IDRF Final Report:

Assessment of biogeochemical mercury cycling: Sekotong artisanal mining area, Lombok, West Nusa Tenggara (WNT) Province, Indonesia

Contract award 2010

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Research Summary

Artisanal and small-scale gold mining activities have been extensively described for the Kalimantan and Sulawesi areas of Indonesia. But the increased gold price over recent years has seen operations extend to the West Nusa Tenggara (WNT) Province islands of Lombok and Sumbawa. For the current research, an environmental assessment was conducted across the Sekotong, Sekarbela and Sumbawa ASGM locations of WNT Province. Gold is recovered by miners through a two-stage process of amalgamation and cyanidation. The waste is discharged to land or to sea with no concern for the contaminant loading of the tailings. The gold grade being exploited by miners is in some cases very high, up to 5,000 mg/kg. The mean grade of the amalgamation tailings is approximately 7 mg/kg, dropping to 1.2 mg/kg for the cyanidation tailings. The mean mercury concentration of the amalgamation tailings is approximately 3,000 mg/kg and greater than 1,600 mg/kg for the cyanidation tailings. Process discharge waters regularly show detectable levels of dissolved mercury. Samples of rice collected adjacent to cyanidation tailings ponds show methyl mercury concentrations greater than 100 ng/g. This is five times above the Chinese permissible level for total mercury in food crops. Samples of hair collected from ASGM workers on Lombok Island do not show methyl mercury concentrations significantly above a control group on this island. However, this may be a result of the recent onset of mining activities in this part of Indonesia. By our assessment the uncontrolled discharge of tailings represents a serious threat to the ecosystem. To protect the environment and to enhance the sustainability of ASGM, we propose that tailings be collected and planted with an appropriate crop species. A phytoextraction operation could be run where the residual gold in the tailings is removed by plants. The gold grade of the tailings indicates that a gross profit is possible, providing an economic imperative to implement phytoextraction. The environmental benefit would be containment of the mine waste, and management of the mercury burden of the tailings.

International Development Research Fund project

Assessment of biogeochemical mercury cycling: Sekotong artisanal mining area, Lombok, West Nusa Tenggara (WNT) Province, Indonesia

Final Report

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Introduction

The continuing global economic crisis has seen a dramatic rise in the market price of gold. This rise is driven by increased demand for the metal as a financial instrument to preserve or protect wealth.

Associated with this demand has been increased exploitation of gold-bearing rocks by formal and regulated mining operations, and by illegal or artisanal small-scale mining operations.

Artisanal and small-scale mining (ASGM) is practiced throughout the developing world. The subject of the research developed in this IDRF project is an assessment of the effects of this mode of mining on the environment at the Sekotong artisanal mining district, in Lombok, Indonesia.

ASGM at Sekotong

ASGM operations began operating in Lombok in 2008, but during the past 24 months the scale of operations has increased dramatically.

The mining process follows the following sequence:

1. Ore is extracted by hand from a simple mine shaft or exposure, packaged into sacks, and sold to village-based process operators
2. The first stage of processing is a preliminary grind using a hammer, or for larger-scale operations, a mechanical crusher

3. The ore is then placed into rod mills, and ground to a fine paste with water and elemental mercury
4. The resulting mercury-gold amalgam is separated from the water/rock paste, and squeezed through a cloth to recover excess mercury. This can be used in subsequent grinds. The waste rock (amalgamation tailings) is re-bagged and sold to secondary process facilities. The mercury-gold amalgam is sold to a gold buyer
5. The secondary stage of processing is a cyanide leach circuit. The amalgamation tailings are leached with sodium cyanide and calcium hydroxide, and the leached gold is recovered on carbon
6. Carbon from the cyanide leach circuit is burnt, and the gold again recovered using mercury. The waste from the leach (cyanide tailings) is disposed directly to land, rice paddies, streams or the ocean without further treatment.

There are positive aspects to ASGM in Lombok: employment, income and profit for investment. However, the detrimental environmental effects of ASGM operations have been widely reported worldwide. An assessment for the potential risk of mercury cycling through the Lombok environment (soil-water-plants-animals), and the development of ideas to promote environmental protection and sustainability, are the objectives of the current research.

As part of the project, ASGM operations on the island to the west of Lombok, Sumbawa, were also investigated. ASGM on Sumbawa is very recent, but the emerging problems are the same as those at Sekotong.

Project participants

The research team for this project comprised four key scientists:

- Dr Christopher Anderson, Institute of Natural Resources, Massey University
- Dr. Dewi Krisnayanti, Faculty of Agriculture, University of Mataram, Lombok, Indonesia
- Prof. Wani Utomo, Faculty of Agriculture, Brawijaya University, Java, Indonesia
- Prof. Xinbin Feng, Institute of Geochemistry, Chinese Academy of Science, Guiyang, China

Project Schedule Report

Task	**Schedule**	**status**
Project start • Communication with sub-district government to finalise plans for the sampling visit	1 Nov 2010 – 31 Jan 2011	Complete • Ethics and research approvals for site visits and sampling were obtained prior to the commencement of field work

Field visit Mataram • Site selection • Survey and sample collection • Sample dispatch to laboratories	1 Feb 2011 – 28 Feb 2011	Complete • The project partners met in Sekotong and Malang • Eight amalgamation facilities and three cyanide facilities were visited in Sekotong, and a further five amalgamation facilities were visited in Mataram. Three locations were visited on Sumbawa • Ore/tailings samples were collected at each location, and water and hair samples collected according to a sampling plan. Rice samples were collected at two location • Ore/tailings samples for gold analysis and fertility testing were transported to NZ; hair and plant samples for methyl mercury analysis sent to China; and soil/tailings and water samples for total mercury testing were retained in Indonesia
Sample analysis • Gold NZL and INO (actual NZL) • Mercury NZL, INO, CHN (actual INO, CHN) • Soil properties NZL, INO (actual NZL)	1 Mar 2011 – 31 May 2011	Complete • Gold analysis is complete • Fertility testing is complete • Mercury analysis in China is complete • Mercury analysis in Indonesia is complete • New capability and capacity for mercury and gold analysis has been created in Indonesia (Mataram and Brawijaya)
Project consideration • Placement of Sekotong risk with international understanding • Reporting on findings • Preliminary assessment of necessary response	1 June 2011 – 31 July 2011	Complete • The research data has been analysed. Results and discussion have been incorporated into a draft manuscript to be submitted to the journal '*Science of the Total Environment*'. This document compares apparent risk in WNT Province to well-described

		Chinese examples of mercury pollution • Mercury discharge into the environment at all surveyed ASGM facilities presents a direct risk to the health of workers and the community. Apparent risk is greatest for cyanidation facilities • The project team has formulated a response to the observed environmental issues • A new research centre has been established in Indonesia (The International Research Centre for the Management of Degraded and Mining Lands) to facilitate ongoing assessment of environmental risk and to implement remediation and management solutions • Funding agencies have been engaged with ideas for subsequent work
Meetings in Lombok (field) and Jakarta • Result presentation to local government, Ministry of Environment, community, workers and miners of Sekotong district, Asian Development Bank • Discussion on potential strategies for sustainable risk management and remediation	1 Aug 2011 – 31 Aug 2011	Complete • The findings of the project were presented to stakeholders in Mataram on 21 December 2011 by Dr. Dewi Krisnayanti • Strategies for risk management and remediation were discussed • Further consultation with stakeholders will occur during a Feb 2012 conference on artisanal mining to be held in Malang, Indonesia, and a subsequent field workshop for NGOs at the Sekotong ASGM area
Research conclusion • Final Project reporting • Peer review of findings • Proposals submitted for further action	1 Sept 2011 – 30 Nov 2011	Complete • The final report to NZAid is now presented • The findings of the research have been discussed and reviewed by Indonesian stakeholders

		• The scientific aspects of the research will be peer reviewed upon journal submission • A detailed research proposal for extensive next-stage participatory research has been submitted to NSF/USAid • Limited follow on funding has been granted by the Indonesian Government

Commentary

Scientific reporting

The research data generated during the contract has been analysed and prepared for publication. The draft manuscript to be submitted to the journal '*Science of the Total Environment*' is presented as Appendix 1.

Capacity building

Throughout the contract period, Dr. Anderson and Prof. Feng have spent considerable time and effort building analytical capacity within the two Indonesian partner Institutions. A new mercury analysis capability has been created at Brawijaya University in Malang, with a technician and postgraduate student trained in techniques for sample preparation and analysis. The University of Mataram has recently purchased a new analytical system that can determine the concentration of gold in geochemical samples (purchase external to this project). Time spent at Massey University through the NZAid project has allowed Dr. Dewi Krisnayanti to learn appropriate sample preparation and analytical skills such that this machine can be used for ongoing ASGM research.

Subsequent to the field survey conducted by the project team in February 2011, Dr. Krisnayanti was engaged to complete a more detailed survey of mercury pollution at ASGM operations on Sumbawa.

New research centre

As a direct outcome of the IDRF supported research, a new research centre has been established in Indonesia to build upon the findings of the current research. This new centre, The International Research Centre for the Management of Degraded and Mining Lands, (IRC-MEDMIND) is jointly hosted by Brawijaya University and the University of Mataram. The Institute of Geochemistry, Chinese Academy of Sciences and Massey University join with these two Indonesian universities as the founding institutions of the centre. Both institutions will serve in an ongoing advisory capacity for the research centre.

Engagement with community and government.

On the 21st December 2011 the findings of the IDRF-sponsored research were presented to government officials from West Nusa Tenggara Province. Dr. Dewi Krisnayanti made a presentation to this meeting on behalf of the project team. A report on this meeting is presented as Appendix 2.

In February 2011 Dr. Anderson and Prof. Wani Utomo presented the objectives of the IDRF-sponsored research to the Agency for Research and Development of the Ministry of Energy and Mineral Resources in Jakarta. As a direct result of this meeting, US$30,000 of funding over three years was granted to IRC-MEDMIND in December 2011 to implement the findings of the IDRF-funded research.

In August 2011 planning began for an International conference on the environmental, socio-economic and health impacts of artisanal and small scale mining. This conference is to be held in Malang, Indonesia on February 7 and 8, 2012, and is hosted by IRC-MEDMIND (www.eshi-asm.fp.ub.ac.id). Dr. Anderson is a keynote speaker at this conference and will present the findings of the IDRF-sponsored research.

A working relationship with the NGO Balifokus has been established as a result of the IDRF-sponsored research. Balifokus is active in ASGM operations, and has international scope to its activities through partnership with other NGOs. Balifokus will co-host a field visit and workshop on ASGM in Mataram following the Feb Malang conference. Dr. Anderson and Prof. Xinbin Feng will present at this workshop as members of IRC-MEDMIND (Appendix 3).

Ongoing dialogue is also occurring between the Mataram-based members of IRC-MEDMIND and the NGOs Live and Learn, and WWF regarding ASGM on Lombok

Throughout 2011 a dialogue was entered by Dr. Anderson and Ms. Halshka Graczyk, a consultant on child labour issues to the International Labour Office in Geneva, Switzerland. Ms. Graczyk has agreed to join the project team in subsequent studies to be conducted by IRC-MEDMIND.

Research proposals generated during the IDRF contract

Through October and November 2011, Dr. Anderson assisted IRC-MEDMIND develop a detailed proposal for follow on research to the IDRF-sponsored project. Prof. Wani Utomo was hosted by Dr. Anderson at Massey University in November 2011 to finalise aspects of the funding application. This proposal was submitted to the PEER fund in the USA, a joint initiative of USAid and NSF (US$150,000 over three years). This fund necessitated the linkage of IRC-MEDMIND to a US collaborator with current NSF funding. With Dr. Anderson’s help, the Indonesian research has been linked to that of Assoc. Prof. Marc Buetel at Washington State University in Pullman, Washington State. The application is being reviewed, with a funding decision expected in March 2012.

Concluding Statement

The research performed during the IDRF-sponsored project has investigated a real-world problem that is affecting the health of the environment and people in one of the poorer parts of Indonesia. This problem is mercury pollution, arising from the informal and illegal mining techniques practised by small scale and artisanal gold miners. This is a problem that is apparent worldwide, and is of concern to a range of multinational private companies, governmental groups and non-governmental organisation.

This problem will not go away. What are needed are new ideas to better manage the apparent issues.

The IDRF-sponsored research has quantified, for the first time, the extent of environmental risk in West Nusa Tenggara. This project is the first assessment of mercury flux in this part of Indonesia. More importantly, this research has developed significant capacity and capability within Indonesia for ongoing research and environmental monitoring. The research has proposed a potential management system for mercury-contaminated waste which will be tested upon the securing of appropriate funds (some funding has been received).

As a direct result of IDRF-funding, a new research centre has been established in Indonesia. This is the International Research Centre for Management of Degraded and Mining Lands, jointly hosted by Brawijaya University and the University of Mataram. All members of the IDRF-sponsored project will continue their collaborative efforts through the new centre. Their efforts will be supported by new research partners engaged during the period of IDRF-contracted research.

Dr. Christopher Anderson, Project Leader

25 January 2012

Artisanal gold mining on Lombok and Sumbawa Islands, West Nusa Tenggara Province, Indonesia: Background environmental study and novel strategy for tailings management

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Abstract

Artisanal and small-scale gold mining activities have been extensively described for the Kalimantan and Sulawesi areas of Indonesia. But the increased gold price over recent years has seen operations extend to the West Nusa Tenggara islands of Lombok and Sumbawa. For the current research, an environmental assessment was conducted across the Sekotong, Sekarbela and Sumbawa ASGM locations. Gold is recovered by miners through a two-stage process of amalgamation and cyanidation. The waste is discharged to land or to sea with no concern for the contaminant loading of the tailings. The gold grade being exploited by miners is in some cases very high, up to 5,000 mg/kg. The mean grade of the amalgamation tailings is approximately 7 mg/kg, dropping to 1.2 mg/kg for the cyanidation tailings. The mean mercury concentration of the amalgamation tailings is approximately 3,000 mg/kg and greater than 1,600 mg/kg for the cyanidation tailings. Process discharge waters regularly show detectable levels of dissolved mercury. Samples of rice collected adjacent to cyanidation tailings ponds show methyl mercury concentrations greater than 100 ng/g. This is five times above the Chinese permissible level for total mercury in food crops. Samples of hair collected from ASGM workers on Lombok Island do not show methyl mercury concentrations significantly above a control group on this island. However, this may be a result of the recent onset of mining activities in this part of Indonesia. By our assessment the uncontrolled discharge of tailings represents a serious threat to the ecosystem. To protect the environment and to enhance the sustainability of ASGM, we propose that tailings be collected and planted with an appropriate crop species. A phytoextraction operation could be run where the residual gold in the tailings is removed by plants. The gold grade of the tailings indicate that a gross profit is possible, providing an economic imperative to implement phytoextraction. The environmental benefit would be containment of the mine waste, and management of the mercury burden of the tailings.

1. Introduction

Gold mining in developing countries can be organized and regulated, with mechanisms in place to protect workers and the environment. But mining can also be informal and small-scale, with minimal regulatory control of activities. This second form of mining is described as artisanal or small-scale gold mining (ASGM), and in Indonesia is known as PETI, an abbreviation of the term 'Pertambangan Emas Tanpa Izin'. Numerous health, environmental and social problems are typical of ASGM operations. Primitive and low-cost technologies lead to high levels of work-place hazard; fatal accidents are common. Workers migrate from mine-site to mine-site, creating friction, resentment and social instability. Poor infrastructure for water, sanitation, education and law and order are all manifestations of the illegal industry (Veiga and Hinton, 2002).

A 2001 survey by the International Institute for Economic Development estimated that 713 ASGM operations were in place throughout Indonesia (Aspinal, 2001). The rise in the international gold price to over US$1600/ounce by the end of 2011 has led to an increase in ASGM activity, although this increase is poorly quantified. Most artisanal miners do not make large profits; they strive to make sufficient money to support their immediate family. However, each miner is thought to generate income for a further 10 people (ILO, 1999). ASGM, therefore, represents a significant source of income for some of Indonesia's poorest people. But operations are often illegal and/or poorly regulated. Miners may have no title to the land they are working, and there is no incentive or provision for sustainable land management. Environmental destruction is the most visible outcome of artisanal mining. Environmental affects in Indonesia follow those in other parts of the world and include acid mine drainage, deforestation, soil erosion, river silting and the pollution of soil and water with toxic compounds (Aspinal, 2001).

Mercury amalgamation is the most common method of gold recovery used by artisanal miners. This technique is favoured because it is considered by miners to be effective, easy to use, cheap, and mercury is readily available. However, mercury is highly toxic. Symptoms of human poisoning can vary from minor learning disability to extremely diminished mental capacity (Suzuki, 1979). The United Nations

Environment Programme (UNEP) states that there are serious long-term environmental health hazards in populations living in, near or downstream/wind of artisanal and small-scale mining operations (UNEP, 2009). The most toxic form of mercury for human exposure is methyl mercury, as this is the form of mercury that will most readily accumulate in the body and act as a developmental neurotoxin. Mercury will readily methylate once discharged into the environment (Meech et al., 1998).

The use and cycling of mercury at ASGM locations has been extensively studied. It is estimated that between one and two grams of mercury is lost to the environment per gram of gold produced (Veiga et al., 2006). Worldwide this may lead to the annual release of up to 1,000 tonnes of mercury to the environment. Between 100 and 150 tonnes per year are estimated to be released from Indonesia.

At many ASGM locations a two-stage process of amalgamation followed by cyanidation is used to ensure maximum recovery of gold from ore. Cyanidation is being promoted as an alternative to amalgamation by groups seeking to reduce the mercury consumption of ASGM (for example, by the efforts of the Global Mercury Project sponsored by GEF, UNIDO and UNDP). Throughout Indonesia the two techniques are used sequentially. Cyanide is very effective at making gold soluble, but will also complex with mercury (and other heavy metals) present in the amalgamation tailings being leached. The bioavailability of mercury is increased through cyanidation, and when discharged into the environment shows increased potential to biomethylate and enter the food chain (Gunson and Veiga, 2004; Veiga et al., 2009).

Despite these negative aspects, artisanal mining plays an essential role in developing societies. Small mines can be a major source of revenue for rural communities, and can provide income for investment. Artisanal miners can exploit a mineral deposit considered uneconomic by modern industry. Every $1 generated through artisanal mining generates about $3 in non-mining jobs. In the words of Sir Mark Moody Stewart, Chairman of Anglo- American plc and the then President of the Geological Society of London, speaking at a November 2003 conference on sustainable mining in London 'Artisanal mining should be encouraged; however, the associated poor health, safety and environmental conditions must be improved' (Stewart, 2003). The challenge is to educate miners of the risks associated with the techniques practised at ASGMs, to provide incentives that promote the adoption of better and safer technology, and to promote alternative livelihoods that will support economic development within mining communities. Some commentators believe that conditions at ASGM locations reflect a lack of interest worldwide to transmit knowledge and suitable technologies to the small-scale gold mining sector (Hylander et al., 2007).

1.1. Artisanal gold mining in West Nusa Tenggara (WNT) Province

Exploration for gold and copper mineralisation in West Lombok was initiated in the 1980s by the international mining company Newmont. The area has well understood epithermal vein and porphyry deposits, with the type of deposit depending on the age of mineralisation (local knowledge and unpublished Indonesian geology reports). Newmont relinquished its mining rights to exploration areas in West Lombok during the late 1980s and 1990s as the company shifted its focus to development of the Batu Hijau mine on the adjacent island of Sumbawa (PT Newmont Nusa Tenggara). The Canadian company Southern Arc Minerals Inc. subsequently took over the mining and exploration tenements and has an active exploration program in the area.

Despite Newmont's decision not to develop the Sekotong area, visible grades of gold were recorded. These were noted by the field assistants that worked with Newmont's geologists. Word spread within the Sekotong community of the presence of gold at select locations. Artisanal miners from Lombok and other islands quickly moved to exploit the resource and today ASGM activities are underway at many locations.

