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Removal of barriers to the introduction of cleaner artisanal gold mining and extraction technologie in Kadoma, Zimbabwe

Part B: Health Assessment

Final Report

Geoscience for a sustainable Earth

Removal of barriers to the introduction of cleaner artisanal gold mining and extraction technologie in Kadoma, Zimbabwe

Part B: Health Assessment

Final Report

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1. Executive summary

Kadoma is a typical small-scale mining area with approximately 235,000 inhabitants in the Midlands in Zimbabwe. Artisanal small-scale miners use mercury to extract gold from the ore. It is estimated that approximately a few hundred thousand people work and live in similar small scale mining communities all over Zimbabwe.

In the selected area there is no clean and safe drinking water, no waste disposal for the toxic mercury or any other waste or human discharge. Hygienic standards are extremely low and are a reason for many infectious diseases such as diarrhoea, malaria and parasitism.

Accidents in insecure tunnels and amalgamation plants, acute respiratory tract infections, malaria, tuberculosis, and sexually transmitted diseases including AIDS are the dominant causes of morbidity and mortality. No proper health service exists in the mining communities. The District Hospital in Kadoma has very limited means.

The extraction of gold with liquid mercury releases serious amounts of mercury, especially high toxic mercury fumes into the local environment. The health status of 218 volunteers in Kadoma and 55 from a control area in Chikwaka was assessed with a standardised health assessment protocol from UNIDO (Veiga 2003) by an expert team from the University of Munich/Germany in April 2004.

The mercury levels in the human bio-monitors were much higher in the exposed population in Kadoma than in the control group. The exposed population was divided into sub-groups to compare the levels of exposure. As to be expected the control group was within a normal range and the amalgam-burners had the highest exposure levels in all human bio-monitors, while the less exposed population in the mining areas ranged in between. Child mercury exposure due to living in the mining areas and working with mercury show similar levels in the bio-monitors as adult amalgam-burners, children not working but living in the area also have increased levels, mainly compared to children from the control area. The results of the human bio-monitoring show clearly the severe exposure of the total population in the mining areas with mercury; the extreme exposure mainly of amalgam-burners and the especially severe exposure of children working with mercury. The mercury exposure in the mining areas is mainly due to exposure with elemental mercury and not due to exposure with methyl-mercury. The relation of inorganic versus organic mercury in the control population shows the usual exposure of any population, where most of the mercury exposure comes from the consumption of methyl-mercury contaminated fish. Whereas in the mining areas the high amounts of inorganic mercury in hair indicate that the main exposure in the mining areas more then likely comes from elemental mercury, than from methyl-mercury exposure through contaminated food. Exposure with elemental mercury could come from handling mercury with bare hands, but the immanent exposure with mercury vapour might be the more important pathway, since amalgam-burners show the highest human bio-monitor levels.

Typical symptoms of mercury intoxication were prevalent in the exposed group. The medical score sum plus the bio-monitoring results made it possible to diagnose in 70% of the amalgam-burners, 63% of otherwise occupational burdened population and 23% of former occupational burdened population a chronic mercury intoxication. 5% of the not occupationally burdened population showed chronic mercury intoxication and nobody in the control area was intoxicated. These results confirm severe exposure due to working with mercury, either by panning with mercury or smelting amalgam.

Child labour in the mining sites is very common from the age of 10 on, the children work and play with their bare hands with toxic mercury. Of special notice is, that 0% of the children from the control area, 33% of children living in the area, but not working with mercury and 69% of the children working with mercury have a chronic intoxication with mercury.

Mercury can cause severe damage to the developing brain. From 9 breast milk samples taken, 4 showed increased levels of mercury. The different mining areas in Kadoma district use slightly different extraction technologies. A comparison of the various mining areas is difficult due to the relatively small number of participants in each area, and non-comparable subgroups (number of men, amalgam burners etc). But it seems that in the Glasgow mill the exposure to mercury may be even bigger than in the Amber Rose mill, and possibly bigger than in the Tix mill.

Poverty is the main reason for the disastrous health status in the small-scale mining communities. Struggling for pure survival makes mining for gold a necessity to find any financial resource. The daily fight for survival requires the miners to put their own health and the health of their children at risk.

A reduction of the release of mercury vapours from small-scale gold mining into the atmosphere will not only reduce the number of mercury intoxicated people in the and milling areas proper, it will reduce the global pollution of the atmosphere with mercury. Most of the mercury vapours formed by open burning of gold amalgam deposits not locally but is transported by air on long-range distances all over the globe (Lamborg, 2002). The total release of mercury vapour from gold mining is estimated today up to 1,000 metric tons per year (MMSD 2002), while from all other anthropogenic sources approximately 1.900 tons were released into the atmosphere (Pirrone, 2001).

These results correspond to former examinations in Zimbabwe, for example the study from Matchaba-Hove *et al.* (2001). They found, that “mercury poisoning among gold panners in Chiweshe and Tafuna communal lands is of public health importance. Panners should be educated on the possibilities of mercury being a poison. A low cost and safe technology to separate mercury from the amalgam should be introduced to the panners”.

The result is that mercury is a serious health hazard in the small-scale gold mining area of Kadoma. The exposure of the whole community to mercury is reflected in raised mercury levels in the urine, blood and hair. Symptoms of severe damage of the brain (cerebellum) such as ataxia, tremor and movement disorders were found in the mining communities. In 70% of the amalgam-burners in Kadoma mercury intoxication was diagnosed. The background burden in the control group is in the same order of magnitude as in western industrial countries.

Poverty is the main reason for all health and environmental problems:

- At the moment it does not seem to be acceptable that **children** live in Kadoma small scale mining and milling areas. Child labour with hazardous chemicals needs to be especially addressed. Missing sanitary standards and high exposure to mercury are the main problems. Sanitary standards need urgent improvement.
- The **occupational** related **health risk** of mining should be assessed in more detail (accidents, drinking water quality, HIV / AIDS, other sexually transmitted diseases, malaria, tuberculosis). One first step to reduce the health hazards in Kadoma district might be a proper zoning into industrial areas, commercial areas and housing areas. Mainly the smelting of amalgam needs to be performed outside the housing areas, and “away from the nose” people in charge of amalgam roasting. Imposing basic hygienic standards, such as proper drinking water and reduction of Anopheles mosquitoes is essential.
- To reduce the obvious risk of **accidents** in mining sites, raising awareness is necessary. Introducing proper mining techniques is necessary (e.g. tunnel safety).
- The risk of **sexually transmitted diseases** could be reduced, if campaigns for safer sex were more effective.
- To improve the health status of the communities a better financed health service is urgently required.

Referring to the clinical testing and laboratory results, mercury is a major health hazard in the area. Some first suggestions are:

- Child labour with highly toxic substances must be stopped immediately. Legal restrictions on child labour need to be immediately implemented.
- Women in childbearing age need special information campaigns on this risk of mercury to the foetus and the nursed baby.
- The participants with intoxication need medical treatment. It is necessary to build up a system to diagnose and treat mercury related health problems in the area. Capacity building including establishing laboratory facilities in the Kadoma district is required to analyse mercury in human specimens. The financial aspect of treatment and the legal problem of importing drugs (chelating agents like DMPS or DMSA, to sweep mercury out of the body) need to be solved. Funding of preventive campaigns and for treatment facilities is needed now.
- Training programs for the health care providers in the Kadoma district and other health centres in mining areas to raise awareness of mercury as a health hazard.
- Continuous clinical training of local health workers, including a standardised questionnaire and examination flow scheme (MES = mercury examination score).
- Mercury ambulance: A mobile „mercury ambulance“ might easier reach small-scale miners, than any local health office. A bus could be used as a mobile mercury ambulance. Equipped with the necessary medical and laboratory utensils, the bus

could be driven into the mining areas. Two or three specially trained doctors or nurses could perform the examinations, and begin to carry out treatment. The bus could also be used for health awareness programs (e.g. video equipment). Miners in remote areas might welcome any evening entertainment. Soccer videos might attract more miners to the bus, than much other information material. Why not ask e.g. sponsors for such a bus (or truck).

The knowledge on mercury as a health hazard needs to be improved:

- Assessing in a different study design the possibility of mercury related birth and growth defects, increased abortion/miscarriage rates, infertility problems, learning difficulties in childhood or other neuro-psychological problems related to mercury exposure.
- Assessing in a more detailed study the possible transfer of mercury from mother to child via breast-milk and the related possible adverse health effects. Females at childbearing age and before urgently need more awareness to refrain from amalgam burning, at least during pregnancy and nursing.

The release of mercury into the environment needs to be reduced:

- 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.
- The exposure with mercury is avoidable with such simple technology as retorts. Technical solutions need to go hand in hand with awareness raising campaigns.
- To improve the social, health and environmental situation of artisanal small-scale gold miners an alliance of local, regional, governmental and intergovernmental bodies is needed. Cooperation between health, mining and environmental sectors is needed on local, regional, national and intergovernmental level. E.g. UNIDO and WHO in Harare could form a nucleus of a national mercury task force.

2. Study setting and clinical examinations

(Stephan Boese-O´Reilly, Beate Lettmeier, Felicitas Dahlmann)

2.1. INTRODUCTION

The Health Assessment project is part of a major UNIDO project to remove "Barriers to the Introduction of Cleaner Artisanal Gold Mining and Extraction Technologies", which is performed in six countries. The main funding comes from GEF (Global Environment Program) through UNDP (United Nations Development Program) to UNIDO (United Nations Industrial Development Organization). The University of Munich is subcontractor to BRGM for the health assessment in Zimbabwe.

Figure 1 - UNIDO project countries.

The aim of the subcontract was to undertake a medical investigation of approximately 250 people living in the Kadoma area, in the Midlands of Zimbabwe. 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, increasing knowledge and awareness, and providing policy advice on the regulation of artisanal gold mining with due consideration for gender issues.

2.2. MERCURY

Mercury is a silvery-white shiny heavy metal, liquid at room temperature. Mercury exists in different forms:

- Metallic (elemental) mercury (Hg^0)
  Liquid in room temperature (non toxic), as mercury vapor highly toxic.
- Inorganic mercury (salt of Hg^{2+}), Soluble compounds are toxic
- Organic mercury compounds, especially methyl mercury in fish, highly toxic

Picture 1 - Liquid mercury used in Tix mine.

The lungs absorb 80% of mercury vapor. Target organs are the brain (cerebellum) and the kidney. Mercury is a neurotoxin, nephrotoxin and teratogen. Mercury can cause acute and chronic intoxication.

2.3. ZIMBABWE - KADOMA SMALL SCALE MINING AREA

Figure 2 - Map of Zimbabwe – Victoria Falls.

Zimbabwe is in South-East Africa. The Kadoma district is situated in the Midlands. Farming is the main activity of the rural population.

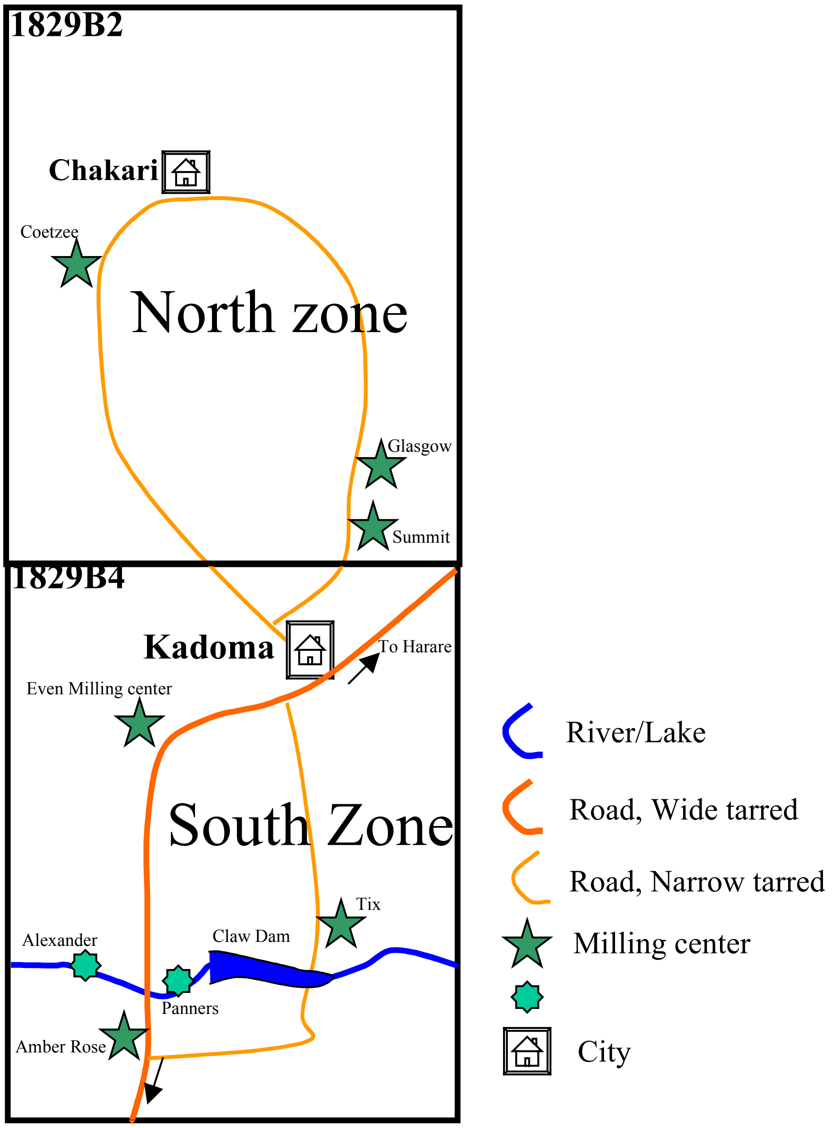


Figure 3 - Local map of Kadoma area (provided by BRGM).

Kadoma is approx. 150 km east from Harare on a good road. The area is slightly hilly, and covered by grassland and woodland. The Kadoma mining area spreads on both sides of the town. The surface is open at many spots, either for tunnels or for amalgamation areas. Mining operations have been carried out in this area since the 1940`s. After 1980 small-scale mining activities began. Since around the year 2000 the activities have increased. The infrastructure in Kadoma is good, in the surrounding mining villages poor. Roads are in an acceptable condition.

Picture 2 - Kadoma village and nearby area.

Picture 3 - Tix mine copper plate and stamp mill.

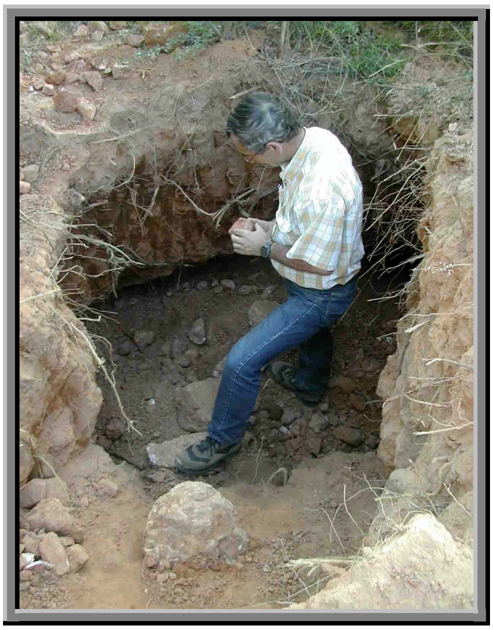
Some miners work in small-scale mining companies, which are licensed. Equipped with generators and other technical equipment miners work in tunnels to extract the ore. The tunnels have a small diameter. The miners try to follow veins, so tunnels are curved, and tend to be very steep. Miners work in shifts.

Tix mine is close to the big Muzvezve River and approx. 6 km southeast of Kadoma town. Tix mine was first opened in 1974. When the ore is removed from the tunnels it is crushed by workers with hammers, and powdered in stamp mills. The ore is then dispersed with water. Using copper plates, the miners try to concentrate the gold containing materials. These copper plates are “loaded” with mercury, then the dispersed fine ore is washed out over the copper plates, during which the gold binds to the mercury.

Picture 4 - Tix mine - scratching of amalgam; squeezing amalgam through a cloth; piece of amalgam; burning amalgam.

After some time the millers stop the process and scratch the amalgam from the copper plates. A cyanide solution is used on the copper plates to enrich the process. This liquorish mercury compound is squeezed through a cloth and a hard piece of amalgam is the result. Sometimes the miners use their mouth to hold the cloth whilst squeezing stronger. The proper amalgam is formed now. The amalgam is smelted on open wooden fire either beside the stamp mill or in the village.

The ore is gained nearby. The artisanal miners work in smaller units. Their equipment and tools are very limited.



Picture 5 - Small artisanal open pit.

Picture 6 - Muzvezve river.

More than 250 miner families live within 400 meters to the Tix mine. Families consist in average of-5-6 members (Mtetwa 2004). Within the village further amalgamation processes take place, including panning and smelting.

Miners use the bush as toilet, since no other facilities exist. The villagers drink the unsafe water from the river, contaminated with mercury and human excrements. The local fish, eaten by the miners is high in mercury (see environmental report).

Amber Rose mine is close to the big Muzvezve River and approx. 7 km southwest of Kadoma town. In this mining area the ore is also crushed by workers with hammers, and then powdered in stamp mills. The mercury is added at the outlet of the stamp mill

Picture 7 - Amber Rose mill: stamp mill; cyclotron.

into a cyclotron, where the gold binds to the mercury in a combination of a gravity method and a chemical reaction.

The amalgam is collected by the ore owner. The amalgam is smelted by the owner either on the spot with a wooden fire or a blow torch, or in his village. The tailings are further processed by the mill owner. After drying the tailings there are reprocessed in big cyanidation tanks. In the "pregnant" solution the gold is recovered and filtered out by carbon. The carbon containing gold is further processed by the stamp mill owner outside the premises.

Picture 8 – Amber Rose mill: tailings and cyanidation tank.

Picture 8 - Amber Rose mill - tailings; cyanidation tank; pregnant solution; filling the tanks with tailings (end).

The ore is gained nearby. The artisanal miners work in smaller units. The artisanal miners have very limited equipment and tools. Some just dig small pits in the area. Other miners dig bigger open pits or even small tunnels.

Approx. 50 miners with their families live on the mining compound, on average with 5 members per family (Mtetwa, 2004).

Blair toilets are used. Drinking water is obtained from boreholes.

Etna mining area

Etna is a large farm approx 30 km south-east outside of Kadoma on off roads. An old abandoned mine was squatted by artisanal miners a few years ago. Outbreaks of violence are reported especially in this area. The old mine is underground, miners nowadays reuse the tunnels, without any safety precautions, and e.g. they take out the pillars. High rate of lethal accidents are a result of this improper mining technology. One stamp mill is operating to crush the ore. A copper plate loaded with mercury plus a ball concentrator with mercury is used to bind the gold to the mercury.

Picture 9 - Primitive sluice box and James table at Etna village.

Many miners crush their ore with pestle and mortar. The powdered ore is panned with mercury. The amalgam is smelted beside the houses. There is no infrastructure at all, poverty is very obvious. Children work in all processes.

Picture 10 - Panning at Etna, piece of amalgam;
one sack of stones collected by a miner in a day.

Picture 11 - Amber Rose village.

All areas

The young and strong men, so called healthy workers, are mainly found in the bigger and technically higher equipped properties. Older people, women of all ages and children mainly work in the smaller artisanal mining properties. Retorts are not used, nor any other protection against any kind of mercury contamination. There is no proper ventilation for the mercury fumes. Housing areas, food stalls and the schools are nearby to the amalgamation and smelting places. Tailings containing mercury are everywhere within the village, beside the farming land or beside the local water wells. The mercury is usually stored in the miner's houses, near to where they and their families sleep. The mercury is available in Kadoma. The gold is sold to governmental dealers, or smuggled to South Africa or Botswana by gold buyers.

2.4. PROJECT DESIGN

The "Protocols for Environmental and Health Assessment of Mercury Released by Artisanal and Small-Scale Gold Miners" were developed by UNIDO in collaboration with the "Institute of Forensic Medicine" and other international experts (Veiga, 2003). The "Health Assessment Questionnaire" was partly translated in Shona and was used (Appendix 2) to examine the general health condition of members of the mining community and to indicate symptoms of mercury poisoning. History / clinical / neurological / toxicological tests were used according to the state of the art. Participants were examined to identify neurological disturbances, behavioral disorders, motor neurological functions, cognitive capabilities, balance, gait, reflexes etc.. The data was compiled for statistical purposes and maintained confidentiality regarding all health related issues.

Team members for the field project were Dr. med. Stephan Boese-O´Reilly (pediatrician, master of public health, environmental medicine), Dr. med. Felicitas Dahlmann (physician) and Ms. Beate Lettmeier (pharmacist). Dr. Dennis Shoko was the National Expert for the Global Mercury Project (UNIDO) with a backup from the University of Zimbabwe. Mr. Pierre Billaud from BRGM is in charge of the environmental and health assessment in behalf of BRGM. He accompanied us during the field project to help organize our project and to complete his environmental assessment. Assigned to the project were nurses to assist the medical examinations, Ms. Tapuwa Mwanjira, Ms. Vigilance Parirenyatwa, and Ms. Joan Marembo and Dr. Edwin Muguti as local medical expert.

The field project took place from the 4th of April 2004 until the 21st of April 2004. The equipment was first set up in the school building near Tix mine (Mayflower Primary School). The school offered its facilities to perform the examination, which was much appreciated by the health assessment team. The facilities were sufficient to perform the examinations (four rooms for the team, electricity, toilet, water), including a mobile analyzer of Hg in urine. In Mayflower school participants from Tix mill, Brompton mine and Amber Rose mill were examined.

Picture 12 - Mayflower school.

The second place for examinations was in Kwayedza secondary school. The facilities were very similar. Participants from Glasgow mill, Summit mill, Lilly, Jani and King Chin were examined there.

Picture 13 - Kwayedza school.

One day the examinations took place in the open. On the mining compound of Amber Rose mill the equipment was set up onto the two pick-ups, local electricity was used. It was possible to work there, but the conditions were not as appropriate as in the schools. Mainly the laboratory equipment was sensitive to the high concentration of mercury within the area. On the other hand it was much easier for the participants from the village to see what a health assessment means, and not to be transported somewhere.

Picture 14 - Mobile field clinic at Amber Rose mill – neuro-psychological testing; history; laboratory; blood sampling.

The control group was examined in Chikwaka. The same method was used, but the nurses were new. The local health unit supported us. Chikwaka is more than 100 km away from the mining area, and mercury is not used there.

Blood, urine and hair will be analyzed for mercury at the University of Munich, Germany.

2.4.1. Questionnaire

The participants filled in a questionnaire with assistance from the nurses. Questions included:

Working with mercury or with mercury polluted tailings?

Burning amalgam in the open?

Picture 15 - Nurses taking the history.

- Melting gold in the open or with inadequate fume hoods?
- Drinking alcohol?
- Having a kind of a metallic taste?
- Suffering from excessive salivation?
- Problems with tremor / shaking at work?
- Sleeping problems?

2.4.2. Neurological examination

All participants were clinically, mainly neurologically examined. Results were mainly primarily scored according to „Skalen und Scores in der Neurologie“ (Masur, 2000):

Picture 16 - Neurological examination (PSR reflex; finger-finger-nose test).

- Signs of bluish discoloration of gums,
- Rigidity, ataxia and tremor,
- Test of alternating movements or test for dysdiadochokinesia,

Picture 17 - Visual field test

- Reflexes: knee jerk reflex and biceps reflex.
- Pathological reflexes: Babinski reflex and mento-labial reflex.
- Sensory examination.
- Test of the field of vision [1].

2.4.3. Neuro-psychological testing

The following tests were carried out (Zimmer, 1984 ; Lockowandt, 1995 ; Masur, 2000):

- Memory disturbances: Digit span test (Part of Wechsler Memory Scale) to test the short term memory.

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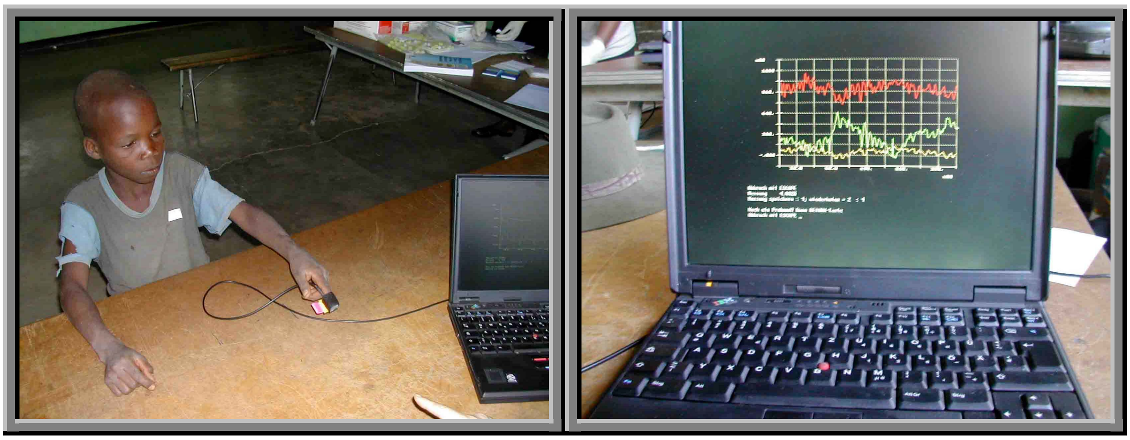
[1] The visual field was measured in a very simple way without the need of any electricity: The test person was sitting in front of a blackboard, when the examination took place in a school building, or in front of a wall at the examination site out in the field. The person was asked to keep her head leaned on the blackboard/ wall, where a line of 50 cm had been drawn to the right and to the left from a point in the middle of the back of her head. Also the distance between the blackboard/ wall and the outer corner of the person's eye had been measured (called "base line" in the test). Then an inch rule was hold onto the 50 cm point at the right in a 90 degree angle to the blackboard/ wall on level with the person's right eye and a red ballpoint pen was moved along this ruler until the test person said: "stop!" to show, that the pen entered her visual field. The inches, in our case "centimetres", the ballpoint pen had been stopped, were recorded. The same procedure had been performed at the left side of the person: The inch rule on the 50 cm point at the left in a 90 degree angle to the blackboard/ wall on level with the person's left eye, the red ballpoint pen moved along the ruler until the test person said "stop!". With these parameters the visual field afterwards can be calculated with mathematical methods.

- Match Box Test (from MOT) to test co-ordination, intentional tremor and concentration.
- Frostig Score (subtest Ia 1-9) to test tremor and visual-motoric capacities.
- Pencil Tapping Test (from MOT) to test intentional tremor and co-ordination.

Picture 18 - Match box text, memory test, pencil tapping test, Frostig test.

2.4.4. Tremor-meter

A new approach to measure tremor in a more objective way was performed. PD Dr. Boetzel from the Neurological Clinic, University Hospital in Munich supplied the team with an instrument to measure tremor. This instrument is still at a developmental stage. A small sensor was placed on the fingertip (right and then left side) of each participant. A special electronic unit, developed by the University, measured the signal and the digital signals were recorded onto a laptop.



Picture 19 - Tremor-meter.

Three different measurements were performed:

- Arms outstretched – for intentional tremor.
- Arms bend with the finger tip pointing to the nose – for intentional tremor.
- Arms outstretched - moving fast for 30 cm from left to right and back – for movement analysis.

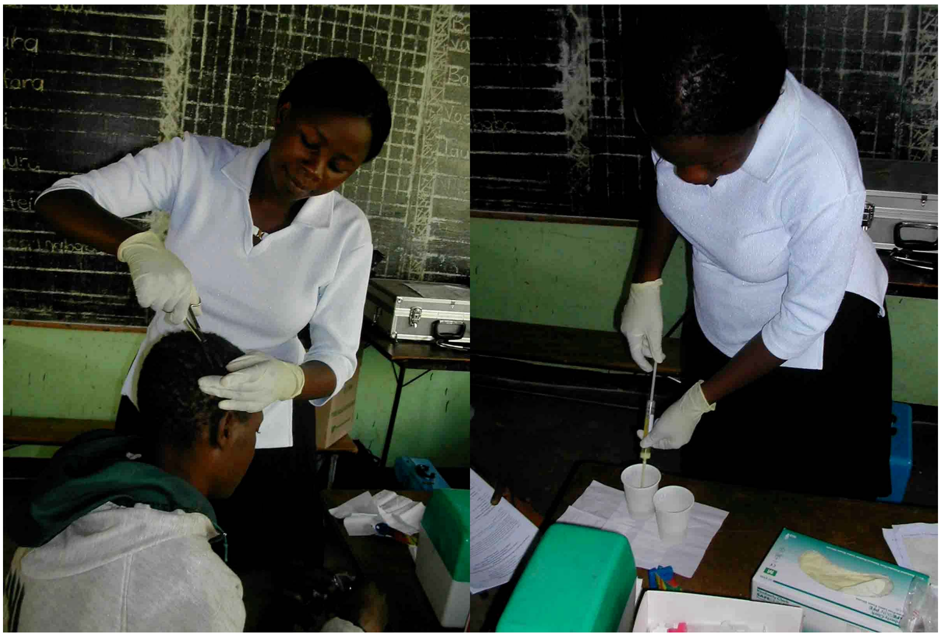
2.4.5. Laboratory field project

a) Specimens

The following specimens were taken, and two tests (Hg in urine and proteinuria) were performed immediately:

- Blood (EDTA-blood 10 ml)
- Urine (spontaneous urine sample 10 ml)
  Urine protein test
  inorganic Hg in urine
- Hair.

The specimen urine and blood were cooled after collection until arrival in the laboratory in Munich, Germany. Video and photo documentation of the examinations was carried out.



Picture 20 - Hair and urine sampling.

b) Lumex

A mobile Hg analyzer (Lumex RA-915+ with liquid attachment RP-91; Maassen GmbH, Germany) was used to quantify inorganic mercury in urine with atomic absorption spectrometry. For this 1 ml or less of the urine was filled with a pipette into the reaction vessel filled with 10 ml of a tin(II)chloride-solution (5% in a 3% hydrochloric-acid). A mercuric nitrate solution (100 ng/ml) was used as standard for calibration and control.

All the solutions were prepared with bottled drinking water due to the lack of distilled water.

