Reducing global mercury pollution

Report on field work carried out in Nicaragua 2014 and 2015 financed by the Danish Ministry of Environment on how to extract mercury and gold from mine tailings from small sale gold mining

Compiled by Peter Appel

Peter W. U. Appel
AppelGlobal
pwuappel@yahoo.dk

Content

Abstract

Seven piles of tailings weighing 4 to 21 tons in total 54,2 tons from seven different small-scale gold mining areas were processed using Oro Industries Inc. Mercury Recovery Plant (MRP) combined with the Danish-Philippine invented Peter Plates at a processing station owned by Resourcos Encinal near San Juan de Limay in Northern Nicaragua. Detailed sampling of the tailings was carried out and the samples were analysed at Actlabs, Canada, University of Copenhagen and at Danish Technical University (DTU). Recovery of mercury varied from 5 to 57% and of gold from 1 to 76%. A Research programme carried out at DTU found that a non-toxic environmentally friendly organic compound will facilitate recovery of mercury and gold. One test of this organic compound resulted in increase in recovery of mercury from 5 to 42%. A successful outcome of the project requires model(s) for safe storage of the mercury extracted from the tailings. Different solutions have been investigated during the project period. One promising model has been developed by an agency under the Spanish Ministerio de Agricultura, Alimantación y Medio Ambiente. Their work is briefly described below.

Background

Worldwide around 20 million people have no means of income and therefor resort to mining. They mainly work in South-East Asia, Africa, Central- and South America. This is not mining in the conventional terminology, but small-sale mining. It is mostly real low technological mining such as three men and a wheelbarrow. The miners dig shafts many tens of metres down and from there a network of tunnels, where they extract commodities such as gold, precious stones or materials for road construction. Another type of small-scale mining is placer mining, where the mines extract various commodities e.g. gold or diamonds from river sediments. Small-scale gold mining is widespread in most developing countries. It contributes significantly to the global gold production. The techniques they use are mostly primitive due to lack of capital for investing in better techniques.

Most of the miners crush their gold ore manually. Next step is milling the gold ore. This is done manually or in metal drums with hard metal rods or balls. Milling liberates the fine gold particles in the gold ore. Next step used to be concentrating the gold particles in a gold digger pan. However, during many hundred-year amalgamation has been a quick and easy way to extract gold grains from milled gold ore.

When gold particles are mixed with mercury a gold amalgam is formed. It has a paste like texture and can easily be separated from the remaining minerals in the milled ore. The miners just add mercury to the milling process and mercury will capture most of the fine gold particles. After end milling the amalgam is recovered and heated whereby mercury evaporates and the gold is left behind. The method is highly efficient, but create a global mercury pollution which will endanger the health of future generations on planet Earth. Mercury pollution from small-scale gold mining is presently the main source of global mercury pollution (AMAP/UNEP, 2013).

It is obvious that immediate action has to be taken to stop mercury pollution from small-scale gold mining. There are two avenues which both have to be followed:

- Teach gold miners to extract gold without using mercury
- Clean the millions of mercury-polluted tailings produced by small-scale gold mining

There are mercury-free gold extraction methods for small-scale gold miners and progress is made to teach miners to use them (Appel & Na-Oy, 2014), A special advantage for the miners to convert to mercury-free gold extraction is that they recover more gold and with no health risks.

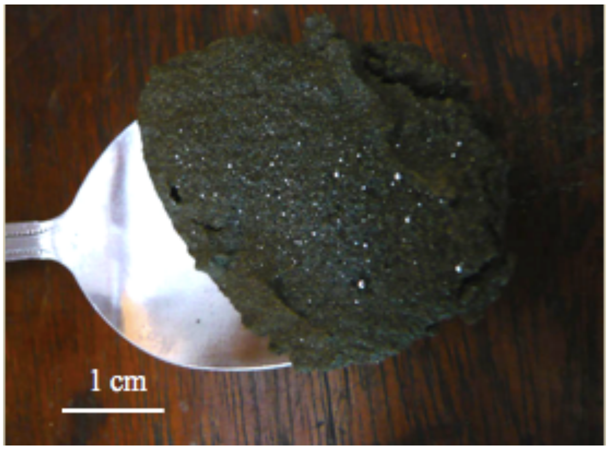
Tailings are mine waste materials after extraction of various commodities. Cleaning mercury polluted tailings from small-scale gold mining is the topic of this project.

In 2014-2015 Phase 1 of a MUDP project financed by the Danish Ministry of Environment testing methods of extracting mercury flour from polluted tailings that was carried out in Nicaragua. The project terminated mid 2015. The present project is a phase 2 and also financed by the Danish Ministry of Environment. It was carried out by Elplatek, Institute of Metallurgy at Danish Technical University and AppelGlobal.

The present Phase 2 was planned to consist of two test runs in San Juan de Limay in Northern Nicaragua. First one in the autumn of 2915 and the second in the spring in 2016. The autumn session was successfully carried out whereas the spring session unfortunately had to be cancelled. An explanation is presented in the last chapter of this report.

Mercury-polluted tailings

Gold mainly occurs as mm-sized grains irregularly distributed in the ore. Some of the grains are so small and have a flaky shape which make the grains able to float on water. It is obvious that the nature of gold makes it very difficult to capture the gold grains with simple means. Adding mercury does the trick. Thorough mixing will facilitate that mercury amalgamates with gold grains and amalgam is easy to capture for the miners. There is, however, one serious problem. When mechanically mixing mercury with gold ore a high proportion of the mercury is beaten up into tiny spheres called mercury flour. The spheres easily float on water and therefor escapes recovery. The spheres are coated with with very thin film of mercury oxide which prevents the spheres to coalesce. This means that mercury flour cannot be recovered by the miners, but ends in their tailings.



