1% of the powder materials used are released into the atmosphere. This amount was distributed for different particle sizes (< 2.5 um, >2.5 um and < 10 um) according EPA. APPENDIX B.2. GENERALIZED PARTICLE SIZE DISTRIBUTIONS. https://www3.epa.gov/ttn/chief/ap42/appendix/appb-2.pdf (accessed 15.7.24).
[52] Ecoivent process used was: Hydrogen cyanide. It has been assumed that the cyanide salt is dissolved in water forming hydrogen cyanide, and given its boiling temperature of 25.6°C, at room temperature it tends to evaporate and leave the system during the cyanidation process.
[53] Ecoinvent process used was: Mercury. It represents the mercury emission to air generated during thermal separation. A plant mercury recovery efficiency of 99.9% was assumed.
[54] Ecoinvent process used was: Cyanide compounds. It represents cyanide-based compounds that are released into the environment when effluents are dispersed into the environment after neutralization. Chemical reactions between NaCN and H2O2 and with CaO were examined. The emission was divided into two equal parts between the water and soil compartments.
[55] Ecoinvent process used was: Mercury compounds. It represents mercury-based compounds that are released into the environment when effluents are dispersed into the environment after neutralization. The chemical reaction between Hg with NaCN was examined. The emission was divided into two equal parts between the water compartment and the soil compartment. The portion of mercury needed to close the mass balance, which was 3.61 g, was added.
[56] Ecoivent process used was: Hydrogen peroxide. Through chemical reactions, it was found that part of the hydrogen peroxide does not react. This portion leaks into the soil and water at the end of the process along with the contents of the effluent tank. The emission was divided into two equal parts between the water and soil compartments.
[57] Ecoinvent process used was: Cyanide compounds. It represents cyanide-based compounds that are released into the environment when effluents are dispersed into the environment after neutralization. Chemical reactions between NaCN and H2O2 and with CaO were examined. The emission was divided into two equal parts between the water and soil compartments.
[58] Ecoinvent process used was: Mercury compounds. It represents mercury-based compounds that are released into the environment when effluents are dispersed into the environment after neutralization. The chemical reaction between Hg with NaCN was examined. The emission was divided into two equal parts between the water compartment and the soil compartment. The portion of mercury needed to close the mass balance, which was 3.61 g, was added.
[59] Ecoivent process used was: Hydrogen peroxide. Through chemical reactions, it was found that part of the hydrogen peroxide does not react. This portion leaks into the soil and water at the end of the process along with the contents of the effluent tank. The emission was divided into two equal parts between the water and soil compartments.
[60] Ecoinvent process used was: Zinc compounds. It represents the zinc compound contained in the glassy waste that comes out of the melt and is stored on the ground and unreacted zinc during precipitation.

DETAILS OF THE MODIFICATIONS PERFORMED ON THE METHODS RECIPE 2016 MIDPOINT (H) AND RECIPE 2016 ENDPOINT (H)

The impact assessment methods used in the present study are Recipe 2016 Midpoint (H) and Recipe 2016 Endpoint (H) modified by the authors in order to add them with relevant emitted substances that were originally not considered in the methods. For the specificity of the study, the following changes were made to the method:

Mercury compounds and Cyanide compounds were added in the modified Recipe 2016 Midpoint (H) method for both emissions in water and emissions in soil. Particularly:

- "Cyanide compounds" substance was considered to contribute to the impact categories Human carcinogenic, Terrestrial ecotoxicity, Freshwater ecotoxicity and Marine ecotoxicity.
- "Mercury compounds" substance was considered to contribute to the impact categories Human carcinogenic, Human non-carcinogenic, Terrestrial ecotoxicity, Freshwater ecotoxicity and Marine ecotoxicity.

The TRACI 2.1 method was taken as a reference because it contains both "Mercury compounds" and "Cyanide compounds", together with the further substances "Mercury (II)" and "Cyanazine", the latter two being also considered within the original (i.e., unmodified) ReCiPe 2016 Midpoint (H) method. The ratio between the TRACI 2.1 and ReCiPe 2016 midpoint characterization factors of "Mercury (II)" substance, was used to calculate the ReCiPe 2016 midpoint characterization factor of "Mercury compounds" under the assumption of the environmental impacts proportionality between Recipe 2016 Midpoint (H) method and TRACI 2.1 method. Similarly, under the same assumption, the ratio between the TRACI 2.1 and ReCiPe 2016 midpoint characterization factors of "Cyanazine" substance, was used to calculate the ReCiPe 2016 midpoint characterization factor of "Cyanide compounds".