There is a good published record of ASGM operations in North Sulawesi and Kalimantan with some record of activities in Western Java. These studies investigate the efficiency of gold recovery (Veiga et al., 2009) as well as the effects of mercury on the environment and people (Limbong et al., 2003; Castilhos et al., 2006; Bose-O'Reilly et al., 2010). However, the current work represents the first published record of ASGM activities in West Nusa Tenggara province. This paper contributes to the discussion on ASGM by reporting the grade of gold as well as mercury in mine wastes, presenting a preliminary report on the extent of recent ASGM activities in WNT Province that should facilitate more detailed surveys in the region. This paper also presents a novel strategy for the management of this waste based on the value of the residual gold contained within the ASGM tailings.

2. Methods and Materials

2.1. Research location

The research was conducted through a field survey of the Sekotong (south west Lombok; Figure 1a), Sekarbela (near Mataram City, Lombok; Figure 1b) and Sumbawa (Figure 1c) ASGM areas of WNT Province during February 2011. During a one-week period, each mining area was visited, and random operations selected for a field survey. Eighteen individual locations were sampled across the three mining areas (Figure 1). Two types of operation were visited; amalgamation facilities, and cyanidation facilities. Samples of primary ore and amalgamation tailings were collected from amalgamation facilities, while samples of the cyanide ore (amalgamation tailings) and cyanidation tailings were collected from the cyanidation facilities. Where possible, samples of discharge water from each facility and well water were collected. In all locations, well water was used in the ASGM process. In most cases this was the same water that was used for cooking and cleaning. An initial health survey of ASGM workers was conducted and this included hair sampling from participants in the survey. Sites of primary ore extraction were visited but not sampled in this work. On Lombok, hard-rock mining occurs throughout the Sekotong region, with ore transported as far as Mataram for processing (Sekarbela). Amalgamation and cyanidation facilities have been constructed in Sumbawa close to the focal point for ore extraction. The extent of mining activity is increasing in both Sekotong and Sumbawa (Onishi, 2011).

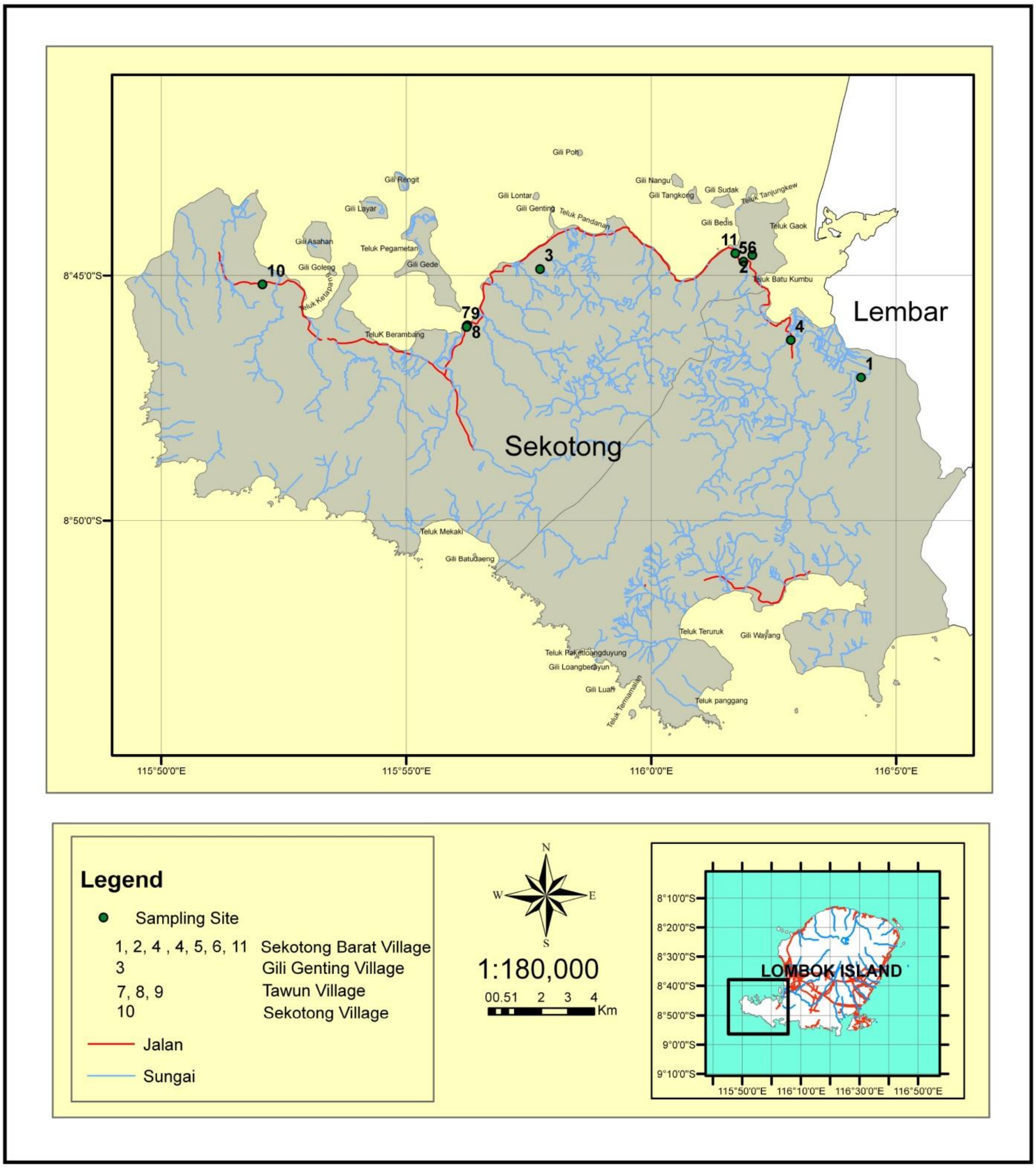

Figure 1a. The Sekotong ASGM area and record of the locations sampled in this research. Locations 1, 2 and 3 are cyanidation facilities. The remaining locations are amalgamation facilities

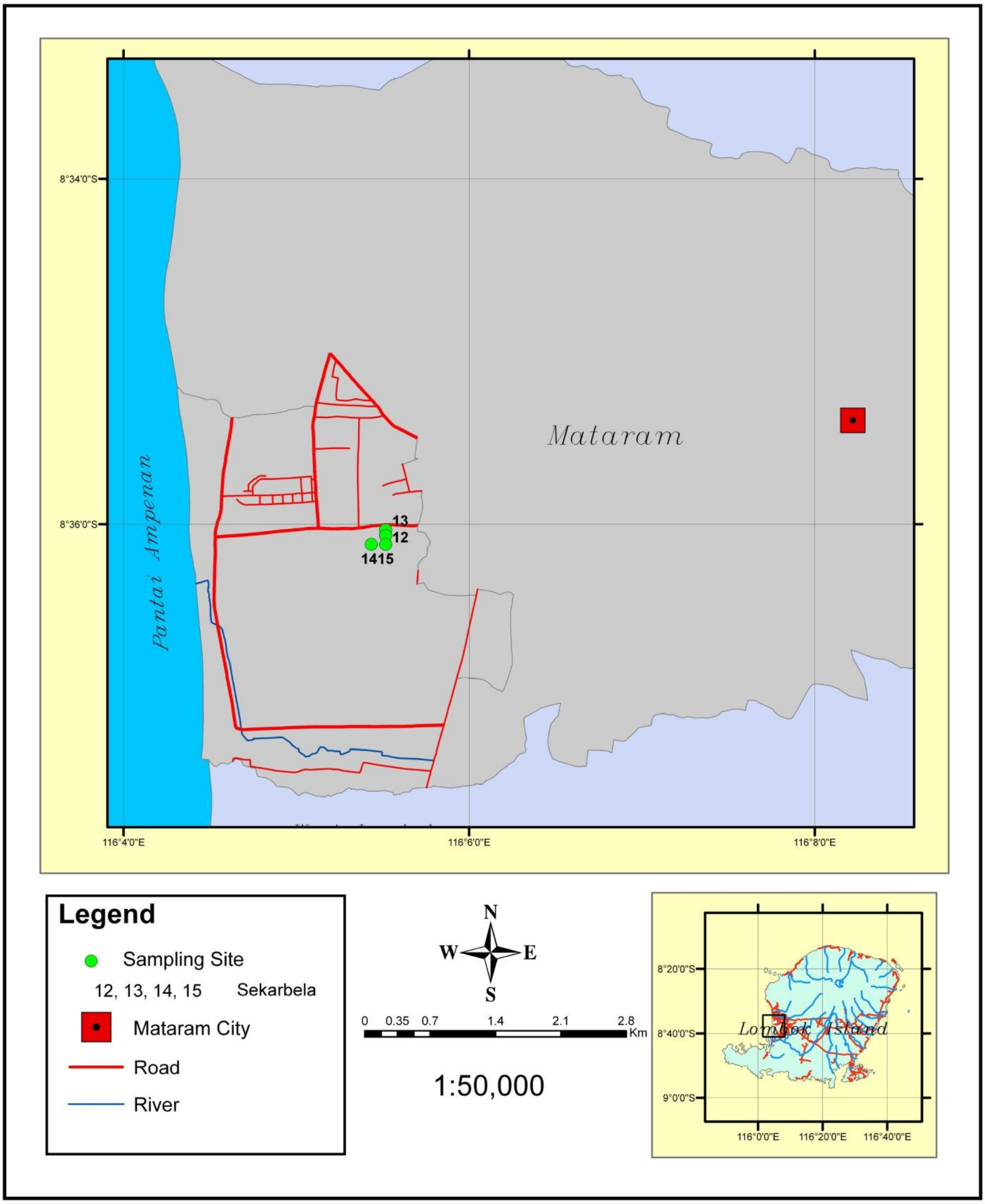

Figure 1b. The Sekarbela ASGM area and record of the locations sampled in this research. The four locations are amalgamation facilities

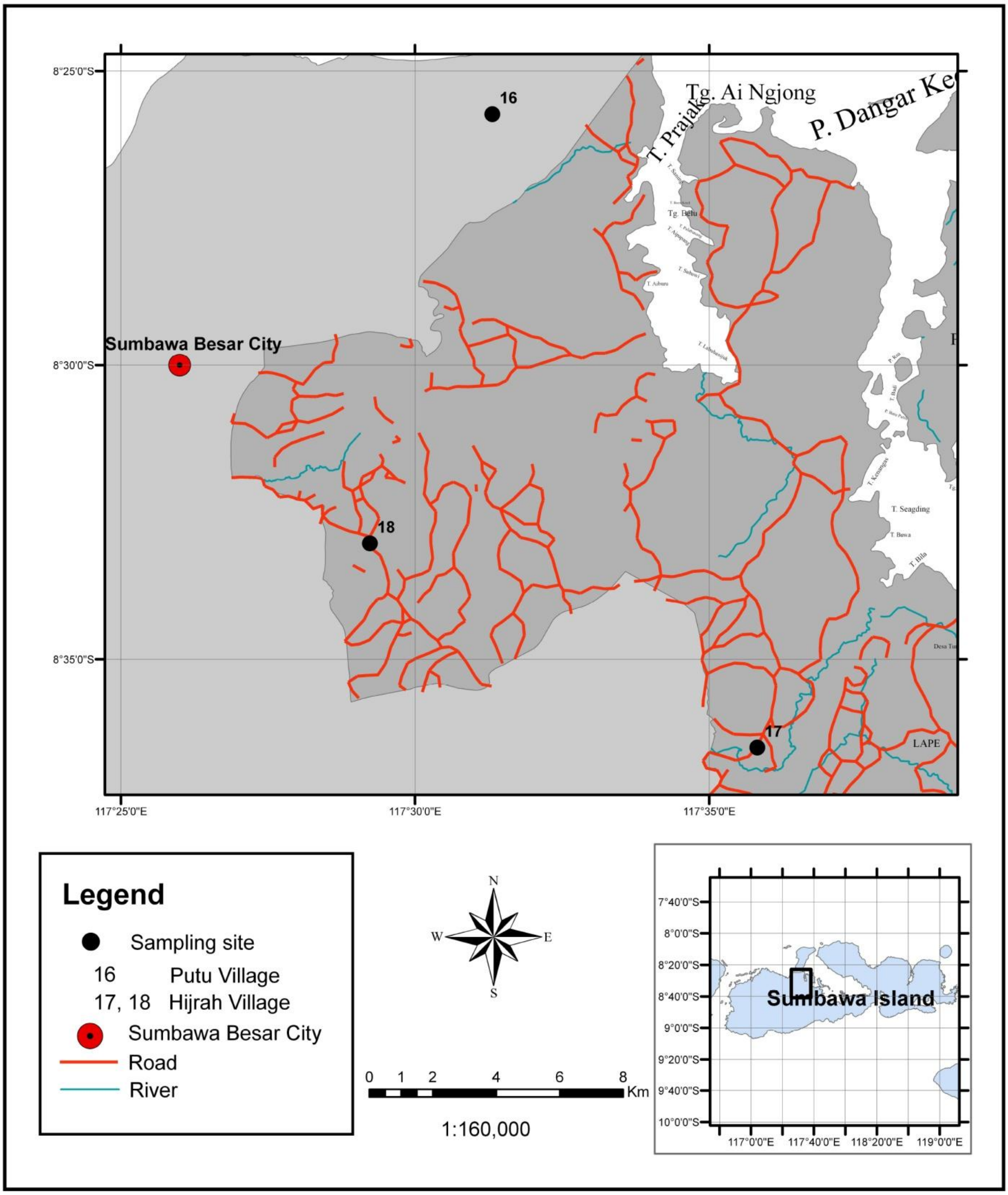

Figure 1c. The Sumbawa ASGM are and record of the locations sampled in this research. Locations 16 and 18 are amalgamation facilities. Location 17 has multiple amalgamation and cyanidation facilities

2.2. Sample collection

Primary ore and tailings samples were collected from visually identified sources at each location. Triplicate samples of ore were collected, while a single sample of the more homogeneous tailings was collected. Sample size was a minimum 100 g and, in some cases, up to 1 kg wet weight. Duplicates of every defined sample (including triplicates) were collected and placed in labelled polyethylene cliplock bags for transport to the laboratory. Water samples were collected by immersing clean polyethylene bottles (100 mL) in the water source. The bottles were then labelled and sealed for transport to the laboratory.

At two cyanidation locations (1 and 3), samples of rice plant material were collected. At location 1, the rice crop had set seed, so samples of edible rice grain could be collected. At location 3, only leaf material from rice plants could be collected. All plant samples were collected in paper envelopes.

As part of the study an initial health survey of workers was conducted. A total of 21 volunteer participants answered a short questionnaire, and allowed the sampling of hair for subsequent analysis. Hair samples were cut with stainless steel scissors from the occipital region of the scalp and sealed in polyethylene for transport to the laboratory. Two replicate hair samples were collected from each individual. A control group of 23 individuals were randomly selected through visiting areas away from the mining activity. The control group were subject to the same questionnaire and hair sampling. The control population came from both the Sekotong area and from Mataram city.

2.3. Sample preparation

Upon return to the field laboratory (Mataram University), samples were checked against the record list. Of the two substrate replicates collected, one set was packaged and transported to Massey University in New Zealand for total gold analysis. The other replicate was packaged and transported to the University of Brawijaya in Indonesia for total mercury analysis. Upon receipt in each laboratory all substrate samples were air dried. Tailings samples were homogenised using a mortar and pestle. Ore samples were ground using a ring grinder. Plant material was rinsed under running water in the field laboratory, then air dried in the paper bags ready for transported to the Institute for Geochemistry in Guiyang, China for methyl mercury analysis. One replicate of hair sample was transported to China for methyl mercury analysis with the other replicate kept on file at Mataram University. Once in China, hair samples were washed with non-ionic detergent, distilled water, and acetone, and dried in an oven at 60°C overnight. Water samples were transported to the University of Brawijaya and frozen upon receipt for subsequent total mercury analysis. A set of sub-samples from the ore and tailings material sent to New

Zealand for total gold analysis was subjected to standard soil fertility testing by the Fertilizer & Lime Research Centre, Massey University, Palmerston North.

2.4. Analytical methods

Total gold (*quasi total*) analysis of ore and tailings samples was performed in the Soil and Earth Sciences Group Research Laboratory, Massey University, Palmerston North, New Zealand using graphite furnace atomic absorption spectroscopy (GFAAS; Perkin Elmer AAnalyst 800). Subsamples of ground tailings and ore (1 g) were digested in borosilicate tubes with aqua regia (10 mL) for 2 hours at 120°C using a heating block. The resulting digest solution was made to 20 mL and then filtered (Whatman No. 42). The aqueous solution was quantitatively extracted into methylisobutyl ketone, and the organic fraction analysed for total gold concentration.

Total mercury (*quasi* total) analysis of ore, tailings and water samples was performed in the laboratory of the International Centre for Management of Degraded and Mining Lands at Brawijaya using cold vapour atomic absorption spectroscopy (CVAAS; Hua guang model F732-S, China). Sub-samples (1 g) of substrate were pre-digested overnight, at room temperature, with aqua regia (15 mL) in borosilicate beakers. The following day the preparations were digested at 120°C for two hours. Deionised water was then added (20 mL), the digest solutions filtered (Whatman No. 42), and then made to 100 mL. Ten mL aliquots were analysed with 1 mL of 5% nitric acid and 1 mL of freshly prepared $SnCl_2$ (10%) as the reducing agent. Sequential 1:10 dilutions were performed in nitric acid (5%), where necessary, to yield an absorbance on the standard curve. Water sample were defrosted, filtered (Whatman No. 42), and, acidified with an equal volume of 5% nitric acid. Aliquots (10 mL) were subsequently analysed using the procedure described for the substrate samples.

Analysis of hair and plant samples for methyl mercury was performed at the State Key Laboratory of Environmental Geochemistry in Guiyang, China. Sub-samples of rice plant (0.2-0.5 g) or hair (0.1-0.3 g) were digested using a KOH-methanol/solvent extraction technique (Liang et al., 1996). After completion, the digest was acidified with concentrated HCl. Methyl mercury in the digest solutions was extracted with methylene chloride, back-extracted from the solvent phase into water and in the later phase ethylated. The ethyl analogue of methyl mercury, methylethyl mercury ($CH_3HgCH_2CH_3$), was separated from solution by purging with N_2 onto a Tenax trap. The trapped $CH_3HgCH_2CH_3$ was then thermally desorbed, separated from other mercury species by an isothermal gas chromatography (GC) column, decomposed to Hg^0 in a pyrolytic decomposition column (800°C) before being detected by CVAFS (Brooks Rand Model III, Brooks Rand Labs, Seattle, WA, USA) following USEPA method 1630 (USEPA, 2001).

All soil fertility parameters were measured according to the standard New Zealand methods of Blakemore et al. (1987).

2.5. Analytical quality control

A quality control (QC) procedure was implemented for all components of the analytical study by using parallel standard reference materials (SRMs) or commercial external laboratories (for soil fertility analysis). A summary of the QC procedure for this work is presented as Table 1.

Table 1. Description of the standard reference materials used as part of the analytical quality control procedure for the current study.

Parameter	SRM used	QC result
Total Au	PTM 1a (Natural Resources Canada) Noble metal-bearing copper-nickel matte	Average concentration differed by 15% from the certified value
Total Hg	CRM051-050 (Resource Technology Corp, USA) Clay reference material for trace Metals	Average concentration differed by less that 20% from the certified value
Me-Hg (hair)	TORT-2 (National Research Council Canada) Lobster hepatopancreas reference material for trace metals	Average concentration differed by less that 8% from the certified value
Me-Hg (plant)	TORT-2 (National Research Council Canada) Lobster hepatopancreas reference material for trace metals	Average concentration differed by 15% from the certified value

The certified total gold and mercury concentrations are for a total digest procedure employing sequential use of strong acids. *Aqua regia*, as used in the current study, is a *quasi* total procedure. An analysed concentration below the certified value is expected.

2.6. Data analysis

All sample data was processed using Microsoft Excel. Provisional statistical testing was conducted using Excel. Where statistical differences were apparent between means, or where data correlations were apparent, further statistical investigation was performed using SAS 9.1.2 statistical software.

