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Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

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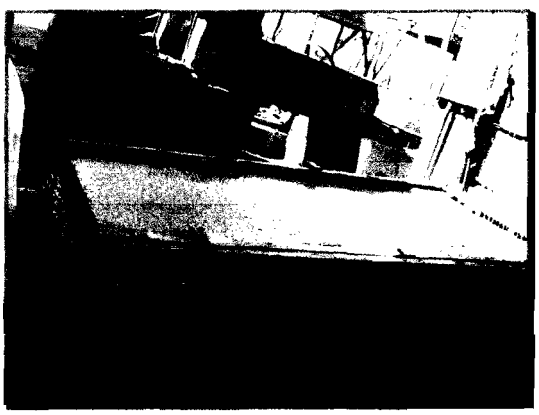
Community Awareness on Hazards of Exposure to Mercury and Supply of Equipment for a Transportable Demonstration Unit (TDU) for Mercury-Cleaner Gold Processing Technologies in the Kadoma-Chakari District of Zimbabwe



Final Report

UNIDO Project NO. EG/GL/01/G34 P.O. No. 160010/ML

UNIDO Contract NO. 16001056

United Nations Industrial Development Organization

Institute of Mining Research

CommunityAwareness on Hazards of Exposure to Mercury and Supply of Equipment for a Transportable Demonstration Unit (TDU) for Mercury-Cleaner Gold Processing Technologies in the Kadoma-Chakari District of Zimbabwe

Final Report

Trust T. Masiya

Institute of Mining Research, University of Zimbabwe

P.O. Box MP167

Mount Pleasant

Harare, Zimbabwe

Tel: +263 4 336418

e-mail: imr@science.uz.ac.zw or tmasiya@science.uz.ac.zw

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EXECUTIVE SUMMARY

The Kadoma-Chakari area is within one of the largest gold belts of Zimbabwe and has the highest density of small scale gold miners, millers and panners of all the country's gold belts. The area is approximated to be a host to 25,000 artisanal and small scale miners, representing about 10% of the national figure. In almost all of the Kadoma-Chakari area whole ore amalgamation in which 2-4 teaspoons of mercury are added into the centrifugal bowl or on the copper plates is practiced. This mercury is easily pulverized in the centrifugal bowl or scratched from the copper plates and is lost with the tailings which, will be leached by the cyanidation process. Therefore, emphasis during the training workshops was that miners should concentrate first the ore before mercury amalgamation, and in this way reduces the amount of mercury that reports to the tailings, hence the environment. The baseline data also indicated that the miners rarely use retorts for amalgam burning and that no amalgam burning and smelting sites were used, thus exposing them to the toxic mercury vapour. Again the training sessions emphasized on the importance of the retorts and demonstrations on the use of the retorts, RHYP type and the simple kitchen bowl retorts were done on all the 12 mine sites that were visited. The miners were also taught on how to make the simple kitchen bowl retort and where to buy the RHYP retorts.

The total number of mine sites that were visited for both the training workshop and technology demonstrations was twelve. The sites chosen were found to be key areas in which there was massive miner/panner congregations. The project managed to get in contact with 723 people from mining communities surrounding the Kadoma-Chakari area. In fact the figure is higher as people, later, after "*Operation Chikokoza Chapera*", were no longer willing to have their names written down in the project register. The following issues were covered during the training sessions:

- basic geology
- mining and safety, occupational health and the environment
- mineral processing techniques
- mercury use and associated hazards and health effects, and

- general health and sanitation

The nature of the approach used for the training was participatory based on practicals with practical examples. Of the total registered participants 246 were women, representing 34%. The dangers of mercury to developing babies and children were emphasized. Members from the Ministry of Mines and Development (4), Ministry of Health and Child Welfare (2), Zimbabwe Panners Association (4) and the University of Zimbabwe (2) were involved in the training and awareness campaign of the hazards of mercury and use of cleaner technology in the extraction of gold. See **Appendix I**, List of trainers and the role played by each member.

Availability of clean water, poor sanitation, occurrence of infectious diseases and prevalence of sexually transmitted diseases (STIs) were found to be the main problems affecting the mining communities. The GMP team facilitated with selection of community Health Coordinators in seven of the mine sites visited. The role of these coordinators was to provide a linkage between the mining communities and the Kadoma General Hospital and provide basic health care to the communities.

Exhibitions at Kadoma-Chegutu Agricultural Show in the project area and MINE ENTRA in Bulawayo were also used to disseminate information on community awareness on hazards of exposure to mercury and the use of cleaner technology in the extraction of gold. The project exhibits included brochures, pictures of processing gold, panning dishes, retorts, mercury measurement equipment, sluice box technology and carpets. A total of 154 visitors toured the exhibition stand at the Agricultural Show and more than 200 at MINE ENTRA.

The awareness campaign was also done through the distribution of t-shirts, brochures, posters and training manuals. A total of 150 t-shirts, 230 brochures and posters were distributed during the exhibitions and the community outreach programs. 60 GMP manuals for training artisanal and small scale gold miners were distributed to mine and

mill managers whilst photocopies of Chapters 8 to Chapter 10 of the same manuals were given to health coordinators.

Demonstrations were done on the use of retorts, reactivating floured mercury and the effectiveness of the sluice box technology as an alternative to whole-ore amalgamation on copper plates and centrifugal bowls. Demonstrations on the complete TDU were limited only to the transportable sluice box, as the economic situation and lack of funds made it costly and impossible to fully assemble the whole unit. Demonstrations on the transportable sluice box were also limited to three sites, M & K, Chimukute and Imperani mine. The main reasons for this was the frequent power blackouts that were being experienced throughout the country and stoppages in small scale gold mine operations experienced during the period December, 2006 and April, 2007 as a result of "*Operation Chikorokoza Chapera*". It is however, important to note that the sluice box technology was proved to be an effective concentrator with better recovery than whole-ore amalgamation in centrifugal bowls. With the sluice box technology mercury-free tailings are produced, hence no contamination of the environment with mercury. In one of the demonstrations more than 100g of gold was recovered using the sluice box technology. As a result of the demonstrations a sluice box was installed at Imperani Mine and is still being used now. It was well received by the miners especially when used in conjunction with the vinyl loop carpet. About 251 people were present during demonstrations on the sluice box technology that were done in July and August, 2007.

GMP awareness was also done through theatre and was based on the community play 'Nakai'; the story of farmer's daughter exposed to mercury by her artisanal boyfriend. The play highlighted issues on conflicts between miner and farmer, health effect of mercury and preventative measures. Communication of hazards of mercury through the play 'Nakai' performed in August, 2007 reached over 200 people at Imperani mine. The audience on theatres included all ages, children, women and men.

1. INTRODUCTION

A thriving artisanal and small scale gold mining industry exists in Zimbabwe today. This industry is providing an income for many thousands directly and millions indirectly and foreign currency to the nation (***Blenkinsop, 1990***). It is an important part of the Zimbabwean economy that benefits the individual directly, without foreign direct investment. Their ability to exploit small deposits which are uneconomic for large scale operations give them a unique opportunity to contribute to the national development. The short implementation period (lead time) has placed the sector in a strategic position to take advantage of short-term booms in the mining industry (***Maponga, 1991***). This is well illustrated in the Kadoma-Chakari area.

Despite the above positive aspects, the activities of the artisanal and small scale miners in the area and nationwide have had devastating repercussions on the environment and on the health of the miners, mainly because of the nature of the technologies they are using to extract gold. There is excessive use of mercury on the copper plates and during whole ore amalgamation processes in centrifugal bowls that are being incorrectly used by the small scale miners. These practices release large amounts of the toxic mercury into the local environment. ***Boese-O' Reilly et. al*** (2004) estimated the total release of mercury from gold mining to be around 1000 metric tonnes per year. The result is that mercury, as already confirmed by health studies, is a serious health and environmental hazard in the small scale mining area of Kadoma-Chakari, and needs to be abated soon (***Boese-O' Reilly et al., 2004***). The mercury exposure in the mining area is mainly due to exposure to elemental mercury, either from amalgamating with mercury or burning and smelting amalgam. Miners, millers, panners and their families are therefore exposed to high levels of mercury at the milling centres and mine villages/compounds

Besides issues that are related to mercury poisoning, the hygienic standards in the area are extremely low and are the reason for many infectious diseases such as diarrhea, malaria and parasitism. There is no clean and safe drinking water, no waste disposal for human discharge or any other waste. Acute respiratory tract infections, malaria,

tuberculosis, and sexually transmitted disease including AIDS are the dominant causes of morbidity and mortality in the area. Miners and panners are also exposed to accidents in insecure tunnels and work without even the most basic personal protective equipment such as footwear of any kind.

It is for these reasons that the Institute of Mining Research of the University of Zimbabwe was contracted by UNIDO (which funded the project) through the Global Mercury Project to undertake community awareness on hazards of exposure to mercury and supply equipment for mercury-free cleaner gold processing technologies in the Kadoma-Chakari district of Zimbabwe. Miners and panners, legal and illegal, alike need to be educated on the poisonous nature of mercury. Low cost and safe technologies to separate mercury from the amalgam should be introduced to these workers.

The overall goals of the project are to improve efficiency of existing technology for gold recovery so as to increase income, while at the same time reducing release and exposure of people to mercury and minimize off-site and environmental contamination.

The overall broad objectives of the project are:

1. to improve gold recovery,
2. to reduce the use of mercury, and
3. to raise awareness of health risks associated with exposure to mercury

The ultimate aim of the whole UNIDO project is to replace mercury amalgamation in the project demonstration sites with new technology, while improving the income of the miners through more efficient recovery methods, increasing knowledge and awareness.

2. DESCRIPTION OF THE KADOMA-CHAKARI AREA

The Kadoma-Chakari area is within one of the largest gold belts of Zimbabwe and has the highest density of small scale gold miners, millers and panners of all the country's gold belts. There are no exact data reporting the number of artisanal and small scale miners but the area is approximated to be a host to 25,000 artisanal and small scale miners (ASSM), representing about 10% of the national figure. Mining activities within the area are characterized by shallow shafts and tunnels, custom milling and panning along rivers. The mining communities in the area are characterized by lack of education, non-existence of safe drinking water, disposal systems for toxic mercury waste and human waste, and delocalized burning of amalgam. Miners, millers, panners and their families are exposed to high levels of mercury at the milling centres and mining villages/compounds.

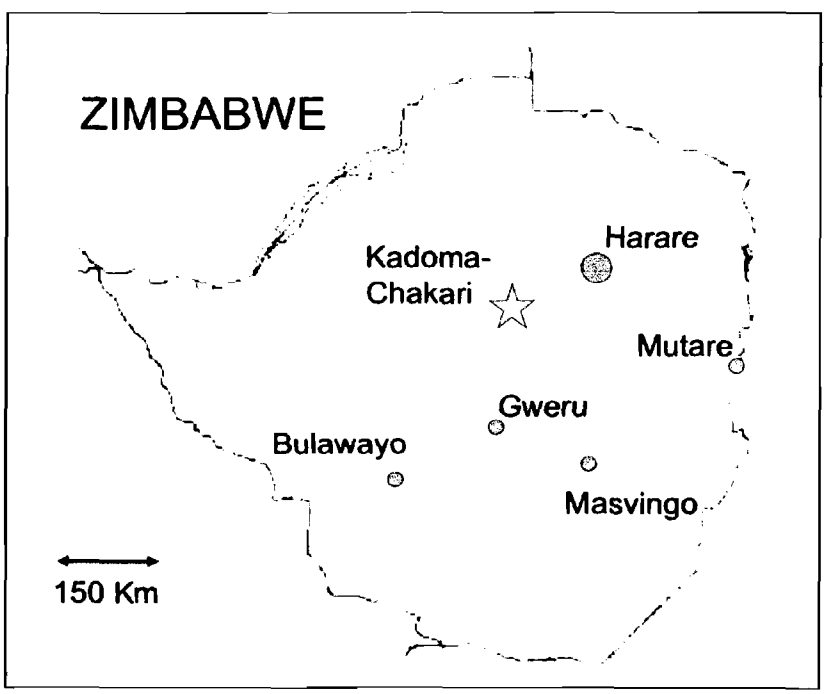


Figure 1: Map of Zimbabwe showing the location of Kadoma-Chakari

Geographically, the project area is situated in Mashonaland West province about 140km south-west of Harare along the Harare-Bulawayo highway, see **Figure 1**. The general relief in the area is in the region of 1250 -1300m above sea level. The major drainage system in the area is that of Muzwezwe river, a major tributary of the Munyati river in the Kadoma area. The Chakari area is drained by the Shagari river, a tributary of the Mupfure River which drains into the Munyati river which in turn is a tributary of the Zambezi river. The area has a tropical climate, with distinct wet and dry seasons. The wet season (November-March) is marked by brief convectional thunderstorms and drizzles. The maximum air temperatures are lowest between June and July, with the highest temperature being recorded in October.

Mining activities are administered by the Mining Commissioner assisted by representatives from the Mining Engineering, Geological Survey and Metallurgy department (all from the Gweru Ministry of Mines office). The small scale mining associations include the Miners Federation of Zimbabwe (MFZ), National Miners Association of Zimbabwe (NMAZ), Women in Mining and the Zimbabwe Panners Association (ZPA), which, at the time of the awareness campaign represented mostly the illegal miners/panners, assisted in the mobilization of miners and panners for the training workshops. It is estimated that over 25,000 small scale miners are active within the project site area. Less than 5,000 of these are involved in reef mining and dump re-treatment while the bulk are alluvial gold panners. The latter category accounts for more than 70% of the mercury users. Where reef mining occurs, there are shallow shafts and tunnels and manpower access and with ore hoisting being done by windlass and bucket. Hand tools such as picks, shovels, hammer and chisels are used to extract the ore from soft material while explosives may be used for the hard material. The mined out ore is normally transported by road to the nearest functional stamp or ball mill for milling.

The main income-generating activity besides mining in the Kadoma-Chakari area is farming. All the mining activities in the area are situated within commercial and resettlement agricultural areas which have a tradition for being the leading producers of cotton and significant quantities of maize in the country. Almost all part-time farmers are

engaged in mining (i.e. are part-time miners). They do farming during the rainy season when its not conducive to mine due to the filling up of shafts with water and related incidences of shaft collapses due to wetness of the earth. Farming is, therefore, an alternative source of income and subsistence for miners. Of those engaged in full-time mining, the majority are mill workers since mill operations are done throughout the year.

2.1 Description of Gold Mining and Processing in the Project Area

About 20,000 to 30,000 people are directly involved in artisanal gold mining operations in the Kadoma-Chakari region and they are categorized into three groups: miners, millers and panners **(Shoko and Veiga, 2004)**.

2.1.1 Miners

These are people who excavate and extract gold ore from narrow shafts as deep as 50m and take this for processing at nearby custom milling facilities. They usually work in groups of 4 or 5 people with an average monthly ore production of 10-15tonnes. It is estimated that about 3,000 to 5,000 people are involved in this activity. They normally wait 2-4weeks at custom milling centres before their ore can be milled.

2.1.2 Millers

These are the people who own or work in the milling centres where the ore is milled and concentrated for the miners. It is reported that there are about 1,000 to 2,000 people working in milling facilities in the Kadoma-Chakari region. In most instances millers have more capital and more education than the majority of the miners and panners. On each mill is a manager who oversees the supervision and running of the mill. The miller also processes the tailings from the gravity concentrators by cyanidation to recover the residual gold (normally more than 60% of the gold brought by the miner).

2.1.3 Panners

These are individuals who work in most cases on alluvial gold by panning the gravels in creeks and rivers or re-processing tailings from former/historical industrial mining operations. Instances are also reported of this group of people being involved in extracting gold from support pillars of old mine workings. They represent the majority of individuals extracting gold. They are nomads and in most cases illegal, and can represent a contingent of up to 15,000 in the project area. This group of people is difficult to gather formally as they are always running away from authorities.

3.0 COMMUNITY AWARENESS CAMPAIGN

Mill and mine sites (**Figure 2**) distributed across the Kadoma-Chakari area were selected for the community awareness campaign on the hazards of exposure to mercury and demonstrations on mercury-cleaner gold processing technologies. These centres or sites chosen were found to be key areas with massive miner/panner congregations. At each site and other platforms identified for the community awareness information dissemination of the GMP campaign was through:

1. GMP training manuals which were given to mill and mine managers
2. community theatres (dramas)
3. t-shirts
4. brochures and posters
5. exhibition shows at Kadoma-Chegutu Agricultural Show (in the project area) and MINE ENTRA in Bulawayo
6. demonstrations on:
    - use of RHYP retorts, and kitchen bowl retorts
    - activating floured or 'sick' mercury
    - measurement of mercury in the air around the copper plates
    - effectiveness of the sluice box as an alternative to whole-ore amalgamation

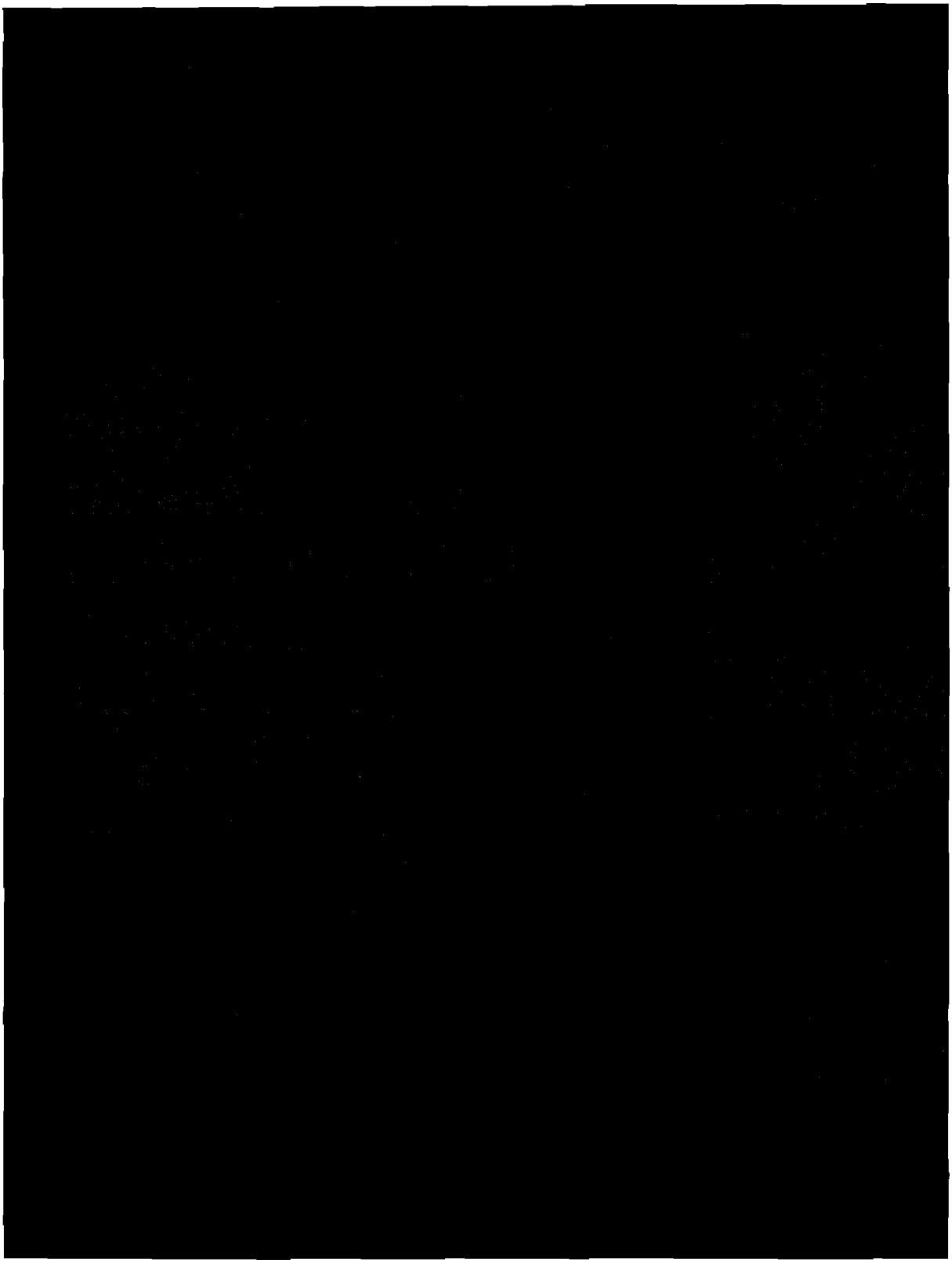


Figure 2: ***Map of Kadoma-Chakari showing sites for the GMP awareness campaign***

3.1 Description of the Sites

The description of the sites in this section depicts the state of the mines and mills when the GMP team and trainers visited the sites. Information gathered about the sites was to form the basis on which evaluation of the project was going to be done and, which areas to focus on during the training sessions. The data that was collected included type of concentrator used, presence of the amalgam barrel, retorts and amalgam burning sites, issues pertaining to hygiene, approximate site population *et cetera*. For Venice, Battlefields, Etna, Brompton, Buffalo and Tiger, Lily and Mandela Mines this baseline information was destroyed and made irrelevant by the "Operation Chikorokoza Chapera" (Operation End Illegal Panning/Mining) in which structures existing on mines, and villages (source of participants) were destroyed and all mining operations stopped for at least three months, December, 2006 to April, 2007. The participants were also forced out of the mining compounds as they were classified as illegal residents and miners, again depriving the GMP team training workshop participants. When mine operations reopened in May, 2007, the number of participants who were coming for the workshops and demonstrations diminished greatly. The mine stoppages also disrupted the smooth running of the mercury awareness campaign and made it difficult to write a register for all the participants.

