AGC-PAC Field Report: Technical Intervention Assessment

PAC ASM Gold Project (PPA)

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Executive Summary:

The Artisanal Gold Council (AGC) was contracted by PAC to help with their gold project in the DRC with the aim of helping create incentives for artisanal miners to produce gold responsibly and to sell it through a legal transparent supply chain ultimately in compliance with OECD due diligence guidelines. One broadly recognized incentive to bring about this this behavioral change is to assist the artisanal miners at the grass roots level to in meaningful ways that do not set them back in terms of their quality of life – their livelihoods. One common cornerstone to this approach is to increase their productivity – more gold for a similar effort and costs – while assuring them through clear communication and working together to build trust that the ultimate outcome will be to their benefit. The benefits come in terms of increased income, increased stability, improved health, improved access to capital, and improved self confidence amongst other benefits and with the first one, improved income being of fundamental importance on short or immediate time scales. Fortunately, improved incomes through formal technical, social and governance assistance can easily lead to improved incomes, living conditions, environmental performance and longer term organization. At the ground level, in the field, working directly with the miners, this can be obtained principally in two ways: (i) through better recovery of the gold contained in the materials that the miners process through improved methods and better technology; and (ii) through increased production, essentially by moving more material using the same effort/time. There can be a balance between these two approaches but the former, improved recovery, should be a primary goal and is the focus of this technical intervention because it has, beyond the benefits already listed, the clear benefit of decreasing the environmental footprint of mining operations and ultimately helping to comply with minimum recovery guidelines that often exist in mining codes – generally described as good or proper land productivity.

The AGC in direct collaboration with PAC arranged to have appropriate equipment transported to the DRC and trained miners in its use. This led to a 30% increase in gold recovery from the same amount of material processed. A forum was held where gold purity and how to increase assurance in it was demonstrated and discussed with local gold buyers and miners. Some investigation of the current gold supply chain and pricing was carried out. It was discovered that at the Mangi site colluvial gold is produced without the use of mercury but there are also sites (likely vein mining) that do utilize mercury. Sponge gold was the evidence of this. A local team of Congolese Mr. Ghislain Lokonda, Mr. André Muamba and Mr. Victor Kangela (PAC project coordinator) assisted in the work and were trained to carry it forward. An additional separate site (Nia-nia to Wamba axis, including PK25-PK51) several hundred km distant, that exclusively mines veins and uses mercury for 100% of production as well as a more sophisticated processing system was visited and evaluated for a future similar intervention.

Introduction

The PAC Gold Project in the DRC is designed to coax artisanal gold production back into legal export channels. Currently, most artisanally produced gold in the DRC gets exported illegally via neighbouring countries including Uganda and Burundi. These illegal export channels enjoy a price advantage over legal channels, simply because they avoid government mineral royalties and taxes. These illegal channels deprive the DRC government of tax revenue but principally through losses on revenues normally accrued from the taxes collected on the secondary economy which is conservatively five times larger than the primary value of the mineral. Taxes lost on gold royalties are theoretically based on the current 20% royalty system in place in the DRC. This is strictly theory as no country is known to be able to effectively collect such a large royalty on artisanal gold. Ethiopia for example is currently paying above the international price simply to ensure that gold flows through the legal channels and by doing so are enabling themselves to (a) collect the much larger tax revenues from the secondary economy; (b) prevent unwanted black market elements from developing; (c) and allowing themselves to easily trade their gold in the international market. On the contrary In the DRC, some of the clandestine gold chains can fund armed groups, contributing to the DRC's ongoing domestic conflict. Tax reform, along with interventions as described in this report, are likely to be important activities to remove barriers and bring artisanal gold into the formal DRC domestic and international market.

The PAC project aims to induce artisanal producers to sell their gold through legal channels by providing these producers with technical assistance and equipment that will enable them increase their gold recovery and production. In essence, though artisanal producers will be required to carry out additional due diligence tasks that do have real costs, they will end up with more money in their pocket because of increased yields. This is a virtuous circle as entering the formal economy brings other benefits such as increased access to capital and increased stability and security that can further increase productivity but also allow artisanal miners and gold merchants to more easily diversify their economies. Collaborating in creating a legal gold chain should thus result in a net financial and social benefit for artisanal producers.

During the first, Research phase of this project, PAC surveyed the artisanal mining landscape of Orientale Province with a view to identifying general areas (axes) where the project could proceed, as well as specific test sites. In a second, Enumeration phase, baseline data on some 11,000 artisanal gold miners was collected along the three axes identified axes (Banalia-Kole axis including Mangi site; Buta axis; Nia-Nia to Wamba axis, including PK25-PK51).

The Mission

For the Mechanization phase, PAC proposed to study the geology, grain size distribution and production methods of artisanal miners in the two identified test sites, with the aim of developing technical interventions — over both the short and medium term— that would increase miners overall gold recovery, either by increasing miners' yields (gold recovery per volume of material) or throughput (volume of material per unit of time) but with the first approach, increased recovery as a primary goal – for reasons explained above. PAC further proposed to examine the environmental impact of these interventions, with a view to mitigating environmental impacts over the near to medium term.

Dr. Kevin Telmer of the AGC was commissioned to lead this Mechanization phase study. Lead by Dr. Telmer, the AGC - PAC mission to Orientale Province, DRC, took place from October 7-21, 2013, and visited the two primary test sites, Mangi (Oct 9-16) and PK25-51 (Oct 16-21).