3. Results and discussion

3.1 The artisanal mining system in WNT Province

Mining at the Sekotong, Sekarbela and Sumbawa locations generally follows the system described by Veiga et al. (2009) for North Sulawesi, although mining in WNT is perhaps even less regulated owing to the very recent onset of activities. There appears to be no government effected restriction on the sale or use of cyanide. Any pressure to limit the illegal use of cyanide is ASGM may be coming from mining companies exploring in the area. At both locations rock is removed by hand from simple mine shafts, and transported from the mining sites in sacks (generally 20 kg). These sacks are sold to processors who grind the rock with water in simple rod grinders (in Indonesian 'gelongdong'). There is no grade control or assurance of gold content in the rock. The purchaser of the rock makes a gamble that there will be some gold present. Fraud is likely commonplace with sacks of rock filled from the road side being reportedly sold by some miners. Mercury is added during the later stages of grinding, and the amalgam is panned off. First-hand reports indicate that each sack of rock is ground with mercury three times to ensure maximum removal of gold. The amalgam is squeezed through cloth to separate excess mercury which is recycled, and the final amalgam ball sold to gold buyers, with a price determined by weight and purity. Local buyers heat the amalgam using gas burners to leave the pure metal. The infrastructure for smelting varies from open air pans to constructed heating chambers, although there is no apparent effort to collect volatilised mercury. There was no evidence for the use of retorts. Pure gold is eventually sold to goldsmiths in Mataram city.

It is difficult to fully track the fate of the amalgamation tailings. It appears that a large proportion of the tailings are sold to cyanidation plants that dispatch agents to travel the roads of the mining areas collecting sacks of amalgamation waste (US$2 per 20kg sack of tailings). However, it seems likely that some proportion of the tailings (with residual mercury) is discharged into creeks, rivers, the sea or onto land. There is no regulation controlling the disposal of the tailings. Presumably where there is money to be made by preserving the tailings (i.e. on sale to cyanidation plants), the tailings will be collected. However, where on-sale is not an option, tailings will be likely disposed of in the easiest or cheapest manner.

Cyanidation plants are present at both mining areas, although the exact number of facilities is unknown. The plants may be owner-operated or toll processing facilities. In February 2011 toll operators were charging approximately US$300 per use, and on average 10 rentals could be accommodated per month. A tailings slurry is placed in the leaching tanks, calcium hydroxide is added to increase the pH and sodium cyanide added to dissolve residual gold. Tanks generally contain 8,000 kg of tailings at a water:tailings ratio of 1:3. The target pH of the leach is 10.5, and approximately 10 kg of cyanide is used per tank. Oxygen is sometimes supplied to the leach through compressed air lines. Agitation is effected through diesel-driven impellers within the leach tank. After a two-to-three day leach period, activated carbon (20 kg) is added to the tank and the leach continues. The carbon adsorbs gold from the cyanide solution. The content of the leach tank is then screened to remove the carbon which is rinsed and burnt in open drums. Gold in the ash is collected using a final amalgamation step. The barren cyanide solution and tailings is discharged through the screening process directly to adjacent land or to sea. In some operations, discharge to land is into rudimentary tailings ponds (excavated holes). But in many cases rice paddies receive the cyanidation waste. There is no apparent awareness of the danger of the combined mercury, cyanide and heavy metal burden of the tailings, and no apparent safety protocols in place to protect the community from environmental risk.

3.2. Gold and mercury grades across the Lombok and Sumbawa mining areas

A summary of the gold and mercury concentration recorded for the collected samples is presented in Table 2 (Lombok locations) and Table 3 (Sumbawa locations).

Lombok The gold grade of the primary ore was variable, highlighting a lack of grade control. Nine ore samples were collected from eight individual locations on Lombok Island. The range of gold grade was from a low of 0.32 mg/kg to a maximum concentration of 731 mg/kg. This maximum value is an extremely high gold grade, but is likely not reflective of the general ore body being mined. The mean gold grade was high (88.6 mg/kg), but this was associated with a large standard deviation as a result of the range of grade values.

Table 2. Summary of the gold and mercury concentration in primary ore, amalgamation tailings and cyanidation tailings across the sampled Lombok locations. n describes the number of samples analysed. N describes the number of locations from where these samples were collected. All concentrations are reported as mg/kg

	Metal concentration (mg/kg)		
	Mean ± SD	max	Min
	Primary ore n=9 N=8		
Au	88.6 ± 241	731	0.32
Hg	1,736 ± 2,666	8,364	112
	Amalgamation tailings n=25 N=14		
Au	6.89 ± 5.09	20.6	1.68
Hg	3,002 ± 1,964	7,874	741
	Cyanide tailings n=63 N=4		
Au	1.20 ± 1.04	6.58	0.41
Hg	1,628 ± 1,127	6,615	103

The mean gold grade of the amalgamation tailings was lower than that of the primary ore (6.89 mg/kg), although the range was again large. There was some confusion during miner interviews as to the number of times the sampled tailings had been put through the amalgamation process. To simplify data presentation, no consideration has been given to the number of times that tailings have been processed. Samples of amalgamation tailings were collected directly from the amalgamation facilities, but also from sacks of tailings present at cyanide facilities. Amalgamation tailings represent the ore for cyanide leaching.

A large number of cyanide tailings samples were collected from four cyanidation facilities. Samples were collected from tailings dams at four depths where possible (0-7.5 cm, 7-5-15 cm, 15-23.5 cm, 23.5-30 cm). There was no correlation of gold concentration with depth. The mean gold concentration of the cyanide tailings was significantly lower than that of the amalgamation tailings, but was appreciable (1.20 mg/kg). This gold grade is economic for some modern mines. The maximum gold grade for the cyanide tailings was 6.58 mg/kg.

The data in Table 2 highlight the level of mercury that has been released into the ASGM environment on Lombok. The values reported are a mean concentration across both the Sekotong mining area and the Mataram suburb of Sekabela. The maximum mercury concentration in each of ore, amalgamation tailings and cyanide tailings exceeds 6,600 mg/kg, with the mean concentration above 1,500 mg/kg for each material. The concentration of greatest concern is that in the cyanide tailings, as this represents the final waste stream from mining that is left in unlined tailings ponds, or discharged directly into rivers or the sea. The mean mercury concentration of this waste was 1,628 mg/kg ranging from 103 to 6,615 mg/kg (63 samples from four locations). Sampling of tailings was again conducted as a function of depth. However, as for gold, there was no correlation of mercury concentration with depth. All tailings samples exceeded the maximum permissible concentration for Mercury in soil set by the Indonesian Government (20 mg/kg).

The range of data for the amalgamation tailings indicates variable use of mercury by the artisanal miners. There is no set amount of mercury prescribed for use in grinding, and no defined number of times that grinding will occur. It is likely that rock ground a number of times will have a higher residual mercury concentration (Veiga et al., 2009). There is no correlation of gold concentration with mercury concentration for the amalgamation tailings.

There is an almost 50% decrease in the concentration of mercury in the cyanidation tailings relative to the input amalgamation tailings. However, given the variability in the data, this result is not significant. For one location (site 3) there was an increase in the mercury concentration of the cyanide tailings relative to the amalgamation tailings. This increase may reflect differential concentrations in the tailings (input and output) over time.

The mean mercury concentration of the primary ore was high, although this may be affected by two values significantly above 1,000 mg/kg. These two values may represent contamination of the ore with mercury through spills or handling. However, a geologically high concentration of mercury in the rock cannot be discounted. The geology agency of Indonesia conducted a survey of the currently exploited mining area in 2006, and reported that some samples contained a high concentration of mercury, although no values were specified (Gunradi, 2006). By our assessment there are no published English language mineralogy reports of the ore processed in the Sekotong and Sekabela areas.

Sumbawa Less samples were collected from Sumbawa (three sampling locations), but the results follow those of the sampling on Lombok (Table 3). The mean gold concentration of ore on Sumbawa was very high (955 mg/kg) however this is distorted by the range of values recorded. The highest gold grade was 4,680 mg/kg (almost 0.5%) and was confirmed through triplicate analysis of the ore sample collected from the corresponding sampling point. This gold grade is similar to that of ore mined by artisanal methods at the Serra Pelada mine in the Brazilian Amazon during the early 1980s (Cabral et al., 2002), regarded by many as the most infamous ASGM mining operation of recent history. The mean gold grade in amalgamation tailings was still high (6.89 mg/kg), and had reduced to the same concentration in the cyanidation tailings as was reported for Lombok (1.17 mg/kg).

The average mercury concentration in amalgamation and cyanide tailings collected from Sumbawa was very similar to the concentration recorded from Lombok. The mean, maximum and minimum concentration of mercury recorded in the primary ore was lower than for the Lombok samples. This may reflect a lower mercury concentration in the ore, or less contamination owing to the more recent onset of mining activities. Only three samples were collected from a single cyanidation facility in Sumbawa. This is insufficient data to present meaningful data analysis of the mercury concentration in the cyanide tailings, although the mean value is presented for discussion.

Table 3. Summary of the gold and mercury concentration in primary ore, amalgamation tailings and cyanidation tailings across the sampled Sumbawa locations. n describes the number of samples analysed. N describes the number of locations from where these samples were collected. All concentrations are reported as mg/kg

	Metal concentration (mg/kg)		
	Mean ± SD	max	Min
	Primary ore n=5 N=2		
Au	955 ± 2,083	4,680	0.51
Hg	299 ± 422	1,021	nd[1]
	Amalgamation tailings n=8 N=3		
Au	7.28 ± 6.54	19.29	1.68
Hg	2,856 ± 1,286	4,587	811
	Cyanide tailings n=3 N=1		
Au	1.17	[2]-	-
Hg	1,953	-	-

Notes. 1) The report of nd for a minimum concentration shows that the mercury concentration was below detection. 2) No data analysis parameters are reported for the Sumbawa cyanide tailings as only one location was sampled (N=1).

3.3. Dissolved mercury in water

Samples of well water and discharge water from the amalgamation process were collected where possible. On Lombok, 12 well water samples were collected from 11 ASGM locations, and 17 discharge samples from 12 locations. On Sumbawa, four well water and four discharge samples were collected from two locations. The permissible limit for mercury in water in Indonesia is 10 ng/mL. Analysis of the water samples generally showed a mercury concentration in water below this limit. No mercury was detected in any well waters sampled on Lombok, but eight discharge water samples on this island showed mercury. One of these discharge samples exceeded the permissible concentration (15.75 ng/mL). Fewer samples were collected from Sumbawa. Mercury was detected in one of four well samples (3.06 ng/L), while mercury was found in three of four discharge waters collected. One of these discharge samples exceeded the guideline value (79.61 ng/mL). A single sample of river water at an ASGM location and of paddy water collected from adjacent to a location showed no detectable mercury.

3.4. Methyl-mercury in rice

In any consideration of human developmental neurotoxicity, the mercury species of greatest concern is methyl mercury. Locations that will favour the methylation of mercury and concentration of the toxin in a food crop should therefore be identified and studied. Across the ASGM areas of Lombok and Sumbawa, ASGM occurs alongside farming, and the agriculture sector is dominated by rice production. In many locations rice paddies can be seen directly adjacent to amalgamation or cyanidation operations. At several of the visited locations in Sekotong, cyanidation waste is discharged directly into rice paddies which have been informally re-designated as tailings dams. These dams have no system for leachate containment, and therefore soluble complexed mercury, presumably including Hg-CN, is free to move throughout the environment. The physiochemical conditions present in a rice paddy environment have been stated to facilitate mercury methylation due to the presence of a flora of sulphur-reducing bacteria (Wind and Conrad, 1995; Stubner and Conrad, 1998).

Replicate samples of rice plant material were collected from sampling locations 1 and 3 at Sekotong (Figure 1). Rice seed was separated from the rice hull for the samples collected from location 1. Only leaf samples were collected and analysed from location 3 as rice seed had not yet formed for the plants at this location. A summary of the methyl mercury concentrations recorded in these rice plant samples are presented as Table 4.

Table 4. Summary of the MeHg concentration in rice collected from paddy fields adjacent to cyanidation facilities in the Sekotong artisanal mining area

			Me-Hg concentration ng/g dry weight		
Location	sample	n	Mean ± SD	max	min
1	Rice seed	6	57.7 ± 42.9	115	10.6
1	Rice hull	6	28.6 ± 25.3	64.9	4.33
3	Rice leaf	7	36.0 ± 24.9	103	0.63

There are no defined permissible levels for methyl mercury in food crops. Guideline values are prescribed for total mercury only. For example, the maximum permissible limit of total mercury in food crops recommended by the Chinese National Standard Agency is 20 ng/g (Meng et al., 1011). There is no safe level of methyl mercury in food. The average methyl mercury concentration reported for rice sampled from ASGM cyanidation facilities in Sekotong exceeds the Chinese mercury guideline level based solely on the methyl mercury concentration. Values reported in Table 1 are similar to those reported by Horvat et al. (2003) and Meng et al. (2011) for methyl mercury in rice at the Wanshan mining area in Guizhou province, China, regarded as an area of serious mercury contamination. The recorded methyl mercury values for Sekotong represent a potential threat to the health of local residents, but consumption of this rice is likely restricted to the mining area. A control sample of rice obtained from a market in Mataram recorded a methyl mercury concentration of 1.02 ng/g.

3.5. Methyl-mercury in hair

The concentration of methyl mercury in hair was determined for research subjects in the Sekotong ASGM area who agreed to participate in the mercury survey (Table 5). Those directly associated with mining constitute the exposed group, whereas the control group was people on farms away from the mining operations or living in Mataram city. The age range for the exposed group was from a boy of 9 to a 47 year old male. There were six children of age 16 or younger in the exposed group, although it is not known to what extent these children were actively working and thus we can make no comment on the extent of child labour in the area. The exposed group was dominated by females (62%).

Table 5. Comparison of age and Me-Hg concentration between the control and exposed group on Lombok island (Sekotong, Sekabela and Mataram city)

	The exposed group (n=21)		**The control group (n=23)**	
	Mean ± SD	Range	Mean ± SD	range
Age	28 ± 8	11-50	24 ± 11	9-47
Me-Hg (ng/g)	1,004 ± 605	356-2,550	755 ± 383	188-1,530

There was no significant difference in the mean hair methyl mercury concentration between the two groups. Given the exposure pathways for mercury reported in this work (tailings, water and plant), this was a surprising result, but may reflect the recent nature of ASGM activities in the area. With time levels of methyl mercury in hair may increase for the exposed group. There was no correlation of methyl mercury concentration with age for either the exposed or control group.

The hair methyl mercury concentrations from the current study agree with those reported by Li et al. (2008) for a control group from Wuchan in Guizhou province, China, but are nominally lower than the concentrations reported for an exposed group at artisanal mercury mines at this location (2.32 ± 1.26 ng/g range 830-5,890 ng/g). Six of the 22 workers from the Li et al. exposed group showed clinical signs of mercury poisoning. There was a greater incidence of headache reported for the exposed group in the current research than for the control group.

3.6. A remediation plan for WNT Province ASGM locations to mitigate environmental risk

The data presented in this paper highlight the potential for detrimental impacts on the environment and the health of the population in the ASGM mining areas of Lombok and Sumbawa. In our opinion the major concern is the fate of mercury discharged into the environment with cyanidation tailings. Levels of methyl mercury recorded in rice growing adjacent to CN tailings indicate that Hg-CN compounds are moving into the wider environment, methylating, and being accumulated by plants. Meng et al. (2011) showed that methyl mercury behaves as if a mobile nutrient in rice, meaning that methyl mercury accumulated throughout plant tissues during growth is moved to the seed as it ripens. This further increases the risk of exposure of the ASGM communities to methyl mercury.

Despite the negative impacts of ASGM, the desired objectives of mining to generate livelihoods, employment and income are positive. The purpose of our field work was not to generate a case in support of the closure of mining, but to establish the level of environment risk such that an appropriate environmental plan can be implemented.

A largely ignored area of environmental risk in ASGM areas relates to the uncontrolled or poorly managed disposal of waste tailings. Many technology projects have focussed on mercury use and have attempted to develop a system where mercury is used more safely, for example retorting, or where the amalgamation process is replaced by alternative technology (Hylander et al., 2007; Veiga et al., 2009). However the issue of tailings disposal in ASGM operations has been less studied. A system whereby miners are encouraged to contain the waste in a properly designed facility would mitigate many of the environmental concerns. But there needs to be an economic driver for this to occur. No artisanal miner will spend money on a waste containment system where no follow on revenue from such infrastructure can be expected.

Our proposed remediation system to manage ASGM tailings (amalgamation or cyanidation) is phytoextraction, where the tailings are impounded within an appropriate dam and then planted with a suitable plant species. With appropriate soil amendments, these plants could remove or stabilise a portion of the gold and mercury burden of the waste. The concept of gold phytoextraction (phytomining) is firmly established in scientific literature (Anderson et al., 1999; Anderson et al., 2005), and extensive and ongoing research has shown that significant mercury uptake can be induced into plants (Moreno et al., 2005; Wang et al., 2011). Recent discussion by Tack and Meers (2010) and Lottermoser (2011) has placed phytoextraction and phytomining in the context of mine waste rehabilitation. The average gold grade of the cyanidation tailings surveyed in this research (Tables 2 and 3) was greater than 1 mg/kg for both the Lombok and Sumbawa ASGM locations. This should yield an appreciable gold recovery in plants (defined here as a dry weight concentration of approximately 50 mg/kg). A gold phytomining research trial conducted in Brazil during 2003 (Anderson et al., 2005) showed that *Brassica juncea* and *Zea mays* could be induced to accumulate an average gold concentration of 39 and 20 mg/kg respectively when growing on a high-pH (8.9), low-grade ore with a gold concentration of 0.64 mg/kg.

A key issue underpinning this system is the viability of the ASGM tailings as a substrate for plant growth. To explore this issue, samples of ore, amalgamation tailings and cyanidation tailings were analysed for plant nutrient parameters (Table 6). Each substrate is lacking in organic matter (carbon and nitrogen), has a high pH and has a low concentration of plant-available phosphorus. Potassium and magnesium fertility is generally acceptable. The plant available calcium concentration is greater for the cyanidation tailings than for the ore or amalgamation tailings due to the addition of $Ca(OH)_2$ to the amalgamation tailings during cyanidation to increase the pH of the slurry. The cation exchange capacity (CEC) of the substrates is low, reflecting the deficiency of organic matter and clay 'soil' minerals.

The fertility level of the tested substrates indicates that amendment and fertilisation of the substrate will be required to promote plant growth. However, selection of appropriate plant species should see effective revegetation of the mine wastes. Preliminary work in late 2011 on the cyanidation tailings of location 1 showed that cassava (*Manihot esculenta*) will grow without apparent toxic effect on biomass production. If a dry weight biomass of 10 t/ha can be harvested, with a gold concentration of 50 mg/kg, this would yield 500 g of gold per hectare unit of working operation. At a gold price of US$1,600 per ounce, this would yield revenue of over US$28,000 / ha. There will be associated costs with the construction of the tailings containment facility, the growing, treatment and harvesting of the crop, and the processing of the biomass to recover metal for sale. But modelled costs indicate that the operation should return a gross profit. This represents a financial incentive to run a phytomining operation, thereby containing the mercury-contaminated waste, and mitigating the risk that uncontrolled discharge has on the communities of the mining area. Such an operation might be run by the miners, by famers, or by new business. The environmental benefit of this scenario could be the removal of a portion of the mercury burden of the mine waste in the plants, and stabilisation of a portion through absorption to organic matter in the tailings (soil) that is increased through the action of plant growth. However, past research has shown that revegetation of mercury mine waste will promote volatilisation into the atmosphere, and this is a consequence of revegetation that should be monitored (Moreno et al., 2005).

Table 6. Summary of plant nutrient parameters for primary ore, amalgamation tailings and cyanide tailings for the Lombok and Sumbawa ASGM areas

	Primary ore (n=3)		**Amalgamation tailings (n=7)**		**Cyanide tailings (n=6)**	
	mean	SD	mean	SD	mean	SD
pH	6.9	1.3	7.4	1.6	9.6	0.4
Olsen P (mg P/kg)	3.9	2.1	4.2	2.4	7.6	4.2
SO_4 (mg S/kg)	206.7	112.4	130.6	76.6	132.6	148.6
K (me/100g)[1]	0.7	0.5	0.2	0.1	0.3	0.1
Ca (me/100g)	8	6.2	9	14.1	15.5	6.7
Mg (me/100g)	1.3	0.7	0.5	0.5	0.5	0.1
Na (me/100g)	0.5	0.1	0.9	1.4	3.2	1.8
CEC	2	0.3	10.6[2]	-	[3]	-
Total C (%)	0.249	0.161	0.081	0.027	0.182	0.074
Total N (%)	0.019	0.017	0.003	0.009	0.026	0.012

Note. 1) the units of base cation concentration are expressed as units of exchangeable plant nutrient (milliequivalents per 100g of soil). To convert to mg/kg multiple the value by the relative atomic mass of the element. 2) CEC was not determined due to the pH of the substrate. An indicative value will be the sum of the exchangeable base concentrations (as me/100g), 3) The CEC of the cyanidation tailings cannot be inferred as the high exchangeable Ca concentration may represent soluble salt that is not fully adsorbed to tailings exchange sites.