Tailings with numerous small drops of mercury (mercury flour)

Mercury flour will gradually either be washed out from the tailings and end in the drainage system polluting the water ways or mercury flour will slowly evaporate. In either way contribute to the global mercury pollution. There is another but not health related problem with mercury-flour. That is that the flour contains high amounts of gold. It is estimated that the hundreds of thousand small-scale gold miners e.g. in Philippines loose several tons of gold to the tailings yearly. This means a significant loss of income for the miners and also for the countries.

The present project explores a way to extract mercury flour from the millions of tailings littering countries in South-East Asia, Africa, Central- and South America. Cleaning all those tailings will improve the health situation for generations on planet Earth, and at the same time generate significant income.

Description of field work autumn 2015

Field work was carried out at San Juan de Limay near the town of Esteli, Northern Nicaragua at a site where an Oro Industries Inc. California constructed Mercury Recovery Plant (MRP) was placed. This is the same site as used during MUDP Phase 1 the year before. The owner of the site (Resourcos Encinal) which is a local Nicaraguan company generously allowed us to use the site and supplied local manpower for us during the Autumn 2015.

Sampling programme

Tailings from several different processing sites in the general area of Esteli were gathered and piled up at the processing site. Before processing each pile of tailings it was important to obtain the content of mercury and gold in each pile. This is not an easy task. Incremental sampling technique has to be used (Esbensen & Julius. 2009). In short it works as follows. From a pile of tailings a shovel with about 1 kg of tailings was collected. From the shovel a spoon full of tailings was taken and placed in a tub. The remaining material from the shovel was put aside. It is shown in the photos below.

Processing line

Halfway through the intensive task of moving a complete original lot one shovel at the time, taking great care to extract an increment from each shovel

Incremental sampling from each shovel used to transport all original lots

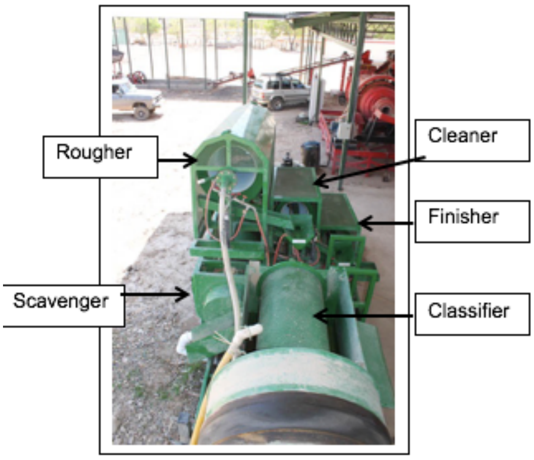
Loading the project riffle-splitter. Sub-sampling is made effective by the fact that the sample to be split does not need to be split all in one, but can be subjected to riffle-splitting in an intermittent loading process, Esbensen & Julius-Petersen (2009)

This was done until the original pile of tailings was emptied and moved to a neighbouring site. The material in the tub was split again and again until a final sample weight of around one kg was obtained. The samples were shipped to Actlabs, Canada for chemical analysis. By following this procedure a reliable content of mercury and gold in the delivered tailings can be established.

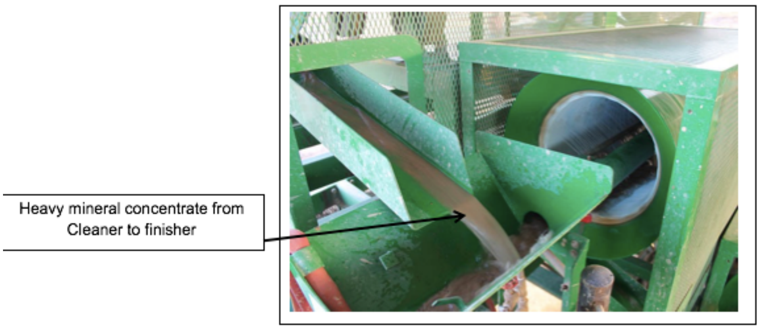
Next step is separating the heavy minerals such as mercury and gold from the light minerals such as quartz and feldspars. This is done by the MRP like it was done during the first phase of MUDP project 2014 to 2015. There is one major difference from the set up during MUDP 2015-2016 as before. During phase 2 the MRP is combined with a set of Peter Plates.
The MRP uses simple gravitational processing whereby light and heavy minerals stepwise are separated to a final step where a heavy mineral concentrate is produced.

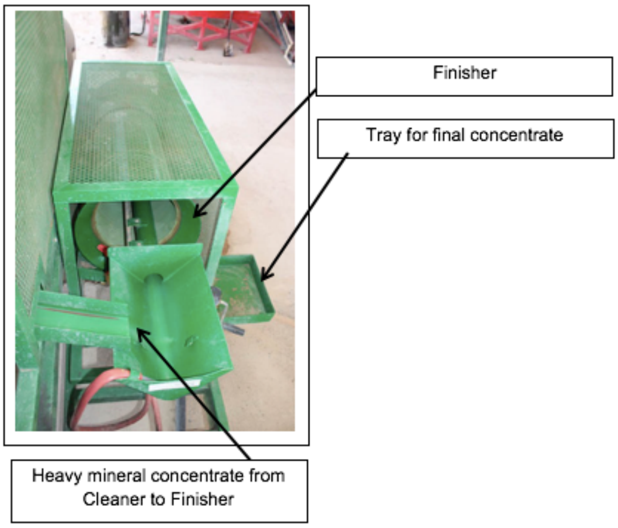
Mercury Recovery Plant (MRP)

Separation takes place through a series of spirals where the concentrate from each spiral is directed to the next spiral. The tailings from the two first spirals rougher and cleaner is directed to the scavenger which is a centrifuge. The concentrate from the centrifuge is directed to the last spiral which is the finisher (see photo below). The MRP produces in the order of 10 to 20 kg heavy minerals including mercury and gold.