Results – Mangi Site

As delineated below in greater detail, the results of the mission were extraordinarily encouraging. At the Mangi site, grain size analysis established that a highly significant fraction of the gold – approximately 30% to 50% - was found in the smaller fractions (100 gauge sieve and below 100 gauge). The results were a surprise to local miners, who largely neglect finer gold in favour of larger flakes. When asked whether most of their gold would be in the large pieces or the fine powder, they universally answered that it would be in the large pieces.

In pursuit of these smaller grain sizes, Dr. Telmer added a second scavenger sluice with an artificial liner to the existing single sluice configuration. In addition, a collector basin (overflow basin) was placed at the end of the new zig-zag sluice configuration, to pick up any heavy material not caught in the sluices. Miners were trained to process this formerly discarded material using by first using 12 and 50 gauge sieves, in order to facilitate more uniform grain size panning

Though results are preliminary, in several trials with this new configuration, miners achieved yields 30% higher than with their standard setup. The increase in yield using this new setup was undeniably demonstrated, as the additional gold came from the scavenger sluice or collector basin, material the miners had previously discarded.

Miners were extremely enthusiastic about these new techniques. A PAC technical outreach officer (‘junior mechanization officer’) was trained in applying these new strategies, and will remain at Mangi to instruct miners for the remainder of the mechanization phase.

In addition, miners in Mangi were introduced to use of the blue bowl vortex, which proved to be very effective for a final cleaning of the concentrate from sluice and container. This is an important process (even if the blue bowl is not ultimately the tool chosen) because it creates a disincentive to use mercury to capture the fine gold in concentrates – a common practice elsewhere in the DRC.

An attempt was also made to introduce the miners to pressurized washing of their primary saporlitic ore matrix using a motorized pump and hose. The pressurized washing would not only allow miners to process ore more quickly, but would also more effectively remove gold-bearing soil from around the small cobbles that are part of the ore, thus increasing both productivity and recovery.

Unfortunately, technical challenges slowed the experiment significantly. Finding an effective hose nozzle proved to be a challenge, as pumps are used locally only to remove water from pits. Dr. Telmer was able eventually to demonstrate to miners that vastly greater throughput was possible with a hose and pump. However, miners feared that gold was being lost in the increased water flows resulting from use of a pump.

Application of this technique remains extremely promising, but further work will be required to demonstrate to miners that pressure washing can increase recovery and production economically.

Finally, in the medium and longer term, Dr. Telmer recommended (i) a simple prospecting program, to establish and secure ore supplies and to increase land productivity and mining productivity – less trial and error; and (ii) the development of a tailings/waste management program in order to deal responsibly with tailings which are currently simply pumped into the jungle or local streams. This is not particularly challenging with a moderate amount of additional organization – something that the miners seem very willing to do and something that is ultimately required to join the formal mining sector, perhaps as model operators.
NO MERCURY, GOOD LAND PRODUCTIVITY, GOOD WASTE MANAGEMENT.

Results – Mineral Chain

In addition to the work with miners, the mechanization mission also focused attention on those higher up in the mineral chain, notably negociants, the small traders who purchase gold from miners and sell to exporters. One of the problems faced by both miners and negociants is uncertainty about the purity and grade of the gold they sell and buy. In the absence of diagnostic tools and hard data, miners and negociants use agreed-upon assumptions and second-hand reports of purity (from exporters, typically) as the basis for their gold trades. This frequently leads to mistrust and conflict and acts in favour of the larger buyers that have the know-how to determine purity and proper weights.

The mechanization mission attempted to address these concerns during a one day workshop held in Mangi village, attended by a mixed group of PDGs (mining bosses) and negociants. As a first demonstration, Dr. Telmer addressed the question of impurities in the gold. The local rule of thumb is that Mangi gold contains 5% impurities. This assumption is built into the local price of gold. By measuring weight before and after, and then treating a sample of gold in a bath of nitric acid, Dr. Telmer was able to show that the impurity level in a sample of Mangi gold is closer to 3-2%.

The second assumption governing the sale of gold in Mangi is that locally produced gold is 92% pure (22 carat). This assumption is based on information supplied by the exporters who purchase Mangi gold. During the workshop, Dr. Telmer explained to PDGs and negociants the commercial advantages of certainty in buying and selling – of knowing exactly the purity of the gold being traded. Initially, Dr. Telmer had intended to demonstrate a relatively simple field technique whereby Mangi gold could be purified up to 24 carat (99.5%) purity.

Unfortunately, neither of the torches obtained for the demonstration could reach temperatures sufficient to melt gold. However, Dr. Telmer was able to demonstrate the first few steps of the process (melting silver and then pebble-quenching it in water), and then explain the rest of the process with reference to a visual guide (the UNEP Practical Guide to Reducing Mercury in Artisanal and Small Scale Mining authored by the AGC).

Audience interest in the technique, the Guide and the benefits of gold purification was gratifyingly high. A follow up workshop – with adequate equipment – is under consideration for subsequent project phases.

It is also highly noteworthy to explain PAC's team and efforts. Led by Shawn Blore and Victor Kangela (the Congolese coordinateur for PAC), the project was exceptionally well organized, efficient, and professional. This is particularly true considering the time frame under which this phase was arranged and the limited time in the field (2 weeks). PAC was able to make all necessary arrangements including visas, letters of permission, introductions to essential government personnel, importation of equipment, and international and local travel, and then put together a crack field team led by Victor and Shawn that made Dr. Telmer's mission possible.

