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Removal of barriers to the introduction of cleaner artisanal gold mining and extraction technologies in the Ingessana Hills

Blue Nile State, Sudan

Part B: Health Assessment – Final Report.

September, 2005

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Keywords: Mercury, health assessment, epidemiology, neurology, artisanal minong, Ingessana hills, Blue Nile State, Sudan.

In bibliography, this report should be cited as follows:

CASELLAS C., FENET H., LALOT M-O., ELBASHIER H., MEDANI K. (2005) - Removal of barriers to the introduction of cleaner artisanal gold mining and extraction technologies in the Ingessana Hills, Blue Nile State, Sudan. Part B: Health Assessment – Final Report. 28 p., 11 figures, 3 tables, 2 appendixes.

Contents

List of illustrations

List of appendixes

1. Socio-economic study of the ingessana hills artisanal gold mining community, blue nile state, sudan

The sociological study was performed before the human health study by Prof. Khalil A. Al Medani (Al Medani, 2003). The general aim of this study is to probe the community's habitat, behavior, characteristics, and activities. Several important informations are given in this report. We will extract the structure and demography of the people living in the selected site, type of occupations, food composition and eating habits, levels of education.

- Since 1997 gold was discovered in the center of Ingassana Hills ~80 kilometers to southwest El Damazin town, the capital of the Blue Nile State. The discovery of gold around Gugub village has attracted massive population especially those displaced by civil war in the southern parts of the region. Now there are about 1,000 multi-ethnic individuals practicing artisanal gold mining in Ingessana district. Both alluvial and primary types of artisanal gold mining are practiced excessively.
- Gugub village of around 1,000 inhabitants is the major center of activities. Among the artisanal mining community of Gugub, Dawala ethnic group make 80% of the population. The bigest cluster of activities is Khor Gidad located 7 km (drinving distance) north of Gugub village. There are 800 individuals currently practise artisanal gold mining.
- The biggest concentrations of sedentary Ingessana artisanal gold miners are found in Taga village located 5 km east of Gugub Taga. In this village, about 70 % of the 300 artisanal miners are from Ingessana ethnic group.
- Age range of active miners is 15-50 years (Figure 1). Few are older than 50 years. Women and children artisanal gold miners constitute ~50% of the total participants. Children make ~10%.
- About 90% of respondents are married. 38% of the male miners have two wives. 28% of male and 6% of female miners attended school. ~95% of these are from Dawala ethnic group. The majority of the Ingessana artisanal miners are illiterate (~95%).
- The most common diseases reported in are Malaria, chest pain, dyspnea, eye problems, fatigue, irritability and depression especially among women. Daily injures are common. People argue that treatment from diseases is very costly for them since the nearest clinic is at Bau, ~10 km away. In serious cases of illness, they go to El Damazin hospital ~80 km away.

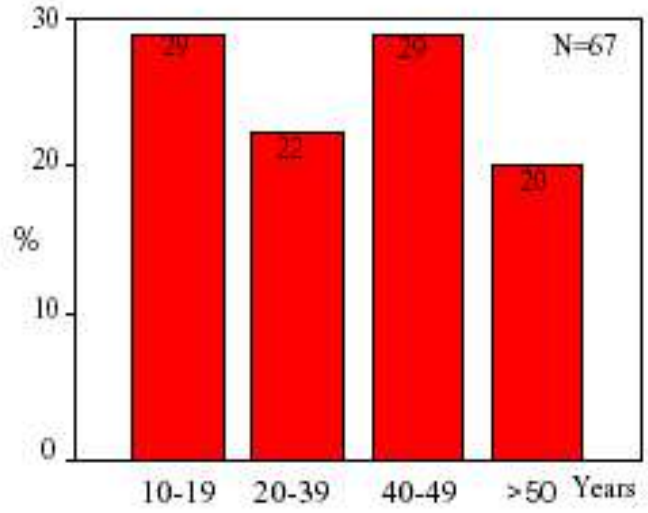

Figure 1 - Age distribution of artisanal gold miners in Gugub (in percent). (Socio-economic survey of AGM sites –Khlalil Al Medani, 2003).

- Average family in Gugub area eats two meals a day. Sorghum and maize porridge/pan cakes is the main staple. 62 % eats meat 2 to 3 times a week, 66.6 % drink milk everyday, 25 % eats chicken and 17 % eats eggs once a week. Almost all eats vegetables, and fruits occasionally. The nearest source of fresh food supply is about 20 km away. Being located ~50 km away from the Blue Nile western banks, the community of Gugub and the surroundings have no frequent access to fresh fish supply. In the survey, only 2 % of the sample report eating fish occasionally. However, dry fish is available in Gugub market.
- Water sources are springs and bore holes located ~2 km from the sites. Water is salty and contaminated by bacteria.
- Pitting on stream terraces/ quartz veins is the main method of artisanal gold mining. Gold extraction is through wooden plate panning (alluvium) or by both panning and amalgamation (primary). Amalgam is burned on frying pan at the miners homes or at the shops verandahs in Gugub.
- Awareness about environmental and health hazards associating mercury mishandling in gold processing is low.
- The mean number of children per family in Gugub is 4 children per family.

The panel of people was chosen with the help of the sociologist. This people had to give their consent before participating.

2. Data collection

2.1. Introduction

A contract was signed in July 2003 between the United Nations Industrial Development Organisation (UNIDO) and the BRGM, in order to carry out the environmental and health surveys in the Ingessana Hills in the Blue Nile State. The operation was carried out between French teams (BRGM, University of Montpellier and University of Bordeaux) and Sudan teams from the Geological Research Authoruty of Sudan (GRAS) and the University of Nileen. The University of Montpellier headed the health assessment survey. BRGM in cooperation with the GRAS were in charge of the coordination of the environmental assessment. The sampling campaign and health survey took place from March 29th to April 18th, 2004. A previous field report (Récoché *et al*., 2004) details the information collected in the field and the sampling methodology both for the health and environmental assessments.

This report is the second part of the Sudan survey describing the health assessment. Part A describes the environmental assessment (Récoché *et al*., 2005).

The aim of this survey was to collect environmental and health data in some selected areas (Ibrahim, 2003) and to evaluate the potential impacts caused by mercury to the local population and their close environment.

2.2. Cohort recruitment

The study area was composed of two villages (Gugub and Taga). Artisanal goldminers are scattered amongst these two sites. The biggest cluster of activities, known as Khor Gidad, is located ~7 km (driving distance) north of Gugub village. There are approximately 220 households in the two villages (around 1,000 adults and children). Given the mean family unit revealed by the sociological study (4 children per family), the number of children is estimated at 650, thus leaving only some 350 adults (>15 years old) that could be included in the study. These villages, chosen by UNIDO and GRAS, were thus too small for the recruitment of 250 volunteers. Moreover, many families were not in the village of Gugub itself but in the mining area of Khor Gidad. A meeting was organised to inform the population of the objectives of the study in Gugub and Khor Gidad. This alone was not sufficient to mobilise the population. The sociologist and the epidemiologist had to go to the village and the mining area themselves to make people aware of the study and persuade them to go to the school and participate in the study. Despite the efforts of the medical team, only 150 volunteers were recruited.

Another village was selected as a reference: Taga. The selection criteria were (i) the lack of any mining tradition in the village and (ii) a similarity in sociological and

environmental conditions. A group limited to 30 people, was recruited in Taga village; the main activity of this village was farming.

The sampling concerned 72 women and 109 men, and 31 married couples were identified. Hair samples were also collected from 54 children of the sampled couples.