The urine samples will be re-analyzed in the “Institute of Forensic Medicine”, Munich, Germany, to verify the results.

Picture 21 - Mobile Hg analyser for urine (Lumex).

2.4.6. Test for protein in urine

Proteinuria was tested with a commercial kit (Bayer). The test is based on the error-of-indicator principle.

Test reagents are 0.3% w/w tetrabromophenol blue; 99.7% w/w buffer and non-reactive ingredients. At a constant pH, the development of any green color is due to the presence of protein. Colors range from yellow for “negative” reaction to yellow-green and blue-green for a “positive” reaction. The test area is more sensitive to albumin than to globulin, hemoglobin, Bence-Jones proteins and muco-proteine. The test area is sensitive to 15 mg/dl albumin. The test strip was dipped into the native urine and the result was taken after 1 minute.

The test is semi-quantitative. Possible results are 0, 10, 20, 30, 100 and 300 mg Protein/dl urine.

2.5. GENERAL HEALTH PROBLEMS IN KADOMA DISTRICT

Doctors, nurses, engineers, teachers and participants were interviewed on possible health effects in relation to the mining and milling activities. The data from the two sociological studies were very useful sources of information (Mtetwa, 2003 and Mtetwa, 2004).

2.5.1. Health care system in Kadoma district

The population is estimated to be 238,122 for the year 2003 (< 1 year of age are 7,620, < 5 years 35,004, 5-14 years 66,912, > 15 136,206). 56,911 women are in the age group 15-49, 10,573 women were pregnant.

The health service for the wide spread mining communities is situated in Kadoma town. Village health workers can be found in the villages. They can treat minor illnesses as well as primary malaria treatment. They support family planning, including distribution of condoms. This service is provided free of charge.

The next district hospital is in Kadoma town. General surgery is performed in Kadoma, and most of the infectious diseases can be treated in Kadoma, otherwise patients have to be referred to Harare. The medical services in the hospital are charged to the patients. Some patients cannot afford the charges in the hospital, but even more problematic are the high medication costs. Kadoma district hospital is soundly built but there is a great lack of financial resources to maintain the hospital and the equipment. Most of the more technically advanced laboratory equipment does not function anymore. The pharmacy in the hospital lacks many essential medication. The pediatric ward, for example cannot obtain the necessary medication to treat asthma or some kinds of pneumonia. Children die due to these lack of resources. Also there is no ambulance available to transport injured miners, the miners cannot afford private transport expenses if they are injured. The staff fluctuation is also a problem as experienced staff leaves the hospital to work in the private sector or to work abroad. Our team was urgently asked to provide essential technical and medical equipment to the hospital.

The public health service is based at the district hospital. Mother and child care, family planning, follow-up of the chronically ill, providing health information, and environmental health are the duties of the public health service, all of which are free of charge.

Several private medical practitioners treat patients in Kadoma. Traditional healers (herbalists), so-called “machiremba”, are part of the health care system.

All health care services have been steadily declining since a few years due to a drainage of experienced and well trained health care providers to other developed countries, caused by a lack of financial resources and unfavorable working conditions.

2.5.2. General health data

Health indicators can be used to compare health situations in this case between countries. Life expectancy at birth is one commonly used health indicator. Life expectancy for females in 2002 in Zimbabwe was 38.0 years, and for males 37.7 years (WHO 2004).This is an extremely low life expectancy, even compared to other countries in the area like Tanzania (47.5 years for females and 45.5 years for males) or Ghana (58.8 for females, 56.3 for males) and Indonesia (67.9 for females, 64.9 for males) (WHO 2004).

In 2003, 235,531 people were registered in the Kadoma district . A high percentage of young people, 14.7 % under 5 years, and 28.1 % between 5 and 14 years were noted (see table 1).

	Number	**In %**
Total population as of 2003	235531	100
Population under 1 year	7537	3.2
Population under 5 years	34623	14.7
Population 5-14 years	66184	28.1
Population 15+ years	134724	57.2
Women 15 - 49 years	56292	23.9
Pregnant women	10458	4.44
Expected deliveries 4.32	10191	4.32

Table 1 - Kadoma district demographic data (by Mr. Gift from Kadoma District Hospital).

	Absolute No	% of Total New Cases
1.Acute Respiratory Infections	15385	35.0
2.Malaria	5369	12.2
3.Diarrhoea	4804	10.9
4.Skin Diseases	3785	8.6
5.Diseases of the eye	1840	4.2
6.Symptoms & ill Defined Conditions	1660	3.8
7.Injuries	1638	3,7
8.Nutritional Deficiency	740	1.7
9.Dysentery	226	0.5
10.STD	112	0.3
Remaining Diseases	8340	19.0
Total New Cases	43899	100.0

Table 2 - Main causes of out-patient morbidity (under 5 years) (data from Mr. Gift from Kadoma District Hospital).

		Absolute No	% of Total New Cases
1	Acute Respiratory Infections	44339	21.9
2	Malaria	31887	15.8
3	Skin Diseases	12955	6.4
4	Diarrhoea	12831	6.3
5	Symptoms & ill Defined Conditions	12734	6.3
6	STD	12340	6.1
7	Injuries	11818	5.8
8	Diseases of the Eye	5606	2.8
9	Dental Conditions	2692	1.3
10	Dysentery	1298	0.6
	Remaining Diseases	53593	26.5
	Total New Cases	202093	100.0

Table 3 - Main causes of out-patient morbidity (all ages) (date from Mr. Gift from Kadoma District Hospital).

The main causes of out-patient morbidity for children in the Kadoma district are mainly acute respiratory tract infection, and malaria or diarrhoea (see table 2). The main causes of disease to be admitted to hospital for children are acute respiratory tract infection, diarrhoea, problems around birth (perinatal pathology) and malaria (see table 4). The main causes of death for children are the same as for hospital admission (see table 6).

The estimated infant mortality rate in Kadoma district with 38.8 deaths per year / 1000 live births is compared to the country wide rate of 70.7 relatively low; to compare Tanzania 109.2, Ghana 61.6, and Indonesia 39.3 (WHO 2004). Kadoma district seems to be in the upper region of health indicators within Zimbabwe.

For adults acute respiratory tract infections, malaria and skin diseases are the main causes of out-patient morbidity (see table 3). Apart from birth deliveries the main causes to be admitted to hospital for adults are acute respiratory tract infections, injuries and malaria (see table 5). The main causes of death for adults are AIDS related diseases, acute respiratory tract infections, diarrhoea, tuberculosis and malaria (see table 7).

		Absolute No	% of Total New Cases
1	Acute Respiratory Infections	741	50.1
2	Diarrhoea	206	13.9
3	Perinatal Pathology	101	6.8
4	Malaria	85	5.8
5	Symptoms & ill Defined Diseases	75	5.1
	Total New Cases	1478	100.0

Table 4 - Main causes of in-patient morbidity (under 1 year of age) (data from Mr. Gift from Kadoma District Hospital).

		Absolute No	% of Total New Cases
1	Normal Deliveries	3634	25.5
2	Acute Respiratory Infections	1178	8.3
3	Injuries and Poisonings	1112	7.8
4	Malaria	1041	7.3
5	Aids Related Diseases	809	5.7
	Total New Cases	14247	100.0

Table 5 - Main causes of in-patient morbidity (5 years and over) (data from Mr. Gift from Kadoma District Hospital).

		No. of Deaths	Infant mortality rate / 1000 live births
1	Acute Respiratory Infections	106	
2	Diarrhoea	31	
3	Perinatal Pathology	25	
4	Malaria	11	
5	Symptoms & ill Defined Disease	11	
	Total Under 1 Deaths	215	
	Total Live Births	5547	38.8

Table 6 - Top five causes of mortality (under 1 year) (data from Mr. Gift from Kadoma District Hospital).

		No. of Cases	No. of Deaths	Case Fatality Rate (%)
1	Aids Related Diseases	809	208	25.7
2	Acute Respiratory Diseases	1178	159	13.5
3	Diarrhoea	686	123	17.9
4	Tuberculosis	780	123	15.8
5	Malaria	1041	105	10.1

Table 7 - Top five causes of mortality (5 years and over) (data from Mr. Gift from Kadoma District Hospital).

AGE GROUP IN YEARS	FEMALE			MALE		
	HIV Tests	No. +ve	% +ve	HIV Tests	No. +ve	% +ve
0 - 4	38	22	57.9	44	26	59.1
5 – 14	45	28	62.2	16	9	56.3
15 -19	25	17	68.0	6	1	16.7
20 - 29	138	101	73.2	126	106	84.1
30 - 39	203	167	82.3	256	194	75.8
40 -49	75	49	65.3	110	62	56.4
50 - 59	28	19	67.9	56	23	41.1
60+	8	5	62.5	23	10	43.5
AGE UNKNOWN	4	0	0.0	36	19	52.8
TOTAL	564	408	72.3	673	450	66.9

Table 8 - HIV/AIDS (data from Mr. Gift from Kadoma District Hospital).

The HIV/AIDS data from Kadoma district is very frightening (see table 8). Most applied tests were positive (66% in males, 72% in females). The main age group of positive tests is in the 20-29 and 30-39 year old population-group. These age groups are the most sexual active age groups. At the same time these younger people are the main work force at the moment and for the near future. The very high percentage of positive tested people gives very serious concern to the public health sector, and might explain the very low life expectancy in Zimbabwe.

2.6. GENERAL HEALTH PROBLEMS IN KADOMA DISTRICT

The main health problems in the mining area seem to be:

Dangerous tunnels, many lethal accidents occur each year in the Kadoma district. Exact figures seem not to exist. Best estimations are in the range of 50 lethal accidents per year in the mining areas. Miners reported of collapsing tunnels, due to improper mining technologies (missing tunnel safety precautions). Medical treatment is not available in the informal mining area proper, only in the nearby town of Kadoma.

Infectious diseases are widespread. A very high percentage of the surveyed population had malaria, many of them within the last year. Malaria is diagnosed clinically and treated orally mainly with Chloroquine and SP (Fansidar). Tuberculosis is endemic, but not epidemic. Tuberculosis is treated under a governmental program. According to the WHO scheme daily-observed treatment (DOT) with quadruple treatment for 2 months (Isoniazid, Rifampicin, Pirazinamid, Etambutol) and follow-up double treatment for 4 months (Isoniazid, Rifampicin) is performed. Bilharzia occurs occasionally, no screening program is performed at the moment, and treatment with Prazaquantile is available in the hospital.

Sexually transmitted diseases (STD) are common. Promiscuity and prostitution are common in the mining areas. Gonorrhea and cancroids are common. No screening is performed, in the hospital gonorrhea is treated syndromatically with Benzadine-penicillin, Doxycyclin, Metronidazole and Kanamycin.

HIV/Aids data was not available for the surveyed population. Cases of Aids are known and treatment of the symptoms is available in the hospital. Antiviral treatment is not available in the hospital, except for the mother child program. Prescriptions of antiviral medication are available from the private medical practitioners, but the medication is too expensive for most patients. Testing for HIV/Aids is voluntary.

Malnutrition in Zimbabwe has increased within the past two years due to drought over a period the last years. The first food supply donations began last year (2003) Malnutrition together with the HIV increases the susceptibility for other lethal infections such as TB and malaria.

The dental status of people differs. Some people have many stumps but many people have fairly good teeth. Most children have quite good teeth. The dental service in Kadoma district hospital is closed due to the lack of a dentist.

Insufficient sanitary conditions cause diarrhea. It is a major cause of infant mortality in the mining areas in Kadoma district.

Pneumonia, upper respiratory infections, skin diseases, eye diseases (cataracts, conjunctivitis) are other important causes of diseases in the mining areas in Kadoma district.

The volunteers, we examined, presented diseases such as asthma, skin infections, scars, hematuria etc.. These conditions should have been diagnosed and treated much earlier.

Smoking is more common among men than among women. Alcohol consumption seems to be higher in the informal small-scale mining areas. Drinking is very common in the villages, mainly for men, since there are no other activities in the small-scale mining areas for example no TV. The illegal use of smoking “dagga” seems to be done amongst younger male miners.

2.6.1. Children’s health in Kadoma district

A high proportion of the population in the area is children under the age of 12. The main health problems of children in the Kadoma informal mining areas seem to be malnutrition and malaria: Due to poor sanitary conditions infectious diseases like gastro-intestinal infections and malaria are very common and are a risk for children’s health.

Children experience high exposure to mercury in the area. They have access to fluid mercury and play with this mercury with their hands. They live within the huts where amalgamation and smelting is carried out and are therefore also exposed to mercury fumes.

Some children do not attend school. Many children and teenagers work after school or at weekends. Children begin to work in this area as young as 10 years of age. They work in the amalgamation and smelting process with direct contact to mercury.

This is child labor at its worst limits, partially physically very hard, partially related to a high exposure of mercury. Accidents related to work are a health hazard for these children.

Not only mercury is a health hazard for children working in the mines. Some of the children also work with cyanide, or with nitric acid. They inhale the toxic gases and are in danger of damaging their respiratory system. The team examined three 8-12 year old boys who had been coughing heavily in a dry manner. These children were not only using cyanide but also nitric acid for cleaning the copper plates. Two of them might have been mentally retarded, their look was almost dull, e.g. the orders for carrying out the neuro-psychological tests had to be repeated several times until they reacted. The children would prefer to go to school instead of working as a “panner” or miner, as one 10 year old boy expressed, but they have no choice due to the poverty of their family.

Picture 22 - Children from Kadoma, all working as miners.

2.7. PRELIMINARY CLINICAL RESULTS OF THE HEALTH ASSESSMENT

The health assessment was performed according to the UNIDO health assessment protocol (Veiga, 2003). The declaration to volunteer was translated in Shona (see appendix 2). The 3 nurses interviewed all 217 participants. These participants were physically examined including neurological testing. Specimens (blood, urine, hair) of nearly all participants were taken at that time. A mobile Hg analyser was used to determine total mercury in urine. Video and photo documentation was carried out.

2.7.1. Clinical and neurological examination

The clinical impression was, that some workers from Kadoma showed severe symptoms, related to the classical picture of a mercury intoxication. They reported sleep disturbances, excessive salivation, tremor, and metallic taste. Intentional tremor, mainly fine tremor of eye lids, lips and fingers, ataxia, dysdiadochokinesia and altered tendon reflexes were observed.

One woman, who had been working since 14 years with mercury showed severe symptoms of a clinical mercury intoxication with ataxia, strong hypomimia, altered reflexes and primitive reflexes. A seventeen year old young man, working since the age of 10, had a very strong tremor of the eyelids, and could not even close the eyes completely anymore.

Other health problems observed were keloid formation due to hypertrophic scars. This is not related to mercury, but shows the lacking capacities of the health care system. One participant showed a severe scar on his foot due to a mining accident (collapsing unprotected tunnel). Another participant had a scar at his neck due to a fight in the mining area.

Picture 23 - Participants with hypertrophic skin, scars due to mining accident, scar due to a knife injury

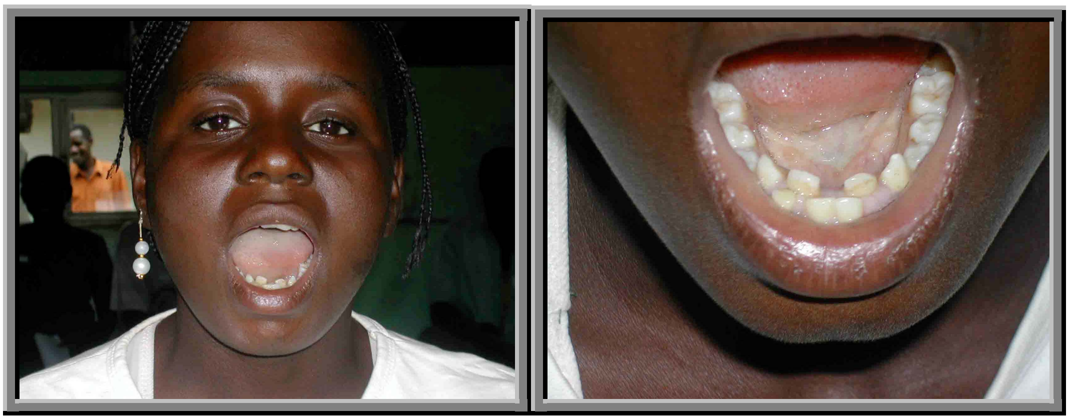
It should be noted that many workers from Kadoma were primarily very healthy and strong young men (healthy worker effect).

Participants who worked for more than 5 to 10 years in the area seemed to have more severe clinical symptoms. But most miners did not work for that long in this area. It is possible that we missed the most severe cases. Due to the lack of a highly developed social system in Zimbabwe, some very sick workers might also have moved back to their original homes and families elsewhere in Zimbabwe.

2.7.2. Children's health in Kadoma mining area

The health status of the children in the area is poor. Malnourished and undernourished small children are not uncommon (Kwashiorkor). Many children suffer from skin problems, diarrhea and upper respiratory tract infections. Malaria is by far the most serious health hazard for children in this area. Most children were physically fairly fit, and well socialized.

One child showed a dental malformation, a double formation of front teeth. In Minamata disease skeletal malformations were linked to mercury. A single case cannot be linked to a special cause, but it would be of great interest to analyze with a different approach malformations in the area. A first clinical impression was, that some children were either mentally retarded, or physically retarded.



Picture 24 - Dental malformation.

Picture 25 - Control area Chikwaka.

The control group in Katoro was healthy and did not show any special health problems (55 people).

2.7.3. Hygienic problems

The interviews highlighted some other problems:

In Kadoma town hygienic standards differ within the different town areas. The town is overcrowded with migrant workers. Most people in the town have access to safe drinking water. In town there is a waste water system draining to sewage tanks. Waste collection functions.

In contrast the hygienic condition is poor in the villages where informal small-scale mining occurs. Water is gained from the river, boreholes, or wells. Water is not safe due to inappropriate hygienic conditions, and due to mercury leaking into the waterways. The drinking water is sometimes turbid, which is a sign of insufficient hygienic quality. Due to mining activities there are many small pools in the area. These pools are certainly an excellent habitat for transmitters of vector borne diseases, like Malaria. Most informal small-scale miners to not have any toilet, they just use the bush.

2.7.4. Social problems

In Kadoma district approximately half of the population is directly involved in the mining and milling activities in the area. Estimations are in the range of 30,000 miners plus family members, in total approximately 150,000 people. Some miners live with their families in the mining areas, others live in Kadoma town, where no mining activities take place.

Only few of the miners have a licensed small-scale mine, most miner work as artisanal small scale miners. Many of these miners are work migrants. Lack of other employment and hope of getting "easy money" (gold-rush) are the main reasons to migrate to the Kadoma area and to begin to work as a small-scale miner. It is possible to get legal permits for mining in Kadoma at the office of the department of the ministry of mines by paying an affordable fee.

Living in remote villages means living outside of the security regulations. Since the gold rush in the year 2000 and later, miners squatted some areas. Mainly old mines, that were not in use anymore were penetrated. Miners enter the tunnels without any safety precautions. Occasionally fights break out between miners to get personal access to the gold promising ores. Sometimes miners exiting the tunnels with ore containing gold are attacked from other miners. Gold buyers also run the risk of being attacked. Fights between miners, often drunken, occur often in the villages. There are just very rough estimations on the death toll of these conflicts, possibly more than 100 miners die each year due to criminal activities. Neither the police, nor the mining or health authorities have any exact figures nor do they have any control over the situation. Investigations by specialists in forensic medicine do not exist.

Some miners are aware of the possibility of environmental and health hazards due the use of mercury. But due to the lack of job opportunities elsewhere they continue to use mercury.

2.7.5. General problems during the field project

The infrastructure in the Kadoma district is poor but sufficient to perform the examination. It is only due to excellent preparation of the field project by UNIDO Harare, Dennis Shoko and BRGM, Pierre Billaud, that the project was successful at all.

The regional health authorities accepted the project. But on the national level there was no support for the project. When asked for support before the start of the project, the Ministry of Health did not support the health assessment. At the end of the project there was some support from the Ministry of Health due to the intervention of Dr. Muguti, so that at least the team could export the human bio-monitoring samples.

A problem was the poverty of the population in the area. Many participants suffered from severe diseases that had not been adequately diagnosed or treated for months and years due to a lack of resources. During the field project the medical experts (pediatrician, general practitioner and a surgeon) and the pharmacist diagnosed, referred or treated many people in Kadoma. Medication was provided free of charge to the people. This medication was donated by Allacher Apotheke (Munich).

2.7.6. Participation

After the team had finished the examinations at the end of the project, it visited the workers of Tix mill in their village. As many of the miners had been previously examined by our team, the acceptance for our team within the village was greater than expected. On previous projects our teams had been treated with more suspicion. Many of the Tix miners spoke with the team about the project, about the results of the examinations and asked, when they would receive the results of their personal mercury burden of blood and urine.

When the health assessment team came to Tix mill in the first days, the miners were a little bit suspicious of its intentions. But then most of the people came to the examination site as if to a feast - often in their best clothes. For them this also seemed to be a question of honour and dignity.

The people first had to gain confidence in the team and when the team made it’s final visit to the Tix mine community the team members almost seemed to be “old friends”.

3. Specimen analysis and statistical results

(Gustav Drasch, Beate Lettmeier)

3.1. LABORATORY METHODS

3.1.1. Material and sample storage

From 273 participants in Zimbabwe 269 blood samples, 273 urine samples and 233 hair samples were taken. The blood samples were taken in EDTA-coated vials. The urine samples were acidified with acetic acid. To avoid de-gradation, all blood and urine samples were stored permanently and transported by flight to Germany in an electric cooling box. Until analysis these samples were stored continuously at 4 °C.

3.1.2. Sample preparation

Hair: 20 mg – 200 mg (if available) hair was cut in small pieces and weight exactly. Missing hair samples are mainly due to the very short hair style of men and children. Some women refused to give hair samples. All mercury was extracted from the hair samples by shaking with 10 ml hydrochloric acid 6 N for 15h at room temperature in the dark. Parts of the elute were analysed by CV-AAS with two different reduction agents (see below).

Intentionally washing steps with water, detergents or organic solvents like acetone were not performed before the elution. Washing procedures with different solvents are frequently applied before hair analyses with the aim to remove air-borne heavy metal pollution from the surface of the hair. But as shown in literature, a distinct differentiation between air-borne and interior mercury cannot be achieved which such washing procedures (Kijewski, 1993). Orientating pre-experiments with washing hair samples from burdened groups supported this assumption. After washing some samples from the same strain, the results were not reproducible. Therefore the hair samples were eluted without any further pre-treatment.

Blood, urine: Aliquots of up to 1.0 ml were analysed directly without further pre-treatment (method see below).

3.1.3. Mercury determination and quality control

The *total* amount of mercury in the samples (blood, urine, elute from hair) was determined by means of so-called cold-vapour atomic absorption spectrometry (CV-AAS), using a Perkin-Elmer 1100 B spectrometer with a MHS 20 and an amalgamation unit, Perkin-Elmer, Germany. Sodium-borohydride ($NaBH_4$) was applied for the reduction of all mercury (inorganic and organic bound). $NaBH_4$ reduces inorganic mercury quicker than organic bound mercury like methyl-mercury. Nevertheless it is possible with this method, to determine the correct amount of *total* mercury, because all nascent mercury vapour is inter-collected on a gold-platinum-net. In a second step the net is heated and all trapped metallic mercury is released at once and could be quantified by CV-AAS. The accuracy of the method for inorganic as well as organic mercury compounds was proved by inorganic and methyl-mercury standard solutions. The determination limit for total Hg in blood or urine was 0.20 µg/l, for total Hg in hair 0.02 µg/g (calculated for a 100 mg hair sample).

In addition, in the elutes of the hair samples, the amount of inorganic mercury was determined by CV-AAS, using a Lumex Zeeman mercury analyser RA-915+, Lumex Ltd., St. Petersburg, Russia. This equipment operates with $SnCl_2$ (tin-II-chloride) for reduction. With this method, only inorganic mercury can be detected, because under acid conditions $SnCl_2$ reduces only inorganic mercury and not organic bound mercury like methyl-mercury. This was proven by inorganic mercury standards (which show a signal) and methyl-mercury standards (which show no signal at all). The determination limit for inorganic Hg in hair is 0.05 µg/g (calculated for 100 mg hair).

All analyses were performed under strict internal and external quality control. The following standard reference materials served as matrix-matched control samples: human hair powder GBW No. 7601 (certified Hg 0.36 ± 0.05 µg/g) and Seronorm whole blood No. 201605 (certified Hg 6.8 – 8.5 µg/l). Since many years the lab participates successfully in external quality control tests for mercury in human specimen.

3.2. STATISTICAL ANALYSIS

3.2.1. Statistical methods

Statistics were calculated by means of the SPSS 9.0 programme (SPSS-software, Munich, Germany). As expected, the mercury concentrations in the bio-monitors (blood, urine, hair) were not distributed normally but left-shifted. Therefore in addition to the arithmetic mean (only for comparison to other studies) the median (50% percentile) is given. For all statistical calculations distribution-free methods like the Mann-Whitney-U-test for comparing two independent groups, the Kruskal-Wallis-test for comparing n independent groups, the Chi-square test for cross-tables or the Spearman rank test for correlation were used. “Statistically significant” means an error probability below 5% ($p < 0.05$).

Some graphs were shows as so-called “box-plots”. For a brief explanation: The “box” represents the inter-quartile (this means from the 25% to the 75% percentile). The strong line in the box is the median (50% percentile). The “whiskers” show the span. Outliners are indicated by dots.

3.2.2. Description of mercury levels in urine, blood and hair

In table 9 the total mercury concentrations of all analysed blood, urine and hair samples are summarised. In 8 blood samples and in 47 urine samples the mercury concentration was below the detection limit of 0.20 µg/L (equal for blood and urine). For statistical purposes, in these cases the value was set to ½ of the detection limit

(0.10 µg/L). In one hair sample the content of total mercury was below the detection limit (0.02 µg/g). In 196 cases the concentration of inorganic mercury in hair was above the detection limit of 0.05 µg/g. In these cases the concentration of organic bound mercury could be calculated by the difference total Hg minus inorganic Hg (table 10).

For comparison the results of the project site in Indonesia (Drasch 2004a) are reported in the same table 9; further, for blood and urine, the result of a representative epidemiological study, performed 1990/92 in Germany, an industrial country in Western Europe (Krause 1996). For a better comparison of the (total) hair values, recently published own data from Germany are cited (Drasch, 1998). The organic bound Hg in hair (table 10) was compared to the project in Indonesia, too (Drasch, 2004a).

In recent literature from Europe and Northern America similar Hg concentrations in blood, urine and hair have been reported (Drasch, 2004a). From populations with a high consumption of methyl-mercury-contaminated sea food like in Japan, the Faeroes Islands, the Seychelles or Canadian Inuit higher Hg values in the bio-monitors have been reported recently e.g. on the International Conferences on “Mercury as a Global Pollutant” 1996 in Hamburg, Germany, 1999 in Rio de Janeiro, Brazil and 2002 in Minamata, Japan (for literature in detail see proceedings). From other areas with small scale gold mining like in the Amazon, Brazil, mercury concentrations, comparable to the found levels, have been reported e.g. at these congresses or summarised in the book “Mercury from Gold and Silver Mining: A Chemical Time Bomb?” by de Lacerda and Salomons (1998).

		This project	**For comparison**	
		Zimbabwe	Indonesia (gold mining area)	Germany
Hg-blood [µg/l]	case number	269	491	3958
	span	< 0.2 – 100.8	1.45 – 429	< 0.2 – 12.2
	median	5.62	8.4	0.6
	arithmetic. mean	12.55	16.6	0.51
	literature			(Krause 1996)
Hg-urine [µg/l]	case number	273	492	4002
	span	< 0.2 – 1530.3	< 0.2 – 5240	< 0.2 – 53.9
	median	17.06	4.6	0.5
	arithmetic. mean	65.32	40.47	1.11
	literature			(Krause 1996)
Hg-urine [µg/g creatinine]	case number	273	492	4002
	span	< 0.20 – 666.8	< 0.20 – 1697	< 0.1 – 73.5
	median	15.59	2.7	0.4
	arithmetic. mean	42.13	17.99	0.71
	literature			(Krause 1996)
total Hg-hair [µg/g]	case number	233	488	150
	span	< 0.02 – 112.18	0.33 – 792	0.04 – 2.53
	median	2.48	2.64	0.25
	arithmetic. mean	6.8	9.15	
	literature			(Drasch 1998)

Table 9 - Concentration of total mercury in blood, urine and hair.

		Zimbabwe (this project)	Indonesia
Organic Hg-hair [µg/g]	case number	211	467
	span	< 0.07 – 16.56	< 0.10 – 326
	median	0.62	1.74
	arithmetic. mean	1.53	3.98

Table 10 - Concentration of organic mercury in hair.

All mercury concentrations in the different bio-monitors blood, urine and hair are highly significant rank correlated (table 2 in appendix 1). Despite this, the individual values scatter widely (see fig. 5-7).

3.2.3. Exclusion of data

From the total group 19 cases were excluded from further statistical analysis:

- 5 seniors older than 59 years
- 2 participants with severe neurological diseases (1 with Parkinson and 1 with brain injury caused by car accident)
- 8 participants due to acute high consumption of alcohol
- 3 former miner now living in the control area
- 1 participant discontinued the examinations

It was necessary to exclude these 19 participants for the statistical analysis, as their symptoms might be due to other reasons.

Nevertheless, for these 19 cases an individual diagnosis of a mercury intoxication was performed as well.

3.2.4. Forming subgroups due to residence and occupation

To distinguish between the possible sources of mercury burden the remaining 254 participants were subdivided due to residence and occupation criteria to the following subgroups:

- **Chikwaka control group adults:**
  36 adults from Chikwaka, without any special Hg burden.
- **Kadoma, not occupational burdened:**
  21 adults, living around Kadoma without any special occupational Hg burden.
- **Kadoma, other occupational burdened:**
  19 adult workers (miners and mineral-processors)
- **Kadoma, amalgam-burners:**
  117 adult amalgam-burners from the mining areas

- **Kadoma, former occupational burdened:**
  21 retired workers, still living in the mining areas
- **Chikwaka control group children:**
  12 children from Chikwaka up to 15 years, without any special Hg burden
- **Kadoma, children not working with Hg:**
  12 children (up to 15 years) from the mining areas, not working with mercury
- **Kadoma, children working with Hg:**
  16 children (up to 15 years) from the mining areas, working with mercury

Unless other indicated, all further statistical analysis was performed with these subgroups.