3.1.1 Tix Mining Area

It is approximately 8km south-east of Kadoma town and is very close to Muzwezwe River, *Site 9* on map. The set-up at the milling centre consists of two 1450lbs three-stamp mills. Ore together with water are introduced into the mill and the ore is crushed to size (determined by mesh size of the mill discharge). The mill discharge is allowed to run over copper plates to allow the liberated free gold to combine with mercury and form an amalgam. One of the stamp mills is used to mill ore brought by miners from nearby mines, whilst the other is used to process the miller's ore which is mined through contracts with miners from the surrounding communities. More than 250 miner families live within 500m of the Tix Mine.

Table 1: Summary of baseline data for Tix Mine

Item	Description
Milling Equipment	There are two 3-stamp mills
Concentrator used	Copper plates are used to concentrate and recover free gold
Use of amalgam barrel	There is an amalgam barrel, but rarely used by the miners
Use of retorts	A retort is also available and its use is not mandatory
Amalgam burning/smelting site	An amalgam burning site is present, and its location is near the milling site and is mainly used in the case of the miller's ore
Ore ownership at mill site	Miners contracted to work on miller's claims bring the ore for milling on one of the mills. The other mill being reserved for custom milling ores from the surrounding mines
Cyanidation of gravity tailings	Cyanidation of copper plates tailings is practiced in vat leaching tanks
Mine compound	There is a mine compound within 200m of the mine. Mine and mill workers and vendors constitute the residents. There are also those living illegally within the compound, that is illegal miners and panners, population of the mine village is estimated at more than 250
Toilets	Poorly designed Blair toilets are used
Domestic water	Borehole water is used
Health Coordinator	One was selected with assistance from the project team

3.1.2 Thistle-Etna Mining Area

Etna is a large farm approximately 30km southeast of Kadoma, along the Kadoma-Ngezi road which branches off from the Kadoma town-Effiel Flats road, *Site 3* on map. Etna is

an old abandoned mine working and at the beginning of the GMP project was squatted by mostly illegal nomadic artisanal miners. Cases of outbreaks of violence (sometimes fatal) have been reported in this area. The old mine was an underground operation, the miners and panners extract gold from the mine pillars and this has sometimes resulted in high rates of lethal accidents being reported. There is a stamp mill within the area, but most miners use the mortar and pestle to liberate the gold and these processes are sometimes done on back yards. Amalgamation process is secretive and can be done anywhere oblivion or unaware of the dangers of mercury.

Table 2: Summary of baseline data for Etna mine

Item	Description
Milling Equipment	1450 three-stamp mill near the mine compound. Pestle and mortar are also used for high grade ore (including material from mine pillars) by individuals; this being practiced within the villages
Concentrator used	Centrifugal bowl in which 2-3 teaspoons mercury are added depending on the amount of ore
Use of amalgam barrel	No amalgam barrel was found on site
Use of retorts	No retorts were seen or reported on-site, amalgam burning done on open fires
Amalgam burning/smelting site	No specific site is used for burning the amalgam. Burning of the amalgam is even practiced within the village and sometimes inside the huts
Ore ownership at mill site	Miners from surrounding mines bring their ore for custom milling
Cyanidation of gravity tailings	It is practiced using vat leaching tanks
Mine compound	There is a mine compound 50-100m from the mill which houses more than 300 people who include, mill workers, miners, panners and their families, vendors, and also prostitutes
Toilets	Almost filled-up makeshift blair toilets
Domestic water	Borehole is used, sometimes underground mine water
Health Coordinator	One was selected with assistance from the project team

Picture 1: Miners at Etna mine showing the centrifugal bowl

3.1.3 Amberose Mine

It is situated approximately 7km southwest of the Kadoma town and is also very close to Muzwezwe River, *Site 10* on map. The mill set-up is that of a stamp mill for crushing and grinding followed by gravity concentration of the gold in a centrifugal bowl. Mercury in most cases is added into the concentrator as the miners feel that this improves the gold that can be recovered. Also within the mill site are facilities for cyanidation of tailings from the mill by either heap leaching or leaching in vat tanks.

Picture 2: Mill and concentrator at Amberose mine

Table 3: Summary of baseline data for Amberose mine

Item	Description
Milling Equipment	Stamp mills are used for ore milling
Concentrator used	Whole ore amalgamation is practiced in centrifugal bowls
Use of amalgam barrel	An amalgam barrel is present and its use by miners is not mandatory
Use of retorts	Available and use is optional
Amalgam burning/smelting site	Present and still there is no strictness on use
Ore ownership at mill site	Miners bring their ore for custom milling and the miller also has mines which he also mills at the site
Cyanidation of gravity tailings	Tailings are reprocessed by the cyanidation process using vat leaching and heap leaching
Mine compound	Approximately 50 mine and mill workers live in the mining compound
Toilets	Blair toilets are used
Domestic water	Boreholes are used for domestic water
Health Coordinator	One was selected with assistance from the GMP team

3.1.4 Lily Mine

Lily mine is located 20km north west of Kadoma, about 5km from Golden Valley mine along the Patchway-Sanyati road, *Site 5* on map. The mine is underground is located within the owner's farm. No custom milling facilities are offered as the mill rely solely on the owner' ore. A three-stamp mill is used for milling the ore with copper plates being used for recovery of free gold.

Table 4: Summary of baseline data for Lily mine

Item	Description
Milling Equipment	1450 three-stamp mill
Concentrator used	A copper plate is used
Use of amalgam barrel	None
Use of retorts	None on on-site
Amalgam burning/smelting site	No special site for amalgam burning and smelting of the amalgam dore being with a blow torch
Ore ownership at mill site	No custom milling done
Cyanidation of gravity tailings	Vat tanks are used for recovery of residual gold from copper plates tailings
Mine compound	Sited about 50-100m away, mostly for mine and mill workers and their families, estimated at approximately at 100 people
Toilets	Blair toilet system is used
Domestic water	Borehole water is used and shared with the mine operations
Health Coordinator	One was selected with aid of the GMP team

3.1.5 Mandela Milling Centre

The mill is situated in the Chakari area. The mill is a three stamp mill and uses a copper plate to recover liberated free gold, *Site 7* on map. At the time of the visit the mill and mine were not operational.

Table 5: Summary of baseline data for Mandela

Item	Description
Milling Equipment	There is a three stamp mill (was not operational at the time of the visit)
Concentrator used	If operational a copper plate is available
Use of amalgam barrel	No amalgam barrel in place
Use of retorts	No evidence present of the use of retorts, mine was not operational
Amalgam burning/smelting site	Amalgam burn practiced anyway

Ore ownership at mill site	Miners bring ore for milling
Cyanidation of gravity tailings	Present and utilize vat tanks for leaching
Mine compound	Within a distance of 50m from the mill, with an estimate of more than 150 residents (women, men and children)
Toilets	Blair toilets available but in a poor state
Domestic water	Sourced from a borehole
Health Coordinator	Present

3.1.6 Chimukute Milling Centre

It is situated approximately 10km north-west of Kadoma town along the Kadoma-Chakari road, *Site 8* on map. This was one of the few mines and mills operating after "Operation Chikorokoza Chapera". The facilities for miners camping on the mill are very good as there are rooms/sheds for the miners to sleep and showers are also provided.

Table 6: Summary of baseline data for Chimukute Milling Centre

Item	Description
Milling Equipment	There five 1450lbs three-stamp mill in operational
Concentrator used	Centrifugal bowls are used for each mill, with an option to use a copper plate; mercury is added into the concentrator (whole ore amalgamation practiced)
Use of amalgam barrel	No amalgam barrel on site, but the amalgamation is done on a selected site
Use of retorts	No retorts are used
Amalgam burning/smelting site	Done in a closed workshop using a blow torch (see picture below)
Source of mercury	the mill sells mercury to miners, who can also use own mercury sourced elsewhere
Ore ownership at mill site	Miners bring ore for custom milling
Cyanidation of gravity tailings	Vat tanks (for sands) and agitation tanks (slimes) are both used to recover gold from concentrator tailings by cyanidation
Mine compound	Mine compound present, but about 500m away

Toilets	Good flashing system toilets available for the camping miners
Domestic water	Sourced from boreholes
Health Coordinator	None

Picture 3: Miners preparing to burn an amalgam in a workshop using a blow torch at Chemukute Milling Centre

3.1.7 Venice Mine

Venice mine is situated 12km south-west of Kadoma, 5km off the Kadoma-Kwekwe highway along Empress road, *Site 1* on map.

Picture 4: Mills at Venice mine and heaps of ore

Table 7: Summary of baseline data for Venice mine

Item	Description
Milling Equipment	Two 1450lbs three-stamp mills
Concentrator used	Centrifugal bowls in which 3-4 teaspoons of mercury are added
Use of amalgam barrel	None was identified on site
Use of retorts	None was being practiced on-site
Amalgam burning/smelting site	No
Ore ownership at mill site	Custom milling
Cyanidation of gravity tailings	Cyanidation of the tailings done in vat leach tanks
Mine compound	A mine compound exists about 50m away from the mine and is resident to about 20people. Miners bringing ore for milling are from the surrounding communities
Toilets	Almost filled up and bush toilets are sometimes used
Domestic water	Sourced from a borehole
Health Coordinator	One was selected with assistance from the GMP team

3.1.8 Brompton Mine

Brompton mine is located 14km to the south of Kadoma town, *Site 4* on map.

Table 8: Summary of baseline data for Brompton mine

Item	Description
Milling Equipment	A stamp mill
Concentrator used	Shaking table
Use of amalgam barrel	An amalgam barrel is present
Use of retorts	Present but rarely used
Amalgam burning/smelting site	No common burning site identified
Ore ownership at mill site	Miners bring ore for custom milling, and miners contracted to mine the miller's ore
Cyanidation of gravity tailings	Done in vat leach tanks
Mine compound	About 100m away from the mill with an estimated population of 100
Toilets	Blair toilets
Domestic water	Sometimes sourced from the borehole on the mine
Health Coordinator	One was selected with assistance from the GMP team

3.1.9 Imperani Mine

The mine is located about 4km north-west of Kadoma on Railway Farm No. 10A, *Site 12* on map. This was one of the sites chosen for demonstrations of the transportable sluice box technology.

Table 9: Summary of baseline data for Imperani mine

Item	Description
Milling Equipment	There are two three-stamp mills on site
Concentrator used	Each mill is served by a centrifugal bowl with a copper plate on standby should the miner require its use
Use of amalgam barrel	No amalgam barrel was found on site
Use of retorts	There was no evidence of the use of retorts
Amalgam burning/smelting site	No specific site for amalgam burning; smelting of gold dore being using a blow torch near the

	workshop
Ore ownership at mill site	Miners bring their own ore for custom milling
Cyanidation of gravity tailings	Leaching of tailings is done in vat tanks
Mine compound	There is a compound nearby 100m away which is resident to both mine, mill and farm workers
Toilets	Blair toilets almost filled up.
Domestic water	Sourced from a borehole
Health Coordinator	There was one already serving the compound

Picture 5: A miner using bare hands and a pan dish to amalgamate free gold from centrifugal bowl concentrate

Picture 6: After amalgamating the miner then uses a piece of cloth to filter out the excess mercury, leaving the amalgam as the substrate

Picture 7: Miner using 'mvuto' to burn amalgam in open air

Picture 8: Open burning of amalgam

3.1.10 Tiger and Buffalo Mine

It is situated about 18km north-west of Kadoma, 1.5km off the 8km peg along the Golden Valley/Patchway-Sanyati road, *Site 6* on map.

Table 10: Summary of baseline data for Tiger and Buffalo mine

Item	Description
Milling Equipment	A three-stamp is near the mining village, within 70m of the village/compound
Concentrator used	Centrifugal bowl used with mercury being added into the concentrator by the miner
Use of amalgam barrel	Present on the site but rarely used
Use of retorts	Not seen on site
Amalgam burning/smelting site	No common amalgam burning site was identified
Ore ownership at mill site	Miners bring their ore for custom milling with some coming from the miller's mines who contracts miners to work on the mines
Cyanidation of gravity tailings	Cyanidation of concentrator tailings is practiced with use of vat tanks
Mine compound	50m away from the mill is the mine village in which

	more than 150 people resides. These are mostly mill and mine workers and their families. Also in the compound are the illegal panners.
Toilets	Poorly designed Blair toilets
Domestic water	Sourced from a borehole on mine
Health Coordinator	One was selected with assistance of the project team

3.1.11 M and K Milling Centre

The mill is situated about 8km north of north-west of Kadoma, *Site 11* on map. There are mining communities within 150m from the mill. The place was used for demonstrations on the transportable sluice box technology and retorts both RHYP retort and the simple kitchen-bowl retort.

Table 11: Summary of baseline data for M &K mine

Item	Description
Milling Equipment	Three-stamp mill is used for milling the ore.
Concentrator used	Centrifugal bowl in which mercury is also added
Use of amalgam barrel	None was found on site
Use of retorts	Amalgam burning is in the open air
Amalgam burning/smelting site	None was seen on the site, can be done anywhere as the process is done secretly in most cases
Ore ownership at mill site	Miners from the surrounding communities bring their ores for milling.
Cyanidation of gravity tailings	Practiced and vat leaching tanks are utilized
Mine compound	There are mining communities within 150m of the mill
Toilets	Poorly designed Blair toilets
Domestic water	Sourced from boreholes which are also utilized by the mill
Health Coordinator	None

3.1.12 Battlefields Mine

The mine is situated about 32km south-west of Kadoma town along the Kadoma-Bulawayo highway, *Site 2* on map.

Table 12: Summary of baseline data for Battlefields mine

Item	Description
Milling Equipment	One three-stamp mill is used for milling the ore.
Concentrator used	Copper plate is used
Use of amalgam barrel	None was identified on site
Use of retorts	No use of retorts was seen on mine
Amalgam burning/smelting site	No common burning site was seen
Ore ownership at mill site	Miners bring ore for custom milling
Cyanidation of gravity tailings	Practiced in vat leach tanks
Mine compound	Within 50m of the mine with an estimated population of 80
Toilets	Blair toilets
Domestic water	Sourced from a borehole
Health Coordinator	None

3.1.13 All Sites

The most common concentrator is the copper plate, but more and more milling centres are now using the centrifugal bowl, which some miners believe is more efficient than the copper plates. In almost all places whole-ore amalgamation in which 2-4 teaspoons of mercury are added either into the centrifugal bowl or on the copper plates is practiced. This mercury is pulverized or scratched from the copper plates and is lost with the tailings. On cyanidation, the residual mercury of these tailings can easily be transformed into methylmercury, the more poisonous form of mercury. Amalgam barrels are not used despite there being a law that requires every mill to have one and amalgam burning is done anywhere without use of retorts. This shows that the gold extraction methods presently used by small-scale miners in large parts of the project area create a ticking bomb for the environment and for the health of the people of Kadoma and Chakari. This

ticking bomb can, however, with inexpensive means, mainly an awareness campaign and education, be disarmed.

Availability of clean water and poor sanitation were found to be the main problems affecting the mining communities. Of the sites visited the GMP team facilitated with the selection of seven Health coordinators for the mine villages/compounds. The health coordinators were trained in hygiene and basic health care and form the linkage between Kadoma General Hospital and the mining communities. They were also made aware of the health effects of mercury exposure and Chapter 8-10 of the training manual was dedicated to them. They will be responsible for reporting all outbreaks of infectious diseases to the hospital and provide their communities with access basic health care. The coordinators will visit the hospital at least once every month.

3.2 Training Workshops on Mine, Mill Sites and Villages

The training and awareness curriculum on mine and mill sites and its timetable were devised in such a manner that it maintains the interest of participants and at the same time minimizing disruptions of their daily activities. As such lessons were scheduled to start at 1000hrs in the morning and end at 1400hrs, normally after lunch, which was funded by the project.

The first day of the week (Monday) was dedicated to the transportation of equipment from Zimbabwe Panners Association (ZPA) office to the training site. The following days Tuesday to Friday were training and demonstration sessions. Each day usually started in some cases with mobilizations of the trainees by members of the Zimbabwe Panners Association (whom the panners and miners trusted) followed by the training proper of the participants. Basic geology, mining techniques and mineral processing were done the first day for each group and; mercury use and associated hazards and health effects, general health and sanitation issues were conducted the following day for the same group. The training approach used was of a participatory nature based on practicals with practical examples. The main emphasis for each session was as summarized in the Table 13 below:

Table 13: Critical points being emphasized on each session

Subject Session	Main Emphasis
Geology	1. In order to fully utilize the gold resources you need proper evaluation of your ores 2. exploration techniques 3. lets graduate from artisanal miners to organized small scale miners
Mining, Safety, Occupational Health and Environment	1. safe mining techniques 2. avoidance of haphazard mining methods 3. need for ventilation and support 4. safe use of explosives
Mineral Processing	1. Good liberation result in more gold being recovered 2. advantages of open circuit over closed circuits 3. role of mercury on gold recovery 4. Concentrate the ore first then amalgamate (no to whole-ore amalgamation) 5. encouraged the use of simple technology such as the sluice box over copper plates 6. demonstrations
Mercury and Associated Hazards	1. handling, exposures and routes of entry into body 2. basic chemistry and toxicology 3. mercury poisoning and symptoms thereof 4. mercury in the food chain 5. Safe ways of burning amalgam (use of retorts) 6. recycling of mercury 7. formation of amalgam burning centres/places 8. demonstrations with retorts
Health and Sanitation	1. For you to work properly and increase your production you need a health body 2. to enjoy the fruits of your labour you need to maintain a healthy body 3. safe drinking water 4. prevention against malaria and other diarrheal diseases, STIs, HIV/AIDS 5. personal hygiene

3.2.1 Training Workshops: Outreach Programme

The project managed to get in contact with 723 people from mining communities surrounding Kadoma. Of the total participants 246 were women and 477 were men. The participants included mine, mill workers and their wives, illegal and legal panners, and vendors who resided in mining compounds. A register was circulated and each

participant would write down his/her name and sex. Unfortunately the participant's ages were not recorded for all sites visited but all women who took part in the training workshops were of child bearing age. After "Operation Chikorokoza Chapera" some of the participants were no longer willing to have their names written down as they feared that the project team will forward their names to the police. List of the people who participated in the outreach program are found as scanned pages in Appendix IV. Included in the register were the names of mines/mills, date of training session, names of participants in their own handwriting, and sex.

