TAUW

Responsibility

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Glossary

ASGM	Artisanal and Small-scale Gold Mining
m bgl	Meter below ground level
CSM	Conceptual Site Model
COP	Conference of Parties
CN	Cyanide
d.w.	dry weight
EU	Europe/European
Hg	Mercury
ICSM	Initial Conceptual Site Model
NGO	Non-Governmental Organisation
TOR	Terms of Reference
WHO	World Health Organisation

Abstract

1 Introduction

1.1 The issue

Artisanal and Small-Scale Gold Mining, referred to as ASGM, is responsible for a large part of mercury contamination on earth. Indonesia is the third largest contributor of the global mercury pollution. This is caused by mercury used to extract gold from ore as an amalgam in ASGM. The amalgam is segregated from the mined ore by gravity, and then the amalgam is heated to evaporate mercury and extract gold. Due to exposure to mercury during this ASGM process, including the atmospheric deposited mercury from the burning, health and environmental problems occur. Among these are mercury groundwater contamination in domestic shallow water wells in the rural communities practicing ASGM.

NEXUS3 Foundation (before Bali Focus and in this report referred to as NEXUS3) is an Indonesian Non-Governmental Organisation (NGO) working in Indonesia to reduce the human mercury exposure in these ASGM communities. NEXUS3 and Durham University developed a polymer that bind heavy metals. The polymers are made of alginate, derived from brown algae, and pomelo peels (agricultural waste). Lab tests demonstrated that these polymers successfully bind mercury and lead from water and reduced its concentrations (Bailes et al., 2019 unpublished).

NEXUS3 and TAUW have since a few years contact and the call from the TAUW Foundation for tenders in 2020 was seen as an opportunity to pilot the polymers, a potential and simple and sustainable groundwater remediation technique for mercury contaminated water.

A tender for such pilot was submitted to the TAUW Foundation and granted. After a delay of almost two years due to COVID-19 a collaboration agreement between NEXUS3 and TAUW was signed on the 9th of March 2022. TAUW and NEXUS3 established a consortium, with NEXUS3 in the general lead and TAUW leading for the soil and groundwater investigation and remediation. The project name is “Mercury removal from shallow wells”. Besides the consortium partners the project has subcontracted the Mataram University situated in Lombok. Oher donating project partners are the mining company PT Aman Mineral at Sumbawa, the Durham University in England and Flinders University in Australia. Aman Minerals has a Cooperate Social Responsibility Program and is involved in solving the ASGM problems as well. They donated to the Mataram University an analyser that can measures total mercury and its various compounds including methylmercury, the analyser will be used to analyse the samples that are and will be taken in the scope of this pilot project.

The project intends to apply the above-mentioned sustainable groundwater remediation technique by installing a barrier and/or filters with these biopolymers in a selected village where mercury-contaminated groundwater is domestically used. When successful, a cheap and local applicable (1) emergency measure to supply safe drinking water on the short-term and (2) a groundwater remediation technique to remediate mercury contaminated groundwater are available. Besides this, using pomelo peels will stimulate local production of pomelo juice generating income and the pomelo peels are no longer waste. The biopolymer will also use seaweeds that are available locally. Due to the simplicity of the technical it is replicable.
When this technique is successful it improves the domestic water quality and creates an extra source of income and will make this technique attractive for ASGM communities confronted with the same problems.

1.2 Scope

The project scope, including the planning and the deliverables and the roles of the various partners of the project are summarized below. The summary is based on Project Work Packages, as formulated in the TAUW Foundation contract. The project is a pilot project and comprises of the four phases. This document reports the inception phase.

1.2.1 Phase 1: Inception phase

During the inception, preliminary site investigations of ASGM sites with suspected mercury contamination are carried out at West Lombok and West Sumbawa. Field data on both technical and social aspects are collected. Initial Conceptual Site Models (ICSMs) of these representative ASGM sites are drafted and used to establish the potential sources of mercury contamination, the potential source-receptor pathways, possible receptors and the potential human health risks, risks for the ecosystem and risks for migration of contaminants. These risks are referred to as environmental risks. From these preliminary investigated sites, two sites are selected to be investigated in detail and with the detailed information two Conceptual Site Models (CSM) are constructed and the environmental risk are established.

The detailed site investigations are carried out on sites where the preliminary site investigations suggested mercury contamination to be present in the soil and/or groundwater and causes environmental risks. Each of the two detailed site investigations comprise of:

- Gap analysis of ICSM
- Site investigation and sampling and analyses plan design
- Fieldwork campaign in line with the site investigation plan involving the installation of soil boreholes and wells and sampling soil and groundwater
- Analyses of the samples in line with the sampling and analyses plans. This will be done with the donated analyser when delivered and installed at the Mataram University. If the analyser is not yet operational the sample analyses will be outsourced. But in this case only total mercury can be analysed
- Data interpretation and evaluation
- Updating the ICSM to a CSM
- A tier 2 risk assessment

The objectives of the two detailed site investigations are to establish quantitatively the contamination situation and the associated environmental risks related to mercury. Based on the results of the detailed site investigation, the updated CSM and the tier 2 risk assessment, the need for remediation is determined.

From these two detailed investigated sites, one site is selected to proceed with a pilot remediation. All collected information will be used to design a holistic site remediation, using the various remediation techniques including biopolymers to filter groundwater. Collected materials (soil, water and sludge) will be subjected to bench scale testing at the Mataram or Durham or Flinders University to support the design of the pilot remediation. The design will be used to write the Terms of Reference (TOR) for contracting a local company to install the pilot remediation installations, Phase 2 of the project.

1.2.2 Phase 2: The site remediation

The outcome of Phase 1 provides the necessary input for Phase 2. This phase includes the installation of the proposed remedial measures by a contractor selected in Phase 1. The installation of the remediation measures including monitoring wells, to be used in the next phase, the monitoring of the remediation by the consortium. The design and set-up of all remediation measures will be documented and made public.

1.2.3 Phase 3: Monitoring of the remediation

The pilot remediation will be monitored for a period of 12 months to establish the effectiveness. After 12 months, the effectiveness will be evaluated and recommendations for optimization of the remedial approach will be presented. The results will be reported and made public.

1.2.4 Phase 4: Outreach

Throughout the project, outreach to both local and international stakeholders will take place. This will include the following outreach actions:

- Presentation at TAUW mercury webinar "A sustainable and innovative approach to manage mercury contaminated sites. The challenges, possible innovative solutions, and lessons learned" (online via Microsoft TEAMS on 14 June 2021, 16:00 - 18:00 (GMT+2)
- Present on the Pre- Conference of Parties (COP) 4.2 Side Event of the Minamata Convention: From Minamata to Bolivia and Indonesia - mercury contaminated sites and releases (Wednesday, 9 March 2022 11:00-12:00)
- Attendance to Minamata Convention COP 4.2 2022 in Bali to bring attention to the project (COP 4.2 took place from 21-25 March in Bali, Indonesia and was attended by NEXUS3)
- One day workshop/conference on contaminated site management in Lombok in cooperation with the local university (held on 28 March 2022)
- Participate (virtual) at the 15th International Conference on Mercury as a Global Pollutant (ICMGP) 2022, 24-27 July 2022 organised in South Africa. The announcement is provided in this link https://www.ilmexhibitions.com/mercury2022/abstract-submission/
- In close cooperation with Durham and Mataram University the suitability of the results for a scientific publication will be assessed. An easily accessible guideline for installation of the remedial measures at ASGM contaminated sites, including the use of the polymer, will be written and published on the website of the NEXUS3

1.2.5 Project planning

After a delay of almost two years due to the COVID-19, the project started in March 2022 and will be finalized in February 2024. The overall project planning is presented in Table 1.1.

Table 1.1: The project planning

1.3 Structure of report

Before this Introductory an abstract of the Phase 1, the project inception, is given. Following this introduction, Chapter 2 provides the information on the ASGM process including the social context in the visited villages at Lombok and Sumbawa. Chapter 3 presents the results of sites visits, the three ICSMs of the selected ASGM sites and the CSM of one site at Lombok. Chapter 4 presents the same, but now it concerns the sites at Sumbawa. Chapter 5 reports the next Phase, the site remediation. In this section results of the remediation assessment including the specification of the proposed site remediation of one site are provided. Chapter 6 summarizes the conclusions and recommendations of this Inception Phase.

2 Artisanal and Small-Scale Gold Mining

The information shared in this chapter is based on visits to ASGM villages in Sekotong at West Lombok and West Sumbawa, in March and April 2022, the end of the rainy season. The villages were visited by NEXUS3, the Mataram University, representatives of the local competent authorities and TAUW. Information about the ASGM process and the social issues were collected by observations, interviews and various publications on ASGM. This Chapter gives a description of the ASGM process as observed in Section 2.1. Section 2.2 reports the observed steps phasing out the gold mercury amalgamation in the ASGM villages visited in the scope of this project.

2.1 The ASGM process

The ASGM sites visited are all located in villages practising, besides ASGM, subsistence farming. In all villages an abundance of mills is present to process (mill) ore containing gold. At a village on West Sumbawa, it was said that more than 200 mills were operating at a certain time. In general, each platform, made out of a concrete slab, has one to eight mills, larger platforms with more mills do exist. The mills are drums with a lid on the side, of around 100 litters, secured on small concrete supports. The drum is rotated by an electro motor connected with a V-belt. Together with the ore, water and mercury are added to these drums for the gold mercury amalgamation. The drums of the mills that were opened during our visits were all using iron rods for the milling.

The ore is manually mined in the nearby hills or mountains. These mines are mostly small saft mines. The ore from these mines is put in 20 litres rice sacs containing an estimated amount of 30 kg ore. These sacks are carried to the rod-mill locations and are stacked, awaiting to be (manually) crushed before processing (milling and amalgamation) in the rod-mills. The ore processing sites are either in the vicinity of the mines itself or crushed at the mining sites itself and then transported to the rod-mill locations in the villages.

At the rod-mill location, crushed ore (20–40 kg) is fed into the rod-mill. Water and mercury are added and after around five hours milling, it is assumed that the ore is fine enough for the gold mercury amalgamation. After milling the content of the rod-mill, process water, milled ore, the amalgam, and the excess of mercury, are drained from the rod-mill drum and separated by gravitation using water. The edges of the concrete slab/platform with installed rod-mills are higher to prevent spiling and to facilitate drainage of the process water with the tailing. The processed ore and water from the drum are poured in a basin, the amalgam and the excess of mercury settle at the bottom of the basin. Excess of water with the tailing are poured on the platform and drained from the platform in a small settlement pit, constructed in the concrete rod-mill platform to reclaim the coarse tailings. From this small pit the tailings, containing the finer particulars (sludge), are drained to mostly an unlined sedimentation pond to drain the process water from the tailings. The bottom of these sedimentation ponds is mostly not lined. The tailings are drained and dried as the process water freely infiltrates in the subsoil.

At the last stage of separation, the excess of mercury and the amalgam in the basin are drained and filtered using a strong fabric cloth to separate the mercury from the amalgam by squeezing. The gold is retrieved by burning the amalgam. The burning is done at the family compound and/or at (specialised) gold shops located in the vicinity of these villages. Finally, the drained/dry tailings from the sedimentation pond are bagged and sold to a cyanidation plant. Noteworthy is that last years more cyanidation plants in West Sumbawa and West Lombok to process these tailings were constructed.

As the tailings and mercury-contaminated water are released into a sedimentation pond the potentially mercury contaminated water enters the soil through infiltration. From literature and the few information obtained the amounts of mercury used vary between 0.3 and 1 kg of mercury to 20 kg ore.

The whole ASGM process from milling, to reclaiming the excess of mercury and finally separating the amalgam uses a lot of water (see Figure 2.1 till 2.6). Therefore, the majority of the rod-mill locations visited, have an open shallow well close by, to provide process water. In general, each family compound has its own shallow well. The water from these wells is besides process water for ASGM also used in households for cooking, sanitation, watering livestock and to irrigate the kitchen garden. Occasionally well water is used as drinking water, but the majority of households use bottled drinking water.

The visited ASGM villages are all situated on alluvial, marine and colluvial deposits as the groundwater table here is shallow. At the time of our site visits (end of the rainy season) the groundwater was mostly within 6 metres below ground level (bgl) and therefor process water was easily available. It was told in some villages, that the shallow wells run dry in the dry season, and in these cases water from a deep well (if present) is used. Based on the observations and the information shared it is concluded that in general, the groundwater for processing the ore is (1) directly taken from on-site, nearby situated, shallow wells, (2) tapped from a nearby irrigation system, (3) pumped from deep wells or (4) drained from a nearby river.


Figure 2.1: ASGM uses an excess of water


Figure 2.2: The excess of mercury and amalgam


Figure 2.3: Mercury and amalgam is poured in cloth


Figure 2.4: The excess of mercury is separated from amalgam


Figure 2.5: Amalgam from around 20 kg of ore


Figure 2.6: The amalgam for burning

Our understanding of the ASGM process is illustrated in Figure 2.6. The cyanidation of the tailing in the Cyanide (CN) plants is represented by “CN plant” in the figure. This process is not detailed as this is out of the scope of this project but the figure illustrates the various source of the potential mercury contamination.

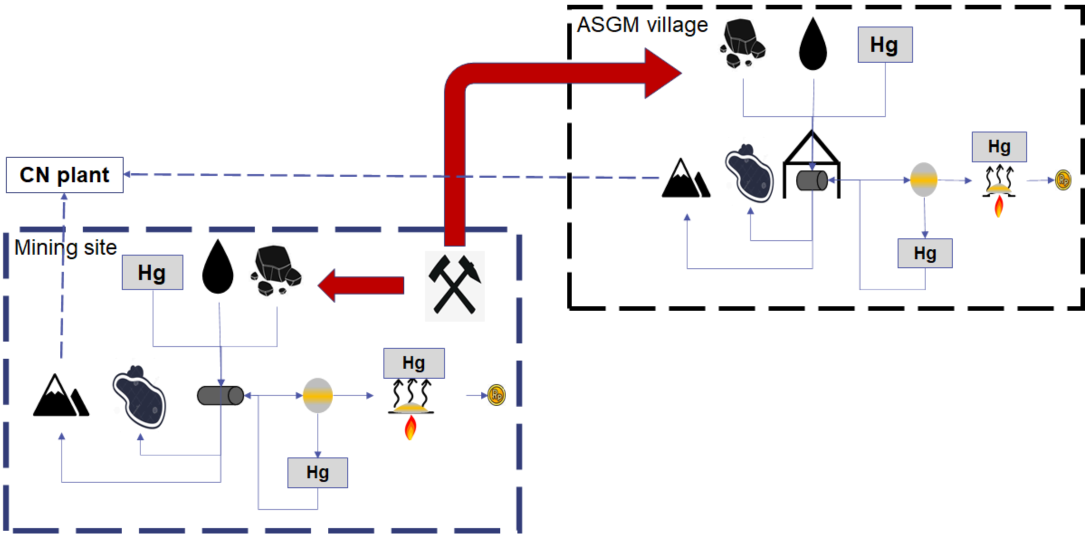

Figure 2.7 Schematic representation of ASGM processes

2.2 The phasing out amalgamation

Based on the economic situation and the circumstance in a household, rod-mills for ASGM are actively used, standing idle waiting for better times, or are removed and transformed for other purposes. On what basis it is decided to stop the ASGM varies from lack of resources, legislation and raised awareness of the health impact using mercury.