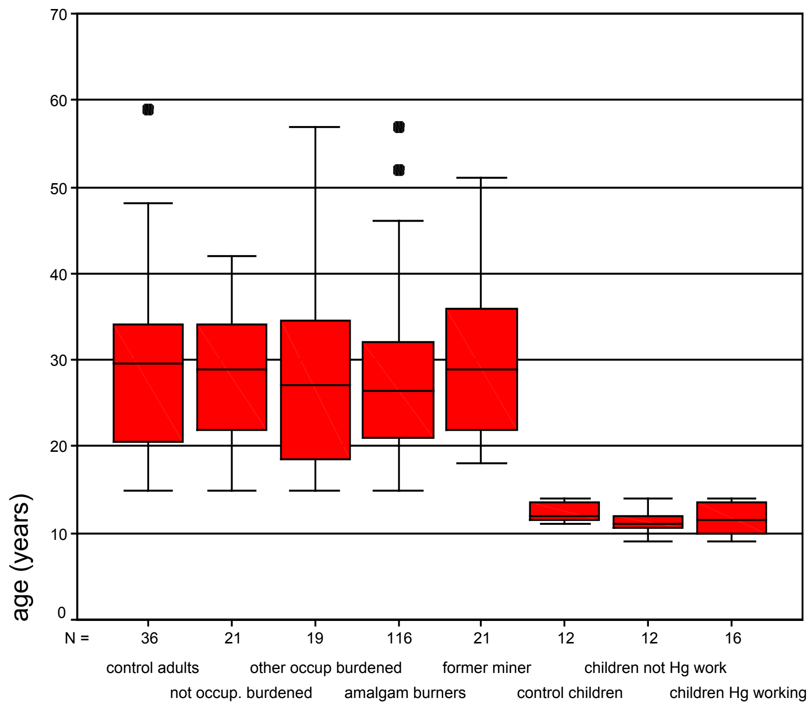


Figure 4 - Age distribution of all volunteers, selected for the statistical evaluation.

Figure 4 shows that the age distribution of the subgroups (as of the adults as of the children) are comparable.

As expected, there is a surplus of males in most of the occupational burdened groups (amalgam-burners and children working with mercury; tables 2 and 3 in appendix 1). This gender difference could not be controlled in field under the given conditions.

Statistical analysis of mercury levels in urine, blood and hair

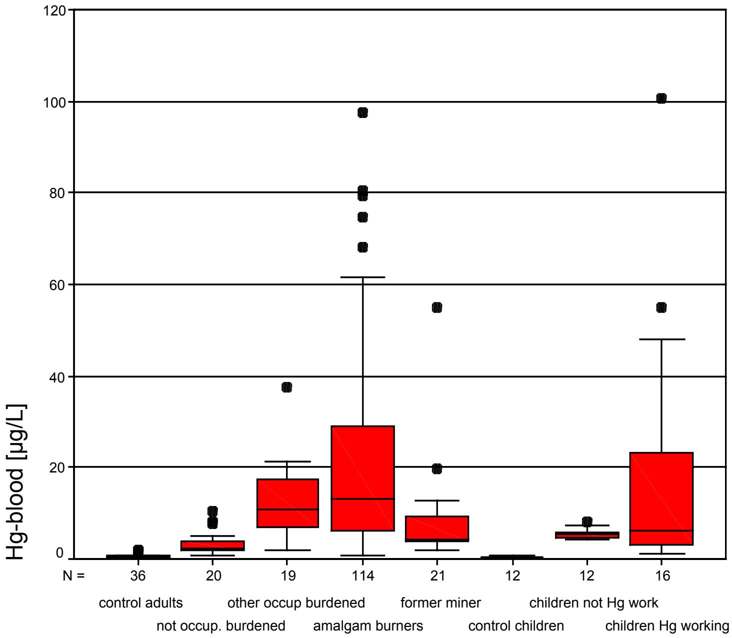


Figure 5 - Total mercury concentration in blood samples.

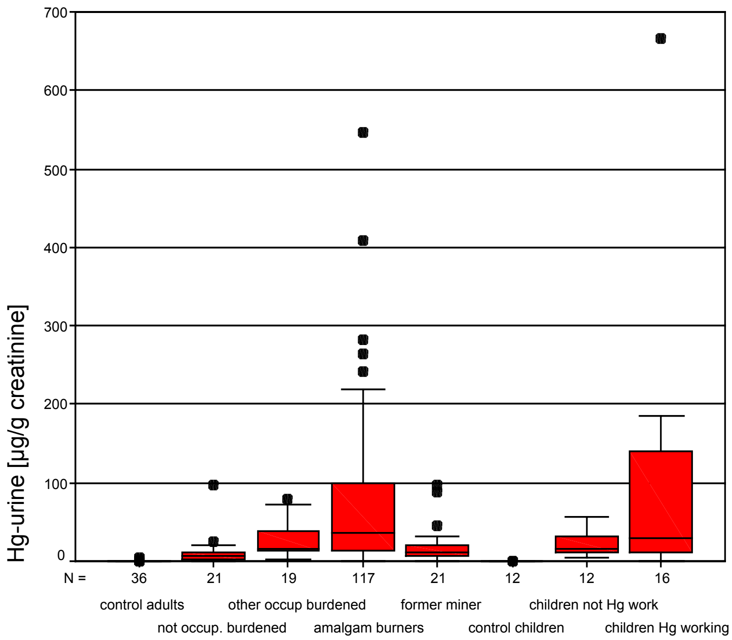


Figure 6 - Total mercury concentration in urine samples.

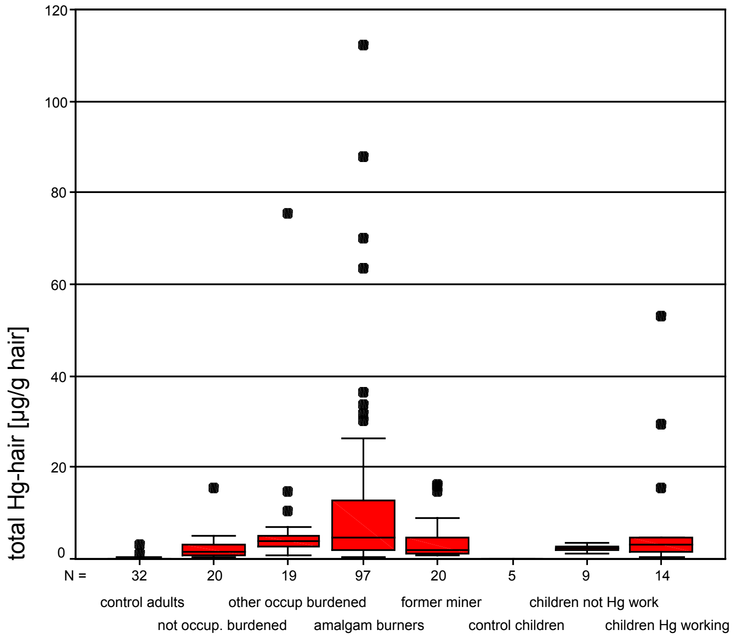


Figure 7 - Total mercury concentration in hair samples.

Statistical testing of the different Hg-burdened subgroups versus mercury concentration in blood, urine and hair show significant results (tables 2 and 3 in appendix 1, fig. 5 to 7).

As expected, the highest mercury concentration is found in the human bio-monitors of the highly occupational burdened amalgam-burners and the children working with mercury, followed by other occupational burdened workers of the Kadoma area. The mercury levels of the not occupational burdened inhabitants of Kadoma are obviously lower than of the occupational burdened groups, but significantly higher than in the control area. Retired workers, still living in the mining area, show still high mercury levels in the bio-monitors.

The mercury concentration in blood, urine or hair of the control group from Chikwaka is in the same order of magnitude than in non burdened populations from Western Europe (see table 1). This is in contrast to the mercury levels of the control population in the Philippines, investigated by the University of Munich on an UNIDO mission in 1999 and 2000 in the Mt. Diwata area (Drasch, 2001 ; Böse-O'Reilly, 2003). There an additional high nutritional burden with methyl mercury from fish and seafood was found. The reversal conclusion is that almost all mercury in the burdened groups of the Kadoma area in Zimbabwe derived from gold mining activities (elemental or metallic mercury).

Figures 8 and 9 show the proportion of spreading of organic and inorganic mercury in hair. The percentage of organic mercury in the hair samples of the control group is obviously higher than in the hair samples of the volunteers living in mercury burdened areas. This means that most of the (low) mercury burden in the control area derives from nutritional methyl mercury.

The additional occupational burden with mercury vapour raises the percentage of inorganic mercury in hair from median values of approximately 30% in the control group to 75 - 80% in the burdened groups.

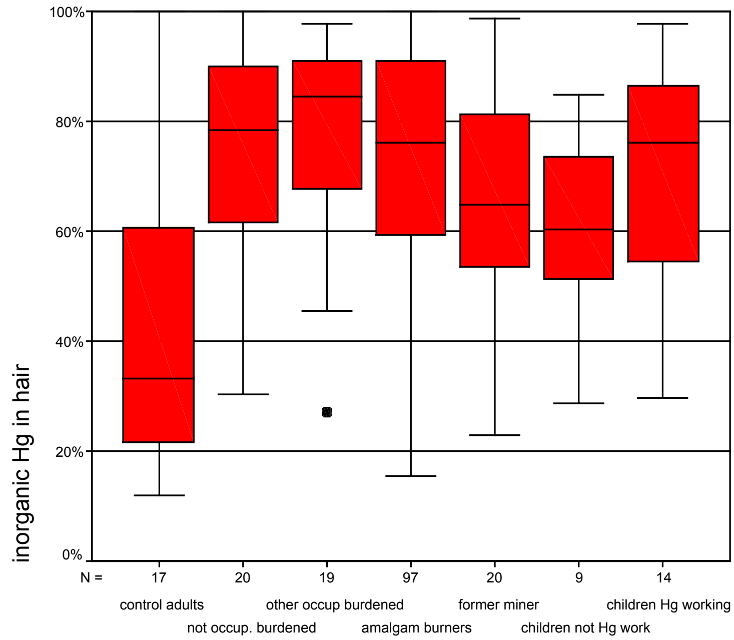


Figure 8 - Percentage of inorganic mercury in hair samples.

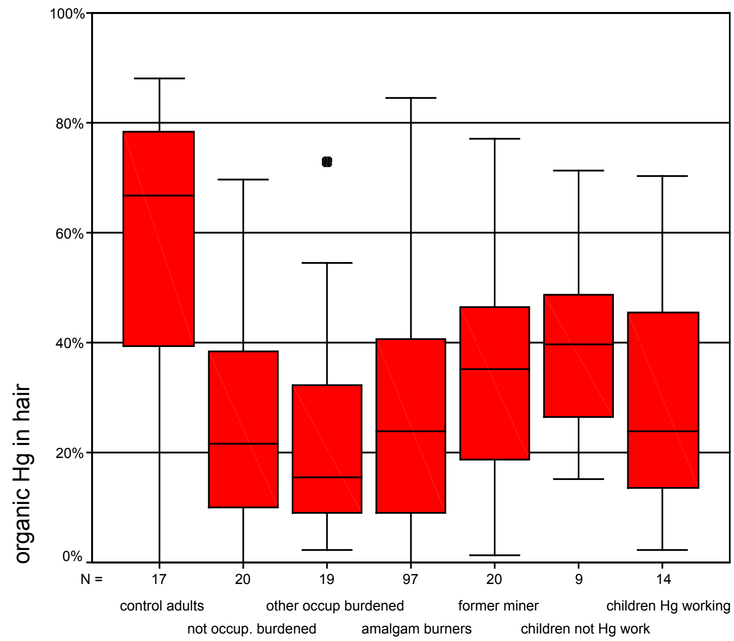


Figure 9 - Percentage of organic bound mercury in hair samples.

3.2.5. Mercury Levels compared to Toxicological Threshold Limits

In the international literature only a few threshold limits for mercury in bio-monitors are recommended. Especially for the exposure to metallic mercury vapour there is not much data on threshold values available. This metallic mercury vapour is the main exposure in small scale gold mining areas (Drasch, 2004a). Most studies in this field are performed in populations with an exclusively methyl-mercury burden from fish or sea-food, such as the former data from Minamata, or the more recent data from the Seychelles (Davidson, 1998), the Faeroes Islands (Grandjean, 1997) or even from the Amazon (Grandjean, 1999). To estimate the toxicological relevance of the burden with predominantly mercury vapour of the investigated population from Kadoma, the following threshold limits were used:

a) German human-bio-monitoring (HBM) values for mercury

In 1999 the German Environmental Agency (“Umweltbundesamt”) published recommendations for human-bio-monitoring-values (HBM) for mercury (“Kommission Human-Bio-monitoring” 1999).

The HBM I was set to be a “**check value**”, this means an elevated mercury concentration in blood or urine, above which the source of the Hg-burden should be searched and, as far as possible, eliminated. But even by an exceeding of this HBM I the authors claimed that a health risk is not to be expected.

In contrast to this, the (higher) HBM II value is an “**intervention value**”. This means, at blood or urine levels above HBM II, especially over a longer period of time, adverse health effects cannot be excluded. Therefore interventions are necessary. On the one hand the source should be found and reduced urgently. On the other hand a medical check for possible symptoms should be performed. For hair, comparable values are not established, but the HBM II in blood is directly derived from the assumption of a stable ratio of mercury in blood and hair (1:300) and the result of the Seychelles study, where adverse effects could be seen at a mercury concentration in hair above 5 µg/g (Davidson 1998). Therefore this value was taken in this project as an analogous value for HBM II for the toxicological evaluation of mercury concentration determined in hair. It must be kept in mind, that this threshold limit in hair was established in a population burdened with *methyl-mercury* from marine food and not with mercury vapour, as is predominant in the mining areas around Kadoma in Zimbabwe, investigated in this project.

	Hg-blood (µg/l)	Hg-urine (µg/l)	Hg-urine (µg/g creatinine)	Hg-hair (µg/g)
HBM I	5	7	5	
HBM II	15	25	20	5 (in analogy)
US EPA bench mark				1
WHO		50		7
BAT for metallic and inorganic Hg	25	100		
BAT for organic Hg	100			
BEI (Biological exposure index)	15 (after working)		35 (before working)	

Table 11 - Toxicologically established threshold limits for mercury in blood, urine and hair (HBM = Human Bio-Monitoring; BAT = "Biologischer Arbeitsstoff-Toleranzwert" (biological work-exposure tolerance limit); BEI = Biological Exposure Indices).

In 1991 the WHO expert group stated that mercury in urine is the best indicator for a burden with inorganic mercury. The maximum acceptable concentration of mercury in urine was set to 50 µg/l (WHO, 1991). A distinct threshold for mercury in blood was not given. Mercury in hair is widely accepted as best indicator for the assessment of contamination in populations exposed to methyl-mercury (de Lacerda 1998). For this, a maximum allowable concentration of 7.0 µg/g hair was set by the FAO/WHO. In 1997 the US EPA calculated the "benchmark limit" for total Hg in hair to 1 µg/g. This benchmark was derived from a burden with methyl-mercury from seafood and not with mercury vapour. US EPA has set a threshold limit for mercury vapour in the ambient air, but not in bio-monitors (US EPA, 1997).

All these limits and others, former published, are respected at the most recent recommendation from the German Environmental Agency 1999, as cited above. The high numbers of recently published investigations on mercury burdened populations from gold mining areas such as South-America or by sea food as on the Faeroes Islands or the Seychelles require a continuous re-evaluation of toxicologically defined threshold limits. Therefore the international latest recommendation from the German Environmental Agency was taken for further comparison. This was committed with UNIDO for the total global programme, to obtain comparable results (Veiga, 2003).

b) Occupational threshold limits (BAT, BEI)

Other toxicologically founded limits are occupational threshold limits. Such limits are established for mercury e.g. in the USA (biological exposure indices BEIs of the American Conference of Governmental Industrial Hygienists) or Germany (BAT value, Deutsche Forschungsgemeinschaft (German Scientific Community) 1999).

Very recently the BAT-values for Hg have been cancelled for revision. But for a better comparison the BAT-values for metallic and inorganic mercury are still taken for this project for a better comparison to the other health assessment studies in Indonesia and Tanzania, performed within the "Global Mercury Project" of UNIDO by the Institute of Forensic Medicine in Munich.

Per definition, these BAT-values are exclusively valid for healthy adult workers under occupational medical control. The occupational burden must be stopped, if this threshold is exceeded. These occupational threshold limits are not valid for the total population, especially not for risk groups like children, pregnant women, and older or ill persons. Nevertheless, the BAT-values were also taken for a further classifying of the highest results found in this project. BAT-values for mercury are established only for blood and urine, but not for hair.

Table 11 gives an overview of the HBM-, BAT- and BEI-values. In the tables 2 and 3 in appendix 1, the percentage of the exceeding of the HBM II- and BAT-limits in the various population groups of our project is summarised.

As shown in the next chapters the biological threshold limits should not be overestimated for the diagnosis. Therefore the question, which of the limits is best for evaluating the results of this project is only of secondary interest.

3.2.6. Reducing of redundant data for statistical analysis

From the very large data volume (see appendix 2), collected on field by the medical team, the most relevant facts and test results were selected by pre-investigations (see tables 2 and 3 in appendix 1). Many test results were primarily scored (for instance: no, moderate, strong, extreme). For the anamnestic and clinical data these results could be reduced to a yes/no decision, which enables a statistical analysis and facilitates the readability of tables 2 and 3 appendix 1 markedly without a relevant loss of information. The neuro-psychological data (memory, match-box, Frostig, pencil tapping) was reduced according to a box-plot procedure. With this procedure the results of the participants could be divided into three categories: The best performing 25% of participants of each group were given a score of 0 points, the worst performing 25% of participants were given a score of 2 points and the middle group of participants received a score of 1 point. In the tables 2 and 3, appendix 1 the results of the statistical analysis of the transformed anamnestic, clinical and neurological data versus the different Hg-burdened subgroups, is shown. The significance of the differences was calculated with Chi-square test. Grey marked fields contain results, differing from the control group on a statistical significant level ($p < 0.05$, one-tailed).

In the figures 10 and 11 two anamnestic criteria, “metallic taste” and “excessive salivation” (only children), are displayed. The figures 12 to 14 show three objective criteria (bluish discoloration of gingiva, ataxia of gait, dysdiadochokinesia), typical for a chronic mercury burden. It is striking that in comparison to the control group, many test results even of the non occupationally Hg-burdened population, living in the mining areas are considerably worse. The negative results increase even more in the subgroup of the amalgam burners, which are directly exposed to mercury vapour. The proportion of children, showing typical symptoms, is elevated in the mining area, too.

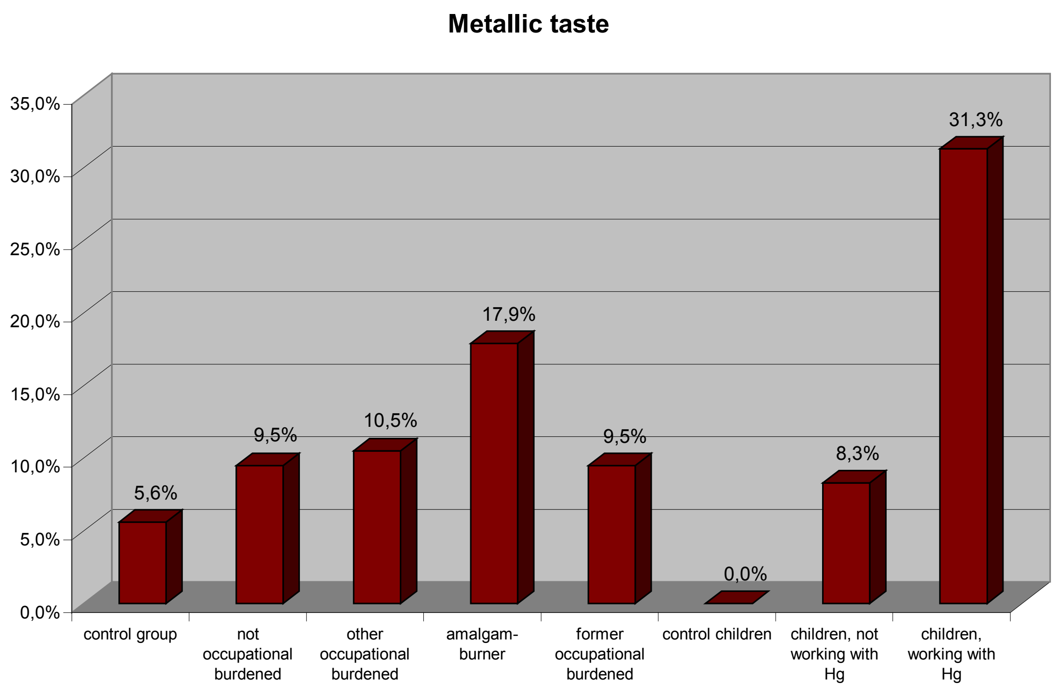


Figure 10 - Frequency of the anamnestic parameter “metallic taste”.

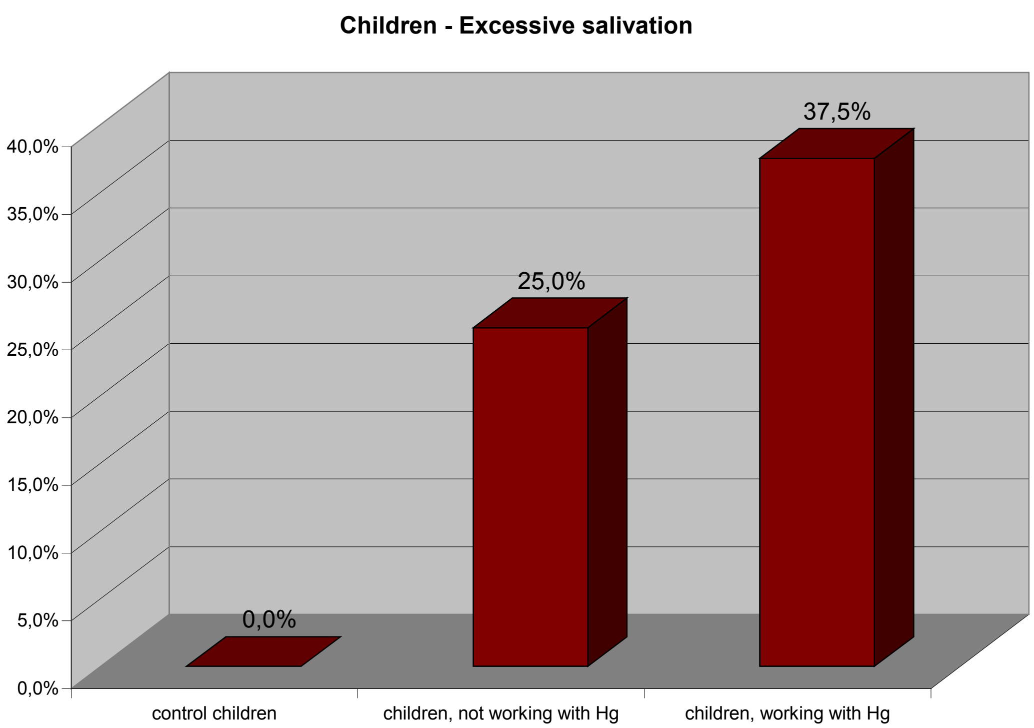


Figure 11 - Children; frequency of the anamnestic parameter “excessive salivation”.

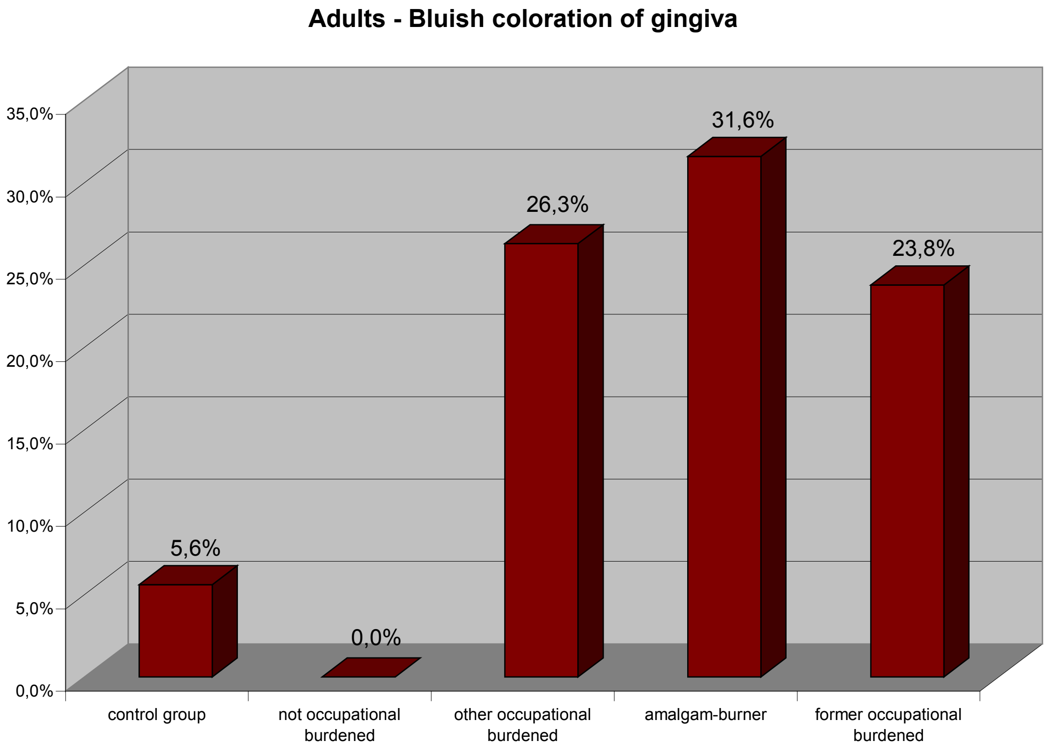


Figure 12 - Adults; frequency of the anamnestic parameter "bluish coloration of gingiva".

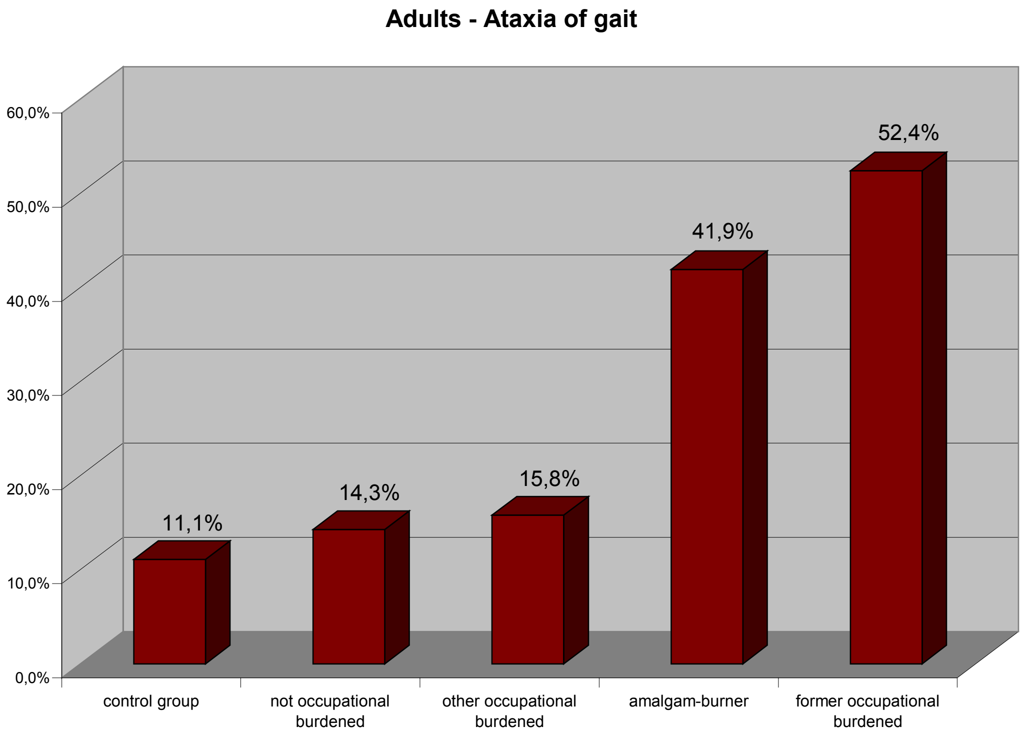


Figure 13 - Adults; frequency of the anamnestic parameter "ataxia of gait".

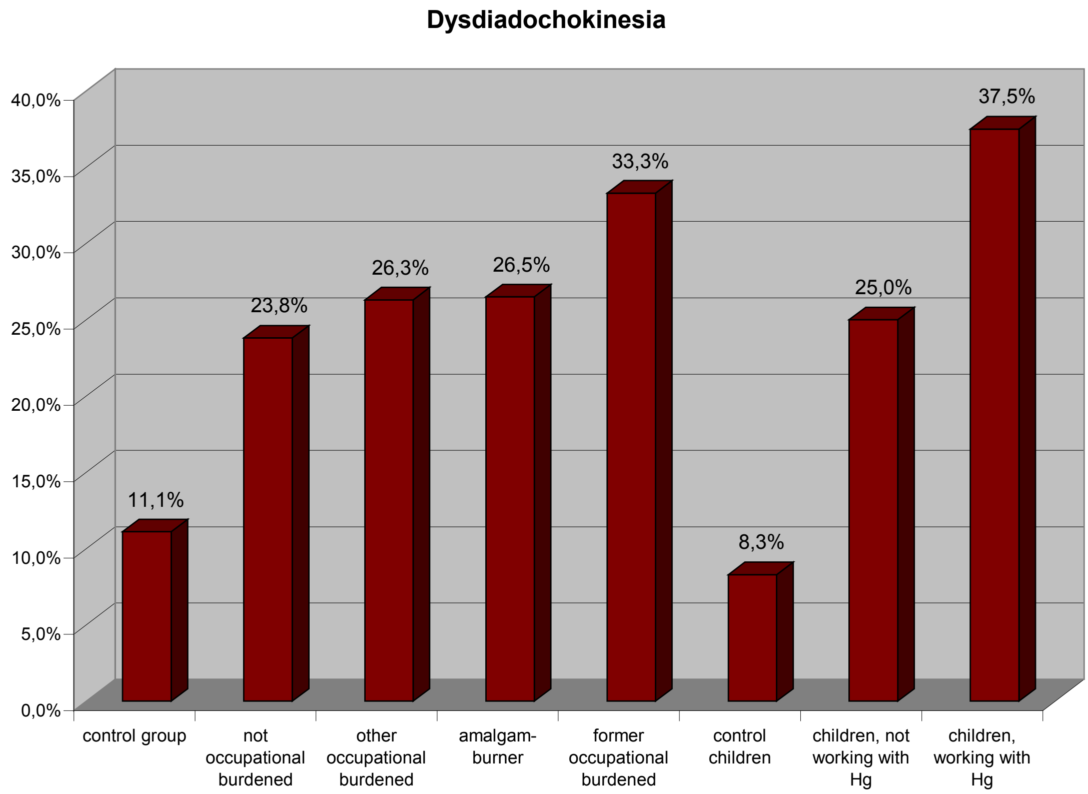


Figure 14 - Frequency of the anamnestic parameter "dysdiadochokinesia".