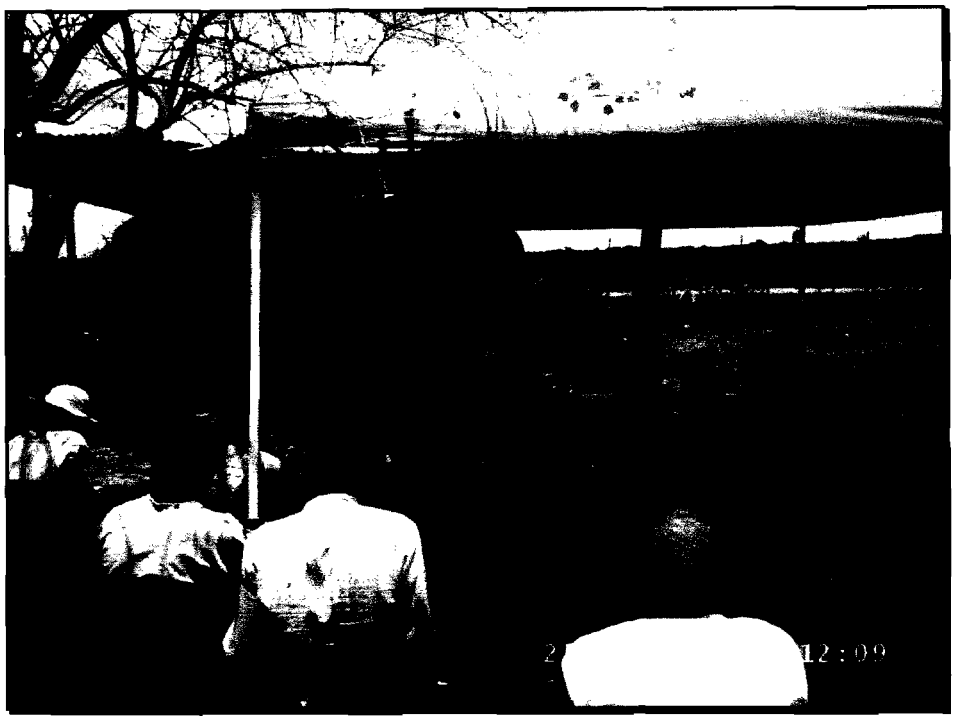
Table 14: List of sites visited and total number of participants who were trained

Mine/Area	Dates Visited	Number of people trained		
		Male	Female	Total
Venice	6-10/09/2006	56	3	59
Battlefields	13-17/09/2006	46	2	48
Etna	04-15/10/2006	63	23	86
Brompton	18-22/10/2006	49	28	77
Lily Mine	7-10/11/2006	24	7	31
	14-17/11/2006	15	18	33
Buffalo & Tiger	20-24/11/2006	30	10	40
	28/11/06-01/12/06	22	24	46
Mandela	04-08/12/2006	47	12	59
	11-15/12/2006	29	61	90
Chimukute	30/04/2007-04/05/2007	30	17	47
Tix	14-25/05/2007	40	29	69
Amberose	28/05/2007-01/06/2007	26	12	38
	Total	**477**	**246**	**723**

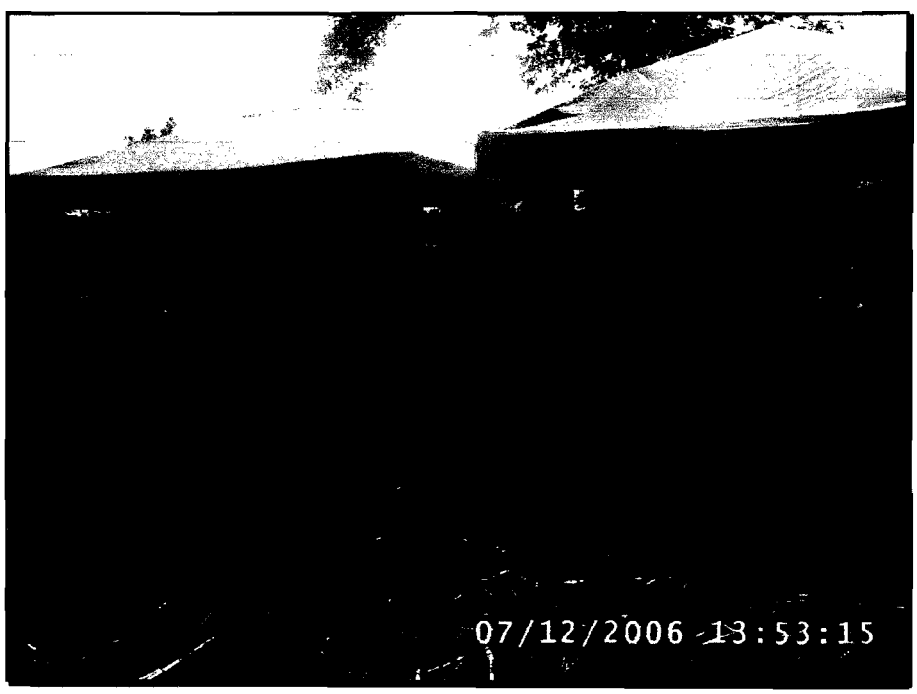
The questions that were frequently asked by the participants during the training workshops are included in this report as Appendix II.

Picture 9: UNIDO trained women trainers at ETNA

Picture 10: Participants listen attentively to one of the mixed sessions conducted at Mandela Milling Centre by GMP trainer (out of picture)



Picture 11: Mr Ruwende (Ministry of Mines) conducting a geological session during mercury awareness campaign and training at Buffalo Mine



Picture 12: Mr O. Phiri (UNIDO trained trainer for artisanal miners) conducting one of the training sessions at Mandela Milling Centre

Picture 13: Sister Tembo, a nurse, illustrating a point to the all women session at ETNA mine

3.3 Exhibition Shows

The Global Mercury Project awareness campaign was further boosted by displays at Mine Entra (an annual mining exhibition in Bulawayo) and at Kadoma-Chegutu Agricultural Show. The Kadoma-Chegutu Agricultural show was held from the 28th of September to the 1st of October 2006 in Kadoma (GMP project area) and the project, in conjuction with the Zimbabwe Panners Association (ZPA), participated with the main objective of furthering the awareness campaign in the project area of the hazards of mercury and the use of cleaner technology in the extraction of gold. The theme of the show was, "Kadoma-Chegutu: District of plenty resources for sustainable development" which was in line with the main objectives of the Global Mercury Project. The project exhibits included brochures, pictures of processing of gold, panning dishes, retorts, mercury measurement equipment (Lumex), demonstration of semi-quantitative measurement of mercury, sluice box and carpets. A decision to participate at the show was to further the awareness campaign in the handling, storage and use of mercury and the hazards associated with them and also to demonstrate cleaner gold production techniques through the use of the sluice box. A total of 154 visitors toured the stand at the Agricultural Show and more than 200 at MINE ENTRA.

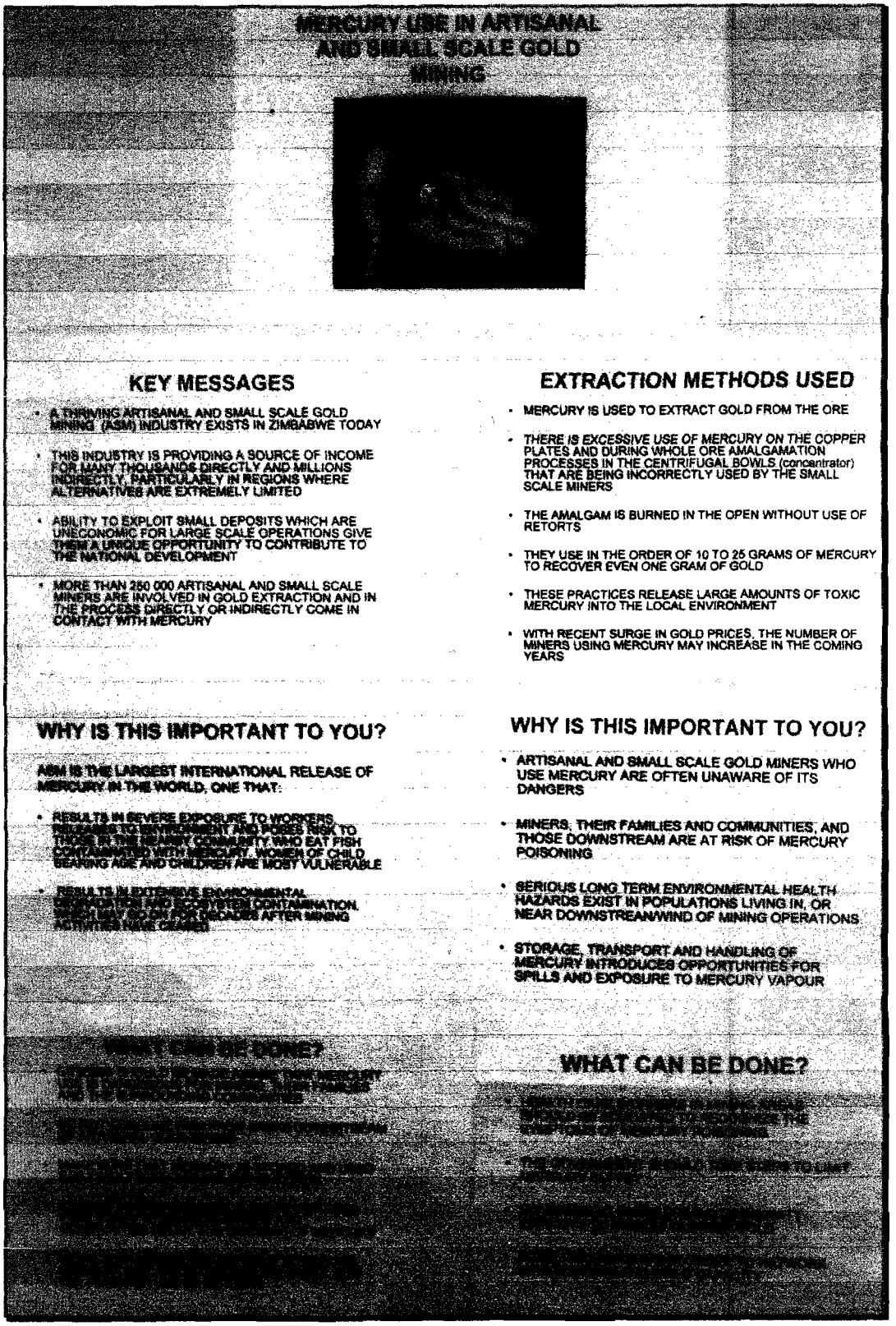
Picture 14: Exhibition at the Kadoma-Chegutu Agricultural show

Picture 15: Mr S. Kahwai, Project Manager, with ZPA artisanal trainers in front of GMP exhibition stand

Picture 16: Mr Kupahurasa showing audience how mercury finds its way into the environment

Picture 17: Lumex for mercury analysis

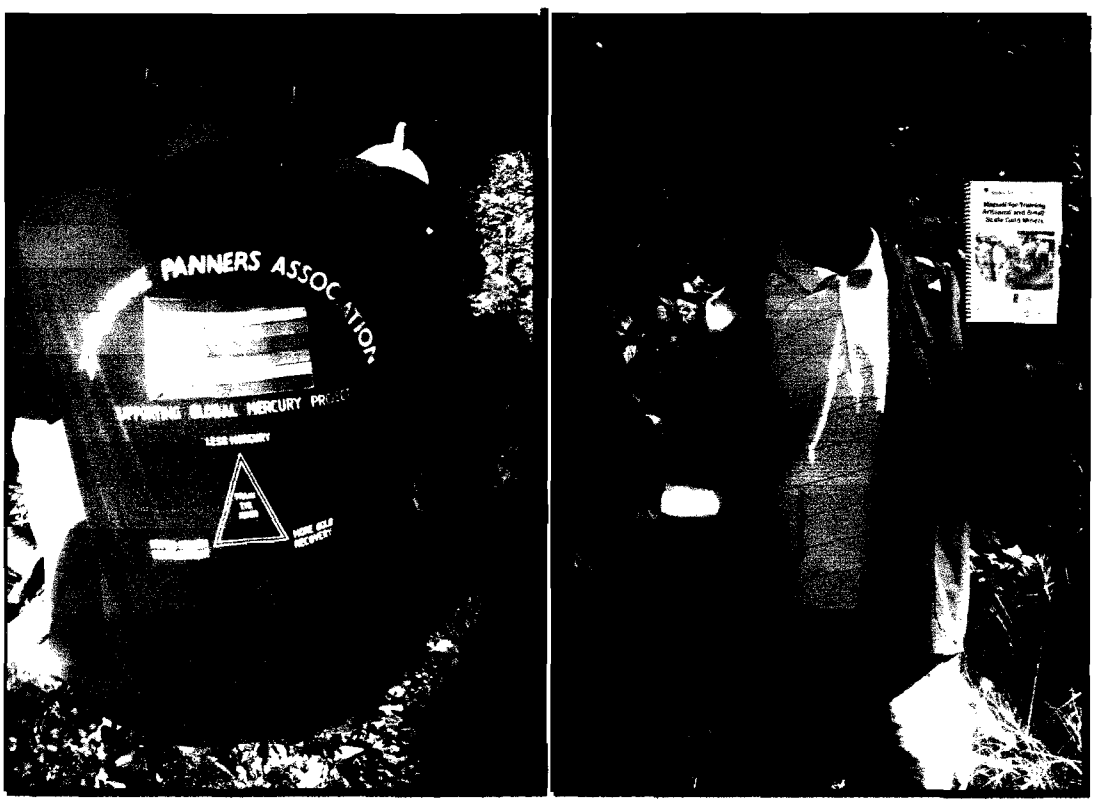
Picture 18: Children were also part of the group that GMP got in contact with at the Exhibition show



Picture 19: Part of the poster exhibits at Mine Entra and at Kadoma agricultural show

3.4 Campaign Material

Different forms of campaign materials were used and these included t-shirts, brochures, posters and training manuals. A total of 150 t-shirts, 230 brochures and posters were distributed. These were distributed at the exhibition shows, at mine and mill sites to miners, millers and panners. 60 GMP training manuals were given to mine and mill managers as this group was considered literate and would be able understand the information and teach others. Photocopies of Chapter 8-10 of the same manual were given to health coordinators of the mining communities visited. Appendix III shows the brochure that was distributed.



Picture 20: Campaign material T-shirts and training manuals

The brochure and posters' contents included, paths of mercury transport in the environment, human exposure routes, the most obvious symptoms of mercury poisoning of humans and preventive measures.

3.5 Demonstrations

Demonstrations were done on the use of retorts, reactivating floured mercury and the effectiveness of the sluice box as an alternative to whole-ore amalgamation on copper plates and centrifugal bowls. Demonstrations on the TDU were limited only to the transportable sluice box, as the prevailing economic situation and lack of funds as will be discussed in Section 5, made it costly and impossible to fully assemble the whole unit. Demonstrations on the transportable sluice box were also limited to three sites, M & K, Chimukute and Imperani mine mainly because of the frequent power blackouts that were being experienced throughout the country and the stoppages in operations experienced during the period December, 2006 and April, 2007. It is however, important to note that the sluice box technology was well received and it proved to be an effective concentrator with better recovery than whole-ore amalgamation in centrifugal bowls, see **Appendix VI**. With the sluice box technology mercury-free tailings are produced, hence no contamination of the environment with mercury. In one of the demonstrations more than 100g of gold was recovered using the sluice plus vinyl loop carpet technology. As a result of the success of the demonstrations a sluice box with vinyl loop carpet was installed at Imperani Mine and is still in operation. A total of 251 people were present during the demonstrations on the transportable sluice box (M&K-70; Chemukute-96; Imperani-85) done in July and August, 2007.

Picture 21: Trainers being assisted by miners to fix the transportable sluice box on the mill at M & K

Picture 22: Sluice box with vinyl carpet in operation at Imperani mine

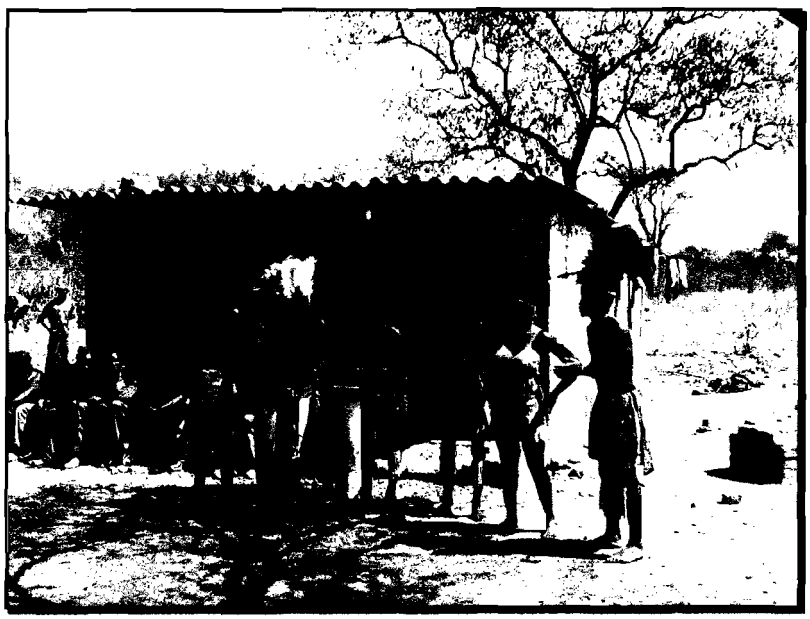
Picture 23: Demonstrations of RHYP retort

Picture 24: Trainer and miners cleaning sluice vinyl carpet

Picture 25: Women trainers demonstrating the use of the kitchen bowl retort

3.6 Global Mercury Project Awareness Campaign through Community Theatre

The awareness campaign was also done through the use of community theatres in mining villages/compounds. A total of five performances were done.



Picture 26: Community awareness through theatre

Picture 27: *Theatre campaign at Imperani mining village*

The GMP awareness through theatre was based on the community play 'Nakai', the story of a farmer's daughter exposed to mercury by her artisanal miner boyfriend. The play highlighted issues on conflicts between miner and farmer, routes of exposure, health effect of mercury and preventative measures. Communication of hazards of mercury through the play 'Nakai' performed in August, 2007 reached over 200 people at Imperani mine. The audience on theatres included all ages, children, women and men.

4.0 PROJECT EXPENDITURE

The detail breakdown of the project expenditure is shown in **Appendix V**. Hyperinflation in Zimbabwe made delivery of the awareness campaign and TDU programs extremely difficult. The official foreign exchange rate was fixed at Z$250:1US$ whilst the black market rate was well over Z$4,000:1US$. The operational budget in United States dollars terms became too costly. Supermarkets and shops shelves were stripped of all goods and were only available at extremely inflated prices on the black or parallel market. Low official currency exchange rates and hyperinflation led to constant budget adjustments.

Table 15: Summary of expenditure for the duration of the period

Item	**Cost (US$)**
Equipment and accessories	
Generator	8,500.00
wheel barrows	636.00
Shovels	200.00
camping equipment	1106.00
tent and chairs	2740.00
digital scale	1002.00
sluice box	1387.00
ball mill	14500.00
tool kit	136.00
first aid kit	132.00
Dishes	150.00
jerry cans	250.00
Laptop	950.00
Printer	115.00
Projector	3100.00
hammer mill	3051.00
Sub-total	***37,897.00***
DSA	32250.00
Food & other incidentals	8216.00
Stationery & PPE	3237.00
Fuel and vehicle maintenance	10696.00
professional fees (ZPA & Health)	17500.00
Communication	920.00
IMR contribution	1000.00
Labour cost	90.00
Grand Total	**111,864.00**

5. OPERATIONAL CONSTRAINTS

1. Field operations were affected by the "Operation Chikorokoza Chapera" (Operation End Illegal Gold Panning: an operation meant to curb illegal mining activities) initiated by the Government, which stopped all small scale gold mining operations in the country for over four months and led to arrest of more than 30,000 miners. The merits and demerits of the operation have been subject to debate, but from our own assessment, the operation meant that very few miners were able to mine and send their ores to milling centres for processing. The destruction of mining villages and compounds denied the project of a ready audience for training miners and their families. Furthermore, the miners became suspicious that congregating them at a training session would present the Police an easy opportunity to arrest them. It also became difficult to get the details of trainees as they feared that we were agents of the police and we would forward their names to the police.

2. "Operation Chikorokoza Chapera" virtually caused all mines to close and only allowed to resume operations until all legal requirements were met. The legislation supporting Chikorokoza Chapera was the new Environmental Management Act (EMA), which began requiring miners and millers to have approved Envrionmental Impact Assessments (EIA) and Environmental Management Plans (EMP). The introduction of the need for an EIA before resumption of operations meant that very few miners, even up to now, have opened their mines and most are forced to work clandestinely; citing the prohibitive cost of the EIA and subsequent cost for reviewing the EIA by the Environmental Management Agency.

3. The hyperinflationary environment (official rates more 4,500% per annum, and unofficial rates were estimated at 10 times that figure) experienced during the time of the project meant that prices for goods and services kept on escalating. The price freeze (a government initiative to control inflation) introduced in July, 2007 by the Government worsened the situation as goods and services were only available at

black market rates. There was no fuel from registered dealers and prices were increasing on a daily basis to more than USD1.40 per litre. The exchange rate was also fixed (Z$250 to 1US$) and it meant that there was a huge difference between the official bank rate (from where we obtained our monies) and the black market rate (Z$4000 to 1US$). Our operational budget in United States dollar terms became way too expensive and funds quickly got exhausted. This resulted in failure of implementation of demonstrations on the full TDU unit (demonstrations were then limited only to the transportable sluice box) and those activities which were reserved for the last quarter (towards the end) of the project period such as the billboards, cinematographic record and publication of a comic book based on the play 'Nakai'.