From contacts with the villagers practising ASGM no clear information is obtained on the quantities of mercury that is used for the amalgamation. The once practising ASGM are not willing to share information on the process and especially not on the use of mercury. This demonstrates that they are aware that using mercury is illegal and that it can cause harm (the majority of the households do not drink the groundwater from their shallow wells).

Based on our observations it seems that each ASGM household, processing the mined ore, uses own experiences to fine tune the process and have effective yield. During an interview with a head of family mentioned that he uses 0,5 kg of mercury per 5 kg of ore, which is far more than the figures given elsewhere. He also uses ice to enhance the separation of mercury and amalgam. Another villager uses borax to burn the amalgam. Based on these observations and the discussions it seems that people in the ASGM learn by trail and error and own experience. Resulting in different variation of ASGM processes per household and causing different environmental risks. However, it can be summarized that in general traditional ASGM process uses mercury for the amalgamation, burns the amalgam at or nearby family compounds and sells tailings for cyanidation as these tailings still contain gold.

The visited villages have nearly at each compound a rod-mill location but several stages of transition to phasing out amalgamation have been observed and exist next to each other and are applied at the same rod-mill. What process is used depends on all kinds of reasons. The observed processes are:

1. The traditional ASGM, using mercury in all batches of ore, burn the amalgam in the family compound and sell the tailings for cyanidation

2. The first step in phasing out mercury, shared in interviews is, only using mercury in high prospect batches and burn the amalgam in the family compound. The low prospects are milled without mercury and sold for cyanidation. From both the tailings respectively the milled or are sold for cyanidation
3. The second transition phase is using mercury in all batches of ore, but the burning of the amalgam is done at the shop that sells mercury and buys the gold. But unfortunately, these shops are often in settlements and when not reclaiming the mercury when burning, using for instance retorts, the shop keeper burning and the people living around are exposed to mercury vapour. In this phase also the tailings are sold for cyanidation
4. The third transition phase is only using mercury in high prospect batches and burn the amalgam in a shop. The low prospects are milled without mercury. From both the tailings respectively the milled or are sold for cyanidation
5. The last phase is not using amalgamation at all. The ore is milled without applying mercury. The milled ore is drained from the rod-mill to the sedimentation pond, collected in sacks and sold for cyanidation

People from the ASGM village in transition, produce more often milled ore without using mercury because there is an increase in cyanidation plants operating that buy the milled ore. This is becoming more profitable because mercury is getting expensive, mercury is not as pure as it was, trading and using mercury is illegal and the cyanidation is more effective than amalgamation. Using only cyanidation has on average a three times higher gold yield than amalgamation. The transition of these ASGM villagers is also made, as they are more aware of the impact of mercury on their health and the environment.

The observed transition of ASGM demonstrates a positive effect of all the efforts made by the authorities involved in the implementation of the Minamata Convention and the NGO community such as NEXUS3.

The different stages of ASGM processes phasing out the use of mercury in the villages visited, are schematically provided in Table 2.1.

*Table 2.1: Steps of phasing out mercury in the ASGM process *

Stages	Using mercury always	Using Mercury only in high prospects	Not using mercury in low prospects	Not using Mercury	Burn in family compound	Burn at the shop	Tailing sold to CN plant	Milled or sold to CN plant
Traditional	X				X		X	
First		X	X		X		X	X
Second	X					X	X	
Third		X	X			X	X	X
Last				X				X

3 Results site investigations West Lombok

NEXUS3, Mataram University and TAUW selected three representative ASGM sites in Sekotong, West Lombok to make ICSMs. The first site is Kayu Putih in the village Pelangan, the second site is in the village Temboulon, the third site is in Cadi Manik. These sites were visted on the 5th and 6th of April 2022. The visits were organized by NEXUS3. The participants of the site visits were the local NEXUS3 staff, representatives of the local authorities, professor Suhardi Suwardji and professor Igmade Kusnarta from the Mataram University, Carlo Bensaïah from TAUW and Boudewijn Fokke an independent soil consultant. The three ICSM are described in Section 3.1. From these three sites, Kayu Putih was selected to construct a CSM. This CSM is described in Section 3.2.

3.1 Initial Conceptual site models

3.1.1 ICSM Site Kayu Putih

Kayu Putih (meaning white wood/eucalyptus) borders to the west the main road (Jalan Raya Palangan) with left and right a trench to drain surface runoff water, and to the north and west a tree (teak) plantation is situated. A few hundred meters east of the site is a foot slope of a hill situated, and to the south and (south)west is a small meandering stream. This small stream enters a river and which subsequently flows into the Java Sea around 1 km North of Kayu Putih (see Figure 3.1).

Figure 3.1: Kayu Putih

The soils of Kayu Putih are young (Entisols and Inceptisols) and are formed on alluvial and party colluvial parent material. The terrain slopes in general to the northwest and the groundwater flow direction is assumed to be also northwest. The southern area of the site surface drainages towards the small stream. The runoff in the northern part drains through the unpaved road between Kayu Putih and the teak plantation to end up in the trench that runs parallel to Jalan Raya Pelangan. The western part of the site drains directly to this trench (see site layout of Figure 3.2).

Kayu Putih has around 17 family compounds and about 70 people are living in this community. Nearly all are or were involved in ASGM.

The potential sources of mercury contamination are all the rod-mill locations that used or are using mercury amalgamation for the ASGM. All steps of the amalgamation on the platforms and sedimentation of the tailings in the ponds may cause direct exposure to liquid mercury and vapourised mercury. The mercury may be flushed during the process into the sedimentation ponds and then leaches into the soil and may reach the groundwater. The mine tailings taken out of the sedimentation ponds and stored and bagged next to these ponds may cause spreading of mercury containing mine tailings in the direct vicinity of these rod-mill platforms. This may contaminate the topsoil with mercury in the village through runoff. One of the major sources of contamination is the mercury vapour coming from the in-compound burning of the amalgam. This causes direct human exposure but also indirect exposure through atmospheric deposition of mercury in the surrounding of the amalgam burning places.

The potential pathways of mercury (metallic mercury, dissolved mercury and methylmercury) are leaching into the soil, phreatic water and groundwater and into the downstream shallow wells which are used by households. Another potential pathway is the runoff which erodes the potential contaminated topsoil. The runoff follows the surface drainage pattern as pictured in Figure 3.2. All runoff enters in the trench along the road or in the small stream south of the site. The sediments together with the abundance of litter in the trench and stream is washed to the river during the times of heavy rains. Together with all the litter these sediments finally are washed into the Java Sea.

The potential receptors of the mercury contaminations are: the people processing ore and burning of amalgam, the villagers living around rod-milling locations, places where amalgam is burned and villagers using the groundwater from the shallow well. The villagers and especially children roaming around are in direct contact with the potential contaminated topsoil. Furthermore, if the soil of the on-site kitchen gardens is contaminated vegetables, herbs and fruits, which may take up mercury are also potentially contaminated. Therefore, residents are potentially exposed by consuming products form their kitchen gardens. Other potential receptors are livestock roaming in and in the surrounding of the village such as chickens and cattle. Additionally, through the consumption of animal products, villagers might be exposed to mercury. All these potential pathways illustrate that if the villagers are using a single food basket the potential exposure rate is higher compared to people consuming from a multiple food basket.

Figure 3.2 provides the site layout and Figure 3.3 is a representative cross-section of Kayu Putih with the multiple potential sources of mercury contamination, the potential pathways and the potential receptors.

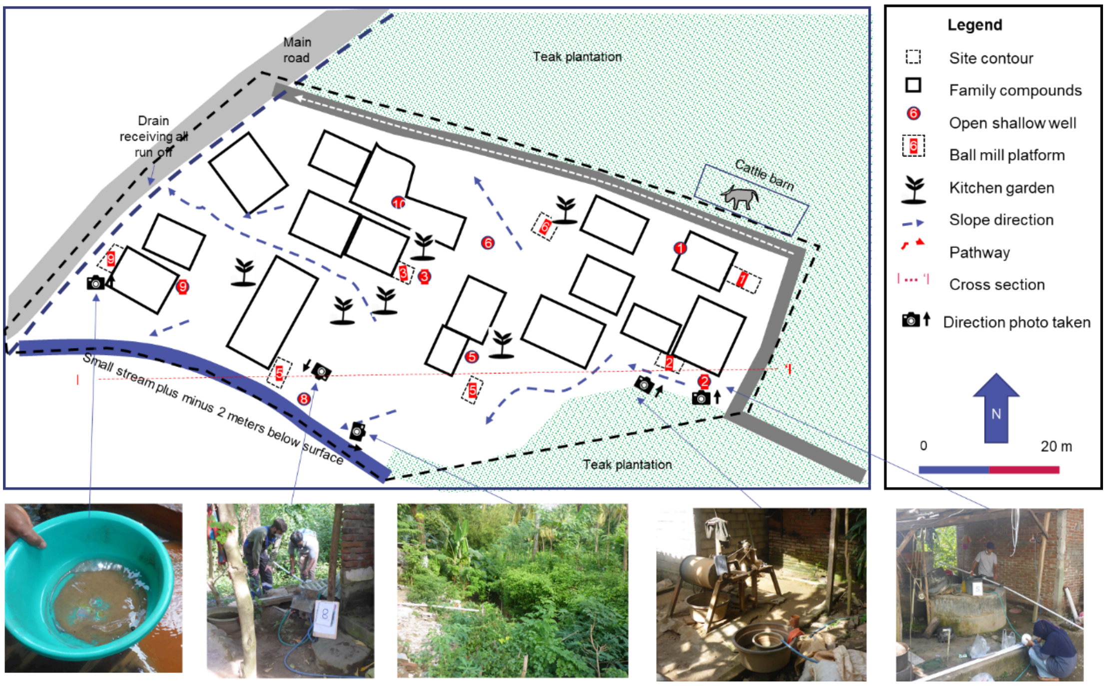

Figure 3.2: Kayu Putih with the multiple potential sources of mercury contamination and the potential pathways

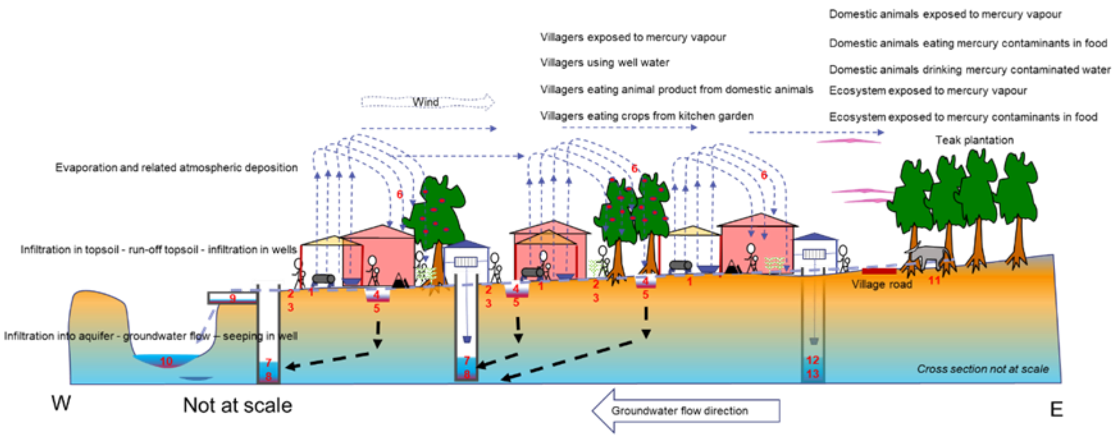

Figure 3.3: The cross-section A – A' of Kayu Putih with the multiple potential sources of mercury contamination, the potential pathways and the potential receptors

3.1.2 ICSM Site Temboulon

Site number 2, situated to the southwest part of the village named Temboulon, in Seketong was visited on the 5th of April. West of Temboulon the site is bordered by paddy fields and north of the study area borders the other parts of the village of Temboulon. To the east and south also paddy fields are present (see Figure 3.4).The Java Sea is situated approximately 250 meters to the west. The study area has around 25 family compounds and about 100 people live in this community of which most are involved in ASGM.

A family that was involved in ASGM activities was visited. One of the children of this family was born deaf and dumb. A medical specialist concluded after a medical examination that this was likely caused by mercury exposure of the parents.

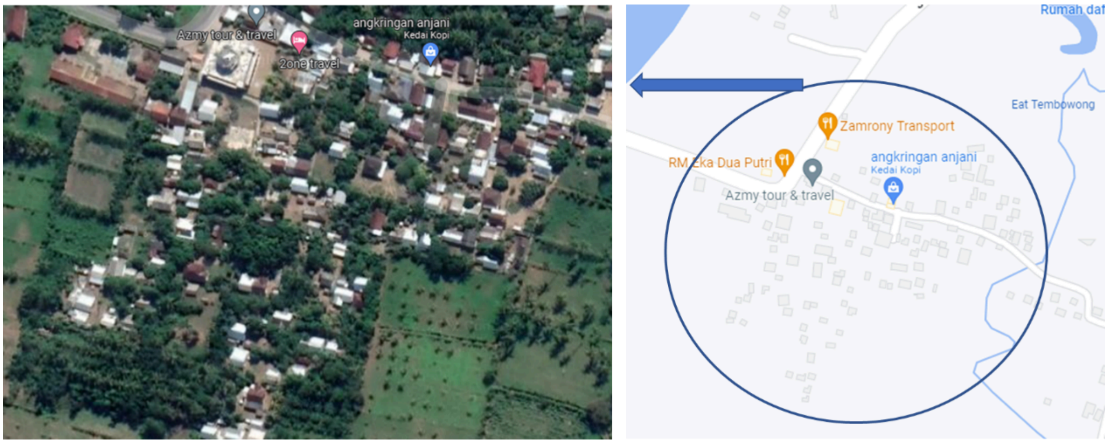

Figure 3.4: The study area of the village Temboulon

The potential sources, pathways and receptors of mercury for the study area of Temboulon are as described for the Kayu Putih site (see Section 3.1.1) and are summarized below.

Potential sources
- All the rod-mill locations that used and or are using mercury
- The place where mercury is burned (see Figure 3.5)

Potential pathways
- Direct contact with the mercury during handling and the drainage of the tailings
- Mercury vapour from rod-mills, during the drainage of the tailings and burning
- Leaching of ASGM process water to the soil and groundwater
- Runoff of the mine tailings taken out of the sedimentation ponds
- The groundwater flow in the direction of the down-gradient paddy fields
- The use of groundwater from the shallow wells down-gradient and down slope (runoff)
- The groundwater flowing to the down-gradient paddy fields
- Atmospheric deposition of mercury in the surrounding of the rod mill locations and the places where amalgam is burned
- Consumption of rice from the paddy fields, vegetables and fruits from the kitchen gardens contaminated by
    - Atmospheric deposition
    - Uptake of mercury from mercury contaminated soil
- Consumption of animal products raised in and around the ASGM village

Potential receptors
- The people involved in the ASGM process
- The families living in the ASGM village using well water and consuming products from the rice fields, their kitchen garden and animal products from livestock roaming around in the village

- The families living around the places where amalgam is burned
- The surrounding ecosystem

The Figure 3.5 is a map of the layout of the Temboulon study area. The cross-section of Kayu Putih, provided Figure 3.3, is also representative for the multiple potential sources of mercury contamination, the potential pathways and the potential receptors of the Temboulon study area.

