Prevention of Siltation in Artisanal Small-scale Mining

E. Takaluoma[1], T. Samarina[1], A. Peronius[2]

[1]Kajaani University of Applied Sciences, Ketunpolku 1, FI-87100 Kajaani, Finland, esther.takaluoma@kamk.fi

[2]Hangasojan Kulta Oy, Consulting company, Ylä-Mulkujärventie 123, 99800 Inari, Finland

Abstract

Silting of waterbodies caused by sluicing in artisanal small-scale mining is a consquence of sluicing directly into receiving waterbodies. Silting lowers the acceptancy of mining activities by locals. Utilizing flocculants and/or coagulants in circulation ponds quickly reduces the amount of silt and colloids in the water. The flocculant can be applied with low-cost methods and the overall process is economical. The process has been tested in a 3–4 m^3/h pilot in the Finnish Lapland.

Keywords: ASM, Gold Mining, Siltation, Prevention

Introduction

Artisanal small-scale gold mining (ASM) is a livelihood for over 40 million people in 80 countries (Weldegiorgis 2018), and rising gold prices increase ASM attractiveness. While many countries are starting the process of formalizing ASM, several social and environmental problems need to be resolved (Singo 2018). Many researchers focus on the mercury pollution from ASM. However, with the correct techniques suitable to the targeted ore applied, the use of mercury can either be circumvented completely with little to no loss of yield, or the mercury can be safely retorted.

Sluicing of alluvial gold containing ore involves the gravimetric separation of gold particles along a slight decline with the help of large quantities of waters, often several hundred liters to cubic liters per minute. Gold particles are separated at the bottom of the sluice by rifles, with profile, spacing, and height according to the ore being processed. Grizzlies or drum screens help to remove overlarge rocks. Thus, sluicing washes the non-gold material into the receiving waterbody. Larger particles quickly settle to the ground, while small and colloid particles can remain flowing for days and months.

Gold mining in the Finnish Lapland underlies strict regulation and environmental protection laws. Despite high levels of regulation, the Lapland Goldminer's Association currently has around 4100 members. Each claim is subjected to individual rules, imposed by mining authorities and based on the Environmental Protection Act, which forbid the contamination of nature and the reduction of recreational value of nature. These laws are subject to interpretation.

With respect to the sluicing process, the biggest concern is the emission of fine particles downstream. Sludge formation can destroy spawning areas and affect developing hatchlings. Therefore, silting of waterbodies and the increase of turbidity is prohibited (Kerr 1995). All gold mining practices must utilize circulating water with settling pond sizes of at least two hours of pump use. All rainwater and surface runoff water have to be guided into the water circulation. Water purged from the circulation is to be absorped by a leaching field.

The law also requires actors to actively anticipate and prevent emissions. In case of disturbances, this can, however, be difficult, particularly in times of rainstorm or at the beginning and preparing of a new area. Therefore, techniques to quickly settle colloids and floating particles could be beneficial in silting reduction from gold mining.

In this article, the results of a low-cost, low-tech method to introduce coagulant/flocculant into circulating water was tested and piloted at a 3–4 m^3/h scale in a working gold mine are discussed.

Samples:

Samples were taken in July 2018 from five different gold mines with three different bed rock areas. The samples also differed in the life-of-mine stage of the gold mine, ranging from a recently started mine to a tens of years old mature mine. Four mines were processed by excavator and one gold digging place was processed using shovel-operated methods. Coordinates and physical parameters of the samples is gathered in Table 1. Sample Pusku is from a mature settling pond, containing small, plate like colloids, with a particle size of 0.5-2 µm.

Methods

Initially, flocculant testing was performed in the laboratory utilizing JAR-tester and standard methods. The coagulants tested were PIX 105 (Kemira) and PAX XL 100 (Kemira) and they were used as they were received. Flocculants, SA1, Praestol 2500 TR and Drewfloc 270 (Solenis Sweden AB), were prepared as a 0.25% solution 18 h prior to use. The best coagulant/flocculant mixtures were used to test low-cost flocculant addition under field conditions.