3.2.7. Scoring of medical results

The evaluation so far showed statistically significant medical test results versus the different Hg-burdened subgroups. These significant medical test results are typical clinical signs of chronic mercury intoxication, such as tremor, metallic taste, excessive salivation, sleeping problems and worsened health problems (Drasch, 1994; Kommission Human-Bio-monitoring, 1999; Wilhelm, 2000; Drasch, 2004a). Furthermore ataxia, dysdiadochokinesia, pathological reflexes, coordination problems and concentration problems are clinical signs of a damaged central and peripheral nervous system. For a further evaluation of these medical results a medical score was established. The factors, included in this medical score and the score-points per factor are shown in table 2. This score was developed from the results of a mercury burdened group in a gold mining area in the Philippines (Drasch, 2001) and adopted by UNIDO, to get comparable results (Veiga, 2003). The higher the total medical score is, the more typical signs of a chronic mercury intoxication were found.

In principle, alcohol abuse may bias the results. Comparing the heavy drinkers among the amalgam-burners with the other amalgam-burners, there is almost no difference regarding the Hg-levels in the bio-monitors (fig. 15 and 16). Statistically no significant differences were found (Mann-Whitney-U-Test). The implication would be similar for the anamnestic and clinical data of the heavy drinkers in comparison to the other amalgam-burners. The statistical calculations showed no significant differences (chi-square-test), too, with one exception: The heavy drinkers reported more frequently memory problems, a possible bias by alcohol. Beside this, the factor alcohol do not bias the results.

Statistic testing of the different Hg-burdened subgroups versus the total medical score sum showed significant results (tables 2 and 3 in appendix 1 and figure 17). The mean scores of the community of amalgam-burners and children, working with mercury are higher (= worse) than the control groups. But in comparison to the results of the other health assessment studies, performed by the Institute of Forensic Medicine, Munich, within the Global Mercury Project of UNIDO in Indonesia and Tanzania, in Zimbabwe the difference between the control-group and the Hg-burdened groups was not so striking. Finding the possible reasons for this may be subject to further comparisons.

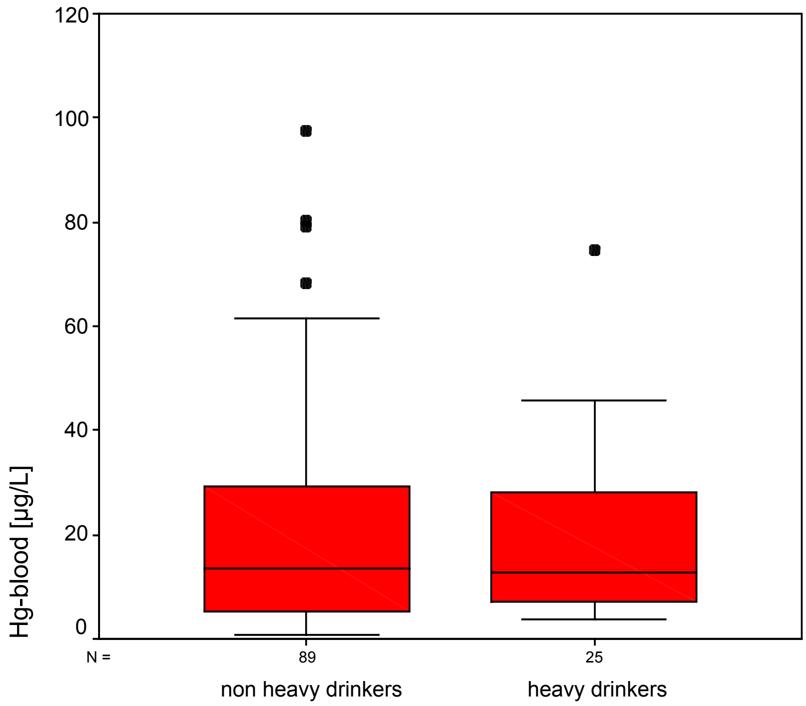


Figure 15 - Hg-concentration in blood; comparison of the heavy drinkers with the non heavy drinkers among the group of amalgam-burners.

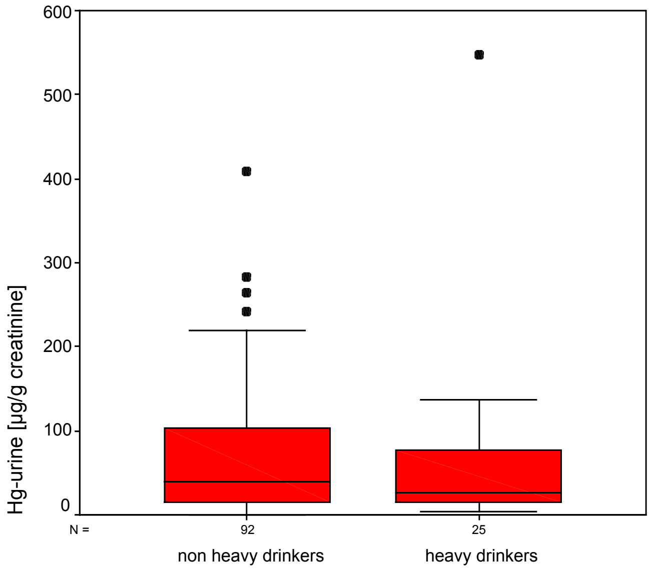


Figure 16 - Hg-concentration in urine; comparison of the heavy drinkers with the non heavy drinkers among the group of amalgam-burners.

Test	Score Points
Anamnestic data	
Metallic taste	0/1
Excessive salivation	0/1
Tremor at work	0/1
Sleeping problems at night	0/1
Health problems worsened since Hg exposed	0/1
Clinical data	
Bluish coloration of gingiva	0/1
Ataxia of gait	0/1
Finger to nose tremor	0/1
Dysdiadochokinesia	0/1
Heel to knee ataxia	0/1
Heel to knee tremor	0/1
Mento-labial-reflex	0/1
Proteinuria	0/1
Neuro-psychological tests	
Memory test	0/1/2
Matchbox test	0/1/2
Frostig test	0/1/2
Pencil tapping test	0/1/2
Maximum	21

Table 12 - Anamnestic, clinical, neurological and neuro-psychological scoring scale.

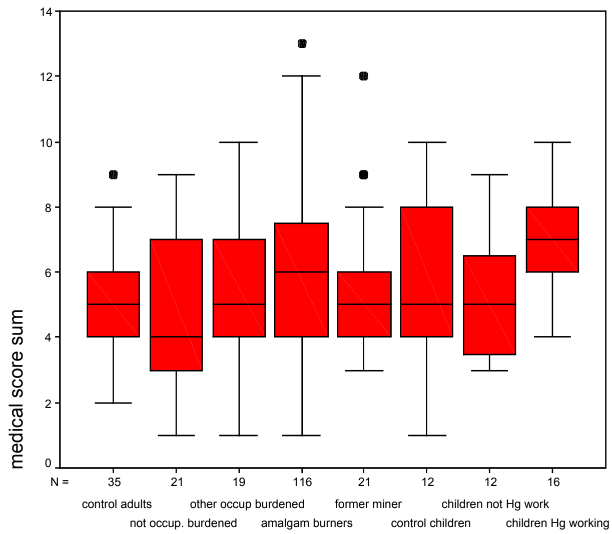


Figure 17 - Medical score sum of the different subgroups.

3.2.8. Statistical analysis of mercury levels versus clinical data

Correlation tests between mercury concentrations in the bio-monitors and clinical data were performed on the subgroup of the amalgam-burners only. These group was selected, because it is the highest burden group with the highest mercury concentration in the bio-monitors and the highest frequency of health disturbances, characteristic for a mercury burden. Performing the same analysis including all investigated persons, or all volunteers from the gold mining areas, will just “water down” the results.

As can be seen from tables 13 to 17, just a few of the medical data correlate significantly to the Hg concentration in the bio-monitors (Chi-square-test, Spearman rank correlation).

Anamnestic data	**Hg-Urine (µg/g crea.)**	**Hg-Blood**	**total Hg-Hair**	**MeHg-Hair**
Male/female	+	+	+	+
Age	-	-	-	-
Alcohol consumption	-	-	-	-
Metallic taste	-	-	-	-
Salivation	-	-	-	-
Tremor daily	-	-	-	-
Tremor at work	-	-	-	-
Sleeping problems	-	-	-	-
Health problems worsened since Hg exposed	-	-	-	-
Lack of appetite	+	-	+	-
Sleep disturbances	-	-	-	-
Easily tired	-	-	-	-
Loss of weight	+	-	+	+

Table 13 - Significant correlations between anamnestic data and mercury concentration in bio-monitors (group of amalgam-burners only, n = 116).+ = $p < 0.05$.

Anamnestic data	Hg-Urine (µg/g crea.)	Hg-Blood	Total Hg-Hair	MeHg-Hair
Rest more	-	-	-	-
Feel sleepy	-	-	+	-
Problems to start things	+	+	+	+
Lack of energy	-	-	-	-
Less strength	-	-	-	-
Weak	-	-	-	-
Problems with concentration	-	-	-	-
Problems to think clear	-	-	-	-
Word finding problems	-	-	-	-
Eyestrain	-	-	-	-
Memory problems	-	-	-	-
Feel nervous	-	-	-	-
Feel sad	-	-	-	-
Headache	-	-	-	-
Nausea	-	-	-	-
Numbness	-	-	-	-

Table 14 - Significant correlations between anamnestic data and mercury concentration in bio-monitors (group of amalgam-burners only, n = 116).+ = p < 0.05.

Clinical Data	Hg-Urine (µg/g crea.)	Hg-Blood	Total Hg-Hair	MeHg-Hair
Bluish coloration of gingiva	-	-	-	-
Gingivitis	-	-	-	-
Ataxia of gait	-	-	-	-
Finger to nose tremor	-	-	-	-
Finger to nose dysmetria	-	-	-	-
Dysdiadocho-kinesia	-	-	-	-
Tremor of eyelid	-	-	-	-
Field of vision	+	-	+	+
Heel to knee ataxia	-	-	-	-
Heel to knee tremor	-	-	-	-
PSR pathologic	-	-	-	-
BSR pathologic	-	-	-	+
ASR pathologic	-	-	-	-
Babinski reflex positive	-	-	-	-
Mento-labial reflex positive	-	-	-	-
Bradykinesia	-	-	-	-
Hypomimia	-	-	-	-
Proteinuria	-	-	-	-

Table 15 - Significant correlations between clinical data and mercury concentration in bio-monitors (group of amalgam-burners only, n = 116) .+ = p < 0.05.

Neuro-psychological test	Hg-Urine (µg/g crea.)	Hg-Blood	Total Hg-Hair	MeHg-Hair
Memory test	-	+	-	-
Matchbox test	-	-	-	-
Frostig test	-	-	-	-
Pencil tapping test	-	-	-	-

Table 16 - Significant correlations between neuro-psychological test classes and mercury concentration in bio-monitors (group of amalgam-burners only, n = 116). + = $p < 0.05$.

Medical Scores	Hg-Urine (µg/g crea.)	Hg-Blood	Total Hg-Hair	MeHg-Hair
Anamnestic score	-	-	-	-
Clinical score	-	-	-	-
Neuro-psychological test score	-	+	-	-
Medical score sum	-	+	-	-

Table 17 - Significant correlations between medical scores and mercury concentration in bio-monitors (group of amalgam-burners only, n = 116). + = $p < 0.05$.

3.3. DISCUSSION OF THE STATISTICAL ANALYSIS

The relatively poor correlation of classic clinical signs of mercury intoxication to the mercury concentrations in the bio-monitors (blood, urine, hair, MeHg hair) of the amalgam-burners may be explained by factors like:

- The mercury concentration in the target tissues, especially the brain, correlates to the mercury concentration in bio-monitors like urine, blood or hair. This correlation is statistically significant and good enough to mirror different burden of different groups (here e.g. workers, non-workers and controls). But the *inter-individual differences* are so large that it is rather pointless to conclude the heavy metal burden in the target tissue of an individual from the concentration in the bio-monitors (Drasch, 1997).
- Most of the amalgam-burners are *chronically burdened* by mercury and not only acute. This means that a reversible or even irreversible damage of the central nervous system may be set months or years before the actual determination of the mercury concentration in the bio-monitors under a quite different burden. The medical score sum distinguishes between the control group and the amalgam-burners.

3.4. DECISION FOR THE DIAGNOSIS OF A CHRONIC MERCURY INTOXICATION

For the different Hg burdened groups (< HBM I; HBM I - HBM II; HBM II - BAT; > BAT) *no* striking differences in the results of the medical and neuro-psychological tests could be seen (for possible reasons, see above). Therefore at least a *chronic* mercury intoxication could not be diagnosed on the basis of the blood, urine and/or hair concentration alone, to what values ever the threshold limits are set (see above). An intoxication is defined by the presence of the toxin in the body and typical adverse health effects. Deriving from this interpretation we have tried to find a balanced result by the combination of mercury concentration in blood, urine and hair and the negative health effects, as summarised in the medical score sum, as described above in detail (Drasch, 2001). The medical test scores were divided in three groups, according to the quartiles (0-25%, 25-75%, 75-100%). Table 18 shows this combination. This definition of mercury intoxication was committed with UNIDO, to get comparable results in the different sites in the global project (Veiga, 2003).

		Medical Score Sum		
		0 – 4	5 – 9	10 - 21
Hg in all bio-monitors	< HBM I	–	–	–
Hg at least in one bio-monitor	> HBM I	–	–	+
	> HBM II	–	+	+
	> BAT	+	+	+

Table 18 - Decision for the diagnosis “chronic mercury intoxication”.

In principle this means, that the higher the mercury concentration in at least one of the bio-monitors was, the lower the number of adverse effects for a positive diagnosis of a mercury intoxication must be and vice versa.

In the present study no case must be classified to be intoxicated with just moderately elevated mercury levels (i.e. between HBM I and HBM II) and a medical test score sum in the upper quartile region (score sum 10-21).

24 cases out of 61 with mercury concentrations above the BAT limit showed low medical sum scores between 0 and 4 (this means without or with just a few clinical signs). In these cases the exceed of the occupational threshold limit BAT was predominantly responsible for the classification of an intoxication.

3.5. PREVALENCE OF THE DIAGNOSIS “MERCURY INTOXICATION”

Group	Total number	Number of mercury intoxicated cases	% cases, mercury intoxicated
Control adults	36	0	0%
Not occupational burdened	21	1	4.8%
Other occupational burdened	19	12	63.2%
Amalgam-burners	117	82	70.1%
Former occupational burdened	21	5	23.8%
Control children	12	0	0%
Children not working with Hg	12	4	33.3%
Children working with Hg	16	11	68.8%

Table 19 - Frequency of mercury intoxication.

By this classification the results shown in the table 19 and the figure 18 were obtained. As expected, no volunteer from the control area of Chikwaka has been found to be mercury intoxicated.

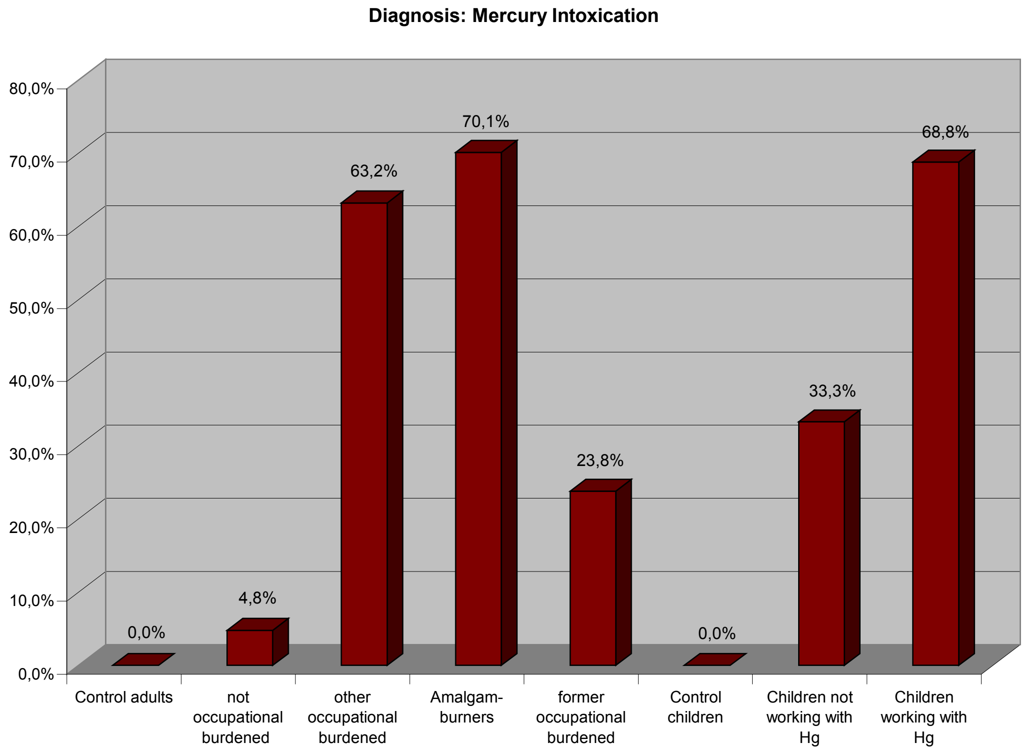


Figure 18 - Frequency of the diagnosis "mercury intoxication".

In this study, 70.1% of the amalgam-burners were diagnosed to be mercury intoxicated. This percentage is markedly higher than we have found recently by comparable investigations within the Global Mercury Project of UNIDO with the same protocol in other small scale gold mining areas of Tanzania (25.3%), Sulawesi, Indonesia (54.1%) and Kalimantan, Indonesia (59.4%).

Some volunteers of the not directly mercury burdened population in Kadoma, Zimbabwe, are considered to be mercury intoxicated, too (adults: 4.8%; children: 33.3%, here: keep in mind the limited number of 12 cases). The frequency of intoxication in the group of children working with mercury (68.8%) is as high as of the adults, occupationally mercury burdened (But again keep in mind the relatively low number of 16 children working with mercury).

3.6. COMPARISON OF VOLUNTEERS FROM DIFFERENT MINES

	Mining areas							
	Tix Mine	Brompton Mine	Amberose Mine	Glasgow Mine	Summir Mine	Lilly Mine	Jani Mine	King Chim Mine
	occupation and area	occupation and area	occupation and area	occupatio n and area	occupation and area	occupation and area	occupation and area	occupation and area
	Anzahl	Anzahl	Anzahl	Anzahl	Anzahl	Anzahl	Anzahl	Anzahl
not occup. burdened	8		8	1		3		
other occup burdened	15		4					
amalgam burners	43	1	19	18	7	4	21	2
former miner	5		10		1	2	2	
children not Hg working	8		4					
children Hg working	7		6		2		1	
Gesamt	86	1	51	19	10	9	24	2

Table 20 - Distribution of the formed subgroups in the different mining areas.

The volunteers in the Kadoma area derived from one region. But within this region there is mining in different local mining areas. In these different areas different techniques for the gold extraction process were used. Therefore, a further differentiation seems to be of interest.

As shown in table 20, the frequency of the subgroups in the different mining areas differs widely. Moreover, the number of cases is partially very low. For this reason the amalgam-burners, presenting the largest subgroup, were selected for a comparison of the different mining areas.

The figures 19 and 20 reveal the large heterogeneity of the distribution of the amalgam burners from the different mining areas by age and gender. The number of volunteers differ widely from mine to mine, too. These differences could not be controlled in field under the given conditions. Therefore, the following statistical results should just taken as tendencies and interpreted with care.

The Brompton mine and King Chim mine must be excluded from the comparison, because the number of volunteers from these areas was too low (1 and 2, respectively). A sufficient number of amalgam burners could be achieved for Tix mine, Amberose mine, Glasgow mine, Summit mine, Lilly mine and Jani mine.

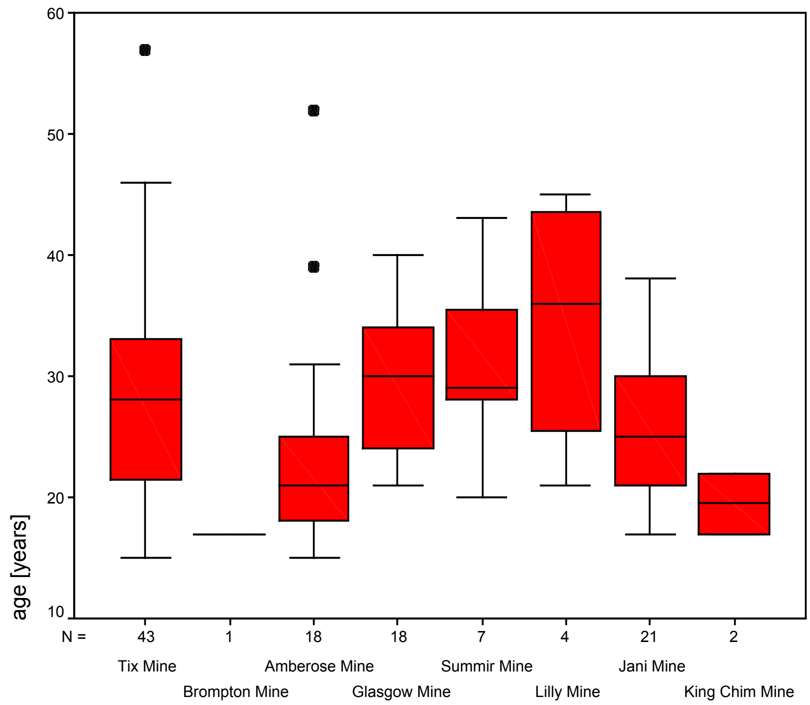


Figure 19 - Distribution of age versus different mining areas; amalgam-burners only.

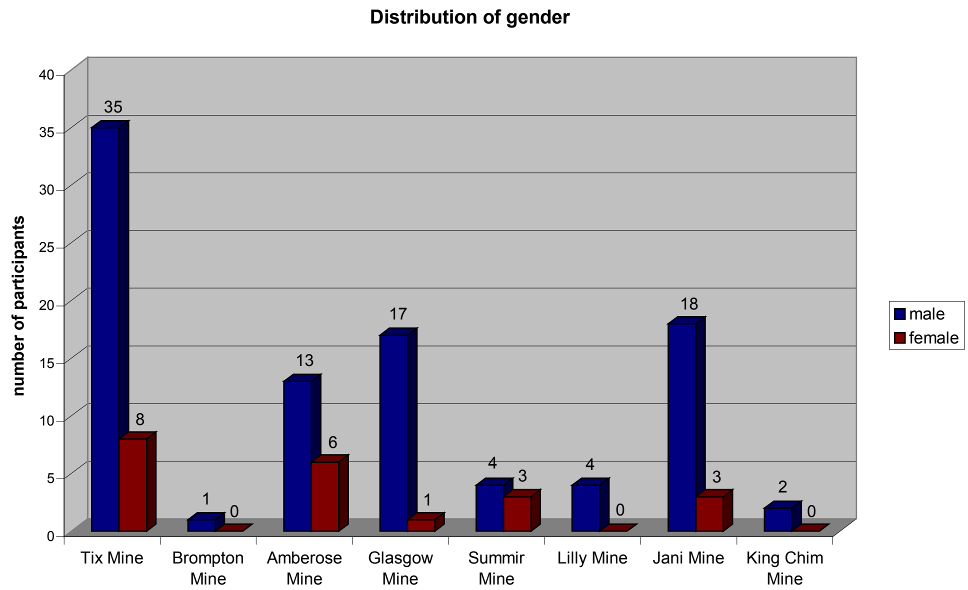


Figure 20 - Distribution of gender versus different mining areas; amalgam-burners only.

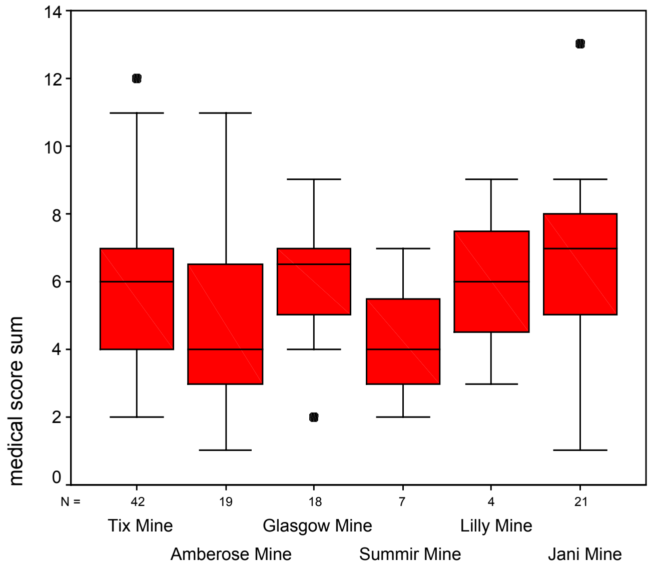


Figure 21 - Medical score sum versus different mining areas; amalgam-burners only.

Regarding the median values, the medical score sum is low (good) for Amber Rose and Summit mine, and higher (worse) for the other mining areas (see Fig. 21).

The mercury concentration in the three biomonitors urine, hair and blood of the amalgam burners from Jani mine is markedly lower than in the specimen taken from amalgam burners in other mining areas (see fig. 22 to 24). At a further ranking, the low case number of the participants from Lilly mine (4) should be kept in mind.

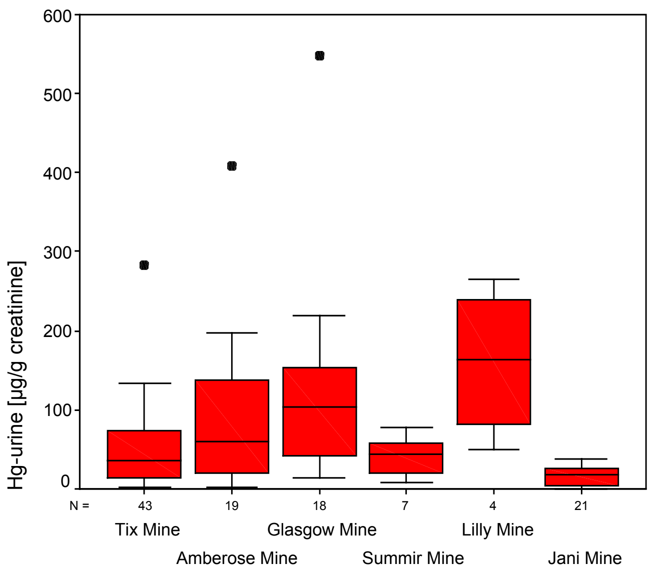


Figure 22 - Hg-concentration in urine versus different mining areas; amalgam-burners only.

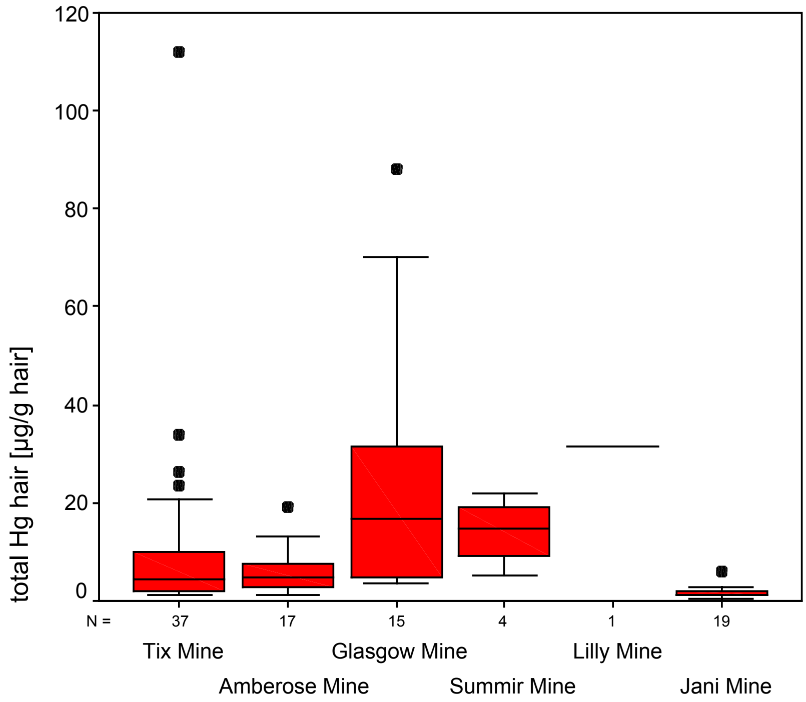


Figure 23 - Concentration of total Hg in hair versus different mining areas; amalgam-burner only.