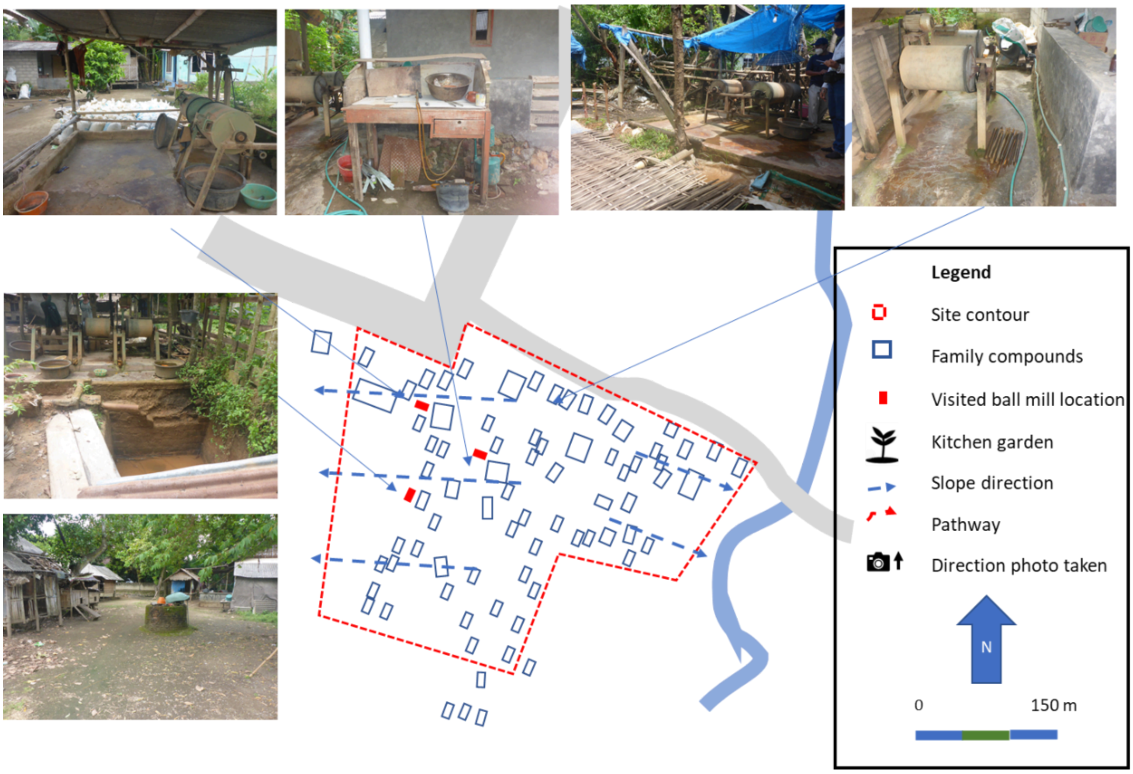

Figure 3.5: Site lay-out study area of the village Temboulon and photographs illustrating the on-site situation

3.1.3 ICSM Site Cadi Manik

Site number 3, Cadi Manik, in Seketong was visited on the 6th of April. This site is surrounded by a forested hill in the south, west and east. To the north the main road (Jalan Raya Sekotong, Lembar) is situated and opposite this road are lower laying paddy fields. The site itself is on the foot slope of the surrounding mountain/hill. The soils of the southern part of Cadi Manik are young (Entisols and Inceptisols) and are formed on colluvial parent material. The slope direction of the site is south to north oriented towards the paddy fields. The groundwater flow direction is expected towards the north (see Figure 3.6). It was told that the groundwater level drop could be more than 3 meters and shallow wells run dry during dry season. A 15 meter deep-well is installed to provide water during the dry season in the village.

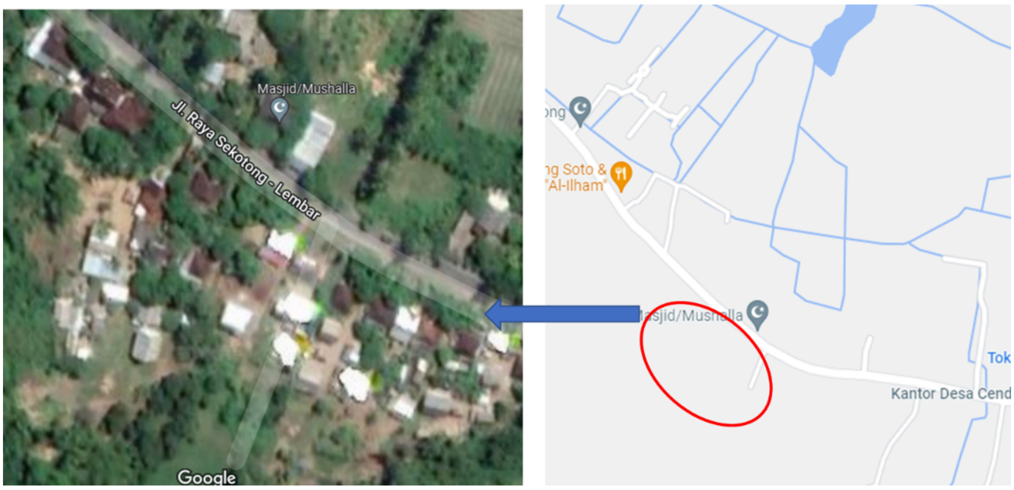

Figure 3.6: The location of the study area in Cadi Manik

The study area in Cadi Manik has around 25 family compounds and about 70 people are living in this community. Nearly all villagers are involved in ASGM. Also, on this site the potential sources, pathways and receptors of mercury are as described for Kayu Putih (see Section 3.1.1) and can be summarized as follows:

Potential sources
- All the rod-mill locations that used and or are using mercury
- In-compound burning of the amalgam

Potential pathways
- Direct contact with the mercury during handling and drainage of the tailings
- Mercury vapour from rod-mills, during the drainage of the tailing and burning
- Leaching of ASGM process water to the soil and the groundwater
- Runoff of the mine tailing taken out of the sedimentation ponds
- The groundwater flow in the direction of the down-gradient paddy fields
- The use of groundwater from the shallow wells down-gradient and down slope (runoff)
- The groundwater flowing to the down-gradient paddy fields
- Atmospheric deposition of mercury in the surrounding of the rod mill locations and the places where amalgam is burned
- Consumption of rice, vegetables and fruits from the kitchen gardens contaminated by
    - Atmospheric deposition
    - Uptake of mercury from mercury contaminated soil
- Consumption of animal product raised in and around the ASGM village

Potential receptors
- The people involved in the ASGM process
- The families living in the ASGM village using well water and consuming products from their kitchen garden and animal products
- The families living around the places where amalgam is burned
- The surrounding ecosystem

3.2 Kayu Putih Conceptual Site Model

A detailed site investigation is required when a preliminary site investigation has suggested contaminations to be present in the soil and/or groundwater and causing potential environmental risks. All three preliminary assessed ASGM sites at Lombok, have potential mercury contaminations and potential environmental risks (see ICSMs Section 3.1).

3.2.1 Selection of Kayu Putih site

For the selection of one of the three preliminary assessed sites to construct a CSM, 13 criteria with rating of per criterium per site have been used. The results are presented in Table 3.1. The rating used, is 3 as best to 2 as middle and the lowest rate is 1. All ratings per site are added and the Kayu Putih site scores the highest rate. Therefore, the Kayu Putih site is selected and subjected to a detailed site investigation. By gathering information, the CSM is made and the environmental risks are assessed. This is reported in the following sections.

*Table 3.1 Criteria, scor*ing to select a *ASGM sites* for a *detailed site investigation*

Criteria	Score		
Site name	**Temboulon**	**Kayu Putih**	**Cadi Manik**
Stage of phasing amalgamation	Best site is the site that phased out the use of mercury		
Amalgamation is phased out			
Several families started to phase out	2	2	
Few signs of phasing out use			1
Active ASGM period	Best site is the site with the longest active period		
More than 4 years	3	3	
Between 2 and 4 years			2
Less than 2 years			
Seize of site	Best site is the smallest site		
Smaller than 1 hectare		3	3
Around 1 hectare			
Large than 1 hectare	1		
Number of rod-mills	Best site is the site with the most rod-mills		
More than 20	3		
Around 20		2	2
8 or less			
Surrounding site use	Best site is the site with no ASGM upstream		
Upstream no ASGM		3	3
Upstream possible ASGM			
Upstream ASGM	1		
Groundwater well present	Best site is the site with up - and down gradient wells		
up-, down gradient	3	3	3
Only one or two wells are present			
No wells are present			
Groundwater depth	Best site is the site with a groundwater not deeper than 1 m		
Groundwater not deeper than 1 m			
Groundwater between 1 and 3 m deep	2	2	
Groundwater between 3 and 5 m deep			1
Availability data	Best site is the site with the most available data		
Data on soil, groundwater and ASGM		3	
Few data are available			
No data at all are available	1		1
Soil composition	Best site is the site where boreholes can be installed manually		
No pavement and no obstacles in subsoil	3	3	
No pavement and few obstacles in the topsoil			
Soil paved and obstacles in subsoil			1
Health and safety	Best site is the site that is mot littered		

Criteria	Score		
No waste, rubble, faeces are observed			
Some waste is present		2	2
Waste and faeces are everywhere	1		
Accessibility	Best site is the site that can be easily reached by car		
Easy to reach by care		3	3
Site max 15 min walking distance	2		
Site more than 15 min walking distance			
Cooperation villagers	Best site is the site where villagers are cooperative		
Cooperative		3	
Indifferent	2		2
Hostile			
Cooperation authorities	Best site is the site where authorities are cooperative		
Permission obtained and cooperative	3	3	3
Permission			
Indifferent			
Total score	27	35	27

3.2.2 Gap analysis and sampling and analyses plan

The Kayu Putih ICSM drafted in Section 3.1.1, is partly based on facts and partly on assumptions. The assumptions are the knowledge gaps of the ICSM. Identifying all gaps in the understanding of the site contamination situation, is called gap analysis. With a detailed site investigation bridging all gaps, the ICSM can be improved and updated to a complete CSM to quantitatively asses all environmental risks. The gap analysis therefore creates the basis for the design of the site investigation plan. Through conducting a gap analysis, designing a sampling and analyses plan and carrying out this plan, the following questions should be answered:

- What are the sources for the mercury soil and groundwater contamination?
- What is the extent, quantity and degree of the mercury soil and groundwater contamination at these sources?
- What are the source receptor pathways of the mercury contaminants?
- What is the extent, quantity and degree of the mercury soil and groundwater contamination of the source receptor pathways?
- What and who are the receptors of the mercury contaminations?
- What is the impact on the receptors?

In total ten, more or less identical (former) rod-mill locations were in Kayu Putih at the time of the detailed site investigation. For an overall overview and cross section reference is made to Figure 3.3 in Section 3.1.1. The general layout of rod-mill location including the knowledge gaps is presented in Figure 3.7 and a schematic cross section is provided in Figure 3.8. To structure the gap analysis and the detailed site investigation each gap is consequently numbered. These gaps are listed in Table 3.2. Based on the gaps a sampling and analyses plan is made and presented in Section 3.2.3.

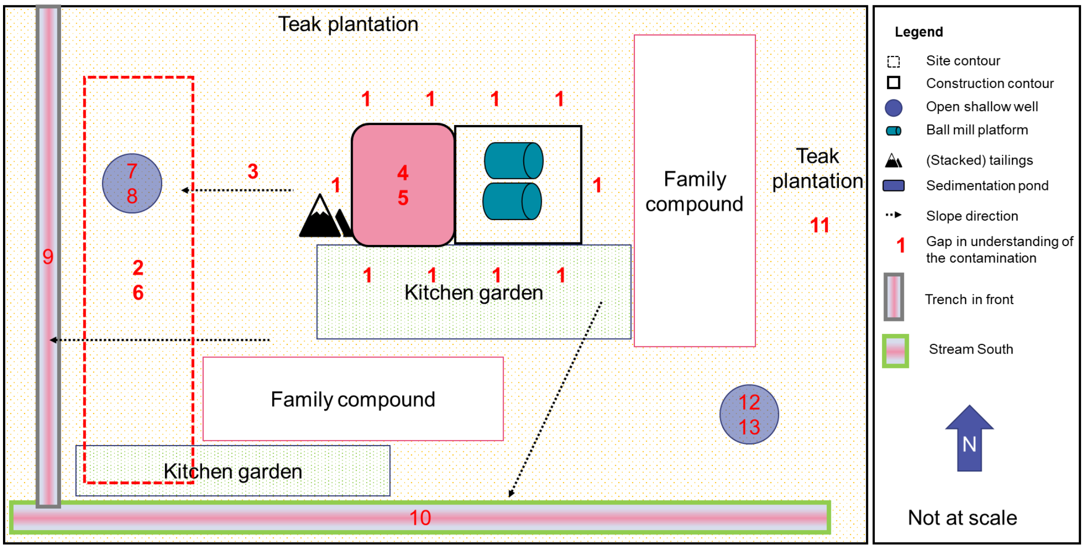

Figure 3.7: The general layout of a rod-mill location in Kayu Putih with the knowledge gaps

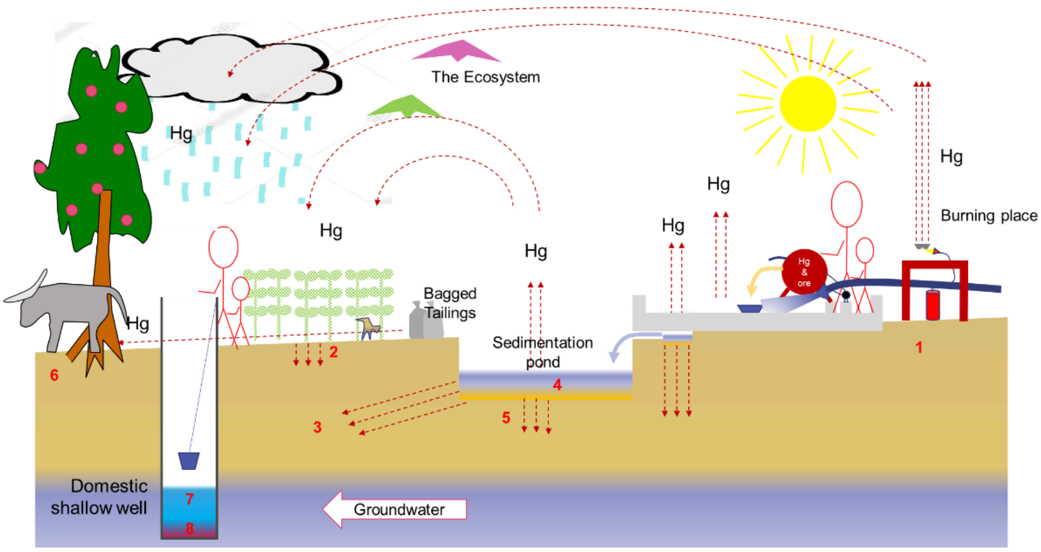

Figure 3.8: A representative cross section of a rod-mill location in Kayu Putih with the knowledge gaps

Table 3.2 Gap analysis related to ASGM of Kayu Putih ICSM

Number	Source	Pathways	Gap
1	Rod-mill location*	Spilling of mercury and mercury contaminated water	Is the topsoil around the rod-mill location contaminated with mercury?
2	Rod-mill location*	Runoff	Is the topsoil downslope the rod-mill locations contaminated with mercury?
3	Rod-mill location*	Infiltration	Is the subsoil down slope the rod-mill location contaminated with mercury
4	Sedimentation pond	Infiltration	Is the sludge on the bottom of the sedimentation pond contaminated with mercury?
5	Sedimentation pond	Infiltration	Is the soil below the bottom of the sedimentation pond contaminated with mercury?
6	Burning place	atmospheric deposition	Is the topsoil in the village contaminated with mercury?
7	ASGM**	Infiltration	Is the groundwater in the down slope/gradient shallow wells contaminated with mercury?
8	ASGM**	Infiltration	Is the sludge layer in the shallow wells contaminated with mercury?
9	ASGM**	Runoff	Are the sediments in the trench contaminated with mercury?
10	ASGM**	Runoff	Are the sediments in the stream contaminated with mercury?
11	Baseline soil	Assumed not to be influenced by ASGM	What is the quality of the topsoil (up-hill) not influenced by ASGM?
12	Baseline groundwater	Assumed not to be influenced by ASGM	What is the quality of the groundwater in the (upstream) shallow well not influenced by ASGM?
13	Baseline sludge	Assumed not to be influenced by ASGM	What is the quality of the sludge layer in the (upstream) shallow well groundwater not influenced by ASGM?