Table S4 shows the calculated characterization factors. The same procedure was also applied to the Recipe 2016 Endpoint (H) method, the results are shown in **Table S5**.

Table S4. Characterization Factors of Mercury compounds and Cyanide compounds as implemented in Recipe 2016 Midpoint (H) method.

Impact category	Substance	Characterization Factors [kg1.4 -DCB/kg]
Human carcinogenic	Mercury compounds in water	1.39E+02
	Mercury compounds in soil	1.21E+00
	Cyanide compounds in water	1.76E+01
	Cyanide compounds in soil	1.33E+01
Human non-carcinogenic	Mercury compounds in water	5.63E+04
	Mercury compounds in soil	4.91E+02
Terrestrial ecotoxicity	Mercury compounds in water	2.54E-15
	Mercury compounds in soil	4.06E-18
	Cyanide compounds in water	3.10E-02
	Cyanide compounds in soil	8.31E-02
Freshwater ecotoxicity	Mercury compounds in water	6.04E+01
	Mercury compounds in soil	1.50E-01
	Cyanide compounds in water	1.09E+02
	Cyanide compounds in soil	4.07E+01
Marine ecotoxicity	Mercury compounds in water	6.24E+01
	Mercury compounds in soil	8.43E-02
	Cyanide compounds in water	2.09E+01
	Cyanide compounds in soil	7.81E+00

Table S5. Characterization Factors of Mercury compounds and Cyanide compounds in Recipe 2016 Endpoint (H) method.

Impact category	Substance	Characterization Factors [kg1.4 -DCB/kg]
Human carcinogenic	Mercury compounds in water	4.60E-04
	Mercury compounds in soil	4.00E-06
	Cyanide compounds in water	5.84E-05
	Cyanide compounds in soil	4.41E-05
Human non-carcinogenic	Mercury compounds in water	1.28E-02
	Mercury compounds in soil	1.11E-04
Terrestrial ecotoxicity	Mercury compounds in water	2.89E-26
	Mercury compounds in soil	4.63E-29
	Cyanide compounds in water	3.53E-13
	Cyanide compounds in soil	9.47E-13
Freshwater ecotoxicity	Mercury compounds in water	4.20E-08
	Mercury compounds in soil	1.04E-10
	Cyanide compounds in water	7.61E-08
	Cyanide compounds in soil	2.83E-08
Marine ecotoxicity	Mercury compounds in water	6.55E-09
	Mercury compounds in soil	8.85E-12
	Cyanide compounds in water	2.21E-09
	Cyanide compounds in soil	8.20E-10