Figure 2 - Medical office.

The medical consultations were performed in a private environment and the biological sampling was carried out in good conditions (Figure 2). Thanks to the school committee, we were able to install our team in the Gugub village school, thus providing the physicians, nurses, and interviewers with a specific place to perform their duties in good conditions.

2.3. Health assessment questionnaire

The “Protocols for Environmental and Health Assessment of Mercury Released by Artisanal and Small-Scale Gold Miners” were developed by UNIDO in collaboration with international experts (Veiga, 2003). The “Health Assessment Questionnaire” was slightly modified by the Health team in order to adapt it to the local conditions at Gugub (Appendix 1). Confidentiality was maintained regarding all health-related issues. The questionnaire detailing their way of working and living, their former medical problems and the perception of their health was systematically filled out.

2.4. Biological samples collection

Two nurses performed the sampling.

Sample preservation:

· Urine samples were preserved in a refrigerator.

- Blood samples were preserved in a refrigerator.
- Hair are kept in their secured sachets at ambient temperature until analysis.

However, the preservation of the biological samples was difficult due to the distance between the village and the camp (approximately a one-hour drive) and a high ambient temperature (around 40° C).

2.5. Medical examination

Participants were examined to identify neurological disturbances, behavioural disorders, tremor, cognitive capabilities, equilibrium, gait, reflexes, etc (Figures 3 and 4). Bau hospital kindly placed some medical material (weighing scales, examination table, etc.) at our disposal. Drasch *et al.* (2001) have suggested to check the following mercury poisoning indicators:

- signs of bluish discoloration of gums,
- ataxia,
- tremor,
- test of alternating movements,
- test of the field vision,
- reflexes,
- pathological reflexes,
- sensory examination.

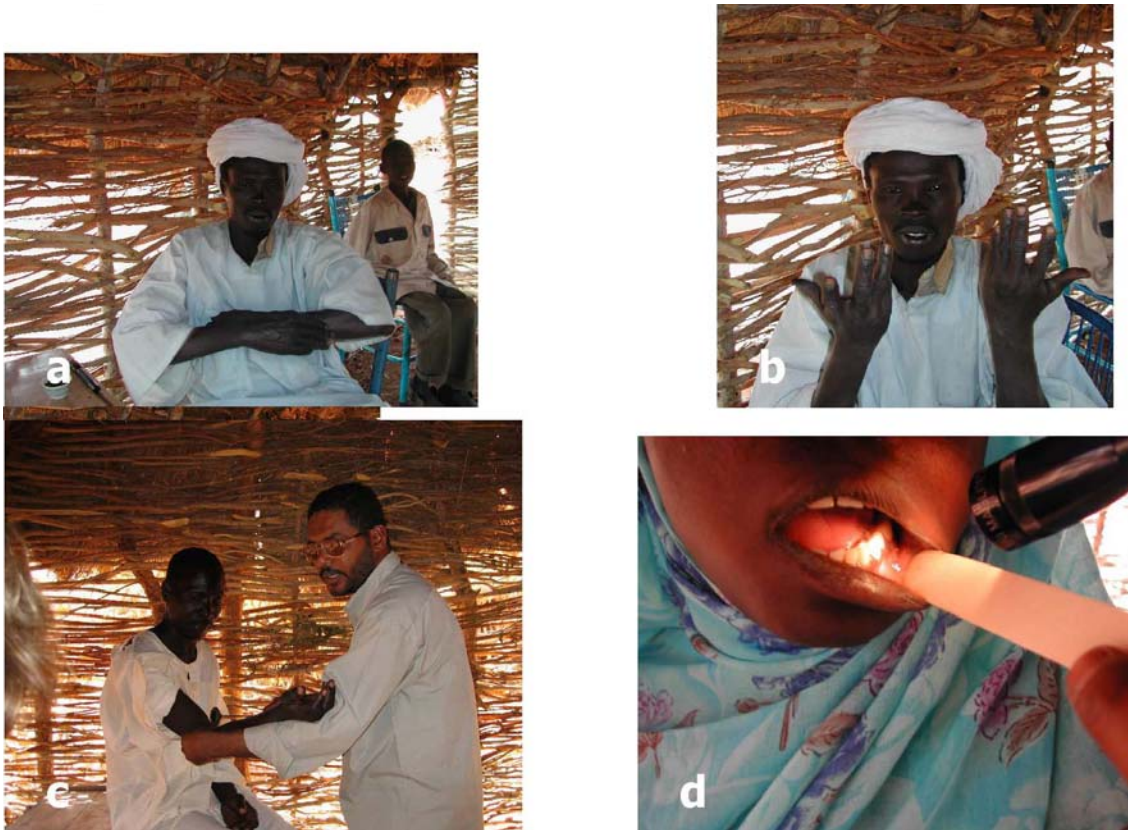

Figure 3 - Medical examination (a, b) dysdiadochokinesis, (c) reflexes, (d) examination of the gums.

Figure 4 – Medical examination (a) finger to nose test , (b) pathological reflexes.

In summary, the following information was collected and brought back to France:

- Questionnaires: 183
- Blood samples: 165
- Urine samples: 180
- Hair samples: 231 (including 52 children)

3. Preparation of sampling material

Ultra-clean sampling procedures, handling, and preparations are of utmost important if precise and exact results are required in the analysis of mercury in environmental and biological. The materials and vessels to be used for the sampling were preserved under very strict protocol. Polyethylene gloves are worn at all times during washing and handling.

3.1. Sample preservation

Urine and blood were kept at the field camp in a freezer powered by a diesel generator. Globally, these conditions guaranteed only refrigerator temperature (around 0°C).

- Urine samples are kept refrigerated until analysis.
- Blood samples are kept refrigerated until analysis.
- Hair are kept in their secured sachets at ambient temperature until analysis.

3.2. Sample transport

All samples, sealed in double zip-lock bags, and sometimes tied together with tapes are transported in pre-cooled ice-chests filled with frozen ice packs. Blood and urine samples were transported by the Aramex Company to the Pasteur Cerba Laboratory in France for analysis. Urine and blood samples arrived 48 h after their drop off at Aramex bureau to Pasteur Laboratory. The samples were still refrigerated (communication from Pasteur laboratories).

4. Experimental

4.1. Blood and urine

Blood and urine mercury determinations were performed by Laboratoire Pasteur Cerba (Laboratoire Pasteur Cerba 95066 Cergy-Pontoise cedex 9). Appendix 2 summarizes their qualification as a QA/QC laboratories. Blood was mineralised previous to analysis using a MAXIDIGEST MX350 (Prolabo). Total mercury was determined with an automate, by the cold vapour – atomic absorption technique FIMS 400 (Flow Injection Mercury System Perkin Elmer) using the continuous flow approach. The procedure involves organic mercury decomposition giving inorganic mercury by using $KMnO_4$ and $KBr/KbrO_3$ mixture. Detection limits were 1 µg L^{-1}.

4.2. Hair

Mercury in hair was analysed by BRGM laboratory. Between 20 mg and 50 mg of the hair samples were weighed in a beaker and then transferred in a polypropylene bottle in order to avoid weight errors introduced by electrostatic forces between the samples and the walls of the polypropylene containers. Hair samples were not washed (Drasch *et al.* 2001). A 3 mL volume of aqua regia is added. The propylene bottle is corked and is placed on a shaker to agitate overnight (16 hours). Then the solutions were diluted with deionised water. Total mercury is determined by the cold vapour – atomic fluorescence technique (CV – AFS) using the continuous flow approach. The procedure involves an online reduction of Hg^{2+} to Hg0 vapour by $SnCl_2$. Typically, the reductant is 5 % m/v $SnCl_2$ in 15 % HCl. The mercury vapour is swept by argon as carrier gas to the AFS detector. Quantification limit was 0.4 µg g^{-1}.