Results – PK 51

As noted in greater detail below, the artisanal techniques being employed at PK25-51 on the Nia-Nia to Wamba corridor are different and in some aspects more sophisticated than at the Mangi site, due in large measure to the nature of the ore deposit (hard rock versus colluvial). In a visit of only a couple of days, the mission was able to map out the existing production chain, and suggest several likely technical interventions.

In the short term, suggested technical interventions in this corridor could include but are dependent on budget (Dr. Telmer is not aware of the size of the budget):

In the medium term, interventions at PK25-51 should include improved crushing and milling, gravimetric separation (centrifuge and/or shaking tables), and possibly a centralized leaching plant for tailings left over from these processes.

As further noted below, the higher level of mechanization at this site has resulted in a greater environmental impact. Mercury is extensively used in this corridor, with no evidence of retorts or other mitigation measures. Both acid mine drainage and unamalgamated mercury are dumped extensively in local water courses.

Dr. Telmer therefore recommended that any technical intervention include a plan for addressing these issues: a roadmap for a transition to mercury-free (or less mercury intensive) gold extraction, and a plan for better managing tailings and acidic drainage.

Full Intervention pk25-51:

To go only half way is risky but possible. Equipment ordering, set up requirements, tech specs, etc. are not a small task for this site and will require multiple people. Dr. Telmer's tentative small budget plan which comes with no guarantees is as follows:

- Since the bottleneck is the milling and the milling is also the poorest functioning aspect of pk51, a new mill would yield more gold. A wet pan mill like the one the AGC is installing in Burkina Faso may be suitable. AGC has been in touch with three Chinese manufacturers and have asked one to produce a custom mill for a cost of 10,000 US$. It weighs roughly 5 tonnes and has a capacity of 1 to 1.5 tonnes per hour – more than the current octagonal Tanzanian Mills in practice and with superior performance in terms of liberating gold. Pan mills are also wet mills but ones that require very little water (it can be recycled easily) and so this will reduce the highly significant health hazard associated with the dust produced by the current dry milling practices.
- Feeding size is important so normally you would also install with a crusher... which is $2000. It needs 5-7 KW of energy. Possibly this could be accomplished by a diesel engine but a gen set is much more efficient and reliable.
- A 40kW genset is 3-5000$.
- Sluicing with better carpets ($1200) and better sluices will capture more gold on the first pass (they pass the material 3 times at pK51) and save time but without better milling the outcome is difficult to predict. The problem here is that better sluicing may produce greater amounts of concentrate with better carpets. I can't quite predict how to re-configure the sluicing but that will certainly have to be done.
- To eliminate mercury a separation system is needed. We will use a shaker table in Burkina Faso. There are cheap Chinese tables but so far the reviews of their performance are terrible. A good table costs 20,000US$. If you want to go mercury free, then you need a way to upgrade the concentrate to at least 25% gold. This would be either a table (more intuitive and easier to operate or a centrifuge (not a vortex like the blue bowl). A centrifuge costs 6000 to 10,000. Centrifuges require a higher level of technical capacity to operate and maintain. A simple field model like the Icon 150 needs to be cleaned out each 15 minutes. It has not been shown to be more effective than a table in some comparisons but is certainly trickier to operate. A good clean water source and pumps and pressure are needed.
- Installation. The mill and generator need to have a layout and to be installed on a concrete foundation. So does a shaker table. The waste management (tailings) needs to be planned.
- Flotation may be another option that could help with recoveries just adding it to the current system (plus some grain size control - sieving). A mixing tank is 1500 - need skimmer or collection system and training, maybe a cell based system, and you need to know what to float - metallurgy, probably sulphides but we don't currently know.

Simplest possible intervention at pk 25-51:

- Crusher and better carpets (sluicing) and a generator or a retrofit diesel engine. This could be done for capital costs of ($2000 + $1200 + engine or generator (1000 to

2500)). This would minimally change the operation towards more mechanization and eliminate the mortar and pestle crushing but would not eliminate the main bottle neck of milling, nor would it improve gold liberation which happens at the milling stage. You could sieve 100% of what comes out of those Octagonal Tanzanian mills but there are significant health hazards to do with those dry mills and dust inhalation and sieving would likely increase this hazard – perhaps there are ways around this like using dust masks. Also, this would not change the use of mercury and it might not improve recovery – perhaps production. But maybe it is one step towards an improved system that can later be further upgraded.

A tailings collection and processing system needs to be designed and set up to prevent the currently significant environmental impacts to the local waterways. The use of mercury is unfortunately a highly persistent contaminant so the sooner this is abated the better.

Medium Term Implementation: Buying Centres.

One other suggestion that came out of discussions among the team was the concept of centralized buying centres. As noted by Dr. Telmer below, over time the efficacy of the trade at the heart of the PAC program – technical assistance in exchange for legal sales – will likely degrade, as miners adapt or obtain technological improvements independent of PAC.

One technique to address this challenge would be to establish centralized buying houses at significant sites such as Mangi and PK25-51. The buying houses would work on the basis of proper and transparent weights and measures, and sell directly to international refiners/buyers.

