Investigation of human and environmental exposure to mercury in the upper part of Maroni River, French Guiana, from 2004 to 2009

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Introduction

Many Amerindians have been lived in the upper part of the Maroni River, French Guiana. In the area, clandestine gold mining contaminates numerous sites, both on the terrestrial and the aquatic. Divalent and organic mercury can enter and pollute biological systems. In last instances, human exposure to mercury has been detected using by monitoring of hair mercury. Some reports have mentioned that Amerindians are exposed to mercury by the consumption of the mercury-polluted fishes, because the mercury concentration of hair in Amerindians showed high value. However, there has been no reports post-2002.

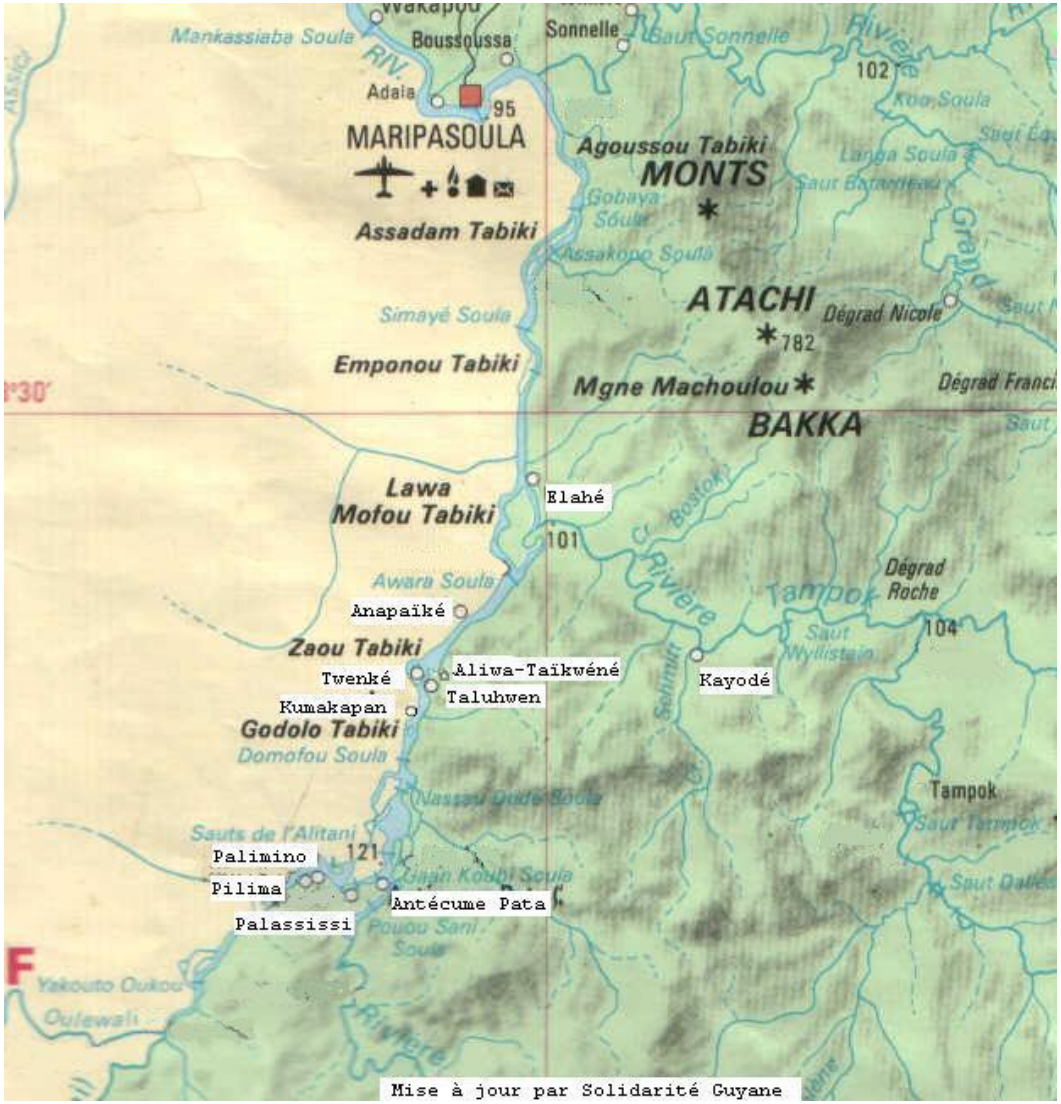
In this study, we investigated the mercury concentration of hair in Amerindians for 6-years from 2004 to 2009 in the upper part of the Maroni River. Hair samples of 387 inhabitants were taken (male: 153, female: 234). In 2008, we performed the investigation of fish consumption for 37 subjects. Furthermore, we investigated the mercury concentration of the polluted fishes and river water in the upper part of Maroni River in 2009.