4.3. Creatinine in urine

Creatinine was analysed by Pasteur Laboratories following the “Jaffé Method", a kinetic test without deproteinisation. Creatinine, in an alkaline picrate solution, forms a colored orange-red complex. The delta absorbance at fixed times during conversion is proportional to the concentration of creatinine in the sample.

The reagents and the standard are ready-to-use and stable up to the end of the indicated month of expiry, if contamination is avoided and stored at 2 – 25 °C.

- R1: Sodium Hydroxide 0.16 mol L^{-1},

- R2: Pikric acid 4.0 mmol L^{-1},

- Standard: 2 mg dL^{-1} (177 µmol L^{-1}),

- Specimen: dilute urine 1 + 49 with distillated water.

Normal range:

-Urine: 1000 -1500 mg/24 h

-Creatinine clearance: Men: 98 – 156 mL min^{-1}; Women: 95 – 160 mL min^{-1}

5. Results and discussion

5.1. Social and occupational data

183 adults were recruited, including 111 men and 72 women. 95 men and 64 women declared to be artisanal gold miners (AGM). Most of the AGM men are partial time, they often declared to be also farmer. They usually have another activity associated to their AGM activity. This other activity (called alternative activity) is shown in the figure 5. Most of the women are AGM full time, 23 AGM declared to be farmer (figure 5).

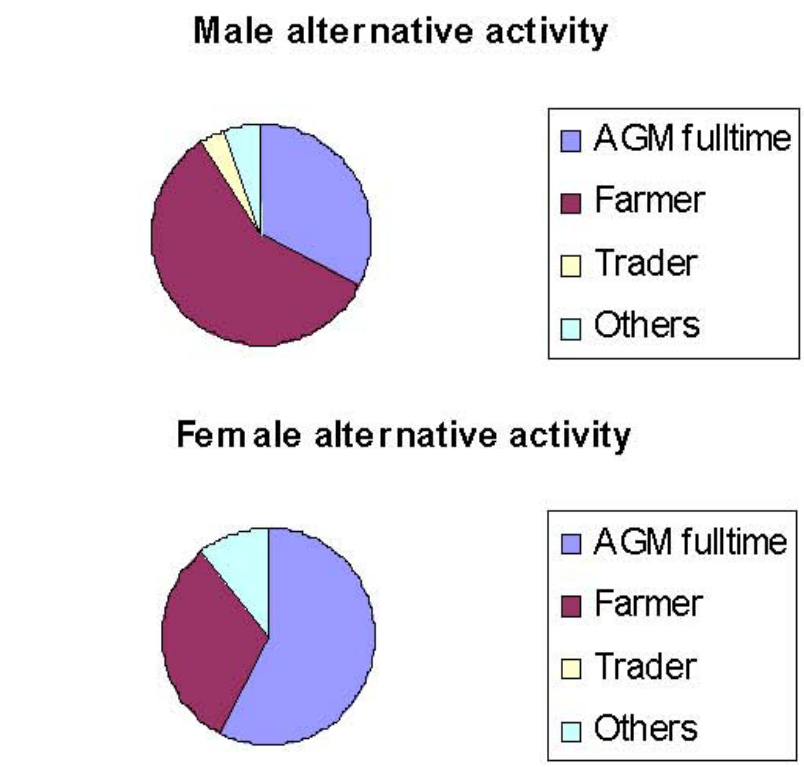

Figure 5 - Alternative activity of artisanal gold miners a-men b-women .

Non-artisanal gold miner population was considered as a possible control. The population is rather young (Figure 6). Men age is normally distributed (mean age = 37) while women are younger (mean age = 28). The number of children per family is 4.

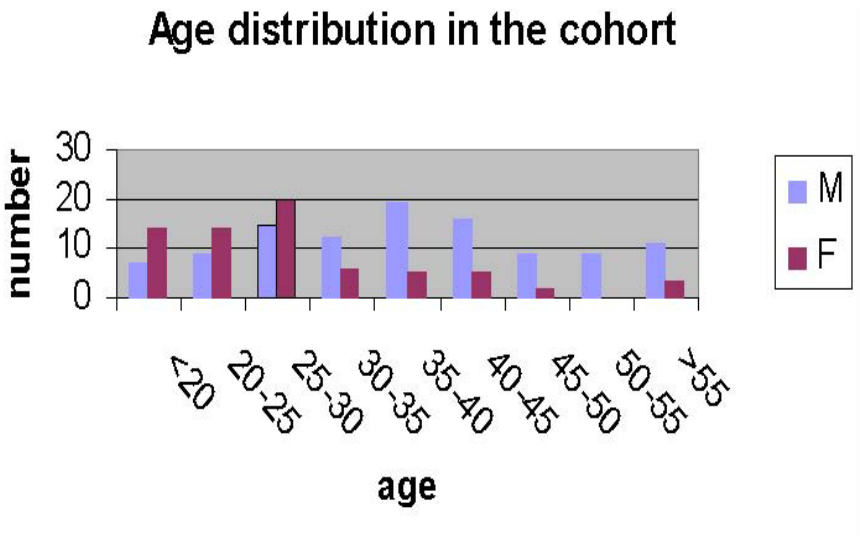

Figure 6 - Age distribution in the cohort.

The repartition between migrants and natives shows that 70 % of the male are non native from the Dawala ethnic group (figure 7). 27 % of the male are native from the Ingessana ethnic group. In the studied population, most of the women are non native from the Dawala ethnic group.

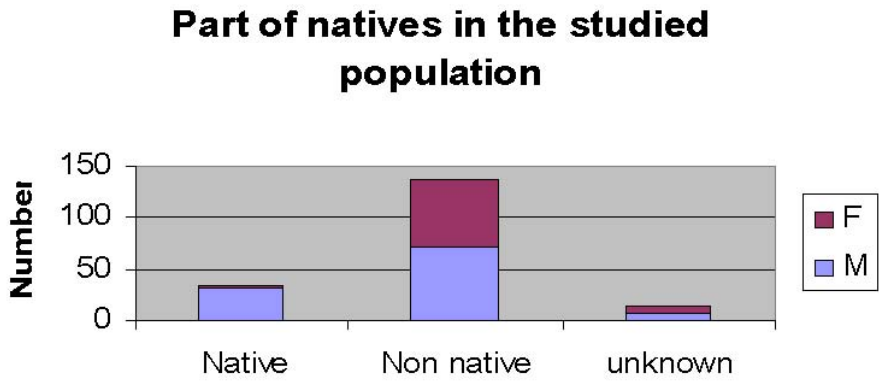

Figure 7 - Part of natives in the studied population.

58 % of the male have never been to school. 23 % have been to primary school and 13 % have attended secondary school. Most of the women are illiterate (Figure 8).