SUPPLEMENTARY RESULTS

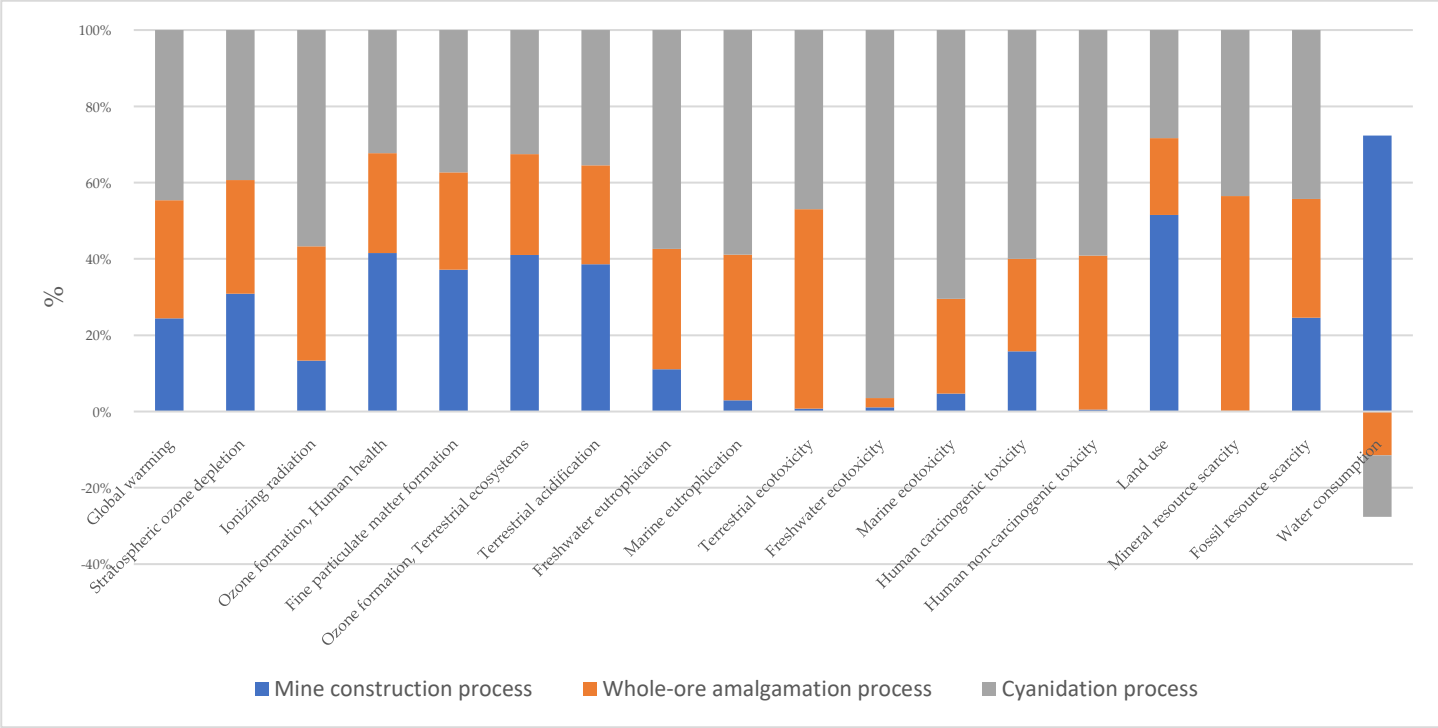


Figure S30. Midpoint environmental impacts associated to the obtainment of 1 kg of Mina Nueva products comprising both Doré (0.48835 kg) and CyG (0.51165 kg).

Table S6. Midpoint environmental impacts associated to the obtainment of 1 kg of gold, contained in *ca*. 2.49 kg of Mina Nueva products, by using the Recipe 2016 Midpoint (H) method modified by the authors.

Impact category	Unit	Total	Mine construction process	Whole-ore amalgamation process	Cyanidation process
Global warming	kg CO_2 eq	1.16E+04	2.83E+03	3.58E+03	5.19E+03
Stratospheric ozone depletion	kg CFC11 eq	8.86E-03	2.74E-03	2.63E-03	3.49E-03
Ionizing radiation	kBq Co-60 eq	1.50E+02	2.00E+01	4.49E+01	8.49E+01
Ozone formation, Human health	kg NOx eq	7.25E+01	3.01E+01	1.90E+01	2.34E+01
Fine particulate matter formation	kg PM2.5 eq	2.16E+01	8.03E+00	5.49E+00	8.03E+00
Ozone formation, Terrestrial ecosystems	kg NOx eq	7.47E+01	3.07E+01	1.97E+01	2.43E+01
Terrestrial acidification	kg SO_2 eq	4.56E+01	1.76E+01	1.18E+01	1.62E+01
Freshwater eutrophication	kg P eq	1.84E+00	2.04E-01	5.80E-01	1.05E+00
Marine eutrophication	kg N eq	1.15E+00	3.39E-02	4.38E-01	6.74E-01
Terrestrial ecotoxicity	kg 1,4-DCB	3.65E+06	2.69E+04	1.91E+06	1.71E+06
Freshwater ecotoxicity	kg 1,4-DCB	4.48E+03	4.90E+01	1.11E+02	4.32E+03
Marine ecotoxicity	kg 1,4-DCB	1.95E+03	9.16E+01	4.85E+02	1.38E+03
Human carcinogenic toxicity	kg 1,4-DCB	4.98E+03	7.87E+02	1.21E+03	2.98E+03
Human non-carcinogenic toxicity	kg 1,4-DCB	1.48E+05	8.06E+02	5.98E+04	8.76E+04
Land use	m^2a crop eq	2.06E+03	1.06E+03	4.15E+02	5.82E+02
Mineral resource scarcity	kg Cu eq	4.14E+03	6.66E+00	2.33E+03	1.80E+03
Fossil resource scarcity	kg oil eq	3.20E+03	7.86E+02	9.99E+02	1.42E+03
Water consumption	m^3	-8.44E+02	-1.36E+03	2.17E+02	3.03E+02