Trials to investigate the feasibility of gold phytoextraction to pay for the containment of mercury waste are underway in the Sekotong mining district. Where feasibility is proven, a participatory approach will be used to implement the system within the mining community. Phytoextraction as described could represent a low cost, low technology system for tailings management that may be readily adopted by the ASGM communities.

4. Conclusion

The extent of artisanal and small scale gold mining is increasing in Indonesia, despite the illegal nature of the activity. Mining has shifted from the traditional areas of Sulawesi and Kalimantan to West Nusa Tenggara Province. Background data on the effect of mining on the environment and on the health of workers and the community is lacking in these new mining areas. The sequential use of amalgamation and cyanidation to liberate gold from often very high grade rock, followed by the discharge of cyanidation tailings into the environment, has resulted in concentrations of mercury in tailings and water above safe limits. Where cyanidation tailings are discharged into an agricultural environment, levels of methyl mercury in rice above total permissible mercury levels for food have been recorded. Hair samples collected from ASGM workers in the Sekotong and Sekarbela operations do not show concentrations of methyl mercury significantly above a control population. However, this may be reflective of the recent onset of mining activities. Appropriate technology is essential in these mining areas to manage the toxic burden of the discharged tailings. We propose that the waste be contained and planted with appropriate species that are selected based on the chemistry of the tailings. The gold grade of the waste should permit a gross economic profit where gold is phytoextracted by the plants. This profit should encourage miners, famers or small business to implement phytoextraction technology. The gold revenue, in this scenario, would pay for the containment and management of the mercury burden of the tailings, protecting the environment from uncontrolled mercury release.

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Wang, J., Feng, X., Anderson, C. W. N., Qiu, G., Ping, L., & Bao, Z. 2011. Ammonium thiosulphate enhanced phytoextraction from mercury contaminated soil - Results from a greenhouse study. *Journal of Hazardous Materials*, 186(1), 119-127.

Wind, T. and Conrad, R. 1995. Sulfur compounds, potential turnover of sulfate and thiosulfate, and numbers of sulfate-reducing bacteria in planted and unplanted paddy soil. *FEMS Microbiology Ecology*, 18: 257-266.

Report of a meeting to discuss ASGM in the Sekotong mining area, held on the 21st December 2011 at the Environmental Agency of West Nusa Tenggara, Mataram, Indonesia

Report author: Dr. Dewi Krisnayanti (the report has not been edited by Chris Anderson).

List of invited persons

1. Chief of Police Department of West Nusa Tenggara Province
2. Head of law agency, West Nusa Tenggara Province
3. Manager of Hg and CN trading of industry and trade department, West Nusa Tenggara Province
4. Head of mining and energy department, West Nusa Tenggara Province and West Lombok regency
5. Head of health department, West Nusa Tenggara Province
6. Manager of mining affairs from regional board, West Nusa Tenggara Province
7. Head of maritime and fisheries department, West Nusa Tenggara province
8. Association of Geologist Indonesia
9. Dr. Dewi Krisnayanti from Mataram University
10. Association of Mining Indonesia
11. Santiri-NGO
12. Head of environmental agency, West Lombok regency

The results of “**Assessment of biogeochemical mercury cycling: Sekotong artisanal mining area, Lombok, Indonesia**” project had been presented in Mataram, Indonesia in December 2011. The aim of the meeting was to provide important information about the impact of ASGM at West Nusa Tenggara that urgently need to understand by government in order to protect community health and environment. The meeting was attended by Environmental Agency, Health Department, Industry and Trade Department, Law Firm, Mining and Energy Department, Maritime and Fisheries Department of West Nusa Tenggara Province, NGO and Association of Geologist Indonesia.

Dr. Krisnayanti presented the results of Hg concentration in amalgamation tailing from 3 different ASGM locations which were Sekotong-West Lombok, Lape-Sumbawa, and

Sekarbela-Mataram. The results showed that the concentrations of Hg in tailings from these areas were ranging from 391.61- 8363.64 ppm. In addition, Dr. Krisnayanti informed to the audiences that the concentration of Hg on miners hair and their relatives at Sekotong were relatively low. In contrast, the concentration of methylmercury found in rice husk near CN tailing pond at Sekotong was very high.

In the discussion section, mostly the audiences were aware with the situation, and agreed that regular monitoring of water system surrounding gold processing area is necessary. The Mining and Energy Department of West Lombok district urged the audiences and the presenter to hold the information from journalist. Due to, Sekotong is conflict area where the mining and tourism sectors are collided, thus political and business issues are involving in this district.

Based on the results of this study, Dr. Krisnayanti strongly recommended the provincial government of West Nusa Tenggara Barat through department/institution or related parties needs to do regular monitoring on water quality in Sekotong, Lape and Sekarbela water system and also to educate miners how to manage mercury safely and wisely. A close supervision on tailing management, particularly implementation of regulation prohibiting miners to release tailing and water tailing either to river or to agriculture field in the vicinity is badly needed. Miners must be obliged to have proper design of tailing pond.

Workshop on Sustainable ASGM Practices
Mataram, Indonesia, 9-11 February, 2012

PROPOSED AGENDA

Day-1, Thursday, Feb 9, 2012

Time	Agenda	Person in Charge
13.00 – 18.00	Participants arrival and registration	Organizer and hotel
19.00 – 21.00	Welcome dinner reception hosted by Provincial Government of West Nusa Tenggara	West Nusa Tenggara Provincial Government (BLHP NTB) and organizer

Day-2, Friday, Feb 10, 2012

Time	Agenda	Remarks
08.30 – 08.45	Opening	Moderator
08.45 – 09.15	Opening remarks by Masnellyarti Hilman, Deputy Hazardous Chemicals and Hazardous Waste, Indonesia Ministry of Environment/KLH	Moderator
09.15 - 09.45	Opening remarks Mr. Ridha Saleh Indonesia Human Right Commission (to be confirmed)	Moderator
09.45 – 10.15	Indonesia's policy and strategy on ASGM	Deputy of Environment, Indonesian Ministry of Energy and Mineral Resources/ESDM
10.15 – 10.30	Coffee/tea break	Organizer and hotel
10.30 – 11.30	Panel of Sub-regional presentations: Sumatera, Java and discussion	Moderator
11.30 – 12.00	Discussion	Moderator
12.00 – 14.00	Lunch break and Friday pray	Organizer and hotel
14.00 – 16.00	Panel of Sub-regional presentations: Kalimantan, Sulawesi and discussion	Moderator
16.00 – 16.15	Coffee/tea break	Organizer and hotel
16.15 – 17.30	Introduction to the technical session	Moderator
	Mercury reduction technique	YTS/Blacksmith
	Mercury-free technique - Borax	Ban Toxics!
	Mercury-free technique – Cyanidation in ball milss	PT. Uyabo
	Phytoremediation techniques	IRC-MEDMIN
17.30 – 18.30	Wrap up and conclusion	Moderator
19.00 – 21.00	Dinner at the hotel	Organizer and hotel

Day-3, Saturday, Feb 11, 2012
Field Trip and Closing Remark

Time	Agenda	Person in Charge
08.00 - 09.00	Field trip to Sekotong, West Lombok	Organizer
09.00 – 10.30	Field visit	Organizer and West Lombok Environmental Agency
10.30 – 10.45	Refreshment	Organizer and West Lombok Environmental Agency
10.45 – 12.15	Technical Presentations and Discussion	Moderator
	Mercury reduction technique	YTS/Blacksmith
	Mercury-free technique - Borax	Ban Toxics!
	Mercury-free technique – Cyanidation in ball milss	PT. Uyabo
	Phytoremediation techniques	IRC-MEDMIN
12.15 – 13.00	Lunch break	Organizer and West Lombok Environmental Agency
13.15 – 14.30	Discussion and technical presentation continued	Moderator
14.30 – 15.00	Wrap up and recommendations	Moderator
15.00 – 15.30	Closing	Moderator

The speaker for IRC-MEDMIND will be Dr. Chris Anderson.

An amalgamation facility in the Sekotong ASGM area. Ore is ground, with tailings loaded into sacks for transport to cyanidation facilities (main photo). The bottom right photo shows panning of the final mercury-gold amalgam.

Coastal cyanidation facility in the Sekotong ASGM area. Tailings is discharged into the containment pond which was once used for aquaculture. This pond is open to the sea.

One of many primary ASGM ore deposits being exploited on Sumbawa (top photo). The exposed dirt was a recent landslide (Jan 2011) that claimed several lives. The bottom photo shows sacks of ore ready for amalgamation. Each building is a grinding facility.

A cyanidation facility on Sumbawa. The bottom photo shows sacks of amalgamation tailings ready for leaching. Spent tailings are discharged into an excavated hole (main photo)

The end result of ASGM in WNT Province. These rice paddies are behind a cyanidation facility. Tailings discharge leads to a high risk of mercury poisoning through direct contact and absorption of mercury compounds by rice.

Research proposal submitted by the International Research Centre for the Management of Degraded and Mining Lands to the PEER programme, a joint initiative of the National Science Foundation (NSF) and USAid (35 pages)

PARTNERSHIPS FOR ENHANCED ENGAGEMENT IN RESEARCH (PEER) GRANT APPLICATION FORM

1. Cover Sheet

Project title
Alternative livelihoods in artisanal gold mining areas of West Nusa Tenggara (WNT) Province, Indonesia.

Field and subfield of proposed project
Environmental protection. Agricultural development

Duration and Proposed Start Date
Three years from 1 March 2012

Principal Investigator
Professor Dr. Wani Hadi Utomo

E-mail hadi_utomo@hotmail.com	**Telephone Number** +628149490979

Principal Investigator's Institution
Brawijaya University - International Centre for the Management of Degraded and Mining Lands (IRC-MEDMIND)

Address of Principal Investigator's Institution
Faculty of Agriculture, Brawijaya University
Jl. Veteran 61545, Malang, Indonesia

Other Developing Country Institutions Involved (If Any)
State Key Laboratory for Environmental Geochemistry, Chinese Academy of Sciences, Guiyang, China (no funding sought for the involvement of this institution).

U.S. Partner
Associate Professor Marc Beutel

U.S. Partner's Institution
Washington State University

Title and Award Number of U.S. Partner's NSF Grant
CAREER: Fundamental Understanding of Mercury Cycling in Lakes and Use of Reservation-Based Research to Recruit American Indians into Environmental Engineering and Science (#0846446)

Signature of Principal Investigator Date 9/11/2011	**Authorized Institutional Official (Name, Title, and Signature)** REKTOR Date 9/11/2011

2. **Project Summary**

Project Title

Alternative livelihoods in artisanal gold mining areas of West Nusa Tenggara Province, Indonesia.

Summary

Mining makes a positive contribution to the economy of Indonesia, with gold mining a widely practised activity. But not all gold mining is regulated. Indonesia has a significant Artisanal and Small Scale Gold Mining (ASGM) industry, defined as any informal and unregulated system of gold mining. These operations are often illegal, unsafe and are environmentally and socially destructive. Mercury amalgamation is the technique used by ASGM miners throughout Indonesia to recover gold from rock. Mercury in the environment is highly toxic, and the United Nations Environment Programme states that there are serious long-term environmental health hazards in populations living in, near or downstream or downwind of ASGM operations.

ASGM is practised in the Sekotong region of West Nusa Tenggara Province (WNT). Miners fill sacks with rock dug from simple mine shafts, then sell this in local villages and towns. The rock is crushed by hand, and then pulverized using simple rod mills. Liquid mercury is added during the final stages of grinding for amalgamation. The mercury-gold amalgam is separated from the waste rock (tailings), before the waste is disposed of to land or water, or sold to cyanidation plants. A final cyanide leach of the amalgamation tailings will recover more gold, before the cyanidation tailings are disposed of, again to land or water. The gold product recovered at each step is sold to the local market.

New technology is needed to protect the safety and health of communities and the environment at ASGM locations in Indonesia. This technology must be simple, cheap, easy to operate and financially rewarding. A proven option that should be promoted is phytoextraction, a farming activity that could develop agriculture as an alternative livelihood in ASGM areas. This is technology where plants are used to extract metals from waste rock, soil or water. These metals can be recovered from the plant in pure form, and sold or recycled. Gold phytoextraction is a commercially available technology, while international research has shown that phytoextraction will also work for mercury. In the context of this proposal, tailings would be contained in ‘farming areas’ and cropped using phytoextraction technology. Gold and some mercury would be extracted in the crop, with the remaining mercury burden of the tailings becoming adsorbed to soil constituents. The system would be financially rewarding to the ‘gold farmers’. The economic value of this scenario could facilitate the clean-up and management of mercury pollution, reducing the movement of mercury from tailings into soil, water and plants, thereby mitigating environmental and human risk in the mining areas.

Scientists from the International Centre for the Management of Degraded and Mining Lands propose to establish phytoremediation demonstration plots at ASGM locations in the Sekotong district of WNT Province (Lombok Island). By way of a participatory rural appraisal, farmers will volunteer to become involved with the demonstration plots. A number of these farmers will subsequently establish plots on their own land (farmer participatory research). Up to ten plots will be established over the three years of the project. Project researchers will oversee all aspects of the phytoremediation cycle (preparation, planting, management and harvest). The project team will implement an extensive training and outreach plan through the course of this work. This outreach will be conducted by Indonesians, but with the support and guidance of Dr. Marc Beutel, an NSF-funded USA collaborator who has extensive experience in mercury-related outreach with disadvantaged and indigenous communities.

The goal of the described research is to promote agriculture as an alternative livelihood in ASGM areas. The gold value of the phytoremediation crop should provide a cash incentive to artisanal farmers who develop this new agricultural enterprise. The benefits will be social, environmental and economic, as opportunities for education, employment, new business, the containment of toxic mercury, food safety and security, and revenue, are all realized.

3. Project Description

3.a Background and Rationale

Mining contributes significantly to the economy of Indonesia through employment and export revenues. Indonesia is a major supplier of tin, coal, copper, nickel and gold to the world market. But Indonesia's environment has suffered as a result of mining practices. Large areas of waste rock and mine tailings that leach contaminants to soil and water are the legacy of a history of mining. Land management systems are necessary to protect the quality of the environment at active mining locations, to rehabilitate locations where mining has now ceased, and to protect the livelihoods of communities living in these mining areas.

Mining in Indonesia, like all countries, can be organized and regulated, with mechanisms in place to protect workers and the environment; or mining can be informal and small-scale. This second form of mining is described as artisanal or small-scale mining (ASGM), and is used to recover gold from several locations throughout West Nusa Tenggara (WNT) province. The Indonesian language describes ASGM as 'PETI', an abbreviation of the term 'Pertambangan Emas Tanpa Izin'.

Numerous health and social problems are typical of many ASGM communities. Primitive and low-cost technologies lead to high levels of work-place hazard; fatal accidents are common. Workers migrate from mine-site to mine-site, creating friction, resentment and social instability. Poor infrastructure for water, sanitation, education and law and order are all manifestations of the illegal industry (Veiga and Hinton, 2002).

A 2001 survey by the International Institute for Economic Development estimated that 713 'PETI' operations were in place throughout Sumatra, Java, Kalimantan, Sulawesi and WNT (Aspinal, 2001). The rise in the international gold price to over US$1700/ounce by the end of 2011 has led to an increase in ASGM activity, although this increase is poorly quantified. Most artisanal miners do not make large profits; they strive to make sufficient money to support their immediate family. However, each miner is thought to generate income for a further 10 people (ILO, 1999). ASGM, therefore, represents a significant source of income for some of Indonesia's poorest people. But operations are often illegal and/or poorly regulated. Miners may have no title to the land they are working, and therefore there is no incentive or provision for sustainable land management. Environmental destruction is the most visible outcome of artisanal mining. Problems include acid mine drainage, deforestation, soil erosion, river silting and the pollution of soil and water with toxic compounds.

Mercury amalgamation is the most common method of gold recovery used by artisanal miners. This technique is favoured because it is considered by miners to be effective, easy to use, cheap, and mercury is readily available. However, mercury is highly toxic. Symptoms of human poisoning can vary from minor learning disability to extremely diminished mental capacity (Suzuki, 1979). The United Nations Environment Programme (UNEP) states that there are serious long-term environmental health hazards in populations living in, near, or downstream/wind of artisanal and small scale mining operations (UNEP, 2009).

The use and cycling of mercury at ASGM locations has been extensively studied. It is estimated that between one and two grams of mercury is lost to the environment per gram of gold produced. Worldwide this may lead to the annual release of up to 1,000 tonnes of mercury to the environment. Between 100 and 150 tonnes per year are estimated to be released from Indonesia (Veiga *et al.*, 2006).

At many ASGM locations a two-stage process of amalgamation followed by cyanidation is used to ensure maximum recovery of gold from ore. Where used sequentially, there is a risk that mercury in tailings can become mobilized through the formation of soluble mercury cyanide compounds that can leach into soil and water. Amalgamation followed by cyanidation occurs at all ASGM locations in WNT, and the implications of this practice must be managed. Provisional findings of the International Research Centre for Management of Degraded and Mining Lands (IRC-MEDMIND) show that levels of methylmercury, the most toxic form of mercury, in rice collected near ASGM cyanidation tailings areas of Lombok are amongst the highest in the world, and represent a clear danger to human health.

Despite these negative aspects, artisanal mining plays an essential role in developing societies. Small mines can be a major source of revenue for rural communities, and can provide income for investment. Artisanal miners can exploit a mineral deposit considered uneconomic by modern industry. Every $1 generated through artisanal mining generates about $3 in non-mining jobs. In the words of Sir Mark Moody Stewart, Chairman of Anglo-American plc and the then President of the Geological Society of London, speaking at a November 2003 conference on sustainable mining in London:

"*Artisanal mining should be encouraged; however, the associated poor health, safety and environmental conditions must be improved*."

The challenge is to educate miners of the risks associated with the techniques practised at ASGMs, to provide incentives that promote the adoption of better and safer technology, and to promote alternative livelihoods that will support economic development within mining communities. These are the objectives of the International Research Centre for the Management of Degraded and Mining Lands. Some commentators believe that conditions at ASGMs reflect a lack of interest worldwide to transmit knowledge and suitable technologies to the small-scale gold mining sector (Hylander *et al*., 2007). Outreach is necessary to change the current paradigm. However this is a challenging task that will require experienced educators and communicators. The NSF-funded USA scientist on the project team (Marc Beutel) has a proven track record for mercury-related outreach to a resource limited and indigenous outreach audience, namely the American Indian community of the Colville Indian Reservation in WA state. Assoc. Prof. Beutel has a key role to play in guiding and assisting the Indonesian scientists of the research Centre to achieve the objectives stated in this proposal. The described outreach will only be successful where conducted by Indonesian practitioners, but these practitioners will only be successful if they can benefit from the contribution of experienced and qualified international scientists.

Aspinall, C., 2001. Small-scale mining in Indonesia. International Institute for Environment and Development and the World Business Council for Sustainable Development, England.

Hylander, L.D., Plath, D., Miranda, C.R., Lucke, S., Ohlander, J. and Rivera, A.T.F., 2007. Comparison of different gold recovery methods with regard to pollution control and efficiency. *Clean*, 35: 52-61.

International Labour Office, 1999. Social and labour issues in small-scale mines. Report for the Tripartite meeting on social and labour issues in small-scale mines. Geneva, 17-22 May.

Suzuki, T., 1979. Dose-effect and dose-response relationships of mercury and its derivatives. In: Nriagu JO, ed. *The Biogeochemistry of Mercury in the Environment*. Amsterdam, The Netherlands: Elsevier Press, 399-422.