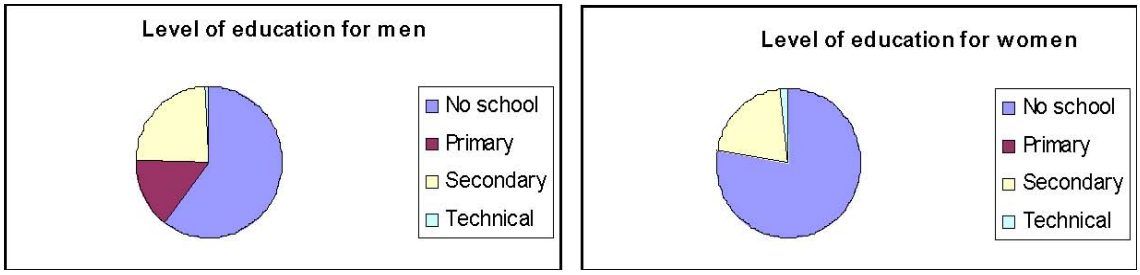

Figure 8 - Level of education for men and women.

As it was expected from the sociological report, the studied population almost never eats fresh fish. However 71 % of the studied population declared to eat dry fish (Figure 9).

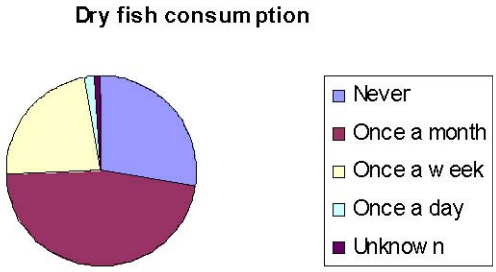

Figure 9 - The frequency of dry fish consumption of the studied population.

5.2. Health perception

60% of the male and the female sub-group studied declared to have no health problems (Figure 7). 31 % of the male sub-group and 24 % of the female sub-group declared to have one health problem. Most of the declared pathologies were related to the respiratory and kidney system. 89 % of the people, being artisanal gold miners or not, do not declare feeling any metallic taste. In the 11 % of individuals feeling a metallic taste, 1 % was not handling mercury. 78 % of the people, being artisanal gold miner or not, do not declare salivation problems; 6 % declared to have salivation problems at least once a day. 79 % of the people, being artisanal gold miner or not, do not declare tremors. In the 21 % of individuals declaring tremor, 6 % were not handling mercury.

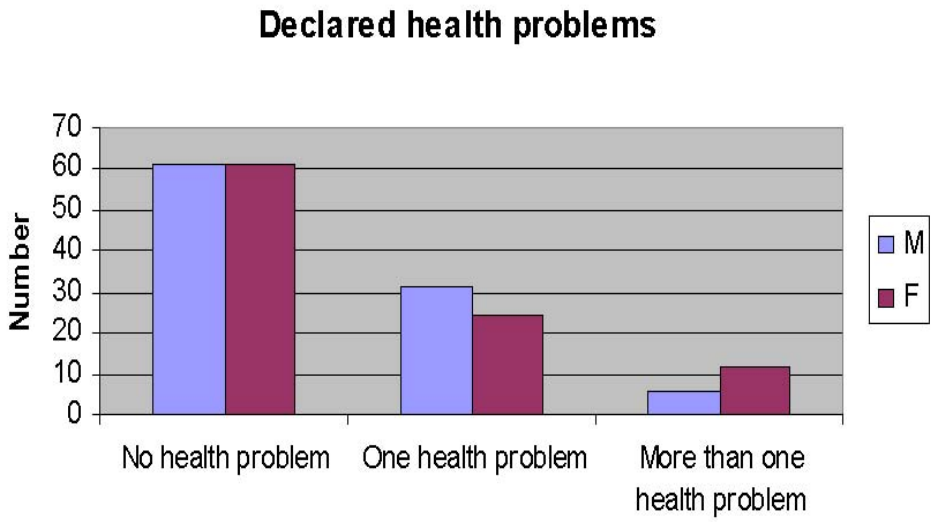

Figure 10 - Percent of persons declaring health problems.

Only 10 % of the studied population declared to be aware of any health hazard associated with the use and handling of mercury.

5.3. Exposure assessment

5.3.1. Human-biomonitoring (HBM) values for mercury

World Health Organization (WHO) considers a value of 4 µg L^{-1} in urine as a normal Hg level and 50 µg L^{-1} as the maximum occupational exposure limit. In order to compare Hg levels from different individuals, urine values should be normalised to creatinine, and should be expressed in µg Hg g^{-1} creatinine. If urine is very diluted (relative density < 1.010), interpretation of the result may be difficult. In the case of people not professionally exposed to mercury, urine levels rarely exceed 5 µg g^{-1} creatinine. (Veiga and Baker, 2003).

In blood, the normal concentration of total Hg ranges between 5 - 10 µg L^{-1} (in individuals without regular consumption of Hg contaminated fish). A MeHg level of 200 µg L^{-1} in blood, corresponding to Hg concentration of about 50 µg g^{-1} in hair, is associated with a 5% risk of neurological damage to adults (Veiga and Baker, 2003).

The normal Hg level in hair is less than 1-2 µg g^{-1}. Hazardous effects to the fetus are likely above 20 µg g^{-1} Hg in the hair of pregnant women. Levels of 10 µg g^{-1} must be considered as the upper limit guideline for pregnant women. Recent evaluation considers 5 µg g^{-1} Hg in hair as a safety guideline for pregnant women. The WHO reports that based on statistical analyses, pregnant women with Hg concentrations in hair above 70 µg g^{-1} exhibit more than a 30% risk to show a neurological disorder in the offspring.

The HBM-values are assessed by toxicological considerations (Drasch *et al.*, 2001). 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 sought and, as far as possible, eliminated. However, even when exceeding this HBM I value, 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’. For blood or urine levels above HBM II, especially for a longer time, adverse health effects cannot be excluded, therefore interventions are necessary. On the one hand the source should be found and reduced urgently; a medical check for possible symptoms should be performed.

Other toxicological limits are occupational threshold limits. Such limits are established for mercury, e.g. in France and the USA (biological exposure indices BEIs) or Germany (BAT value). From the 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, older or ill persons. Nevertheless, the BAT-values were taken for a further classifying of our high results, if any. BAT-values for mercury are established only for blood and urine, but not for hair.

Table 1 gives an overview of the HBM-, BAT-and BEI-values.

	Hg-blood	Hg-urine	
	µg L^{-1}	µg L^{-1}	µg g^{-1}creatinine
HBM I - Human Bio Monitoring	5	7	5
HBM II - Human Bio Monitoring	15	25	20
BEI - Biological Exposure Index	15 (after working)		35 (before working)
BAT - Biologischer Arbeitsstoff-Toleranzwert	25	100	

Table 1 - Mercury threshold values according to Drasch et al. (2001). NB: for hair, the HBM II is 5 µg g^{-1} (in analogy) and WHO proposes a treshold limit of 7 µg g^{-1}.