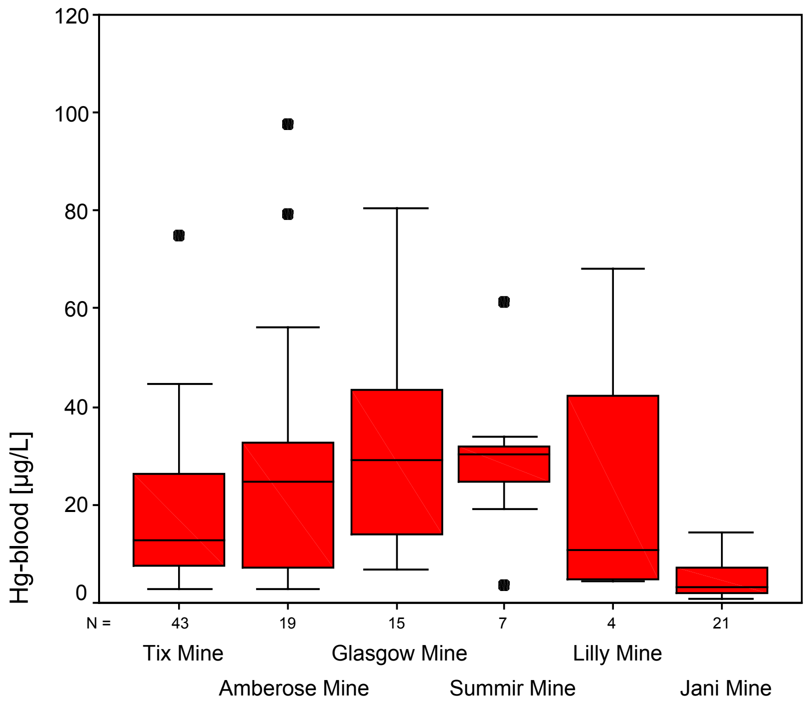


Figure 24 - Hg-concentration in blood versus different mining areas; amalgam-burner only.

The anamnestic, clinical, neurological and neuro-psychological data of the amalgam burners from the different mining areas, relevant for the medical score sum are listed in table 4, appendix 1. Some examples of the comparison of clinical data are shown in the figures 25 to 27.

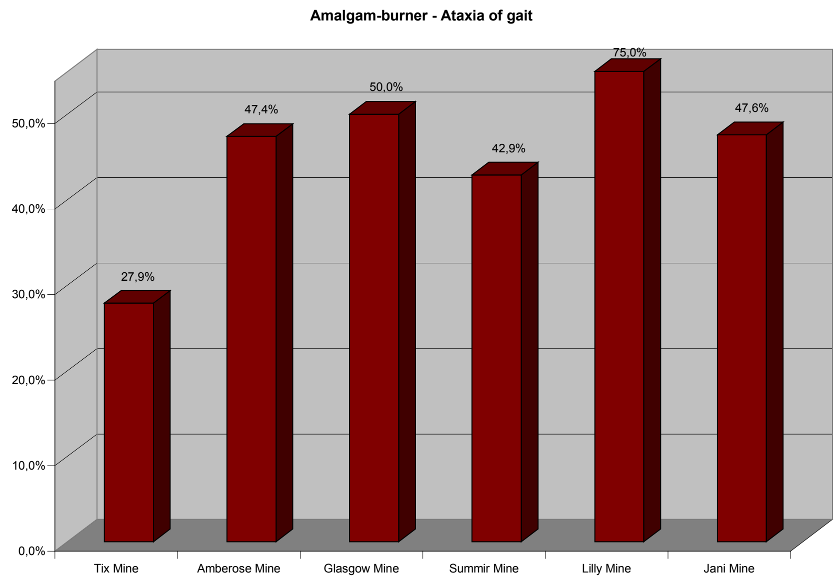


Figure 25 - Frequency of the clinical parameter “ataxia of gait”; amalgam-burner only.

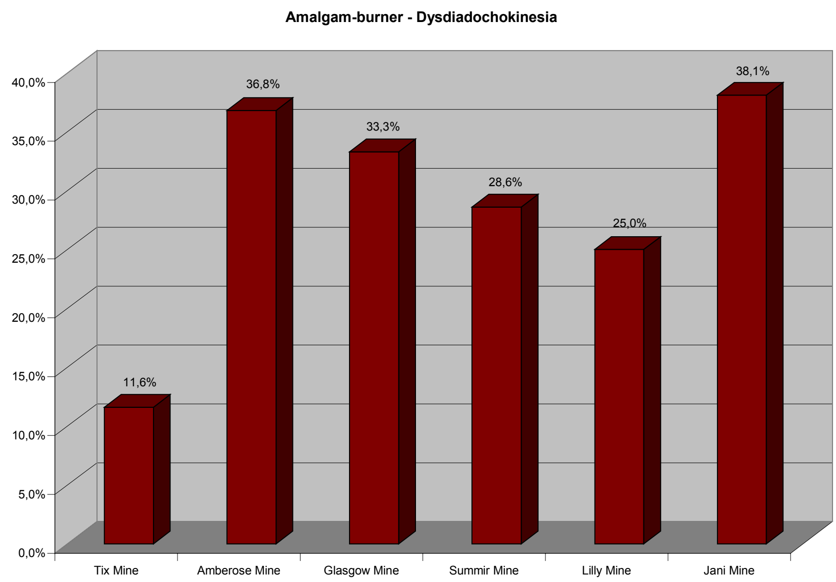


Figure 26 - Frequency of the clinical parameter “dysdiadochokinesia”; amalgam-burner only.

The rate of mercury intoxication for amalgam-burners is the highest in Lilly mine (but remind the low number of just 4 cases!). Next are Glasgow and Summit mine. The lowest incidence was found in Jani mine (see figure 27).

Regarding the selected parameters (clinical data, mercury-levels in biomonitors, mercury-intoxication) just tendencies could be reflected.

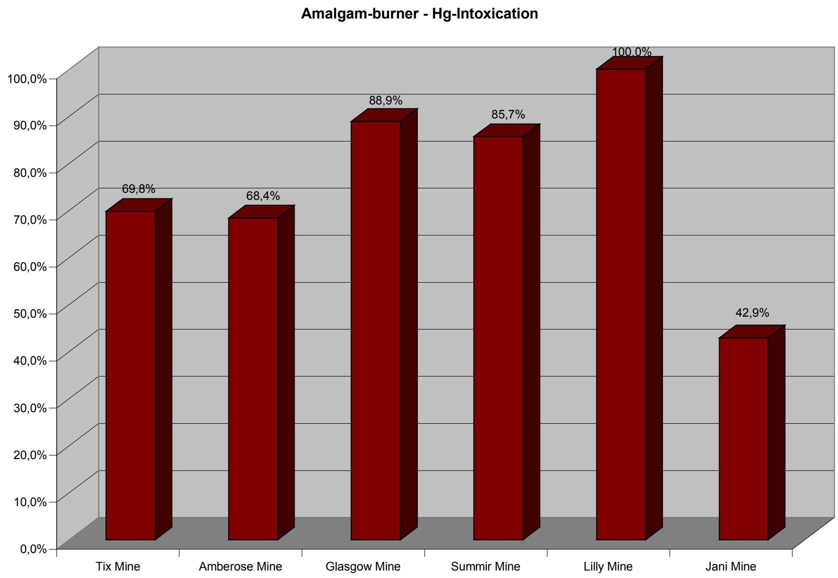


Figure 27 - Frequency of the diagnosis of a mercury intoxication; amalgam-burner only.

To summarize: In Glasgow mine and Summit mine almost all (approximatelx 9 of 10) amalgam burners are mercury intoxicated. A comparable percentage (85,4%) of intoxicated amalgam-burners were diagnosed by us in 1999 in the small scale gold mining region of Mt. Diwata in the Philippines, using the same protocol (Drasch, 2001). In the Tix mine or Amberose mine approximately 70% of the amalgam burners were intoxicated. The lowest incidence of mercury intoxications was found for the amalgam burners in Jani mine: “just” less more than 40%. The burden in the Lilly mine, King Chim mine and Brompton mine cannot be assessed finally due to the low case numbers of 4, 2 and 1 volunteer, respectively. Nevertheless it is remarkable, that all 4 volunteers from Lilly mine must be classified as mercury intoxicated.

3.7. INFLUENCE ON NURSED BABIES

One major problem of mercury is a known adverse effect on the growing foetus and baby due to a high maternal burden and a cross of mercury through the placenta or to the breast-milk. High numbers of miscarriages, stillbirths and birth defects have been reported as consequence of the mass intoxication with mercury in Minamata, Japan, 1956 or the Iraq, 1972/73 (Drasch, 2004a). This project in Zimbabwe was not designed to detect possible adverse effects on the foetus, but as a side result some data on mercury in breast-milk samples were obtained.

10 samples of mature breast-milk were collected (1 in the control area, Chikwaka and 9 in the mining areas) and analysed for total mercury. In table 21 the cases are shown individually in decreasing order of the Hg concentration in the breast-milk samples. In the control-sample from Chikwaka the Hg-concentration is below the detection limit of 1 µg Hg/L breast milk; the range of the breast milk samples from mothers living in the mining areas is up to 9.70 µg Hg/L. For comparison: In some recent studies from Germany samples from mature breast-milk maximal mercury concentrations below 2 µg/L have been found (Drasch, 1998).

The highest mercury concentration, determined in this project was 9.7 µg/L. The mother had been identified as "intoxicated", despite a relatively moderate mercury concentration in her human bio-monitors. A full nursing of a baby with approximately 850 ml breast milk per day with this mercury concentration of 9.70 µg/L, results in a daily uptake of approximately 8 µg inorganic mercury. US EPA has calculated the so-called "Reference Dose" for inorganic mercury to 0.3 µg/ kg body weight and day (US EPA, 1997). For a 6 kg baby this means a maximum daily uptake of 1.8 µg inorganic mercury. The real uptake of this baby was approximately 4 times higher. Moreover it must be considered that the absorption rate for inorganic mercury especially from milk in the gastro-intestinal tract of babies is markedly higher than of adults (Drasch, 2004a).

Area	Mother's Profession	Hg-Breastmilk (µg/L)	Total-Hg Hair (µg(g)	MeHg-Hair (µg/g)	Hg-U (µg/ g creatinine)	Hg-B (µg/L)	Mother intoxicated
Mining area	mineral processor	9.70	4.57	0.70	39.39	12.00	yes
Mining area	miner	7.75	2.48	0.05	16.25	14.00	no
Mining area	former miner	4.20	2.80	0.07	14.02	4.40	no
Mining area	amalgam-burner	3.50	2.14	0.53	35.27	7.00	yes
Mining area	amalgam-burner	2.70	1.93	0.95	6.46	4.48	no
Mining area	mineral processor	2.40	5.05	0.70	4.32	8.96	yes
Mining area	former miner	1.60	0.83	0.41	8.09	3.70	no
Mining area	other job	< 1.00	1.13	0.47	3.30	2.11	no
Mining area	amalgam-burner	< 1.00	1.04	0.28	1.07	1.12	no
Control area	farmer	< 1.00			< 0.20	0.21	no

Table 21 - (Total) mercury concentration in breast-milk samples compared to other data from the mothers.

3.8. SCREENING OF MERCURY URINE CONCENTRATION IN FIELD

In field a mobile Hg analyser (Lumex RA-915+, Lumex Ltd., St. Petersburg, Russia) was used to screen for inorganic mercury in urine. In the reaction-vessel 5 ml of a solution of 5% tin(II) chloride in hydrochloric acid 3% was filled in and up to 1 ml urine was added. The formed mercury vapour in the gas phase above the liquid transferred to a quartz cell by a drawing pump, where it was detected by atomic emission spectrometry. Bottled drinking water (as to be got locally) was used for all dilutions, and a mercuric nitrate solution for standard. The detection-limit was approximately 0.5 µg/L urine. As the HBM limits for Hg in urine are 7 and 25 µg/L, respectively (see table 11), this method seems to be sufficient sensitive for urine Hg screening in the field. One analysis lasts approximately 3 minutes. 174 urine samples could be analysed with this method in field. Out of them, 45 were below the detection limit (0.5 µg/L). In 129 cases inorganic mercury concentrations above the detection-limit could be detected quantitatively.

The correlation between the concentration of inorganic Hg, determined with this method in field, and the concentration of total Hg, as determined in lab, was excellent (Spearman-r_o = + 0.91, n = 129, statistical highly significant). A scatter plot of the results above the detection-limits (fig.19) proves the sufficient correspondence of both methods. In all cases of inorganic Hg-U values in field below the detection limit of 0.5 µg/L, low total Hg-U values (up to 5.5 µg/L) were found in the lab, too. It must kept in mind that with this field method just *inorganic* mercury can be detected. But at least in the mining areas most of the mercury burden of men is inorganic. Furthermore it is known, that inorganic mercury is much better excreted in urine than organic bound mercury like methyl-mercury. From this it could be concluded that most mercury in the urine samples has been in the inorganic form. Nevertheless, as expected, in the mean the *total* mercury concentration in urine (as detected in the lab), was higher than the *inorganic* mercury concentration determined in field (see regression line in figure 28).

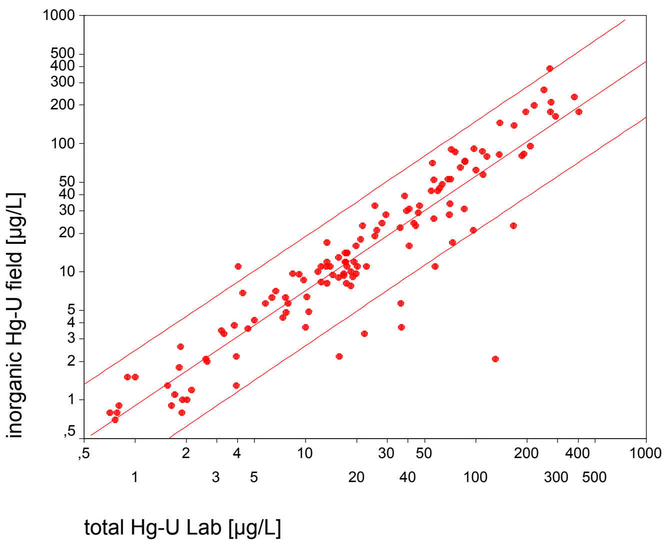


Figure 28 - Comparison of the concentration of inorganic Hg-U, as determined in field and the total Hg-U concentration, as determined in the lab (Linear regression line and 90% confidence intervals).

		Lab Result		Total
		not intoxicated	intoxicated	
Field Result	not intoxicated	115	12	127
	intoxicated	0	37	37
Total		115	49	164

Table 22 - Comparison of the preliminary classified “mercury intoxicated” in field and by all lab results.

All data from the medical investigations and from the urine screening were put during the field project into an excel data sheet . The medical sum score could be calculated and 37 cases preliminary classified as “mercury intoxicated” by the combination of the medical sum score and the Hg concentration in urine, as determined in field (according to table 4 in appendix 1). From the medical sum score and the final lab results, all of the 37 intoxications could be confirmed. In 12 additional cases, the intoxication was diagnosed by elevated Hg concentrations in blood and/or hair. Overall, the urine mercury screening during the field project has proved to be a sound method to get quick information during the field project on the order of magnitude of the mercury burden of sub-groups of the population. Together with a computer based evaluation of the medical results during the field project it was possible to select 3/4 of mercury intoxicated individuals just during the field mission and to give a primarily estimation of the local burden situation. Nevertheless, it is necessary to take in addition blood and hair samples in field and analyze them later in the lab. This is to remind especially in the case of a predominant burden with methyl-mercury.

4. Summary and Recommendations
(Gustav Drasch, Stephan Boese-O´Reilly)

4.1. SUMMARY

Kadoma is a typical small-scale mining area with approximately 235,000 inhabitants in the Midlands in Zimbabwe. Artisanal small-scale miners use mercury to extract gold from the ore. It is estimated that approximately a few hundred thousand people work and live in similar small scale mining communities all over Zimbabwe.

There is no clean and safe drinking water, no waste disposal for the toxic mercury or any other waste or human discharge. Hygienic standards are extremely low and are a reason for many infectious diseases such as diarrhoea, malaria and parasitism.

Accidents in insecure tunnels and amalgamation plants, acute respiratory tract infections, malaria, tuberculosis, and sexually transmitted diseases including AIDS are the dominant causes of morbidity and mortality. No proper health service exists in the mining communities. The District Hospital in Kadoma has very limited means.

The extraction of gold with liquid mercury releases serious amounts of mercury, especially high toxic mercury fumes into the local environment. The health status of 218 volunteers in Kadoma and 55 from a control area in Chikwaka was assessed with a standardised health assessment protocol from UNIDO (Veiga, 2003) by an expert team from the University of Munich/Germany in April 2004.

The mercury levels in the human bio-monitors were much higher in the exposed population in Kadoma than in the control group (see figure 4, 5 and 6). The exposed population was divided into sub-groups to compare the levels of exposure. As to be expected the control group was within a normal range and the amalgam-burners had the highest exposure levels in all human bio-monitors, while the less exposed population in the mining areas ranged in between. Child mercury exposure due to living in the mining areas and working with mercury show similar levels in the bio-monitors as adult amalgam-burners, children not working but living in the area also have increased levels, mainly compared to children from the control area. The results of the human bio-monitoring show clearly the severe exposure of the total population in the mining areas with mercury; the extreme exposure mainly of amalgam-burners and the especially severe exposure of children working with mercury. The mercury exposure in the mining areas is mainly due to exposure with elemental mercury and not due exposure with methyl-mercury (see figure 8). The relation of inorganic versus organic mercury in the control population shows the usual exposure of any population, where most of the mercury exposure derives from the consumption of methyl-mercury contaminated fish. Whereas in the mining areas the high amounts of inorganic mercury in hair indicate that the main exposure in the mining areas more then likely derives from elemental mercury, than from methyl-mercury exposure through contaminated food. Exposure with elemental mercury derive from handling mercury with bare hands, but the immanent exposure with mercury vapour might be the more important pathway, since amalgam-burners show the highest human bio-monitor levels.

Typical symptoms of mercury intoxication were prevalent in the exposed group. The medical score sum plus the bio-monitoring results made it possible to diagnose in 70% of the amalgam-burners, 63% of otherwise occupational burdened population and 23% of former occupational burdened population a chronic mercury intoxication. 5% of the not occupationally burdened population showed a chronic mercury intoxication and nobody in the control area was intoxicated. These results confirm severe exposure due to working with mercury, either by panning with mercury or smelting amalgam.

The different mining areas in Kadoma district use slightly different extraction technologies. The following differences could be found: In Glasgow mine and Summit mine almost 90% of the amalgam burners are mercury intoxicated, in Tix mine and Amber Rose mine approximately 70%. The lowest incidence of mercury intoxications was found for the amalgam burners in Jani mine: “just” less more than 40%. The burden in the Lilly mine, King Chim mine and Brompton mine cannot be assessed finally due to the low case numbers.

Child labour in the mining sites is very common from the age of 10 on, the children work and play with their bare hands with toxic mercury. Of special notice is, that 0% of the children from the control area, 33% of children living in the area, but not working with mercury and 69% of the children working with mercury have a chronic intoxication with mercury.

Mercury can cause severe damage to the developing brain. From 9 breast milk samples taken, 4 showed increased levels of mercury.

Poverty is the main reason for the disastrous health status in the small-scale mining communities. Struggling for pure survival makes mining for gold a necessity to find any financial resource. The daily fight for survival requires the miners to put their own health and the health of their children at risk.

A reduction of the release of mercury vapours from small-scale gold mining into the atmosphere will not only reduce the number of mercury intoxicated people in the mining area proper, it will reduce the global pollution of the atmosphere with mercury. Most of the mercury vapours formed by open burning of gold amalgam deposits not locally but is transported by air on long-range distances all over the globe (Lamborg 2002). The total release of mercury vapour from gold mining is estimated today up to 1,000 metric tons per year (MMSD, 2002), while from all other anthropogenic sources approximately 1,900 tons were released into the atmosphere (Pirrone, 2001).

These results correspond to former examinations in Zimbabwe, for example the study from Matchaba-Hove *et al*. (2001). They found, that “mercury poisoning among gold panners in Chiweshe and Tafuna communal lands is of public health importance. Panners should be educated on the possibilities of mercury being a poison. A low cost and safe technology to separate mercury from the amalgam should be introduced to the panners".

The result is that mercury is a serious health hazard in the small-scale gold mining area of Kadoma. The exposure of the whole community to mercury is reflected in raised mercury levels in the urine, blood and hair. Symptoms of severe damage of the brain (cerebellum) such as ataxia, tremor and movement disorders were found in the mining communities. In 70% of the amalgam-burners in Kadoma a mercury intoxication was diagnosed. The background burden in the control group is in the same order of magnitude as in western industrial countries.

4.2. CONCLUSIONS AND RECOMMENDATIONS

4.2.1. How to improve "general health"?

Poverty is the main reason for all health and environmental problems.

- At the moment it does not seem to be acceptable that **children** live in Kadoma small scale mining areas. Child labour with hazardous chemicals needs to be especially addressed. Missing sanitary standards and high exposure to mercury are the main problems. Sanitary standards need urgent improvement.
- The **occupational** related **health risk** of mining should be assessed in more detail (accidents, drinking water quality, HIV / AIDS, other sexually transmitted diseases, malaria, tuberculosis). One first step to reduce the health hazards in Kadoma district might be a proper zoning into industrial areas, commercial areas and housing areas. Mainly the smelting of amalgam needs to be performed outside the housing areas, and "away from the nose" of the amalgam-burners. Imposing basic hygienic standards, such as proper drinking water and reduction of Anopheles mosquitoes is essential.
- To reduce the obvious risk of **accidents** in mining sites, raising awareness is necessary. Introducing proper mining techniques is necessary (e.g. tunnel safety).
- The risk of **sexually transmitted diseases** could be reduced, if campaigns for safer sex were more effective.
- To improve the health status of the communities a better financed health service is urgently required.

4.2.2. How to reduce "mercury as a health hazard"?

Referring to the clinical testing and laboratory results, mercury is a major health hazard in the area. Some first suggestions are:

- Child labour with highly toxic substances must be stopped immediately. Legal restrictions on child labour need to be immediately implemented.
- Women in childbearing age need special information campaigns on this risk of mercury to the foetus and the nursed baby.

- The participants with intoxication need medical treatment. It is necessary to build up a system to diagnose and treat mercury related health problems in the area. Capacity building including establishing laboratory facilities in the Kadoma district is required to analyse mercury in human specimens. The financial aspect of treatment and the legal problem of importing drugs (chelating agents like DMPS or DMSA, to sweep mercury out of the body) need to be solved. Funding of preventive campaigns and for treatment facilities is needed now.
- Training programs for the health care providers in the Kadoma district and other health centres in mining areas to raise awareness of mercury as a health hazard.
- Continuous clinical training of local health workers, including a standardised questionnaire and examination flow scheme (MES = mercury examination score).
- Mercury ambulance: A mobile „mercury ambulance" might easier reach small-scale miners, than any local health office. A bus could be used as a mobile mercury ambulance. Equipped with the necessary medical and laboratory utensils, the bus could be driven into the mining areas. Two or three specially trained doctors or nurses could perform the examinations, and begin to carry out treatment. The bus could also be used for health awareness programs (e.g. video equipment). Miners in remote areas might welcome any evening entertainment. Soccer videos might attract more miners to the bus, than much other information material. Why not ask e.g. sponsors for such a bus (or truck).

4.2.3. How to improve the "knowledge on mercury as a health hazard"

- Assessing in a different study design the possibility of mercury related birth and growth defects, increased abortion/miscarriage rates, infertility problems, learning difficulties in childhood or other neuro-psychological problems related to mercury exposure.
- Assessing in a more detailed study the possible transfer of mercury from mother to child via breast-milk and the related possible adverse health effects. Females at childbearing age and before urgently need more awareness to refrain from amalgam burning, at least during pregnancy and nursing.

4.2.4. How to reduce the "release of mercury into the environment"

- 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.
- The exposure with mercury is avoidable with such simple technology as retorts. Technical solutions need to go hand in hand with awareness raising campaigns.
- To improve the social, health and environmental situation of artisanal small-scale gold miners an alliance of local, regional, governmental and intergovernmental bodies is needed. Cooperation between health, mining and environmental sectors is needed on local, regional, national and intergovernmental level. E.g. UNIDO and WHO in Harare could form a nucleus of a national mercury task force.

4.3. LITERATURE

Aaseth J., Jacobsen D., Andersen O., Wickstrom E. (1995) - Treatment of mercury and lead poisoning with dimercaptosuccinic acid and sodium dimercaptopropane-sulfonate: A review. *Analyst* **120**, p. 23-38.

Achmadi U.F. (1994) - Occupational exposure to mercury at the gold mining: a case study from Indonesia. *In:* Environmental mercury pollution and its health effects in Amazon River Basin. National Institute Minamata Disease and Inst. Biophysics of the University Federal do Rio de Janeiro. Rio de Janeiro, p. 10-16.

Akagi H. *et al.* (1994) - Methyl-mercury pollution in Tapajós River Basin, Amazon. *Environ. Sci*. **3**, p. 25-32.

Akagi H., Castillo E., Maramba N., Francisco A.T. (1999) - Health assessment for mercury exposure among children residing near a gold processing and refining plant. Proc. of the Int Conference Mercury as a Global Pollutant, Rio de Janeiro, Brazil, p. 421.

Aposhian H.V. *et al.* (1995) - Mobilization of heavy metals by newer, therapeutically useful chelating agents. *Toxicology* **97**, p. 23-38.

Barbosa A.C. *et al.* (1995) - Mercury contamination in the Brazilian Amazon. Environmental and occupational aspects. *Water Air Soil Pollut* **80**, p. 109-121.

Boese-O'Reilly S., Drasch G., Beinhoff C., Maydl S., Vosko M.R., Roider G. (2003) - The Mt. Diwata Study on the Philippines 2000 - treatment of mercury intoxicated inhabitants of a gold mining area with DMPS (2,3-Dimercapto-1-propane-sulfonic acid, Dimaval ®). *The Science of the Total Environment*, **307**, p. 71-82.

Boischio A.A.P., Henshel D., Barbosa A.C. (1995) - Mercury exposure through fish consumption by the upper Madeira River population, Brazil. *Ecosyst Health* **1**, p. 177-192.

Branches F.J.P., Erickson T., Aks S.E., Hryhorczuk D.O. (1993) - The price of gold: mercury exposure in the Amazon Rain Forest. *J. Clin. Toxicol*. **31**, p. 295-306.

Câmara V.M. (1994) - Epidemiological assessment of the environmental pollution by mercury due to gold mining in the Amazon River Basin. In: Environmental mercury pollution and its health effects in Amazon River Basin. National Institute Minamata Disease and Inst. Biophysics of the University Federal do Rio de Janeiro. Rio de Janeiro, p. 80-84.

Castillo E.S., Maramba N.F.C., Akagi H., Francisco-Rivera A.T.T. (1999) - Quality assurance of blood mercury levels among schoolchildren exposed to elemental mercury in Apokon, Tagum, Davao del Norte, Philippines, 1998. Proc. of the Int Conference Mercury as a Global Pollutant, Rio de Janeiro, Brazil, p. 422.

Castro M.B., Albert B., Pfeiffer W.C. (1991) - Mercury levels in Yanomami indians hair from Roraima, Brazil. Proceedings 8th Int. Conference Heavy metals in the environment. Edinburgh 1, p. 367-370.

Cichini G. *et al.* (1989) - Effekt von DMPS und D-Penicillamin bei inhalativer Intoxikation mit metallischem Quecksilber. *Intensivmed Notf Med* **26**, p. 303-306.

Cleary D. *et al.* (1994) - Mercury in Brazil. *Nature*, p. 613-614.

Davidson P.W. *et al.* (1998) - Effects of prenatal and postnatal merthylmercury exposure from fish consumption on neurodevelopment. *J. Am. Med. Assoc*. **280**, p. 701-707.

de Lacerda L., Salomons W. (1998) - Mercury from Gold and Silver Mining: A Chemical Time Bomb? Springer, Berlin, Heidelberg.

Deutsche Forschungsgemeinschaft (ed) (1999) - MAK- und BAT-Werte-Liste 1999. VCH-Verlagsgesellschaft, Weinheim, Germany.

Drasch G. (1994) - Mercury. *In*: Seiler HG, Sigel A, Sigel H (eds.): Handbook on metals in clinical and analytical chemistry. New York: Marcel Dekker, p. 479-494.

Drasch G. *et al.* (1997) - Are blood, urine, hair, and muscle valid bio-monitoring parameters for the internal burden of men with the heavy metals mercury, lead and cadmium? *Trace Elem. Electrolytes* **14**, p. 116-123

Drasch G., Aigner S., Roider G., Staiger F., Lipowsky G. (1998) - Mercury in Human Colostrum and Early Breast Milk. Ist Dependence on Dental Amalgam and other Factors. *J. Trace Elem. Med. Biol.* **12**, p. 23-27.

Drasch G., Boese-O´Reilly S., Maydl S., Roider G. (2002) - Scientific comment on the German human biological monitoring values (HBM values) for mercury. *International Journal Hygiene Environmental Health* **205**, p. 509-512.

Drasch G., Boese-O'Reilly S., Beinhoff C., Roider G., Maydl S. (2001) - The Mt. Diwata study on the Philippines 1999 - assessing mercury intoxication of the population by small scale gold mining. *The Science of the Total Environment* **267**, p. 151-168.

Drasch G., Horvat M., Stoeppler M. (2004) - Mercury. in: Merian E, Anke M, Ihnat M, Stoeppler M (eds.) Elements and their Compounds in the Environment, Vol. 2. Wiley-VHC Verlag, Weinheim, Germany.

Florentine M.J., Sanfilippo D.J. (1991) - Elemental mercury poisoning. *Clin. Pharm.* **10**, p. 213-221.

Forsberg B.R. *et al*. (1994) - High levels of mercury in fish and human hair from the Rio Negro basin (Brazilian Amazon): natural background or anthropogenic. In: Environmental mercury pollution and its health effects in Amazon River Basin. National Institute Minamata Disease and Inst. Biophysics of the University Federal do Rio de Janeiro. Rio de Janeiro, p. 33-39.

Gonzalez-Ramirez *et al*. (1998) - DMPS (2,3-Dimercaptopropane-1-sulfonate, Dimaval) Decreases the Body Burden of Mercury in Humans Exposed to Mercurous Chloride. *J. Pharmacol. Exp. Therap*. **287**, p. 8-12.