Table S7. Uncertainties for the LCA results of 1 kg of Mina Nueva products comprising both Doré (0.48835 kg) and CyG (0.51165 kg) obtained using the Recipe 2016 Midpoint (H) method modified by the authors.

Impact category	Unit	Mean	Median	SD	CV %	2,5%	97,5%
Fine particulate matter formation	kg PM2.5 eq	8.67E+00	8.66E+00	2.95E-01	3.41E+00	8.11E+00	9.28E+00
Fossil resource scarcity	kg oil eq	1.28E+03	1.27E+03	1.26E+02	9.83E+00	1.06E+03	1.55E+03
Freshwater ecotoxicity	kg 1,4-DCB	1.80E+03	1.79E+03	1.79E+01	9.94E-01	1.77E+03	1.84E+03
Freshwater eutrophication	kg P eq	7.43E-01	6.96E-01	2.09E-01	2.81E+01	4.88E-01	1.30E+00
Global warming	kg CO2 eq	4.66E+03	4.64E+03	2.58E+02	5.53E+00	4.18E+03	5.19E+03
Human carcinogenic toxicity	kg 1,4-DCB	1.98E+03	1.88E+03	6.70E+02	3.38E+01	1.05E+03	3.59E+03
Human non-carcinogenic toxicity	kg 1,4-DCB	5.59E+04	5.64E+04	1.48E+05	2.64E+02	-2.31E+05	3.37E+05
Ionizing radiation	kBq Co-60 eq	5.97E+01	3.21E+01	8.32E+01	1.39E+02	7.97E+00	3.19E+02
Land use	m2a crop eq	8,20E+02	7,95E+02	1,23E+02	1,49E+01	6,70E+02	1,11E+03
Marine ecotoxicity	kg 1,4-DCB	7.89E+02	7.16E+02	3.00E+02	3.80E+01	5.47E+02	1.56E+03
Marine eutrophication	kg N eq	4.66E-01	4.40E-01	1.35E-01	2.89E+01	2.82E-01	7.88E-01
Mineral resource scarcity	kg Cu eq	1.66E+03	1.66E+03	2.08E+01	1.25E+00	1.63E+03	1.71E+03
Ozone formation, Human health	kg NOx eq	2.91E+01	2.91E+01	1.55E+00	5.31E+00	2.62E+01	3.23E+01
Ozone formation, Terrestrial ecosystems	kg NOx eq	3.00E+01	2.99E+01	1.60E+00	5.32E+00	2.70E+01	3.33E+01
Stratospheric ozone depletion	kg CFC11 eq	3.54E-03	3.48E-03	4.66E-04	1.32E+01	2.80E-03	4.60E-03
Terrestrial acidification	kg SO2 eq	1.83E+01	1.83E+01	9.62E-01	5.25E+00	1.65E+01	2.03E+01
Terrestrial ecotoxicity	kg 1,4-DCB	1.49E+06	1.07E+06	1.71E+06	1.14E+02	1.92E+05	5.73E+06
Water consumption	m3	-3.76E+02	-3.16E+02	8.74E+02	-2.32E+02	-2.37E+03	1.18E+03

Table S8. Single score results associated to the obtainment of 1 kg of Mina Nueva products comprising both Doré (0.48835 kg) and CyG (0.51165 kg).