5.3.2. Classification of mercury body burden

Classes were defined following the HBM, BTA and WHO system as (Table 2):

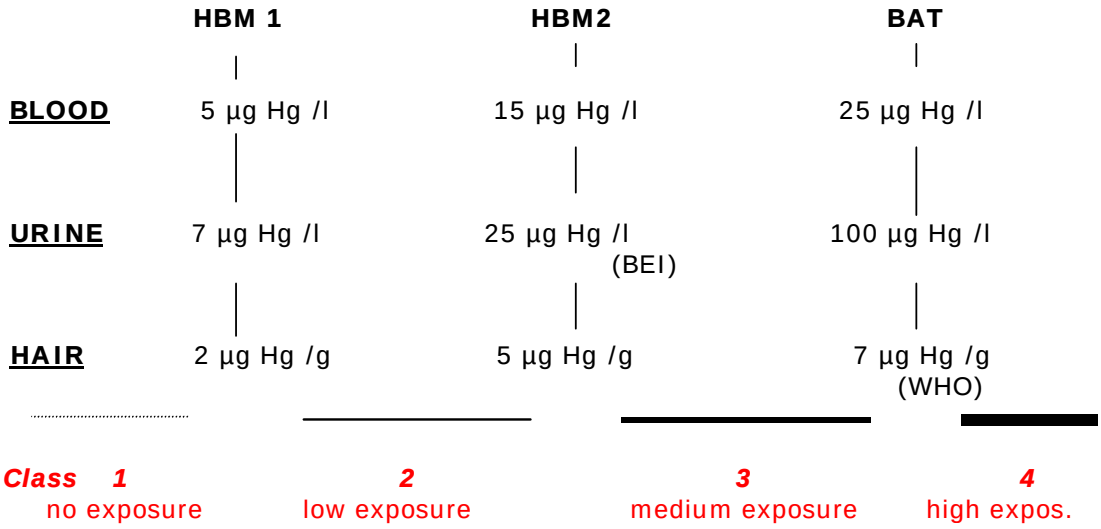

Table 2 - Classes of mercury body burden.

5.3.3. Mercury in blood, urine and hair samples

- In blood sample

All of the analysed blood samples have a concentration below 5 µg L^{-1}. 10 of these blood samples have a concentration higher than the 2 µg L^{-1} (7 men and 4 women). The highest concentration detected was 3.6 µg L^{-1} in a man blood sample. For this man, no Hg was dectected in the urine and in the hair samples.

- In urine sample

Most of the analysed urine samples have a concentration below 7 µg L^{-1}. 13 of these urine samples have a concentration higher than the limit of detection between 1 µg L^{-1} and 5.2 µg L^{-1} (7 men and 6 women). Two samples have a concentration higher than 7 µg L^{-1}, a man and a woman. The woman has an urine concentration of 8.4 µg L^{-1} and a blood concentration of 1.2 µg L^{-1}; the man has an urine concentration of 17.3 µg L^{-1} and a blood concentration of 2.2 µg L^{-1}; no Hg was detected in their hair samples.

- In hair samples

All of the analysed hair samples have a concentration below 2 µg g^{-1}. 10 of these samples have a concentration higher than the limit of detection (0.4 µg g^{-1}) (3 men, 5 women and 2 children). 9 have a concentration between 0.4 and 0.9 µg g^{-1}. A

concentration of 1.6 µg g^{-1} was determined in one woman sample. This woman has an urine concentration of 1.6 µg g^{-1} and a blood concentration of 1.8 µg g^{-1}.

In conclusion, the studied population was no or low exposed to mercury.

5.3.4. Clinical examination

A special section of the collection of epidemiological data was dedicated to neurological health, as mercury is particularly noxious to the nervous system. The clinical examinations consisted in classical tests related to walking, standing, sitting, laying, to the reflexes, the memory and drawing abilities. Tremor of eyelid, lips and fingers (ELF) were also evaluated.

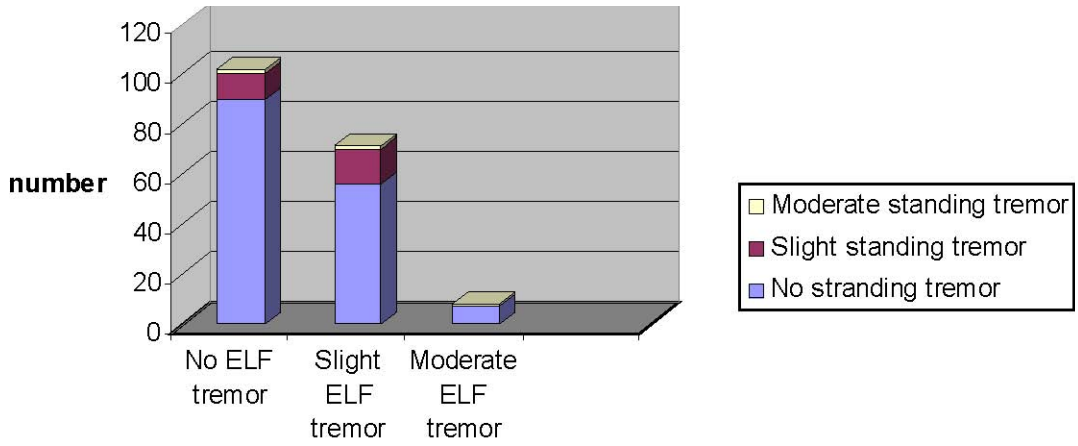

Figure 11 - ELF and attitude tremors observed in the studied population.

	No ELF tremor	Slight ELF tremor	Moderate ELF tremor	Total
No stranding tremor	50.0	31.0	3.8	84.8
Slight standing tremor	5.5	7.7	0.0	13.2
Moderate standing tremor	1.0	0.5	0.5	2.0
Total	56.5	39.2	4.3	100.0

Table 3 - ELF and attitude tremors observed in the studied population.

Figure 11 and table 3 show combinations of attitude tremor and tremor of eyelid, lips and fingers (ELF). These results show concordance between these two tremors evaluation. Globally, 56 percent of individuals have no eyelids, lips and fingers (ELF) tremor, and that around 40 % have slight ELF tremor. Standing tremor was observed on 15 % of the studied population. These results were probably not related to mercury use and could be very likely attributed to emotional context or other type of stress.

The examination of the population did not allow highlighting any important clinical sign of neurological disorder associated to chronic mercury intoxication. The only symptoms observed are a discrete tremor of the ends: eyelids, lips and fingers tremor which are symptoms far from specific; it is very strongly influenced by the emotional context, in particular when the patients feel observed. Tremor due to mercury appears, in a constant way, with modification of writing. The tests of writing, in particular the "Frostig score", are normal for all the studied individuals. In addition the first symptoms of mercury intoxication (disturbance of the psychomotor tests) appear for rates of urinary excretion higher than 25 $\mu g\ g^{-1}$ of creatinine. A discrete tremor can be observed starting from a rate of urinary excretion higher than 50 $\mu g\ g^{-1}$ of creatinine. Taking into account the rates of mercury exposure observed in the population of gold miners, and the unspecific character of the observed symptoms, it is very improbable that the observed symptoms are related to mercury handling.

6. Strategy and conclusions

The first point that should be addressed is that the sociological study is the key for a good epidemiological investigation. In our work, the cluster sampling at a family level was done. Mercury exposure was very low and, in the majority of the studied sample was nul. Children, like their parents, were not exposed to mercury and cluster sampling could not be usefully interpreted.

From this study, answers for two main questions could be proposed:

Is the population exposed to mercury?

In the total sample studied (183), 2 individuals are in classe 2 for urine mercury burden. Our results showed that direct exposure by professional activities (artisanal gold miners) is not present. No indirect or direct exposure of children was observed.

Is the population health affected?

Slight neurological signs in goldwashers group could be due to emotional context. The relationship with mercury use was not demonstrated. Indeed, this population of artisanal gold miners is migrant, coming from a region where gold mining did not exist. They are in the studied region for seven years. Even the natives were not used to be gold miners. Artisanal gold mining in the Ingessana Hills started in 1996. Intensive use of mercury in the area is quite recent (about 3 years or less) and was mainly developed in the Gugub area where gold was first discovered and in Khor Gidad after a gold rush in September 2003.

In perspectives this study could be considered as a point zero for health effects due to mercury use by artisanal gold miners. Three action levels must be considered, at the studied site:

- Information, of the whole population, on mercury health effects and impact on the environment.
- Education of the parents and children on prevention of these effects and the consequences on their environment.
- Equipping the artisanal gold miners with simple tools for preventing their health at the family level and their environment.