United Nations Environment Progamme, 2009. Guidance Document: Developing a national strategic plan for artisanal and small scale gold mining. UNEP Version 1.0, 7 May 2009.

Veiga, M.M. and Hinton, J.J., 2002, Abandoned Artisanal Gold Mines in the Brazilian Amazon: A Legacy of Mercury Pollution. *Natural Resources Forum*, v. 26, p.13-24.

Veiga, M.M., Maxson, P.A. and Hylander, L.D., 2006. Origin and consumption of mercury in small-scale gold mining. *Journal of Cleaner Production*, 14: 436-447

3.b Prior Experience and Relevant Capabilities of Principal Investigator

Prof. Wani Hadi Utomo obtained his PhD in Soil Science from the University of Adelaide, Australia (1981) and thereafter became involved with agricultural development and land management in Indonesia with a range of national and international partners.

His activities have included: development and implementation of the Transmigration Development Program (with the Indonesian Department of Transmigration); development and preparation of estate crops (with the Indonesian Department of Agriculture); control of soil erosion and promotion of soil conservation (with the Indonesian Department of Public Work and Department of Forestry); development of cassava-based cropping systems (with the International Development Research Centre, Canada); nitrogen management for food crops (with the European Economic Community and the Institute for Soil Fertility, The Netherlands);

erosion and soil conservation using a cassava-based agricultural system (with the International Centre for Tropical Agriculture, Asia Office); management of clay soils for rice based cropping systems (with the Australian Centre for International Agricultural Research), the promotion of cassava technology for Indonesian and Timor Leste farmers (with the International Centre for Tropical Agriculture CIAT, Asia office); and more recently, mercury risk assessment and rehabilitation of mine lands in Lombok (with the NZAid Programme, New Zealand Ministry of Foreign Affairs).

Through his experiences and understanding of the range of environmental issues currently faced by the peoples of Indonesia, and his appreciation of the challenges that Indonesia faces with respect to agricultural development and food security, Prof. Utomo in 2011, together with Dr. Christopher Anderson from Massey University and Prof. Xinbin Feng from the Chinese Academy of Sciences, established the International Centre for the Management of Degraded and Mining Lands (IRC-MEDMIND). This research centre brings together the environmental, agricultural and human health capabilities and competencies of Brawijaya and Mataram Universities with the support of key international scientists at Massey University in New Zealand, and the Chinese Academy of Sciences. The PEER program offers the opportunity for further development of the capabilities and competencies of both Prof. Utomo and the IRC-MEDMIND through collaboration with Washington State University.

3.c Project Scope and Objectives

The three-year research plan described in this proposal will build upon the findings of a 2011 NZAid-funded project that characterized mercury contamination in the soil-water-plant system across three ASGM areas in WNT (all on Lombok Island). Serious mercury contamination of the soil-water-plant system was recorded at each of these locations, and an apparent risk to the human population was diagnosed.

Through the PEER program we propose to 1) demonstrate sustainable agriculture as a community-driven technology to mitigate risk associated with the flux of Hg through the soil-water-plant system (phytoremediation), and 2) promote agriculture as a viable alternative livelihood in ASGM areas as we develop the technology.

1) Phytoremediation

Technology to manage environmental risk at ASGM locations must be easily implemented, have a low requirement for capital and infrastructure investment, and must be financially rewarding. Phytoextraction, where a crop of plants is used to extract mercury and gold from mine waste, could satisfy this need. Under the scenario of phytoextraction, amalgamation and cyanidation tailings would be contained within specific areas and the metal burden either removed from the tailings (mercury, Wang *et al*., 2011; gold, Anderson *et al*., 2005), or stabilised in the root zone of the biomass (Moreno *et al*., 2005). Phytoextraction of gold is today a commercially viable technology. The primary aim of phytoremediation at ASGM locations is to contain the hazardous tailings into a manageable area and thereby mitigate the risk of mercury movement into edible crop plants. This would, in turn, secure food safety for ASGM communities.

2) Promotion of agricultural opportunities

Phytoextraction can generate revenue if gold can be recovered from harvested plant material. This represents a source of income from what is currently a waste product. Revenue would allow for the upskilling of the ASGM farmers with modern agricultural techniques. This could in turn lead to a newly educated workforce within ASGM communities that could apply agricultural skills to land more suited to agricultural production. The community would thereby develop new capacity for food production. Extension and support provided in this project by the International Research Centre for Management of Degraded and Mining Lands and the project team would seek niche products of demand to the Indonesian and international markets. The catalyst for this environmental, social and economic development will be metals recovered from harvested biomass. The gold value of the crop should provide a cash incentive to artisanal farmers who adopt the described system of sustainable agriculture.

The primary aim of our system is to mitigate the risk of human mercury exposure, and therefore this proposal describes environmental management. But we propose to achieve this with an alternative metal recovery technology: phytoextraction. The mechanism for environmental management is therefore sustainable agriculture. The United Nations Development Programme Sustainable Livelihoods Project has recognized that miners will show little interest in environmental initiatives if there is no quantifiable and immediate payback. Our system addresses this critical issue. The gold value of the crop should provide a cash incentive to artisanal farmers to contain and stabilize the mercury-contaminated waste, and to develop an alternative livelihood based on sustainable agriculture.

Anderson, C., Moreno, F. and Meech, J., 2005. A field demonstration of gold phytoextraction technology. *Minerals Engineering*, 18: 385-392.

Moreno, F.N., Anderson, C.W.N., Stewart, R.B., Robinson, B.H., Nomura, R., Ghomshei, M. and Meech, J.A., 2005. Effect of thioligands on plant-Hg accumulation and volatilisation from mercury-contaminated mine tailings. *Plant and Soil*, 275: 233-246.

Wang, J., Feng, X., Anderson, C.W.N., Qiu, G., Ping, L. and Bao, Z., 2011. Ammonium thiosulphate enhanced phytoextrction for mercury contaminanted soil – results from a greenhouse study. Journal of Hazardous Materials, 186: 119-127.

3.d Research Plan

Location of study

A participatory demonstration study will be conducted in the artisanal mining area of Sekotong, West Lombok, about 30 km south west of the city of Mataram. Ore is mined from hand-dug shafts at a mining area located at 400 m above sea level, and then brought in sacks to small grinding and amalgamation facilities located in towns and communities between the mountains and the coast. After an initial rough hand grind using hammers, diesel engine or water-powered rod mills are used to pulverize the rock. Mercury is added during the final stages of grinding to effect amalgamation. After grinding, the mercury-gold amalgam is strained through a porous cloth. This separates the valuable amalgam from excess mercury. The amalgam is further refined, and the excess mercury used for subsequent grinding. The amalgamation waste rock is then disposed of onto land, streams or the sea, or sold to a cyanidation plant for secondary processing. The residue after cyanidation is disposed of to land or water. The gold product from both processes is sold to the local market.

Demonstration operation for sustainable agriculture

Phytoextraction demonstration plots will be established on amalgamation and cyanidation tailings according to the methods of Anderson *et al*. (2005) and Wilson *et al*. (2011). Plants grown at these plots will remove gold from the ground, remove a portion of the mercury burden from the ground, and stabilize remaining mercury in the tailings through adsorption to developing soil organic matter. Metal removal and stabilization will occur progressively over several years.

Areas for operation will be secured, fertilized to overcome macro- and micro-nutrient deficiencies, quantified for gold and mercury concentration, and planted with various species of cassava (this plant has been selected due to observed ability to grow on tailings in the Sekotong ASGM area). Plot sizes will range from 10 m^2 to 100 m^2 depending on the amount of tailings available.

Plant growth at each plot will be maintained by locally employed project staff. After about 5 months of growth, once above-ground biomass has produced an equivalent yield of 4 t/acre (dry weight), the plot area will be irrigated with chemical fertilizers to change the soil chemistry, and to promote the solubility of gold and mercury for plant uptake. The treatment system will be carefully modeled and managed to ensure metal is accumulated, not leached. Approximately one week after treatment the biomass will be harvested and processed by a contract engineering company to recover the accumulated metals. The gold and mercury concentration of the biomass and tailings will be re-analyzed to quantify changes in metal partitioning within the soil-plant system as a result of the crop cycle. After a fallow period of 1 to 2 months where soil nutrient levels are checked and adjusted, the plot will be replanted and the cropping cycle continued. Four successive crops are expected over the three-year period of the project.

Analytical protocols

Nutrient analysis will be conducted by tIRC-MEDMIND (Malang and Mataram locations) following established protocols. Gold and mercury analysis will be conducted by IRC-MEDMIND under the supervision of the advisory board of the Centre (Chinese Academy of Sciences and Massey University), and with the assistance of the US partner to the project. Training for relevant IRC-MEDMIND technicians will be provided in NZ, China and WSU.

Participatory study

The community aspect of the research will be implemented as a participatory study following the approach of Howeler *et al.* (2004) and Yunawati *et al*. (2010). The key feature of this approach is that community (here farmers and miners) participate in every step and make all important decisions (Figure 1).

After an initial meeting to explain the objectives of the study and to define the interests of farmers, local leaders (community and government), and extension agencies, the project staff (Indonesian, IRC-MEDMIND and collaborators) will visit the community and conduct a Participatory Rural Appraisal (PRA) (Chambers 1994a; 1994b). This activity will be conducted to learn more about the conditions, needs, and daily activities of the miners and/or the farmers, and to diagnose, together with the target audience, the problems that need attention. The specific issue of child labor in ASGM communities will be considered by an independent consultant on child labor issues (Geneva, Switzerland) who has offered to support the project. After prioritizing the problems and possible solutions, miners and/or farmers will be able to contribute to the design of trials they may want to conduct at their own locations.

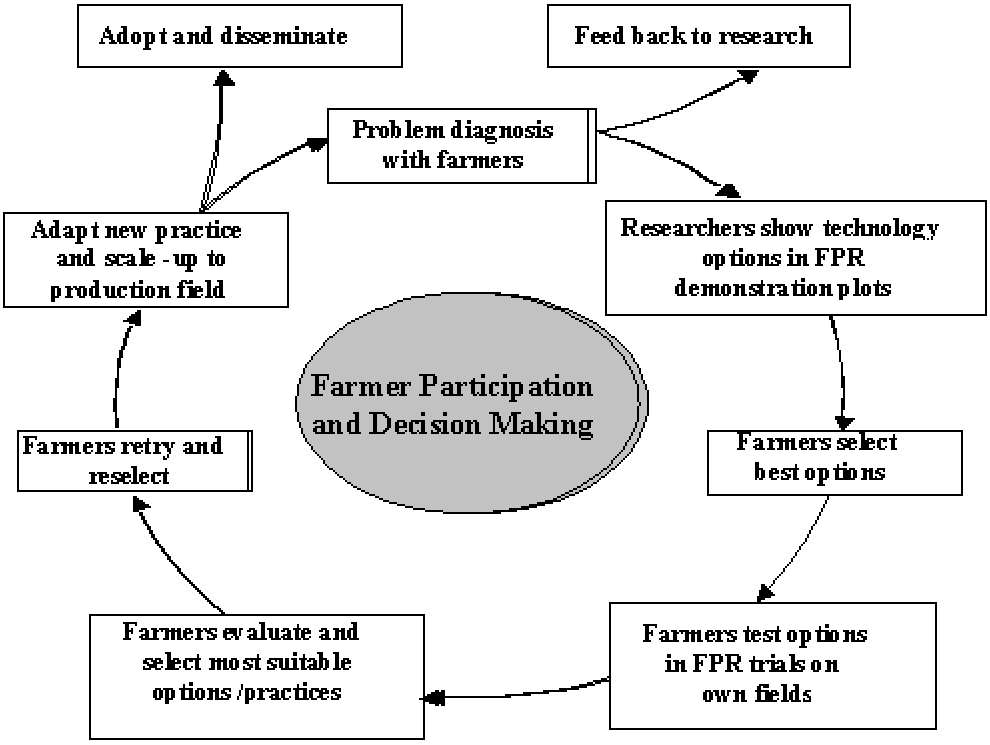

Figure 1. Farmer participatory model used for the development of sustainable agriculture at ASGM areas

Miners and/or farmers who volunteer to join the project will be taken to the demonstration plots established by the research team. Farmers will evaluate and discuss the various treatments being demonstrated and then select those they consider most suitable for their own conditions. Through this process, farmers discuss and decide, while researchers and extension workers help farmers to select reasonable treatments. This is done so that the project staff do not impose their own opinions on the community participants. Once participatory plots are ready for planting, project staff will help the farmers set out the experiments and provide the planting material, seed and fertilizers. Farmers themselves are the owners and managers of the trials, but project staff will visit regularly to discuss and solve any problems that might occur. Project staff will oversee the final stages of the phytoextraction cycle which will involve treatment of the plot areas to promote metal uptake, and harvest of the metal-rich biomass. Project staff will then quantify the metal concentration in the biomass, and pass this onto a contracted engineering company for processing. The eventual aim of the proposed system is to pay the farmers an amount based on the gold concentration of the harvested biomass. During the crop cycles described in this research, a set, pre-determined amount will be paid to the farmers. Up to ten plots (demonstration and participatory) will be established over the project timeframe of three years

Farmer participatory research (FPR) trials will be conducted for two-to-three years until miners and/or farmers have tested and selected the options that work best. The project team expects that farmers from villages not associated first-hand with the project may want to visit participating plots to observe and discuss the benefits of the system subsequent to year one. These farmers may either want to conduct their own FPR trials or to adopt those practices that others have already tested and selected. Such cross-visits between villages is one way to stimulate farmer-to-farmer extension which is often more effective than the traditional extension practices.

Artisanal mining is characterized by a vicious poverty cycle: discovery, migration, and relative economic prosperity are followed by resource depletion, out-migration and economic destitution. After depletion of easily exploitable gold reserves, sites are abandoned, and the miners who remain contend with a legacy of environmental devastation and extreme poverty. These people have little opportunity to escape their circumstances. There is little incentive for the miners to move back to agriculture. The research described in this section will use the concept of farming gold to change the paradox. We seek to achieve this through the cash incentive that would be provided to farmers who grow a crop of metal. The gold revenue from the crop would allow training of the farmers in sound agricultural skills. The final development goal is to see these farmers use these skills to sustainably grow cash crops on suitable (non-mining) community or private land.

Anderson, C., Moreno, F. and Meech, J., 2005. A field demonstration of gold phytoextraction technology. *Minerals Engineering*, 18: 385-392.

Chambers, R., 1994b. Participatory Rural Appraisal (PRA): Challenges, potential, and paradigms. *World Development* 22:1437 -1454.

Chambers, R.,1994a, The origins and practice of participatory rural appraisal. *World Development* 22: 953-969.

Howeler,R..H., Watananonta, W., Wongkasem, W. and Klakhaeng, K., 2004. Working with Farmers: The Challenge of Achieving Adoption of More Sustainable Cassava Production Practices on Sloping Land in Asia. *In* Proc. International Conference on Innovative Practices for Sustainable Sloping Land and Watershed Management, Chiangmai. Thailand. Sept 5-9, 2004.

Wilson-Corral V.; Anderson, C.; Rodriguez-Lopez, M.; Arenas-Vargas, M.; Lopez- Perez, J., 2011. Phytoextraction of gold and copper from mine tailings with *Helianthus annuus* L. and *Kalanchoe serrata* L. *Minerals Engineering,* 24: 1488-1494.

Yunawati, E.D., Irawanto, D.W., Utomo, W.H., Basuki, N. and Howeler, R.H. 2011. Land husbandry, a better approach for sustainable cassava production: 1. Farmers' based technology development: the main key of land husbandry. *International Journal of Applied Agricultural Research* (in press).

3.e Training and Outreach Plan

The PRA approach and participatory research model has an inherent component of farmer training. This will be a central theme to the proposed research, where university staff from the Faculty of Agriculture at Brawijaya and Mataram Universities (IRC-MEDMIND) upskill ASGM communities with modern agricultural skills including crop selection, crop husbandry, fertilizer recommendations and strategies, and promote agricultural opportunities. This training will occur under the guidance of the US collaborator and the scientific advisory committee of the Centre.

Five postgraduate research students from Brawijaya and Mataram Universities will be recruited to monitor aspects of the research throughout the three-year project. These students will have the opportunity to contribute to a world-class project and interact with the US collaborator, as well as members of the international scientific advisory committee of IRC-MEDMIND. Pure science and social-science undergraduate students from Mataram University will participate in the project through focused modules that contribute to their studies (e.g. study of the PRA framework for research, GIS mapping, soil chemistry, analytical chemistry, toxicology of mercury).

The project team will run regular open days to advertise the objectives, results and successes of the research to interested parties who may include representatives of NGOs active in Indonesia, as well as government organizations.

IRC-MEDMIND, as the host organization for the project, will run an annual conference on the ‘environmental, socio-economic, and health impacts of artisanal and small scale mining’. The inaugural conference is scheduled to be held on Feb 7-8 2012 in Malang, Indonesia. The set objective of this conference is ‘to learn of recent ASGM activity trends and to share experiences and knowledge of research work among scientist, industry, community, and policy makers; and to discuss the direction of future collaborative research into the management of ASGM’. This conference will be an annual opportunity to share the findings and experiences of the research to a government, non-government, public and scientific audience.

3.f Role and Responsibilities of U.S. Collaborator

Dr. Beutel has an active five-year (2009-2014) NSF grant in which he is evaluating mercury cycling in natural lakes on the Colville Indian Reservation in eastern Washington State. Dr. Beutel has a fully operative mercury laboratory at WSU that can measure total and methylmercury in water, sediments and plant tissues. Another key component of his NSF grant is to perform outreach to American Indian middle and high school students with the goal of recruiting these under-represented students into BS programs in science and engineering. Through this research and outreach effort, Dr. Beutel brings combined and unique strengths in a fundamental understanding of mercury cycling in the environment, mercury analytical skills and capabilities, and experience in mercury-related outreach to a resource limited outreach audience. He will therefore bring valuable skills and perspective to the planned ASGM participatory research.

Dr. Beutel will play the broad role of project advisor/assistant; this is meant to be a "two-way" role in which all parties involved will share their knowledge base, capabilities and ideas with each other regarding the project. More specifically, Dr. Beutel will host two scientists from the IRC-MEDMIND at WSU in years 1 and 3 of the project. These scientists will be trained in mercury analysis techniques in the WSU mercury lab and assist Dr. Beutel's graduate students with mercury related research and field work. Cost for travel, lodging and per diem for the scientists will be covered by the PEER grant. The length and extent of activities on these visits to WSU (as described in Section 3j) will be increased pending the availability of supplemental funds from Indonesia. Dr. Beutel will also provide analytical support on mercury analyses as needed for the project. This could include analysis of 5-10 monthly quality control samples to confirm the accuracy of analysis in the IRC-MEDMIND labs.

Presuming funding can be garnered from the National Science Foundation as a supplement to his current mercury-related grant, Dr. Beutel and a graduate student will spend 2-3 months at the IRC-MEDMIND in years 2 and/or 3 to work with project stakeholders. Dr. Beutel will bring his mobile Milestone DMA 80 mercury auto-analyzer on this trip to enhance the local stakeholders' opportunities for training and analysis related to mercury contamination and cycling in the study region of West Nusa Tenggara. This will also provide Dr. Beutel with the invaluable opportunity to meet project stakeholders face to face and to see the project area firsthand. He will also work with project stakeholders to disseminate project results through timely publication in peer reviewed journals and international conferences, such as the upcoming Mercury 2013 conference (ICMGP) in Edinburgh, Scotland.

Based on the relationships built through this effort, Dr. Beutel hopes to develop additional research and outreach programs funded through US and international agencies.

3.g Expected Development Outcomes

The research described in this proposal will contribute directly to USAID's interests and objectives in Indonesia. Increased agricultural production and associated economic growth through the diversification of agriculture in WNT province will contribute to the USAID Country Strategy designed to diminish Indonesian poverty. The location of the proposed research (WNT Province) is characterized as having a higher percentage of the population living on less than $2 a day than more developed parts of the archipelago. The revitalization of small-holder agriculture to produce and to market cash crops from ASGM mining areas will lead to increased employment and revenue flows in this area. This will be facilitated by an expansion of research and extension services available to the local community.