* Rod-mill location is the platform, the sedimentation pond and the storage of tailings
** ASGM includes all on-site gold mining activities

3.2.3 Fieldwork and sampling

The fieldwork was performed by staff from NEXUS3 Foundation, Mataram University, and TAUW on the 7th and 8th of April 2022. It was performed by manually using a hand-auger for boreholes till an approximate depth of 1 meter below ground level (bgl). Sediments from the ponds and the sludge in the shallow groundwater wells were manually sampled by using a gouge. Groundwater samples from the wells were taken by manually driven peristaltic pump. For the bore logs reference is made to Appendix 1a and the map with the sample locations, is presented in Appendix 1c.

To investigate if ASGM activities have impacted the soil and groundwater, the topsoil (0.0 – 0.10 m bgl) around each rod-mill location and the down-gradient subsoil down, are sampled. Besides this, the water and the sludge in the wells near (down-gradient) each rod-mill location are sampled to verify if the mercury contamination has infiltrated into the aquifer and reached the well and/or rainwater runoff seeped in to the shallow wells around the wellheads. For the verification if runoff has spread the mercury contamination down-gradient in the topsoil, five lines parallel to the site contours and the sediments in the stream south, and the trench west of the site are sampled (see Figure 3.9). Line 1 is placed as a baseline to compare analytical results of downstream/down slope line samples. Based on interpretation and evaluation of the recorded soil observations soil, groundwater and sediment samples are selected for analyses.

Figure 3.9: The baseline, the three line and the trench with the sample locations to verify of runoff has spread the mercury in the topsoil in the village

Each borehole and well sampled are given the site code KP (Kayu Putih), a number and each sample, is given a sample code as follows:

- The borehole numbers of the boreholes installed around the rod-mill locations (see Table 3.3) are made up by:
  - A serial number 1,2, 3 etc. for the rod-mill location
  - A serial number 1,2, 3 etc. for the installed borehole
  - Each soil sample code starts with: the site code, the rod-mill location number, followed by a sample serial number 1 or 4 and a 'C' for composite soil sample or a 'S' for an individual sample.
  - Sample code examples are KP-1-1-C and KP-1-4-S
- The borehole numbers for the installed boreholes in sedimentation ponds (see Table 3.4) are made up by:
  - A serial number 1, 2, 3 etc. for the rod-mill location
  - A serial number 1, 2, 3 etc. for the installed borehole
  - Each soil sample code starts with: the site code, the rod-mill location number, followed by a sample serial number 2 or 3 for the sedimentation pond and present sludge followed by a 'C' for composite soil sample or a 'S' for an individual sample.
  - Sample code example are KP-1-2-S and KP-1-3-C
- The sample code of the groundwater samples from the shallow wells (see Table 3.5) is made up by:
  - The letter W indicating sampled media is for groundwater from the shallow well
  - A serial number corresponding with the nearest rod-mill location
  - A letter F is added when the sample is filtered in the field
  - Sample code examples are KP-1-W and KP-10-W-F
- The sample code of the sampled sludge from the shallow well (see Table 3.5) is made up by:
  - The site code KP for Kayu Putih
  - A sample serial number
  - The letter M (mud) indication that the media sampled is sediment
  - A sample code example is KP-1-M
- Borehole numbers of the installed boreholes in the lines, baseline and down gradient the balls mill locations (see Table 3.6) are made up by:
  - The letter L for strip/line

- A serial number 1 till 3 for the strip/line
- A number:1 northern part of the line and 2 for the southern part of the line
- Each composite soil sample code starts with: the site code, a L for line, followed by a sample serial number for the line and 1 or 2 for the part of the line. Sample codes examples are KP-L-1-1 and KP-L-1-2

Table 3.3 Installed boreholes and soil samples taken around rod-mill locations

Rod-mill location	Sampled media	m -bgl	Installed boreholes	Samples
KP-1	Topsoil around	0.00 – 0.10	KP-1-1, KP-1-2, KP-1-3, KP-1-4, KP-1-5, KP-1-6, KP-1-7, KP-1-8, KP-1-9	KP-1-1-C
	Subsoil down-hill	1.20 – 1.30	KP-1-17	KP-1-4-S
KP-2	Topsoil around	0.00 – 0.10	KP-2-1, KP-2-2, KP-2-3, KP-2-4, KP-2-5, KP-2-6	KP-2-1-C
	Subsoil down-hill	1.20 – 1.50	KP-2-7	KP-2-4-S
KP-3	Topsoil around	0.00 – 0.10	KP-3-1, KP-3-2, KP-3-3, KP-3-4, KP-3-5, KP-3-6, KP-3-7, KP-3-8, KP-3-9, KP-3-9, KP-3-10	KP-3-1-C
	Subsoil down-hill	0.90 – 1.00	KP-3-16	KP-3-4-S
KP-4	Topsoil around	0.00 – 0.10	KP-4-1, KP-4-2, KP-4-3, KP-4-4, KP-4-5, KP-4-6, KP-4-7, KP-4-8, KP-4-9, KP-4-10	KP-4-1-C
	Subsoil down-hill	0.60 – 1.000	KP-4-16-S	KP-4-4-S
KP-5	Topsoil around	0.00 – 0.10	KP-5-1, KP-5-2, KP-5-3, KP-5-4, KP-5-5,KP-5-6	KP-5-1-C
	Subsoil down-hill		KP-5-12	KP-5-4-S
KP-6	Topsoil around	0.00 – 0.10	KP-6-1, KP-6-2, KP-6-3, KP-6-4, KP-6-5, KP-6-6, KP-6-7, KP-6-8, KP-6-9, KP-6-10	KP-6-1-C
	Subsoil down-hill		KP-6-17	KP-6-4-S
KP-7	Topsoil around	0.00 – 0.10	KP-7-1, KP-7-2, KP-7-3, KP-7-4, KP-7-5, KP-7-6, KP-7-7, KP-7-8, KP-7-9, KP-7-10	KP-7-1-C
	Subsoil down-hill		KP-7-15	KP-7-4-S
KP-8	Topsoil around	0.00 – 0.10	KP-8-1, KP-8-2. KP-8-3, KP-8-4, KP-85, KP-8-6	KP-8-1-C
	Sediment down stream		KP-8-11	KP-8-4-S
KP-9	Topsoil around	0.00 – 0.10	KP-9-1, KP-9-2, KP-9-3	KP-9-1C
	Sediment down stream		KP-9-10	KP-9-4-S
KP-10	Topsoil around	0.00 – 0.10	KP-10-1, KP-10-2, KP-10-3	KP-10-1-C
	Sediment down stream		KP-10	KP-10-4-S

Table 3.4 Installed boreholes and soil samples in sedimentation ponds

Rod-mill location	Sampled media	m – surface*	Installed boreholes	Samples
KP-1	Sludge pond	1.00 – 1.10	KP1-11, KP1-12, KP1-13, KP1-14, KP1-15	KP-1-3-C
	Subsoil pond	1.20 – 1.40	KP1-16	KP-1-2-S
KP-2	Sludge pond	1.30 – 1.50	KP-2-8	KP-2-3-S
KP-3	Sludge pond	0.70 – 0.80	KP-3-11, KP-3-12, KP-3-13, KP-3-14	KP-3-3-C
	Subsoil pond	0.90 – 1.10	KP-3-15	KP-3-2-S
KP-4	Sludge pond	0.70 - 0.80	KP-4-11, KP-4-12, KP-4-13, KP-4-14	KP-4-3-C
	Subsoil pond	0.80 – 1.00	KP-4-15	KP-4-2-S
KP-5	Sludge pond	0.65 - 0.75	KP-5-8, KP-5-9, KP-5-10, KP-511	KP-5-3-C
	Subsoil pond	1.40 – 1.50	KP-5-7	KP-5-2-S
KP-6	Sludge pond	1.00 – 1.10	KP-6-12, KP-6-13, KP-6-14, KP-6-15, KP-6-16	KP-6-3-C
	Subsoil pond	1.40 – 1.50	KP-6-11	KP-6-2-S
KP-7	Sludge pond		KP-7-11, KP-7-12, KP-713, KP-7-14	KP-7-3-C
	Subsoil pond		No sample taken as the bottom is lined	
KP-8	Sludge pond	0.50 – 0.60	KP-8-7, KP-8-8, KP-8-9	KP-8-3C
	Subsoil pond	0.90 – 1.00	KP-8-10	KP-8-2-S
KP-9	Sludge pond	0.90 -1.00	KP-9-4, KP-9-5, KP-9-6, KP-9-7, KP-9-8	KP-9-3-C
	Subsoil pond	1.00 – 1.20	KP-9-6	KP-9-2-S
KP-10	Sludge pond	0.90 – 1.00	KP-10-8, KP-10-9, KP-10-10, KP-10-11, KP-10-12	KP-10-3-C
	Subsoil pond	1.10 – 1.20	KP-10-7	KP-10-4-S

**The depth of the sedimentation pond is the depth of the first sample depth given in m – surface*

Table 3.5 Sampled shallow wells

Rod-mill location	Sampled media on 08-04-2022	m - surface	Code	Ph	EC (µS)	Temp
KP-1	Groundwater	2.55 – 5.80	KP-1-W	6.5 -7.0	1355	30.8
	Sediments	5.80 – 5.90	KP-1-M			
KP-2	Groundwater	2.50 – 5.80	KP-2-W			
	Sediments	5.80 - 5.90	KP-2-M			
KP-3	Groundwater		KP-3-W	6.5 -7.0	1414	29.8
	Sediments	5.00 - 5.10	KP-3-M			
KP-4	Groundwater		KP-4-W			
	Sediments		KP-4-M			
KP-5	Groundwater		KP-5-W	6.5 -7.0	1308	30.3
	Sediments	5.30 – 5.40	KP-5-M			
KP-6	Groundwater		KP-6-W	6.5 -7.0	1396	29.7
	Groundwater (F)*		KP-6-W-F	6.5 -7.0	1396	29.7
	Sediments	5.00 - 5.10	KP-6-M			
KP-7	Groundwater					
	Sediments					
KP-8	Groundwater		KP-8-W	6.5 -7.0		
	Sediments	3.60 – 3.70	KP-8-M			
KP-9	Groundwater		KP-9-W			
	Sediments		KP-9-M			
KP-10	Groundwater		KP-10-W	6.5 -7.0	1713	29.5
	Groundwater (F)*					
	Sediments		KP-10-M	6.5 -7.0	1713	29.5

**Filtered All groundwater samples are taken and analysed in duplo*

Table 3.6 Sampled lined

Strip number	sampled media	m - surface	Installed boreholes and sampled	Code composite soil sample made in the field
KP-L1-1	Topsoil	0.00 – 0.10	KPL-1-1-1 till KP-L1-1-5	**KP-L1-1**
KP-L1-2	Topsoil	0.00 – 0.10	KPL1-2-1 till KPL1-2-5	**KP-L1-2**
KP-L2-1	Topsoil	0.00 – 0.10	KPL2-1-1 till KPL2-2-5	**KP-L2-1**
KP-L2-2	Topsoil	0.00 – 0.10	KPL2-2-1 till KPL2-2-5	**KP-L2-2**
KP-L3-1	Topsoil	0.00 – 0.10	KPL3-1-1 till KPL3-1-5	**KP-L3-1**
KP-L3-2	Topsoil	0.00 – 0.10	KPL3-2-1 till KPL3-2-5	**KP-L3-2**
KP-L4-1	Topsoil	0.00 – 0.10	KPL4-1-1 till KPL4-2-3	**KP-L4-1**
KP-L4-2	Topsoil	0.00 – 0.10	KPL4-2-1 till KPL1-5-5	**KP-L4-2**
KP-L-5-1	Sediment	0.00 – 0.10	KPL5-1-1 till KPL4-2-3	**KP-L-5-1**
KP-L-5-2	Sediment	0.00 – 0.10	KPL5-2-1 till KPL5-2-5	**KP-L-5-2**

During the fieldwork, observations were made that might indicate the presence of soil and groundwater contamination. The presence of bricks, waste such as plastic bags, batteries and food remains was observed to be present at the surface and topsoil. For details, reference is made to the bore logs in Appendix 1a. At the time rod-mill location 9 was sampled the mill was emptied and the mercury from the mercury gold amalgam was separated using a cloth (see Figure 3.2).

3.2.4 Results chemical analyses

<Methods; previous section, here or in Appendix?>

Analytical results of the total mercury concentrations are listed in Table 3.7 including testing results against guideline values for all samples taken at the Kayu Putih site. Each sub table represent the situation at rod-mill location. The line samples are presented in the last sub table. Appendix 1b gives the samples analyses plan.

It is mentioned that the laboratory analysed the total mercury content and has/had not the capacity to analyse the different chemical compositions mercury can be present in the various environmental medium. When the donated analyser by Aman mineral is operational, this will be possible.