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APPENDIXES

APPENDIX 1: Analytical results of human samples

APPENDIX 2: Pasteur Laboratories accreditation certificate

A1 -Table 1: Hg concentration (µg L^{-1} d.w.) in adult blood samples (Id n° code: 1 = male and 2 = female – Result 0 means < LD)

IdN	N° 1 = M, 2 = F, 3 = Child	BLOOD µg L^{-1}	IdN	N° 1 = M, 2 = F, 3 = Child	BLOOD µg L^{-1}
1	1	0	162	1	1.2
2	1	1.6	164	1	0
			167	1	0
3	1	2	181	1	0
5	1	1.2	182	1	0
6	1	0	183	1	2.6
7	1	0	184	1	2.2
8	1	1.2	185	1	1
11	1	0	186	1	0
12	1	0	187	1	3.6
14	1	1.2	188	1	0
16	1	0	189	1	0
18	1	0	190	1	0
22	1	0	191	1	0
40	1	1	195	1	1.4
41	1	0	196	1	0
42	1	0	198	1	0
43	1	2.2	199	1	0
44	1	1	200	1	0
45	1	1.2	201	1	0
46	1	0	202	1	0
47	1	0	250	1	0
49	1	0	251	1	0

IdN	N° 1 = M, 2 = F, 3 = Child	BLOOD µg L^{-1}	IdN	N° 1 = M, 2 = F, 3 = Child	BLOOD µg L^{-1}
50	1	0	253	1	0
51	1	0	254	1	0
53	1	0	261	1	0
54	1	1.2	265	1	0
55	1	1.6	1	2	0
57	1	1.6	2	2	0
76	1	0	3	2	1
77	1	0	7	2	0
78	1	1	8	2	0
79	1	0	9	2	0
80	1	1.2	10	2	1
81	1	0	12	2	0
82	1	0	14	2	1
83	1	0	16	2	2
84	1	1.8	18	2	0
85	1	1	41	2	0
86	1	1.8	42	2	0
87	1	2	43	2	1
88	1	2	44	2	1.2
89	1	0	50	2	0
90	1	0	51	2	0
91	1	0	53	2	0
92	1	1.4	55	2	1
100	1	0	56	2	1
101	1	0	57	2	1

IdN	N° 1 = M, 2 = F, 3 = Child	BLOOD µg L^{-1}	IdN	N° 1 = M, 2 = F, 3 = Child	BLOOD µg L^{-1}
102	1	1.6	59	2	0
103	1	2.2	60	2	0
104	1	0	61	2	0
105	1	0	62	2	0
106	1	0	63	2	0
107	1	0	64	2	0
108	1	0	65	2	1.4
110	1	1.6	70	2	0
111	1	0	75	2	0
112	1	2.2	86	2	2.2
113	1	0	88	2	1.6
114	1	0	89	2	0
115	1	1	90	2	0
118	1	0	100	2	0
121	1	0	105	2	0
123	1	0	107	2	0
124	1	1.4	110	2	1.4
126	1	1.2	116	2	0
127	1	1	117	2	2
128	1	0	118	2	1
130	1	0	119	2	0
131	1	0	120	2	1.2
132	1	1	121	2	1.6
133	1	1.6	124	2	0
135	1	2.6	151	2	1.2

IdN	N° 1 = M, 2 = F, 3 = Child	BLOOD µg L^{-1}	IdN	N° 1 = M, 2 = F, 3 = Child	BLOOD µg L^{-1}
136	1	0	154	2	1.6
137	1	0	155	2	1.8
150	1	1	156	2	0
152	1	2	163	2	1.8
153	1	1.4	165	2	2.2
154	1	1	166	2	2.8
157	1	0	168	2	0
158	1	0	185	2	0
159	1	0	192	2	0
160	1	1	193	2	1
161	1	0	194	2	0
			197	2	0
			203	2	0
			252	2	0
			255	2	0
			256	2	0
			257	2	0
			258	2	0
			259	2	0
			260	2	0
			262	2	0
			263	2	0

A2 -Table 2: Hg concentration (µg L^{-1}) in urine samples (Id n° code: 1 = male and 2 = female – Result 0 means < LD)

IdN	N° 1 = M, 2 = F, 3 = Child	urine µg L^{-1}	urine µg g^{-1} creat.	IdN	N° 1 = M, 2 = F, 3 = Child	urine µg L^{-1}	urine µg g^{-1} creat.
1	1	0	0	187	1	0	0
2	1	0	0	188	1	0	0
3	1	0	0	189	1	0	0
5	1	0	0	190	1	0	0
6	1	0	0	191	1	0	0
7	1	0	0	195	1	0	0
8	1	0	0	196	1	0	0
11	1	0	0	198	1	1.4	0.84
12	1	0	0	199	1	0	0
14	1	0	0	200	1	1.6	1
16	1	0	0	201	1	0	0
18	1	0	0	202	1	0	0
22	1	0	0	250	1	0	0
40	1	0	0	251	1	0	0
41	1	0	0	253	1	0	0
42	1	0	0	254	1	0	0
43	1	17.3	8.5	261	1	0	0
44	1			265	1		
45	1	0	0	1	2	0	0
46	1			2	2	0	0
47	1	0	0	3	2	1.4	1.2
49	1	0	0	7	2	0	0
50	1	1	0.54	8	2	0	0

IdN	N° 1 = M, 2 = F, 3 = Child	urine µg L^{-1}	urine µg g^{-1} creat.	IdN	N° 1 = M, 2 = F, 3 = Child	urine µg L^{-1}	urine µg g^{-1} creat.
51	1	0	0	9	2	0	0
53	1	0	0	10	2	0	0
54	1	0	0	12	2	0	0
55	1	0	0	14	2		
57	1	0	0	16	2	0	0
76	1	0	0	18	2	0	0
77	1	0	0	41	2	0	0
78	1	0	0	42	2	0	0
79	1	0	0	43	2	0	0
80	1	0	0	44	2	0	0
81	1	0	0	50	2	0	0
82	1	0	0	51	2	0	0
83	1	0	0	53	2	0	0
84	1	0	0	55	2	0	0
85	1	5.2	4.1	56	2	0	0
86	1	0	0	57	2	0	0
87	1	0	0	59	2	0	0
88	1	0	0	60	2	0	0
89	1	0	0	61	2	0	0
90	1	0	0	62	2	0	0
91	1	0	0	63	2	0	0
92	1	0	0	64	2		
100	1	0	0	65	2	0	0
101	1	0	0	70	2		

IdN	N° 1 = M, 2 = F, 3 = Child	urine µg L^{-1}	urine µg g^{-1} creat.	IdN	N° 1 = M, 2 = F, 3 = Child	urine µg L^{-1}	urine µg g^{-1} creat.
102	1	0	0	75	2	0	0
103	1	0	0	86	2	0	0
104	1	0	0	88	2	0	0
105	1	0	0	89	2	0	0
106	1	0	0	90	2	0	0
107	1	1.4	0.87	100	2	0	0
108	1	0	0	105	2	0	0
110	1	1.6	1.4	107	2	0	0
111	1	0	0	110	2	0	0
112	1	0	0	116	2	0	0
113	1	0	0	117	2	0	0
114	1	0	0	118	2	0	0
115	1	0	0	119	2	0	0
118	1	0	0	120	2	0	0
121	1	0	0	121	2	0	0
123	1	0	0	124	2	0	0
124	1	0	0	151	2	8.4	5.2
126	1	0	0	154	2	0	0
127	1	0	0	155	2	1.6	1
128	1	0	0	156	2	0	0
130	1	0	0	163	2	1.4	0.87
131	1	0	0	165	2	0	0
132	1	0	0	166	2	4.6	2.87
133	1	0	0	168	2	0	0
135	1	0	0	185	2	0	0