The proposed research will contribute to specific areas where U.S. and Indonesian development interests converge: higher quality basic (applied) education, in this case for ASGM communities; development of capacity of the Indonesian university consortium that hosts the IRC-MEDMIND to resolve tough development problems in ASGM areas (development supported by affiliation with Washington State University and the international scientific advisory board of the Centre), and increased employment. The role of young people in agriculture will be given special consideration, and opportunities for education leading to meaningful employment will be considered with the help of a private consultant for child labor issues (Geneva, Switzerland).

A final goal of the research is to stimulate the interest of private enterprise to manage the phytoremediation of ASGM mine tailings as a viable business at the end of the research project. Re-investment by the private sector and continued research and extension support to the business by local providers will lead to continual increases in agricultural productivity and new agri-business and horticultural opportunities.

3.h Data Sharing and Dissemination Plan

Project results will be communicated to the international scientific community through the annual conference, and will be published in relevant scientific journals. The academic integrity of the work will be verified by the scientific advisory committee of the IRC-MEDMIND prior to the submission of manuscripts for publication.

The results of the research will be actively promoted to district, province and national governmental agencies at informal events to be held through the year and at each annual IRC-MEDMIND conference. A more significant international conference will be held during the final month of the proposed research-period to present final conclusions and recommendations for roll-out of the project.

A periodic international mercury conference (International Conference on Mercury as a Global Pollutant) not run by IRC-MEDMIND will also be targeted to communicate the results of the work to an international audience. The next conference will be held in Edinburgh, Scotland in late July/early August 2013. Each conference will provide an opportunity for the participating Indonesian scientists to network with an international audience.

3.i Timeline

1 Mar 2012 – 30 Jun 2012: project team briefing, demonstration plot construction, PRA, initial farmer selection, initiation of farmer training

1 Jul 2012 – 31 Jan 2013: demonstration crop cycle 1 farming, harvest, analysis and fallow

period (5 month crop with 2 month fallow period)
1 Feb 2013 – 31 Aug 2013: demonstration crop cycle 2 farming, harvest, analysis and fallow period (5 month crop with 2 month fallow period). Provision of extension support to new farmers joining the PRA program
1 Sep 2013 – 31 Mar 2014: demonstration crop cycle 3 farming, harvest, analysis and fallow period (5 month crop with 2 month fallow period). Provision of extension support to new farmers joining the PRA program
1 Apr 2014 – 31 Oct 2014: demonstration crop cycle 4 farming, harvest, analysis and fallow period (5 month crop with 2 month fallow period). Provision of extension support to new farmers joining the PRA program
1 Nov 2015 – end Feb 2015: project conclusion, reporting, final presentation and negotiation for roll-out

3.j Budget Request Justification

Domestic travel (year 1):

air ticket: 12 return trips Malang-Mataram: 6 trips for each of 2 staff @ $150/trip	$1,800
car rental for Malang staff during each site visit: 3 days/visit, 6 visits per year @ $50/day	$900
car rental for Mataram staff: 10 days/crop cycle, 2 cycles per year @ $50/day	$1,000
per diem Malang staff: 2 nights each of 6 visits for each of 2 staff [total 24 nights] @ $75/night	$1,800
per diem Mataram staff: 40 days of site visits for each of 2 staff [total 80 days] @ $40day	$3,200

Budget entries are increased 5% on year 1 values in year 2, and a further 5% in year 3 to cover inflation.

International travel (costs for each country; year 1)

	Airfare (including visa fees and insurance)	Per diem
New Zealand	$1,800	$100
China	$1,000	$100
USA	$2,500	$200

The international travel for year 3 is increased by 10% on year 1 to account for inflation. For schedule of trips see 3k.

Equipment costs (annual)

Small equipment, such as Hg analyzer components (Malang and Mataram), glassware, meters and probes will be purchased annually	$ 5,000 yr 1 $ 2,500 yr 2 $ 1,500 yr 3
Annual budget for materials and supplies (chemicals, fertilizers, seeds etc)	$ 4,500 yr 1 $ 4,000 yr 2 $ 4,000 yr 3

Other direct costs (annual)

Computer services (PC, printer, cartridge, papers)	$ 1,500 yr 1 $ 500 yr 2 $ 500 yr 2
Publication costs: 2 publications year 1, 3 year 2 and 5 year 3 @ $600 per publication to cover professional editing and page charges	$ 1,200 yr 1 $ 1,800 yr 2 $ 3,000 yr 3
Allowance for annual workshop, conference and farmer training events	$ 7,500 yr 1 $ 7,500 yr 2 $10,000 yr 3
External analytical costs: annual budget for Hg and Au analysis in NZ and China Costing is at $20 per sample	$ 2,000 yr 1 $ 4,000 yr 2 $ 2,000 yr 3

Salaries and stipends (annual: costs presented are year 1)

Field assistance (two full-time positions): each 12 months @ $150/month	$3,600
Extension worker (one 50% position): 6 months @ $250	$1,500
Laboratory technicians (one 50% position): 6 months @ $250/month	$1,500
Field workers (budget set to days of work per year) 200 days/crop cycle for 2 crop cycles/year @ $ 7.5/day [total per year is 400 days]	$3,000
Budget allocation to provide a further incentive to the first farmers who join the project: 3 farmers @ $500/farmers	$1,500

Budget entries are increased 5% on year 1 values in year 2, and a further 5% in year 3.

3.k Travel Details

Domestic travel:
Staff from IRC-MEDMIND (Malang) will travel to the Lombok field site three times per crop cycle to oversee planting, monitoring and harvest. Travel will be via direct flight Malang to Mataram.
Each visit to the field site will comprise three days and will utilize a rental vehicle from Mataram airport. IRC-MEDMIND staff from Mataram will join with staff from Malang during each visit.
There will be additional site visits made by IRC-MEDMIND (Mataram) staff each requiring a rental car.

International travel:
During each year of the project an appropriate IRC-MEDMIND staff member will travel to New Zealand to learn protocols for gold analysis of plants and soil at Massey University (20 days in NZ). Analytical protocols will subsequently be adopted at IRC-MEDMIND (Malang and Mataram). Annual trips will allow for additional training in years two and three.
During the second year of the project an appropriate IRC-MEDMIND staff member will travel to China to review advanced protocols for methylmercury (Me-Hg) analysis in plant tissues (20 days in China).
A scientist from IRC-MEDMIND will travel to Pullman, USA at the beginning of the project to facilitate further development of the IRC-MEDMIND – WSU link, and to receive analytical training under the supervision of Dr. Beutel. A second trip is scheduled during the final phase of the project to facilitate additional training and final reporting (10 days each trip).

3.l Other Funding and Other Collaborating Institutions (If Any)

The following institutions and individuals will collaborate with the described research:
Dr. Christopher Anderson, Senior Lecturer in Soil Science, Massey University, New Zealand
Ms. Halshka Graczyk, private consultant for child labor issues, Geneva, Switzerland
No funding from the PEER project will be allocated to these two collaborators.

Funding committed to IRC-MEDMIND

1.Brawijaya University (salary of relevant staff, general project travel, office requirements)	US$ 75,000
2.Mataram University (salary of relevant staff, general project travel)	US$ 15,000

Funding for IRC-MEDMIND under negotiation:

1. Ministry of Energy and Mineral Resources (Indonesia)	US$15,000
2. New Zealand Aid Programme Head of Mission Fund:	US$30,000

3.m Budget

Project Title: Alternative livelihoods in artisanal gold mining areas of West Nusa Tenggara (WNT) Province, Indonesia.

Note: List all amounts in U.S. dollars only		**Year 1**	**Year Two (if requested)**	**Year Three (if requested)**	**Project Total**
Travel	1. Domestic Travel	3,700	3,885	4,400	11,985
	2. Per Diem, Domestic	5,000	5,250	5,500	15,750
	3 International Travel	4,300	2,800	4,730	11,830
	4. Per Diem, International	4,000	4,000	4,400	12,400
Travel Costs Total (A)		17,000	15,935	19,030	51,965
Equipment	1. Instruments	5,000	2,500	1,500	9,000
	2. Materials and Supplies	4,500	4,000	4,000	12,500
Equipment Costs Total (B)		9,500	6,500	5,500	21,500
Other Direct Costs	1. Computer Services	1,500	500	500	2,500
	2. Publication Costs	1,200	1,800	3,000	6,000
	3. Workshops and conferences	7,500	7,500	10,000	25,000
	4. External analytical costs	2,000	4,000	2,000	8,000
Other Direct Costs Total (C)		12,200	13,800	15,500	41,500
Salaries and Stipends (list each position on separate line and indicate % of time to be spent – add more lines if needed)	- Field assistance (2 full time positions)	3,600	3,780	3,960	11,340
	- Extension worker (1 full time position contracted six months per year)	1,500	1,575	1,650	4,725
	- Laboratory technician (1 full time position contracted six months per year)	1,500	1,575	1,650	4,725
	- Field workers (400 days of field work each year)	3,000	3,150	3,300	9,450
	Farmer participants (positions created for 3 farmers per year)	1,500	1,575	1,650	4,725
Labor Costs Total (D)		11,100	11,655	12,210	34,965
Institutional Indirect Costs (if requested, full justification must be provided) (E)		-	-	-	
Grand Total Project Costs (F) (A+B+C+D+E)		$ 49,800	$ 47,890	$ 52,240	$ 149,930

Additional Required Attachments

- **Curricula Vitae:** Please attach brief CVs, no more than two pages each, for the principal investigator and any other key project participants at his or her institution. Each individual's CV should provide citations for no more than 5-10 recent relevant publications. Please do not submit electronic copies of publications or other background materials, as they will not be forwarded to reviewers.

- **Letter of support from U.S. collaborator:** The letter must be written on official institutional letterhead and must list the title and award number of the U.S. collaborator's active NSF grant, provide details on how the proposed project relates to this NSF grant, and explain the U.S. collaborator's expected role in the project. **The letter must be signed by the U.S. collaborator.** If the project is selected to receive PEER funding, the U.S. collaborator will also be required to submit a letter of support signed by an official at his or her institution who is authorized to commit the institution to involvement in the project. However, it is not necessary to include the U.S. institution's support letter in the proposal submission.

- **Letter of support from an official at the principal investigator's institution who is legally authorized to make commitments on the institution's behalf:** If your project involves more than one developing country institution, please submit a separate support letter from each. The letter must be written on official institutional letterhead and must include the following elements:

    1. Confirmation that the institution supports the participation of its staff in the proposed project, would be willing to receive and administer any grant funds awarded, and would be permitted under local regulations to receive grant funds from a foreign sponsor

    2. A brief description of the institution's structures and practices for project management and financial oversight, as well as a description of the process by which the institution could receive grant funds from a foreign sponsor

    3. A brief description of resources that the institution would be making available (if any) to facilitate the project, whether in cash or in kind, for example by paying the salary of the principal investigator or other staff for the time he or she works on the project, providing substitute instructors to cover the principal investigator's teaching duties so he or she is free to work on the project, or providing laboratory or office space, access to equipment, or office support staff

    4. Examples of other grants your institution has received from foreign sponsors (if any), including the project title, sponsoring organization's name, amount, dates, and name and e-mail of contact person at the sponsoring organization

PARTNERSHIPS FOR ENHANCED ENGAGEMENT IN RESEARCH (PEER)

PROPOSAL CHECKLIST

Please review your proposal carefully before submitting it to ensure that you have all the following components. Incomplete proposals will not be reviewed. Please submit this completed checklist as part of your proposal.

- ☐ **Proposal cover sheet has been signed by the principal investigator and an authorized official representative of his or her institution.** **YES**

- ☐ **Proposal cover sheet includes the name of the proposed U.S. partner and lists the title and award number of his or her active NSF grant.** **YES**

- ☐ **Proposal summary (section 2) does not exceed one page.** **YES**

- ☐ **The combined length of sections 3.a through 3.l does not exceed 10 pages.** (Although proposals exceeding this page limit are not permitted, proposals in which sections 3.a through 3.l are extremely brief—only one or two pages in total—are also highly unlikely to be successful.) **YES**

- ☐ **Section 3.j includes full explanations and justifications of all budget line items.** (Make sure to explain the role of each position for which salary or stipend support is requested, including the percentage of time each would spend on the project. Applicants are urged to ensure that their cost estimates for major equipment items to be purchased are accurate, as documentation will be required before the grant is issued. If indirect costs are requested, an explanation of what these costs cover must also be included.) **YES**

- ☐ **Budget table in section 3.m is complete, including cost information for each year of the proposed project if it will last more than one year.** (If the project includes more than one developing country institution, please include a separate budget table showing funds requested by each.) **YES**

- ☐ **Brief curricula vitae are attached for the principal investigator and any other key project participants.** **YES**

- ☐ **Signed letter of support from the U.S. partner is attached.** **YES**

- ☐ **Signed letter of support from an authorized official at the principal investigator’s institution is attached (along with official support letters from other participating developing country institutions, if any).** **YES**

CURRICULUM VITAE

1. **Name**	:	Prof.Dr.Ir.Wani Hadi Utomo
2. **Place and date of birth**	:	Lamongan, 4 December 1949
3. **Employment**	:	Profesor at Brawijaya University, Malang, Indonesia
4. **Specialization**	:	Agriculture/Soil conservation and management
5. **Address (Office)**	:	Fac. of Agriculture Brawijaya University, Jl. Veteran, Malang, Indonesia 65144
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Phone	:	+62-341 – 552744; Mobile: +628124949097
E-mail	:	hadi_utomo@hotmail. com
7. **Education**	:	

a. Brawijaya University, Malang, Indonesia: 1974 (Agricultural Engineer)
b.University of Adelaide, Australia: 1981 (PhD in Soil Science)

8. International training

a.The Use of Isotope for Soil- Plant Study, IAEA, Wina 1990
b. Farmer Participatory Research. CIAT – Asia Office, Rayong (Thailand) 1994

9. Experiences in Agricultural Development, consultation and research cooperation:

a. In partnership with National Agency:

1. Development and Resettlement of Transmigration in Sumatera and Kalimantan (Dept. of Transmigration: 1982-1983).
2. Soil erosion control and conservation in Brantas watershed area (Dept. Public Work/River Brantas Development Project: 1983-1991)
3. Land development for oil palm plantation in Sungai Kampar and Sungai Buatan regency, Sumatera (Dept. of Agriculture/ADB: 1984-1985).
4. Potential development of critical land in forest area for agriculture (Dept. of Forestry/Forestry Estate: 1985-1991).
5. Crop management for sustainable agriculture (Dept. of Agriculture: 1990-1993)
6. Base study for development of community forestry in East Java (Dept. of Forestry/BRLKT VI: 1996-1997)
7. Community development and empowerment in Wonogiri Dam (Dept of Public Work/Bengawan Solo Development Project: 2003).

b. In partnership with International Agency

1. Cassava based cropping system in East Java (International Development Research Centre, Canada: 1985 – 1987)
2. Nitrogen management for food crops in tropical soils (Economic European Community – Institute for Soil Fertility, The Netherlands: 1987-1990).
3. Erosion control and soil conservation in cassava based cropping system. (CIAT, Asia office: 1986 – 1996)
4. Management of clay soil for rain fed lowland rice based cropping systems. (ACIAR ,Australia: 1991 – 1995
5. Farmer's participatory research in soil management (CIAT Asia Office Nipon Foundation: 1995 – 1998)
6. Enhancing the Adoption of Improvement Cassava Production and Utilization System in Indonesia and East Timor (CIAT –ACIAR: 2005 -2008)

7. Risk assessment and rehabilitation of mine lands in Lombok, Indonesia (NZAid in collaboration with Massey University: 2011).

10. International conference/seminar/workshop:

1. Utomo, W.H., and Marmer, T. and Islami, T. 1996. Effect of organic matter on agrochemical lost agricultural soil. 9 th Cont. Of the ISCO. Bonn, Germany.
2. Utomo, W.H. and Islami, T.1998. Farmer empowerment in the dissemination of soil conservation technology. 10 th Conf. ISCO, Purdue, USA,
3. Utomo, W.H. and Heru Santoso 2000. Implementation of FPR in cassava technology transfer. VI ASIAN Cassava Research Workshop. IAS – CIAT, Ho Chi Minh City, Vietnam, 2000.
4. Utomo, W.H, Wargiono, J, and Islami, T. 2006. Cassava production and Utilization in Indonesia, and the strategy for improvement. 14th triennial ISTRC. CTCRI, Symposium, Trivandum, India.
5. Utomo, W.H. 2008. Enhanching of Cassava Production in Indonesia. ASIA Regional Cassava Workshop. Vientaine, Laos.

11. Recent Publications:

1. Masulili, A., Utomo, W.H. and Syekhfani Ms. 2010.Rice husk biochar for rice based cropping system in acidic soils: The characteristics of rice husk biochar and its influence on the properties of acid sulfate soils and rice growth in West Kalimantan, Indonesia. J. of Agric. Sci. (Canada) 2: 39-47
2. Prasetyo, B., Krisnayani, B.D. and Utomo, W.H. 2010. Rehabilitation of artisanal mining gold land in West Lombok, Indonesia 2. Arbuscular mycorrhiza status of tailings and surrounding soils. J. of Agric. Sci. (Canada) 2 :202-209.
3. Widjajani, B.W., Wisnubroto, E. I., Sukresno and Utomo, W. H. 2011. The sustainability of teak forest management in Cepu, Central Java, Indonesia: A soil resources point of view. J. Basic Appl. Sci. Res. 2011 1(9): 1207-1213.
4. Islami, T., Utomo, W.H. and Guritno, B. 2011. Performance of cassava based cropping systems and associated Soil quality changes in the degraded tropical uplands of East Java, Indonesia. J. Trop. Agric. 49: 31-39
5. Sukartono, Utomo, W.H., Kusuma, Z. and Nugroho, W.H. 2011. Soil fertility status, nutrient uptake, and maize (*Zea mays* L.) yield following biochar application on sandy soils of Lombok, Indonesia. J. of Trop. Agric 49: 47-52
6. Yuniwati, E.I., Irawanto, D.I., Utomo, W.H. and Howeler, R. 2011. Land husbandry for sustainable cassava production : 1. Farmers based technology development; the main key of land husbandry. International Journal of Applied Agricultural Research (accepted to be publish).
7. Indrayatie, E.R., Utomo, W.H., Handayanto, E. and. Anderson, C.W.N. 2012. The Use of Vetiver (*Vetivera zizanoides* L.) for the Remediation of Wastewater Discharge from Tapioca Factories". Int. J. Environment and Waste Management (accepted to be publish)
8. Siswanto, B., Krisnayani, B.D. Krisnayani, Utomo, W.H. and Anderson, C.W.N. 2012. Rehabilitation of artisanal gold mining land in West Lomok, Indonesia: 1. Characterization of overburden and the surrounding soils. Journal of Geology and Mining Research (accepted to be publish).

Malang, 7 November 2011..
Wani Hadi Utomo.