Grandjean P. *et al.* (1997) - Cognitive deficit in 7-year-old children with prenatal exposure to methyl-mercury. *Neurotoxicol Teratol* **19**, p. 417-428.

Grandjean P. *et al.* (1999) - Methyl-mercury Neurotoxicity in Amazonian Children Downstream from Gold Mining. *Environ Health Perspect*, **107**, p. 587-591.

Kijewski H. (1993) - Die forensische Bedeutung der Mineralstoffgehalte in menschlichen Kopfhaaren. Schmidt Roemhild Verlag, Lübeck, Germany.

Kommission Human-Biomonitoring des Umweltbundesamtes Berlin - Institut für Wasser-, Boden- und Lufthygiene des Umweltbundesamtes (1999) Stoffmonographie Quecksilber - Referenz- und Human-Biomonitoring-Werte (HBM). Bundesgesundheitsblatt: 42:522-532.

Krause C. *et al.* (1996) - Umwelt-Survey 1990/92, Studienbeschreibung und Human-Biomonitoring. Umweltbundesamt Berlin, Germany (ed.).

Lamborg C.H., Fitzgerald W.F., O'Donnell J., Torgersen T. (2002) - A non-steady-state compartment model of global-scale mercury biogeochemistry with interhemispheric gradients. *Geochim Cosmochim Acta* **66**: p. 1105-1118.

Lockowandt O. (1996) - Frostigs Entwicklungstest der visuellen Wahrnehmung. Weinheim: Beltz.

Matchaba-Hove R.B., Siziya S., Rusakaniko S., Kadenhe R.M., Dumbu S., Chirenda J. (2001) - Mercury poisoning: prevalence, knowledge and frequency of gold panning and doing retort among alluvial gold panners in Chiweshe and Tafuna communal lands in Zimbabwe. *Cent. Afr. J. Med*. **47**: p. 251-254.

Malm O. *et al.* (1995a) - Mercury and methyl-mercury in fish and human hair from Tapajós River Basin, Brazil. *Sci. Tot. Environ*. **175**, p. 127-140

Malm O. *et al.* (1995b) - An assessment of Hg pollution in different gold mining areas, Amzon, Brazil. *Sci. Tot. Environ.* **175**, p. 141-150.

Malm O., Pfeiffer W.C., Souza C.M.M., Reuther R. (1990) - Mercury pollution due to gold mining in the Madeira River Basin, Brazil. *Ambio* **19**, p. 11-15.

Masur H., Papke K., Althoff S., Oberwittler C. (2005) - Skalen und Scores in der Neurologie. 2. Auflage, Thieme, Stuttgart.

MMSD (2002) - Breaking New Ground: Mining, Minerals, and Sustainable Development. International Institute for Environment and Development. Earthscan Publications Ltd, London, UK. As available at http://www.iied.org/mmsd/finalreport/index.html per September 2002.

Mtetwa C., Shava S. (2004) - Sociological survey – Tix and Ambre Rose Mines, Harare, UNIDO.

Mtetwa C., Shava S. (2003) - A sociological survey of small-scale artisanal gold mining in the Kadoma–Chakari area, Harare, UNIDO.

Pirrone N., Munthe J., Barregård L., Ehrlich H.C., Petersen G., Fernandez R., Hansen J.C., Grandjean P., Horvat M., Steinnes E., Ahrens R., Pacyna J.M., Borowiak A., Boffetta P., Wichmann-Fiebig M. (2001) - Ambient Air Pollution by Mercury (Hg) – Position Paper. Office for Official Publications of the EC. (available on http://europa.eu.int/comm/environment/air/background.htm#mercury).

US EPA (1997) - Mercury study report to congress. US EPA, Washington, D.C.

Veiga M., Baker R. (2003) - Protocols for Environmental and Health Assessment of Mercury Released by Artisanal and Small-Scale Gold Miners. UNIDO, Vienna.

WHO (1980) - Recommended health based limits in occupational exposure to heavy metals. Technical Series Report No 647, Geneva.

WHO (1991) - Environmental Health Criteria 118: Inorganic Mercury. Geneva.

WHO (2004) - Selected health indicators for Zimbabwe.
http://www.who.int/whosis/country/indicators.cfm

Wilhelm M. (2000) - Quecksilber In Boese-O´Reilly S, Kammerer S, Mersch-Sundermann V, Wilhelm M, Leitfaden Umweltmedizin, 2. Auflage. Urban und Fischer, München.

World Economic Forum (WEF) (2002) - Global Health Initiative: Private Sector Intervention – Case example. Partnering with African Medical and Research Foundation (AMREF) to offer HIV prevention and care for 1.500 workers and 120.000 community members for US$ 62 per worker per year. www.weforum.org/globalhealth.

Zimmer R., Volkamer M. (1984) - MOT - Motoriktest. Beltz, Weinheim.

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Finally but most importantly we would like to thank all participants of the medical examinations and we hope to be able to improve their future living circumstances.

Appendix 1

Tables

Correlations

			HGU	HGB	HGUCREA	HGHAIR	ANORGHGH	MEHGHAIR
Spearman-Rho	Hg in urine	Coefficient of correlation	1,000	,762**	,916**	,725**	,640**	,411**
		significance (one-tailed)	,	,000	,000	,000	,000	,000
		N = case No.	254	250	254	216	196	196
	Hg in blood	Coefficient of correlation	,762**	1,000	,834**	,855**	,759**	,530**
		significance (one-tailed)	,000	,	,000	,000	,000	,000
		N = case No.	250	250	250	213	193	193
	Hg in urine relating to g Creatinine	Coefficient of correlation	,916**	,834**	1,000	,774**	,696**	,460**
		significance (one-tailed)	,000	,000	,	,000	,000	,000
		N = case No.	254	250	254	216	196	196
	total Hg in hair	Coefficient of correlation	,725**	,855**	,774**	1,000	,950**	,672**
		significance (one-tailed)	,000	,000	,000	,	,000	,000
		N = case No.	216	213	216	216	196	196
	inorganic Hg in hair	Coefficient of correlation	,640**	,759**	,696**	,950**	1,000	,479**
		significance (one-tailed)	,000	,000	,000	,000	,	,000
		N = case No.	196	193	196	196	196	196
	organic Hg in hair	Coefficient of correlation	,411**	,530**	,460**	,672**	,479**	1,000
		significance (one-tailed)	,000	,000	,000	,000	,000	,
		N = case No.	196	193	196	196	196	196

**. = p < 0,01 (one-tailed)

Table 1 - Spearman' rank correlations between the mercury concentration in the different bio-monitors.

Adults in mining areas around Kadoma – Zimbabwe

Data or Test	Value or Score	Chikwaka Control	KadomaBurdened areas			
			Not occupational burdened	other occupational burdened	Amalgam-burner	former occupational burdened
Case number		36	21	19	117	21
Anamnestic data:						
Male/female		18/18	2/18	7/12	96/21	8/13
Mean age (years)		28.8	29.0	28.2	27.6	30.6
Heavy alcohol drinker		2.8%	0%	15.8%	21.4%	9.5%
Metallic taste	0/1	5.6%	9.5%	10.5%	17.9%	9.5%
Excessive salivation	0/1	11.1%	9.5%	5.3%	13.7%	28.6%
Tremor at work	0/1	0%	4.8%	5.3%	16.2%	9.5%
Sleeping problems	0/1	22.2%	0%	15.8%	8.5%	0%
Health problems worsened since Hg exposed	0/1	0%	0%	0%	4.3%	0%

Adults in mining areas around Kadoma – Zimbabwe

Data or Test	Value or Score	Chikwaka Control	Kadoma Burdened areas			
			Not occupational burdened	other occupational burdened	Amalgam-burner	former occupational burdened
Case number		36	21	19	117	21
Anamnestic data:						
Lack of appetite		44.5%	14.3%	31.6%	13.7%	14.3%
Loss of weight		3.8%	0%	0%	2.6%	4.8%
Easily tired		11.1%	19.0%	10.5%	7.7%	4.8%
Rest more		2.8%	19.0%	10.5%	6.0%	4.8%
Feel sleepy		0%	9.5%	5.3%	12.0%	4.8%
Problems to start things		0%	0%	10.5%	3.5%	0%
Lack of energy		2.8%	14.3%	15.8%	12.0%	9.5%
Less strength		2.8%	14.3%	21.1%	10.3%	9.5%
Weak		5.6%	14.3%	21.1%	11.2%	9.5%

Table 2 - Relevant data of the adults, divided in subgroups. Grey shaded fields in the table contain results that differ from the control group on a statistically significant level ($p < 0.05$, one-tailed Chi-square test).

Adults in mining areas around Kadoma – Zimbabwe

Data or Test	Value or Score	Chikwaka Control	Kadoma Burdened areas			
			Not occupational burdened	other occupational burdened	Amalgam-burner	former occupational burdened
Case number		36	21	19	117	21
Anamnestic data:						
Problems with concentration		16.7%	25.0%	31.6%	27.4%	9.5%
Problems to think clear		5.6%	9.5%	0%	3.4%	0%
Word finding problems		0%	0%	0%	0.9%	0%
Eyestrain		5.6%	19.0%	10.5%	20.5%	14.3%
Memory problems		5.6%	19.1%	15.8%	16.2%	4.8%
Feel nervous		8.4%	14.3%	26.3%	14.6%	14.3%
Feel sad		11.1%	28.6%	36.8%	25.2%	23.8%
Headache		25.0%	47.6%	42.1%	26.5%	19.0%
Nausea		0%	14.3%	5.3%	11.1%	9.6%
Numbness		11.2%	19.0%	15.8%	21.4%	9.5%

Adults in mining areas around Kadoma – Zimbabwe

Data or Test	Value or Score	Chikwaka Control	Kadoma Burdened areas			
			Not occupational burdened	other occupational burdened	Amalgam-burner	former occupational burdened
Case number		36	21	19	117	21
Clinical data:						
Bluish coloration of gingiva	0/1	5.6%	0%	26.3%	31.6%	23.8%
Gingivitis		2.8%	0%	0%	0.9%	4.8%
Ataxia of gait	0/1	11.1%	14.3%	15.8%	41.9%	52.4%
Finger to nose tremor	0/1	0%	0%	15.8%	4.3%	0%
Finger to nose dysmetria		2.8%	4.8%	5.3%	5.1%	14.3%
Dysdiadochokinesia	0/1	11.1%	23.8%	26.3%	26.5%	33.3%
Tremor of eyelid		44.4%	57.1%	31.6%	43.6%	42.9%

Table 2 (continued).

Adults in mining areas around Kadoma – Zimbabwe

Data or Test	Value or Score	Chikwaka Control	Kadoma Burdened areas			
			Not occupational burdened	other occupational burdened	Amalgam-burner	former occupational burdened
Case number		36	21	19	117	21
Clinical data:						
Horizontal field of vision (median)		173.2°	174.3°	167.5°	175.4°	175.3°
Heel to knee ataxia	0/1	0%	0%	5.3%	14.5%	4.8%
Heel to knee tremor	0/1	0%	0%	0%	0.9%	0%
PSR normal		85.7%	76.2%	78.9%	76.9%	85.7%
BSR normal		97.1%	90.5%	84.2%	81.2%	95.2%
ASR normal		88.6%	76.2%	68.4%	71.8%	61.9%
Mento-labial reflex pathologic	0/1	33.3%	23.8%	15.8%	29.1%	28.6%
Bradykinesia		5.7%	9.5%	15.8%	16.2%	9.5%
Hypomimia		2.9%	0%	15.8%	13.7%	9.5%
Proteinuria	0/1	8.3%	9.5%	23.5%	6.3%	0%

Adults in mining areas around Kadoma – Zimbabwe

Data or Test	Value or Score	Chikwaka Control	Kadoma Burdened areas			
			Not occupational burdened	other occupational burdened	Amalgam-burner	former occupational burdened
Case number		36	21	19	117	21
Neuro-psychological test						
Memory test	0 - 1	13.9%	4.8%	15.8%	8.6%	23.8%
	2 - 3	66.7%	61.9%	63.2%	57.8%	42.9%
	4 (worst)	19.4%	33.3%	21.1%	33.6%	33.3%
Match box test	13-16 sec	34.3%	33.3%	31.6%	19.0%	33.3%
	17-23 sec	42.9%	47.6%	57.9%	49.1%	42.9%
	24 – 44 sec (worst)	22.9%	19.0%	10.5%	31.9%	23.8%

Table 2 (continued).

Adults in mining areas around Kadoma – Zimbabwe

Data or Test	Value or Score	Chikwaka Control	Kadoma Burdened areas			
			Not occupational burdened	other occupational burdened	Amalgam-burner	former occupational burdened
Case number		36	21	19	117	21
Neuro-psychological test						
Frostig test	14 - 11	36.1%	66.7%	57.9%	65.5%	47.6%
	10 - 9	36.1%	14.3%	31.6%	23.3%	33.3%
	8 - 4 (worst)	27.8%	19.0%	10.5%	11.2%	19.0%
Pencil tapping test	71 - 47	28.6%	28.6%	15.8%	37.1%	23.8%
	46 - 36	48.6%	33.3%	36.8%	37.9%	66.7%
	35 - 11 (worst)	22.9%	38.1%	47.4%	25.0%	9.5%

Adults in mining areas around Kadoma – Zimbabwe

Data or Test	Value or Score	Chikwaka Control	Kadoma Burdened areas			
			Not occupational burdened	other occupational burdened	Amalgam-burner	former occupational burdened
Bio-monitoring						
Hg-urine [µg/l]	No.	36	21	19	117	21
	median	< 0.2	7.63	18.48	54.49	17.09
	> HBM II	0%	19.0%	42.1%	66.7%	33.3%
	> BAT	0%	4.8%	5.3%	30.8%	4.8%
	max.	8.78	130.19	146.24	1530.32	361.74
Hg-urine [µg/g creatinine]	No.	36	21	19	117	21
	median	< 0.2	6.18	16.81	35.69	11.39
	> HBM II	0%	9.5%	42.1%	69.2%	28.6%
	max.	3.57	96.07	79.95	547.42	96.41

Table 2 (continued).

Adults in mining areas around Kadoma – Zimbabwe

Data or Test	Value or Score	Chikwaka Control	Kadoma Burdened areas			
			Not occupational burdened	other occupational burdened	Amalgam-burner	former occupational burdened
Bio-monitoring						
Hg-blood [µg/l]	No.	36	20	19	114	21
	median	0.43	2.34	10.84	13.18	4.12
	> HBM II	0%	0%	31.6%	43.0%	9.5%
	> BAT	0%	0%	5.3%	32.5%	4.8%
	max.	1.88	10.28	37.40	97.60	55.00
Total Hg-hair [µg/g hair]	No.	32	20	19	97	20
	median	< 0.02	1.63	4.02	4.45	1.88
	> 5 µg/g	0%	10.0%	31.6%	45.4%	25.0%
	max.	3.25	15.39	75.42	112.18	16.20

Adults in mining areas around Kadoma – Zimbabwe

Data or Test	Value or Score	Chikwaka Control	Kadoma Burdened areas			
			Not occupational burdened	other occupational burdened	Amalgam-burner	former occupational burdened
Case number		36	21	19	117	21
Medical test score	median	5	4	5	6	5
	0-4	40.0%	57.1%	31.6%	31.9%	47.6%
	5-9	60.0%	42.9%	63.2%	63.8%	47.6%
	10-15 (worst)	0%	0%	5.3%	4.3%	4.8%
HBM II and BAT						
Blood or urine or hair	> HBM II	0%	23.8%	78.9%	79.5%	9.5%
Blood or urine	> BAT	0%	4.8%	10.5%	43.6%	4.8%
Diagnosis						
Hg intoxication	No. (%)	0 0%	1 4.8%	12 63.2%	82 70.1%	5 23.8%

Table 2 (continued).

Children in mining areas around Kadoma – Zimbabwe

Data or Test	Value or Score	Chikwaka Control	Kadoma Burdened areas	
		Children	Children, not working with Hg	Children, working with Hg
Case number		12	12	16
Anamnestic data:				
Male/female		6/6	6/6	15/1
Mean age (years)		12.4	11.3	11.6
Heavy alcohol drinker		0%	0%	0%
Metallic taste	0/1	0%	8.3%	31.3%
Excessive salivation	0/1	0%	25.0%	37.5%
Tremor at work	0/1	0%	0%	12.5%
Sleeping problems	0/1	0%	0%	0%
Health problems worsened since Hg exposed	0/1	0%	0%	0%

Children in mining areas around Kadoma – Zimbabwe

Data or Test	Value or Score	Chikwaka Control	Kadoma Burdened areas	
		Children	Children, not working with Hg	Children, working with Hg
Case number		12	12	16
Anamnestic data:				
Lack of appetite		50.0%	8.3%	18.8%
Loss of weight		0%	0%	0%
Easily tired		0%	8.3%	12.5%
Rest more		0%	0%	0%
Feel sleepy		0%	8.3%	6.3%
Problems to start things		0%	0%	0%
Lack of energy		0%	8.3%	12.5%
Less strength		0%	8.3%	6.3%
Weak		0%	8.3%	12.5%

Table 3 - Relevant data of the children, divided in subgroups. Grey shaded fields in the table contain results that differ from the control group on a statistically significant level ($p < 0.05$, one-tailed Chi-square test).

Children in mining areas around Kadoma – Zimbabwe

Data or Test	Value or Score	Chikwaka Control	Kadoma Burdened areas	
		Children	Children, not working with Hg	Children, working with Hg
Case number		12	12	16
Anamnestic data:				
Problems with concentration		0%	8.3%	25.0%
Problems to think clear		0%	0%	0%
Word finding problems		8.3%	0%	0%
Eyestrain		33.3%	16.7%	18.8%
Memory problems		8.3%	8.3%	18.8%
Feel nervous		8.3%	0%	6.3%
Feel sad		0%	25.0%	6.3%
Headache		50.0%	33.3%	37.6%
Nausea		16.6%	25.0%	6.3%
Numbness		8.3%	25.0%	6.3%

Children in mining areas around Kadoma – Zimbabwe

Data or Test	Value or Score	Chikwaka Control	Kadoma Burdened areas	
		Children	Children, not working with Hg	Children, working with Hg
Case number		12	12	16
Clinical data:				
Bluish coloration of gingiva	0/1	0%	8.3%	18.8%
Gingivitis		0%	0%	
Ataxia of gait	0/1	8.3%	8.3%	12.5%
Finger to nose tremor	0/1	0%	0%	0%
Finger to nose dysmetria		8.3%	8.3%	0%
Dysdiadochokinesia	0/1	8.3%	25.0%	37.5%
Tremor of eyelid		33.3%	50.0%	37.5%

Table 3 – (continued).

Children in mining areas around Kadoma – Zimbabwe

Data or Test	Value or Score	Chikwaka Control	Kadoma Burdened areas	
		Children	Children, not working with Hg	Children, working with Hg
Case number		12	12	16
Clinical data:				
Horizontal field of vision (median)		172.0°	174.8°	175.4°
Heel to knee ataxia	0/1	0%	8.3%	6.3%
Heel to knee tremor	0/1	0%	8.3%	0%
PSR normal		91.7%	75.0%	87.5%
BSR normal		100.0%	83.3%	62.5%
ASR normal		100.0%	83.3%	43.8%
Mento-labial reflex pathologic	0/1	25.0%	8.3%	12.5%
Bradykinesia		0%	0%	12.5%
Hypomimia		0%	0%	12.5%
Proteinuria	0/1	41.7%	41.7%	43.8%

Children in mining areas around Kadoma – Zimbabwe

Data or Test	Value or Score	Chikwaka Control	Kadoma Burdened areas	
		Children	Children, not working with Hg	Children, working with Hg
Case number		12	12	16
Neuro-psychological test				
Memory test	0 - 1	25.0%	8.3%	0%
	2 - 3	41.7%	75.0%	56.3%
	4 (worst)	33.3%	16.7%	43.8%
Match box test	10-16 sec	16.7%	16.7%	18.8%
	17-24 sec	41.7%	66.7%	50.0%
	25 – 44 sec (worst)	41.7%	16.7%	31.3%

Table 3 – (continued).

Children in mining areas around Kadoma – Zimbabwe

Data or Test	Value or Score	Chikwaka Control	Kadoma Burdened areas	
		Children	Children, not working with Hg	Children, working with Hg
Case number		12	12	16
Neuro-psychological test				
Frostig test	14 - 11	25.0%	41.7%	31.3%
	10 - 8	33.3%	50.0%	37.5%
	7 - 4 (worst)	41.7%	8.3%	31.3%
Pencil tapping test	71 - 47	16.7%	33.3%	18.8%
	46 - 35	33.3%	33.3%	37.5%
	34 - 11 (worst)	50.0%	33.3%	43.8%

Children in mining areas around Kadoma – Zimbabwe

Data or Test	Value or Score	Chikwaka Control	Kadoma Burdened areas	
		Children	Children, not working with Hg	Children, working with Hg
Bio-monitoring				
Hg-urine [µg/l]	No.	12	12	16
	median	< 0.2	18.45	17.57
	> HBM II	0%	8.3%	43.8%
	> BAT	0%	0%	18.8%
	max.	0.25	70.53	941.89
Hg-urine [µg/g creatinine]	No.	12	12	16
	median	< 0.2	16.20	29.10
	> HBM II	0%	33.3%	56.3%
	max.	0.59	56.41	666.87

Table 3 – (continued).

Children in mining areas around Kadoma – Zimbabwe

Data or Test	Value or Score	Chikwaka Control	Kadoma Burdened areas	
		Children	Children, not working with Hg	Children, working with Hg
Bio-monitoring				
Hg-blood [µg/l]	No.	12	12	16
	median	0.34	5.52	6.10
	> HBM II	0%	0%	37.5%
	> BAT	0%	0%	18.8%
	max.	0.69	8.16	100.80
Total Hg-hair [µg/g hair]	No.	5	9	14
	median	< 0.02	2.47	3.12
	> 5 µg/g	0%	0%	21.4%
	max.	0.05	3.42	52.96

Children in mining areas around Kadoma – Zimbabwe

Data or Test	Value or Score	Chikwaka Control	Kadoma Burdened areas	
		Children	Children, not working with Hg	Children, working with Hg
Case number				
Medical test score	median	5	5	7
	0-4	41.7%	41.7%	12.5%
	5-9	50.0%	58.3%	75.0%
	10-15 (worst)	8.3%	0%	12.5%
HBM II and BAT				
Blood or urine or hair	> HBM II	0%	33.3%	62.5%
Blood or urine	> BAT	0%	0%	31.3%
Diagnosis				
Hg intoxication	No. (%)	0 0%	4 33.3%	11 68.8%

Table 3 – (continued and end).

Comparison of the amalgam-burners in different mining areas

Data or Test	Value or score	Tix Mine	Amberose Mine	Glasgo w Mine	Summit Mine	Lilly Mine	Jani Mine
case number		43	18	18	7	4	21
Anamnestic data							
metallic taste	0/1	23.3%	10.5%	22.2%	0.0%	0.0%	23.8%
excessive salivation	0/1	18.6%	10.5%	5.6%	0.0%	25.0%	19.0%
tremor at work	0/1	20.9%	0.0%	11.1%	0.0%	50.0%	23.8%
sleeping problems	0/1	9.3%	0.0%	5.6%	14.3%	25.0%	4.8%
health problems worsened	0/1	2.3%	10.5%	5.6%	0.0%	25.0%	0.0%
Clinical data							
bluish coloration of gingiva	0/1	34.9%	10.5%	38.9%	0.0%	0.0%	42.9%
ataxia of gait	0/1	27.9%	47.4%	50.0%	42.9%	75.0%	47.6%
finger to nose tremor	0/1	7.0%	5.3%	0.0%	0.0%	0.0%	0.0%

Comparison of the amalgam-burners in different mining areas

Data or Test	Value or score	Tix Mine	Amberose Mine	Glasgo w Mine	Summit Mine	Lilly Mine	Jani Mine
case number		43	18	18	7	4	21
Clinical data							
dysdiadochokinesia	0/1	11.6%	36.8%	33.3%	28.6%	25.0%	38.1%
heel to knee ataxia	0/1	16.3%	15.8%	11.1%	0.0%	0.0%	23.8%
heel to knee tremor	0/1	2.3%	0.0%	0.0%	0.0%	0.0%	0.0%
mento-labial-reflex	0/1	18.6%	21.1%	44.4%	14.3%	25.0%	47.6%
proteinuria	0/1	9.5%	0.0%	5.6%	0.0%	0.0%	9.5%
neuropsychologi-cal tests							
memory test	0 – 1	11.9%	15.8%	0.0%	0.0%	25.0%	4.8%
	2 – 3	52.4%	73.7%	44.4%	100.0%	75.0%	38.1%
	4 (worst)	35.7%	10.5%	55.6%	0.0%	0.0%	57.1%

Table 4 - Comparison of the amalgam-burners in different mining areas; relevant anamnestic and clinical data and neuropsychological test for the medical test scoring.

Comparison of the amalgam-burners in different mining areas

Data or Test	Value or score	Tix Mine	Amberose Mine	Glasgow Mine	Summit Mine	Lilly Mine	Jani Mine
case number		43	18	18	7	4	21
neuropsychological tests							
matchboxtest	13 – 16 sec	14.3%	31.6%	16.7%	57.1%	0.0%	14.3%
	17 – 23 sec	40.5%	47.4%	55.6%	14.3%	50.0%	76.2%
	24 – 44 sec (worst)	45.2%	21.1%	27.8%	28.6%	50.0%	9.5%
Frostig test	14 – 11	73.8%	42.1%	72.2%	57.1%	50.0%	61.9%
	10 – 9	19.0%	36.8%	16.7%	28.6%	50.0%	23.8%
	8 – 4 (worst)	7.1%	21.1%	11.1%	14.3%	0.0%	14.3%

Comparison of the amalgam-burners in different mining areas

Data or Test	Value or score	Tix Mine	Amberose Mine	Glasgow Mine	Summit Mine	Lilly Mine	Jani Mine
case number		43	18	18	7	4	21
neuropsychological tests							
Pencil tapping test	71 – 47	33.3%	42.1%	44.4%	42.9%	50.0%	33.3%
	46 – 36	33.3%	36.8%	27.8%	14.3%	25.0%	61.9%
	35 – 11 (worst)	33.3%	21.1%	27.8%	42.9%	25.0%	4.8%

Table 4 - (continued and end).

Appendix 2

Health assessment questionnaire

Health Assessment Questionnaire

by Dr. Stephan Boese O'Reilly, Prof. Dr. Gustav Drasch, Stefan Maydl, Dr. Milan Vosko
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Removal of Barriers to the Introduction of Cleaner Artisanal Gold Mining and Extraction Technologies
United Nations Industrial Development Organization (UNIDO)
Global Environment Facility (GEF)
United Nations Development Programme (UNDP)
Health Assessment

Name: ______________________________

Ndinobvuma kupinda muchirongwa che UNIDO. Ndichabvunzwa pamusoro pemagariro angu, pamusoro pehutano hwangu maererano nekushandisa mercury. Ndichaongororwa naanamazvikokota vezvehutano kusanganisira kuongororwa pfungwa (brain). Ropa, mvura yatinorasa nebvudzi zvichatorwa kuti zviongororwe. VeUNIDO kana vachinge vapedza kuongorora zvinenge zvatorwa, vachange vachizondizivisa zvinenge zvabuda. Kuongororwa kwezvinenge zvatorwa izvi kuchaitwa tichiremekedza bumbiro rinonzi 'Recommendation for conduct of clinical research' resangano repasi rose rinonzi 'World Health Organisation Declaration of Helsinki'.

Location and Date: ______________________________
Signature (in case of children signature of parents/guardian)
Witnesses (if needed):
______________________________ and ______________________________
(Name): (Name):

1 Personal Data

1.1 Participant ID Number: ____________

1.1.1 Family Name: ....

1.1.2 Surname ....

1.1.3 Date of Birth: ....

1.1.4 Age: .... **(years)**

1.1.5 Gender:

[ ] 0 Female
[ ] 1 Male

1.1.6 Address: ....

1.1.7 (if possible local codes, like settlement A,B, C ....)

2 General Questionnaire

2.1.1 Date of interview:....................

2.1.2 Name of the interviewer for this section:....................

2.1.3 **Code of the interviewer** ________
(please give every interviewer a code, like A,B,C)

2.2 Zviri maererano nekushanda (work exposure)

2.2.1 Mava nemakore mangana muchigara panzvimbo ino? ______ (living area years)

2.2.2 Basa renyu (Detailed description of the job)

A [ ] Mucheri wendarama, asi handishandise mercury (miner)
B [ ] Mucheri wendarama, ndichishandisa mercury kubata ndarama pasina smelter (amalg.)
C [ ] Mugadziri wendarama nesmelter kana kuti mutengi wendarama (smelter)

D __ Worker at a cyanidation plant, but no contact to mercury
E __ Murimi
F __ Mushandi wemuhofisi
G __ Muchaeri
H __ Mwana wechikoro aingashandi (child)
J __ Rimwe basa ....
K __ Mwana wechikoro anoshanda mukuchera ndarama nokushandisa mercury (child Hg)

2.2.3 Makamboshandira panzvimbo ye __________ area? (area working years)

0 __ Kwete
1 __ hongu

2.2.3.1 Kana zvirizvo, kwemakore mangana _______

2.2.4 Makamboshanda somucheri wendarama muchishandisa mercury here? (Hg working years)

0 __ kwete
1 __ hongu

2.2.4.1 Kana zvirizvo, kubva rinhi kusvika rinhi? ________________________________

- _____ makore okushandisa mercury

2.2.5 Makamboshanda here muchipisa ndarama nemercury? (burn amlgam)

0 __ kwete
1 __ hongu

2.2.5.1 Kana zvirizvo, kubva rinhi kusvika rinhi? ________________________________

- _____ makore okushanda nemercury

2.2.6 Makamboshandisa here inonzi retort? (use retort)

1 __ kwete
0 __ hongu

2.2.7 Munombochengeta mercury here? (store Hg)

0 __ kwete
1 __ kubasa
2 __ kumba

2.2.8 Hembe dzamunoshandisa kubasa dzinombochengetwa kumba dzisina kuwachwa here? (cloth)

0 __ kwete
1 __ hongu

2.2.9 Mava nemakore mangani muchishandisa mercury (Hg years)

0 __ hazvina kumboitika
1 __ makore

2.3 Zvine chekuita nezvokudya (Diet)

2.4 Kudya kunosanganisira hove (Fish)

2.4.1 How frequently do you eat fish?

0 __ handisati ndambodya hove
1 __ kamwe chete pamwedzi
2 __ kamwe chete pasvondo
3 __ kamwe chete pazuva

2.4.2 Kana pari pamwe chete pazuva, munodya hove dzakawanda zvakadii?

2.4.2.1 ________ munodya kangana pazuva

2.4.3 Tiudze mhando dzehove dzamunodya nguva dzose, kana zvichiita taurai mhando yamunodya kunyanya

Zita rehove

2.4.3.1 ____________________
2.4.3.2 ____________________
2.4.3.3 ____________________
2.4.3.4 ____________________
2.4.3.5 ____________________
2.4.3.6 ____________________
2.4.3.7 ____________________
2.4.3.8 ____________________
2.4.3.9 ____________________

Please code the fishes like A, B, D, E, F, ...(Please use useful list of fish according to local habits)

2.4.4 Hove dzamunodya dzinobva kupi? (fish origin)

0 ___ kunzvimbo dziri kure nemughodhi
1 ___ munzizi kana madhamu anowana zvieredzwa zvinobva pamughodhi
9 ___ handizivi kwadzinobva, tinodzitenga pamusika

2.4.5 Mungatiudza here rwizi nenzvimbo kwamunobata hove dzamunodya? (fish catch)

A ___ kwete
B___ hongu, rwizi rwunonzi , dhamu rinonzi ________ ___ ________
(Please give the areas codes, like C, D, E, F ...)