These houses should thus be able to offer a price only 5-10% or so below international spot price (as opposed to the 12% below spot currently on offer in these locations). If these buying houses were run under the auspices of an international NGO, they could devote part of the gold margin (say 1-2%) to community development projects such as health clinics or even road improvements.

The public health expert for the AGC (Myrianne Richard) recommends road improvements first because everybody uses the road and they are in terrible condition. This community development work would serve to foster loyalty, as well as address one of the frequent criticisms leveled at artisanal mining – that it does little to foster important infrastructure development like roads – as compared to the large scale mining sector.

Obviously, a number of issues both practical (licensing, security, staffing) and philosophical (do NGOs buy gold?) would have to be addressed, but the idea remains a deeply intriguing one.

Activities (as per PAC Terms of Reference):

1. Sensitize and consult with local gold producers

I met with many local producers and also a group of buyers – we had a one day forum at the guest house in Mangi (Pic. 1a). At the forum, an attempt to purify gold was made but the temperature required to melt gold saw not obtainable with the available equipment (Pic. 1b). All we could do was melt silver (Pic. 1c). Good enough for killing werewolves but not impressing miners. Nonetheless, silver was melted and poured molten into cold water from a height. This produced perhaps 100 individual droplets of silver. And this was shown to the negociants along with the book we authored for UNEP (*Guide Pratique: Réduire l'utilisation du mercure dans le secteur de l'orpaillage et de l'exploitation minière artisanale*) which illustrates the method and just getting the beginning part done live was enough to capture the attention of most and to become highly interested in learning the method (Pic 1d).

Picture 1: a) Forum at the guest house in Mangi. b) Attempt to purify gold. c) Silver melting. d) UNEP *Guide Pratique* shown to gold negociants.

Temperatures were high enough to cause sponge gold to congeal so we did that with three balls of sponge (Pic. 2a). The presence of sponge gold is absolute proof that mercury is being used to extract gold – but this was only in some areas. For example, miners in some parts of Mangi do not use mercury.

Gold dust was also purified. The particles of gold that are produced from washing and sluicing saprolitic colluvial deposits are collected by panning. The concentrate produced was boiled in Nitric Acid (Pic. 2b). The commonly used principle in terms of setting the price of gold in Mangi is that the gold is 22 karat and the level of impurities is 5%. After boiling in acid it was shown by doing a pre and post weight analysis that impurities were 3% which meant that gold could be sold for 2% more. The level of impurities and the caratage need further investigation (Pic. 2c).

Caratage was independently tested by purifying the acquired gold to 99.5% or 24 karat using the quartering method and a pre and post weight at a later date (Pic. 2d) – this was the method that was attempted earlier live but was not completed due to the inability to obtain high T. Gold from Mangi was confirmed to be 22 karat.

Throughout this procedure Victor and Gishlain and André translated and facilitated discussion and questions with the audience. They were introduced as the projects points of contact and the ones who will carry on with the activities shown and discussed.

Overall I think the attendees were grateful for the information and demonstrations and believe that they see some of the methods of improving the confidence in the true quantity of gold being traded as beneficial to support an improved sector and trading environment.

Picture 2: a) Sponge gold. b) Gold dust to be purified. c) Process of purifying gold dust. d) resulting gold

3. Train a junior 'mechanization expert' (André Muamba) on improved technologies for ASM gold exploitation

This was clearly elaborated to be Gishlain and André. André, who has diamond mining experience, is perhaps more gifted at the actual technical work in the field such as setting up and adjusting sluicing equipment. The strong quiet type; he really turned on in the last few days once it was clear that higher recovery was a reality. Gishlain was a very talented and passionate communicator during any public discussions but in a highly professional and diplomatic way. Victor is wonderfully comfortable as overseer and project manager and is clearly respected by the others. Great team!

4. Conduct a geological and metallurgical analysis of the pilot sites

Site 1 Mangi.

Mangi is as I liked to call it a "mini serra-pelada" – the materials worked by the miners and the style with which they reach the ore is very similar. It is a saprolitic or colluvial deposit (Pic. 3a).

Plus reworked Belgian tailings that were originally derived from a vein that was preserved within the saprolite. This is common in the humid tropics. To the layman it appears to be a deep soil horizon with some layers that are auriferous (gold bearing) and the miners know which layers are gold bearing (Pic. 3b). The materials are the result of millions of years of tropical weathering – so you start with 100m of basalt and rain on it for 5 million years and the only thing left are a couple of meters of the minerals that are not soluble – iron oxides, aluminum oxides (bauxite deposits for example are formed in this way) and many secondary minerals typically referred to as clays – silicates like kaolinite; and other minor or trace materials that are also highly resistant to weathering like gold. So the gold in 100m think slab of bedrock has been concentrated into just 2 m through weathering – a 50 times concentration. Further these materials can be remobilized by fluvial processes (flowing water) that create additional concentration through gravitational sorting. The richest materials in Mangi (the *sable*) appear to be in the lower part of the saprolitic profile where there may have been some reworking by fluvial processes – I couldn't make a detailed study of it in the time available.

To summarize: Primary Mangi gold is mainly free gold particles present in a reworked saprolitic matrix. Secondary Mangi gold is gold extracted from the tailings left behind from the Belgians. This material is excavated from around an old brick Belgian processing centre (Pic. 3c). The tailings are lower grade but easier access. The sable under the saprolite can be very high grade but access is difficult – there can be a considerable amount of overburden removal required.