Evaluation of measured concentrations for soil
The mercury concentrations measured in the soil and sediment samples are tested using the three Dutch STI reference values which are for background ('S') of 1 mg/kg dry weight (d.w.) , the testing value ('T') of 18.1 mg/kg d.w. and the intervention value ('I') of 36 mg/kg d.w. (See Appendix 3 (2)). These values are used as follows:

- Soil with concentrations lower than 1 mg/kg d.w. are assessed as soil with background values and is clean and no action is necessary
- Soil with concentrations between 1 - 18.1 mg/kg d.w. is slightly contaminated but no action is necessary
- Soil with concentrations between 18.1 - 36 mg/kg d.w. is contaminated and need to be surveyed to investigate if there is soil with higher values, if no higher values are encountered, the soil at this site need to be monitored
- Soil with concentrations higher than 36 mg/kg d.w. is strongly contaminated and need to be remediated

The soil is also tested against risk values related to the reuse of excavated soil used in the Netherlands (Besluit Bodemkwaliteit). For testing the reuse options of soil, four values are classified:

- Soil with mercury concentrations below 0.15 mg/kg d.w can be reused without any restrictions
- Soil with mercury concentrations between 0.15 - 0.83 mg/kg d.w. can be reused in residential area but not in gardens and locations where direct contact in ordinary daily is possible
- Soil with mercury concentrations between 0.83 - 4.8 mg/kg d.w.. can only be reused on industrial sites
- Soil with mercury concentrations above 4.8 mg/kg d.w. cannot be reused

Evaluation of measured concentrations for ground and drinking water
For groundwater the Dutch system has two values which are the background value (S) of 0.05 µg/L and the intervention value (I) of 0.3 µg/L. The values are used as follows:

- Groundwater with concentrations lower than (S) 0.05 µg/L are seen as groundwater with background values and therefore is clean and no action is necessary
- Groundwater with concentrations between 0.05 – 0.36 µg/L is contaminated and need to be surveyed to see if there is groundwater with higher values, if no higher values are encountered, the groundwater at this site needs to be monitored
- Groundwater with concentrations higher than 0.36 µg/L need to be remediated

The intervention values for drinking water used by the EPA and the WHO are 2.0 and 6.0 µg/l respectively (ref). The World Health Organisation (WHO) and European (EU) drinking water standards for mercury are a maximum concentration of 2.0 and 1.0 µg/l respectively. The WHO standard for groundwater is 0.5 µg/l (1).

The mercury concentration in the groundwater in the Table 3.7 present tested against the Dutch reference values, the WHO drinking-water standard (WHOd) and the WHO standard for groundwater (WHOg).

Table 3.7 Testing results of the ten rod-mill location including soil, groundwater and sludge. The line samples are listed in the last section of this table.

Sample code	Sampled media and location	Hg concentration (soil mg/kg d.w. water µg/L)	STI	Reuse	WHOd	WHOg
Rod-mill location KP-1 (not active since long sampling sedimentation pit filled with soil and waste)						
KP-1-1-C	Topsoil around rod-mill	1.432	>S<T	Industrial	-	

Sample code	Sampled media and location	Hg concentration (soil mg/kg d.w. water µg/L)	STI	Reuse	WHOd	WHOg
KP-1-2- S	Subsoil sedimentation pond	2.534	>S<T	Industrial	-	
KP-1-3-C	Sludge from sedimentation pond	7.739	>S<T	No reuse	-	
KP-1-4-S	Subsoil down-gradient rod-mill	0.581	<S	Residential	-	
KP-1-M	Sediments from shallow well	1.692	>S<T	Industrial	-	
KP-1-W*	Groundwater from well unfiltered	0.6000 – 0.9000	>I	n/a	>	<
Rod-mill location KP-2 (active during sampling)						
KP-2-1-C	Topsoil around rod-mill	9.194	>S<T	No reuse		
KP-2-2-S	Subsoil sedimentation pond	3.999	>S<T	Industrial		
KP-2-3-C	Sludge from sedimentation pond	0.429.	<S	Residential		
Not sampled	Subsoil down-gradient rod-mill	n/a	n/a	n/a	n/a	n/a
KP-2-M	Sediments from shallow well	10.754	>T<I	No reuse		
KP-2-W*	Groundwater from well unfiltered	0.7000 – 0.9000	>I	>	<	
Rod-mill location KP-3 (not active during sampling)						
KP-3-1-C	Topsoil around rod-mill	6.940	>S<T	No reuse		
KP-3-2-S	Subsoil sedimentation pond	9.397	>S<T	No reuse		
KP-3-3-C	Sludge from sedimentation pond	5.176	>S<T	No reuse		
KP-3-4-S	Subsoil down-gradient rod-mill	1.583.	>S<T	Industrial		
KP-3-M	Sediments from shallow well	0.859 mg/k	<S	Industrial		
KP-3-W	Groundwater from well unfiltered	0.9000 - 1.0000	>I	>	≤	
Rod-mill location KP-4 (not active during sampling)						
KP-4-1-C	Topsoil around rod-mill	7.706	>S<T	No reuse		
KP-4-2-S	Subsoil sedimentation pond	0.691	<S	Residential		
KP-4-3-C	Sludge from sedimentation pond	1.595	>S<T	Industrial		
KP-4-4-S	Subsoil down-gradient rod-mill	0.481	<S	Residential		
Not sampled	Sediments from shallow well					
Not sampled	Groundwater from well unfiltered					
Not sampled	Groundwater from well filtered					
Rod-mill location KP-5 (not active during sampling)						
KP-5-1-C	Topsoil around rod-mill	2.530 .	>S<T	Industrial		
KP-5-2- S	Subsoil sedimentation pond	4.320 .	>S<T	Industrial		
KP-5-3-C	Sludge from sedimentation pond	0.517 .	<S	Residential		
KP-5-4- S	Subsoil down-gradient rod-mill	0.852 .	<S	Industrial		

Reference R001-1279669CBN-V01

Sample code	Sampled media and location	Hg concentration (soil mg/kg d.w. water µg/L)	STI	Reuse	WHOd	WHOg
KP-5-M	Sediments from shallow well	0.635 .	<S	Residential		
KP-5-W	Groundwater from well unfiltered	0.7000 µg/l	>I	>	<	
Not sampled	Groundwater from well filtered					
Rod-mill location KP-6 (not active during sampling just completed a batch and preparing for new						
KP-6-1-C	Topsoil around rod-mill	1.641 .	>S<T	Industrial		
KP-6-2-S	Subsoil sedimentation pond	0.850 .	<S	Industrial		
KP-6-3-C	Sludge from sedimentation pond	0.362 .	<S	Residential		
KP-6-4-S	Subsoil down-gradient rod-mill	0.026 .	<S	All		
KP-6-M	Sediments from shallow well	0.466 .	<S	Residential		
KP-6-W	Groundwater from well unfiltered	0.7000 µg/l	>I	>	<	
KP-6-W-F	Groundwater from well filtered	0.4000 µg/l	>I	>	<	
Rod-mill location KP-7 (not active during sampling)						
KP-7-1-C	Topsoil around rod-mill	0.025 .	<S	All		
Not sampled	Subsoil sedimentation pond					
KP-7-3-C	Sludge from sedimentation pond	0.026.	<S	All		
KP-7-4-S	Subsoil down-gradient rod-mill	0.026	<S	All		
Not sampled	Sediments from shallow well					
Rod-mill location KP-8 (not active during sampling)						
KP-8-1-C	Topsoil around rod-mill	0.073	<S	All		
KP-8-2-S	Subsoil sedimentation pond	0.025	<S	All		
KP-8-3-C	Sludge from sedimentation pond	0.026	<S	All		
KP-8-4-S	Subsoil down-gradient rod-mill	0.026	<S	All		
KP-8-M	Sediments from shallow well	0.542	<S	Residential		
KP-8-W	Groundwater from well unfiltered	0.5000 – 0.6000	>I	>	<	
Not sampled	Groundwater from well filtered					
Rod-mill location KP-9 (active during sampling)						
KP-9-1-C	Topsoil around rod-mill	0.025	<S	All		
KP-9-2-S	Subsoil sedimentation pond	176.592	>I	No reuse		
KP-9-3-C	Sludge from sedimentation pond	162,629	>I	No reuse		
KP-9-4-S	Subsoil down-gradient rod-mill	4.648	>S<T	Industrial		
KP-9-M	Sediments from shallow well	0.377	<S	Residential		
KP-9-W	Groundwater from well unfiltered	0.7000 – 0.8000	>I	>	<	

Sample code	Sampled media and location	Hg concentration (soil mg/kg d.w. water µg/L)	STI	Reuse	WHOd	WHOg
Not sampled	Groundwater from well filtered					
Rod-mill location KP-10 (not active during sampling)						
KP-10-1-C	Topsoil around rod-mill	4.648.	>S<T	Industrial		
KP-10-2-S	Subsoil sedimentation pond	2.006	>S<T	No reuse		
KP-10-3-C	Sludge from sedimentation pond	18.709	>T<I	No reuse		
KP-10-4-S	Subsoil down-gradient rod-mill	2.120	>S<T	Industrial		
Not sampled	Sediments from shallow well					
Not sampled	Sediments from shallow well					
KP-10-W	Groundwater from well unfiltered	0.4000 – 0.6000	>I	>	<	
Sampled topsoil 0.0 -0.1 m minus ground level in lines						
KP-L1-1	Northern part line 1 uphill the village, baseline	2.320 .	>S<T	Industrial		
KP-L1-2	Southern part line 2 uphill the village, baseline	1.962 .	>S<T	Industrial		
KP-L2-1	Northern part first line downhill first rod-mill locations	1.422 .	>S<T	Industrial		
KP-L2-2	Southern part first line downhill first rod-mill locations	2.037 .	>S<T	Industrial		
KP-L3-1	Northern part second line downhill rod-mill locations	1.647 .	>S<T	Industrial		
KP-L3-2	Southern part second line downhill rod-mill locations	1.166 .	>S<T	Industrial		
KP-L4-1	Northern part third line downhill most rod-mill locations	0.941 .	<S	Industrial		
KP-L4-2	Southern part third line downhill most rod-mill locations	0.952	<S	Industrial		
KP-L-5-1-C	Sediment Northern part trench downhill all rod-mill locations	1.645 .	>S<T	Industrial		
KP-L-5-2-C	Sediment Southern part trench downhill all rod-mill locations	1.747 .	>S<T	Industrial		
KP-L-5-2-C-2	Sediment Southern part trench downhill all rod-mill locations	0.797 .	<S	Residential		

3.2.5 The soil and groundwater contamination

Results

We found in all eight shallow groundwater wells elevated levels of mercury, they are below the drinking water norm of the WHO, but all above the Dutch Intervention Value and the WHO standard for groundwater.

In the top- and subsoil, in eight out of ten rod-mill locations we detected mercury. The topsoil is slightly contaminated as the values are above the Dutch background value and below the testing value. When the concentrations are tested against the Dutch reference frame work for reuse of soil, the top- and subsoil can only be reused on industrial sites.

The subsoil and the sludge in seven out of ten sedimentation ponds is slightly, moderately and strongly contaminated with mercury. The highest concentrations are measured in the ponds (KP-9 and 10) which were actively or recently used at the time of the sampling, which is logical. When the concentrations of the samples taken from the sedimentation ponds are tested against the Dutch reference frame work for reuse of soil, the sludge and subsoil from these ponds can only be reused on industrial sites and the soil and sludge from the ones with the highest concentrations cannot be reused.
In the topsoil of the four lines out of five lines in the village, including the above slope, baseline, the topsoil is slightly contaminated with mercury, all concentrations are above the Dutch background value but below the testing value. When the concentrations are tested against the Dutch reference frame work for reuse of soil, the topsoil of all lines can only be reused on industrial sites.

Contamination with mercury
Based on the results, it is concluded that the mercury contamination of the soil and groundwater is occurring. The primary source of the mercury contamination is the ASGM using gold mercury amalgamation. The secondary point source is the sedimentation ponds and the secondary diffuse sources are the topsoil around the rod-mills and the groundwater as a result of the mercury vapour deposits.

Source receptor pathways
The source receptor pathways are the direct burning of the amalgam, other ASGM processes where direct contact with the mercury occurs and contaminated topsoil. Secondly the spreading of the mercury by process water is a pathway towards the sedimentation pond and the surrounding soil. From all these, mercury vapour emits and is deposited in the surrounding community and faraway from the site, providing a diffuse mercury source. When mercury enters the topsoil it is assumed that it partly evaporates and this mercury, together with the evaporated mercury directly coming from the mercury gold amalgamation process, is deposited in the direct surrounding and off site. Resulting in a diffuse contamination with low levels (even below detections limit). This may explain the elevated levels of mercury in all groundwater wells and topsoil of the baseline samples uphill and in all ten rod-mill locations in Kayu Putih.

The ASGM communities visited are also practicing subsistence farming and consume food products from the kitchen gardens, receiving atmospheric mercury deposition and animal products from the livestock roaming around in the ASGM villages. The food chain is therefore a major pathway for human exposure. This is especially true for villagers eating form a single food basket. This single food basket is filled with food products from their kitchen gardens and animal products from their own livestock all exposed to mercury on the soil and in the groundwater and the atmospheric mercury deposition.

The receptors are the villagers, especially involved in ASGM including their family members and mainly due to the burning of amalgam in the family compounds where people live close to each other. These people are also eating from the food basket contaminated with mercury and use the water with mercury from their wells in their household.

Finally, the surrounding ecosystem is another receptor, especially the aquatic ecosystem in the nearby rivers and finally the ocean (Java-Sea).

4 Results site investigations West Sumbawa

In the scope of the project eight inactive ASGM sites were visited in the (vicinity of) villages Tepas Sepaka, Tongo and Taliwang at West Sumbawa. The site visits were on the 31st of March, the 1st and 2nd of April 2022. From these sites, three were selected to construct

ICSM. From these three, one site is selected to construct a CSM. This section describes all site investigations results of the sites at West Sumbawa.

4.1 Selection of three ASMG sites

In total eight inactive ASGM sites were visited. Information regarding the inactive and former ASGM site was collected through interviews with site owners and (local) environmental authorities. For all sites it could be assumed that mercury was used for amalgamation. Specific used mercury amounts are unknown (except for Site 3 in Taliwang), but based on years of activity a rough estimate could be made. Also, it is unknown whether after the amalgamation process, the mercury gold amalgam was heated to separate mercury and retrieve gold on- or off-site.

For the selection of three sites to construct an ICSM, 13 criteria and a rating of each criterium per site have been used. The results are presented in Table 4.1. The rating used, is 3 as best to 2 as middle and the lowest rate is 1. Due to equal outcomes the ASGM activities were counted double. All ratings per site are added and site 01-04-22 site 3, 02-04-22 site 1 and 02-04-22 site 3 have the highest outcome. The ICSM for these sites is made and are presented in Section 4.2.

Table 4.1: Criteria, score and selection of eight inactive ASGM sites.