4. The project was implemented under extremely difficult socio-economic and political environment which added to the above challenges, and restricted the ability of IMR to carry out its mercury awareness campaign and training programs.

6. SUMMARY AND RECOMMENDATIONS

6.1 Summary

In almost all of the Kadoma-Chakari area whole ore amalgamation in which 2-4 teaspoons of mercury are added into the centrifugal bowl or on the copper plates is practiced. This mercury is easily pulverized in the centrifugal bowl or scratched from the copper plates and is lost with the tailings. Therefore the emphasis during the training workshops was that miners should concentrate first the ore before mercury amalgamation, and in this way reduces the amount of mercury that reports to the tailings, hence the environment. The baseline data also indicated that the miners rarely use retorts for amalgam burning and that no amalgam burning and smelting sites were used, thus exposing them to the toxic mercury vapour. Again the training sessions emphasized on the importance of the retorts and demonstrations on the use of the retorts, RHYP type and the simple kitchen bowl retorts, and reactivation of floured mercury were done on all the 12 mine sites that were visited. The miners were also taught on how to make the simple kitchen bowl retort and where to buy the RHYP retorts.

The total number of mine sites that were visited for both the training workshop and technology demonstrations was twelve. The sites chosen were found to be key areas in which there was massive miner/panner congregations. The project managed to get in contact with 723 people from mining communities surrounding the Kadoma-Chakari area. In fact the figure is higher as people, later after "Operation Chikokoza Chapera", were no longer willing to have their names written down in the project register. The following issues were covered during the workshops:

- basic geology
- mining and safety, occupational health and the environment
- mineral processing techniques
- mercury use and associated hazards and health effects, and
- general health and sanitation

The nature of the approach used for the training was participatory based on practicals with practical examples. Of the total registered participants 246 were women, representing 34%. The danger of mercury to developing babies and children was emphasized. Members from the Ministry of Mines and Development (4), Ministry of Health and Child Welfare (2), Zimbabwe Panners Association (4) and the University of Zimbabwe (2) were involved in the training and awareness campaign of the hazards of mercury and use of cleaner technology in the extraction of gold. See **Appendix I**, List of trainers and the role played by each member.

Availability of clean water, poor sanitation, occurrence of infectious diseases and prevalence of sexually transmitted diseases (STIs) were found to be the main problems affecting the mining communities. The GMP team facilitated with selection of community Health Coordinators in seven of the mine sites visited. The role of these coordinators was to provide a linkage between the mining communities and the Kadoma General Hospital and provide basic health care to the communities.

Exhibitions at Kadoma-Chegutu Agricultural Show in the project area and MINE ENTRA in Bulawayo were also used to disseminate information on the community awareness on hazards of exposure to mercury and the use of cleaner technology in the extraction of gold. The project exhibits included brochures, pictures of processing gold, panning dishes, retorts, mercury measurement equipment, sluice box technology and carpets. A total of 154 visitors toured the exhibition stand at the Agricultural Show.

The awareness campaign was also done through the distribution of t-shirts, brochures, posters and training manuals. A total of 150 t-shirts, 230 brochures and posters were distributed during the exhibitions and the community outreach programmes. 60 GMP manuals for training artisanal and small scale gold miners were distributed to mine and mill managers whilst photocopies of Chapters 8 to Chapter 10 of the same manuals were given to health coordinators in mine sites visited.

Demonstrations were done on the use of retorts, reactivating floured mercury and the effectiveness of the sluice box technology as an alternative to whole-ore amalgamation on copper plates and centrifugal bowls. Demonstrations on the TDU were limited only to the transportable sluice box, as the prevailing economic situation and lack of funds as discussed earlier in Section 5, made it costly and impossible to fully assemble the whole unit. Demonstrations on the transportable sluice box were also limited to three sites, M & K, Chimukute and Imperani mine. The main reasons for this was the frequent power blackouts that were being experienced throughout the country and the stoppages in mine operations experienced during the period December, 2006 and April, 2007. It is however, important to note that the sluice box technology was well received by miners and it proved to be an effective concentrator with better recovery than whole-ore amalgamation in centrifugal bowls. With the sluice box technology mercury-free tailings are produced, hence no contamination of the environment with mercury. In one of the demonstrations more than 100g of gold was recovered using the sluice plus vinyl carpet technology. As a result of the success of the demonstrations a sluice box with vinyl carpet was installed at Imperani Mine and is still in operation. A total of 251 people were present during the demonstrations on the transportable sluice box (M&K-70; Chemukute-96; Imperani-85) in July and August, 2007.

GMP awareness was also done through theatre and was based on the community play 'Nakai'; the story of farmer's daughter exposed to mercury by her artisanal boyfriend. The play highlighted issues on conflicts between miner and farmer, routes of exposure, health effect of mercury and preventative measures. Communication of hazards of mercury through the play 'Nakai' performed in August, 2007 reached over 200 people at Imperani mine.

6.2 Conclusions

- The project was implemented under challenging conditions in the project area and the country as a whole. The challenges included "Operation Chikorokoza Chapera" which virtually stopped all small scale gold mining operations for more than four months, frequent power blackouts which made it impossible to do demonstrations

with the transportable sluice box, and the hyperinflationary environment which, caused prices to fluctuate on a daily basis.

- The interest shown on the health effects of mercury was tremendous. There was a general lack of knowledge as to the poisonous effects of mercury.
- Whilst the miners liked the simple sluice box and its vinyl loop carpet because of better recovery than other methods the millers were not willing to adapt the new technology as they felt that it deprived them of high grades values on their tailings which they process by cyanidation.
- There is resistance to change by both the miners and the millers because to them, the methods they are currently using have been practiced for a long time in the country and they consider them more transparent and reliable than new alternatives. They are reluctant to embrace new technologies because they have confidence in the old, well established practices.
- Training or awareness of children can be effectively done through community theatre shows. Theatre can communicate awareness messages to large numbers of people of all ages without the need of grouping them into different training classes. The same message can be effectively accepted by all age groups through theatres than through lectures.
- Increased awareness can reduce the number of miners and their families, who are exposed to mercury and the introduction of new simple technologies such as the sluice box in conjunction with vinyl loop carpet, can reduce the amount of mercury reporting to the environment.

6.3 Recommendations

- Health care workers in mining areas around the country should be educated to recognize the symptoms of mercury poisoning and a similar awareness campaign should also be done in other mining districts of the country.
- Government should take steps to limit mercury supply and build community capacity to market cleaner gold.

- The exposure to mercury for the miners and the community has to be drastically decreased. Proper mining techniques to reduce the burden of accidents and mercury exposure are essentially needed. Small-scale miners need all possible support to introduce cleaner and safer gold mining and extraction technologies.

7. REFERENCES

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2. ***Boese-O'Reilly S., Dahlmann F., Lettmeier B., and Drasch G.(2004),***Removal of Barriers to the Introduction of Cleaner Artisanal Gold Mining and Extraction Technologie in Kadoma, Zimbabwe, Final Report
3. ***Global Mercury Project***, Manual for Training Artisanal and Small-scale Gold Miners, Project EG/GLO/01/G34: Removal of Barriers to Introduction of Cleaner Artisanal Gold Mining and Extraction Technologies
4. ***Shoko D.,and Veiga M.M.,*** Information about the Project Sites in Zimbabwe, Project EG/GLO/01/G34: Removal of Barriers to Introduction of Cleaner Artisanal Gold Mining and Extraction Technologies
5. ***Maponga O.(1991)***, Small-scale Mining Sector in Zimbabwe, IMR Report 1991, University of Zimbabwe

APPENDIX

Appendix I

List of Trainers

Subject	Trainer	Designation
Mining and Environmental Issues	Mr. C. Gambara (Institute of Mining Research, University of Zimbabwe)	Lecturer/ TDU Manager
Safety and Occupational Health	Mr. Mlangeni (Kadoma Mining Department, Ministry of Mines and Develpment)	Mining Engineer
Geology and Related Issues	Mr. T. Ruwende (Geological Survey Department, Ministry of Mines and Development, Gweru)	Regional Geologist
Mineral Processing and Related Issues	Mr T. Masiya (Institute of Mining Research, University of Zimbabwe)	Lecturer
	Mr Dzingai (Department of Metallurgy, Gweru, Ministry of Mines and Development)	Regional Metallurgist
	Mr. W. Chigwida (Department of Metallurgy, Harare, Ministry of Mines and Development)	Regional Metallurgist
Mercury Use, Associated Hazards and health effects	Mr. O. Phiri (Zimbabwe Panner Association)	UNIDO trained trainers for Artisanal Gold miners
	Mr. S.T. Tawengwa (Zimbabwe Panners Association)	
	Ms C. Dingindawo (Zimbabwe Panners Association)	Trained Female trainer
	Ms M. Nyamukure (Zimbabwe Panners Association)	Trained female trainer
Health, Environment and Sanitation and Related Issues	Mr. P. Sibotshiwe (Ministry of Health and Child Welfare)	Environmental Health Officer
	Sister N. Tembo (Kadoma Hospital, Ministry of Health and Child Welfare)	State Registered Nurse

Appendix II

Most Frequently Asked Questions (FAQ)

Throughout the GMP awareness campaign the questions that were mostly asked were compiled and this basically represents what the artisanal miners lack in knowledge and wanted to learn more on. The FAQ were divided into their different sections.

Geology

1. What rocks are usually associated with gold?
2. How long does it take to get a prospecting license and what is the cost of obtaining one?
3. Who is qualified to apply for a prospecting license?
4. Can I prospect on someone's property?
5. How long does the process of acquiring a claim take?

Mining

1. Who is qualified to use explosives?
2. How long does it take to get a blasting license?

Mineral Processing

The miners were mainly concerned with the quality of their final gold product and the following questions were frequently asked:

1. What causes the gold to darken (kusviba)?
2. Can nitric acid be used to clean the gold?
3. What is khakhi, fools and flying gold?
4. Which is the best and efficient method to concentrate our ore?
5. How do we deal with sulphidic ores?

Mercury and its Associated Hazards

1. Is there a cure for mercury poisoning?
2. Does mercury poisoning cause death?

3. Is it similar to HIV infection?
4. Can mercury contamination occur through sex?
5. Should we stop eating fish?
6. How does it pass into our body through hands when working on the copper plates?
7. Is it possible to swallow mercury and recover all of it through anal canal?
8. Where can we get the retorts and how much does it cost to acquire one?
9. Can nitric acid be use to clean mercury?
10. Does roasting remove the mercury within the fish?

Health and Sanitation

The artisanal miners where aware of the disease and sanitation issues that concerned their communities and were more interested in how to get treatment.

1. Where can we access the medicine and is it free?
2. Is water from mine works safe for domestic use?
3. Is there any first aid that can be given to cholera patient before treatment from a health practitioner?
4. How long does a person who has been treated for malaria take before he is re-infected?

Appendix III

BROCHURE

Bringing Solutions to Artisanal Miners

The GMP through the Institute of Mining Research (IMR) is introducing affordable and accessible technology to miners in Zimbabwe. The impacts of mercury both to the environment and human health can be reduced through:

- use of retorts when burning amalgam
- formation of amalgamation centres in mining communities
- use of the most effective amalgamation methods e.g. amalgam barrels
- avoidance of whole-ore amalgamation i.e. do away with the practice of adding mercury into centrifugal bowls, 'separator'
- avoiding burning of mercury near homes, children and women
- discouraging the use of copper plates and promoting the use of the sluice box technology

Kitchen-bowl retort on a bonfire

- community awareness campaigns and training workshops on the dangers of mercury

Training miners in Kadoma on use of retorts

Simple sluice box technology for better gold recovery

Contact:
IMR-Institute of Mining Research
University of Zimbabwe, Box MP167,
Mt Pleasant, Harare
imr@science.uz.ac.zw
Project Funded by UNIDO

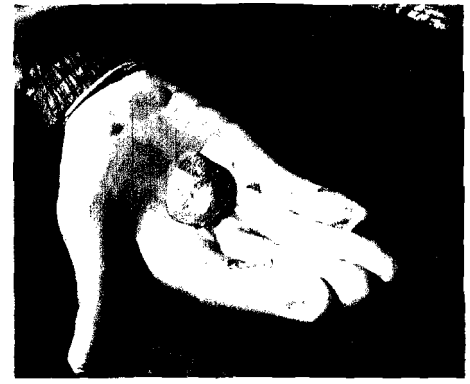
UNIDO

I M R

GLOBAL MERCURY PROJECT

A Global Effort for

Less Mercury, More Gold, and a Better Health



SOLUTIONS FOR
ARTISANAL MINERS

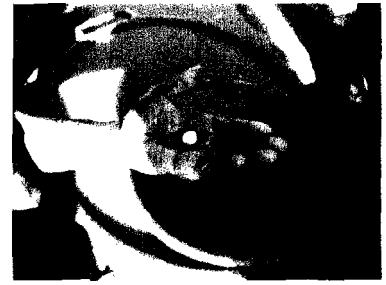
A miner amalgamating gold at Imperani Mine in Kadoma

About the GMP

Zimbabwe and the rest of the world are currently witnessing the biggest gold rush the world has ever seen. It is estimated that there are 300,000 to 400,000 artisanal and small scale miners in Zimbabwe and they use mercury to extract gold from the ore.

The Global Mercury Project (GMP) is an initiative of the United Nations to promote safer and cleaner practices in artisanal mining communities where mercury is used to process gold.

The emergence of this worldwide gold rush is causing unprecedented global mercury pollution. Artisanal and small scale mining releases 1000 tonnes of mercury every year. The GMP is introducing solutions to alleviate health and environmental crises in mining communities and promote cost-effective practices.



A mine showing a gold-mercury amalgam

Mercury, Health and Gold Mining

Artisanal gold mining creates 30-40% of the world's man-made mercury pollution. Mercury is a powerful poison which damages the brain and kidneys, and is very dangerous for developing babies and small children.

Gold miners and people living in and near mining communities are exposed to mercury in three ways:

- mercury can be absorbed directly through the skin during amalgamation process
- mercury vapour is inhaled when miners burn amalgam, and
- mercury is ingested through contaminated fish

After it is released into the environment as vapour or liquid in mining wastes, mercury transforms into a more toxic compound (methylmercury) which is rapidly absorbed by aquatic organisms and goes up in the food chain.

A miner burning gold amalgam using a blow torch

Once mercury has entered the ecosystem, it is very hard to remove it. This is why it is important for miners to reduce or even eliminate the use of mercury.

Exposure to mercury poisoning is increased by burning amalgam on in open fires

Appendix IV

LIST OF PARTICIPANTS

for

OUTREACH PROGRAMME

Location: Lily Mine

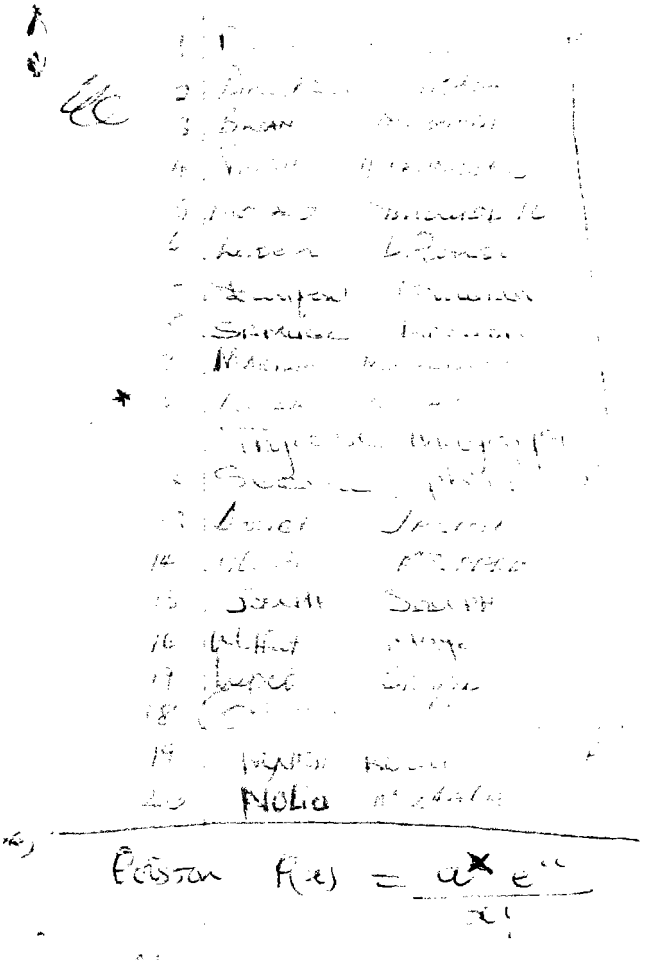
Purpose of Meeting: Training Workshop and Awareness Campaign