There was also discussion with miners/buyers/prospectors about other deposits. It is claimed there are a fair number of veins poking out throughout the Mangi area that are auriferous – what are called "showing outcrops" in English – outcrops of rock that contain or "show" gold.

These potential vein deposits were not confirmed so my feeling is that there are likely veins in the saprolite but there are also some urban legends. A prospecting program would help clarify the resource ultimately available to artisanal miners in Mangi. This could be carried out by walking the land and hand sampling veins, and then possible via higher tech approaches like ground penetrating radar which may be able to “see” the *sable* under the cover. If targets are identified, a cheap and manual exploration program could be done to identify targets and help with raising land productivity and lowering environmental impact.

Currently there is no waste management system at Mangi – a major failing and needed upgrade (Pic. 3 d).

Picture 3. a) and b) Miners working in the saprolitic/colluvial deposit c) Material excavated from old brick Belgian Processing centre (small frame) d) Tailings after material passes through sluice.

Site 2: PK 25, PK 47, PK 51 on the Nia-nia Wamba corridor.

This area of artisanal gold production is much more technologically developed than Mangi. The primary reason is likely the type of ore which is hard rock although other factors undoubtedly play a role in assisting this site to obtain its higher capacities and level of know how.

A basic system here is as follows:
Land owner: he or she owns a concession.
Financier: he or she provides the capital required to obtain a functional denominator of operations – fairly close to the lowest common denominator. Financing goes towards payments to workers to get started; installation of a crude plant primarily consisting of only a mill and a water pump and an electrical generator in terms of mechanization – an octagonal mill similar to many in use in Tanzania and likely the origin of the design used here; some other minor infrastructure and equipment (Pic. 4a).
Miners: These are men and women that carry out a variety of tasks – some are diggers, some are sluicers (Pic. 4b), some are amalgamators, some are crushers (mortar and pestle), some are millers, some operate sieves, some are maintenance and construction.

The ore here is disseminated fine gold in shear zone hosted veins. The Belgians exploited this area and some of their tailings are being re-worked but the very high grade material is coming from newly mined ore. The veins are highly altered by hydrothermal alteration and are sulphidic with the presence of several sulphide minerals, the most common being pyrite. In order to obtain gold from these ores a significant amount of liberation (communition) is required.

This means that ores must be crushed and then milled to a very fine size fraction in order to release the gold from being entrapped inside other host minerals (Pic. 4c). The optimal size that the ore should be milled to is unknown by us or the miners. There may however be metallurgical information existing that I am unaware of - done either by the Belgians or perhaps a geological research group that has visited this area since. PK 25 appears to be at least partially occupied by a formal junior gold exploration company called Loncor. It is likely that they have considerable information about the metallurgy and geology of the deposits being mined by the artisanals. It would be very helpful if they were willing to share that information. As well 3 pieces of ore (rocks) were brought back to Canada. With them there is the potential to investigate the metallurgy to a limited but significant degree. For example the size distribution of gold and where it is hosted (in association what minerals) could be determined. This would be helpful in planning on how to increase recoveries for these operations and what an appropriate technical intervention might be comprised of and how to deploy one.

The three rocks are shown here. The small greyish one contains visible gold (vg). A group of rocks all containing visible gold – hand selected (Pic. 4d) – can be a very high grade ore – 100 grams per tonne for example.

Picture 4. a) Octagonal mill. b) Miners on site c) Crushing and milling to very fine fraction. d) rock with visible gold.

5. Conduct a grain size analysis

Immediately upon arrival when first meeting Mr. Gaston, a village leader in Mangi, we grain size sorted some of the gold he bought from the miners – he is a *commerciant* and buys gold from the miners of his village. This was done by passing about 10 grams of his gold through the four sieves (five size fractions) we brought, and weighing how much gold is in each size fraction (Pic. 5a).

The results of the two trials are shown in Table 1. The miners and Gaston were all confident that most of the gold would be captured by the coarser grain sizes, yet they were surprised by the results. Over the course of two measurements, the amount of gold captured by the two finest-sized fractions – gold captured by and passing through the 100 gauge sieve – was 29% and 34.3%. The finest two fractions thus out-weighed all other fractions. This has helped demonstrate to miners that they are missing out on significant quantities of gold because 1) they don't target it; and 2) they are not using the proper equipment to capture it.

The grain sizes of the materials processed through the sluice also have distinctive amounts and properties but these properties vary across sites. Nonetheless, the gold at Mangi is dominantly in the soft matrix of the saprolite in muds clinging to stones and rocks (Pic. 5b). A key element of capturing the gold is therefore washing the mud off of the clasts (small stones). This is done by splashing it out of the hopper (the Baco) and hand washing and agitating it in a pool of water that passes through a coarse sieve made by drilling a half inch hole in half plastic gasoline jug which has been cut in half. They are not perfect at washing off the clasts so some gold is lost in the residue that is remains clinging to the clasts. More efficient washing will release more gold and make it available to be captured by a sluice (see motorized washing below).