Site number	31-03-22 1	01-04-22 1	01-04-22 2	01-04-22 3	01-04-22 4	02-04-22 1	02-04-22 2	02-04-22 3
ASGM activities (weight 2x)	Best site is the site that stopped most recently							
Stopped last year				6				
Stopped between 2-4 years ago	4	4				4		4
Stopped more than 4 years ago			2		2		2	
Active ASGM period	Best site is the site with the longest active period							
More than 5 years	3							
Between 2 and 5 years		2	2	2	2		2	2
2 years or less						1		
Size of site	Best site is the smallest site							
Smaller than 1.000 m²		3	3	3	3	3	3	3
Between 1.000 - 5.000 m²								
Large than 5.000 m²	1							
Number of rod-mills	Best site is the site with the most rod-mills							
More than 20	3							
Between 10 and 20		2	2	2			2	
Less than 10					1	1		1
Current site use	Best site is the site with no site use							
Outside settlement and fallow		3	3		3			
Outskirt settlement and agricultural	2			2		2		
In the middle of a settlement							1	1
Groundwater well present	Best site is the site with up - and down gradient wells							
Wells up-, down-gradient the source								
Only one or two wells are present	2		2		2	2	2	2
No wells are present		1		1				
Groundwater depth (weight 2x)	Best site is the site with a groundwater level not deeper than 1 m below surface							
Groundwater not deeper than 1 m						6	6	6
Groundwater between 1 - 3 m deep				4				
Groundwater between 3 - 5 m deep	2	2	2		3			
Availability data	Best site is the site with the most available data							
Data on soil, groundwater and ASGM								
Few data are available	2							
No data at all are available		1	1	1	1	1	1	1
Soil composition	Best site is the site with the loss soil and manual drilling is possible							
Loss alluvial material	3	3	3	3	3	3	3	3

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Site number	31-03-22 1	01-04-22 1	01-04-22 2	01-04-22 3	01-04-22 4	02-04-22 1	02-04-22 2	02-04-22 3
Loss soil but with obstacles in topsoil								
Dry consolidated gravelly, stony soil								
Health and safety	Best site is the site that is not contaminated with waste and faeces							
No to some waste		3	3		3	3	3	3
Isolated waste patches	2							
Lots waste rubble faeces are present				1				
Accessibility	Best site is the site that is easily accessible							
Easy to reach by car	3	3	3	3	3	3		3
Site max 15 min walking distance							2	
Site more than 15 walking distance								
Cooperation villagers	Best site is the site where villagers are cooperative							
Cooperative		3	3	3		3		
Indifferent	2				2		2	2
Not cooperative								
Cooperation authorities	Best site is the site where authorities have given permission and are cooperative							
Permission obtained and cooperative	3	3	3	3	3	3	3	3
Permission								
Indifferent								
Total score	**32**	**33**	**32**	**34**	**30**	**35**	**32**	**34**

4.2 Initial Conceptual Site Models

The three ICSMs are made with the information of the desktop study, the site visits and interviews. The objective of the ICSMs is to illustrate our understanding of the soil and groundwater contamination in relation to ASGM activities. An ICSM provides the potential source(s) for the contamination, the potential source receptor pathway(s) for the contamination and the potential receptor(s) of the contamination. In this section the three ICSMs are described and illustrated. The (former) ASGM site practises and comparable settings, result in similar sources, pathways and receptors to that discussed for the Kayu Putih site in Lombok and for the full explanation on these aspects reference is made to Section 3.1.1.

4.2.1 ICSM 1-04-22 Site 3 -Tongo

The site is located in the village of Tongo in West Sumbawa and approximately 600 m north of the Indonesia Ocean (Figure 4.1). The site is situated north to the road to Jl. Raya Sejorong and downstream of a (unnamed) meandering river. The terrain slopes to the north, runoff and groundwater flow direction are also interpreted towards the north, although the latter it is expected to be influenced by local factors. The soil at the site is young (entisols and inceptisols) and formed on alluvial deposits. Adjacent to the west of the site residential buildings and a shop including a restaurant are present. Towards the east a teak plantation and playfield are present.

The former ASGM rod-mill platformer was not maintained and household waste is dumped at the site. Groundwater is extracted 50 m towards the east of the site.

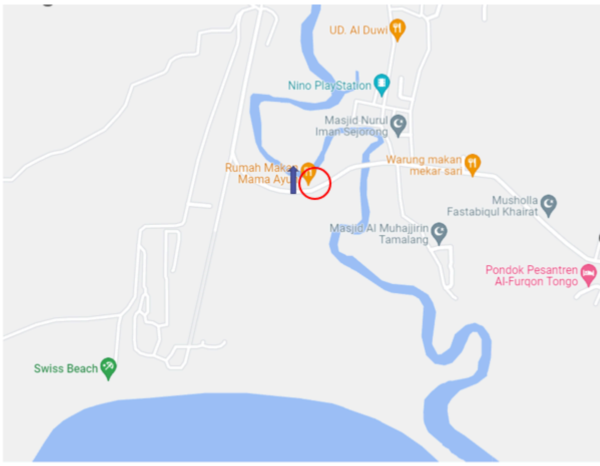


Figure 4.1: Location of 01-04-2022 site 3 in Tongo, West Sumbawa

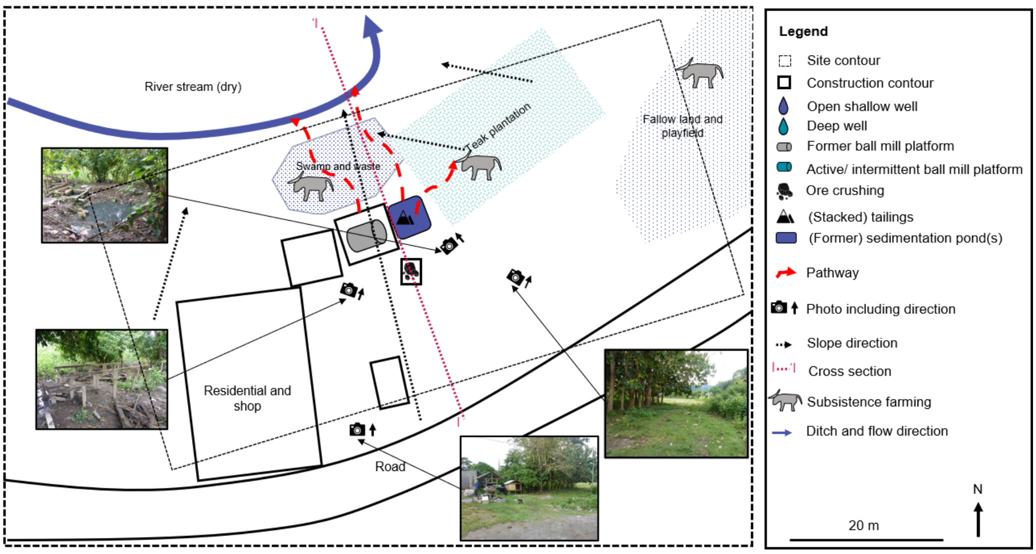
The potential sources, pathways and receptors of mercury for the study area are listed below and depicted in Figure 4.2.

Potential sources
The potential sources of the mercury contamination are:
- The contaminated topsoil around the former rod-mill location
- The sludge in the former sedimentation pond

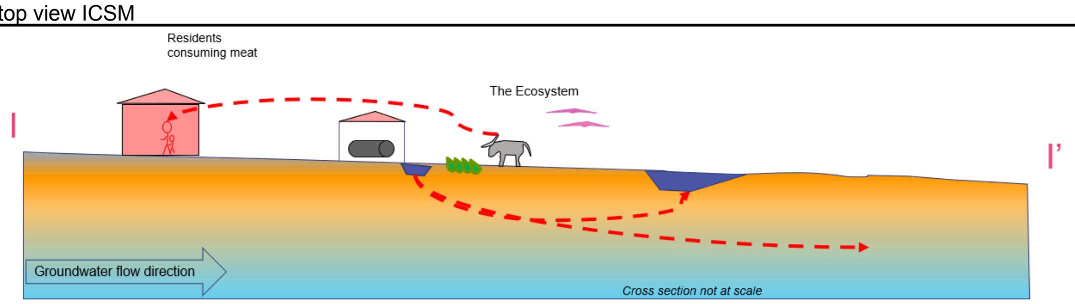
Potential pathways
The potential source receptor pathways are:
- Direct contact with the contaminated topsoil
- Leaching of rainwater in the soil
- The groundwater, flowing to the northern direction
- Direct contact with the contaminated groundwater
- The spreading potentially contaminated topsoil by run off towards the river north of the site
- Spreading by wind of airborne contaminated fine soil particles
- Direct contact by consuming contaminated crops and animal product

Potential receptors
The potential receptors are:
- The people living on the potential contaminated site, using the groundwater, eating agriculture products from the kitchen garden on potential contaminated soil and eating the potential contaminated animal products of the animals roaming on-site
- The ecosystem, soil live and the (small) animals foraging on-site
- The ecosystem, in the river and sediment layer receiving the contaminated groundwater and contaminated runoff

Satellite image and site situation



top view ICSM



Cross section ICSM

Figure 4.2: The ICSM of 1-04-22 Site 3 in the village Tongo on West Sumbawa

4.2.2 ICSM 2-04-22 site 1 – Southwest of the city centre of Kuang

The site is located southwest of the city centre of Kuang in the Taliwang regency in West Sumbawa and approximately 7 km east of the Indonesia Ocean (Figure 4.3). The site is situated south of an unnamed road and approximately 2 km south of a large meandering river. The terrain slopes to the north, runoff is therefore directed towards the north. Groundwater flow direction is interpreted towards the north. The unnamed road is situated on a dike to the north of the site, separated by paddy fields. The soil at the site is young (entisols and inceptisols), formed on alluvial deposits and is used for residential purposes. One house with a well, small swamp/pool, kitchen garden and cattle are present. Approximately 100 m to the east a drinking pool for cattle is situated on-site.

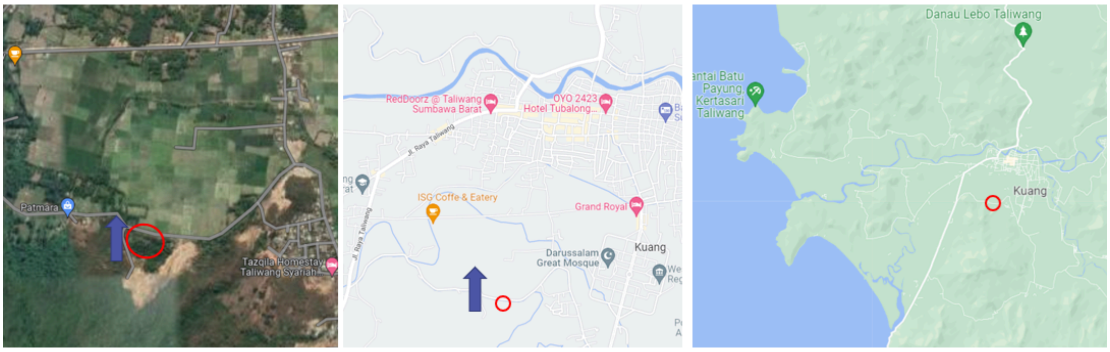


Figure 4.3: Location of 02-04-22 site 1 – Southwest of the city centre of Kuang

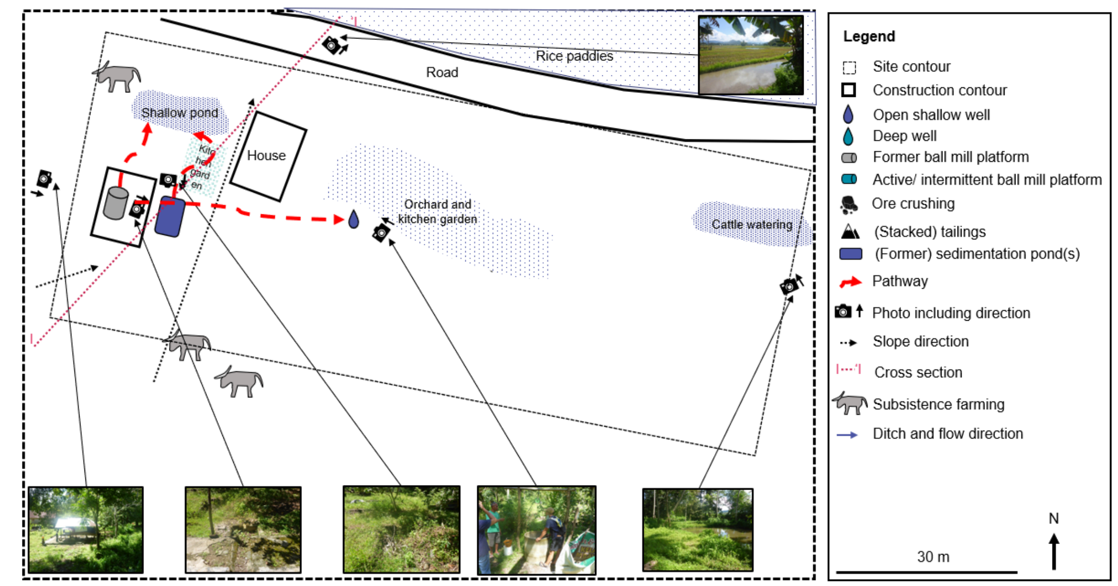
The potential sources, pathways and receptors of mercury for the study area are listed below and depicted in Figure 4.4.

Potential sources
The potential sources of the mercury contamination are:
- The contaminated topsoil around the former rod-mill location
- The sludge in the former sedimentation pond

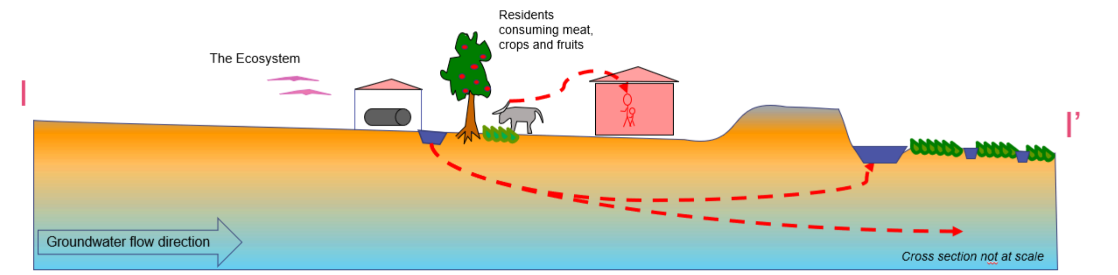
Potential pathways
The potential source receptor pathways are:
- Direct contact with the contaminated topsoil
- Leaching of rainwater in the soil
- The groundwater, flowing to the northern direction
- Direct contact with the contaminated groundwater
- The spreading potentially contaminated topsoil by run off towards the river north of the site
- Spreading by wind of airborne contaminated fine soil particles
- Direct contact by consuming contaminated crops and animal product

Potential receptors
The potential receptors are:
- The people living on the potential contaminated site, using the groundwater, eating agriculture products from the kitchen garden on potential contaminated soil and eating the potential contaminated animal product of the animals roaming on site
- The ecosystem, soil live and the (small) animals foraging on site
- The ecosystem, in the river and sediment layer receiving the contaminated groundwater and contaminated runoff

Satellite image



top view ICSM



Cross section ICSM

Figure 4.4: The ICSM of site 2-04-22 Site 1 southwest of the city centre of Kuang in West Sumbawa

4.2.3 ICSM 2-04-22 site 3 - Kuang

The site is located in the centre of Kuang of the Taliwang regency in West Sumbawa and approximately 7.5 km east of the Indonesia Ocean (Figure 4.4). The site is situated south to the road Jl. Cendrawasih and approximately 500 m south of a large meandering river. The terrain slopes slightly to the south, runoff is therefore directed towards the south, but groundwater flow direction is interpreted towards the north. The soil at the site is young (entisols and inceptisols), formed on alluvial deposits and is used for residential purposes, such as a house, shop, restaurant and kitchen garden. One well is situated on-site and multiple wells were identified at north, east, south and west of the site within a distance of 50 m. No animals were observed to be present o-site.