2.5 Zvimwe zvakanangana nekudya

2.5.1 Tiudzei nzvimbo yamunowana mvura yenyu yokunwa ___________________ (Please give the areas codes, like C, D, E, F ...) (drinking water)

2.5.2 Munowanawo kudya kubva muzvipfuyo zvamunochengeta here zvakaita sehuku, madhadha nemazai acho? (chicken, eggs, ducks)

0 ___ kwete
1 ___ kamwe chete pamwedzi
2. ___ kamwe chete pasvondo
3. ___ kamwe chete pazuva

2.5.3 Munodya here nyama yezvipfuyo zvamunochengeta? (meat)

0 kwete
1 ___ kamwe chete pamwedzi
2. ___ kamwe chete pasvondo
3. ___ kamwe chete pazuva

2.5.4 Munodya here miriwo namafuruti zvinobva muminda yenyu? (veg, fruit)

0 kwete
1 ___ kamwe chete pamwedzi
2. ___ kamwe chete pasvondo
3. ___ kamwe chete pazuva

2.6 Zvinozorodza pfungwa

2.6.1 Munoputa here? (smoke)

0 ___ kwete
1 ___ nenguva dziri kure (midzanga 0-10 pazuva)
2 ___ zviri pakati napakati (midzanga 10-20 pazuva)
3 ___ Chaizvo (midzanga inopfuura 20 pazuva)

2.6.2 Munonwa doro here? (alk)

0 ___ kwete
1 ___ kamwe chete pamwedzi
2. ___ kamwe chete pasvondo
3. ___ kamwe chete pazuva

2.6.3 Munoshanda nepeturu kana paraffin here? (kero)

0 ___ kwete
1 ___ hongu

2.6.3.1 Kana zvirizvo, kubva rinhi kusvika rinhi? ______ (makore)

2.6.4 Munombobata mishonga yokuuraya zvipembenene kana mapise here? (pest-ins)

0 ___ kwete
1 ___ hongu

2.6.5 Munomboshandisa mishonga inotsvukisa here? (skin)

0 ___ kwete
1 ___ hongu

2.6.6 Upenyu hwenyu hwakamira sei panyaya yemari? (finacial)

0 ___ ☺ (hwakanaka)
1 ___ 😐 (pakati napakati)
2 ___ ☹ (hwakashata)

2.6.7 Mugere sei nevamwe? (shamwari, hama, mitambo nezvimwe zvakadaro.) (social)

0 ___ ☺ (hwakanaka)
1 ___ 😐 (pakati napakati)
2 ___ ☹ (hwakashata)

3 Zvinoshupa pabutano zvisinei nemercury

3.1.1 Date of interview:..............................

3.1.2 Name of the interviewer for this section:...

3.1.3 Code of the interviewer ___________
(please give every interviewer a code, like A,B,C)

3.2 Utano hwenyu wakanaka here? (healthy now)

0 ___ hongu
1 ___ kwete
zvikonzero? ____

3.3 Mune kupindwa nechando kana kudziya miviri here? (fever)

0 ___ hongu
1 ___ kwete

3.4 Makmborasikirwa nehuremu here mugore rapfuura? (weigth loss)

0 ___ hongu
1 ___ kwete

3.5 Makambokosora here kwenguva inodarika mwedzi mitatu? (cough)

0 ___ hongu
1 ___ kwete

3.6 Makamboita malaria here? (malaria)

0 ___ hongu
1 ___ kwete

3.6.1 Kana zvirizvo, makapedzisira rinhi kuita malaria? ______ (days or weeks or months or years)

3.7 Africa

3.7.1 Makamboita here chirwere chokurara? (sleeping)

0 ___ hongu
1 ___ kwete

3.7.2 Mune chirwere chomukondombera here? (HIV)

0 ___ hongu
1 ___ kwete
kubva rinhi ______ years

3.7.3 Makamborwara nechirwere chamaperembudzi here? (leprosy)
0 ____ hongu
1 ____ kwete

3.8 Makamboita here chimwe chezvirwere zvinopomerwana? (other inf. dis)

3.8.1 Chirwere chipi chacho ? ______________________

3.9 Makamboita here chirwere cheisvo? (kidney)
0 ____ hongu
1 ____ kwete

3.9.1 Chipi chacho ? ______________________

3.10 Makamboita here chirwere che hepatitis ? (hepatitis)
0 ____ hongu
1 ____ kwete

3.10.1 Chipi chacho? ______________________

3.11 Makamboita here zvirwere zvechipfuva zvakaita se asthma kana pneumonia)? (asthma/pneumonia)
0 ____ hongu
1 ____ kwete

3.11.1 Chipi chacho? ______________________

3.12 Makamboita here TB? (Tb)
0 ____ hongu
1 ____ kwete

3.12.1 Zvakaitika rinhi ? ____________ (days or weeks or months or years) ago

3.13 Makamboita here zvirwre zvezvipupununu zvakaita se epilepsy, stroke, Parkinson nezvimwe zvakadaro) kana kurwara nepfungwa? (neuro)
0 ____ hongu
1 ____ kwete

3.13.1 Zvipi zvacho? ______________________

3.14 Makambopinda mutsaona yemumigwagwa here uye makenda kuchipatara here ? (accident)
0____ kwete
1____ hongu asi yakanga isina kukurisisa (kusamboziva kwe hour rimwe chete)
2____ hongu uye yanga yakakura chaizvo (kusamboziva kwenguva inodarika hour rimwe chete)

3.14.1 Izvi zvakaitika rinhi ? ____________ (days or weeks or months or years) ago

3.15 Exclusion criteria from statistical evaluation

Severe neurological disease such as Parkinson, stroke or severe accident (brain injury), birth trauma, tetanus, polio, diabetes, hyperthyroidism or any acute severe disease, etc...
To be filled in by project doctor.
0 ____ No
1 ____ Yes
Why this individual should be excluded from the assessment:

____

3.16 Munoyamwisa here (vakadzi chete) (breastfeed)
0 ____ hongu
1 ____ kwete

3.17 Mune pamuviri here (vakadzi chete) (pregnant)
0 ____ hongu
1 ____ kwete

<u>4 Health Questions related to mercury exposure</u>

4.1.1 Date of interview:............................

4.1.2 Name of the interviewer for this section:..

4.1.3 **Code of the interviewer** ____________
(please give every interviewer a code, like A,B,C)

4.2 Chirwere chamaimbova nacho kana chamuinacho chiri kuwedzererwa here nemercury? (worsened)
0 _____ handishandisi mercury

1 _____ ndinoshandisa mercury asi hapana zviri kuchinja
2 ____ ndinoshandisa mercury uye urwere huri kuwedzera

4.3 Munofarira chikafu zvakadii? (appetite)

0 ____ ☺ zvakanyanya
1 ____ 😐 zviri pakati napakati
2 ____ ☹ zvishomanana

4.4 Makamboruza bvudzi here mugore rapfuura? (hair)

0 ____ nenguva dziri kure
1 ____ zviri pakati napakati
2 ____ ndiri kuruza zvakanyanya

4.5 Sleep disturbances

How do you feel after a usual night of sleep?
0 ____ ☺ ndinonzwa zvakanaka
1 ____ 😐 ndinonzwa zviri pakati napakati
2 ____ ☹ handinzwi zvakanaka

4.6 Munombonzwa here kuvavira kwesimbi mumukanwa ? (metallic taste)

0 ____ kwete
1 ____ kamwe chete pamwedzi
2. ____ kamwe chete pasvondo
3. ____ kamwe chete pazuva

4.7 Munotambudzika here nokuwandirwa nerute mumukanwa? (salivation)

0 ____ kwete
1 ____ kamwe chete pamwedzi
2. ____ kamwe chete pasvondo
3. ____ kamwe chete pazuva

4.8 Mune chirwere chenhetenwa here? (work tremor)

(Clinical Tremor Rating Scale)
0 ____ kwete
1 ____ hongu asi ndinokwanisa kushanda nokunanzerera
2 ____ hongu asi ndinokwanisa kuita zvose zvimwe ndichikangaisa nokuda kwe nhetemwa
3 ____ hongu vuye handikwanisisi kushanda mamwe mabasa saka ndiri mucheri weghoridhe. Handikwanisizve kuita mamwe mabasa omumba akaita sokuswatanudza hembe.
____hongu uye handikwanisi kuita mabasa okunze nokusanganisira basa remumba

4.9 Fatigue

Score to estimate the state of fatigue (Wessely S, Powell R: Fatigue syndrome)

4.9.1 Munoneta nokukasika here?

0 ____ senguva dzose
1 ____ zviri kuwedzera nokufamba kwenguva
2 ____ Zvanyanya pane zvazvakanga zviri makore apfuura

4.9.2 Munoda kuzorora zvakawedzerwa here?

0 ____ senguva dzose
1 ____ zviri kuwedzera nokufamba kwenguva
2 ____ Zvanyanya pane zvazvakanga zviri makore apfuura

4.9.3 Munonzwa kuneta nehope here?

0 ____ senguva dzose
1 ____ zviri kuwedzera nokufamba kwenguva
2 ____ Zvanyanya pane zvazvakanga zviri makore apfuura

4.9.4 Munokwanisa kutangidza chimwe chinhu here?

0 ____ senguva dzose
1 ____ zviri kuwedzera nokufamba kwenguva
2 ____ Zvanyanya pane zvazvakanga zviri makore apfuura

4.9.5 Munonzwa kushaya simba here?

0 ____ senguva dzose
1 ____ zviri kuwedzera nokufamba kwenguva
2 ____ Zvanyanya pane zvazvakanga zviri makore apfuura

4.9.6 Munonzwa simba munyama menyu ririshoma here?

0 ____ senguva dzose

1 ___ zviri kuwedzera nokufamba kwenguva
2 ___ Zvanyanya pane zvazvakanga zviri makore apfuura

4.9.7 Munonzwa kusasimba here?

0 ___ senguva dzose
1 ___ zviri kuwedzera nokufamba kwenguva
2 ___ Zvanyanya pane zvazvakanga zviri makore apfuura

4.9.8 Munokwanisa kutanga zvimwe zvinhu mozonete nokufamba kwenguva here?

0 ___ senguva dzose
1 ___ zviri kuwedzera nokufamba kwenguva
2 ___ Zvanyanya pane zvazvakanga zviri makore apfuura

4.9.9 Physical fatigue sum: __________ score sum (4.9.1-4.9.8)

4.9.10 Mune dambudziko here nokuramba muchifunga zvakadzama ?

0 ___ senguva dzose
1 ___ zviri kuwedzera nokufamba kwenguva
2 ___ Zvanyanya pane zvazvakanga zviri makore apfuura

4.9.11 Mune dambudziko here rokufunga zvakajeka

4.9.12 0 ___ senguva dzose

1 ___ zviri kuwedzera nokufamba kwenguva
2 ___ Zvanyanya pane zvazvakanga zviri makore apfuura

4.9.13 Munedambudziko here rokuwana mazvi kwawo pakutaura?

0 ___ senguva dzose
1 ___ zviri kuwedzera nokufamba kwenguva
2 ___ Zvanyanya pane zvazvakanga zviri makore apfuura

4.9.14 Munonzwa maziso enyu achiremerwa kana kurwadza here?

0 ___ senguva dzose
1 ___ zviri kuwedzera nokufamba kwenguva
2 ___ Zvanyanya pane zvazvakanga zviri makore apfuura

4.9.15 Munedambudziko rokukanganwa (kana kurangarira) here?

0 ___ senguva dzose
1 ___ zviri kuwedzera nokufamba kwenguva

4.9.16 2 ___ Zvanyanya pane zvazvakanga zviri makore apfuura

4.9.17 Mental fatigue sum: ___________ score sum (4.9.10-4.9.14)

4.10 Well being

4.10.1 Munombonzwa kusagadzikana here?

0 ___ aiwa
1 ___ kamwe chete pamwedzi
2 ___ kamwe chete pavhiki
3 ___ kamwe chete pazuva

4.10.2 Munomboshurukirwa here?

0 ___ aiwa
1 ___ kamwe chete pamwedzi
2 ___ kamwe chete pavhiki
3 ___ kamwe chete pazuva

4.10.3 Munomborohwa nehana here pasina kuvhunduka?

Feeling the heart beating
0 ___ aiwa
1 ___ kamwe chete pamwedzi
2 ___ kamwe chete pavhiki
3 ___ kamwe chete pazuva

4.10.4 Munombotemwa nemusoro here?

0 ___ aiwa
1 ___ kamwe chete pamwedzi
2 ___ kamwe chete pavhiki
3 ___ kamwe chete pazuva

4.10.5 Munombonzwa kuda kubudisa (kurutsa) here?

0 ___ aiwa
1 ___ kamwe chete pamwedzi
2 ___ kamwe chete pavhiki
3 ___ kamwe chete pazuva

4.10.6 Munombonzwa chiveve, kubayiwabayiwa, kana kurwadziwa kwenhengo dzemuviri yenyu here?

Mainly perioral dysesthesia and sensory impairment of the glove and-stocking type
0 ___ aiwa
1 ___ kamwe chete pamwedzi
2 ___ kamwe chete pavhiki
3 ___ kamwe chete pazuva

5 Clinical – neurological examination

5.1.1 Date of neurological examination:...............................

5.1.2 Name of the neurological examiner:...

5.1.3 Code of the examiner __ ______

5.2 Mouth and Teeth Conditions

5.2.1 Clinical signs of stomatitis

0 ___ No
1 ___ Yes

5.2.2 Clinical signs of gingivitis

0 ___ No
1 ___ Yes

5.2.3 Bluish discoloration of the gums

0 ___ No
1 ___ Slight
2 ___ Yes, obvious

5.2.4 How many teeth with dental fillings (Amalgam)?

0 ___ None
(n) ___ One or more → how many _______

5.2.5 Examination of the eyes:

0 ___ No changes
1 ___ Bluish colored iris ring
2 ___ Kayser-Fleischer ring

5.3 Walking

Person is asked to walk up and down, first with eyes open, then with eyes closed.

5.3.1 Ataxia of gait (walking)

Examiner is watching for signs of ataxia (Klockgether Score p 435)
0 ___ Absent
1 ___ Slight (ataxia only visible when walking on tandem or without visual feedback)
2 ___ Moderate (ataxia visible in normal walking; difficulties, when walking on tandem)
3 ___ Marked (broad-based, staggering gait; unable to walk on tandem)
4 ___ Severe (unable to walk without support; wheelchair bound)
5 ___ Most severe (bedridden)

5.3.2 Rigidity of gait (walking)

Examiner is watching the gait, the swing of the arms, general posture and rates
0 ___ Normal
1 ___ Mild diminution in swing while the patient is walking
2 ___ obvious diminution in swing suggesting shoulder rigidity
3 ___ Stiff gait with little or no arm swinging noticeable
4 ___ Rigid gait with arms slightly pronated; this would also include stopped-shuffling gait with propulsion and retropulsion

5.4 Standing

5.4.1 Tremor - finger to nose test

Person is asked to stand still, legs together arms outstretched. Eyes closed. Fingertip should touch the nose. Examiner is watching and rates the **tremor** (modified Clinical Tremor Rating Scale)

0 ___ None
1 ___ Slight to moderate (amplitude < 0,5 cm – 1cm); may be intermittent, may be intermittent
2 ___ Marked amplitude (1-2 cm)
3 ___ Severe amplitude (> 2 cm)

5.4.2 Dysmetria - finger to nose test

Person is asked to stand still, legs together - arms outstretched. Eyes closed. Fingertip should touch the nose. Examiner is watching and rates the dysmetria

0 ___ Normal
1 ___ Moderate pathologic
2 ___ Severe pathologic

5.4.3 Dysdiadochokinesis

Person is asked to twist hands very quickly (alternating movements of the wrists (Klockgether Score)

0 ___ Absent
1 ___ Slight (minimal slowness of alternating movements)
2 ___ Moderate (marked slowness of alternating movements)
3 ___ Severe (severe irregularity of alternating movements)
4 ___ most severe (inability to perform alternating movements)

5.4.4 Tremor – eye lid

Eyes closed. Examiner is watching and rates the **tremor** (Davao Pool score)

0 ___ None
1 ___ Slight
2 ___ Marked

5.5 Lying - Reflexes

Person is asked to lie on the examination bench.

5.5.1 Mentolabial reflex (Positive pyramidal sign)

0 ___ Negative
1 ___ Positive

5.5.2 Babinski reflex (Positive pyramidal signs)

0 ___ Negative
1 ___ Positive

5.5.3 Sucking reflex (Positive pyramidal signs)

0 ___ Negative
1 ___ Positive

5.5.4 Grasp reflex

0 ___ Negative
1 ___ Positive

5.5.5 PSR (quadrizeps reflex)

A No reflex
B Hyporeflexia
C Normal
D Hyperreflexia
E Clonus

5.5.6 BSR (bizeps brachii reflex)

A No reflex
B Hyporeflexia
C Normal
D Hyperreflexia
E Clonus

5.5.7 AR (Achilles reflex, ankle jerk)

A No reflex
B Hyporeflexia

C Normal
D Hyperreflexia
E Clonus

5.6 Lying – other tests

5.6.1 Intentional Tremor - heel-to-shin test

Person is asked to touch with his heel the knee of the other leg. Then to move with the heel along the shin to the foot. Repeat and do it with both sides. Eyes first open, then closed. Rate tremor during heel-to-shin test (Klockgether Score)

0 Absent
1 Slight (slight terminal tremor)
2 ____ Moderate (marked terminal tremor)
3 ___ Marked (kinetic tremor throughout intended movements)
4 ____ Severe (severe kinetic tremor heavily interfering with everyday life)
5 ____ Most severe (maximal form of kinetic tremor making intended movements impossible)

5.6.2 Ataxia - heel-to-shin test

Rate ataxia (Klockgether Score)

0 Absent
1 ____ Slight (slight hypermetria in heel-to-shin test)
2 ____ Moderate (hypermetria and slight ataxic performance of heel-to-shin test)
3 ____ Marked (marked swaying: unable to stand with feet together)
4 ____ Severe (pronounced ataxia in performing heel-to-shin test)
5 ____ Most severe (unable to perform heel-to-shin test)

5.6.3 Sensory disturbances

Sensory disturbances such as sensory impairment of the glove and-stocking type

0 ____ Absent
1 ____ Present

Comments ____________________

5.6.4 Bradykinesia

Rate your observation whether there was any sign of bradykinesia during the examination (slower active movements, absent or altered synkinesia of upper extremities during gait)

0 ____ Absent
1 ____ Present

5.7 Hypo-mimia

Rate your observation whether there you observed an hypo mimic expression of the face during the examination)

0 Absent
1 ____ Present

6 Specific Tests

6.1.1 Date of the specific test:.............................

6.1.2 Name of the tester:...

6.1.3 Code of the tester ___________

6.2 Memory Disturbances (Wechsler)

6.2.1 Forward digit span test (part of *Wechsler Memory Scale)*

Please repeat each column of numbers. Score longest series correctly repeated forward

	Score	Test
	4	6-4-3-9
	4	7-2-8-6
	3	4-2-7-3-1
	3	7-5-8-3-6
	2	6-1-9-4-7-3
	2	3-9-2-4-8-7
	1	5-9-1-7-4-2-3
	1	4-1-7-9-3-8-6
	0	5-8-1-9-2-6-4-7
	0	3-8-2-9-5-1-7-4

6.3 Match Box Test (from *MOT*)

Put **20 matches** on a table , half of each on one side of an open matchbox, approx. 15 cm away. Take the time until all matches are put into the box. Use left and right hand alternatively.
_______ seconds

6.4 Finger Tapping Test (from *MOT*)

Sitting at a table. Elbows should be placed on the table. Try to do as many points as possible on a piece of paper with a pencil. Count the amount of points within **10 seconds**.
. points

6.5 Frostig Score

Draw a line from one symbol to the other. Do not interrupt while drawing. Do not touch the lines.

Score: ____

Please connect with a pencil the symbols. Please try to stay within the lines. ??

F1

0-2

F2

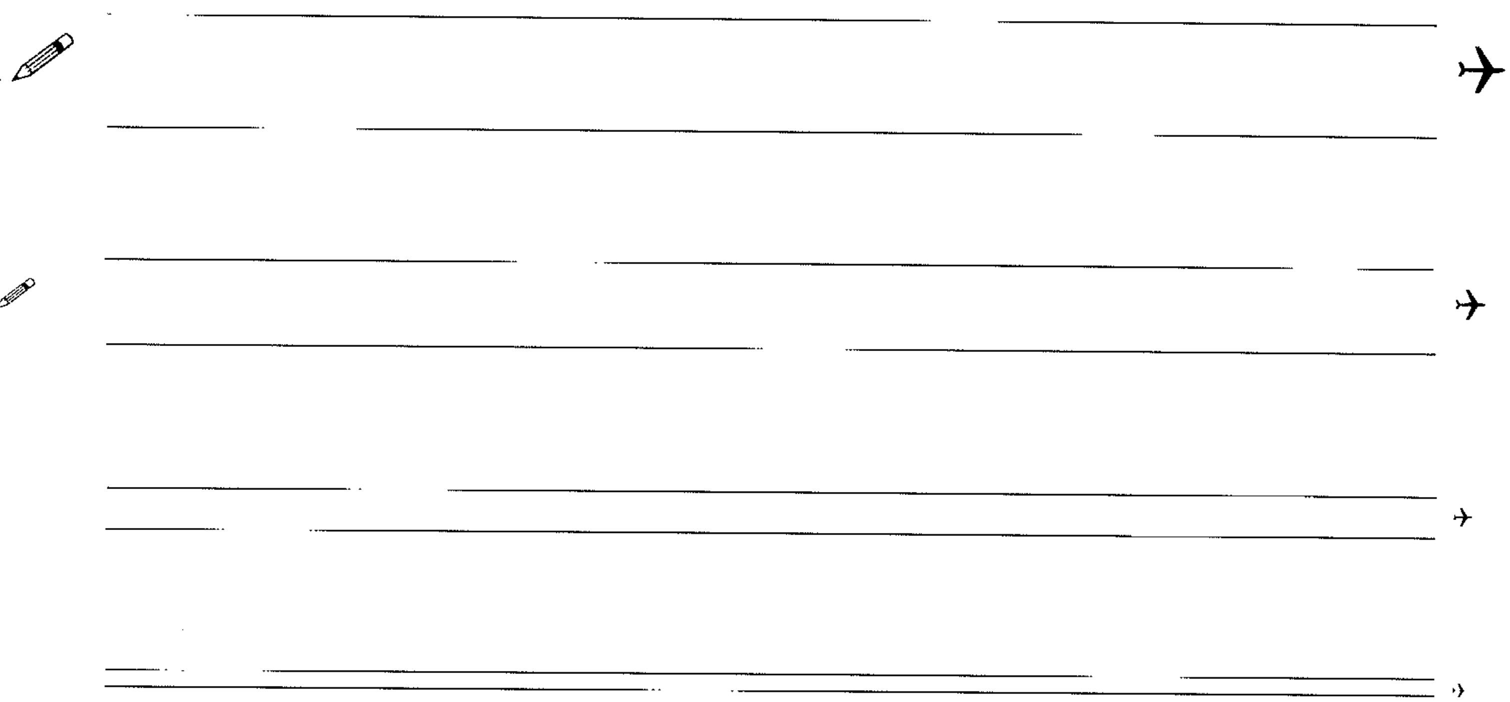
0-2

F3

0-2

F4

0-2

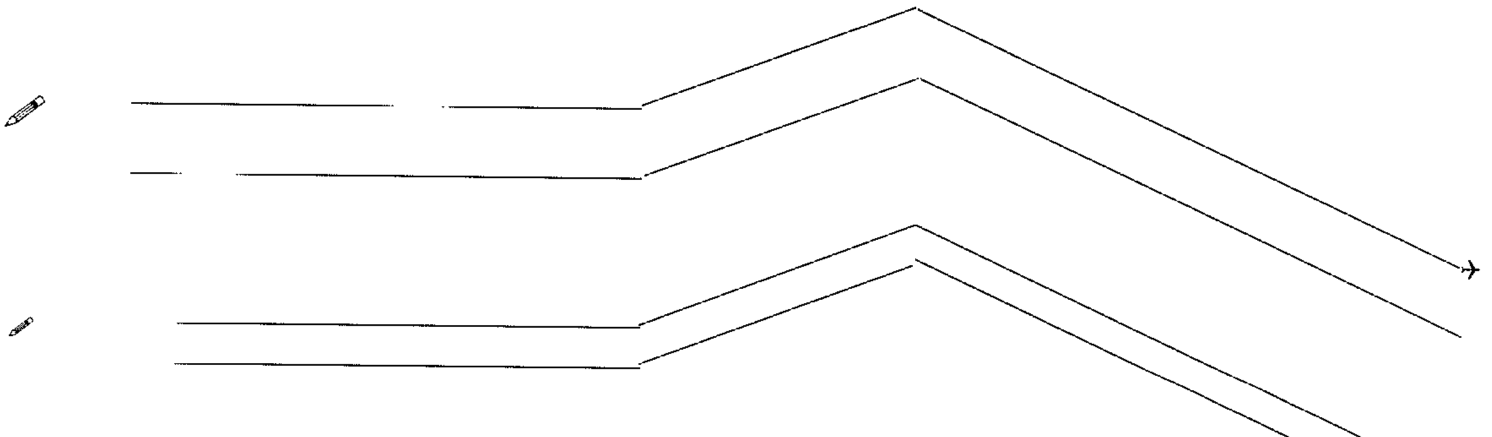


F5

0-2

F6

0-2



Please connect the symbols with a straight line.