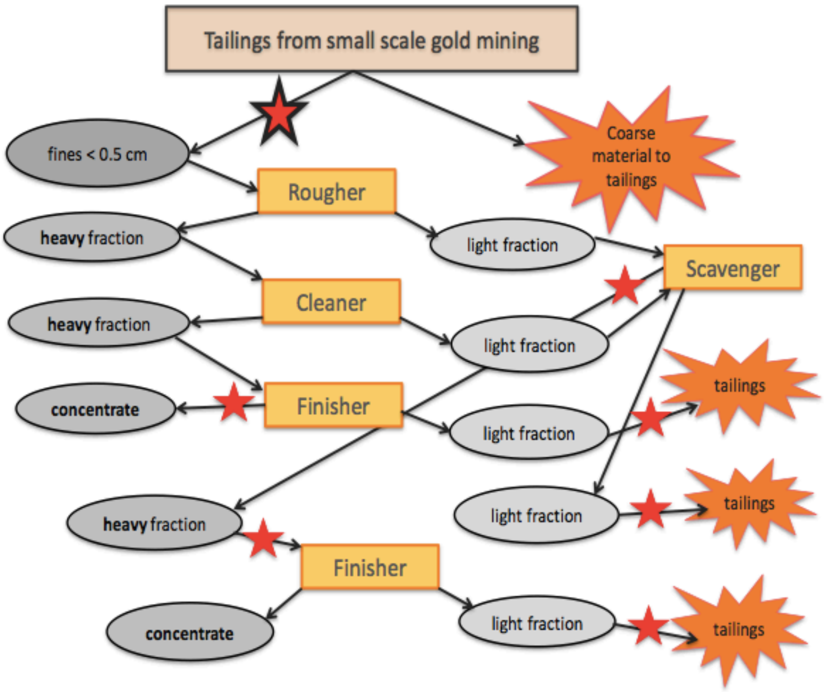
Spirals in the MRP used for producing heavy mineral concentrates





Sampling each step of processing

Samples of tailings from the three spirals and from the centrifuge were collected in the following way (see figure below). Each 5 minutes a spoonful of tailings was collected from each site and those samples were bagged and sent for analysis to Actlabs, Canada. Samples of concentrate from the centrifuge (scavenger) were also collected. List of samples in Appendix 1.



Red stars show sampling sites

Peter Plates hooked up on RPM

Peter Plates were constructed in Philippines about five years ago (Appel et al. 2011) inspired by a gadget called a State Battery which was constructed in Australia around 1850. The Peter Plates is a system of copper plates coated with copper amalgam. The copper amalgam has the ability to capture mercury flour as well as very fine grained gold (gold dust).
The heavy mineral concentrate from MRP is passed over the Peter Plates where mercury flour and free gold is captured. When the plates are saturated the captured material is scraped off and the amalgam is heated in a closed circuit whereby mercury is distilled and captured and the gold is left behind.

How to improve capture of mercury flour from mine tailings

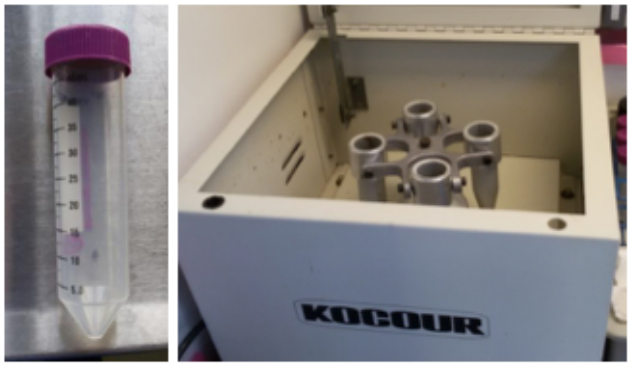
The size of mercury flour and the fact that the flour floats on water makes it impossible to recover it using gravitational methods. That the mercury droplets are coated with a film of mercury oxide prevents them to coalesce. The best solution seems to be to remove the mercury oxide film, which will facilitate the droplets to coalesce. This has to be done in an environmental safe way.
A series of experiments have been carried in out Department of Metallurgy at the Technical University of Copenhagen. Modification of the surface-chemistry of Hg particles in tailings by various chemical treatments followed by a mechanical separation in order to enhance the agglomeration-characteristics of the particles thus increasing the efficiency of the Hg removal.

Processing

100 g uncontaminated tailings were mixed with 50 ml water. Approximately 0.25 g Hg + a predefined chemical mixture was added. The whole mixture was blended in a predefined time-interval in order to disperse the Hg as fine particles throughout the mixture to imitate the real-life scenario.

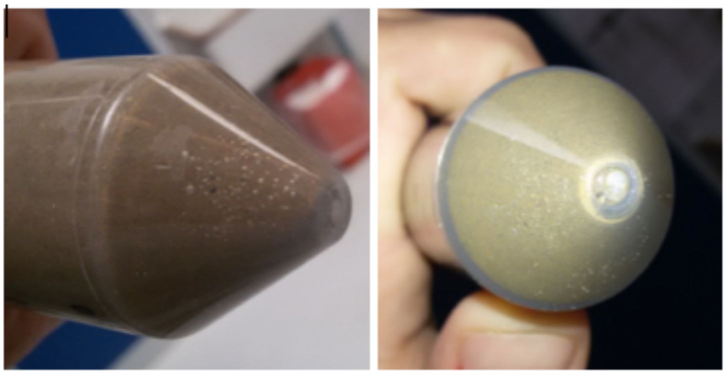
The sample mixture was put into plastic-tubes which were then centrifuged at constant rotation-speed in a predefined time-interval in order to separate the Hg particles from the tailings and achieve agglomeration of Hg-droplets in the bottom of the tubes. The separation-process and agglomeration was evaluated continuously at fixed intervals during the centrifuging of the samples

Uncontaminated tailings mixed with water, Hg and chemicals in a beaker. Then blended



Centrifuging of the mixture in laboratory centrifuge

After centrifuging the sample was poured on to a disk and the sizes of the agglomerated Hg droplets were investigated and quantified using light optical microscope