We instigated a system of zig zag sluicing that utilized a flat sluice 30 cm wide and 1 meter long lined with a thin locally acquired polyethelene plastic bag and with some light gauge miners moss brought from Canada (Pic. 5c). This second or scavenger sluice then emptied into a large basin which collected any final heavy materials like gold while the light slurry continuously overflows. This introduced two additional gold traps that were deployed on materials that the miners normally discard. Thus any gold captured in these traps would be additional gold that they would immediately recognize as additional recovery and production (Pic 5d). We also encouraged miners to sieve their materials prior to panning, in order to narrow down the grain size and thus increase recovery. Narrowing the grain size makes panning faster and easier, and reduces the volume of lost gold. For example, panning materials that passes through a 12 gauge sieve but not through a 50-gauge sieve (ie grain sized less than 12 and greater than 50) becomes more predictable and so faster and better. Sieving the material also serves as a secondary wash which may liberate some of the gold trapped in mud still adhering to smaller stones (clasts).

These additional systems do not slow down the amount of material being processed. Their continuous use may require an additional person in the team – a scavenger operator (collector, siever, panner) But they would be easily paid for from the additional gold that was captured. It averaged about 30% higher. So a team of 5 could become a team of 6 but with 30% more gold the overall increase to each individual in the group would be 5/6*30% which is still 25% higher per person.

Table 1. Grain size analysis at Mangi (Canon site)

Trial 1			
Initial Gold Weight	2.86 g		
Sieve Guage	Aperture (mm)	Trapped Gold (g)	% of Total
8	2.36	0.79	28
12	1.7	0.30	10.5
20	0.85	0.30	10.5
50	0.30	0.57	20
100	0.15	0.31	11
<100	<0.15	0.51	18
Lost material		0.08	2
Trial 2			
Initial Gold Weight	5.07 g		
Sieve Guage	Aperture (mm)	Trapped Gold (g)	% of Total
8	2.36	0.83	16.4
12	1.7	0.15	3.0
20	0.85	0.49	9.7
50	0.30	1.57	31.4
100	0.15	0.89	17.5
<100	<0.15	0.85	16.8
Lost material		0.27	5.2

Picture 5. a) Gold sorted through sieves. b) soft matrix of the saprolite in muds clinging to stones and rocks where gold at Mangi is hosted. c) Second or scavenger sluice with miners moss brought from Canada. d) Zig zag sluicing on site. e) Miners using the zig zag sluicing.

6. Introduce new and/or improved sluice washing techniques

We instigated a system of zig zag sluicing that utilized a flat sluice 30 cm wide and 1 meter long lined with a thin locally acquired polyethelene plastic bag and with some light gauge miners moss brought from Canada (Pic 5c). We built the sluice locally minus the moss. This second or scavenger sluice then emptied into a large basin which collected any final heavy materials like gold while the light slurry continuously overflows (Pic 5d and 5e). This introduced two additional gold traps that were deployed on materials that the miners normally discard. Thus any gold captured in these traps would be additional gold that they would immediately recognize as additional recovery and production. We also introduce sieving any materials that will be panned to facilitate narrow grainsize panning practices. A narrow grain size makes panning easier and losses of gold lower. For example, panning the materials that passes through a 12 gauge sieve but not through a gauge 50 becomes more predictable in behavior and so faster and better. The sieving also serves as a secondary wash which may liberate some gold from the adhered clast coatings (Pic 5a).

These additional systems do not slow down the amount of material being processed. Their continuous use may require an additional person in the team – a scavenger operator (collector, siever, panner) But they would be easily paid for from the additional gold that was captured. It averaged about 30% higher. So a team of 5 could become a team of 6 but with 30% more gold the overall increase to each individual in the group would still be 16% higher per person. But it may be manageable without an increase in the number of people.

On the last day in the pit, one miner group began to experiment with placing the miners moss on their traditional primary sluice (Pic 6a). When he did so he captured 6 instead of 4 tige or about 100*(1-4/6) = 33% more. However this may have been due to better trapping or not. To know if this configuration is superior would require a number of tests that would satisfy statistical levels of confidence. He may have simply loaded a rich hopper this time. Whereas working on the waste clearly shows an increased recovery independent of the richness (grade) of the raw ore since it was otherwise going to be discarded.

A 6 HP engine and pump was purchased along with 10 meters of soft fireman hose in order to better washing, for more consistent sluicing conditions and a potential method of increased throughput. However, a nozzle for the outlet was not available and jury rigged ones performed poorly. Nonetheless one Baco was washed down a sluice in 10 minutes which clearly illustrated to the miners that they could easily process double the material in the same day using some low level hydraulic assistance. The pump and hose was worth about $350 US and uses 8L diesel per day. A group of miners that normally recover 2 grams of gold per day ($80) would increase their production by double plus 30% (including the increased recovery with better sluicing and grain size techniques) = 160*1.3 = 208 dollars. So rounding slightly they could pay off this investment in roughly week.

However if hydraulic systems are to be used in Mangi, it would be wise to build a more organized extraction and waste disposal system quickly to prevent unnecessary landscape damage. This needs to be done anyway.

In addition, further outreach work with artisanal miners will also be required before they come to accept the new idea of pump driven washing of ore. While miners could see and appreciate the increased throughput, many felt the increased water flow of a pump would lead to gold being lost in the sieves. Side by side demonstrations comparing traditional washing methods with pump driven washing would likely serve as an effective demonstration of this technique.

Instructions were left and parts identified and assistance with ordering and delivery to Africa to build flat zig zag sluices using a thick top carpet and a thin bottom carpet; a final trap at the bottom of the scavenger (an overflow heavies trap), and implement a standard sieving system pre-panning, and blue bowls for cleaning up concentrates.