CURRICULUM VITAE

1. Personal Identity

Name : **Eko Handayanto**
Place & Date of Birth : Madiun, 5 March 1953
Office Address : Department of Soil Science, Faculty of Agriculture, Brawijaya University
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Telp No : +62341-553623
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2. Education Background

(a) Degree

- Bachelor of Agricultural Science (Soil Science), Brawijaya University, Malang, 1977
- Master of Science (Soil Science), University of Adelaide, Australia, 1983
- Doctor of Philosophy (Soil Biology), Imperial College, University of London, UK., 1993

3. Research Experience and Assignments (since 2000)

(a) Research

1. 2000 *Team Leader:* Evaluation of Reforestation Strategy in Nganjuk Regency of East Java, Indonesia. Funded by Nganjuk Regencial Board of Forestry
2. 2000-2003 *Team member*:: Empowerment of local flora as sources of organic matters for remediation of soil fertility in dry land area of Brantas watershed, East Java. Funden by Indonesian Research Council
3. 2007 *Team member*:: Diversity of soil fauna as bio indicator of saline soil quality Funded by DGHE, Indonesia.
4. 2007 *Team member*:: Mass production of combined entomopathogen nematode bio pesticide, solubilizing bacteria bio fertilizer and humic substance for improving yield and quality of soybean. Funden by Ministry of Research and Technology, Indonesia.
5. 2009 *Team member*:: Optimation of an acid mineral soil productivity for improving soybean yield through detoxification of aluminum and desorption of phosphate by combined humic substance and phosphate-solubilizing bacteria. Funded by Ministry of Research and Technology, Indonesia.
6. 2009 *Team member*:: Phytostabilization potential of indigenous vegetation for gold mine tailing. Funded by DGHE, Indonesia.
7. 2011 *Team member*:: Improvement of maize yield on land contaminated by gold mine tailing containing mercury using phytomining method. Funden by PT Indofood, Indonesia

(b) Assignments

1978-2011	Permanent lecturer at Brawijaya University, Malang, Indonesia
1994-2005	Head of Soil Biology Laboratory, Department of Soil Science, Brawijaya University, Indonesia
1998-2011	Consultant for NGO Citra Borneo Lestari, Central Kalimantan
2000-2011	Reviewer for Research Proposals granted by Directorate General for Higher Education (DHGE), Ministry of National Education, Indonesia
2004-2010	Reviewer for Competitive Infrastructure Grants A-2 / A3 / TPSDP/ PHk-I, Higher Education Council, Ministry of National Education, Indonesia
2004-2011	Research Evaluator: Bogasari Nugraha and Indofood Riset Nugraha (PT Indofood Sukses Makmur Tbk) Jakarta, 2004- at present
2007	Member of Sinergy Team; Bureau of Overseas Collaboration, Secretariat General of Ministry of National Education, Indonesia
2008-2010	Research Proposal Evaluator P2KPT. Agency for Research and Development, Ministry of Agriculture, Indonesia
2011	Director of International Research Centre for Management of Degraded and Mining Lands (IRC Medmind), Malang, Indonesia (a research collaboration between Brawijaya University, Indonesia-Mataram University, Indonesia, Massey University, New Zealand, Institute of Geochemistry, Guiyang, China)

4. Publications

2006	Purwanto, Handayanto, E., Suprayogo, D., and Hairiah, K. (2006). Impact of land use change from forest to coffee agroforestry on nitrification levels: Population and activity inventory of nitrifying bacteria. *Agrivita* 28: 267-285. *(in Indonesian)*
2006	Sugito, Y., Handayanto, E. and Murniyanto, E. (2006). Leaf activity, growth and solar energy efficiency of Edible Arroids tube cops under shades. *Habitat* 28: 1-7. *(in Indonesian)*
2007	Minardi, S., Suntoro, Syekhfani, and Handayanto, E. (2007). Roles of humic and fulvic acids from organic matter in releasing adsorbed P in an Andisol. *Agrivita* 29: 15-22. *(in Indonesian)*
2007	Handayanto, E. dan Hairiah, K. (2007). Soil Biology: Basic for Management of Healthy Soils (in Indonesian): Book. Publisher Pustaka Adipura, Yogyakarta; 198pages ISBN978979-17163-0-7
2010	Handayanto, E. and Sholihah, A. (2010). Nitrogen mineralization by maize from previously added legume residues following addition of new legume residues using ^{15}N labelling technique. *Journal of Tropical Agriculture 48 (1-2) : 23-27.*
2010	Setiawati, T.C. and, Handayanto, E. (2010). Role of Phosphate Solubilizing Bacteria On Availability Phosphorus In Oxisols And Tracer Of Phosphate In Corn By Using ^{32}P. Presented at The 19th World Congress of Soil Science to be held in Brisbane, Australia, 1 - 6 August 2010.
2010	Wahyudi, I., Handayanto, E., Syekhfani and Utomo, W.H. (2010). Humic and fulvic acids of *Gliricidia* and *Tithonia* composts for aluminium detoxification in an Ultisol. *Agrivita Journal of Agricultural Sciences. Vol 32 (3): 216-224.*
2011	Winarso, S., Handayanto, E., Sulistyanto, D. (2011). Effects of humic compounds and phosphate-solubilizing bacteria on phosphorus availability in an acid soil. *Journal of Ecology and the Natural Environment Vol. 3(7), pp. 232-240*

Malang, 22 November 2011

Eko Handayanto

CURRICULUM VITAE

Personal Details:

Name : Baiq Dewi Krisnayanti
Date of birth : Mataram, 10th January 1970
Institution : Soil Department, Agriculture Faculty, Mataram University, Indonesia
Office address : Jl. Majapahit 62 Mataram 83125, Indonesia
Home address : Jl. Ciamis A-12 Taman Indah, Mataram 83127, Indonesia
Email : bqdewi@yahoo.com

Education:

1. PhD in Soil Physics and Science, Lincoln University, New Zealand, 2010
2. Masters of Soil Science, Brawijaya University, Indonesia, 1996
3. BSc in Soil Science, Mataram University, Indonesia, 1994

Research/projects:

1. Improving corn production through pytomining on land contaminated mercury in Artisanal Gold Mining site, 2011 (on-going).
2. Study of mercury concentration on Lantung artisanal mining area, Sumbawa, Indonesia, 2011.
3. Assessment of biogeochemical mercury cycling: Sekotong artisanal mining area, Lombok, Indonesia, 2011 (on-going)
4. A sustainable restoration method for gold mine sites, 2009
5. Using organic matter for tobacco growth, 2003
6. The effect of using compost with activator and soil pathogen inoculation for peanut disease, 2003
7. Implementation of agroforestry and integrated farming system through involving of community, 2002
8. Model of natural resources management for local in East Indonesia, 2002
9. Land use plan of Sumbawa district, 2001
10. Application of organic matter for vegetable, 2001
11. Reef check Lombok, 2001
12. Reef check Bali, 2000
13. Development of soil strength in paddle soil, 2002
14. Study for improvement of irrigation management and empowerment of water use association for enhancement of turnover program, 2000
15. The effect of rice field cultivation on vertisol, 1996

Publications:

1. Rehabilitation of Artisanal Mining gold land in West Lombok, Indonesia: 2. Arbuscular mycorrhiza status of tailings and surrounding soils. *Journal of Agricultural Science :* Vol. 2, No. 3: 56-63, 2010.
2. The effect of using compost with activator and soil pathogen inoculation for peanut disease. Journal of Agronomy, Technology and Social: Vol. 13, No. 2, 2003.
3. The impact of land cultivation on vertisol nature in Lombok. Journal of Agronomy,

Technology and Social: Vol. 8, No. 1, 1998.

Teaching / training:

1. Geology and mineralogy, 2002-2004
2. Introduction of geography information system and system of land evaluation, 2002-2004
3. Cartography, 1998-2004
4. Geomorphology and landscape, 1998-2004
5. Application of hydroponic technology for cities agrobusiness development, 2001
6. Entrepreneurship, 2001
7. Coral reef training for trainer, 2000
8. Remote sensing for young academic lecturer, 1999

Conferences:

1. Indonesia Mining Society Annual Conference, Indonesia, 2011
2. The 40th Association of Indonesian Geologist Conference, Indonesia, 2011
3. The 39th Association of Indonesian Geologist Conference, Indonesia, 2010
4. Indonesia Mining Society Annual Conference, Indonesia, 2010
5. Australia Clay Mineralogy Society Conference, Brisbane, Australia, 2010
6. Soils conference NZ-Australia, Palmerston North, New Zealand, 2008
7. Soils conference, Rotorua, New Zealand, 2005
8. The 32th Association of Indonesian Geologist Annual convention, Indonesia, 2003
9. The 10th Scientific meeting of remote sensing association, Indonesia, 2001
10. Agribusiness for agriculture and animal husbandry, Indonesia, 1999
11. Biodiversity, Indonesia, 1998
12. International conference on water quality and waste treatment, Indonesia, 1998

Organisation:

1. Member of Association of Indonesia geologist, 2003-present
2. Member of Australian Clay Mineralogy Society, 2010-present
3. Member of Soil Science Association of New Zealand, 2005-2010
4. Rinjani Diving Club

Mataram-Indonesia, November 2011

Dr. Baiq Dewi Krisnayanti
Soil Department, Agriculture Faculty
Mataram University, Indonesia
Email: bqdewi@yahoo.com
Mobile: +62 818 0671 6446

CURRICULUM VITAE

Personal Details:

Name : Professor Xinbin Feng
Institution : Institute of Geochemistry, Chinese Academy of Sciences
Office address : State Key Laboratory of Environmental Geochemistry, 46 Guanshui Road, Guiyang, China
Email : **fengxinbin@vip.skleg.cn**
Telephone : 0086 851 5891356

Education:

1. Ph. D., Environmental Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences (CAS) 1997
2. M.S., Environmental Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences (CAS) 1994
3. B. Sc., Geochemistry, China University of Geosciences (Wuhan) 1988

Professional positions held

From 2006 Vice director to State Key Laboratory of Environmental Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences

From 2000 Professor, State Key Laboratory of Environmental Geochemistry, Institute of Geochemistry, Chinese Academy of Sciences

2001-2002 Visiting professor, Department of Chemistry, Biology and Chemical Engineering, Ryerson University, Toronto, Canada.

1997-2000 Post-doctorate fellow at the Department of Inorganic Chemistry, Gothenburg University, Sweden.

1998-1991 Assistant Engineer at the Environmental Protection Research Group, Hubei Geology and Mineral Resource Bureau, Wuhan, Hubei Province.

Present research/professional speciality

My research interests focus on the biogeochemical cycling of heavy metals, such as mercury, cadmium and lead in the environment and human health impacts. Currently my group is studying mercury biogeochemical cycling in newly built reservoirs in Wujiang river and its environmental impacts; mercury transport, transformation, and accumulation in the environment of mercury contaminated sites such as mercury mining areas, gold mining areas, and zinc smelting areas; long range transport of mercury in the atmosphere; human exposure of mercury and health impacts in mercury mining areas and remediation of mercury contaminated sites. We are also investigating the cycling of Cd and Pb in artisanal zinc smelting areas in Guizhou, South western China.

Professional distinctions and memberships

2010 Steering committee member of the 10th International Conference on Mercury as a Global Pollutant
2009 Chair of the 9th International Conference on mercury as a global pollutant
From 2006 Editorial member of the journal of Science of the Total Environment

2007 International committee member of the 7th International conference on biogeochemistry of trace elements in the environment

2006 Steering committee member of the 8th International conference on mercury as a global pollutant

2004 Steering committee member of the 7th International conference on mercury as a global pollutant

Current Referee: Environmental Science and Technology, Environmental Pollution, Applied Geochemistry, Science of the Total Environment, Journal of Geophysical Research, Tellus, Chemical Geology

Publications

Meng B., Feng X.*, Qiu G., Cai Y., Wang D., Li P., Shang L., Sommar J., Distribution patterns of inorganic mercury and methylmercury in tissues of rice (Oryza sativa L.) plants and possible bioaccumulation pathways. *Journal of Agriculture and Food Chemistry,* 2011 (in press)

Zhang H., Feng X*., Larssen T., Shang L., Li P., Bio-accumulation of Methylmercury versus Inorganic Mercury in Rice (Oryza sativa L.) Grain. *Environmental Science and Technology*, 2011, 45(7): 2711-2717.

Fu X., Feng X*., Dong Z., Yin R., Wang J., Yang Z., Zhang H., Atmospheric total gaseous mercury (TGM) concentrations and wet and dry deposition of mercury at a high-altitude mountain peak in south China. *Atmospheric Chemistry and Physics*, 2010, 10: 2425-2437.

Lin CJ, Pan L, Streets DG, Shetty, S. K., Jang, C., Feng, X*., Chu, H. -W., Ho, T. C., Estimating mercury emission outflow from East Asia using CMAQ-Hg. *Atmospheric Chemistry and Physics*, 2010, 10(4): 1853-1864.

Lin Y., Larssen T., Vogt R. D., Feng X*., Identification of fractions of mercury in water, soil and sediment from a typical Hg mining area in Wanshan, Guizhou province, China. *Applied Geochemistry,* 2010, 25 (1): 60-68.

Li P., Feng X*., Qiu G., Shang L., Li G., Human hair mercury levels in Wanshan mercury mining area, Guizhou Province, China. *Environmental Geochemistry and Health,* 2009, 31:683-691.

Zhang J., Feng X*., Yan H., Guo Y., Yao H., Meng B., Liu K., Seasonal distributions of mercury species and their relationship to some physicochemical factors in Puding Reservoir, Guizhou, China. *Science of the Total Environment,* 2009, 408:122-129.

Feng X*., Jiang H., Qiu G., Yan H., Li G., Li Z., Geochemical processes of mercury in Wujiangdu and Dongfeng reservoirs, Guizhou, China. Environmental Pollution, 2009,157: 2970–2984.

Qiu G., Feng X*., Wang S., Fu X., Shang L., Mercury distribution and speciation in water and fish from abandoned Hg mines in Wanshan, Guizhou province, China. *Science of the total Environment*, 2009, 407: 5162–5168.

Li P., Feng X*., Qiu G.L., Shang L.H., Li Z.G., Mercury pollution in Asia: a review of the contaminated sites. *Journal of Hazardous Materials,* 2009, 168: 591-601.

Marc Watson Beutel

Associate Professor
Department of Civil and Environmental Engineering, Washington State University
PO Box 642910, Pullman, WA 99164-2910
509.335.3721 mbeutel@wsu.edu

Professional Preparation

University of California, Los Angeles, BS, cum laude, Civil Engineering, 1990

University of California, Berkeley, MS, Civil and Environmental Engineering, 1994

University of California, Berkeley, PhD, Civil and Environmental Engineering, 2000

University of California, Berkeley, Post-Doctoral Researcher, 2000

Swiss Federal Institute for Environmental Science and Technology, Fulbright Doctoral Fellowship, Limnology Researcher, 2000-2001

Appointments

2011-Present	Associate Professor, Civil and Environmental Engineering Department, WSU
2004-2011	Assistant Professor, Civil and Environmental Engineering Department, WSU
2001-2004	Principal Engineer, Water Resources, Brown and Caldwell, Walnut Creek, CA
1990-1993	Junior/Assistant Engineer, East Bay Municipal Utility District, Oakland, CA

Publications

Gebremariam, S.Y., M.W. Beutel, D.R. Yonge, M. Flury and J.B. Harsh. 2011. Sorption and Desorption of Chlorpyrifos. *Review of Environmental Contamination and Toxicology*. 215:123-175.

Gebremariam, S.Y., M.W. Beutel, T.F. Hess and D. Christian. 2011. Research advances and challenges in the microbiology of enhanced biological phosphorus removal - A review. *Water Environment Research*. 83:195-219.

Betancourt, C., F. Jorge, R. Suárez, M.W. Beutel and S.Y. Gebremariam. 2010. Manganese sources and cycling in a tropical eutrophic water supply reservoir, Paso Bonito Reservoir, Cuba. *Lake and Reservoir Management.* 26:217-226.

Gebremariam, S.Y. and M.W. Beutel. 2010. Effects of drain-fill cycling on chlorpyrifos mineralization in microcosms containing wetland sediment. *Chemosphere*. 78: 1337-1341.

Allen, J.G., M.W. Beutel, D.R. Call and A.M. Fischer. 2010. Effects of oxygenation on ammonia oxidation potential and microbial diversity in sediment from surface-flow wetland mesocosms. *Bioresource Technology*. 101:1389-1392.

Palmer, H.R., M.W. Beutel and S.Y. Gebremariam. 2009. High rates of ammonia removal in experimental oxygen-activated nitrification wetland mesocosms. *ASCE Journal of Environmental Engineering*. 135: 972-979.

Beutel, M.W., C.D. Newton, E.S. Brouillard and R.J. Watts. 2009. Nitrate removal in surface-flow constructed wetlands treating dilute agricultural runoff in the lower Yakima Basin, Washington. *Ecological Engineering.* 35:1538-1546.

Lancaster, C., M.W. Beutel and D.R. Yonge. 2009. Evaluation of roadside infiltration to manage stormwater runoff in semi-arid eastern WA. *Environmental Engineering Science*. 26(5):935-940.

Beutel, M.W., T.M. Leonard, S.R. Dent and B.C. Moore. 2008. Effects of aerobic and anaerobic conditions on P, N, Fe, Mn and Hg accumulation in waters overlaying profundal sediments of an oligo-mesotrophic lake. *Water Research*. 42:1953-1962.

Gebremariam, S.Y. and M.W. Beutel. 2008. DO levels and nitrate loss in batch wetland mesocosms: Cattail versus bulrush. *Ecological Engineering*. 34:1-6.

Synergistic Activities

WSU Imagine Tomorrow. Mentoring students from rural Lake Roosevelt High School, WA, that participate in Imagine Tomorrow, a WSU-sponsored competition in which over 150 high school teams presented design innovations related to energy sustainability. Teams in 2008, 2009 and 2010 have won major competitive prizes. (Dent, S.R. and M.W. Beutel. Targeted outreach can enhance diversity of participation in university sustainability competitions. *ASCE Journal of Professional Issues in Engineering Education and Practice*. Revised manuscript in secondary review)

NSF Graduate Teaching Fellows in K-12 Education. Facilitating involvement of two of my graduate students with the WSU Culturally Relevant Engineering Application in Mathematics Program, funded through the NSF Graduate Teaching Fellows program. My graduate students are sharing their research in nutrient and metal cycling in lakes with students at Lake Roosevelt High School, WA, a rural school dominated by students from the Colville Indian Reservation.

Outreach to Colville Indian Reservation. Implementing CAREER outreach to high school students related to mercury bioaccumulation in reservation lakes. Effort includes a summer science camp, chaperoning students to engineering conferences (AISES), and inviting student Working with PhD student and WSU assessment experts to evaluate self efficacy, teamwork and design skills of students from Lake Roosevelt High School, WA.

Secretary/Treasurer, American Ecological Engineering Society, 2007-2009. Managing finances and membership development for progressive 200-member society that promotes ecological engineering, the integration of humans and ecosystems for the benefit of both. Support key aim of the Society to promote student involvement through discount memberships and travel scholarships to conferences.

Research Training for Women and Undergraduates. Promoting inclusion of women and undergraduates in my engineering research group. Three of my seven MS students to date have been female. Six undergraduates, three female and three male, have played meaningful research roles in my lab. Three of the undergraduates have continued on to highly-ranked graduate programs (UC Davis, UC Berkeley, John Hopkins).

Collaborators & Other Affiliations

Collaborators and Co-Editors
Burgoon, Peter, Water Quality Engineering, Wenatchee, WA; Burley, Nathan; UC Davis; Bowman Kavanagh, Karen, Flow Sciences, Harrisonburg, VA; Churchill, Jillian, Peace Corp, Caribbean; Gill, Gary, Battelle Marine Science Laboratory, Sequim, WA; Hannoun, Imad, Flow Sciences, Harrisonburg, VA; Horne, Alex, UC Berkeley, Professor Emeritus; Lancaster, Cory, CDM, Cambridge, MA; Leonard, Theo, Coughlin, Porter, Lundeen, Seattle, WA; Losee, Richard, Metropolitan Water District of Southern California; Moore, Barry, Mike Barber, Markus Flury, Dave Yonge, Rick Watts, Washington State University; Pasek, Jeff, San Diego Water Department; Taylor, Bill, Metropolitan Water District of Southern California; Whitney, Randy, Metropolitan Water District of Southern California.

Graduate and Postdoctoral Advisors
Alex Horne, University of California, Berkeley, Professor Emeritus; Rene Gächter, Swiss Federal Institute for Environmental Science and Technology.

Thesis Advisor and Postgraduates-Scholar Sponsor
Total Number of Advisees: 7 graduates; 6 ongoing graduates; No postdoctoral scholars.
Theo Leonard, Coughlin, Porter, Lundeen; Huck Palmer, Water Quality Engineering; Jillian Churchill, Peace Corp; Crystal Newton, Non-affiliated; Jennifer Allen, Non-affiliated; Victoria Whritenour, Wetland Scientist; Jon Erlenmeyer, Non-affiliated; Stephen Dent, current PhD student; Seyoum Gebremariam, current PhD student; Lanka Desilva, current PhD student; Brandon Reed, current MS student; Suzanne Cox, current MS student; Piper Marshall current MS student.