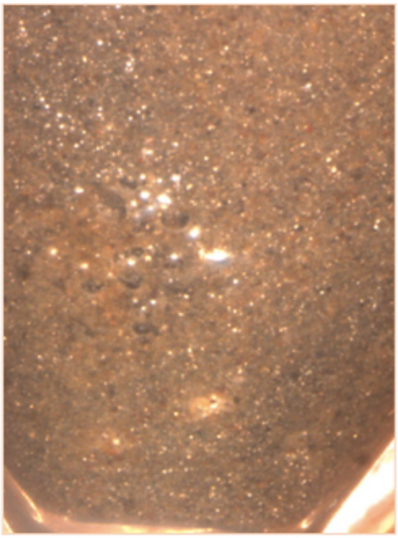


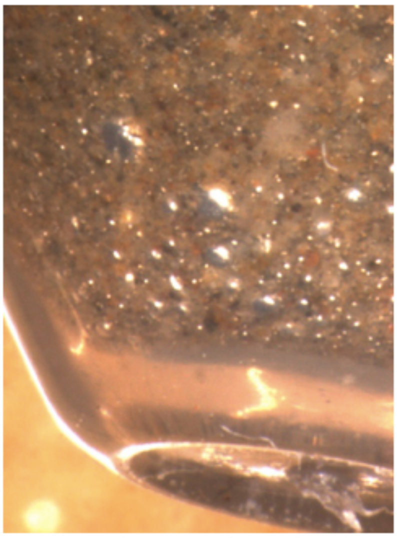
Result after centrifuging a tailing sample. Hg droplets are separating and agglomerating in the bottom of the tube

Visual check of the sample after centrifuging to quantify the Hg droplets by size

Preliminary results

Main observations are that mechanical separation (centrifuging) seems to work satisfactory to some degree as the Hg-particles are observed to migrate through the sand and towards the bottom of the tube – Longer time-interval of centrifuging yields longer migrating-paths and more particles in the lower part of the tube as observed below


Hg particles in bottom of tube after 5 min. of centrifuging


Hg particles in bottom of tube after 10 min. of centrifuging

Furthermore it seems that certain chemical mixtures resulted in somewhat faster separation and larger agglomerations in the bottom of the tubes. Some mixtures yielded several small droplets, while other treatments resulted in fewer larger droplets after centrifuging indicating that the chemicals have an effect on the agglomeration-characteristics of the Hg. Other types of mechanical separation techniques – as opposed to centrifuging - are also being considered which could yield more clear results

The most efficient compound that gave the best results is an organic compound. This compound has fortunately absolutely no adverse effects on health and environment.

Chemical and mineralogical analytical work

Chemical analysis of major and trace elements

The collected samples were sent to Actlabs Laboratories in Canada. The samples were dried at low temperatures to avoid evaporation of mercury. The samples were split and one split was analysed at Actabs for twenty elements using various techniques.

The most important elements in the analytical programme were: Gold, silver, mercury, copper, bismuth, lead zinc and arsenic. Apart from mercury the mentioned elements give indications as to which type of gold mineralization were exploited by the local small-scale gold miners.

Of particular interest to the present project is the contents of mercury, gold and silver. Seven piles of tailings with a total weight of 54 tons have an average gold content of over 7 ppm (gr/ton) with a peak value of 13.5 ppm (gr/ton). Analysing mercury contents is difficult so the detection limit is 10 ppm. All piles of tailings had mercury contents at or above 10ppm (gr/ton) with peak value of 40 ppm (gr/ton).

These contents are very high. In commercial mining companies exploit gold ores with as little as 1 ppm (1gr/ton) gold. Small-scale miners often require slightly higher gold grades, but the figures above show that they lose very high amounts of gold during their processing and a large part of that gold is locked up in large amounts of mercury.

The complete set of analysis can be seen in Appendix 3.

Mineralogical analytical work

Two types of mineralogical analysis were carried out at Geological Institute, University of Copenhagen (X-ray diffraction) and at CCSEM analysis at Geological Survey of Denmark and Greenland Appendix 4. The results are combined in a report which is seen in Appendix 5.

X-ray diffraction analysis

In X-ray Diffraction method the sample is irradiated with X-rays and the radiation scattered by the sample is measured. The radiation scattered under defined angles with defined relative intensity enables identification of minerals in the sample by comparison with data from a large database. The quantification of the relative contents of different minerals in the sample was in this research made by the best match of the observed scattering pattern and the one calculated using varying contents of the identified minerals (Rietveld method).

CCSEM analysis

Prior to CCSEM analysis, grains from a sample are set into an epoxy mount. The epoxy mount is polished and then coated with carbon. The CCSEM fires a beam of electrons to analyze the sample and produce a series of grey-scale images. The shades of grey in these images correspond to the density of the minerals, with denser minerals appearing lighter and lighter minerals appearing darker. The sample is also analyzed using a computer that automatically records the size, shape and chemistry of the individual grains. This information then cross-referenced with a database of mineral information which enables automatic mineral classification. It takes approximately two hours to analyze 800-1200 individual grains (Keulen et al. 2008).

Results and discussion

The XRD results showed a number of significant differences in the relative abundances of gangue mineral in the unprocessed tailings. All tailings contained quartz, feldspars, illite and mica and the majority also contained calcite, chlorite and epidote. The proportion of quartz in the samples varies from approximately 30% to over 80%. The XRD results show that the dominating mineral in all untreated tailings is quartz. Other important minerals are feldspars (K-feldspar and plagioclase) and mica + chlorite. The presence of calcite in some of the tailings means that the deposits cannot be high-sulphidation, which forms in an acidic environment, and a most likely low-sulphidation (as opposed to intermediate-sulphidation) (White and Hedenquist 1995). In Santa Rosa and San Juan de Limay (El Morcillo) the feldspars (especially K-feldspar) dominate. In San Francisco (El Nancital Rastra #1, #2 and #3) and San Juan de Limay (El Portillo) the amount of feldspars is equal to the amount of mica and chlorite. In San Francisco (Rastra las Agua) the phyllosilicates (mica + chlorite) are more abundant than feldspars. Only the San Juan de Limay (El Morcillo) has more total feldspars than quartz.