Date: 7/11/2006 to 10/11/2006

Total Number of Participants

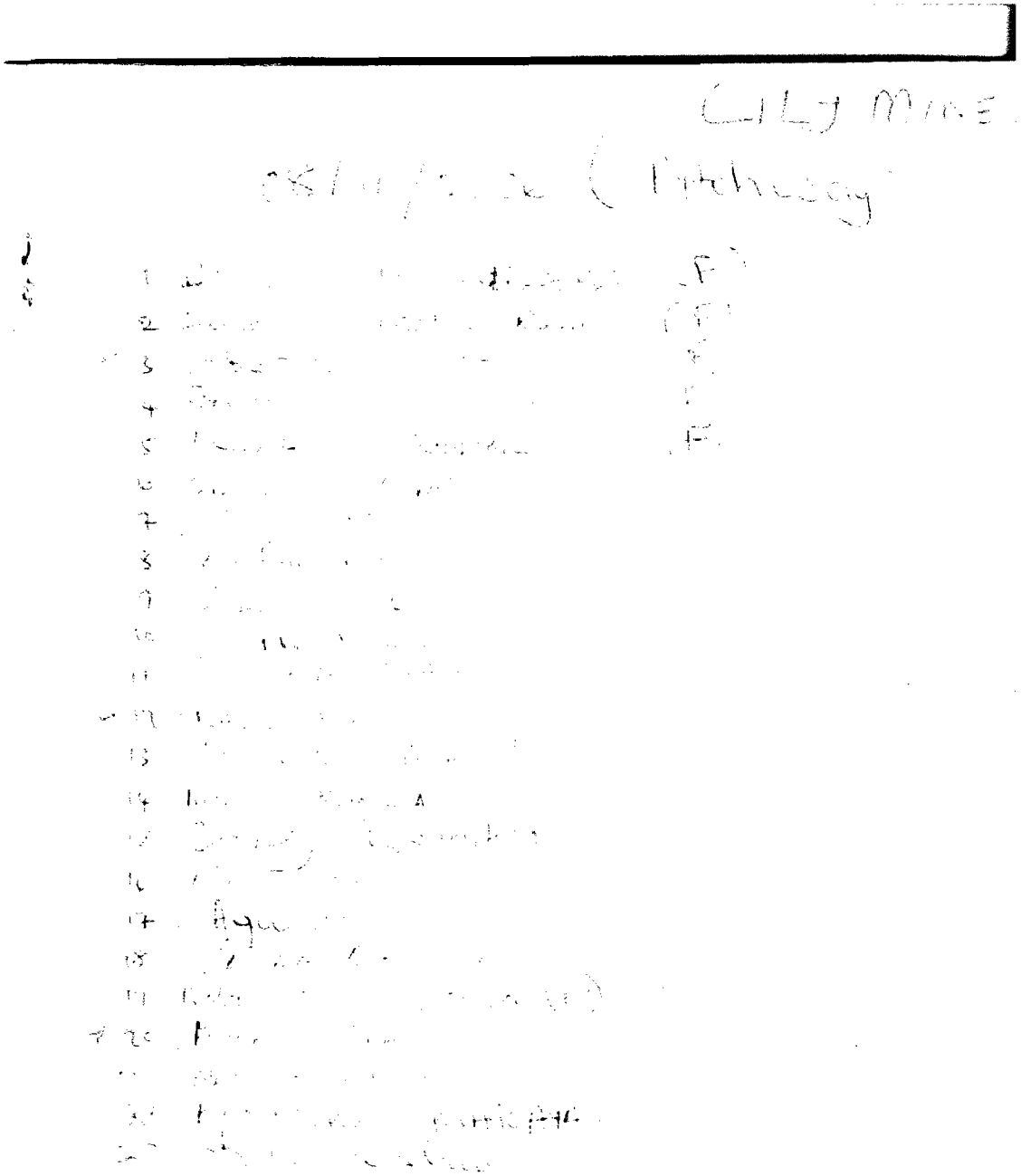
39 males

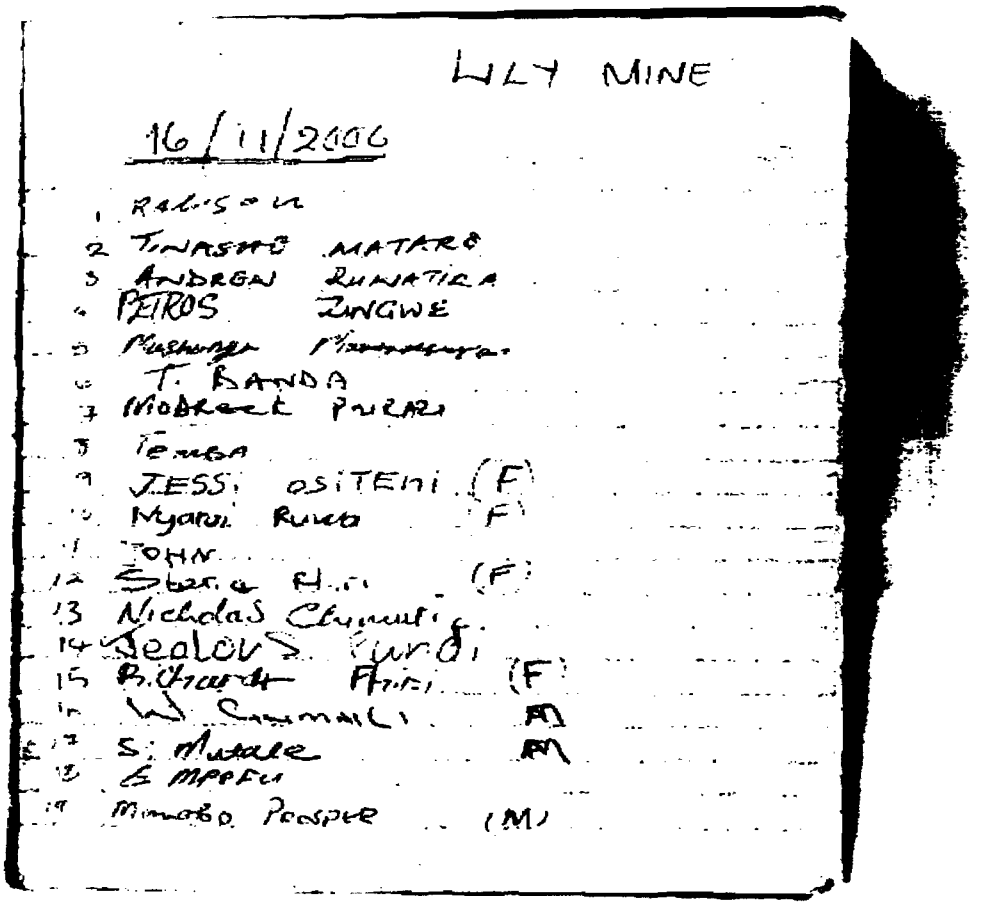
25 females



Poisson $P(x) = \frac{a^x e^{-a}}{x!}$

Mean = $V(x)$





LILY MINE

16/11/2006

1 RALISON
2 TINASHE MATARO
3 ANDREW RUNATIRA
4 PETROS ZINGWE
5 Mushonga
6 T. BANDA
7 Robert PURAZI
8 Teresa
9 JESSI OSITENI (F)
10 Myaui Ruvo (F)
11 JOHN
12 Sharon H... (F)
13 Nicholas Chimuti
14 Sealous Furusi
15 B. Uriah Phiri (F)
16 W Samuel (M)
17 S. Mutale (M)
18 E Mpofu
19 Mmabo Prosper (M)

Location: Brompton Mine

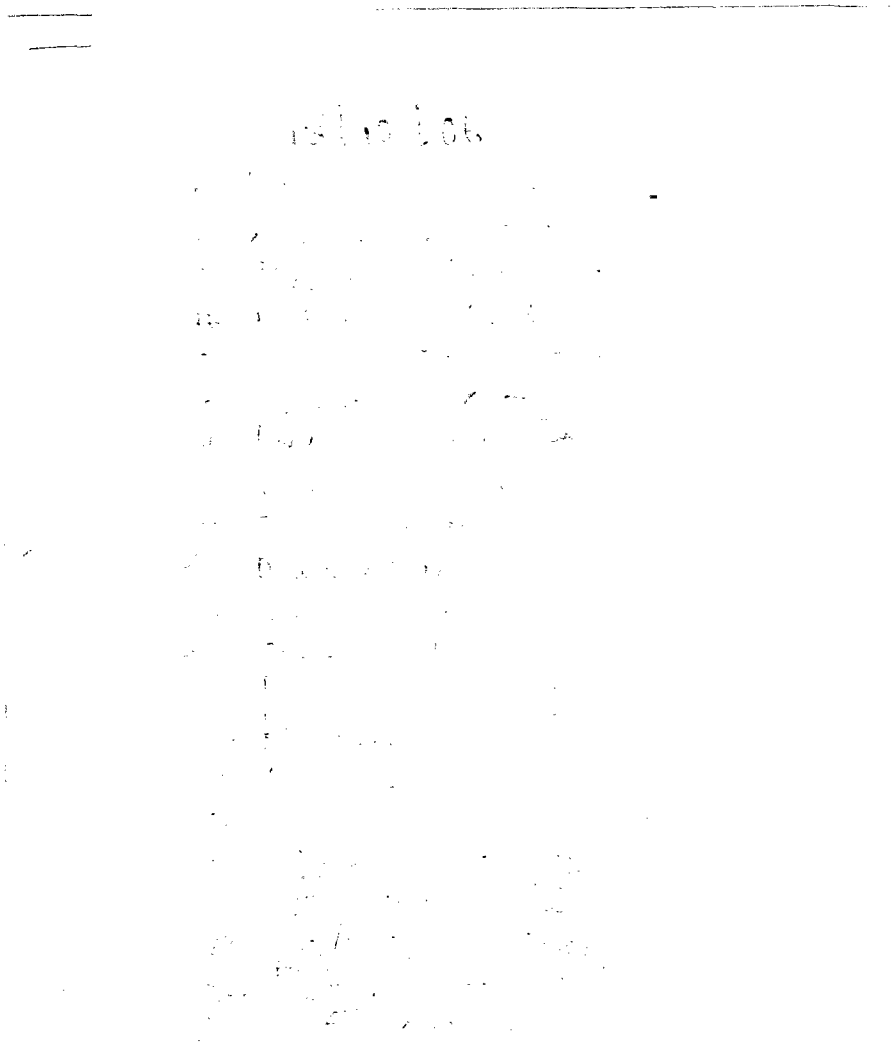
Purpose of Meeting: Training Workshop and Awareness Campaign

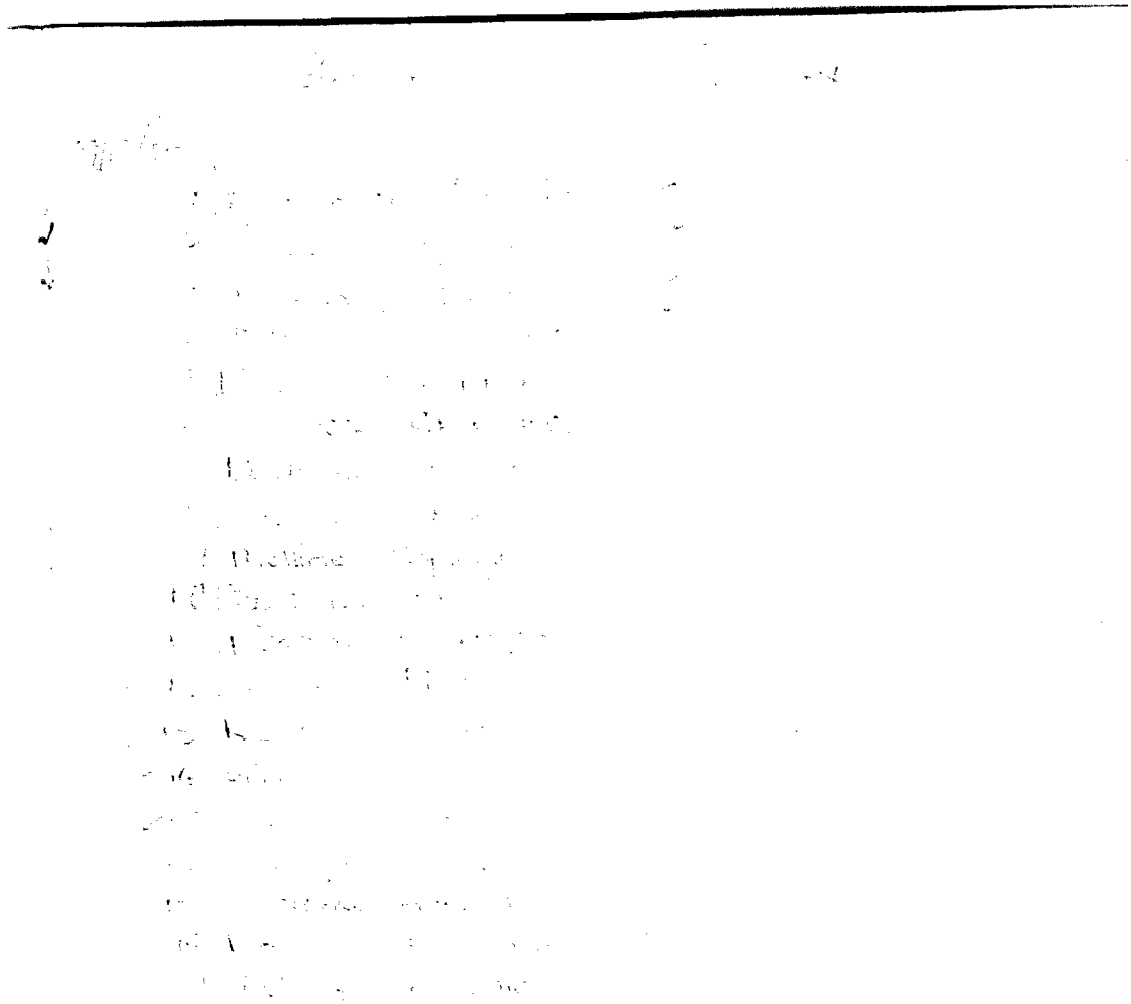
Date: 18/10/2006 to 22/10/2006

Total Number of Participants

49 males

28 females





Location: Venice Mine

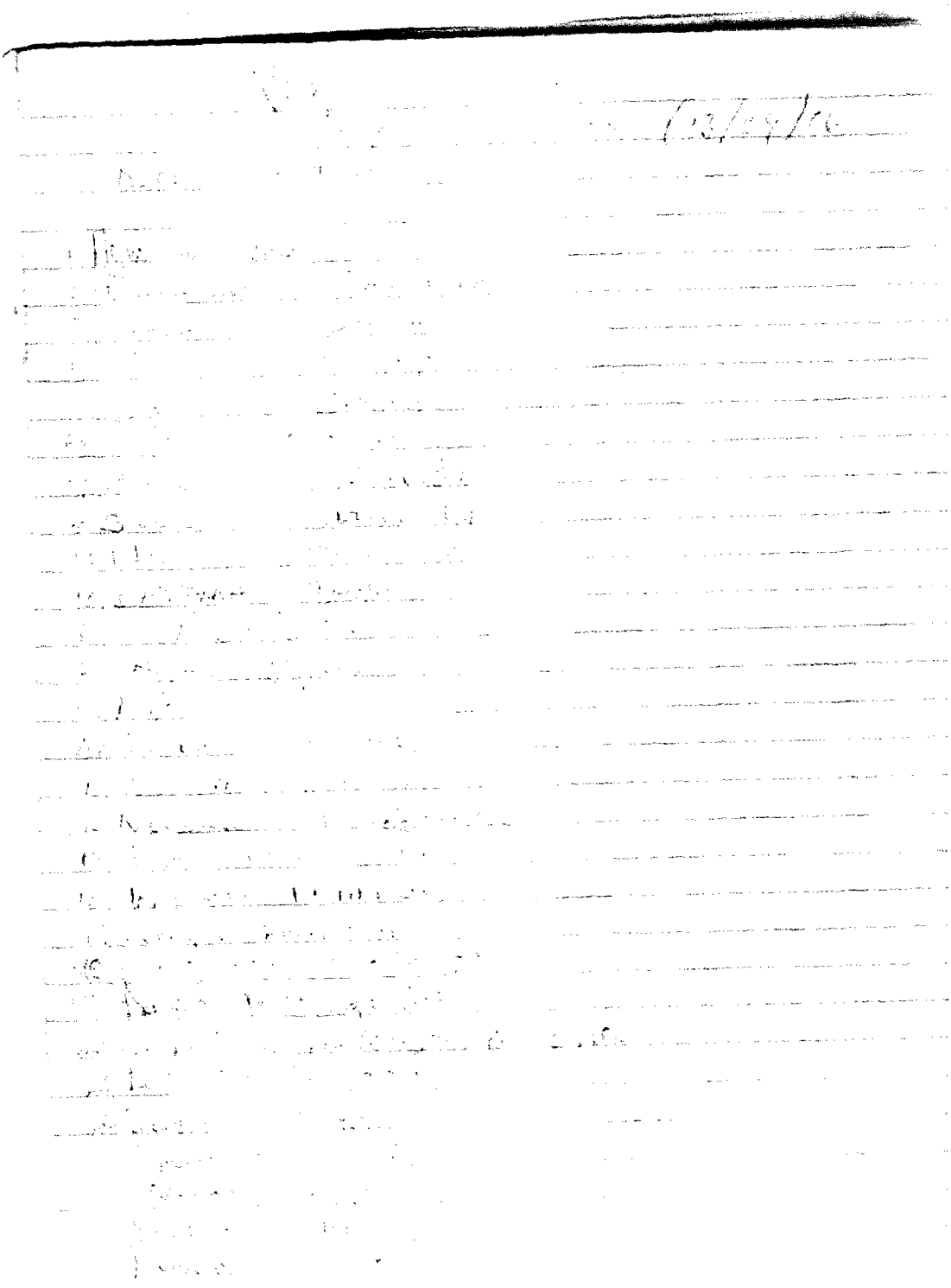
Purpose of Meeting: Training Workshop and Awareness Campaign