IdN	N° 1 = M, 2 = F, 3 = Child	urine µg L^{-1}	urine µg g^{-1} creat.	IdN	N° 1 = M, 2 = F, 3 = Child	urine µg L^{-1}	urine µg g^{-1} creat.
136	1	0	0	192	2	0	0
137	1	0	0	193	2	5.2	4.1
150	1	0	0	194	2	0	0
152	1	0	0	197	2	0	0
153	1	0	0	203	2	0	0
154	1	0	0	252	2	0	0
157	1	0	0	255	2	0	0
158	1	0	0	256	2	0	0
159	1	0	0	257	2	4.2	2.7
160	1	0	0	258	2	0	0
161	1	1	0.62	259	2	0	0
162	1	0	0	260	2		
164	1	0	0	262	2	0	0
167	1	0	0	263	2	0	0
181	1	0	0	264	2		
182	1	0	0				
183	1	0	0				
184	1	0	0				
185	1	0	0				
186	1	0	0				

A3 -Table 3: Hg concentration (mg kg^{-1}) in hair samples (Id n° code: 1 = male and 2 = female – Result 0 means < LD)

IdN	N° 1 = M, 2 = F, 3 = Child	Hair mg kg^{-1}	IdN	N° 1=M, 2=F, 3=Child	Hair mg kg^{-1}	IdN	N° 1 = M, 2 = F, 3 = Child	Hair mg kg^{-1}
1	1	0	56	2	0	132	1	0
1	2	0	57	1	0	132	3	0
1	3	0	57	2	0	132	22	0
2	1	0	59	2	0	133	1	0
2	2	0	60	2	0	135	1	0
2	3	0	60	3	0	136	1	0
3	1	0.4	61	2	0	137	1	0
3	2	0	62	2		150	1	0
5	1	0	62	3	0	151	2	0
6	1	0	63	2	0	152	1	0
7	1	0	64	2	0	153	1	0
7	2	0	64	3	0	153	3	0
7	3	0	65	2	0	154	1	0
8	1	0	65	3	0	154	2	0
8	2	0	70	2		155	2	1.6
9	2	0	75	2	0	156	2	0
9	3	0	76	1	0	156	3	0
9	4	0	77	1	0	157	1	0
10	2	0	78	1	0	158	1	0
10	3	0	79	1	0	159	1	0
10	22	0	80	1	0	160	1	0

IdN	N° 1 = M, 2 = F, 3 = Child	Hair mg kg^{-1}	IdN	N° 1=M, 2=F, 3=Child	Hair mg kg^{-1}	IdN	N° 1 = M, 2 = F, 3 = Child	Hair mg kg^{-1}
11	1	0	81	1	0	161	1	0
12	1	0	82	1	0	162	1	0
12	2	0.9	83	1	0	163	2	0
12	3	0	84	1	0	164	1	0
12	31	0	85	1	0	165	2	0
12	32	0	86	1	0	166	2	0
12	33	0	86	2	0	167	1	0
12	34	0	87	1	0	168	2	0
12	35	0	88	1	0	181	1	0
12	36		88	2	0	182	1	0
12	37	0	89	1	0	183	1	0
14	1	0	89	2	0	184	1	0
14	2	0	89	3	0	185	1	0
14	3	0	90	1	0	185	2	0
14	4	0	90	2	0	185	3	0
16	1	0	91	1	0	185	22	0
16	2	0	92	1	0	186	1	0
16	3	0	100	1	0	187	1	0
16	4	0	100	2	0.5	188	1	0
18	1	0	100	3	0	189	1	0
18	2	0	101	1	0	190	1	0
18	3	0	102	1	0	191	1	0

IdN	N° 1 = M, 2 = F, 3 = Child	Hair mg kg^{-1}	IdN	N° 1=M, 2=F, 3=Child	Hair mg kg^{-1}	IdN	N° 1 = M, 2 = F, 3 = Child	Hair mg kg^{-1}
22	1	0	103	1	0	192	2	0
22	3	0	104	1	0	193	2	0
40	1	0	105	1	0	194	2	0
41	1	0	105	2	0	195	1	0
41	2	0	106	1	0	196	1	0
41	3	0	107	1	0	197	2	0
42	1	0	107	2	0	197	3	0
42	2	0	107	3	0.4	198	1	0
42	3	0	108	1	0	199	1	0
42	22	0	108	3	0	200	1	0
43	1	0	110	1	0	201	1	0.5
43	2	0	110	2	0	202	1	0.5
43	3	0	111	1	0	203	2	0
43	4	0	112	1	0	250	1	0
44	1	0	113	1	0	251	1	0
44	2	0	114	1	0	252	2	0
44	3	0	115	1	0	253	1	0
44	4	0	116	2	0	254	1	0
45	1	0	117	2	0	255	2	0
46	1	0	117	3	0.4	256	2	0.4
47	1	0	118	1	0	257	2	0
49	1	0	118	2	0	258	2	0

IdN	N° 1 = M, 2 = F, 3 = Child	Hair mg kg^{-1}	IdN	N° 1=M, 2=F, 3=Child	Hair mg kg^{-1}	IdN	N° 1 = M, 2 = F, 3 = Child	Hair mg kg^{-1}
50	1	0	118	3	0	259	2	0
50	2	0	118	4	0	260	2	0
50	3	0	119	2	0	261	1	0
51	1	0	119	3	0	262	2	0
51	2	0	120	2	0	263	2	0
51	3	0	121	1	0	264	2	0
53	1	0	121	2	0	265	1	0
53	2	0	121	3	0	300	31	0
53	3	0	123	1	0	300	32	0
54	1	0	124	1	0	300	31	
55	1	0	124	2	0	300	32	
55	2	0	126	1	0			
55	3	0	127	1	0			
			128	1	0			
			130	1	0			
			131	1	0			