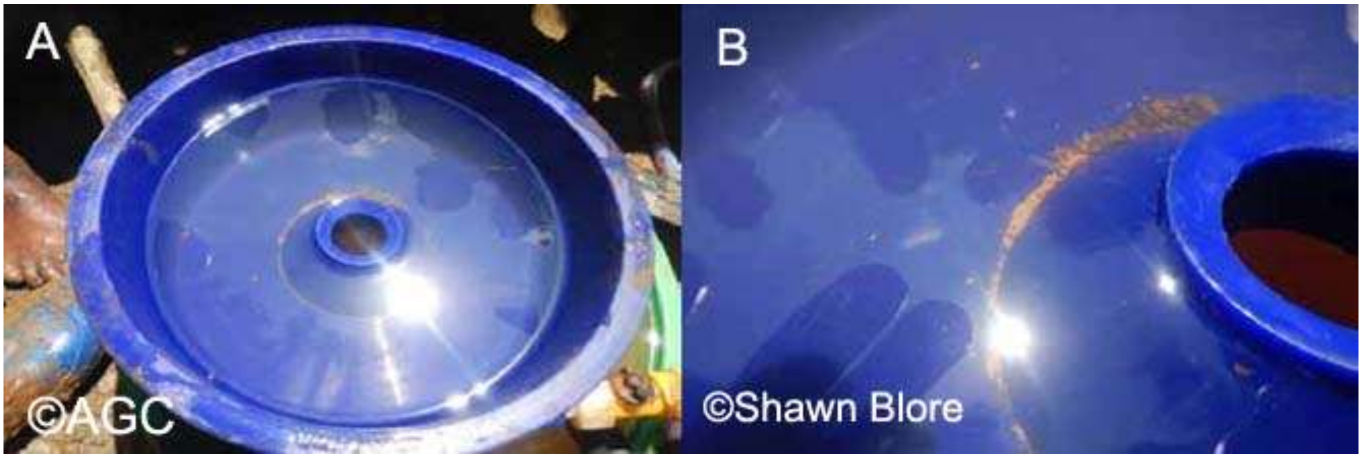
The risk that mercury will be used on Mangi materials is not zero. Setting up non-mercury good gold recovery systems and establishing welcomed legal supply chain, however, would likely deter mercury from ever arriving. In this sense the project is to some degree, a mercury prevention program.

Picture 6. a) Miner experimenting with miners moss on primary sluice. b) Miner washing the carpets. c) Purchase of 6 HP engine. d) Transport of engine to mine site.

7. Introduce new and/or improved yield-increasing technologies

The blue bowl is officially a “vortex” but the local name became centrifuge. The pump requires a fully charged 12V motorcycle battery, relatively clear water. A typical batch would take 5 minutes for small amounts of concentrate. It was highly effective at cleaning up final concentrates from being a mix of heavy minerals and gold to just gold including the fines that run the risk of being lost while doing traditional panning (Pic. 7a and 7b).

The spiral travelled from Canada to Mangi and back to Canada but was never used due to lack of time. It is difficult to know if it could play a role in higher gold recovery as it was not tested. If a large spiral allowed the processing of large volumes of carpet concentrate, it may be very effective and consistent way of further concentrating carpet concentrates.



Picture 7. a) and b) Blue bowl used in Mangi. The gold can be observed after the processing.

8. Introduce new and/or improved processing techniques/techniques for weighing on site

As explained above, temperatures sufficient to melt gold could not be made so the purification demonstration became half hands on (Pic. 1b) and half lecture with pictures using the Guide Practique (Pic. 1d). There was considerable frustration that there were only 10 copies of the Guide to hand out. I suggest a system of sharing be suggested and implemented if possible - some kind of library system based out of Gaston’s house or some other suitable location.

Nonetheless, levels of impurities were demonstrated by boiling in Nitric Acid.

Determining density by weighing in air and then in water was not possible to demonstrate with the equipment available. A relatively high precision scale is needed (precision at 0.1mg) and one could not be obtained locally nor in Canada before departing. This method would be helpful to introduce as it will further improve confidence, precision, and trust in gold trading.

9. Measure the efficiency of intervention techniques

The best direct measure of the success of the technical intervention was the 30% increased gold recovery. But there are other successes that come along with the technical aspects that are less tangible that were not measured. Increase in trust, interest in engaging, elevation of the spirit of innovation, improved health, many others. In order to measure the change in these aspects a pre-and post-survey of some sorts would be required.

10. Develop a technical intervention plan for both pilot sites (Mangi & PK51)

Short and Long Term:
Short term Mangi: production is increased through both higher recoveries through use of simpler improved technology such as the improved sluicing and concentrating as was demonstrated in the field and as will be rolled out by PAC over the next months; and through higher throughput by using hydraulic assistance for processing ore. However to make this sustainable over the next 10 or 20 years, a longer term plan of a more organized sector is required and should be implemented asap.