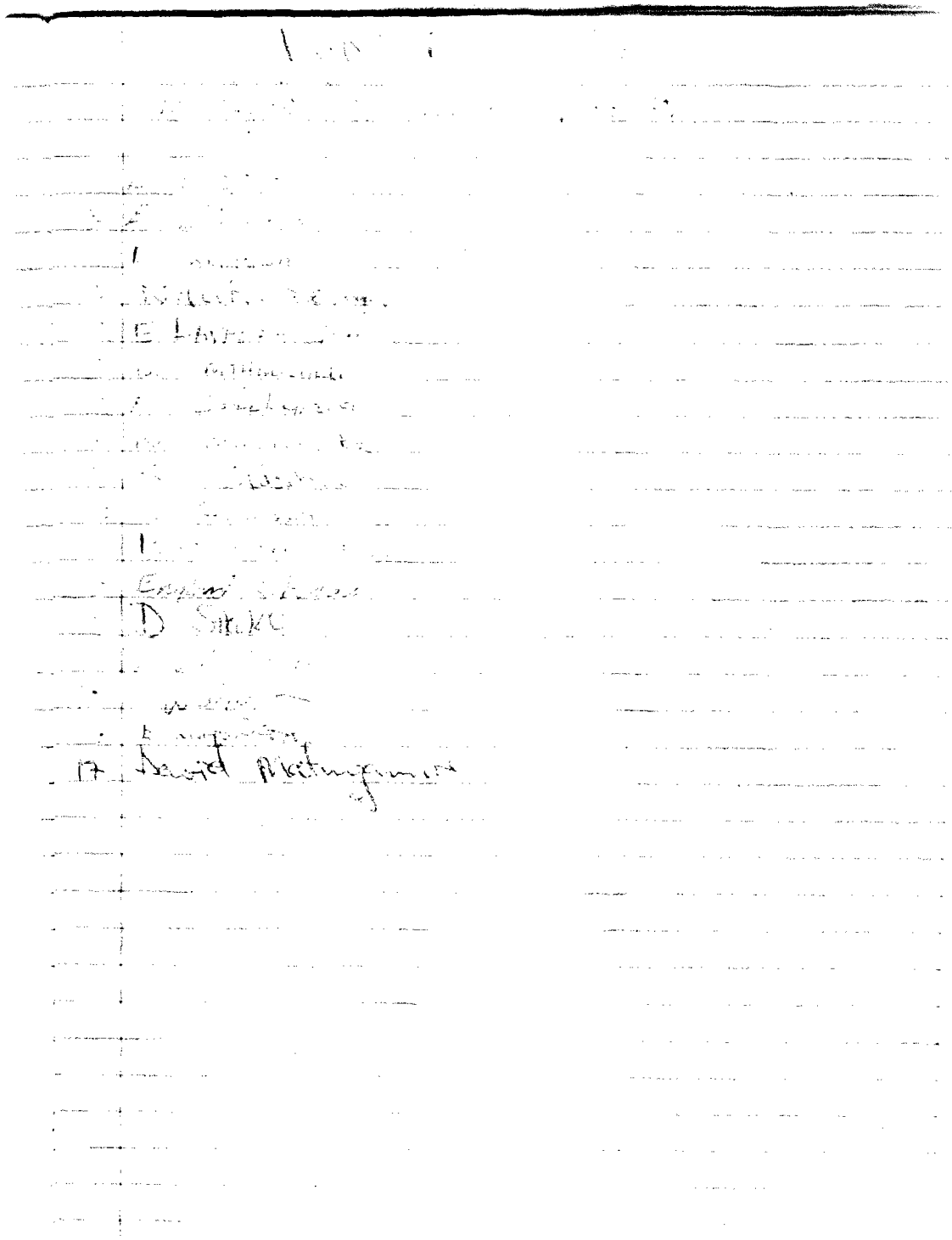
Date: 06/09/2006 to 10/09/2006

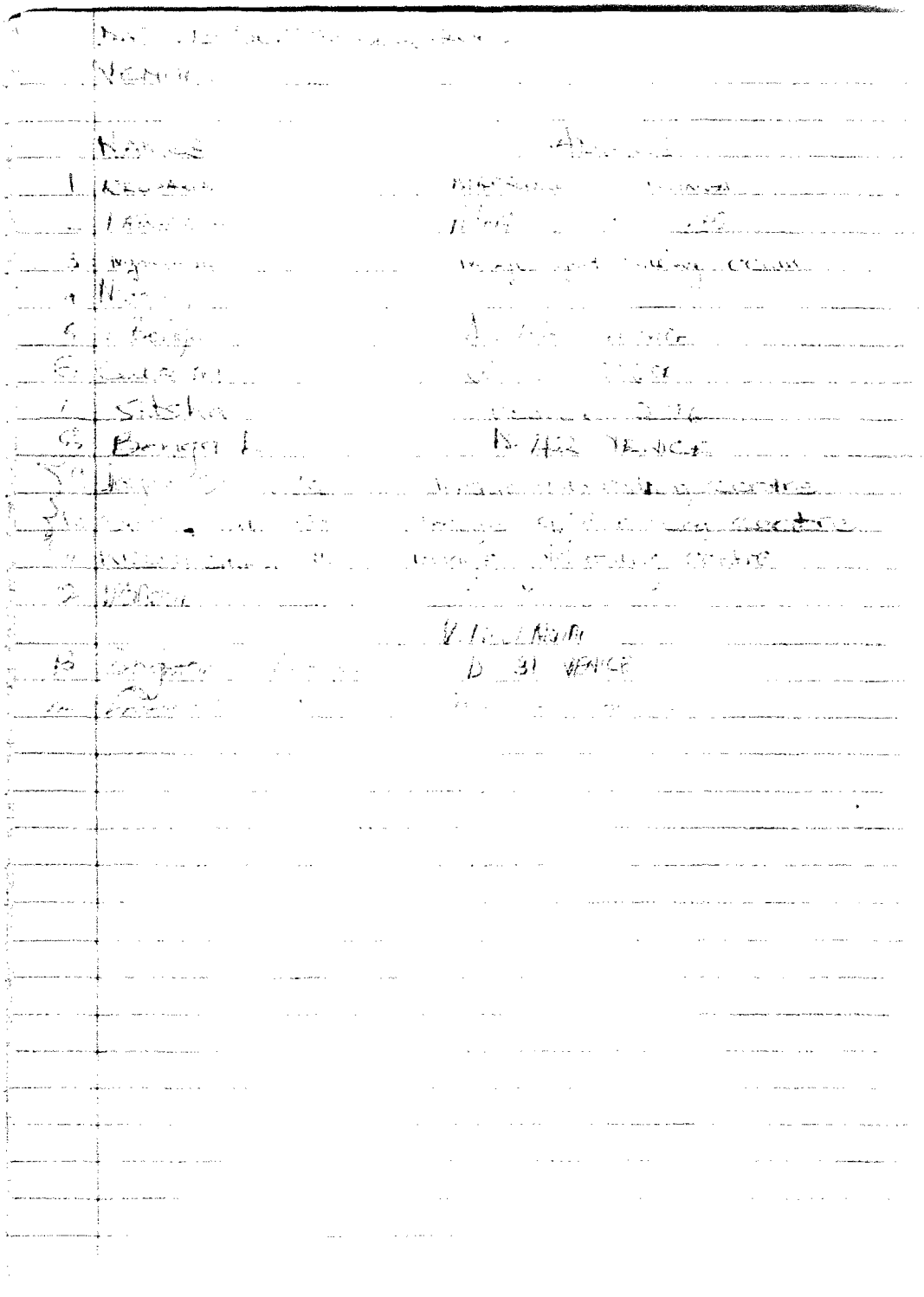
Total Number of Participants

56 males

3 females







Location: Battlefields Mine

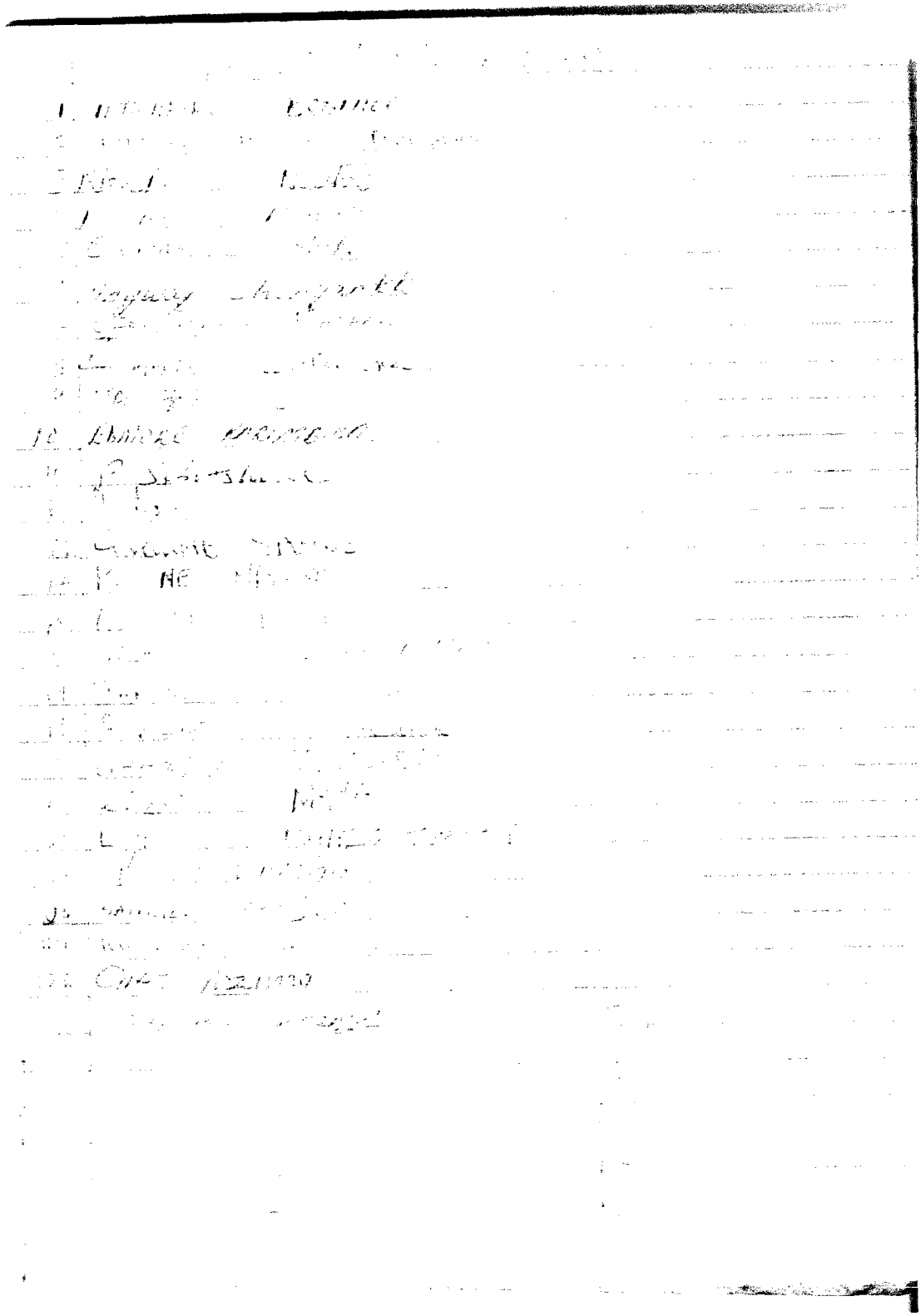
Purpose of Meeting: Training Workshop and Awareness Campaign

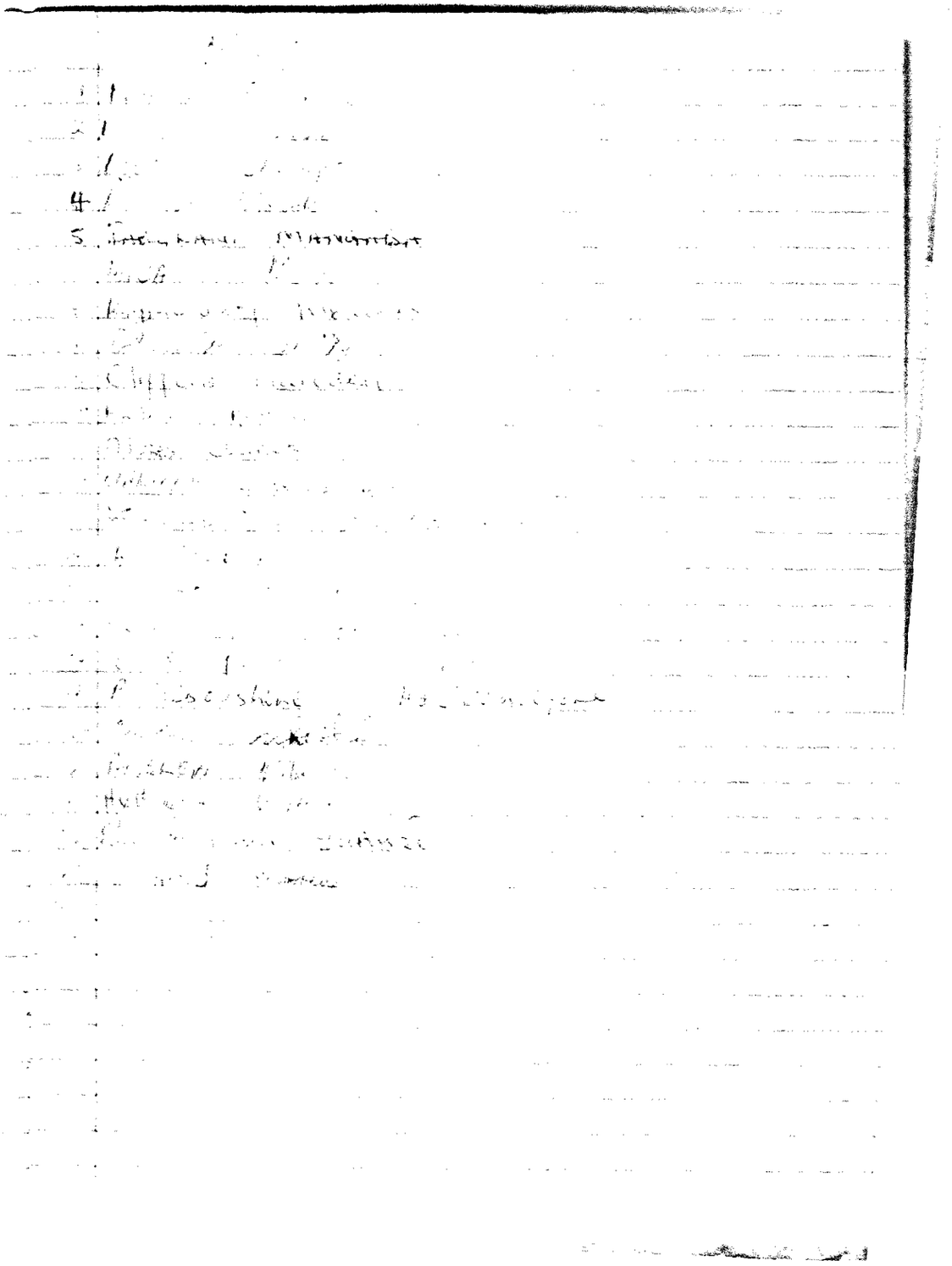
Date: 13/09/2006 to 17/09/2006

Total Number of Participants

46 males

2 females





Location: Etna Mine

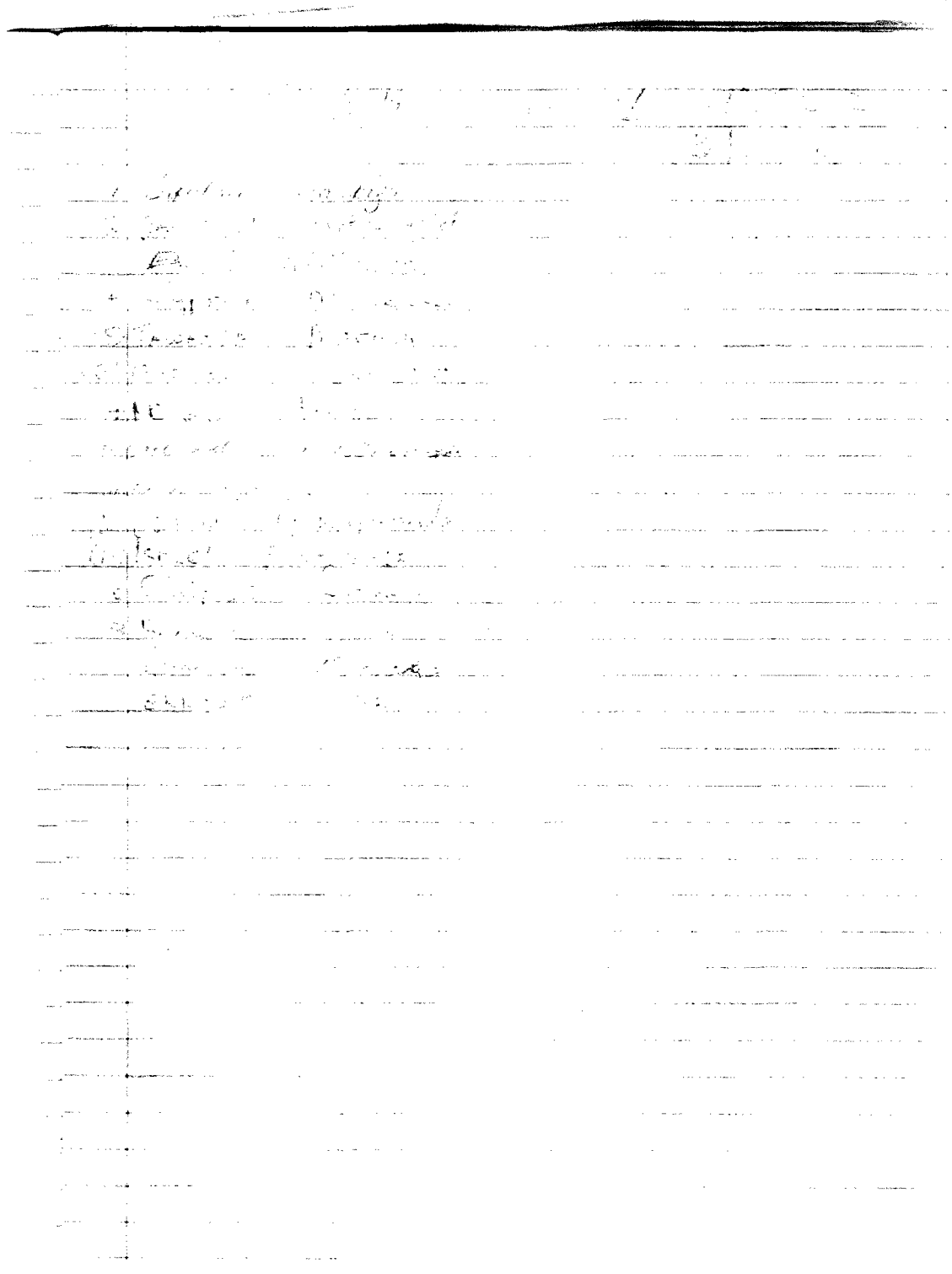
Purpose of Meeting: Training Workshop and Awareness Campaign

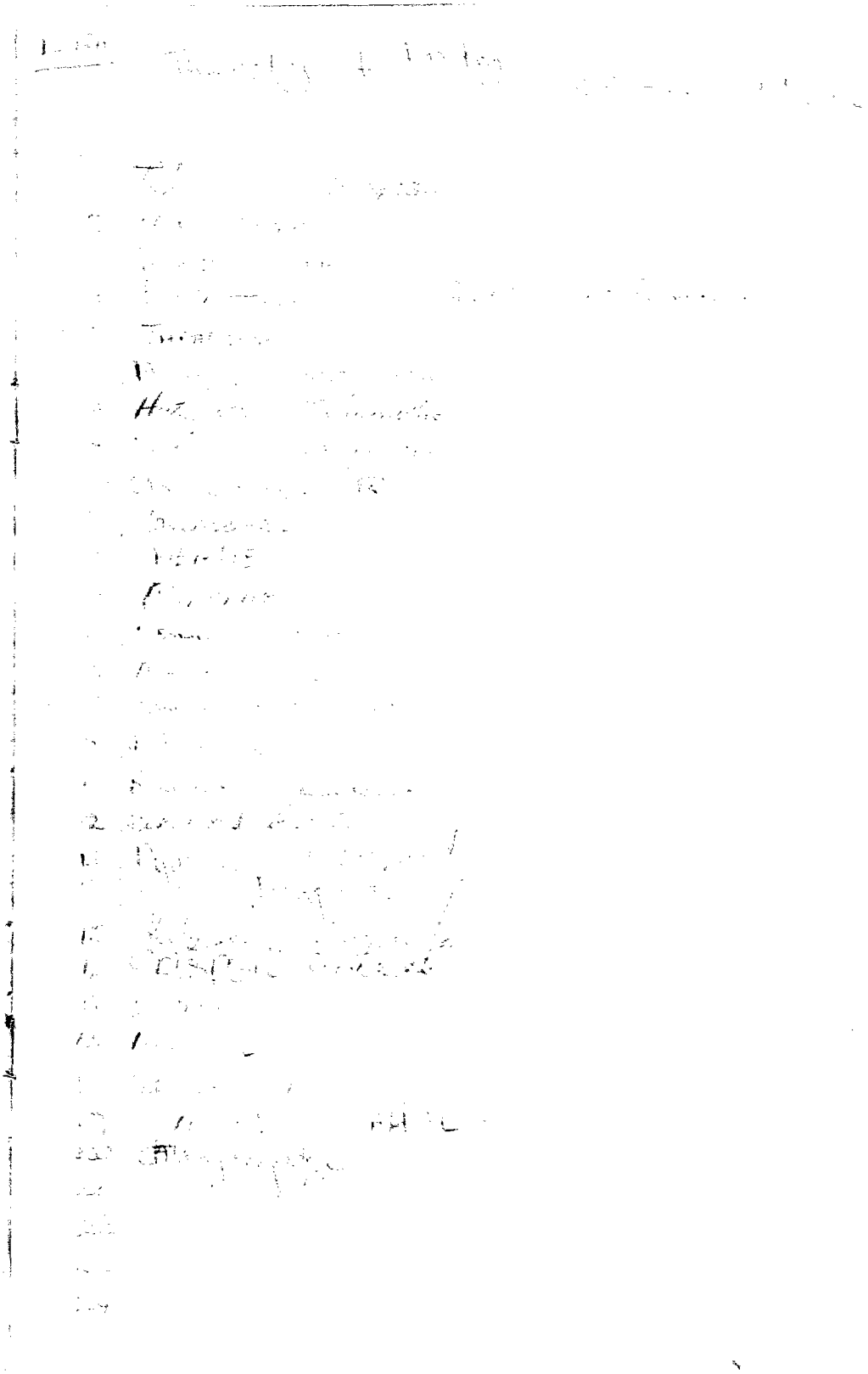
Date: 04/10/2006 to 15/10/2006

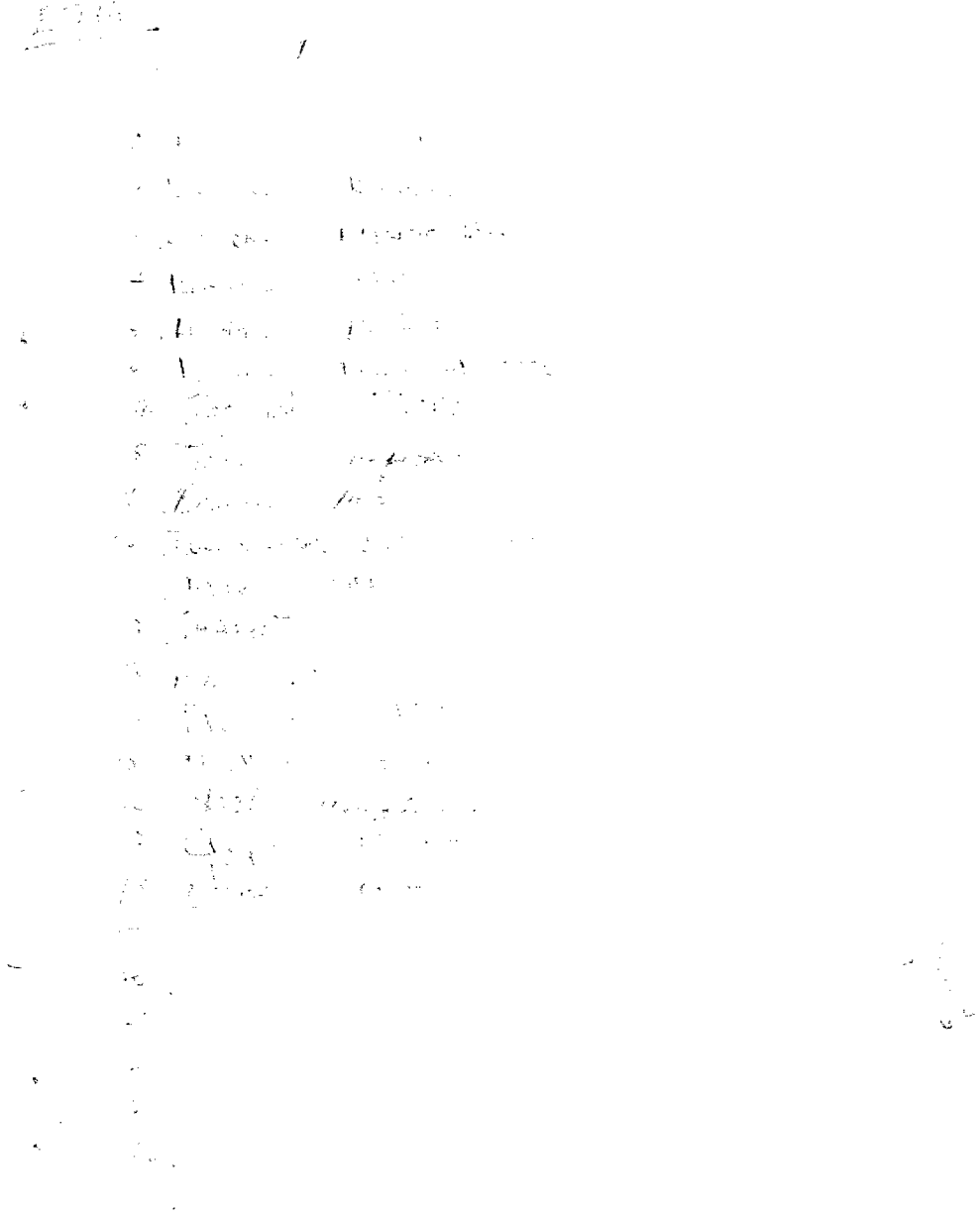
Total Number of Participants

63 males

23 females







Location: Buffalo and Tiger Mine

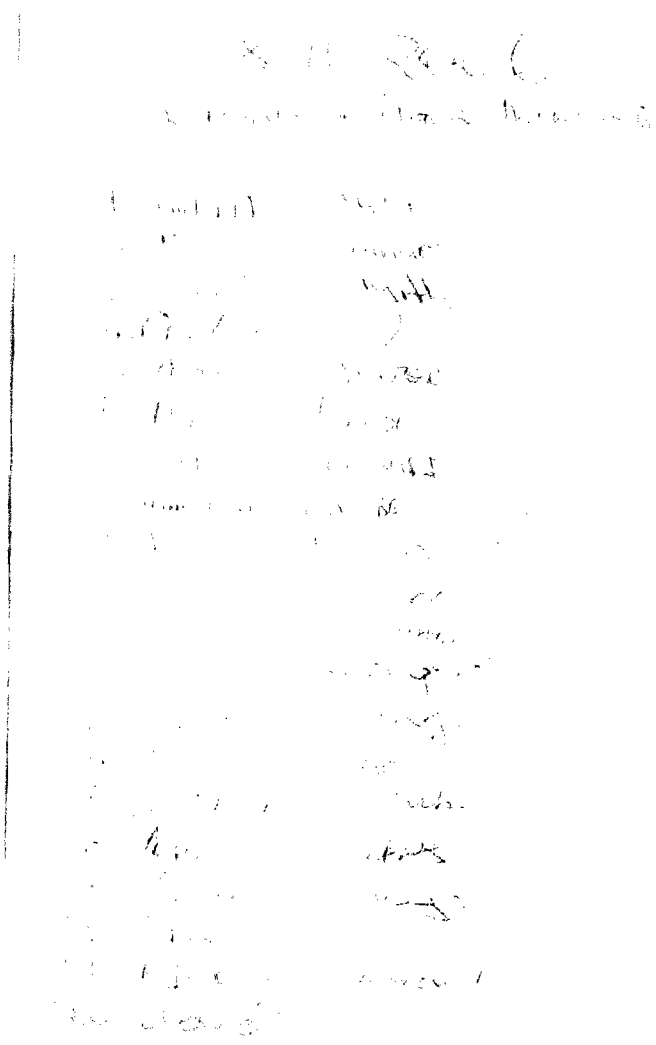
Purpose of Meeting: Training Workshop and Awareness Campaign