Damage category	Unit	Total	Mine construction process	Whole-ore amalgamation process	Cyanidation process
Human health	Pt	4.82E+02	5.00E+01	1.64E+02	2.67E+02
Ecosystem	Pt	1.09E+01	7.67E-01	4.59E+00	5.58E+00
Resources	Pt	6.44E+00	9.68E-01	2.71E+00	2.76E+00

Table S9. Single score results associated to the obtainment of 1 kg of gold, contained in *ca*. 2.49 kg of Mina Nueva products.

Damage category	Unit	Total	Mine construction process	Whole-ore amalgamation process	Cyanidation process
Human health	Pt	1.20E+03	1.25E+02	4.09E+02	6.66E+02
Ecosystem	Pt	2.72E+01	1.91E+00	1.14E+01	1.39E+01
Resources	Pt	1.60E+01	2.41E+00	6.75E+00	6.88E+00

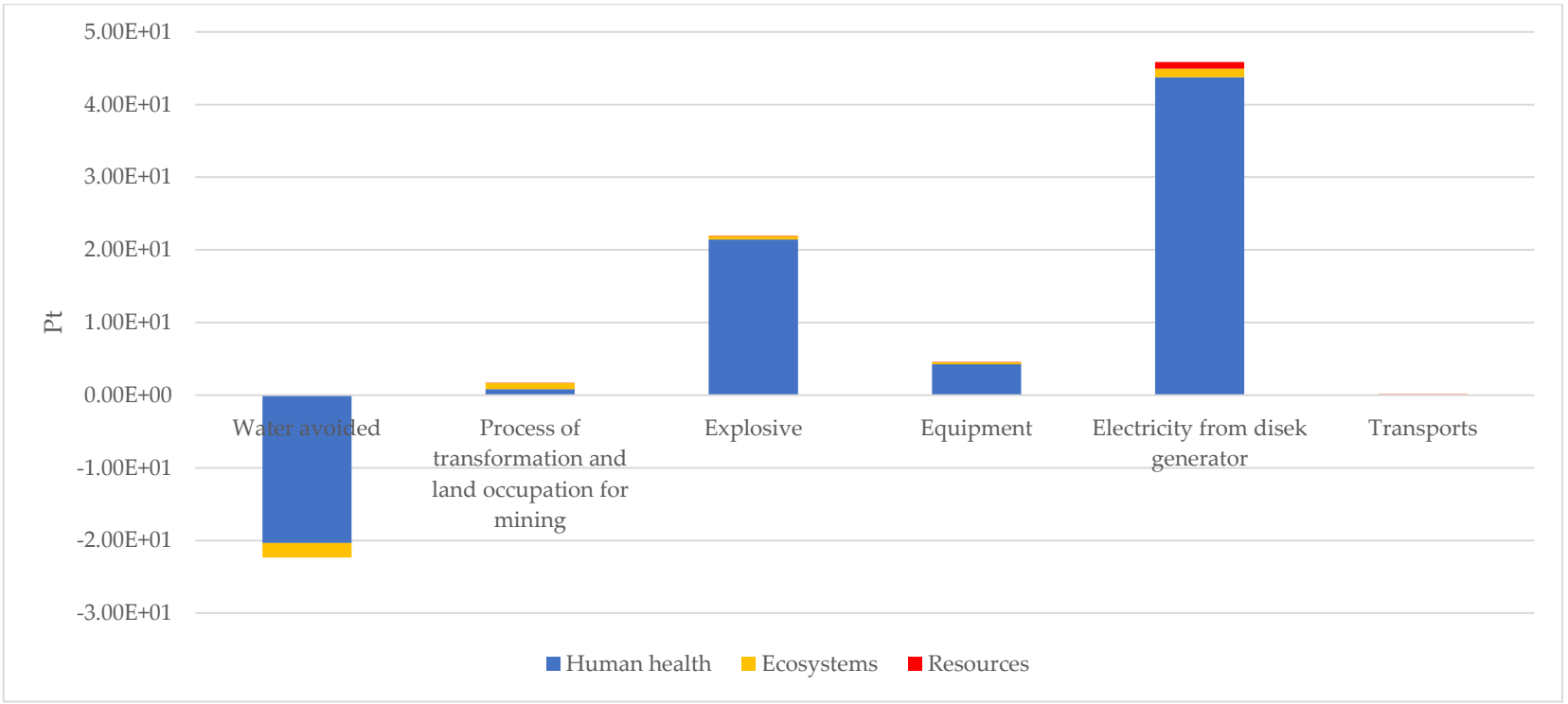


Figure S31. Single score results by damage categories of the Mine Construction process of 1 kg of Mina Nueva products comprising both Doré (0.48835 kg) and CyG (0.51165 kg).