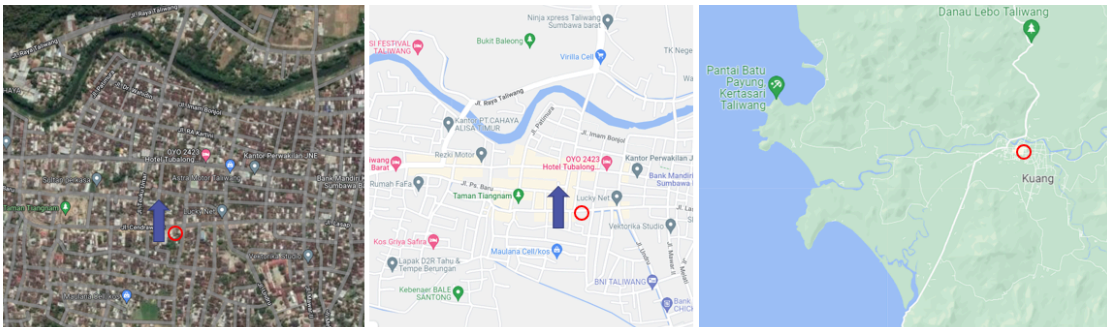


Figure 4.5: Site 02-04-2022 site 3 in Kuang, West Sumbawa

The potential sources, pathways and receptors of mercury for the study area are listed below and depicted in Figure 4.6.

Potential sources

The potential sources of the mercury contamination are:

- The contaminated topsoil around the former rod-mill location
- The sludge in the former sedimentation pond

Potential pathways

The potential source receptor pathways are:

- Direct contact with the contaminated topsoil
- Leaching of rainwater in the soil
- The groundwater, flowing to the northern direction
- Direct contact with the contaminated groundwater
- The spreading of potentially contaminated topsoil by runoff towards the south of the site and neighbouring parcels
- Spreading by wind of airborne contaminated fine soil particles
- Direct contact by consuming contaminated crops

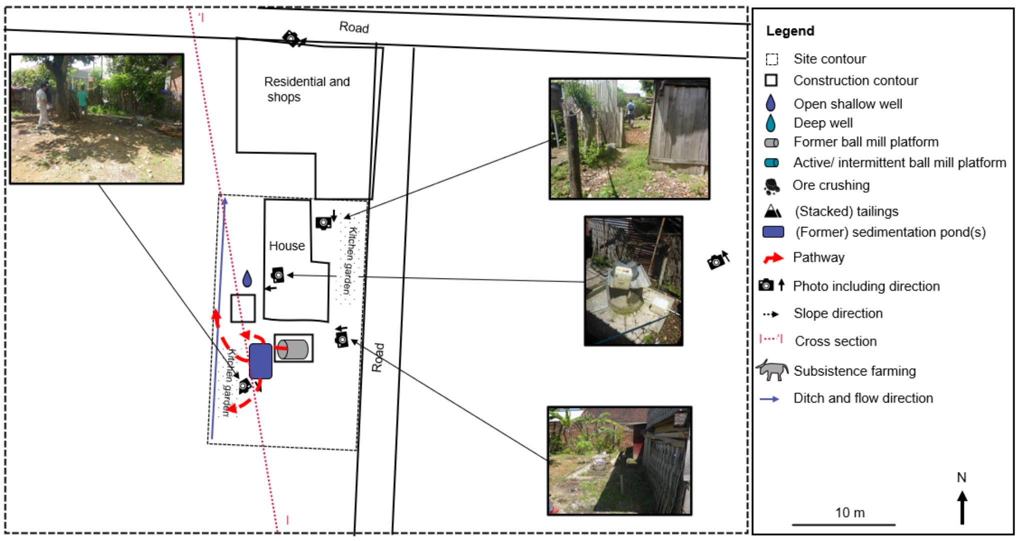
Potential receptors

The potential receptors are:

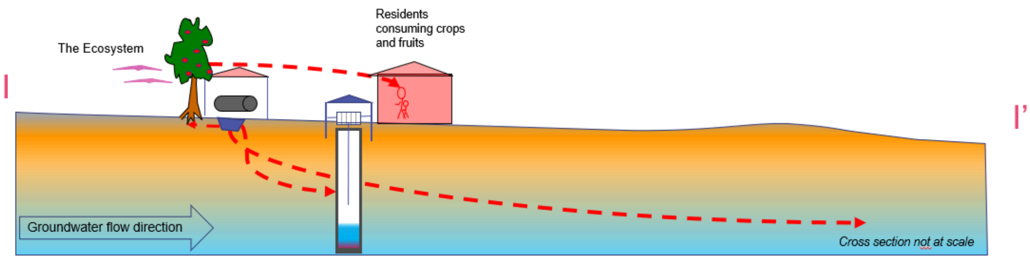
- The people living on the potential contaminated site, using the groundwater and eating agriculture products from the kitchen garden on potential contaminated soil
- The ecosystem and soil life on site
- The ecosystem, in the river and sediment layer receiving the contaminated groundwater and contaminated runoff

Reference R001-1279669CBN-V01

Satellite image



top view ICSM



Cross section ICSM

Figure 4.6: The ICSM of 2-04-22 site 3 in the village of Taliwang on West Sumbawa

4.3 Taliwang Conceptual Site Model

Site 02-04-22 site 3 is hereafter referred to as the Taliwang site. This site has the highest score of all visited sites (see Section 4.1), and therefore it was decided to investigate the Taliwang site to construct a CSM. The aim of the investigation was to confirm or reject the assessed on-site situation described in the ICSM. To do so the ICSM was subjected to a gap analysis and based on this. a site-specific sampling and analyses plan for the site investigation was made and carried out.

4.3.1 Gap analysis and sampling and analyses plan

The Taliwang ICSM is drafted in Section 4.2.3. This ICSM is subjected to a gap analysis to design a sampling and analyses plan. By carrying out this plan, the following questions should be answered:

- What are the sources for the mercury soil and groundwater contamination?
- What is the extent, quantity and degree of the mercury soil and groundwater contamination at these sources?
- What are the source receptor pathways of the mercury contaminants?
- What is the extent, quantity and degree of the mercury soil and groundwater contamination of the source receptor pathways?
- What and who are the receptors of the mercury contaminations?
- What is the impact on the receptors?

This site had only one, rod-mill location, but the mill and all other installation were removed two years before. The supposed layout of this rod-mill location with the knowledge gaps is presented in Figure 4.6. A representative site lay-out and cross section of a rod-mill location with the knowledge gaps are presented in Figure and 3.7 and 3.8 respectively. To structure the gap analysis and consequently the detailed site investigation each gap is illustrated with a number. These gaps are listed for the Taliwang site in Table 4.2. Based on these gaps a sampling and analyses plan is made and presented in Section 4..2.

Table 4.2 Gap analysis ICSM for the Taliwang site

Number	Source	Pathways	Gap
1	Rod-mill location*	Spilling of mercury and mercury contaminated water	Is the topsoil around the former rod-mill location contaminated with mercury?
2	Rod-mill location*	Runoff	Is the topsoil downslope the former rod-mill locations contaminated with mercury?
3	Rod-mill location*	Infiltration	Is the subsoil down slope the former rod-mill location contaminated with mercury
4	Sedimentation pond	Infiltration	Is the sludge on the bottom of the backfilled sedimentation pond contaminated with mercury?
5	Sedimentation pond	Infiltration	Is the soil below the bottom of the backfilled sedimentation pond contaminated with mercury?
6	Burning place	atmospheric deposition	Is the topsoil on the site contaminated with mercury?
7	ASGM**	Infiltration	Is the groundwater in the down slope/gradient shallow wells contaminated with mercury?
8	ASGM**	Infiltration	Is the sludge layer in the shallow well contaminated with mercury?
9	ASGM**	Runoff	Are the sediments in the trench contaminated with mercury?
10	Baseline soil	Assumed not to be influenced by ASGM	What is the quality of the topsoil (up-hill) not influenced by ASGM?

Number	Source	Pathways	Gap
11	Baseline groundwater	Assumed not to be influenced by ASGM	What is the quality of the groundwater in the (upstream) shallow well not influenced by ASGM?
12	Baseline sludge	Assumed not to be influenced by ASGM	What is the quality of the sludge layer in the (upstream) shallow well groundwater not influenced by ASGM?

* Rod-mill location is the platform, the sedimentation pond and the storage of tailings
** ASGM includes all on-site gold mining activities

4.3.2 Fieldwork and sampling

The fieldwork was carried out on the 12th of April 2022 except for the sampling of the two monitoring well which took place on the 13th of April 2022. Fieldwork was performed by the staff from the Mataram University, Nexus3 and TAUW. Fieldwork comprised the installation of boreholes to sample the soil, the sampling of the open shallow groundwater wells and the sediments in the well, the installation of two monitoring wells to sample the groundwater. All boreholes were installed with a manual operated auger and the groundwater was sampled using a hand driven peristaltic pump.

An overview of the fieldwork activities performed related to the soil and mud sampling and groundwater sampling is listed in Table 4.3 and 4.4. In Appendix.2c, a site location map with sampling locations is provided. To structure the fieldwork each borehole and well sampled, is given a number and each sample is given a sample code as explained in section 3.2.3. The site code for Taliwang is TW.

During the field work, observations were made that might indicate the presence of soil and groundwater contamination. On some place on the topsoil presence of bricks, waste such as plastic bags and food remains were observed. For details, please refer to the bore logs in Appendix 2a.

Table 4.3 Performed fieldwork for soil sampling at Rod-mill location TW-1

Sampled media	m - surface	Installed boreholes	Samples
Topsoil around rod-mill location	0.00 – 0.10	TW-1-1, TW-1-2, TW-1-3, TW-1-4, TW-1-5, TW-1-6, TW-1-7, TW-1-8, TW-1-9	TW-1-1-C
Backfilled sedimentation pond - bottom	1.20 – 1.40	TW-1-10	TW-1-2-S
Backfilled sedimentation pond - remains of sediment	0.70 – 0.90	TW-1-11, TW-1-12, TW-1-13	TW-1-3-C
Lower part (small ditch) west of rod-mill location	0.00 – 0.10	TW-D-1-S	TW-D-1-S
Line down-slope rod-mill location	0.00 – 0.10	TW-L-1-1, TW-L-1-2, TW-L-1-3.TW-L-1-4	TW-L-1-C
Line North of rod-mill location	0.00 – 0.10	TW-L-2-1, TW-L-2-2, TW-L2-3	TW-L-2-C
Sludge in open shallow well	5.00 – 5.20	TW-M-1	TW-1-M

A shallow well 7 meters down-stream (north) of the rod mill location is present and named TW-1-W. To create insight in the mercury concentrations in the surrounding area of this former ASGM site, the following shallow wells are sampled:

- TW-2-W around 10 meter opposite the street East of the former ASGM site
- TW-3-W around 15 meters South of the former ASGM site
- TW-4-W around 20 meters West of the former ASGM site
- TW-5-W around 35 meters North down-stream of the former ASGM site

No ASGM activities were observed or mentioned to be present at these shallow well locations.

On-site one monitoring well of 3.7 m bgl with two filters situated at 1.80 – 2.00 m bgl and 3.50 -3.70 m bgl were installed approximately 15 meters north (down-stream) the rod-mill location. The field measurements on the groundwater samples are shown in Table 4.4.

Table 4.4 Performed fieldwork for groundwater sampling in duplo

Open shallow well Installed well	Depth filter (m bgl)		Date	Groundwater table (m bgl)	pH (-)	EC (μS/cm)	Turbidity (ntu)	Filtered	Unfiltered
TW-1-W	-	-	08-04-22	0.50	6.75	1104	-	yes	yes
TW-2-W	-	-	08-04-22	0.75	6.85	1113	-		yes
TW-3-W	-	-	08-04-22	0.74	7.05	795	-		yes
TW-4-W	-	-	08-04-22	0.52	6.89	1113	-		yes
TW-5-W	-	-	08-04-22	2.7	7.84	800	-		yes
TW-6-W-S	1.80	2.00	09-04-22	0.50	6.80	846	-	yes	yes
TW-6-W-D	3.50	3.70	09-04-22	0.50	7.02	1405	-	yes	yes

- not measured / not applicable

4.3.3 Chemical analyses

Table 4.5 presents the analytical results and the evaluation of all the samples taken at and around the Taliwang site. Appendix 2b gives the samples analyses plan. The mercury concentrations measured in the soil, sediment samples and water samples are tested like the samples from the Kayu Putih. For guideline values reference is made to Section 3.2.4.

Table 4.5 Rod-mill location TW-1 (not active for two years sampling sedimentation pit back filled)

Sample code	Sampled media and location	Hg concentration (soil mg/kg d.w. water μg/L)	STI	Reuse	WHOd
TW-1-1-C	Topsoil around rod-mill location	0.909	<S	Industrial	
TW-1-2-S	Backfilled sedimentation pond - bottom	1.415	>S<T	Industrial	
TW-1-3-C	Backfilled sedimentation pond - remains of sediment	1,097.613	>I	No reuse	
TW-D-1-S	Ditch west of rod-mill location	135.024	>I	No reuse	
TW-L-1-C	Line down-stream rod-mill location	84.044	>I	No reuse	
TW-L-2-C	Line north of rod-mill location	18.493	>S<T	No reuse	
TW-1-M	Sludge in open shallow well	13.177	>S<T	No reuse	
TW-1-W	Groundwater from well unfiltered	0.9000	>I	>	<
TW-1-W-F	Groundwater from well filtered	0.5000	>I	>	<
TW-2-W	Groundwater from well unfiltered	0.6000	>I	>	<
TW-3-W	Groundwater from well unfiltered	0.6000	>I	>	<
TW-4-W	Groundwater from well unfiltered	0.6000	>I	>	<
TW-5-W	Groundwater from well unfiltered	0.6000	>I	>	<
TW-6-W-S	Groundwater from monitoring well unfiltered	0.5000	>I	>	<
TW-6-W-S	Groundwater from monitoring well filtered	0.6000	>I	>	<
TW-6-W-D	Groundwater from monitoring well unfiltered	0.7000	>I	>	<
TW-6-W-D	Groundwater from monitoring well filtered	0.5000	>I	>	<

Table 4.6 present the results of the texture analyses and the fraction of the organic matter. The topsoil around the rod-mill location and in the northern part of the compound is sandy loam. The deeper soil samples have a heavier texture.