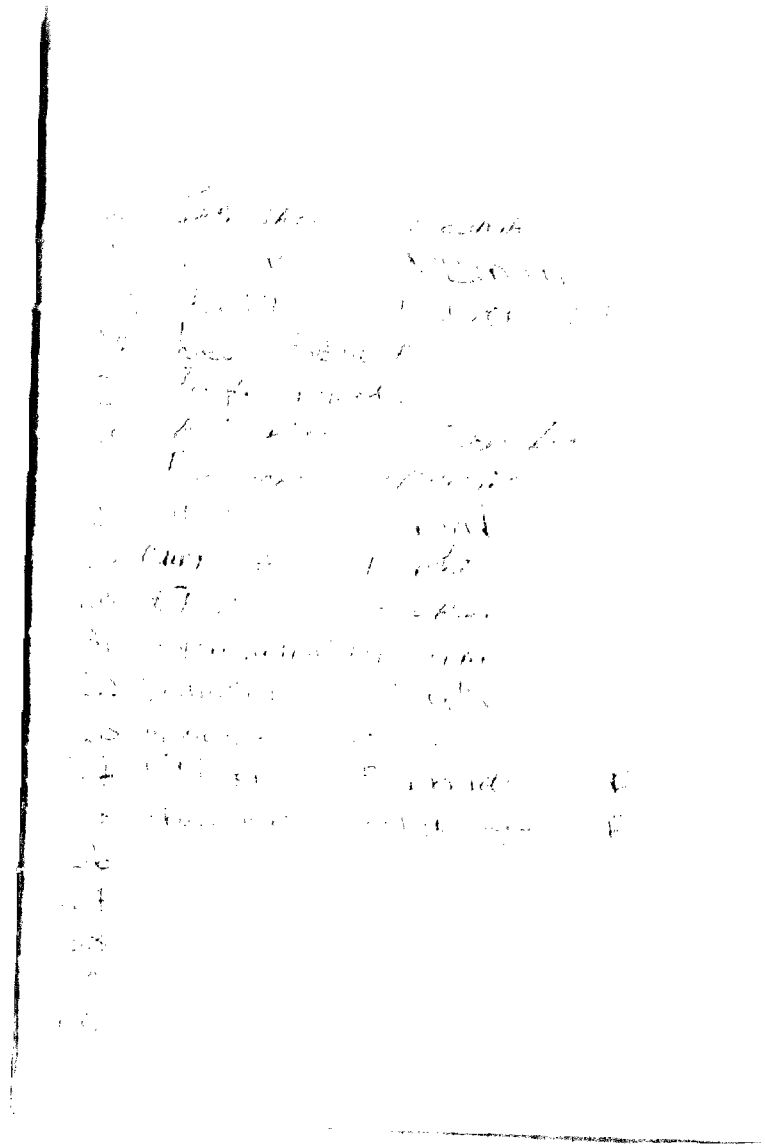
Date: 20/11/2006 to 01/12/2006

Total Number of Participants

52 males

34 females





Location: Mandela Mine

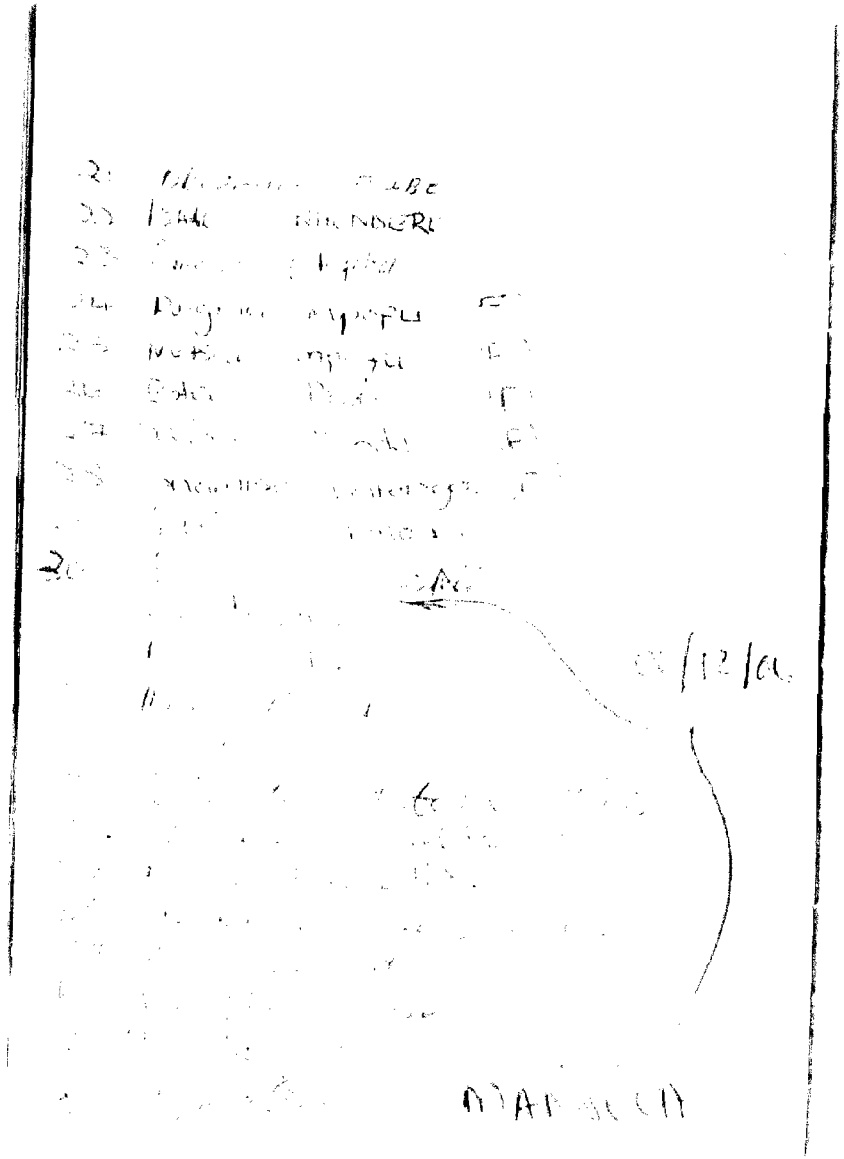
Purpose of Meeting: Training Workshop and Awareness Campaign

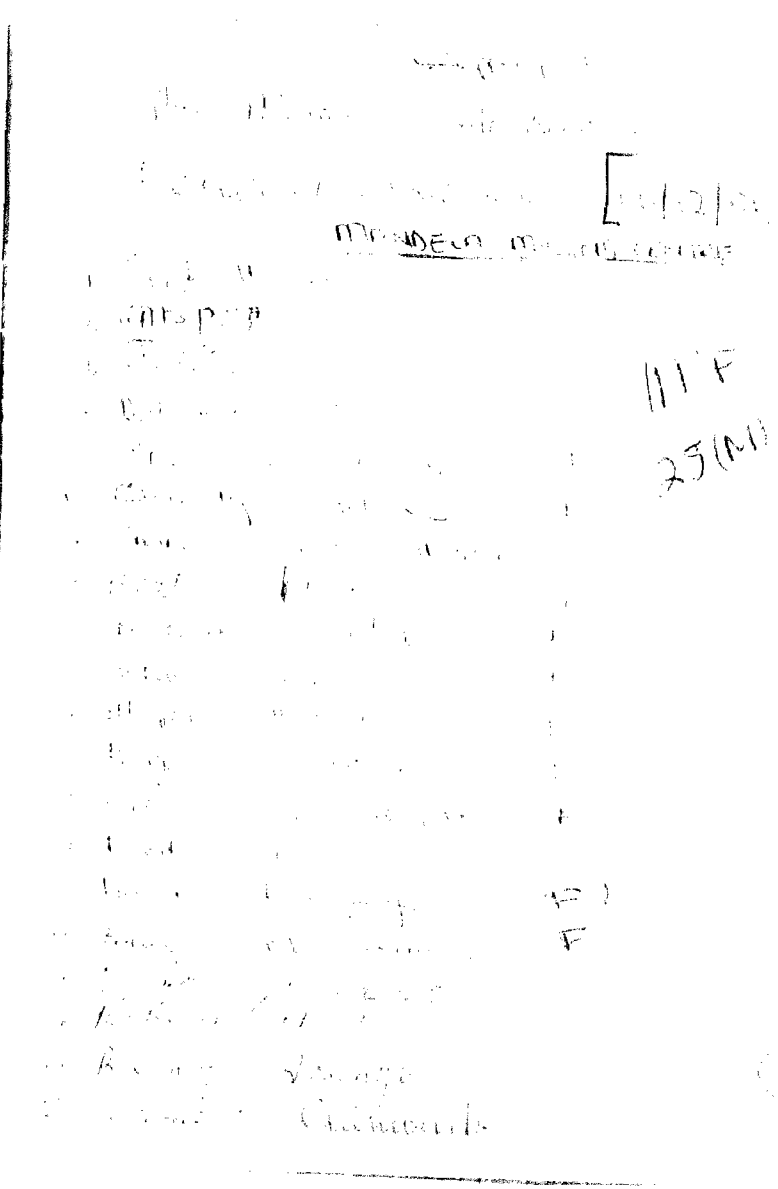
Date: 04/12/2006 to 15/12/2006

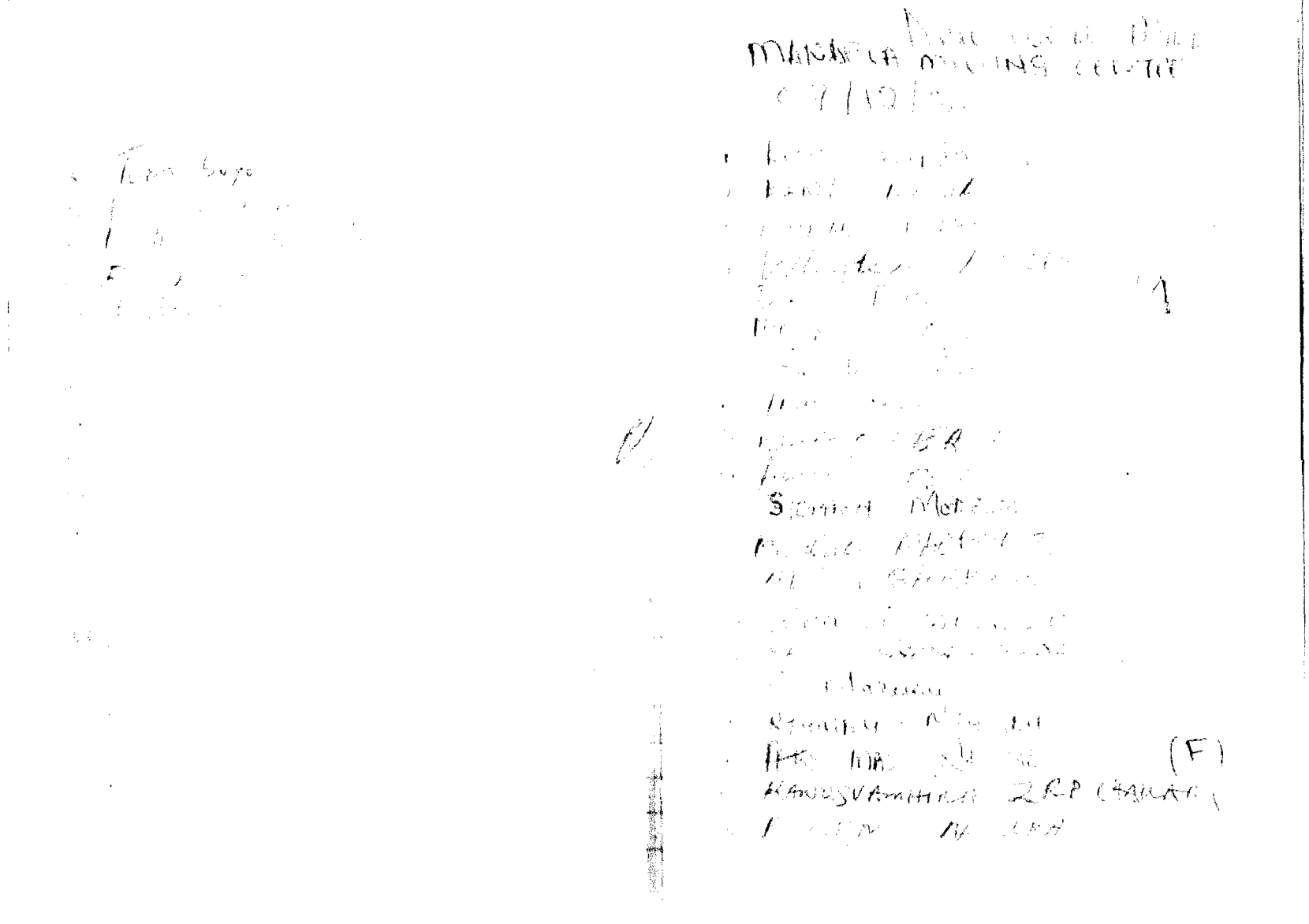
Total Number of Participants

76 males

73 females







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27	Betty	Mwarogapemaya
28	Angela	Phiri
29	Constance	Chache
30	Rachia	machiringa
31	Nyaradzo	Chabuda
32	Mary	Tazira
33	Tambudzai	Mwanza
34	Shupi	Murunguzha
35	Sara	Aiseres
36	Mariya	~~Mwai~~ muhoni
37	Rachel	Banda
38	~~Ete~~ Agness	Mware
39	Never	Kamaramanjo.
40	Rejina	piri.

12/12/06 (All women session)

Mr. C. Phiri
Sister Tembo (4+8)
E. Kupahwasa
Mr C Gatsibara
MR Mapanga x
L Chirchime
Mrs A. Mzembe
M. Fakaso
Navaness (Loveness)
Mrs A. Muraferi
Enah Nzavarema-aka
Charity Sithole
EDNATH Nyamsiye
Sifelani Nyoka (Zulu)
Margaret nyoni
Retina Kathiyawo
Edina yaziati
Rosemary Nyazo

20 Faith [illegible]
21 Matewisa Rize
22 Jess Banda
23 Gertrude [illegible]
24 Cosmas Moyo
25 S Chagwisa
26 Regina
27 Alice Balaki
28 Sylvia Muchuzo
29 Betty Dzoro
30 Jaime Mukemasango
31 Nyamu Zulu
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Appendix V

Expenditure from September 2006 November 2007

Item	Sept. 06	Oct. 06	Nov. 06	Dec. 06	April 07	May 07	June 07	July 07	Aug. 07	Sept. 07	Oct. 07	Nov. 07	Total
Food and other incidentals	556.56	1500	1300	891	1000	900	970	900	78	120	0	0	**8215.56**
Fuel	1106.8	828	904	904	1505	0	1505	0	1505	0	0	0	**8257.80**
Generator	0	7500	0	0	0	0	0	0	0	0	0	0	**7500.00**
Wheel barrows	636	0	0	0	0	0	0	0	0	0	0	0	**636.00**
Shovels	200	0	0	0	0	0	0	0	0	0	0	0	**200.00**
PPE	88	0	0	0	0	0	0	0	0	0	0	0	**88.00**
Camping equipment	0	1106	0	0	0	0	0	0	0	0	0	0	**1106.00**
Tent and Chairs	2740	0	0	0	0	0	0	0	0	0	0	0	**2740.00**
Digital Scale	112	0	0	0	0	0	0	0	0	0	0	0	**112.00**
Digital Scale (200kg)	890	0	0	0	0	0	0	0	0	0	0	0	**890.00**
Sluice Box	1386.78	0	0	0	0	0	0	0	0	0	0	0	**1386.78**
Ball Mill	0	0	0	12000	2500	0	0	0	0	0	0	0	**14500.00**
Vehicle maintenance	134	0	524	223.50	497.5	500	84.6	230.0	43.5	170.5	29.6	0	**2437.20**
Tape (5m)	3.30	0	0	0	0	0	0	0	0	0	0	0	**3.30**
Stationary	762.56	0	1218	0	1110	0	57.8	0	0	0	0	0	**3148.36**
Tool Kit	132	0	0	0	0	0	0	0	0	0	0	0	**132.00**
First Aid kit	132	0	0	0	0	0	0	0	0	0	0	0	**132.00**
5 Dishes	100	0	0	0	50	0	0	0	0	0	0	0	**150.00**
5 Jerry cans	250	0	0	0	0	0	0	0	0	0	0	0	**250.00**
ZPA	1000	1000	1000	1000	1000	1000	1000	1000	1000	0	0	0	**9000.00**
Health	1000	1000	1000	500	1000	1000	1000	1000	1000	0	0	0	**8500.00**
C.Z.Gambara	1000	1000	1000	400	800	800	800	800	800	800	0	0	**8200.00**

T.Masiya	1000	1000	1000	400	800	800	800	800	800	800	0	0	**8200.00**
Lesley	0	0	1000	400	0	0	0	0	0	0	0	0	**1400.00**
S.Kahwai	250	1000	1000	0	1000	0	0	0	0	0	0	0	**3250.00**
E.Madongorere	640	0	0	0	0	0	0	0	0	0	0	0	**640.00**
T.Ruende	400	1000	0	0	0	800	0	0	0	0	0	0	**2200.00**
E.Dzingai	400	900	1000	0	0	0	0	0	0	0	0	0	**2300.00**
Mutare Trip	0	0	460	0	0	0	0	0	0	0	0	0	**460.00**
Airtime	50	100	100	0	100	100	100	100	100	100	70	0	**920.00**
Dhliwayo	0	0	0	0	800	800	0	0	0	0	0	0	**1600.00**
Chigwida	0	0	0	0	0	800	800	800	800	800	0	0	**4000.00**
Laptop	0	0	0	0	0	950	0	0	0	0	0	0	**950.00**
Printer	0	0	0	0	0	115	0	0	0	0	0	0	**115.00**
Projector	0	0	0	0	0	3100	0	0	0	0	0	0	**3100.00**
Hammer Mill	0	0	0	0	0	2368	0	0	0	0	0	0	**2368.00**
H/Mill Motor	0	0	0	0	0	325	0	0	0	0	0	0	**325.00**
H/Mill access*.	0	0	0	0	0	300	0	0	14.7	0	29.6	15.3	**359.60**
B/ mill access*.	0	0	0	0	0	0	0	0	0	0	0	0	**0**
Electrician	0	0	0	0	0	0	0	0	90	0	0	0	**90.00**
Generator accessories	0	0	0	0	0	750.5	0	0	0	0	0	0	**750.5**
Generator Pad	0	0	0	0	0	250	0	0	0	0	0	0	**250.00**
Vehicle hire	0	0	0	0	0	0	0	0	0	0	0	0	**0**
IMR contribution	0	0	0	0	1000	0	0	0	0	0	0	0	**1000.00**
Total	**14970**	**17934**	**11506**	**16718.5**	**13162.5**	**15658.5**	**7117.4**	**5630**	**6231.2**	**2790.5**	**129.2**	**15.3**	**111863.10**

*accessories

Appendix VI

Evaluation of the sluice box technology as an alternative method for the recovery of gold by the artisanal and small-scale miners in the Kadoma-Chakari Area, Zimbabwe

Project done in conjuction with GMP Awareness Campaign

Evaluation of sluice box technology as an alternative method for the recovery of gold by the artisanal and small scale miners in the Kadoma-Chakari Area, Zimbabwe

Trust T. Masiya

Institute of Mining Research, University of Zimbabwe

Wonder Chigwida

Department of Metallurgy, Ministry of Mines and Development

Introduction

A thriving artisanal and small scale gold mining industry exists in Zimbabwe today. This industry is providing an income for many thousands directly and millions indirectly and foreign currency to the nation, ***Blenkinsop (1990)***. It is an important part of the Zimbabwean economy that benefits the individual directly, without foreign capital or exploitation. Their ability to exploit small deposits which are uneconomic for large scale operations give them a unique opportunity to contribute to the national development. This is well illustrated in the Kadoma area.