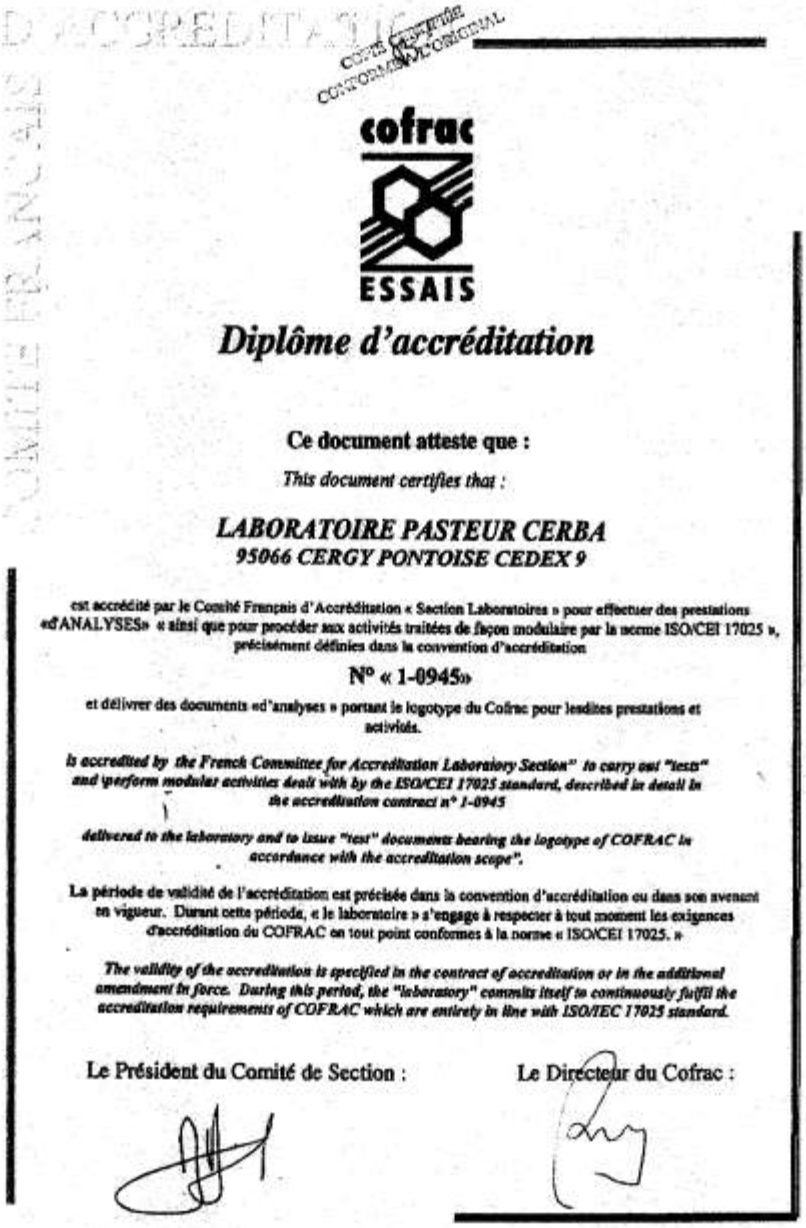
A4 -Table 4: Creatinine concentration (g L^{-1}) in instantaneous urine samples

Identification	creat in urine mmol L^{-1}	Identification	creat in urine mmol L^{-1}	Identification	creat in urine mmol L^{-1}
100-1	12.17	159-1	32.35	41-1	16.41
100-2	4.55	160-1	19.14	41-2	13.66
101-1	3.84	16-1	5.96	42-1	26.99
10-2	6.30	16-1	7.17	42-2	12.29
102-1	13.24	161-1	14.36	42-2	6.09
10-22	6.71	16-2	11.79	43-1	17.95
103-1	6.12	162-1	14.45	43-2	17.73
104-1	18.24	163-2	14.03	44-1	9.37
105-1	11.02	164-1	12.78	44-2	3.76
105-2	10.07	165-2	6.12	45-1	2.98
106-1	7.91	166-2	14.20	46-1	8.67
107-1	14.15	167-1	27.67	47-1	1.33
107-2	11.94	168-2	15.26	49-1	20.17
108-1	8.92	18-1	3.19	50-1	16.55
1-1	19.94	181-1	2.18	50-2	11.63
110-1	10.36	18-2	<	5-1	21.79
110-2	8.23	182-1	17.74	51-1	16.96
11-1	20.45	183-1	15.98	51-2	6.96
111-1	11.36	184-1	10.85	53-1	12.63
112-1	20.25	184-1		53-2	0.93
113-1	8.01	185-1	12.82	54-1	20.50
114-1	26.86	185-2	18.04	55-1	10.55
115-1	16.64	185-22	6.24	55-2	9.38
116-2	17.78	186-1	9.84	56-2	1.06

Identification	creat in urine mmol L^{-1}	Identification	creat in urine mmol L^{-1}	Identification	creat in urine mmol L^{-1}
117-2	15.82	187-1	14.55	57-1	22.00
118-1	26.07	188-1	12.58	57-1	23.68
118-2	13.21	189-1	17.46	57-2	
119-2	15.54	190-1	6.93	59-2	13.26
1-2	5.03	191-1	20.04	60-2	12.53
120-2	5.33	192-2	4.96	6-1	16.92
12-1	4.65	193-2	11.27	61-2	7.28
121-1	9.19	194-2	12.29	62-2	4.03
121-2	13.76	195-1	20.02	63-2	22.12
12-2	4.50	196-1	16.11	64-2	10.90
123-1	11.13	197-2	9.03	65-2	9.16
124-1	18.05	198-1	14.88	7-1	15.35
124-1	10.85	199-1	17.94	7-2	3.89
124-2		200-1	14.04	8-2	1.56
126-1	20.07	201-1	8.58	75-2	9.42
127-1	11.85	202-1	5.88	76-1	10.06
128-1	16.07	203-2	15.68	77-1	11.84
130-1	19.26	2-1	12.71	78-1	13.18
131-1	11.72	2-2	7.78	79-1	2.26
132-1	10.01	22-1	2.90	80-1	13.08
132-22	9.94	250-1	27.95	8-1	11.88
133-1	14.20	251-1	16.95	81-1	14.89
134-1		252-1	2.34	82-1	25.93
135-1	28.97	252-2	7.23	83-1	8.68
136-1	20.12	253-1	21.98	84-1	18.37

Identification	creat in urine mmol L^{-1}	Identification	creat in urine mmol L^{-1}	Identification	creat in urine mmol L^{-1}
137-1	12.48	254-1	6.67	85-1	11.36
14-1	25.13	255-2	10.06	86-1	2.45
14-2		256-2	15.37	86-2	13.90
150-1	13.55	257-2	13.73	87-1	7.27
151-2	14.45	258-2	17.78	88-1	15.29
152-1	15.05	259-2	9.54	88-2	15.74
153-1	18.99	261-1	9.74	89-1	17.03
154-1	3.31	262-1	10.38	89-2	3.67
154-2	11.61	263-2	7.62	90-1	8.42
155-2	13.86	265-1		90-2	10.35
156-1	8.67	3-1	15.58	91-1	25.63
157-1	21.52	3-2	10.39	9-2	15.02
158-1	24.41	40-1	14.24	92-1	19.86

8.2 APPENDIX 2: Pasteur Laboratories accreditation certificate



cofrac

ESSAIS

Diplôme d'accréditation

Ce document atteste que :

This document certifies that :

LABORATOIRE PASTEUR CERBA
95066 CERGY PONTOISE CEDEX 9

est accrédité par le Comité Français d'Accréditation « Section Laboratoires » pour effectuer des prestations «d'ANALYSES» « ainsi que pour procéder aux activités traitées de façon modulaire par la norme ISO/CEI 17025 », précisément définies dans la convention d'accréditation

N° « 1-0945»

et délivrer des documents «d'analyses » portant le logotype du Cofrac pour lesdites prestations et activités.

is accredited by the French Committee for Accreditation Laboratory Section" to carry out "tests" and perform modular activities dealt with by the ISO/CEI 17025 standard, described in detail in the accreditation contract n° 1-0945

delivered to the laboratory and to issue "test" documents bearing the logotype of COFRAC in accordance with the accreditation scope".

La période de validité de l'accréditation est précisée dans la convention d'accréditation ou dans son avenant en vigueur. Durant cette période, « le laboratoire » s'engage à respecter à tout moment les exigences d'accréditation du COFRAC en tout point conformes à la norme « ISO/CEI 17025. »

The validity of the accreditation is specified in the contract of accreditation or in the additional amendment in force. During this period, the "laboratory" commits itself to continuously fulfil the accreditation requirements of COFRAC which are entirety in line with ISO/IEC 17025 standard.

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