F7

F8

0-2

6.6 Visual field test
left ____ cm
right ____ cm
base line ____ cm

6.7 Objective tremor assessment
Result ____________________________

6.8 Weight in ________kg

6.9 Height in _______ cm

7 Specimens

7.1.1 Date of the specimen...

7.1.2 Time of the specimen sampling..

7.1.3 Name of the specimen taker:............................

7.1.4 Code ___________

7.2 Blood **(EDTA-blood 10 ml)**
0 ____ Yes
1 ____ No

7.3 Urine **(spontaneous urine sample 10 ml)**
0 ____ Yes
1 ____ No

7.3.1 Proteinuria
0 ____ negative
1 ____ positive ____ score

7.3.2 Urine **total mercury (field test) (additional)**
____ Result ____ unit

7.4 Hair
0 ____ Yes, sample collected
1 ____ No

7.5 Others (breast milk)
0 ____ Yes, sample collected
1 ____ No sample

8 Laboratory Analysis Results

Material/test
Result
Unit

8.1 Blood

8.1.1 Total mercury

______ µg/l

8.1.2 Methyl-mercury

_____ µg/l

8.1.3 Selenium

_____ µg/l

8.2 Urine

8.2.1 Total mercury

_____ µg/l

8.2.2 Total mercury / g crea

______ µg / g crea

8.2.3 Methyl mercury

_____ µg/l

8.2.4 Methyl mercury / g crea

_____ µg/ g crea

8.3 Hair

8.3.1 Total mercury

_____ µg / g

8.3.2 Methyl mercury

_____ µg / g

8.4 Others (breast milk)

8.4.1 Total mercury

_____ µg/l

9 Comments:

____
____
____
____
____
____
____

10 Medical Score Sum

Test	Score Points	Results
Anamnestic data		
Metallic taste	0/1	
Excessive salivation	0/1	
Tremor at work	0/1	
Sleeping problems at night	0/1	
Health problems worsened since Hg exposed	0/1	
Clinical data		
Bluish coloration of gingiva	0/1	
Ataxia of gait	0/1	
Finger to nose tremor	0/1	
Dysdiadochokinesis	0/1	
Heel to knee ataxia	0/1	
Heel to knee tremor	0/1	
Mento labial reflex	0/1	
Proteinuria [1]	0/1	
Neuropsychological tests		
Memory test [2]	0/1/2	
Matchbox test [3]	0/1/2	
Frostig test [4]	0/1/2	
Tapping test [5]	0/1/2	
Maximum	21	

10.1.1 Medical score sum ___________

[1] Proteinuria 1 = more then trace, 0 = 0 or
[2] Memory test: 2 = score 0, 1 = score 1-2, 0 = score 3-4
[3] Matchbox test: 2 = 21 seconds or more, 1 = 16-20 seconds, 0 = 0-15 seconds
[4] Frostig test: 2 = 0-9 correct answers, 1 = 10-12 correct answers, 0 = 13-16 correct answers
[5] Tapping test: 2 = 0-53 dots, 1= 54-64 dots, 0 = 65 or more dots

11 Decision for the diagnosis of a "chronic mercury intoxication"

11.1 Threshold limits for mercury

	Hg-blood (µg/l)	Hg-urine (µg/l)	Hg-urine (µg/g crea)	Hg-hair (µg/g)
HBM I	5	7	5	
HBM II	15	25	20	5 (in analogy)
WHO		50		7
BAT for metallic and inorganic Hg	25	100		
BAT for organic Hg	100			
BEI (Biological exposure index)	15 (after working)		35 (before working)	

Table: Toxicologically established threshold limits for mercury in blood, urine and hair (HBM = Human Bio-Monitoring; BAT = Biologischer Arbeitsstoff-Toleranzwert; BEI = Biological Exposure Indices)

11.2 Decision for the diagnosis of a "chronic mercury intoxication"

		Medical Score Sum		
		0 – 4	5 – 9	10 - 19
Hg in all biomonitors	< HBM I	–	–	–
Hg at least in one biomonitor	> HBM I	–	–	+
	> HBM II	–	+	+
	> BAT	+	+	+

Table: Decision for the diagnosis "chronic mercury intoxication"
Intoxication

________ no
________ yes

Appendix 3

Zimbabwe clinical main data

ID-No.	Area	Occupation	Hg-blood [µg/L]	Hg-urine [µg/L]	Hg-urine [µg/g crea]	inorg Hg [µg/g hair]	MeHg [µg/g hair]	tot-Hg [µg/g hair]	medical score sum	intox
1	Tix Mine	mineral processor	37.40	5.83	51.41	12.35	2.35	14.70	5	intox
2	Tix Mine	mineral processor	21.10	31.99	16.38	3.91	0.11	4.02	8	intox
3	Tix Mine	mineral processor	8.80	146.24	40.04	2.49	0.30	2.79	5	intox
4	Kadoma town	gold smelter	51.60	275.50	242.33	13.57	0.94	14.52	9	intox
5	Tix Mine	mineral processor	21.10	50.64	79.95	10.20	0.35	10.55	5	intox
6	Tix Mine	mineral processor	18.40	20.09	10.65	2.84	0.14	2.98	5	intox
7	Tix Mine	gold smelter	28.10	15.61	134.11	---	---	---	4	intox
8	Tix Mine	gold smelter	9.36	138.05	54.90	95.62	16.56	112.18	6	intox
9	Tix Mine	gold smelter	39.20	96.35	60.15	33.68	0.18	33.86	2	intox
10	Tix Mine	gold smelter	20.00	11.78	76.10	19.00	0.89	19.89	4	not intox
11	Tix Mine	gold smelter	18.10	55.66	30.30	---	---	---	4	not intox
12	Tix Mine	mineral processor	10.24	13.30	36.94	69.94	5.47	75.42	4	not intox
13	Tix Mine	gold smelter	27.00	86.31	80.86	7.02	0.55	7.57	5	intox
14	Tix Mine	gold smelter	32.60	271.20	106.84	3.60	2.47	6.06	9	intox
15	Tix Mine	gold smelter	30.10	97.67	52.51	4.44	5.46	9.90	8	intox
16	Tix Mine	gold smelter	8.06	25.54	13.87	4.26	0.80	5.06	6	intox
17	Tix Mine	gold smelter	9.00	7.35	3.17	1.03	2.59	3.61	8	not intox
18	Tix Mine	school child working	14.60	56.65	92.43	2.36	3.10	5.46	6	intox
19	Tix Mine	school child working	3.50	10.17	17.26	---	---	---	6	---
20	Tix Mine	mineral processor	18.60	17.53	16.47	2.94	1.77	4.71	4	not intox
21	Tix Mine	school child working	1.23	4.77	5.88	0.38	0.32	0.71	8	---
22	Tix Mine	gold smelter	28.80	249.75	283.00	19.96	0.60	20.56	4	intox
23	Tix Mine	other job	1.66	1.63	0.87	0.29	0.09	0.39	4	not intox
24	Tix Mine	former miner (mining area)	2.38	0.80	0.37	0.45	0.26	0.71	4	not intox
25	Kadoma town	former miner (mining area)	2.09	2.01	0.67	0.36	0.29	0.65	9	not intox
26	Tix Mine	former miner (mining area)	5.22	0.10	0.10	---	---	---	---	---
27	Tix Mine	gold smelter	31.00	3.81	29.35	3.72	5.57	9.29	---	intox
28	Tix Mine	former miner (mining area)	3.78	5.50	46.18	0.45	0.77	1.23	3	not intox
29	Tix Mine	gold smelter	74.80	9.12	3.94	16.51	9.73	26.24	---	intox
30	Brompton Mine	gold smelter	14.04	4.28	36.93	0.57	1.43	2.00	5	intox
31	Brompton Mine	gold smelter	18.80	1.32	10.42	3.03	0.08	3.11	---	---
32	Tix Mine	school child not working	7.52	70.53	56.41	1.07	0.19	1.26	7	intox
33	Tix Mine	gold smelter	17.00	136.46	105.15	1.80	1.13	2.93	3	intox

34	Tix Mine	school child not working	5.54	19.26	40.57	1.39	0.50	1.89	5	intox
35	Tix Mine	school child working	16.16	16.76	82.68	2.81	0.56	3.37	6	intox
36	Tix Mine	gold smelter	6.16	0.78	1.54	1.19	0.07	1.26	12	intox
37	Tix Mine	gold smelter	3.86	5.02	4.61	0.73	0.64	1.37	6	not intox
38	Tix Mine	school child working	11.28	116.28	66.19	---	---	---	5	intox
39	Tix Mine	school child not working	5.54	1.87	4.13	0.63	1.40	2.03	9	not intox
40	Tix Mine	gold smelter	14.84	190.74	105.22	1.69	0.38	2.06	7	intox
41	Tix Mine	gold smelter	13.52	54.49	20.67	0.96	0.70	1.66	7	intox
42	Tix Mine	gold smelter	7.52	46.55	26.70	1.62	0.77	2.39	6	intox
43	Tix Mine	school child working	1.00	1.15	0.79	1.05	0.37	1.42	6	---
44	Tix Mine	gold smelter	11.56	40.51	70.96	2.48	0.52	2.99	10	intox
45	Tix Mine	mineral processor	10.32	12.38	14.41	2.56	0.62	3.18	3	not intox
46	Tix Mine	miner	14.00	17.06	16.25	2.42	0.05	2.48	5	not intox
47	Tix Mine	gold smelter	39.00	3.21	27.41	18.39	0.00	18.08	11	intox
48	Tix Mine	gold smelter	10.16	19.74	14.23	---	---	---	5	not intox
49	Tix Mine	school child not working	4.70	13.38	29.18	1.31	1.23	2.54	5	intox
50	Tix Mine	gold smelter	33.30	401.83	124.35	6.37	0.49	6.86	6	intox
51	Tix Mine	gold smelter	7.16	44.43	35.69	---	---	---	5	intox
52	Tix Mine	mineral processor	4.28	40.51	25.90	1.28	1.53	2.81	6	intox
53	Tix Mine	school child not working	5.50	9.62	11.06	2.08	0.73	2.81	6	not intox
54	Tix Mine	mineral processor	2.14	6.70	3.34	0.88	0.33	1.22	2	not intox
55	Tix Mine	gold smelter	4.98	207.78	65.76	1.90	0.53	2.43	5	intox
56	Tix Mine	gold smelter	11.16	80.81	64.19	2.45	1.25	3.70	7	intox
57	Tix Mine	gold smelter	7.84	9.95	14.39	4.48	0.93	5.42	3	not intox
58	Tix Mine	miner	11.00	36.64	19.29	1.95	1.24	3.19	1	not intox
59	Tix Mine	other job	3.52	1.84	0.96	0.51	0.27	0.78	1	not intox
60	Tix Mine	other job	1.85	1.55	1.04	0.76	0.08	0.84	2	not intox
61	Tix Mine	other job	1.59	3.91	2.29	1.99	0.00	1.97	7	not intox
62	Tix Mine	mineral processor	2.09	35.86	13.16	0.74	0.12	0.86	7	intox
63	Tix Mine	school child working	6.94	18.37	10.78	1.30	1.22	2.52	8	not intox
64	Tix Mine	school child working	1.93	196.88	176.46	3.75	0.76	4.51	4	intox
65	Tix Mine	gold smelter	4.60	63.14	23.25	19.21	4.25	23.46	4	not intox
66	Tix Mine	gold smelter	15.52	45.71	63.97	4.46	2.66	7.12	4	not intox
67	Tix Mine	gold smelter	19.90	186.85	82.27	9.60	0.83	10.43	6	intox

68	Tix Mine	gold smelter	13.92	109.60	57.09	2.40	0.66	3.06	6	intox
69	Tix Mine	gold smelter	11.84	86.12	27.83	1.15	0.47	1.61	6	intox
70	Tix Mine	gold smelter	12.84	12.35	9.62	1.09	3.37	4.45	4	not intox
71	Tix Mine	other job	8.18	2.65	4.55	2.85	0.00	2.73	5	not intox
72	Tix Mine	gold smelter	11.84	17.51	23.51	0.60	0.91	1.52	7	intox
73	Tix Mine	former miner (mining area)	6.42	10.43	5.21	0.79	0.86	1.65	6	not intox
74	Tix Mine	mineral processor	8.96	4.01	4.32	4.35	0.70	5.05	7	intox
75	Tix Mine	school child not working	4.48	18.87	15.58	---	---	---	3	not intox
76	Tix Mine	school child working	22.40	292.55	184.05	1.91	2.14	4.05	4	intox
77	Tix Mine	school child not working	8.16	22.69	35.46	1.99	1.12	3.11	7	intox
78	Tix Mine	school child not working	6.04	17.43	18.81	0.98	2.44	3.42	4	not intox
79	Tix Mine	mineral processor	16.68	16.77	16.81	1.93	5.21	7.14	10	intox
80	Amberose Mine	mineral processor	5.14	7.90	11.07	3.98	0.76	4.75	4	not intox
81	Amberose Mine	gold smelter	28.20	72.90	116.79	7.41	0.30	7.71	3	intox
82	Tix Mine	worker at cyanidation plant	10.28	7.63	9.53	1.73	0.23	1.95	9	not intox
83	Tix Mine	gold smelter	3.86	9.70	13.99	0.89	0.68	1.57	8	not intox
84	Amberose Mine	mineral processor	10.84	56.44	71.27	2.02	0.29	2.31	9	intox
85	Amberose Mine	gold smelter	15.28	75.50	59.85	3.39	0.15	3.54	5	intox
86	Tix Mine	gold smelter	44.60	220.74	124.08	12.43	2.63	15.06	4	intox
87	Tix Mine	gold smelter	25.90	38.19	49.67	1.39	1.67	3.06	4	intox
88	Tix Mine	other job	0.67	0.44	0.33	0.53	0.12	0.65	8	not intox
89	Kadoma town	other job	3.02	3.93	1.73	3.03	0.66	3.69	3	not intox
90	Tix Mine	other job	1.93	130.19	96.07	0.38	0.36	0.74	3	intox
91	Tix Mine	gold smelter	2.69	13.96	5.63	---	---	---	5	not intox
92	Amberose Mine	mineral processor	5.32	70.04	28.15	3.10	2.05	5.15	7	intox
93	Amberose Mine	former miner (mining area)	4.12	36.31	20.03	1.07	0.30	1.37	5	intox
94	Amberose Mine	gold smelter	42.60	165.68	137.07	2.05	10.95	13.00	6	intox
95	Amberose Mine	school child not working	4.08	15.72	15.68	1.49	0.98	2.47	6	not intox
96	Amberose Mine	school child not working	4.60	21.50	12.25	---	---	---	3	not intox
97	Tix Mine	gold smelter	3.52	19.81	11.47	1.23	0.41	1.65	9	not intox
98	Tix Mine	gold smelter	6.92	2.16	4.08	1.13	0.74	1.87	7	not intox
99	Tix Mine	gold smelter	5.10	68.74	29.14	0.88	0.38	1.26	6	intox

100	Tix Mine	gold smelter	28.60	22.07	11.00	1.40	6.42	7.83	4	intox
101	Tix Mine	former miner (mining area)	3.64	3.37	1.61	1.39	0.02	1.41	8	not intox
102	Tix Mine	former miner (mining area)	55.00	96.24	31.31	2.04	6.90	8.95	6	intox
103	Amberose Mine	former miner (mining area)	19.90	361.74	96.41	4.28	2.17	6.45	3	intox
104	Amberose Mine	gold smelter	25.00	119.14	66.14	---	---	---	7	intox
105	Amberose Mine	gold smelter	29.20	383.69	137.61	5.42	0.24	5.67	7	intox
106	Amberose Mine	gold smelter	79.20	326.13	139.53	---	---	---	4	intox
107	Amberose Mine	gold smelter	21.00	3.63	15.89	2.75	2.21	4.95	4	not intox
108	Amberose Mine	former miner (mining area)	9.40	8.85	10.04	1.15	1.35	2.49	4	not intox
109	Amberose Mine	gold smelter	7.16	44.99	8.87	2.81	0.28	3.09	2	not intox
110	Amberose Mine	other job	4.36	4.50	1.65	0.99	1.01	2.00	1	not intox
111	Amberose Mine	other job	3.58	15.09	10.57	4.02	0.00	3.96	7	not intox
112	Amberose Mine	former miner (mining area)	3.77	17.90	15.56	1.68	0.12	1.80	3	not intox
113	Amberose Mine	mineral processor	12.00	18.48	39.39	3.86	0.70	4.57	6	intox
114	Tix Mine	gold smelter	6.74	18.70	19.36	1.16	2.68	3.84	9	not intox
115	Tix Mine	gold smelter	6.62	41.90	27.56	7.64	2.77	10.41	8	intox
116	Amberose Mine	gold smelter	97.60	592.78	196.45	12.48	0.48	12.96	2	intox
117	Amberose Mine	former miner (mining area)	5.62	10.69	8.66	13.78	1.10	14.88	8	intox
118	Amberose Mine	school child working	36.40	868.04	409.41	13.37	5.86	19.23	6	intox
119	Amberose Mine	other job	7.08	5.38	2.63	0.42	1.62	2.04	7	not intox
120	Amberose Mine	gold smelter	4.14	2.51	2.30	1.13	1.57	2.69	9	not intox
121	Amberose Mine	school child working	9.64	15.30	31.33	0.85	2.03	2.88	7	intox
122	Amberose Mine	school child working	24.70	97.60	97.62	4.73	0.22	4.95	3	not intox
123	Amberose Mine	school child working	56.20	203.89	144.83	9.70	0.15	9.85	4	intox
124	Amberose Mine	school child working	100.80	941.89	666.87	25.38	3.99	29.37	7	intox
125	Amberose Mine	school child working	24.00	2.20	0.83	1.64	0.20	1.84	6	intox
126	Amberose Mine	school child working	48.00	37.31	113.06	11.88	3.42	15.30	8	intox
127	Amberose Mine	school child working	55.00	41.58	165.66	49.04	3.93	52.96	10	intox
128	Amberose Mine	school child not working	5.84	21.94	16.71	---	---	---	3	not intox
129	Amberose	gold smelter	8.38	3.56	15.20	1.85	0.00	1.77	3	not

	Mine									intox
130	Amberose Mine	gold smelter	25.70	32.63	56.95	5.08	1.75	6.83	1	intox
131	Amberose Mine	gold smelter	60.80	9.24	63.16	13.23	5.33	18.56	9	intox
132	Kadoma town	gold smelter	5.62	17.56	10.99	3.09	0.12	3.22	5	not intox
133	Amberose Mine	gold smelter	41.60	4.09	51.06	6.25	3.10	9.35	6	intox
134	Glasgow Mine	gold smelter	22.80	90.35	102.13	9.84	2.90	12.73	8	intox
135	Glasgow Mine	gold smelter	14.24	226.80	41.03	3.15	0.28	3.43	7	intox
136	Glasgow Mine	gold smelter	8.64	21.36	13.06	2.86	0.98	3.84	9	not intox
137	Glasgow Mine	gold smelter	41.10	156.21	99.21	7.22	0.99	8.21	5	intox
138	Glasgow Mine	gold smelter	21.90	142.02	71.68	---	---	---	6	intox
139	Glasgow Mine	gold smelter	6.76	25.87	22.25	3.39	1.06	4.45	7	intox
140	Glasgow Mine	gold smelter	80.40	228.35	104.03	24.37	12.15	36.52	7	intox
141	Glasgow Mine	gold smelter	29.20	188.22	120.54	18.28	4.58	22.86	7	intox
142	Glasgow Mine	gold smelter	9.12	11.78	24.71	3.81	0.90	4.71	4	not intox
143	Glasgow Mine	gold smelter	22.80	19.54	47.65	7.74	1.70	9.43	12	intox
144	Glasgow Mine	gold smelter	34.70	214.15	127.22	2.66	14.35	17.01	9	intox
145	Kadoma town	gold smelter	29.80	313.60	210.61	---	---	---	8	intox
146	Glasgow Mine	other job	---	26.89	25.93	2.90	0.98	3.88	3	not intox
147	Glasgow Mine	gold smelter	48.00	265.15	127.53	12.46	4.17	16.63	6	intox
148	Glasgow Mine	gold smelter	45.60	1530.32	547.42	87.45	0.55	87.99	5	intox
149	Glasgow Mine	gold smelter	13.88	53.69	58.50	4.59	0.29	4.89	6	intox
150	Glasgow Mine	gold smelter	---	321.06	191.67	56.85	6.44	63.29	7	intox
151	Glasgow Mine	gold smelter	45.60	342.50	161.21	---	---	---	2	intox
152	Glasgow Mine	gold smelter	41.00	396.48	154.13	56.88	13.10	69.99	4	intox
153	Glasgow Mine	gold smelter	---	46.19	19.95	---	---	---	5	intox
154	Glasgow Mine	gold smelter	---	436.80	219.16	24.28	2.19	26.47	8	intox
155	Summit Mine	gold smelter	33.90	79.21	78.37	16.08	6.05	22.12	5	intox
156	Summit Mine	gold smelter	30.10	30.53	69.26	12.73	3.76	16.48	2	intox
157	Summit Mine	gold smelter	3.56	41.89	8.31	---	---	---	6	intox

158	Summit Mine	gold smelter	19.30	18.40	13.82	---	---	---	3	not intox
159	Summit Mine	gold smelter	29.90	67.24	43.10	5.24	0.02	5.26	7	intox
160	Summit Mine	gold smelter	33.70	254.65	280.70	18.58	2.30	20.89	9	intox
161	Summit Mine	gold smelter	61.40	50.31	45.91	---	---	---	4	intox
162	Summit Mine	school child working	5.14	3.10	13.15	---	---	---	8	not intox
163	Summit Mine	former miner (mining area)	4.40	37.91	14.02	2.73	0.07	2.80	3	not intox
164	Summit Mine	school child working	5.26	29.22	31.09	3.93	0.09	4.03	6	intox
165	Summit Mine	gold smelter	30.10	16.59	27.21	9.74	3.41	13.15	3	intox
166	Lilly Mine	other job	4.96	17.40	19.84	12.28	3.11	15.39	3	not intox
167	Lilly Mine	school child not working	1.28	13.23	6.68	0.32	0.09	0.42	4	not intox
168	Lilly Mine	farmer	3.27	85.33	17.27	4.57	0.55	5.13	2	not intox
169	Lilly Mine	gold smelter	16.20	377.20	214.89	24.23	7.33	31.56	3	intox
170	Lilly Mine	gold smelter	5.70	26.08	50.81	---	---	---	6	intox
171	Lilly Mine	former miner (mining area)	6.14	99.68	88.92	---	---	---	6	intox
172	Lilly Mine	former miner (mining area)	4.12	18.48	18.77	2.03	0.51	2.54	6	not intox
173	Lilly Mine	gold smelter	4.19	274.21	112.88	---	---	---	9	intox
174	Jani Mine	gold smelter	0.60	0.48	0.19	0.40	0.12	0.52	1	not intox
175	King Chim Mine	school child working	3.80	5.80	3.48	1.52	0.14	1.66	3	not intox
176	King Chim Mine	gold smelter	7.32	71.83	23.62	27.42	2.65	30.07	8	intox
177	Lilly Mine	gold smelter	68.20	168.21	264.52	---	---	---	6	intox
178	Jani Mine	gold smelter	6.48	59.86	19.52	5.24	0.80	6.04	8	intox
179	Jani Mine	gold smelter	12.08	28.16	17.66	0.53	0.43	0.96	8	intox
180	Jani Mine	gold smelter	8.12	71.13	25.84	0.97	0.73	1.69	3	not intox
181	Jani Mine	gold smelter	7.14	17.20	21.64	0.50	0.46	0.96	8	intox
182	Jani Mine	gold smelter	2.74	13.29	11.50	0.82	0.43	1.25	5	not intox
183	Jani Mine	gold smelter	9.92	61.18	26.54	---	---	---	13	intox
184	Jani Mine	gold smelter	8.76	21.04	37.71	1.27	0.25	1.52	9	intox
185	Jani Mine	gold smelter	1.72	14.47	9.64	0.83	0.21	1.04	8	not intox
186	Jani Mine	gold smelter	2.81	7.66	2.37	0.43	2.00	2.43	4	not intox
187	Jani Mine	gold smelter	1.23	29.61	20.23	---	---	---	5	intox
188	Jani Mine	gold smelter	3.18	0.90	0.89	0.42	0.84	1.25	9	not intox
189	Jani Mine	gold smelter	2.55	2.14	1.29	0.99	1.74	2.73	6	not intox
190	Jani Mine	gold smelter	4.22	4.57	3.56	2.42	0.14	2.56	9	not

										intox
191	Jani Mine	gold smelter	2.11	8.40	4.48	0.99	0.12	1.11	11	intox
192	Jani Mine	gold smelter	1.12	1.70	1.07	0.76	0.28	1.04	6	not intox
193	Jani Mine	former miner (mining area)	2.97	2.60	2.06	0.50	0.29	0.79	12	not intox
194	Jani Mine	gold smelter	1.62	6.35	4.04	0.35	0.22	0.57	8	not intox
195	Jani Mine	gold smelter	14.28	43.23	35.50	0.78	0.32	1.10	5	intox
196	Jani Mine	gold smelter	1.96	15.56	4.29	0.49	0.37	0.86	2	not intox
197	Jani Mine	gold smelter	6.04	109.24	25.05	1.17	0.81	1.98	7	intox
198	Jani Mine	former miner (mining area)	2.82	17.09	9.11	0.81	0.57	1.38	9	not intox
199	Jani Mine	gold smelter	5.16	39.21	18.50	0.87	0.34	1.21	4	not intox
200	Jani Mine	school child working	2.42	25.54	27.11	0.32	0.13	0.45	7	intox
201	Jani Mine	gold smelter	3.15	57.54	25.73	1.74	0.24	1.99	9	intox
202	Amberose Mine	former miner (mining area)	12.80	19.84	11.39	11.09	5.11	16.20	4	not intox
203	Amberose Mine	school child not working	4.44	18.02	11.01	0.99	0.84	1.83	4	not intox
204	Amberose Mine	gold smelter	4.48	2.92	6.46	0.98	0.95	1.93	3	not intox
205	Amberose Mine	gold smelter	2.84	90.64	33.11	0.87	0.30	1.16	6	intox
206	Amberose Mine	other job	2.27	18.73	6.55	0.79	0.27	1.06	3	not intox
207	Amberose Mine	former miner (mining area)	3.92	27.59	16.70	1.63	0.34	1.96	4	not intox
208	Amberose Mine	former miner (mining area)	9.28	15.45	7.16	12.51	3.44	15.95	3	not intox
209	Amberose Mine	former miner (mining area)	9.48	45.29	21.82	1.81	1.34	3.16	4	not intox
210	Amberose Mine	gold smelter	7.00	55.25	35.27	1.61	0.53	2.14	8	intox
211	Amberose Mine	gold smelter	7.38	3.93	24.47	4.33	0.85	5.18	11	intox
212	Amberose Mine	former miner (mining area)	3.70	6.43	8.09	0.42	0.41	0.83	5	not intox
213	Amberose Mine	school child working	3.44	8.24	10.16	1.02	0.34	1.36	10	intox
214	Amberose Mine	other job	2.40	40.85	16.04	1.70	0.13	1.83	4	not intox
215	Amberose Mine	other job	1.38	4.78	2.05	0.46	0.97	1.43	9	not intox
216	Amberose Mine	other job	1.85	17.63	7.36	---	---	---	9	not intox
217	Amberose Mine	other job	7.86	10.25	6.18	0.35	0.80	1.15	7	not intox
218	Amberose Mine	other job	2.11	2.87	3.30	0.66	0.47	1.13	5	not intox
219	Chikwaka control	farmer	0.24	0.10	0.10	0.025	---	0.06	5	not intox
220	Chikwaka	other job	0.24	0.10	0.10	0.025	---	0.08	2	not

	control									intox
221	Chikwaka control	other job	0.56	0.10	0.10	0.025	---	0.17	2	not intox
222	Chikwaka control	other job	0.75	0.10	0.10	0.025	---	0.07	4	not intox
223	Chikwaka control	farmer	0.32	0.10	0.10	0.025	---	0.03	5	not intox
224	Chikwaka control	school child not working	0.29	0.10	0.10	---	---	---	7	not intox
225	Chikwaka control	farmer	0.45	0.10	0.10	0.025	---	0.09	6	not intox
226	Chikwaka control	farmer	0.21	0.10	0.10	0.025	---	0.04	6	not intox
227	Chikwaka control	former miner (control area)	0.88	0.10	0.10	0.025	---	0.06	5	not intox
228	Chikwaka control	former miner (control area)	0.75	1.90	1.73	0.09	0.11	0.20	4	not intox
229	Chikwaka control	farmer	0.43	0.26	0.17	0.07	0.09	0.16	6	not intox
230	Chikwaka control	farmer	0.59	0.10	0.10	0.025	---	0.11	6	not intox
231	Chikwaka control	other job	0.10	0.10	0.10	---	---	---	.	not intox
232	Chikwaka control	school child not working	0.48	0.10	0.10	---	---	---	3	not intox
233	Chikwaka control	school child not working	0.24	0.10	0.10	0.025	---	0.02	9	not intox
234	Chikwaka control	school child not working	0.40	0.10	0.10	0.025	---	0.05	5	not intox
235	Chikwaka control	other job	0.32	0.10	0.10	0.025	---	0.04	5	not intox
236	Chikwaka control	farmer	0.24	0.10	0.10	---	---	---	5	not intox
237	Chikwaka control	other job	0.56	0.10	0.10	---	---	---	3	not intox
238	Chikwaka control	farmer	0.64	1.00	0.36	0.77	0.24	1.01	5	not intox
239	Chikwaka control	farmer	0.61	0.10	0.10	0.025	---	0.21	7	not intox
240	Chikwaka control	farmer	0.61	0.10	0.10	0.025	---	0.01	6	not intox
241	Chikwaka control	other job	0.37	0.10	0.10	0.025	---	0.10	5	not intox
242	Chikwaka control	farmer	0.64	0.76	0.61	0.025	---	0.08	6	not intox
243	Chikwaka control	school child not working	0.64	0.10	0.10	0.06	0.21	0.27	2	not intox
244	Chikwaka control	other job	0.24	0.10	0.10	0.025	---	0.07	.	not intox
245	Chikwaka control	farmer	0.10	0.10	0.10	0.025	---	0.02	7	not intox
246	Chikwaka control	other job	0.10	0.10	0.10	0.025	---	0.03	6	not intox
247	Chikwaka control	school child not working	1.88	0.10	0.10	0.025	---	0.30	8	not intox
248	Chikwaka control	other job	0.29	0.10	0.10	0.025	---	0.13	4	not intox

249	Chikwaka control	school child not working	0.10	0.10	0.10	0.025	---	0.05	8	not intox
250	Chikwaka control	other job	0.10	0.10	0.10	0.025	---	0.04	4	not intox
251	Chikwaka control	school child not working	0.21	0.25	0.12	---	---	---	5	not intox
252	Chikwaka control	school child not working	0.59	0.10	0.10	---	---	---	10	not intox
253	Chikwaka control	farmer	0.56	0.10	0.10	0.025	---	0.30	5	not intox
254	Chikwaka control	farmer	0.69	0.10	0.10	0.025	---	0.06	6	not intox
255	Chikwaka control	farmer	0.43	0.10	0.10	0.025	---	0.09	4	not intox
256	Chikwaka control	other job	0.10	0.10	0.10	0.025	---	0.07	9	not intox
257	Chikwaka control	school child not working	0.10	0.10	0.10	0.025	---	0.04	5	not intox
258	Chikwaka control	school child not working	0.10	0.10	0.10	---	---	---	4	not intox
259	Chikwaka control	farmer	0.27	1.81	1.09	---	---	---	6	not intox
260	Chikwaka control	school child not working	0.69	0.10	0.10	---	---	---	4	not intox
261	Chikwaka control	other job	0.27	0.71	0.41	0.025	---	0.03	4	not intox
262	Chikwaka control	farmer	1.79	0.10	0.10	0.025	---	0.07	4	not intox
263	Chikwaka control	school child not working	0.53	0.10	0.10	0.025	---	0.15	3	not intox
264	Chikwaka control	school child not working	0.56	0.10	0.10	---	---	---	1	not intox
265	Chikwaka control	school child not working	0.75	0.10	0.10	0.025	---	0.18	2	not intox
266	Chikwaka control	other job	0.59	3.32	2.82	0.08	0.00	0.07	4	not intox
267	Chikwaka control	school child not working	0.37	0.10	0.10	0.025	---	0.04	5	not intox
268	Chikwaka control	school child not working	0.24	0.10	0.10	0.025	---	0.04	4	not intox
269	Chikwaka control	farmer	0.29	0.10	0.10	0.025	---	0.02	7	not intox
270	Chikwaka control	farmer	1.44	0.10	0.10	0.025	---	0.10	3	not intox
271	Chikwaka control	school child not working	0.43	0.10	0.10	---	---	---	8	not intox
272	Chikwaka control	school child not working	0.27	0.10	0.10	0.025	---	0.05	7	not intox
273	Chikwaka control	farmer	1.55	8.78	3.57	1.97	1.27	3.25	3	not intox

Geoscience for a sustainable Earth

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