The results show that the Rougher mostly removes quartz. As a result, the other significant minerals (feldspars and phyllosilicates) are concentrated. Compared to the Rougher, we can observe different characteristics in the Cleaner tailings from the San Francisco and San Juan de Limay areas. In material from the San Francisco areas, the Cleaner does not appear to remove further significant quantities of quartz, but instead removes feldspars. The tailings from the Cleaner have a higher abundance of feldspars than the original tailings. In San Juan de Limay material, significant volumes of quartz is removed in that Cleaner and are feldspars further concentrated. It is difficult to conclude what has caused this discrepancy, however is most probably due the lithology and how the minerals were situated in the protolith.

The most interesting conclusions can be made about the action of the Centrifuge. The analytical results show that the tailings from the Rougher and tailings from the Centrifuge have almost identical mineral compositions. This means that supplying tailings from the Rougher to the Centrifuge dilutes the tailings from the Cleaner (which have a larger concentration of heavy minerals). This implies that the Centrifuge does not incorporate tails from the Rougher into its concentrate and so adding the Rougher tails to the Centrifuge is not worthwhile. It is corroborated by the available compositions of the two samples of the concentrate from Centrifuge (Limay 34 and 40, to be compared with Limay 32 and 38, respectively).

The CCSEM results were able to provide some very general information about the types of minerals present in the tailings and were about to provide a reference for the more detailed XRD analyses, however there were some issues with this analytical technique which limited its effectiveness. The CCSEM analyzed 1200 individual points, rather than the whole sample. Although this is a large sample size, achieving a truly mixed sample is a virtual impossibility, and so there will likely be a discrepancy between the recorded and true proportions of these minerals. Additionally, the recorded mineral types are often very general, for example classifying minerals as 'white mica' or 'feldspar'. Although this provides some information it is far too general to be used to classify the minerals properly. The results from X-Ray diffraction (XRD) were more useful and any further investigation of the tailings should use this method.

Trace element chemistry has been used to further classify the deposit type by highlighting element enrichment. For this study, a sample was considered to be enriched in an element if the concentration was five times over crustal abundance. The samples are enriched in gold, copper, lead, arsenic, silver and mercury which are commonly found in epithermal gold deposits (White and Hedenquist 1995), as well as antimony and tin. However, the enrichment in mercury in the tailings samples is likely due to the prior processing and chemical treatment that the tailings have undergone. The tailings are also enriched in bismuth, which is typical of high-sulphidation type deposits and selenium, which is typical of low-sulphidation deposits (White and Hedenquist 1995). The trace elements were not diagnostic of a specific type of epithermal gold deposit.

Mercury, gold and silver recovered by the Peter Plates

Heavy mineral concentrates from the MRP were passed once of the Peter Plates. The recovered mercury was weighed. Next step was to distil mercury. This was done by heating the recovered material in a retort and capture the mercury vapour in a cool trap. A mixture of gold and silver was left behind and weighed. Subsequent chemical separation of gold and silver was carried out and the outcome was weighed and the result is seen in the table below.

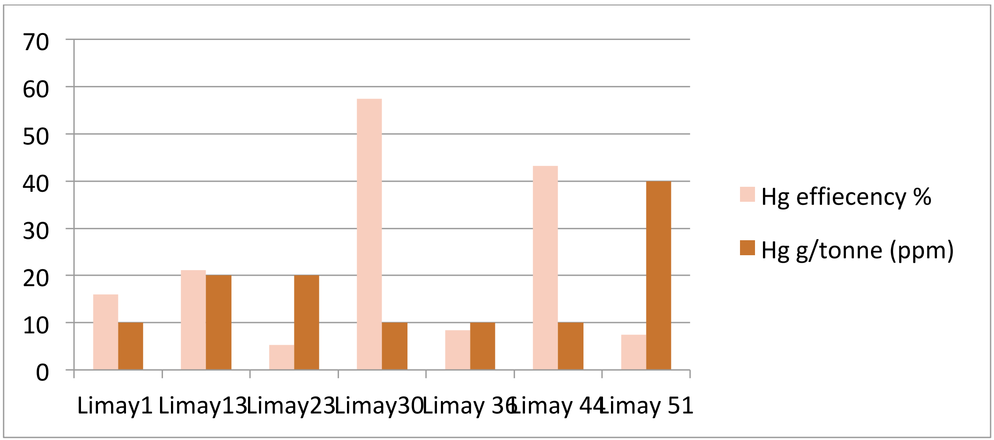
Peter Plates

Sample No	Area	Siurce of taiings	Mine	Tons	Recovered amalgam	Hg after retorting	Au gr	Silver gram	Amalgam per ton	Hg/ton	Au/ton	Ag/ton
Limay 1 to 6	San Francisco	El Nancital Rastra #1	Mina Las Rastras	21	41,6	33,7	6,8	1,1	1,98	1,6	0,32	0,05
Limay 7 to 12	San Francisco	El Nancital Rastra #1	Mina Las Rastras	7	10,1	7,3	--------	--------	1,44	1,04	--------	--------
Limay 14 to 19	San Francisco	Rastra Las Agua	Minas Los colorados, Mina Los Cedros	4	27,6	16,9	7	3,7	6,9	4,23	1,75	0,925
Limay 23 to 29	San Juan de Limay	EL Portillo	Mina Las Piñuelas	4,2	7,8	4,4	1,6	1,8	1,86	1,05	0,36	0,43
Limay 30 to 35	San Juan de Limay	El Morcillo	Mina El Hondureño	5	37,9	34,2	1,26	2,44	7,58	5,74	0,252	0,488
Limay 37 to 43	San Francisco	El Nancital Rastra #2	Mina Los Colorados	6,65	10,2	8	0,6	1,2	1,5	0,84	0,09	0,12
Limay 44 to 50	San Francisco	El Nancital Rastra #3	Los Ubuto	6,3	35,6	27,2	3,6	3,7	5,65	4,317	0,571	0,587
Limay 51 to 57	San Francisco	Rastra Las Agua	Mina El Ubuto, Mina Los Cedros	5,25	38,4	15,7	15,9	6,8	7,314	2,99	3,02	1,295

Efficiency of the processing line

Below is a comparison of the mercury and gold content of the initial tailings and how much mercury and gold was extracted on the Peter Plates.