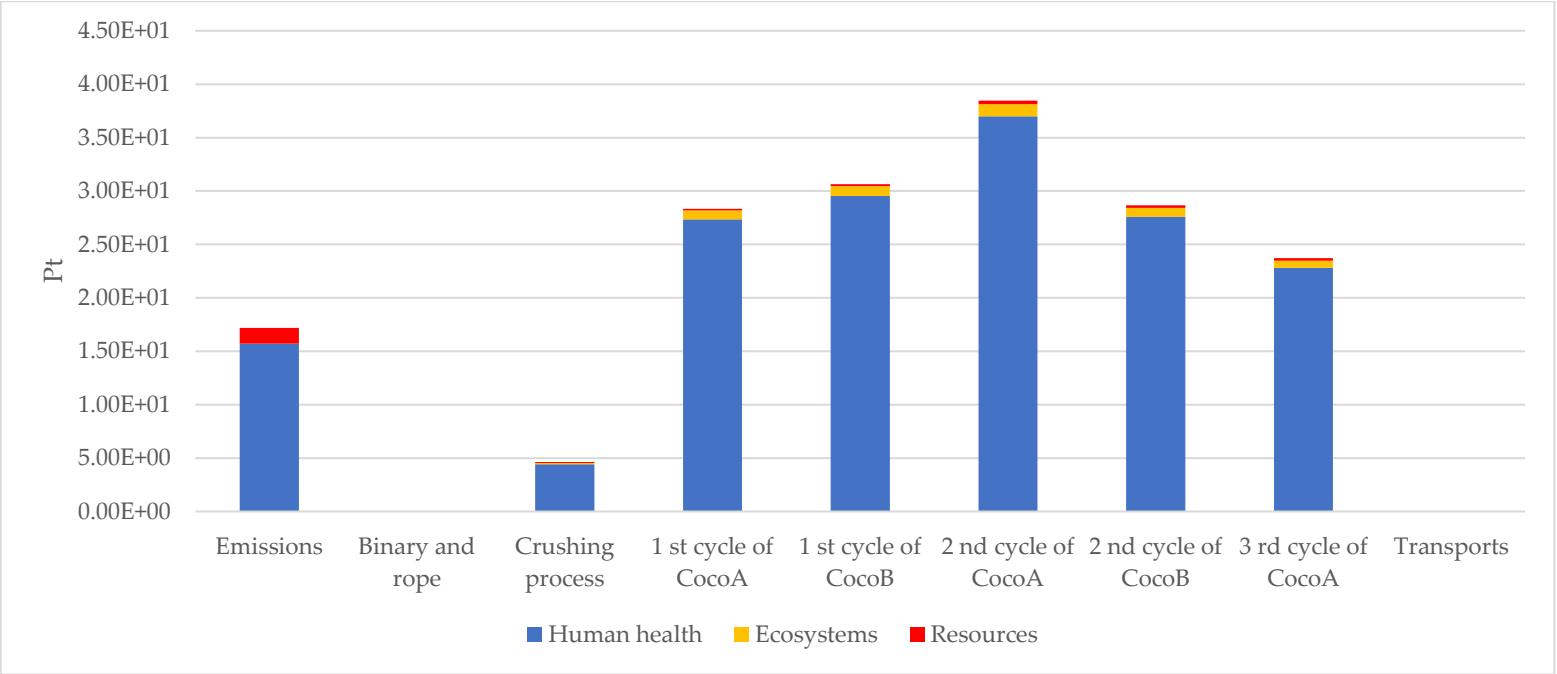


Figure S32. Single score results by damage categories of the Whole-ore amalgamation process of 0.48835 kg Dorè.