Table 4.6 Performed fieldwork and chemical analyses

Sampling codes	Sand (%)	Silt (%)	Clay (%)	Texture Class	Organic-C (%)
TW-1-1-C	63.33	20.00	16.67	Sandy Loam	0.39
TW-1-2-S	13.33	46.67	40.00	Silty Clay Loam	0.34
TW-1-3-C	50.00	6.67	43.33	Sandy Clay	0.26
TW-D-1-S	30.00	20.00	50.00	Clay	1.92
TW-L-1-C	20.00	46.67	33.33	Silty Clay Loam	2.40
TW-L-2-C	60.00	20.00	20.00	Sandy Loam	0.87
TW-1-M	30.00	23.33	46.67	Clay	0.23

4.3.4 The soil and groundwater contamination

Results
In all five open domestic shallow groundwater wells and the two installed monitoring wells elevated levels mercury were identified. Concentrations are tested below the drinking water norm of the WHO, but all above the Dutch Intervention Value and WHO standard for groundwater.

In all the soil samples mercury is measured. The mercury concentration in the sample taken from the remains of sediment in the backfilled sedimentation pond, is 30 times the Dutch intervention value. The concentration of the sample taken from the bottom of the backfilled sedimentation pond is lower but the soil is still slightly contaminated.

The other topsoil samples have all mercury levels above the intervention value (except for the soil surrounding the rod-mill platform) therefore are strongly contaminated with mercury. The sludge in the well is slightly contaminated with mercury.

Contamination with mercury
Based on the results, it is concluded that the mercury contamination of the soil and groundwater has taken place. Although the site is not an active ASGM site, the people living here are exposed. For this site the sources of contamination are the contaminated topsoil, the soil in the backfilled sedimentation pond and the water in the domestic wells.

Source receptor pathways
The pathways are direct contact with the contaminated topsoil and the water from the domestic well used in the household. This site is a fenced backyard of house and shop together with a kitchen garden was observed. No livestock was observed at the site. Soil is therefore a major pathway and should be remediated.

Before remediation, the remaining gaps in our understanding of the on-site situation should be filled. These gaps are:
- It is not known if the construction material of the rod-mill platform has taken up mercury and therefore a potential source
- It is assumed that, based on the results, the top 10 cm of the whole backyard (20x15 m) is contaminated with mercury. This should be verified.

5 Next steps

5.1 Introduction
Based the above presented results it is assumed that soil and groundwater are not (yet) major/acute pathways for human exposure to mercury on the Kayu Putih ASGM site. The opposite is true at the Taliwang site, although the ASGM at this site has stopped, the legacy in soil and groundwater is there, soil is a confirmed major pathway.

For both surveyed sites soil and groundwater are one of the many exposure pathways which altogether form a significant human and ecological impact. This is especially for villagers eating form a single food basket filled with food products from kitchen gardens and animal products harvested in the ASGM village.

In Kayu Putih, site remediation is only justifiable when the application of mercury within ASGM is completely stopped. To implement emergency measures such as was proposed in the TAUW Foundation proposal (filter the groundwater with polymers made out of pomelo peels and alginate) is questionable. A more effective measure is to raise awareness and advise the few that still drink water from the wells to drink bottled water. NEXUS3 is already active in Kayu Putih, but the results of the survey give a strong argument to intensify the awareness raising. The proposed awareness raising actions are discussed in Section 5.2.

For the site in Taliwang a remediation can be justified as the identified mercury concentrations in the soil are high and above guideline values and ASGM has stopped, excluding recontamination. The proposed remedial activities are discussed in Section 5.3 and Appendix 4 is the bill of quantities of the proposed remedial actions in Taliwang.

5.2 Awareness raising Kayu Putih (NEXUS3)
Intensify awareness actions focussed on the phasing out of the use of gold mercury amalgamation

5.2.1 5.2.1 current status awareness raising

5.2.2 5.2.3 Proposed additional actions

5.3 Remediation assessment
The Taliwang site has stopped using mercury and nearly all ASGM installations are removed except for the platform the rod-mills were installed. As concluded, remediation is necessary to avoid on-site human exposure to the mercury in the soil and groundwater. To select a remedial approach a remediation assessment should be carried out. A remediation assessment comprises of the evaluation of the various applicable remedial techniques, followed by the preliminary design of a few feasible options and finally the selection of the best option. The best option is the one that reduces as much as possible the environmental risks (human, ecological and migration) with the best environmental merits not entailing excessive costs. For the remediation of the ASGM sites one standard approach should be designed tested and updated. When updated it provides the opportunity to share this with the ASGM community as a toolkit to remediate ASGM sites that stopped using mercury. This project is the first step in this direction.
As the mercury contaminated ASGM sites on Lombok and Sumbawa are more or less identical and many in the rural community and the people that are involved have not the resource to hire experience consultants and contractors to remediate their sites, the remedial approach should have the following criteria.

Site survey
- Capacity should be built within the NGO and scientific community to carry out site surveys
- The NGO and scientific community should be equipped to carry out these site surveys
- The analytical capacity, the donated analyser by Aman minerals, should be operational for low costs
- Reporting of the survey results should be facilitated by simple formats providing direct the information to design a remediation

Soil remediation design
- The treatment of soil from the hot spots should be off-site
- The remediation design of the hot spots should be based on a set of standardized simple measures such as:
    - Excavation of contaminated soil and backfilling with clean soil
    - Demolition of the contaminated platform (should be confirmed)
    - Sealed and controlled transport of soil and demolish waste to a secured treatment cell

    - Pre-treatment of contaminates soil and demolish waste
    - Treatment in controlled cells by for instance biochar
    - Monitoring remediation
    - Final phyto-containment of soil with immobilized mercury with biochar
- The remediation of large area's with slightly contaminated soil should be on-site
- The remediation design of large area's with slightly contaminated should be based on a set of standardized simple measures such as:
    - Excavation of contaminated soil and replacement with clean from the on-site treatment/remediation plot
    - Transport the contaminated soil to the on-site remediation plot
    - Treat/immobilize mercury in the contaminated soil with biochar
    - Phyto-contain the soil with immobilized mercury
    - Monitoring and maintain the phyto-containment plot

Biochar is a lightweight black residue, made of carbon and ashes, remaining after the pyrolysis of biomass. The biochar immobilizes the mercury. If the mercury is immobilized the soil can be reused in an isolated/contained environment. This could be a phyto-containment plot with for instance trees that could be used for construction.

Groundwater remediation design
The levels in the groundwater indicate that mercury reaches the groundwater and when this groundwater is domestically used people are exposed, but it is not the major source receptor pathway. To justify remediation extensive research and piloting of the proposed polymers made out of pomelo and alginate, a risk assessment for especially the exposure to the groundwater should be carried out. One of the objectives of the pilot is to see if the polymers are able to reduce the found mercury concentration in the groundwater. Meanwhile the awareness raising campaign should focus on the use of bottled drinking water instead of well water.

5.4 Pilot remediation Taliwang

This project provides the opportunity to develop a ASGM site remediation toolkit. An important aspect of this opportunity is to pilot the sketched remedial approach. This section therefore provides a description of such remediation applying the above listed criteria. Appendix 4 is the bill of quantities for such remediation of the Taliwang site

Preparation of the Taliwang site remediation
1. Verification survey by sampling and analyses of:
    - Topsoil from 0.0 - 0.10 m bgl to verify the results and map in vertical direction
    - Subsoil from 0.0– 0.25 and 0.25-0.50 to establish the depth the mercury contamination
    - Concrete slab and bricks used to construct the platform
2. Based on verification survey, detail design the remediation for:
    - The removal of the platform
    - The excavation of the topsoil
    - The excavation of the sedimentation pit

The remediation
3. Excavate the topsoil with mercury levels above around 1 mg/kg d.w.
4. Excavate the former sedimentation pond till at least 1.6 m bgl
5. Bring all the soil and the remains of the platform to an off-site depot to treat to soil with biochar. A possibility is to involve the project partner Aman Mineral at Sumbawa. As they have a secured site to treat the mercury contaminated soil safely. The investment made for a treatment facility can then be used for other sites that have phased out amalgamation
6. Pre-treat the soil and the remains of the platform by crushing
7. Mix the soil and the crushed materials with biochar
8. Place the soil with biochar in a depot and sample to verify if the mercury is immobilized
9. Repeat biochar application when not all mercury is immobilized

10. Bring all soil to a phyto-containment plot

Reference R001-1279669CBN-V01

Appendix 1

Kayu Putih data

Reference R001-1279669CBN-V01

Appendix 1.a

Bore logs

Reference R001-1279669CBN-V01

Appendix 1.b

Sample analyses plan

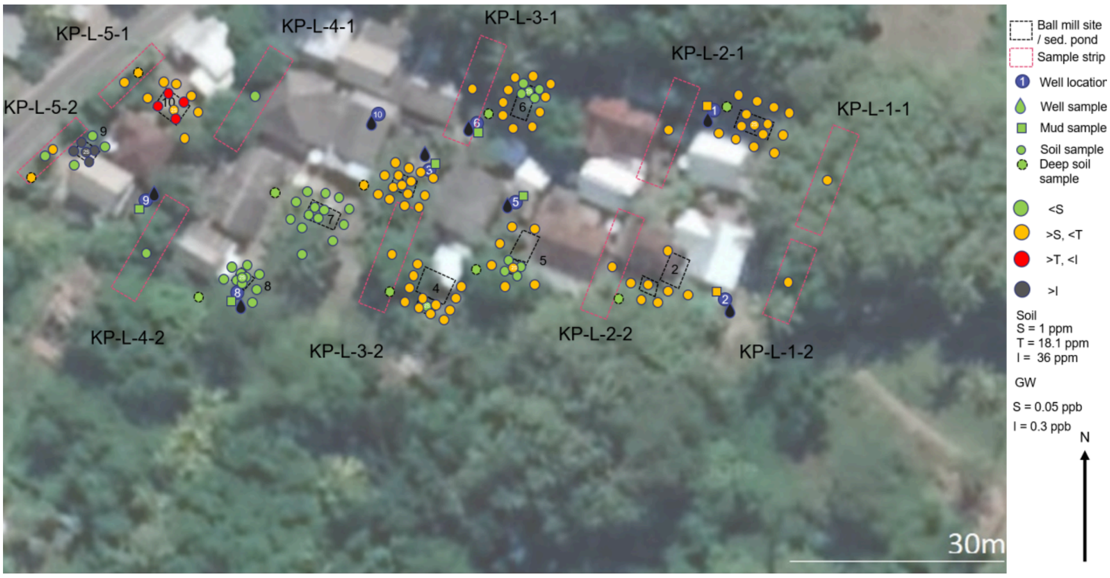
32 soil samples from ten rod-mill locations for mercury inclusive dry weight1)	KP-1-1-C, KP-1-2-S, KP-1-3-C, KP-1-4-S KP-2-1-C, KP-2-2-S, KP-2-4-S KP-3-1-C, KP-3-2-S, KP-3-3-C KP-4-1-C, KP-4-2-S, KP-4-3-C, KP-4-4-S KP-5-1-C, KP-5-2-S, KP-5-3-C, KP-5-4-S KP-6-1-C, KP-6-2-S, KP-6-3-C, KP-6-4-S KP-7-1-C, KP-7-3-C, KP-7-4-S KP-8-1-C, KP-8-2-S, KP-8-3-C KP-10-1-C, KP-10-2-S, KP-10-3-C, KP-10-4-S
10 soil samples from five lines for mercury inclusive dry weight1)	KP-L-1-1-C, KP-L-1-2-C KP-L-2-1-C, KP-L-2-2-C KP-L-3-1-C, KP-L-3-2-C KP-L-4-1-C, KP-L-4-2-C KP-L-5-1-C, KP-L-5-2-C, KP-L5-2-C-2
2 soil samples from 1 line (base line) for heavy metals2) incl. dry matter, organic matter, grain size distribution and CEC	KP-L-1-1-C, KP-L-1-2-C
1 soil sample from 1 rod-mill location for mercury, dry weight, organic matter, grain-size distribution	KP-3-4-S
5 sludge samples from 5 open shallow wells from for mercury, dry weight, organic matter	KP-1-M KP-3-M KP-5-M KP-6-M KP-8-M
2 sludge samples from 2 open shallow wells for heavy metals2), dry weight, organic matter, grain-size distribution	KP-2-M KP-9-M
8 unfiltered groundwater samples in duplo from 7 open shallow wells for mercury	KP-1-W KP-2-W KP-3-W KP-5-W KP-6-W KP-8-W KP-10-W
2 filtered groundwater samples in duplo from 2 open shallow wells for mercury for mercury	KP-6-W-F KP-10-W-F
2 groundwater samples in duplo from 2 open shallow wells for heavy metals	KP-2-W KP-9-W

1)

2)*Metals (antimony, arsenic, barium, boron, cadmium, chromium, chromium IV, cadmium, cobalt, copper, mercury, lead, molybdenum, nickel, selenium, silver, tin and zinc)*
**Combined with coring KP-9-10*

Appendix 1.c

Site location map with boreholes and wells



Appendix 2

Taliwang data

Reference R001-1279669CBN-V01

Appendix 2.a

Bore logs

Appendix 2.b

Sample analyses plan

2 soil samples from the rod-mill locations for mercury inclusive dry weight[1)]	TW-1-1-C, TW-1-2-S
2 soil samples from the rod-mill locations for heavy metals[2)] incl. dry matter, organic matter and grain size distribution	TW-1-3-C
2 soil samples from three lines for mercury inclusive dry weight[1)]	TW-1-3-C KP-L-1-1-C, KP-L-1-2-C TW-D-1S
3 soil samples from three line for mercury incl. dry matter	KP-L-1-1-C, KP-L-1-2-C, TW-D-1-S
1 sludge samples from open shallow wells for heavy metals[2)], dry weight, organic matter, grain-size distribution	TW-1-M
8 unfiltered groundwater samples in duplo from 7 open shallow wells for mercury	TW-1-W-U TW-2-W-U TW-3-W-U TW-4-W-U TW-5-W-U TW-6-W-U-S
2 filtered groundwater samples in duplo from 2 open shallow wells for mercury for mercury	TW-1-W-F TW-W-6-F-D
2 groundwater samples in duplo from one open shallow well for heavy metals	TW-W-6-U-D, TW-W-6-F-D

[2)]*Metals (antimony, arsenic, barium, boron, cadmium, chromium, chromium IV, cadmium, cobalt, copper, mercury, lead, molybdenum, nickel, selenium, silver, tin and zinc)*

Appendix 2.c

Site location map with boreholes and wells

Appendix 3

Reference

(1) WHO Guidelines for Drinking-Water Quality, 4th ed.; WHO: Geneva, Switzerland; Available online: https://www.who.int/publications/i/item/9789241549950
(2) Wet Bodembescherming S, T en I waarden https://wetten.overheid.nl/BWBR0033592/2013-07-01
(3) EPA, 1991 https://www.epa.gov/ground-water-and-drinking-water/national-primary-drinking-water-regulations
(4)