Despite the above positive aspects, the activities of the artisanal and small scale miners have had devastating repercussions on the environment and on their health, mainly because of the nature of the technologies they are using to extract gold. There is excessive use of mercury on the copper plates and during whole ore amalgamation processes in centrifugal bowls that are being incorrectly used by the small scale miners. These practices release large amounts of the toxic mercury into the local environment. ***Boese-O' Reilly et. al*** (2004) estimated the total release of mercury from gold mining to be around 1000 metric tonnes per year. The result is that mercury, as already confirmed by health studies, is a serious health and environment hazard in the small scale mining area of Kadoma, and needs to be abated soon (Boese-O' Reilly et al., 2004).

This study seeks to evaluate an alternative technology to whole ore amalgamation processes currently being practiced in most milling centres. The technology should be simple, acceptable, cheap and readily available to the small scale mining sector. This technology should improve the separation of gold and at the same time reduce the amount of mercury used and reporting to the tailings dam by avoiding the use of whole ore amalgamation. For this technology to be accepted by the mining communities the investigations were carried out in the field where the gold extraction activities are taking place. A reduction of the release of mercury into the environment by small scale miners will not only reduce the number of people affected by mercury in the milling areas but will also reduce the global pollution of the environment with mercury.

Material and Methods

Sites Description and Process Flowsheet

The first sets of the investigations were done on two sites in the Kadoma-Chakari area. These milling sites are Chimukute Milling Centre and Imperani Milling Centre. Poor delivery of ore and unwillingness to participate by most miners at Chimukute Milling Centre resulted in most of the investigations being done at Imperani Milling Centre where 8 of the 10 first set of experiments were performed.

The general set-up at these milling centres consist of 1450lbs three-stamp mills with capacity in the range 0.5 -1.5 tonne/h depending on the hardness of the material being treated. Most of the ores treated at these milling centres is supplied by miners within 20-25km radius of the milling centres and the ores in most cases are of different types and could be any of the following but not limited to rubble/gravel, quartz and schist material.

Once the ore has been delivered to the mill it is subjected to a comminution process on the stamp mills. The stamp mills operate with water and the pulp is discharged through a 1.0mm mesh screen. The pulp (about 20% solids) is discharged into a centrifugal bowl commonly referred to as "separator" by most miners and millers in the area. In other

instances for example at Chimukute a miner can request the use of a copper plate for gold recovery. The centrifugal bowls used in the study area are 120° cones with riffles on the wall. There is no fluidization to promote mineral exchange in the concentrate bed and it seems that gold is lost once the riffles are full. The milling centres have their own operators but they leave the amalgamation step to the miners who bring their own mercury and use as much as they want. Most miners add 2-3 teaspoons (about 100-150g) of mercury into the "separators". This poor practice "flours" part of the mercury and this in most cases is lost with the tailings. After completion of a mill run the concentrate in the "separator" is washed out into a bucket and the mortar box cleaned. An amalgamation process is then performed on the "separator" concentrate and the mortar box material usually after screening through a 1 or 2mm screen. The amalgamation process in most cases is manual and is done by adding mercury into pans or plastic bowls followed by panning. Unfortunately this method does not always provide enough contact with the gravity concentrate to promote good recovery. The ability of the panner determines the amount of gold that can be captured at his stage. The amalgam produced is then burnt, rarely in retorts but on wood fire without any protection.

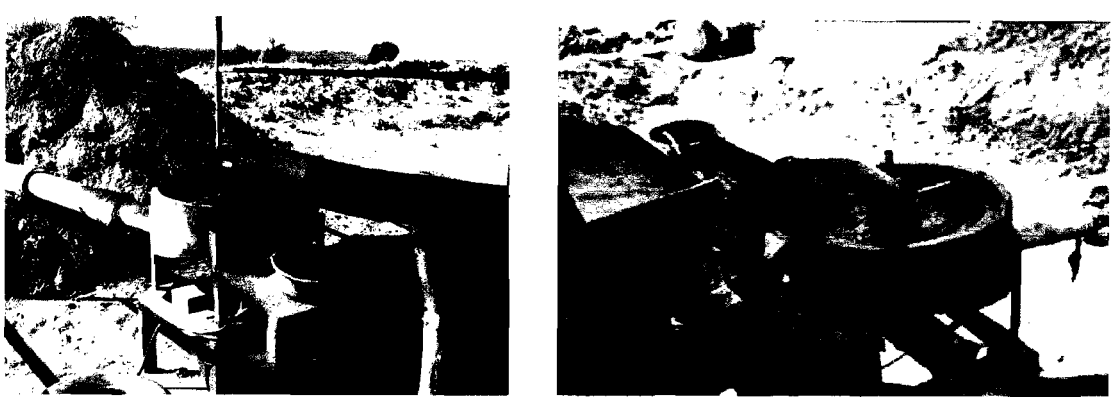

Figure 1: Pulp from the stamp mill being discharged into a "separator"

Methods

Sluice Box Technology Investigations

The investigations were done using a sluice box that was manufactured locally using steel angles and sheets. The bottom of the sluice was lined with a Chinese made vinyl-type carpet as the trapping mechanism that can capture particles of gold and other heavy minerals. Figure 2 shows the structure of the carpet which was used for the investigations. Sluices work on the principal that heavy particles tend to sink to the bottom of a stream of flowing water while the lighter particles tend to be carried down stream and discharge off the end of the sluice. The carpet aids in trapping gold particles and prevent them from being lifted back up into the current by turbulence.

Figure 2: Top and cross-sectional view of the Chinese vinyl type carpet used as the gold and heavy mineral trapping mechanism for the investigations.

Ore mixed with water discharged from the stamp mill was allowed to run over the carpet lined sluice box. The dimensions of the sluice box used for the investigations were as follows; 2.0m long, 1.0m in width and a trough height of about 0.1m. The sluice slope was 1 in 10 and this was in most cases determined by the mill set-up on the site the

investigations were being carried out. It was difficult to vary the slope given the conditions under which the experiments were run.

The experimental flowsheet consisted of the discharge from the stamp mill running over the sluice with an effective carpet length of 1.8m. The sluice tailings were passed through a secondary concentrator, a "separator" in this case as per miner's operating practice. Figure 3 and Figure 4 shows the set-up at Imperani Milling Centre and Figure 5a, 5b and 5c the set-up at Chimukute Milling Centre, which were used for the investigations. Different types of ores were investigated, mainly because the ores were from different miners from different locations. Trapping efficiency was monitored by checking a sample of the sluice tailings constantly by panning. If the panning indicates that there is gold in the tailings, the carpet is removed and a new one is used as a replacement (one carpet in operation, one in clean-up).

Figure 3: Front view of the experimental set-up at Imperani Milling Centre

Figure 4: Side view of the experimental set-up with miners and the research team working on the set-up at Imperani Milling Centre

Figure 5a

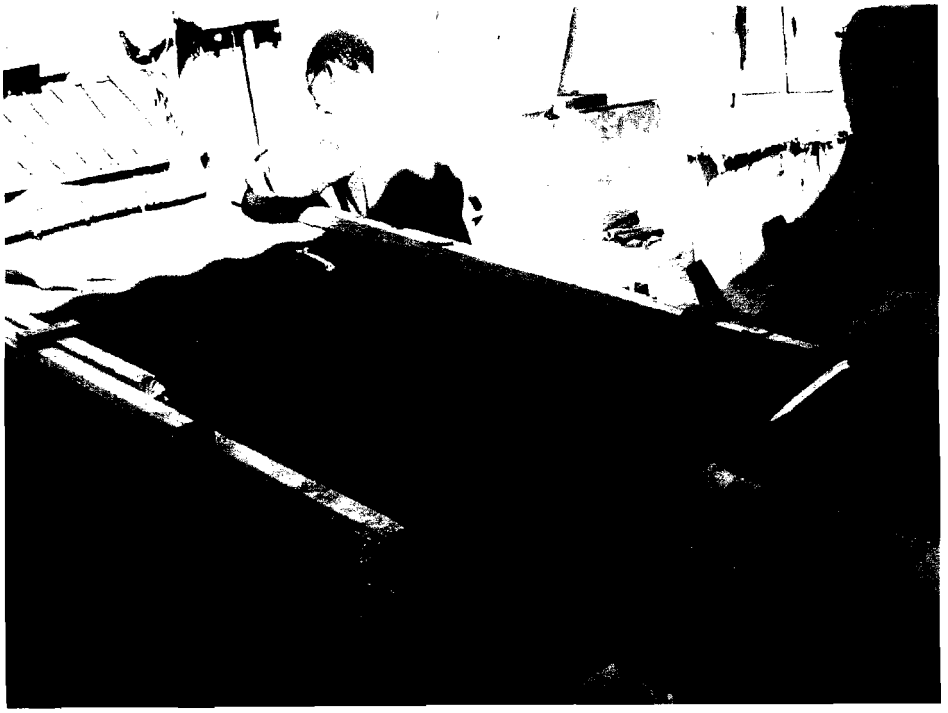

Figure 5b

Figure 5c

Figure 5a, 5b and 5c shows the experimental set-up at Chimukute Milling Centre

Sampling Technique

Ore samples were taken during the test in order to be able to determine the recovery efficiency of the method. Two representative samples were collected for the material that fed the sluice and that which had passed the sluice to determine how much gold was captured in the process. The sluice feed sample was difficult to collect because the miners felt that the research team was taking their gold. The sample size was therefore limited, giving question marks as to how representative this sample was. The "nugget effect" usually associated with the head samples further complicates the sampling.

Sampling of the sluice tailings was done as follows:

1. When the sluice concentrator was running, a cup (about 250ml) of the pulp of the tailings at the end of the sluice was collected after every 20mins and tossed into a bucket until the run was completed,
2. After siphoning the water out the wet tailings were spread on a plastic tarp and allowed to dry in the sun. The dried samples, after breaking the chunks, were then subjected to both sieve and chemical analysis in the Institute of Mining Research laboratory.

Results and Discussions

Table 1 shows the recovery efficiency of the sluice Chinese carpet for the tests done at Imperani Milling Centre (Charge 1 to 7) and Chimukute Milling Centre (Charge 8). Results for Charge 9 and 10 are not reported in this paper because their chemical analysis results are still pending. The recovery efficiency is calculated using the amount of gold that feeds the sluice box (i.e. excluding the gold that remains in the mortar box) and the amount of gold in the sluice discharge/tailings. The carpet recovery efficiency as calculated varied from 18.6% to 69.8% for the 8 test done so far. The highest value of

69.8% (with maximum physical gold caught = 25.6g) was at Imperani Milling Centre and it was for gold ore from quartz material. The lowest value 18.6% of recovery efficiency was at Chimukute Milling Centre and the ore was also from quartz material.

Table 1: Gold recovery efficiency of the sluice carpet at milling sites investigated

Product	**Weight (t)**	**Au Content (g/t)**	**Fine Au (g)**	**Carpet Au Recovery (%)**
Charge 1				
Physical Au recovered			8.9	22.0
Tailings	5.0	6.3	31.5	78.0
Calc. Head Grade	5.0	8.1	40.4	100.0
Charge 2				
Physical Au recovered			25.6	69.8
Tailings	3.0	3.7	11.1	30.2
Calc. Head Grade	3.0	12.2	36.7	100.0
Charge 3				
Physical Au recovered			4.9	46.0
Tailings	2.5	2.3	5.75	54.0
Calc. Head Grade	2.5	4.26	10.65	100.0
		Charge 4		
Physical Au recovered			2.3	27.9
Tailings	0.6	9.9	5.94	72.1
Calc. Head Grade	0.6	13.73	8.24	100.0
		Charge 5		
Physical Au recovered			11.0	20.4
Tailings	5.0	8.6	43.0	79.6
Calc. Head Grade	5.0	10.8	54.0	100.0

		Charge 6		
Physical Au recovered			19.6	50.9
Tailings	21	0.9	18.9	49.1
Calc. Head Grade	21	1.83	38.5	100.0
		Charge 7		
Physical Au recovered			6.1	68.5
Tailings	14	0.2	2.8	31.5
Calc. Head Grade	14	0.6	8.9	100.0
		Charge 8		
Physical Au recovered			2.33	18.6
Tailings	1.4	7.3	10.22	81.4
Calc. Head Grade	1.4	8.96	12.55	100.0

The variation in gold recovery between and within different sites might be attributed to the difference in the ore quality since the ores are from different mines (i.e. have different mineralogy, grades and grain size). Of the 8 test done, only 3 have carpet recovery efficiency greater than 50%. This might be attributed to low degree of liberation by the stamp mill resulting in most of the gold not being exposed to mercury during the amalgamation process and reporting to the sluice tailings, for e.g. more than 80% for charge 8.

Tailing samples of 5 of the 8 charges (Charge 1 to 5) were subjected to sieve analysis and the gold distribution in each fraction determined. This was done to check if there is enough gold liberation. Table 2 shows the results obtained.

Table 2: Gold distribution in different size fractions of the tailing samples for charges 1 to 5

Charge	*Fraction (µm)*	*Weight %*	*Weight % Cumulative*	*Gold content (g/t)*	*Fine Units*	*%Distribution*	*% Cum. Distrib.*
	+500	7.8	7.8	18.3	141.9	27.7	27.7
	-500 +250	24.2	32.0	5.3	128.4	25.0	52.7
1	-250 +75	31.9	63.9	2.1	67.0	13.1	65.8
	-75 +53	13.8	77.7	2.7	37.3	7.3	73.1
	-53 +0	22.3	100.0	6.2	138.4	27.0	100.0
	+500	12.0	12.0	11.1	133.4	24.0	24.0
	-500 +250	42.7	54.7	4.1	175.1	31.4	55.4
2	-250 +75	38.9	93.6	4.4	171.2	30.7	86.1
	-75 +53	2.6	96.2	6.3	16.3	2.9	89.0
	-53	3.8	100.0	16.0	60.8	10.9	100.0
	+500	15.7	15.7	2.1	33.0	15.0	15.0
	-500 +250	23.3	39.0	2.8	65.2	29.7	44.7
3	-250 +75	26.1	65.1	1.6	41.8	19.1	63.8
	-75 +53	10.8	75.9	1.3	14.0	6.4	70.2
	-53	24.1	100.0	2.7	65.3	29.8	100.0
	+500	14.7	14.7	26.6	391.0	26.4	26.4
	-500 +250	30.2	44.9	18.7	564.7	38.1	64.5
4	-250 +75	30.3	75.2	10.7	324.2	21.9	86.4
	-75 +53	19.8	95.0	6.6	130.7	8.8	95.2
	-53	5.0	100.0	14.5	72.5	4.8	100.0
	+500	12.6	12.6	11.3	142.4	21.7	21.7
	-500 +250	27.1	39.7	7.8	211.4	32.1	53.8
5	-250 +75	28.1	67.8	4.9	137.7	20.9	74.7
	-75 +53	15.1	82.9	4.4	66.4	10.1	84.8
	-53	17.1	100.0	5.8	99.8	15.2	100.0

More than 50% of the gold in the tailings is found in the +250µm size fraction which is a relatively coarse fraction. Since the amount of non-liberated gold that is trapped in the tailings is high, milling to finer particle size will greatly increase the amount of gold that is recovered.

Table 3 shows the gold balance across the whole experimental set-up and how the physically recovered gold is distributed across the set-up. The results clearly show that the mortar box acts as a primary concentrator. Of all the physical gold recovered 5.1 to 68.7% for the 8 test is from the mortar box. This can be explained in two ways:

1. if the gold is coarse, i.e. more than the screen size (1.0mm), it will not proceed to the concentrator and will remain in the mortar box
2. the way the mortar box is designed is that it acts more like a jig concentrator in which the plunging action of the stamp shoe on the pulp result in heavy gold particles accumulating at the bottom of the box with the light particles at the top (see Figure 3 which shows the amount of material that remains in the box after a run).

Figure 6: Mortar box showing the amount of material that remains after milling in which most of the gold is concentrated

Table 3: Distribution of recovered gold across the experimental set-up

Charge	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Mortar	27.20g	80.90g	4.50g	4.10g	2.93g	13.50g	5.10g	13.33g
box	**40.2%**	**68.7%**	**29.7%**	**33.2%**	**5.1%**	**25.9%**	**34.2%**	**50.4%**
Carpet	8.9g	25.60g	4.90g	2.30g	11.00g	19.60g	6.10g	2.59g
	13.2%	**21.8%**	**32.3%**	**18.6%**	**19.3%**	**37.5%**	**40.9%**	**9.8%**
Separator	1.50g	1.00g	0.60g	0.40g	3.73g	0.20g	0.90g	0.29g
	2.2%	**0.9%**	**4.0%**	**3.2%**	**6.6%**	**0.4%**	**6.0%**	**1.1%**
Total Au	37.6g	107.50g	10.00g	6.80g	17.66g	33.30g	12.10g	16.21g
Recovery	**55.6%**	**91.3%**	**66.0%**	**55.1%**	**31.0%**	**63.8**	**81.2%**	**61.3%**
Tailings	30.00g	10.20g	5.15g	5.54g	39.25g	18.90g	2.80g	10.22g
	44.4%	**8.7%**	**34.0%**	**44.4%**	**69.0%**	**36.2%**	**18.8%**	**38.7%**

The physical gold recovered on the carpet ranges from a low figure of 9.8% to 40.9% whilst the quantities of gold retained on the "separator" were very low and ranges from 0.4% to a maximum of 6.6%. This means that more than 50% of the gold in the ores tested is recovered in the mortar box and carpet alone whilst less than 6% of the gold was scavenged from the sluice tailings by the "separator". This scavenged figure can be reduced or completely eliminated if optimization (which was not done for the current investigations) of the operational sluice parameters was done. The overall gold recovery during the experimental investigations was more than 55%, which is acceptable and can be increased by further grinding as most of the gold is not liberated.

Challenges

1. The major challenge from this investigation was sampling for a representative sample. The miners were not willing to allow the research team to get a large sample size especially for the head (the feed to the carpet) as they felt that they were taking part of their gold. Therefore there were question marks as to how representative the sluice samples were. The situation was also made complex by the "nugget effect" which was likely for the head sample.

2. Cleaning of the carpets require a lot water mostly under pressure and the Chinese carpet is not as flexible as the Nomad carpet is.
3. Sluice set-up is dependent on the mill set-up

Conclusions

1. The sluice box is an effective method for recovering free gold and it eliminates the practice of whole-ore amalgamation on copper plates and the addition of mercury into "separators", which is believed by the miners to improve gold recovery even though it result in mercury reporting to the slimes dam
2. More than 50% of gold in the ore can be recovered by the use of the Chinese vinyl carpet as the trapping mechanism on the sluice box
3. The amount of non-liberated gold in the tailings is high (more than 50% of the gold is in the +250μm fraction) and milling of the ore to a finer particle can greatly increase the amount of gold that is recovered.
4. The sluice box technology is a simple, cheap method and can easily be adapted by the small scale miners.
5. The miners are willing to adapt this technology as they felt that it increased their gold recoveries significantly, whilst the millers on other hand are not willing to change to this technology as to them it means less gold to the cyanidation tanks. The research team had to leave one of the carpets at Imperani Milling Centre on request by the miners

Recommendations

1. There is need to evaluate the efficiency of the "separators" as stand alone concentrators and prove that even without mercury in separator the same amount of gold can still be recovered
2. The number of data sets should be increased to 20 to 30 for the project area in order to have a thorough evaluation of the technology in the area.

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