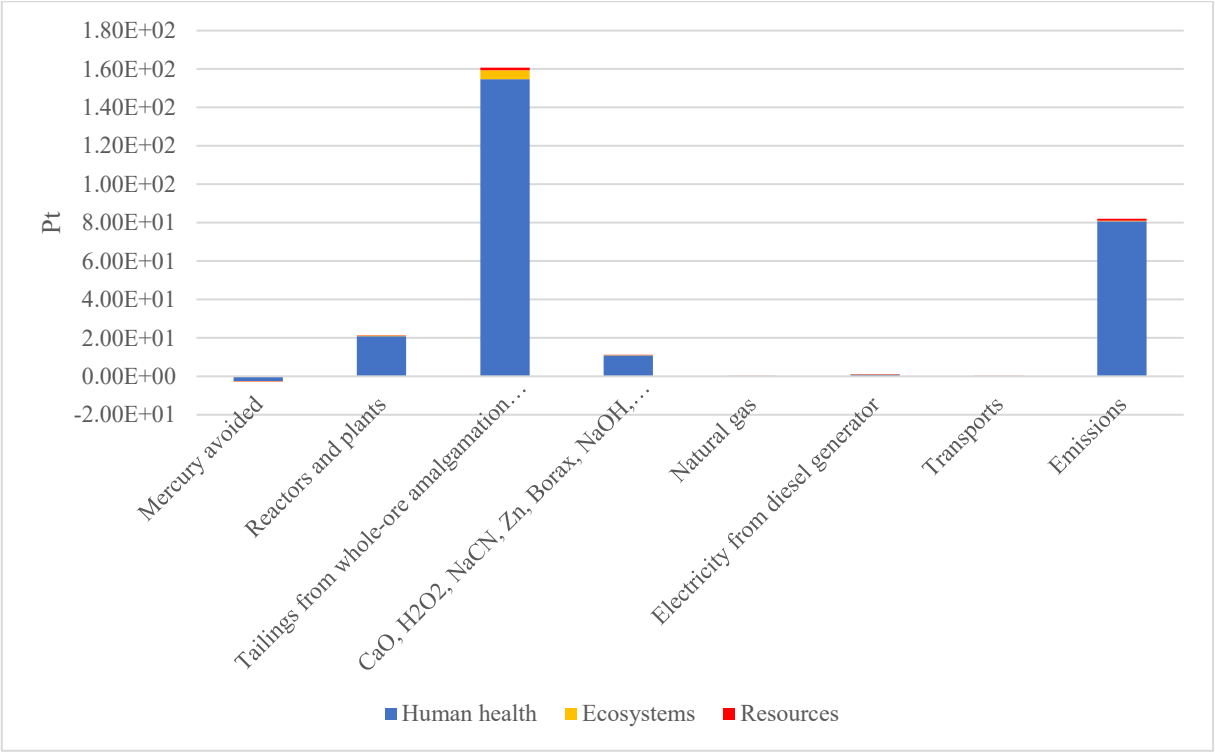


Figure S33. Single score results by damage categories of the Cyanidation process of 0.51165 kg CyG.

Table S10. Single score results by damage categories of the Mine Construction process of 1 kg of Mina Nueva products comprising both Doré (0.48835 kg) and CyG (0.51165 kg).

Damage category	Unit	Water avoided	Process of transformation and land occupation for mining	Explosive	Equipment	Electricity from diesel generator	Transports
Human health	Pt	-2.04E+01	8.49E-01	2.14E+01	4.26E+00	4.38E+01	9.54E-02
Ecosystem	Pt	-2.01E+00	8.03E-01	5.12E-01	2.69E-01	1.19E+00	2.71E-03
Resources	Pt	0.00E+00	2.02E-04	2.95E-02	2.58E-02	9.10E-01	2.13E-03

Table S11. Single score results by damage categories of the Whole-ore amalgamation process of 0.48835 kg of Dorè.

Damage category	Unit	Binary and rope	Crushing process	1st cycle of Coco A	1st cycle of Coco B	2nd cycle of Coco A	2nd cycle of Coco B	3rd cycle of Coco A	Transports	Emissions
Human health	Pt	9.06E-04	4.42E+00	2.73E+01	2.95E+01	3.70E+01	2.76E+01	2.28E+01	5.89E-04	1.57E+01
Ecosystem	Pt	4.36E-06	1.26E-01	8.59E-01	9.34E-01	1.15E+00	8.42E-01	6.83E-01	1.67E-05	7.66E-04
Resources	Pt	1.17E-06	9.78E-02	1.45E-01	1.63E-01	3.33E-01	2.52E-01	2.43E-01	1.31E-05	1.48E+00

Table S12. Single score results by damage categories of the Cyanidation process of 0.51165 kg CyG.