In the longer term Mangi requires: (a) a resource estimate through a simple prospecting survey; there are likely a mix of deposit types there – both colluvial and vein; (b) simple gravimetric methods such as those introduced for the sluicing can be further perfected. Ultimately, equipment such as a true centrifuge may be effectively deployed and economically viable; (c) better land productivity is obtained. This is done through land use planning and capturing higher percentage of the resource (gold) per unit of material processed using improved technologies. The planning includes creating mining corridors or concessions where ore exists and no go zones where it does not (for starters); and a waste disposal and land reclamation system is developed and begun. This would likely involve backfilling of pits while excavating new ones – so simply better organizing existing techniques leaving the landscape in the best possible condition to become reforested or used for agricultural purposes. This would be facilitated through a better understanding of the shape of the deposits that are available for artisanal miners to exploit and through a better coordinated mechanism of exploitation and trade. Ultimately, a system of registered small producers that in fact is similar to the existing system but with but with a longer term mining plan and increased access to capital and expertise and stability through selling through a legal supply chain.

PK25-51: A significant difference between PK25 and Mangi is how the gold is hosted in the ore.

At PK25, it is encapsulated in other minerals like sulphides and must be liberated through comunition (milling) and as well, its particle size distribution is likely skewed toward even finer sizes. This makes improvements in crushing and milling and the subsequent gravity based capture system the most important targets for technical intervention – quite sophisticated approaches could be utilized but there are relatively simple improvements possible as well.

Also, ultimately a chemical leaching step for final treatment of the tailings from the gravimetric processing will be successful at raising recoveries to a maximum. This is for example how the large industrial mining sector operates. This however is a tricky aspect that needs to be introduced in a way that leads to good environmental and governance practices.

A regional semi-centralized tailings collection and treatment plant is likely to be the most appropriate approach so that sophisticated “black box” technologies can be properly used without serious risks to people or the environment. Both cyanide and chloride leaching technologies could be investigated as suitable. Notably, this would develop a trade in tailings which would allow for them to be properly collected, processed and stored in an appropriate disposal system. Gold extracted from the tailings would pay for the system. If this were employed, total recoveries at the end of all processing would likely be above 90% of total gold present in the ore.

Short term improvements at PK25-51 would be improved crushing and milling – this is currently the most common bottleneck in the production system – the milling. It is done in octagonal mills which, simply by their octagonal form are inefficient. As well, they are batch processed meaning that the materials are not processed to a particular grain size but simply for a fixed time. This occurs because milling is typically run as a service by private mill operators and they charge per unit mass and time. Better, milling could be obtained by either a simple pan mill or a continuous ball mill with the pan mill being cheaper and easier and more intuitive to run but slower than modern continuous flow ball mills. Better milling will better liberate encapsulated allowing more of it to be captured. Along with better milling better fist stage gravimetric practices could be introduced – better sluicing with a primary and secondary (scavenger) sluice followed by a concentrate separation technology like a centrifuge or a shaking table. Shaking tables are easier to maintain and more intuitive to operate. Recoveries of 60-70% are feasible with an enhanced gravity plant (crushing, milling, grav separation, smelting). This should lead to discontinuing the use of mercury however this can be a gradual process and in the interim mercury reduction and health programs should be introduced to help make the transition to zero mercury.

In the long term, the waste stream from the enhanced gravimetric plant would go to the more centralised chemical leaching plant and ultimately produce tailings for permanent disposal.

Picture 8. a) Example of an IconTM centrifuge b) Example of a shaking table used in a small-scale operation in Mongolia.

Gold Buying at Mangi and PK25-51:
The incentive to trade gold through legal channels at Mangi and K25-51 is improved recovery
– sort of a trade where miners sell gold legally for access to higher recovery technologies. This is a good start and will be popular but may not be sustainable. How long can a monopoly on improved technologies and higher recoveries be maintained before miners simply take these measures for granted? When that happens they will again be looking for the highest bidder to sell their gold.

There are two strategies that could help in preventing gold trade to return to the black markets:
(1) work with the government to get tax rates on gold low enough so that the black market is not competitive. Some intangible benefits such as stability may be included in such a cost
benefit analysis, but ultimately it means a very low tax level on primary gold production. Where the government should focus the collection of tax revenues on the secondary economy that surrounds gold mining: fuel, equipment, food, transportation can all be taxed at a reasonable level without risk of creating a black market for these goods. (2) a central gold buying house stationed in PK25-51 and one in Mangi where all the small buyers will sell their gold at spot minus a few percent. A high competitive price for gold plus techniques that

guarantee proper weights are the basis for trading (purification and assaying for example) as well as government support will make this central buying system successful and sustainable. It can also act as a central coordinating office for many other community related matters. The gold from this premise would be sold directly to an international refinery. One model that may work would be to have a not-for profit or social enterprise run the gold buying house and turn any profits acquired back towards community improvement projects – like road construction for example. An expected revenue stream from such a gold buying house might be 2 or 5% of the value of the gold it processes. Operating costs plus community service would need to come from that revenue.

Picture 9. Different gold shops throughout the region.

11. Propose mercury free recovery/processing techniques

See above

12. Carry out a preliminary assessment of the environmental impacts (actual and forecasted) of the proposed technical interventions

Environmental impacts are currently near a maximum with no organization or tailings disposal system in place in Mangi and with extensive use of mercury (universal) and no tailings man-agement at PK25-51. Ultimately, almost all waste, including mercury contaminated waste and highly acidic waste (acid rock drainage from the sulphide minerals) enters aquatic ecosystems uncontrolled.

In terms of footprint, the introduction of a system that leads to better recoveries lowers the footprint by producing less waste per unit gold.

Picture 10. a) and b) Examples of the environmental impact seen at PK25-51.