WASHINGTON STATE UNIVERSITY
Department of Civil and Environmental Engineering
College of Engineering and Architecture

Marc Beutel, PhD, PE
Associate Professor
Washington State University
Pullman, WA 99163
November 21, 2011

RE: 2011 PEER Proposal

To Whom it May Concern:

I am writing in support of the 2011 PEER proposal entitled, "Alternative livelihoods in artisanal gold mining areas of West Nusa Tenggara Province" with the Principal Investigator Dr. Wani Hadi Utomo of the Brawijaya University's International Centre for the Management of Degraded and Mining Lands. I am an associate professor from Washington State University with an active five-year (2009-2014) grant from the National Science Foundation entitled: "CAREER: Fundamental Understanding of Mercury Cycling in Lakes and Use of Reservation-Based Research to Recruit American Indians into Environmental Engineering and Science" (#0846446).

The proposed project relates to my NSF grant in a number of ways. I am evaluating mercury cycling in natural lakes on the Colville Indian Reservation in eastern Washington State. I am also perform outreach to American Indian middle and high school students with the goal of recruiting these underrepresented students into BS programs in science and engineering. Through this research and outreach effort, I can bring to the PEER project my combined and unique strengths in a fundamental understanding of mercury cycling in the environment and experience in mercury-related outreach to a challenging and resource limited outreach audience. Another key similarity of the proposed PEER project and my NSF grant is their applied nature, and their focus on the practical management of mercury pollution so as to minimize health impacts on humans and wildlife.

My expected role as the U.S. collaborator in the project is to act as a project advisor/assistant; this is meant to be a "two-way" role in which all parties involved will share their knowledge base, capabilities and ideas with each regarding the project. More specifically, I will host two students from the IRC-MEDMIND at WSU in years 2 and 3 of the project for 1-2 month during the summer. Students will be trained in mercury analyses techniques in the WSU mercury lab and assist my graduate students with mercury related research and field work. I will also provide analytical support on tissue mercury analyses as needed for the project. Presuming I get funding from the National Science Foundation as a supplemental to my current mercury-related grant, I plan to spend 2-3 months at the IRC-MEDMIND in years 2 and/or 3 to work with project stakeholders. I will bring my mobile Milestone DMA 80 mercury auto-analyzer on this trip to enhance the local stakeholder's opportunities for training and analysis related to mercury contamination and cycling in the study region of West Nusa Tenggara. This will also provide me with the invaluable opportunity to meet project stakeholders face to face and to see the project area firsthand. I also look forward to working with project stakeholders to disseminate project results through timely publication in peer reviewed journals and international conferences, such as the upcoming MERCURY 2013 conference in Edinburg, Scotland. Based on the relationships built through this effort, I hope to develop additional research and outreach programs funded through US and international agencies.

Thank you for your consideration of this compelling proposal.

Sincerely,

Marc Beutel

PO Box 642910, Pullman, WA 99164-2910 USA
509-335-2576 • Fax: 509-335-7632 • www.ce.wsu.edu

KEMENTERIAN PENDIDIKAN NASIONAL
UNIVERSITAS BRAWIJAYA
Jl. Veteran, Malang 65145, Indonesia
Telp. : +62-341-551611, 575777 ; Fax : +62-341-565420
http://www.ub.ac.id E-mail: rektorat@ub.ac.id

Subject: **PEER Proposal**

Letter of Support

Ref. 5650/UN10/LL/2011

This is to certify that University of Brawijaya fully supports the 2011 PEER Proposal entitled: Alternative livelihoods in artisanal gold mining areas of West Nusa Tenggara Province Agricultural development and food security. The supports given in the form of:

1. The University of Brawijaya permits the participation of her staffs in the proposal to execute the research works.
2. The University of Brawijaya permits the use of any facilities (office, laboratory) required for the project; University pays the salary of the staffs involved in the projects; University providing substitute instructors to covers the teaching duties of the staffs involved in the project.
3. The University of Brawijaya will be responsible to receive and administer the funds grant awarded. Under the national regulations the University of Brawijaya is allowed to receive grant fund from a foreign sponsor.
4. To administer the proposed project, University of Brawijaya has a Research Institute and Community Services, under which the International of Research Centre for Management of Degraded and Mining Land is attached. The Institute will supervise, monitor and evaluate the research works. To meet the national regulation, the grant should be transferred to University account.

University had experience to receive and manage grant from foreign sponsors, some of them are:

1. 1984-1996, Nitrogen Management for Food Crops Production in Tropical Farming System; in Cooperation with Institute for Soil Fertility, Harren, The Netherlands; Sponsored by European Community; US $ 600,000.-; Contact person: M.VANNOORDWIJK@CGIAR.ORG
2. 1992-1995, Management Clay Soils for Rainfed Lowland Rice-based Cropping Systems; in Cooperation with University of Queensland; funded by Australian Centre for International Agricultural Research (ACIAR); US $ 300,000.- contact person: Gunnar Kirchhof Email: g.kirchhof1@uq.edu.au
3. 1996 – 2000. Modeling and measuring N and C dynamics in agroforestry systems in the humid tropics: A test of the hypothesis on the safety-net role of deep-rooted trees. Research project collaboration between Brawijaya University- Wye Collage, London University and ICRAF-SE Asia). DFID-UK. US $ 300,000.- Contact person: Prof Georg Cadisch, University of Hohenheim: georg.cadisch@uni-hohenheim.de

4. 2002- 2005. Smallholder Agroforestry Options for Degraded Soil (SAFODS) (Cooperation between Brawijaya University and Lampung University, Indonesia; University Philippine Los Banos; Wye College, UK (continue with University of Hohenheim, Germany) INRA, France; Cordoba University, Spain; and World Agroforestry Centre, ICRAF-SE Asia.); Europe Community. EU $ 105,000.- Contact person: Prof Georg Cadisch, University of Hohenheim: georg.cadisch@uni-hohenheim.de
5. 2005-2006. Study of mass movement and possible factors determining slopes failure in Sumberjaya, West Lampung: Role of tree root systems on slopes stability (Unversity of Brawijaya-ICRAF SE Asia). World Agroforestry Centre. Contact person:M.VANNOORDWIJK@CGIAR.ORG
6. 2005-2010, University of Kentucky (UKy), through USAID grant, have been collaborated with Universitas Brawijaya, (UB), Universitas Lampung and Universitas Syiah Kuala Banda Aceh, to strengthened higher education in Indonesia, especially technical assistances on agriculture, business, education and engineering. Contact person: mrreed@uky.edu
7. 2007-2008. LINKING ABOVEGROUND AND BELOWGROUND DIVERSITY: Formation of Soil Biopore by earthworm with various quality of litter input (Team CSM_BGBD-phase 2). World Agroforestry Centre.
Contact person:M.VANNOORDWIJK@CGIAR.ORG

Date: November 24, 2011

Rector,

Prof.Dr.Ir. Yogi Sugito

KEMENTERIAN PENDIDIKAN NASIONAL
UNIVERSITAS BRAWIJAYA
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Subject: **International Research Centre for Management of Degraded and Mining Lands (IRC-MEDMIND)**

Letter of Commitment

Ref. 5628 /UN10/LL/2011

This is to certify that University of Brawijaya, Malang, Indonesia (together with University of Mataram, Mataram, Indonesia; Massey University, Palmerston North, New Zealand; and State Key Laboratory for Environmental Geochemistry, Chinese Academy of Sciences, Guiyang, China) willing to establish the "International Research Centre for Management of Degraded and Mining Lands (IRC-MEDMIND)". University of Brawijaya will responsible for:

1. Provides office and the necessary administration requirements
2. Allocates their staffs to manage and conduct research works on behalf of the Research Centre
3. Give access to the Centre to use the facility of University of Brawijaya (include Laboratory and conference/seminar room).
4. For the first year University of Brawijaya will provide a necessary funds to administer the Research Centre

Date: November 24, 2011

Rector,

Prof.Dr.Ir. Yogi Sugito

中國科學院地球化學研究所
Institute of Geochemistry Chinese Academy of Sciences

Professor Dr. Wani Hadi Utomo
Brawijaya University - International Centre for the Management of Degraded and Mining Lands (IRC-MEDMIND)
Faculty of Agriculture, Brawijaya University
Jl. Veteran 61545, Malang, Indonesia

2011-11-29

Dear Professor Dr. Wani Hadi Utomo,

I hereby confirm that my institution approves and endorses my involvement in the PEER application entitled “Alternative livelihoods in artisanal gold mining areas of West Nusa Tenggara (WNT) Province, Indonesia”. Please let me know if you need me to provide any further information.

Sincerely yours,

Xinbin

Prof. Xinbin Feng,PhD
Vice Director in General
Institute of Geochemistry, Chinese Academy of Sciences
Vice Director
State Key Laboratory of Environmental Geochemistry
Institute of Geochemistry, Chinese Academy of Science
Guiyang 550002, China
E-mail: fengxinbin@vip.skleg.cn

CVs for two advisors to the proposed research are presented on the following four pages.

No funding is sort in the proposal for these collaborators.

Halshka Graczyk, BA, MSPH

Rue du Jura 4, Lausanne, Switzerland, CH-1004
Office : + 41.22.799.8069 Personal: + 41.78.685.8060 Email: g8ipec@ilo.org

EDUCATION

May 2010 **Master of Science of Public Health (MSPH),** Occupational and Environmental Health
Johns Hopkins University, Bloomberg School of Public Health, Baltimore, USA

May 2010 **Certificate in Risk Sciences and Public Policy**
Johns Hopkins University, Risk Sciences and Public Policy Institute, Baltimore, USA

May 2008 **Certificate in International Development**
Warsaw School of Economics, Collegium of Socio-Economics, Warsaw, Poland

Dec 2008 **Bachelor of Arts (BA),** Public Health Sciences (1) and Economics (2)
Johns Hopkins University, Krieger School of Arts and Sciences, Baltimore, USA

PROFESSIONAL EXPERIENCE

Sept 2011- **International Consultant - focal point for child labour in agriculture**
United Nations International Labour Office (ILO), International Program on the Elimination of Child Labour (IPEC), Geneva, Switzerland

- Liaison between ILO and UN Food and Agriculture Organization (FAO) for child labour and agriculture issues to support International Agriculture Partnership project
- Managed IPEC's participation in 2011 Global South-South Development Exposition
- Provided technical assistance for global projects on child labour in agriculture

Oct 2010 - Aug 2011 **International Consultant - hazardous child labour and child labour in mining**
United Nations International Labour Office (ILO), IPEC and SAFEWORK departments, Geneva, Switzerland

- Assessed the public health aspects of hazardous child work and developed extensive Compendium of Knowledge document for capacity building in community health
- Developed analytical reports for monitoring and evaluation efforts at the field level
- Organized and managed a technical conference of public health experts to assess best practice methodologies in child labour intervention projects

May 2010- Sept 2010 **International Consultant – childhood environmental exposures**
World Health Organization (WHO), Department of Public Health and the Environment

- Co-authored guidance document on childhood mercury exposure and coordinated document edits and preparation for publication
- Developed educational curriculum concerning community health for capacity building initiatives in developing nations

Dec 2007 - Jan 2010 **Community Health Program Associate**
National Coalition to End Childhood Lead Poisoning**,** Baltimore, MD. USA

- Developed and conducted monitoring and evaluation surveys for community health programs in disadvantaged urban populations
- Coordinated and supervised community health outreach initiatives and managed an extensive network of stakeholders and collaborators

May 2009- Aug 2009 **Research Associate**
Health Sciences University of Mongolia. Ulaanbaatar, Mongolia

- Developed and supervised investigative field research on the human and environmental health effects of mercury exposures due to artisanal gold mining
- Coordinated a research network between NGOs, local governments, and university collaborators to translate research into effective public policy efforts on mining laws

May 2007-
Aug 2007
External Evaluator
International Development Research Centre (IDRC), Quebec, Canada

- Assisted in a critical external evaluation of more than one hundred IDRC community health projects to assess best practice methodologies

May 2006-
April 2007
Laboratory Assistant
Johns Hopkins Bloomberg School of Public Health, Baltimore, MD, USA

- Assisted in the implementation of large-scale research project assessing the vulnerability of HIV afflicted populations to pathogen exposure
- Conducted statistical analysis for research results and prepared final draft of research manuscript for professional publication

SELECTED PUBLICATIONS

Childhood Exposures to Mercury Compounds. Children's Health and the Environment. WHO, Geneva, Switzerland, 2010. http://whqlibdoc.who.int/publications/2010/9789241500456_eng.pdf

Hazardous Child Labour: What we know, what we need to do. ILO Geneva, Switzerland, 2011. http://www.ilo.org/global/publications/books/WCMS_155428/lang--en/index.htmI

Graczyk H, Goldman L, Etzel R. Training for the Health Sector: Introduction to Reproductive Health and the Environment. WHO (2011). Children's Health and the Environment, Geneva, Switzerland.

Graczyk H, Goldman L, Etzel R. Training for the Health Sector: Case Studies of Real Life Female Environmental Reproductive Health. WHO (2011). Children's Health and the Environment, Geneva, Switzerland.

Jambaljav J, Lkhasuren O, Nyamjav S, **Graczyk H**. 2010. *Occupational Diseases Among Copper Miners of Erdenet Mining Company in Mongolia.* Mongolian Journal of Public Health.

Graczyk H. 2009. *True Price of Gold: Mercury Use in Small Scale Mining.* Epidemic Proportions 6(1), 25-27.

Graczyk H. 2008. *Cultural Incongruence: the Mental Health of Refugees in America*. Epidemic Proportions, 5(1), 15- 16.

Graczyk H. 2007. *Women and Public Health Inequality: Disproportionate Susceptibility to TB/HIV Co-infection*. Epidemic Proportions, 4(1), 45-47.

Graczyk T, Tamang L, **Graczyk H**. 2005. Human protozoan parasites in molluscan shellfish. Advances in Food and Nutrition Research. Book Chapter. Elsevier Academic Press, 50C: 79-100.

Graczyk H, Conn B, Marcogliese D, DeLafontaine Y. 2006. *Bioaccumulation of human waterborne parasites by Dreissena polymorpha and Corbicula fluminea*. Aquatic Invaders, 17 (3): 1214.

SKILLS AND INTERESTS

Languages	English (native); Polish (native); French (fluent); Russian (proficient); Ukranian (proficient); Spanish (basic)
Computer	STATA, Microsoft Office Suite, PLONE, Refworks, EPIinfo, ETO (Efforts to Outcomes, Case Management Software), Flash, Open Office Impress, Photoshop
Professional	Experience working within UN and NGO system; extensive professional writing and editing experience (analytical reports, policy briefs, federal and private grants); monitoring and evaluation; qualitative and quantitative field research through needs assessments and surveys
Interests	Environmental health research, photography, world travel and cultures, running

CURRICULUM VITAE

Personal Details:

Name	Dr. Christopher William Noel Anderson
Institution	Institute of Natural Resources, Massey University
Office address	Soil and Earth Sciences Group, Private Bag 11-222 Palmerston North, New Zealand
Citizenship	New Zealand
Email	**c.w.n.anderson@massey.ac.nz**
Telephone	0064 6 356 9099 ext 7584

Education:

1. Ph. D., Earth Science, Massey University (2000)
2. B.Sc. (Hons 1st Class), Soil Science, Massey University (1996)
3. B. Sc., Chemistry and Earth Science, Massey University (1997)

Professional positions held

From 2009	Senior Lecturer, Soil and Earth Sciences Group, Massey University Director and Consulting Scientist to the New Zealand biotechnology company Tiaki International Ltd.
From 2006	Company Secretary, Tiaki USA US Corp.
2004-2007	Contract Lecturer and research supervisor to the Soil and Earth Sciences Group, Massey University
2003-2008	Director and Chief Scientist, Tiaki International Ltd.
2001-2004	Director, Chairman and consulting scientist, Phytomine Environmental Ltd.
2000-2003	NZ Science and Technology PostDoctoral Fellow, Massey University.

Present research/professional speciality

Environmental geochemistry, phytoremediation, phytomining, land rehabilitation, environmental risk assessment, analytical chemistry, commercialisation of new science and technology.
I have significant experience in the application of new scientific techniques (analytical and technology-based) to current science and technology questions and problems.

I am actively developing phytoextraction projects for gold in several locations around the world. These projects are not solely being conducted for profit. I foresee significant environmental, social and economic good that will come through the coupling of gold and mercury phytoextraction/phytoremediation at global artisanal and small-scale gold mining locations.

Professional distinctions and memberships

2011 Appointed to the International Advisory Board of the International Research Centre for the Management of Degraded and Mining Lands (Indonesia)

2010 NZ Aid Program International Developmental Research Fund award for research into the biogeochemical cycling of mercury at artisanal mining areas of Lombok Island (Indonesia)

2009 Massey Lincoln and Agricultural Industry Trust, Partnership for Excellence research award for joint agricultural sustainability research with Lincoln University (New Zealand)

2007 Invited foreign expert to the 1st Ningbo Forum on Contaminated Soil and Rehabilitation, Ningbo, China, Sept 21-22

2006 Invited speaker to the Fiji-New Zealand Business Council annual meeting, Suva, Fiji

2005 Invited lecturer to the 2nd USEPA phyto-technologies workshop, Atlanta, April 19-22

2004 Invited keynote speaker to the 2nd International SoilRem Conference, Nanjing, China, November 9-12

2004 Invited keynote speaker to the United Nations Industrial Development Organisation (UNIDO) Global Biotechnology Forum, March 2-5, Concepcion, Chile

2004 Nominee for the 2004 Tech Museum (USA) award for the environment

2003 Founder, Director and Inaugural Chairman of the New Zealand company Tiaki Resources Ltd. which offered innovative biotechnology for gold processing (now Tiaki International Ltd.)

2003 Award of a US Air Force research grant for nanoparticle research (AOARD). Second award followed in 2005

2000 Award of a Akzo Nobel (Dutch) industry grant to study gold uptake by plants, second award followed in 2002

2000 Foundation for Research, Science & Technology Post Doctoral Fellowship

Select publications relevant to the IRC-MEDMIND propsal

Wilson-Corral, V., Anderson, C. W., Rodriguez-Lopez, M., Arenas-Vargas, M., & Lopez-Perez, J., 2011. Phytoextraction of gold and copper from mine tailings with Helianthus annuus L. and Kalanchoe serrata L.. *Minerals Engineering*, 24: 1488-1494.

Wang, J., Feng, X., Anderson, C. W. N., Qiu, G., Ping, L., & Bao, Z., 2011. Ammonium thiosulphate enhanced phytoextraction from mercury contaminated soil - Results from a greenhouse study. *Journal of Hazardous Materials*, 186(1): 119-127.

Ko, B-J., Anderson, C.W.N., Huh, K-Y., Vogeler, I. and Bolan, N.S.B., 2008. Potential for the phytoremediation of arsenic contaminated mine tailings in Fiji. *Australian Journal of Soil Research*, 46: 1-9.

Moreno, F.N., Anderson, C.W.N., Stewart, R.B. and Robinson, B.H., 2008. Phytofiltration of mercury-contaminated water: volatilisation and plant-accumulation aspects. *Environmental and Experimental Botany*, 62: 78-85.

Moreno, F.N., Anderson, C.W.N., Stewart, R.B. and Robinson, B.H., 2005. Mercury volatilisation and phytoextraction from base-metal mine tailings. *Environmental Pollution*, 136: 341-352.

Moreno, F.N., Anderson, C.W.N., Stewart, R.B., Robinson, B.H., Ghomshei, M., Meech, J.A. and Nomura, R., 2005. Effect of thioligands on plant-Hg accumulation and volatilisation from mercury-contaminated mine tailings. *Plant and Soil*, 275: 231-243.

Moreno, F.N., Anderson, C.W.N., Stewart, R.B., Robinson, B.H., Ghomshei, M. and Meech, J.A., 2005. Induced plant uptake and transport of mercury in the presence of sulphur-containing ligands and humic acid. *New Phytologist*, 166: 445-454.

Anderson, C., Moreno, F., Guerts, F., Wreesmann, C., Ghomshei, M. and Meech, J., 2005. A comparative analysis of gold-rich plant material using various analytical methods. *Microchemical Journal*, 81: 81-85.

Anderson, C., Moreno, F. and Meech, J., 2005. A field demonstration of gold phytoextraction technology. *Minerals Engineering*, 18: 385-392.