Lab test conclusions

All samples could be clarified by a suitable coagulant/flocculant mixture. Because silt particles are usually negatively charged, cationic coagulants and flocculants were used. PIX was favored over PAX because of potentially problematic aluminium concentrations in mine effluent. As such, over dosage of iron-based coagulant would result in natural precipitation of iron oxide hydrates and would, therefore, be environmental benign. The dosage depended on the type of particles in question and on the amount fines in the water. For the samples tested, suitable dosages ranged from 50 mL PIX per m^3 and 2 L polymer to 60 mL PIX and 10 L polymer. To keep treatment costs low, it was preferred that the polymer was increased over an increase of PIX dosage.

It also needed to be taken into account that the dosage was based on the rapid formation of thick flock, which settles fast, to allow quick removal of clarified water. A thick flock was also preferred due to the possibility of strong currents in the clarification ponds, as the gold washing process might be in progress.

Scheme for field tests

The goal of field testing was the proof of concept for a low-cost low-tech-method for silt removal in ASM. The developed method would not require slow-mixing and utilized simple technology, so that could it could easily be copied by miners around the globe. Due to the strict environmental laws, no chemicals or flocculants were allowed to enter the surrounding nature, and the tests were conducted with a side stream-utilizing international bulk container (IBC). Formed sludge was removed from the IBC and disposed of later. according to permissions. The overall concept is depicted in Figure 1 and the implementation in a field test can be seen in Figure 2. The tests were performed at claim "Rinnekulta" while sluicing was in progress during the period of 27.8.-31.8.2018.

Calculation of coagulant and flocculant dosage was based on laboratory tests. An average solid particle content in a circular pond in a running mine is about 10 %. However, the distances from the sluice and the feed, as well as particle size distribution, may vary greatly and only an estimation can be given. Flocculant was administered in a 0.1% solution.

The settling speed of particles was determined in a 500 ml volumetric flask, and the speed of clarification for optimized runs is shown in Figure 3. Utilizing PAC instead of PIX increased the speed of clarification,

Table 1 *Sampling parameters of for water sampling.*

Name	Coordinates		Altitude m a.s.l.	pH	TDS mg/L	Conductivity µS
Palsin tulli	N 68,4577	E 26,9571	254	7.52	20	45.5
Rinnekulta	N 68,45566	E 26,93117	275	6.92	9	20.8
Vehviläinen	N 68,4555	E 26,9309	245	7.38	22	48.7
Mäkärä	N 68,1482	E 26,9791	247	6.81	12	26.6
Roivainen	N 68,0453	E 27,1112	275	6.59	10	19.9
Pusku	N 68,64141	E 25,70372	-	6.64	14	30.7

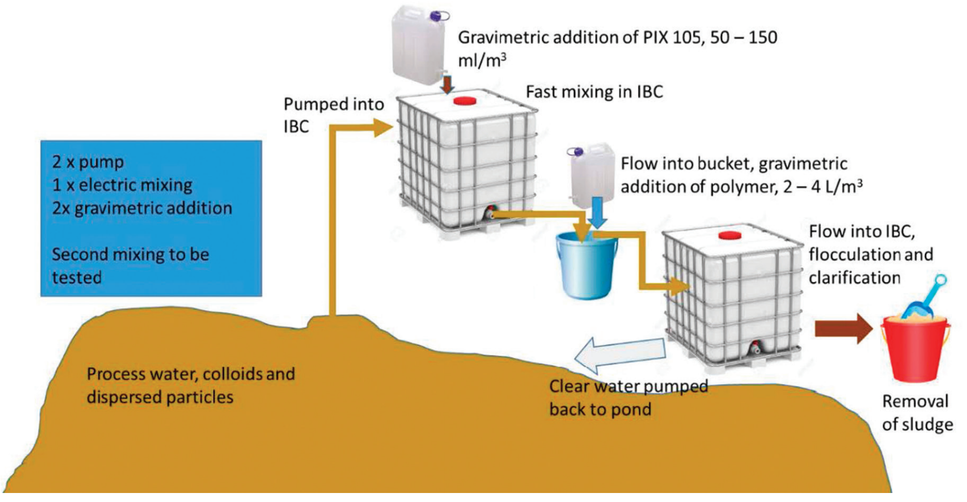

Figure 1 *Scheme for the field tests with equipment used.*

and a larger amount of coagulant (10 mL/min vs 8 mL/min) produced a thicker, heavier flock, that formed a denser sludge. Positively charged coagulant was necessary to neutralize the negatively charged silt particles. PIX, being iron-based, is environmentally more benign. Accidently release of PAC, an aluminium-based coagulant, can affect fish population.