	Municipality	Location	Hg Tailings g/tonne	Mercury recovery g/tonne	Efficiency (%)
Limay1	San Fransisco	El Nancital Rastra # 1	10	1,6	16,00
Limay13	San Fransisco	Rastra las Agua	20	4,23	21,15
Limay23	San Juan De Limay	El Portillo	20	1,05	5,25
Limay30	San Juan De Limay	El Morcillo	10	5,74	57,40
Limay 36	San Fransisco	El Nacital Rastra #2	10	0,84	8,40
Limay 44	San Fransisco	El Nacital Rastra #3	10	4,317	43,17
Limay 51	San Fransisco	Rastra las Agua	40	2,99	7,48



Graph comparing the amount of mercury in the tailings with the calculated efficiency of the system for recovering mercury.

Gold recovery showed no apparent correlation with mercury abundance. A strong correlation was noted between the initial amount of gold in the tailings and the efficiency of the process is noted showing that the higher the concentration of gold in the tailings is, the lower the efficiency. This is trend is so pronounced that that significantly less gold is recovered in samples with higher initial gold. For example, the El Nacital Rastra samples had particularly high volumes of gold in the tailings, and conversely had a very low recovery of gold, as low as 0,09 ppm.

This observed trend may be due to differences in the way gold is hosted in the tailings. For examples gold could be located among other minerals (known as 'free gold') or hosted in the lattice of a variety of ore minerals (known as 'invisible gold'). Additionally, as native gold may be hosted as inclusions in the sulphides, it may not be liberated, and may also be discarded.

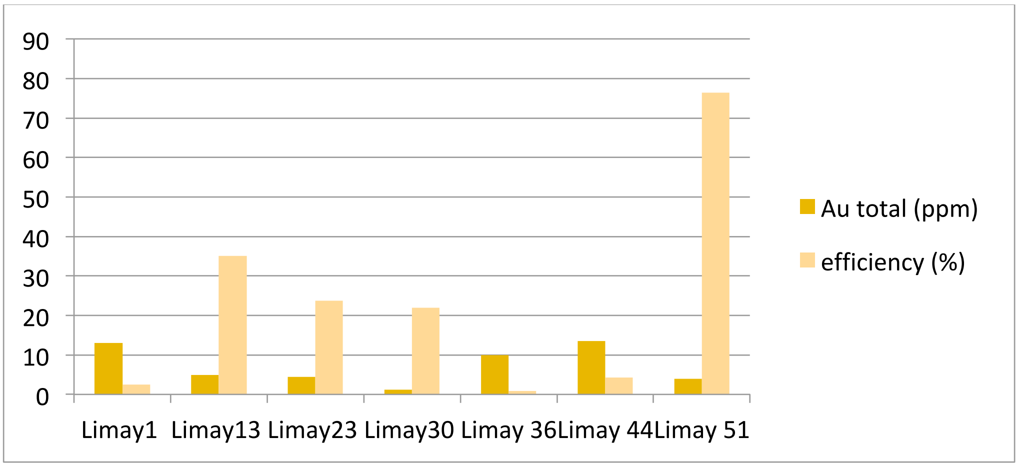
An alternative idea is that many of the gold grains may be small, and therefore too light to sink through the water which flows over the Peter Plates. As a result, they are washed over the peter plates, rather than sinking and attaching to the plates. A solution to this may be to add dish soap to the water that runs over the Peter Plates, in order to break the surface water tension and allowing smaller gold particles to sink. More detailed investigations of the size of gold particles in the tailings would be beneficial to any future studies.

The CCSEM and XRD major element chemistry indicates that the tailings have a low sulphur content, which is indicative of low amounts of sulphide minerals. It is likely that the ore from which the tailings are derived has a higher sulphide content, however they may have been removed either through the original ore processing. Alternatively, as rain water and oxic conditions may result in weathering, which would liberate sulphides and results in the loss of sulphur from the tailings. The presence of iron oxides and oxy-hydroxides such as hematite and geothite may be evidence for weathered sulphides.

Sulphides are found in two samples from the El Nastra Rastra region, however the abundances are small, with 0,61 % arsenopyrite in one sample and 0,083% pyrite in another. Investigations of the proportions of gold relative to sulphides in the system have shown that there are too low volumes of sulphides in the tailings for the gold to be incorporated into the sulphide structure as invisible gold (Cook 1990). Therefore gold in the tailings cannot be exclusively invisible gold and may be hosted as inclusions, in sulphides or other minerals, or as gold grains.

Unit Symbol		Au Tailings	g/tonne		g/tonne
				Au total	
Detection Limit			0,03	recovery	Efficiency (%)
Analysis Method	Municipality	Location	FA-GRA		
Limay1	San Fransisco	El Nancital Rastra # 1	13	0,32	2,46
Limay13	San Fransisco	Rastra las Agua	4,99	1,75	35,07
Limay23	San Juan De Limay	El Portillo	4,41	1,05	23,81
Limay30	San Juan De Limay	El Morcillo	1,15	0,25	21,91
Limay 36	San Fransisco	El Nacital Rastra #2	9,87	0,09	0,91
Limay 44	San Fransisco	El Nacital Rastra #3	13,5	0,57	4,23
Limay 51	San Fransisco	Rastra las Agua	3,95	3,02	76,46

Information on the initial gold value of the tailings, and the amount of gold recovered (in ppm)