Damage categories	Unit	Mercury avoided	Reactors and plants	Tailings from whole-ore amalgamation process	CaO, H2O2, NaCN, Zn, Borax, NaOH, Silice	Natural gas	Electricity from diesel generator	Transports	Emissions
Human health	Pt	-2.42E+00	2.09E+01	1.55E+02	1.08E+01	5.81E-03	9.56E-01	1.03E-01	8.06E+01
Ecosystem	Pt	-1.04E-01	2.74E-01	4.74E+00	2.96E-01	1.84E-04	2.59E-02	2.94E-03	3.43E-01
Resources	Pt	-4.18E-04	1.54E-01	1.32E+00	1.51E-01	8.43E-04	1.99E-02	2.31E-03	1.11E+00

Table S13. Particulate matter emissions calculated for the Scenario 2 of the Mine construction process and associated uncertainties as calculated by the pedigree matrix.

Emissions to air during the Mine construction process (Scenario 2)	Amount (kg)	Distribution	Basic uncertainty	Pedigree matrix values	SD2 or 2SD
Particulates, < 2.5 μm	2.69[1]	Lognormal	3.0[2]	(5,5,5,5,5,n.a.)	4.2
Particulates, > 2.5 μm, and < 10 μm	6.46[3]	Lognormal	2.0[4]	(5,5,5,5,5,n.a.)	3.17
Particulates, > 10 μm	8.79[5]	Lognormal	1.5[6]	(5,5,5,5,5,n.a.)	2.74

[1] Calculated by the formula 0.129125*0.15/(1-0.9928), where 0.12925 is the total amount (kg) of particulates emitted as calculated by the formula 10/0.8*0.01033 (where 10 are the kg of dust emitted for 1 kg of gold concentrate considered in the work by Valdivia and Ugaya [2], 0.8 are the kg of gold contained in 1 kg of gold concentrate considered in the work by Valdivia and Ugaya [2] and 0.01034 are the kg of gold contained in the Functional Unit of the present study as previously reported in Table S1 and Table S2, 0.15 is the fraction of particulates < 2.5 μm considered [14] and 0.9928 is the efficiency of the water system for dust abatement [15], the latter being absent in the present case study.
[2] The SimaPro default value for process emissions of PM2.5 was selected.
[3] Calculated by the formula 0.129125*0.36/(1-0.9928), where 0.12925 is the total amount (kg) of particulates emitted as calculated by the formula 10/0.8*0.01033 (where 10 are the kg of dust emitted for 1 kg of gold concentrate considered in the work by Valdivia and Ugaya [2], 0.8 are the kg of gold contained in 1 kg of gold concentrate considered in the work by Valdivia and Ugaya [2] and 0.01034 are the kg of gold contained in the Functional Unit of the present study as previously reported in Table S1 and Table S2, 0.36 is the fraction of particulates > 2.5 μm and < 10 μm considered [14] and 0.9928 is the efficiency of the water system for dust abatement [15], the latter being absent in the present case study.
[4] The SimaPro default value for process emissions of PM10 was selected.
[5] Calculated by the formula 0.129125*0.49/(1-0.9928), where 0.12925 is the total amount (kg) of particulates emitted as calculated by the formula 10/0.8*0.01033 (where 10 are the kg of dust emitted for 1 kg of gold concentrate considered in the work by Valdivia and Ugaya [2], 0.8 are the kg of gold contained in 1 kg of gold concentrate considered in the work by Valdivia and Ugaya [2] and 0.01034 are the kg of gold contained in the Functional Unit of the present study as previously reported in Table S1 and Table S2, 0.49 is the fraction of particulates > 10 μm considered [14] and 0.9928 is the efficiency of the water system for dust abatement [15], the latter being absent in the present case study.
[6] The SimaPro default value for process emissions of PM>10 was selected.

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