Based on these results, the application of coagulant/flocculant with low-tech gravimetric dosage could be applied to remove colloid particles from ore processing of alluvial gold mining. The dosage of

Figure 2 *Ongoing field tests, left IBC on damn of circulation pond. (photo: E. Takaluoma).*

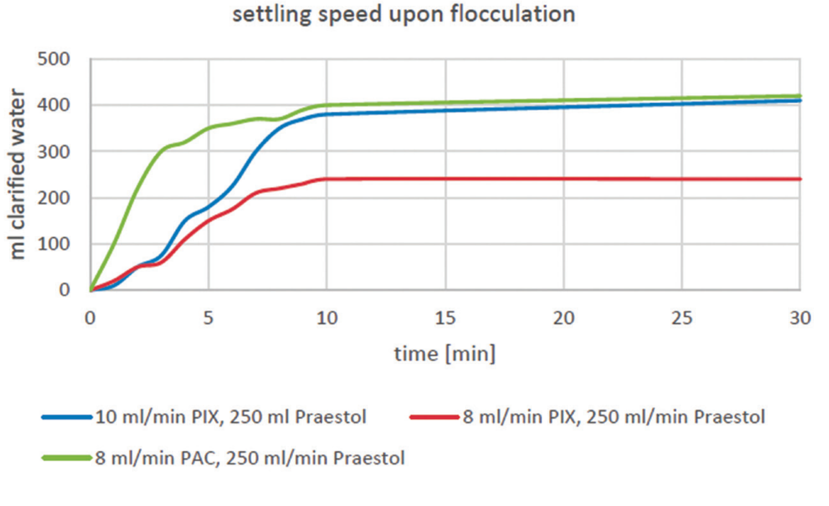

Figure 3 *Settling speed upon flocculation, for three different coagulant/flocculant doses.*

coagulant can be adjusted with respect to environmental discharge permits. A combination of coagulant and flocculant resulted into a thick flock that rapidly settles to the bottom of the pond. After five minutes, the clear water on the surface can be discharged into a receiving water body. This makes the method of coagulation/flocculation a valuable tool for goldminers in the case of sudden failure of pump, flooding, or increase in rain fall. If the goal is purely to utilize the method in the case of emergency, overdosing is not considered a problem.

During the tests, the dosage of coagulant and flocculant was varied. A higher dosage resulted into better flock formation. However, this, in turn, increased the costs. Therefore, the dosage, cost, and desired result before purging in the environment will need to be weighted carefully against each other. It is possible that a smaller amount of coagulant can be sufficient, and the reached flocculation will be within the amounts specified in environmental permits, which varies by claim and area. This will also depend on the flow of the receiving water.

When questioned, Finnish gold miners responded positively towards the water purification methods. There was little concern about the additional workload of mixing and preparing the flocculant/coagulant solution. However, concern over prices was expressed, citing that the use of coagulants should not exceed the pumping costs of the leaching field.

Both PIX and PAC were used as coagulants. Using PIX might be easier to dose, as it does not increase the aluminium concentration, as with PAC. However, liquid PIX is ferrisulfate in sulfuric acid and the pH of the solution is below pH 0. Handling of highly acidic liquids requires trained personal. With PIX, the clarified water had a pH of 4. When PAC was used, the pH of the clarified water remained circumneutral.

In an upcoming project, the formation of flock in pond system will need to be investigated. It can be expected that the wall and bottom structures of the pond, as well as the changes of laminar and turbulent flow, has an effect on the flock formation. The future project will explore this further. It will also be necessary to test the pumpability of formed sludge. In the project, the use of 3D printed mixing tube will be investigated, as an alternative to fast mixing that further eliminates the use of electricity in the concept.

Conclusions

Goldmining in Finnish Lapland can serve as an example for best practices in ASM. The study demonstrated the facile and low-tech method of silt removal from ASM, without the need of slow mixing for flock formation. Coagulation/flocculation can settle the colloids and dispersed particles in circulation and in settling ponds within minutes and remove the need to purge silted water into the receiving body. These results can readily be applied in training for miners and be employed to decrease the environmental impact of ASM. The method can prevent silting of water bodies, which may potentially be drinking water bodies, and therefore greatly increase the social acceptance of mining activities.

References

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