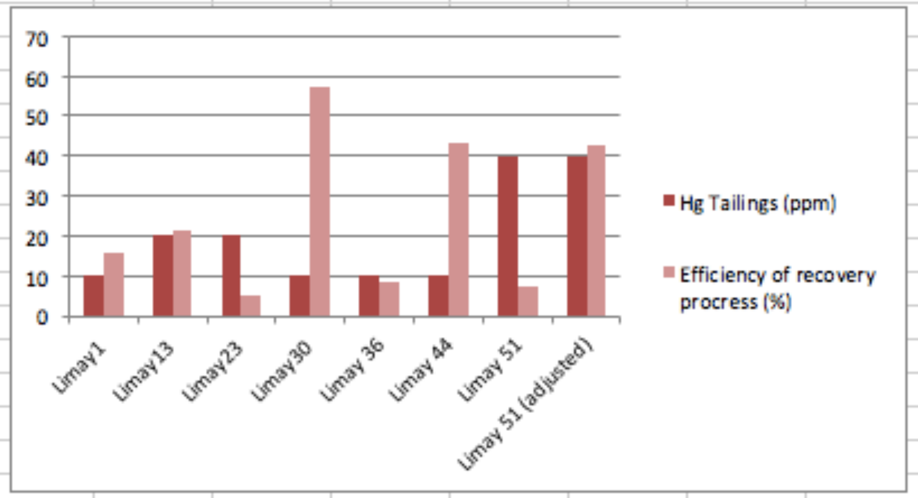


A line plot comparing the total amount of gold in the unprocessed tailings with the amount of gold recovered on the Peter Plates

Adding the organic compound

The organic compound, which we have tested at the Technical University of Copenhagen cannot be bought in Nicaragua, but is available in many countries. A few kilograms of our organic compound was brought to Nicaragua in our luggage. It was only enough to make one test.

Tailings after the Peter Plate run of Limay 51 were stored overnight in a metal drum in a solution of the organic compound. Next day the tailings were passed over the Peter Plates and 14 gram of amalgam was captured. During the first run without organic compound 38,4 gram of amalgam was recovered. Using the organic compound increase recovery from 5% to 42%. Time did not allow to separate the amalgam into mercury and gold.

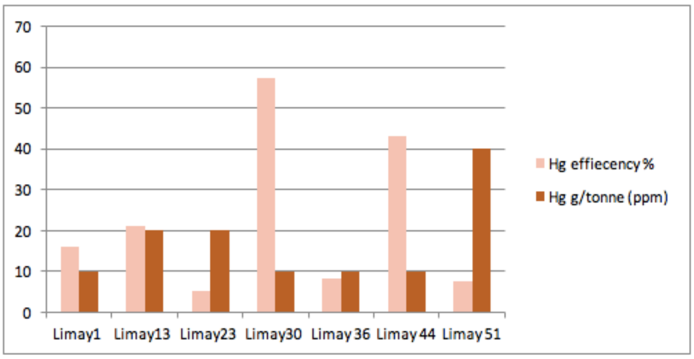


This diagram shows the significant increase in efficiency of the Peter Plates when the tailings are treated with the organic compound. It should be noted that the graph Limay 51 the column shows recovered mercury and the Limay 51 adjusted shows recovered amalgam.

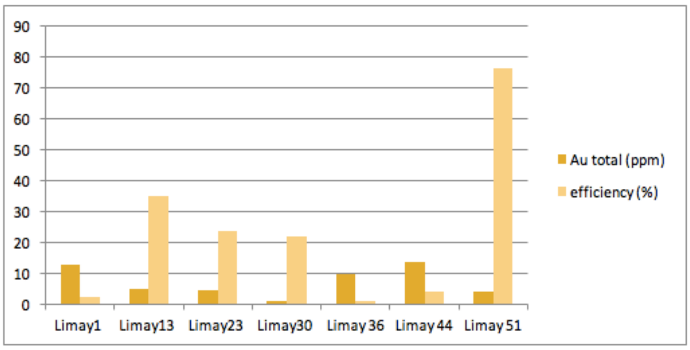
Conclusions

Combining the Mercury Recovery (MRP) with Peter Plates proved to be successful. Instead of producing kilograms of heavy mineral concentrate by the MRP, the Peter Plates extract amalgam containing mercury, gold and silver only. In addition, any free gold is also captured by the Peter Plates.

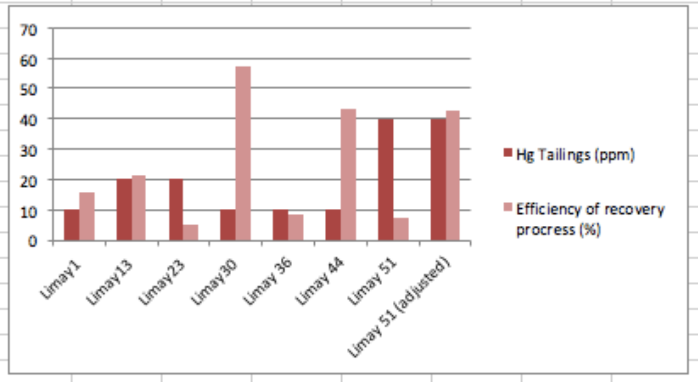
Efficiency mercury recovery of the processing line range from 5% to 57%.



Efficiency of gold recovery of the processing line rang from 1% to 76%



One experiment using the organic compound which removes the mercury oxide film around the mercury flour in sample Limay 51 showed an increase in efficiency in mercury from 5% to 42%



The mineralogical investigations indicated that some modifications of the MRP may improve efficiency of the plant.

Possible safe storage of mercury

When the combination of MRP and Peter Plates has proved the ability to extract large amounts of mercury from tailings and gold has been extracted from the mercury a safe storage model is required. UNEP has not started looking into the storage problem of mercury.

However, the Spanish Ministerio de Agricultura, Alimantación y Medio Ambiente has through their National Technology Center for Mercury Decontamination carried out a number of experiments for safe storage of mercury (Spanish 2012). Spain hosts the large Almadén mercury mine which has supplied mercury for centuries to all parts of the World. It is thus understandable that Spain has made an effort in research on safe storage of mercury.

The model they have invented is to convert metallic mercury to mercury sulphide. Mercury sulphide is the name of a naturally occurring mineral cinnabar which is found worldwide in mercury deposits. The cinnabar is subsequently built into a sulphur polymer cement which reportedly is inert and strong as cement. Further experiments along this avenue may prove to be the solution of safe storage of large amounts of metallic mercury.

Why we could not fulfil the planned programme in Nicaragua

The site where we worked during first MUDP Phase is situated in Northern Nicaragua and is named San Juan de Limay. It is a newly established site where a Nicaraguan company owned by Bill Dumont and American. The main purpose of the site is to process gold ore from a mine nearby which was under construction. The processing plant at the site was purchased from Oro Industries in California. This machine was meant to produce gold in an environmental method without use of chemicals. Bill Dumont purchased another machine (MRP) which was meant to extract mercury from tailings produced by local small-scale gold miners. The extracted mercury was to be distilled in order to extract the gold amalgamated with the mercury. The MRP was also purchased from Oro Industries.
The MRP did not prove to be very efficient in extracting mercury. Bill Dumont and Oro Industries were of course keen to associate with Elplatek in the hope that a combination of the MRP and Peter Plates could be a successful combination. During MUDP phase one several tests using the

MRP proved that the machine could indeed extract mercury from the tailings, but not in sufficient amounts.
During MUDP phase two the MRP was to be linked with Peter Plates. MRP would produce a heavy mineral concentrate which was subsequently treated on the Peter Plates. The Peter Plates captured mercury and free gold. This experiment was carried out in the autumn of 2015. At DTU experiments had been carried out finding ways to break the mercury oxide film around the mercury droplets (mercury flour) in the tailings. This should facilitate capture of mercury on the Peter Plates. One of the main components to be added to the process is grape sugar which will remove the mercury oxide film. Grape sugar is not available in Nicaragua, but a small amount was brought along from Denmark. This sugar was used towards the end of the Autumn mission and it proved very successful.
A full scale testing was planned at Limay in the Spring of 2016. Unfortunately, the owner of the processing site Bill Dumont had a very serious motor bike accident and was hospitalised. His spleen had to be removed and Bill Dumont swiftly lost energy and interest in the processing plant in Limay. The plant was taken over by Nicaraguans with American funding and the new owners had no interest in giving us access to the processing site. We tried very hard to establish a dialog with the help of the Danish Embassy in Mexico, but all attempts to gain access to the plant at Limay were fruitless.

References

AMAP/UNEP, 2013. Technical Background Report for the Global Mercury Assessment 2013. Arctic Monitoring and Assessment Programme, Oslo, Norway/UNEP Chemicals Branch, Geneva, Switzerland. vi + 263 pp.

Arengi, J. T., & Hodgson, G. V. (2000). Overview of the geology and mineral industry of Nicaragua. International Geology Review, 42(1), 45-63.

Appel, P.W.U., Na-Oy, Hatsukawa, y:, Osawa, T., Kystol, J. & Sørensen, L.L. 2011: Cleaning mercury polluted mine tailings in the Philippines. Danmarks. Grønlands. Geol. Unders. Rap. 2011/127, 39 pp.

Appel, P. W. U. & Na-Oy, D. L, 2014: Mercury-free gold extraction using borax for small-scale gold miners. Journ. Environmental Protection, 2014, 5, 493-499

Brigattia M.F., Colonnab S., Malferraria D., Medicic L., Poppia L.. Mercury adsorption by montmorillonite and vermiculite:a combined XRD, TG-MS, and EXAFS study. Applied Clay Science 28 (2005) 1– 8

COMPREHENSIVE CHEMOMETRICS, Wiley Major Reference Works, vol. 4, pp.1-20. Oxford: Elsevier

Cook N.J. & Chryssoulf S.L. ‘Concentration of invisible gold in the common sulphides. Canadian Mineralogist Vol.28, pp. 1-16

Esbensen, K.H. & Julius, L.P. (2009). Representative sampling, data quality, validation – a necessary trinity in chemometrics. in Brown, S, Tauler, R, Walczak,R (Eds.)

Esbensen, K. H. & Appel, P. W. U. 2017: Barefoot sampling in San Juan de Limay, Nicaragua – Remediation of Mercury pollution from small scale gold mining tailings . in press in Thery of Sampling

Keulen, N., Frei, D., Bernstein, S., Hutchison, M. T., Knudsen, C., & Jensen, L. (2008). Fully automated analysis of grain chemistry, size and morphology by CCSEM: examples from cement production and diamond exploration. Geological Survey of Denmark and Greenland Bulletin, 15, 93-96.

Hedenquist, J. W., & Lowenstern, J. B. (1994). The role of magmas in the formation of hydrothermal ore deposits. Nature, 370(6490), 519-527.

Heffernan V (2004) Gold Mining and Exploration in Central America. GeoPen.com

Hradeckỳ (2011) Introduction to the special volume "Subduction-related igneous activity in Central America – its nature, causes and consequences" Journal of Geosciences, 56 (2011), 1–7

Saltus, R. W., & Barnett, A. (2000). Eastern Aleutian volcanic arc digital model-version 1.0 (No. 2000-365). US Geological Survey.

Spanish Ministerio de Agricultura, Alimantación y Medio Spanish technological developments on Hg stabilization and Hg containing wastes. Workshop on mercury management in the Latin America and Caribbean region. Brasilia, 21nd / 22nd May 2012

Taylor, B. E. (2007). Epithermal gold deposits. Mineral Deposits of Canada: A synthesis of major deposit-types, district metallogeny, the evolution of geological provinces, and exploration methods: Geological Association of Canada, Mineral Deposits Division, Special Publication, 5, 113-139.

White, N. C., & Hedenquist, J. W. (1995). Epithermal gold deposits: styles, characteristics and exploration. SEG newsletter, 23(1), 9-