Upper part of Maroni River in French Guiana

French Guiana

Upper Maroni

Upper part of Maroni River in French Guiana



Mercury in Amazonian soil (1/3)

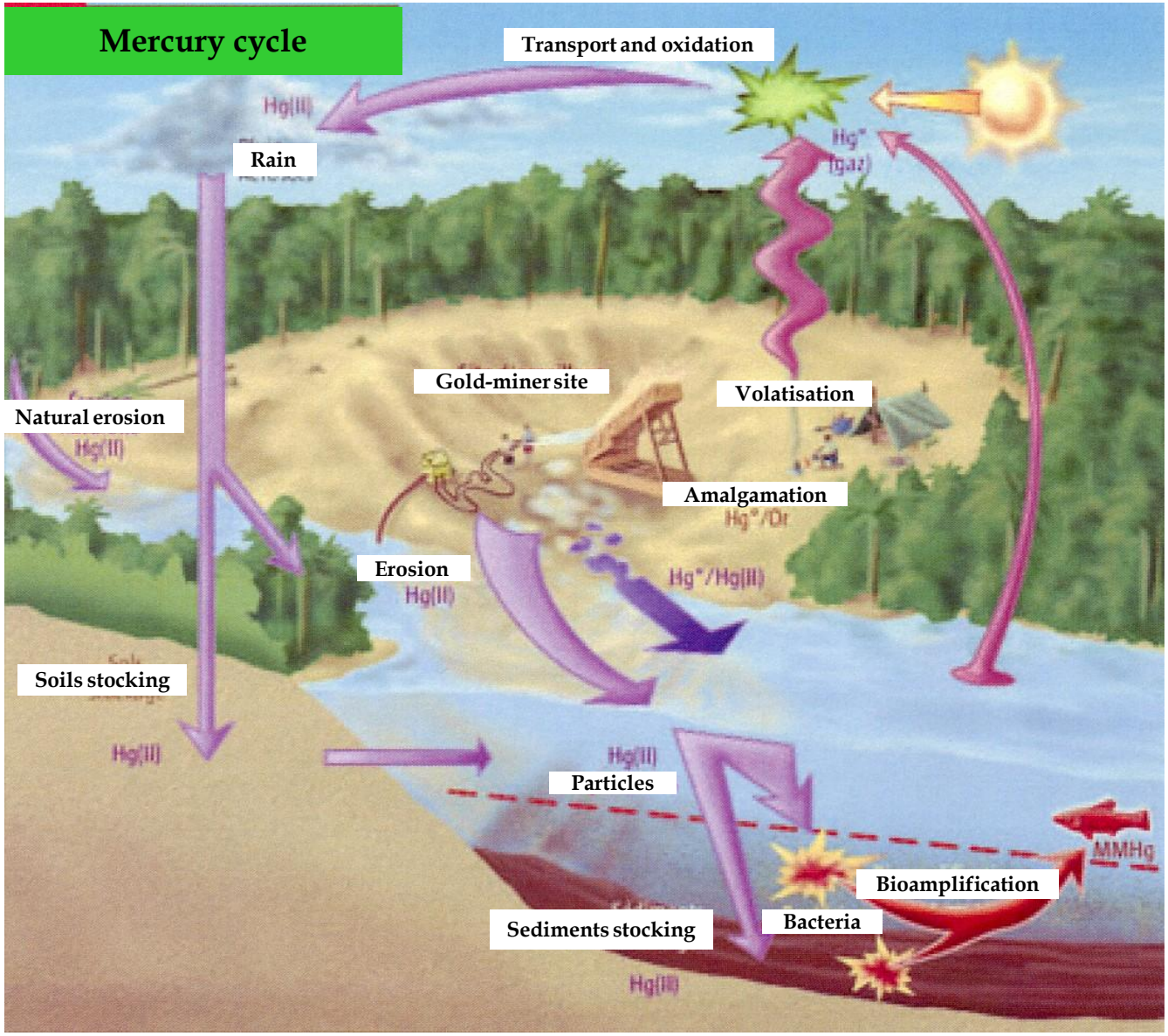
- **Natural mercury**
  - **The elementary mercury (Hg°):**
    - It's accumulated in the tropical grounds since a million years by way of the atmospheric consequences of the volcanic and oceanic emissions (7 times more than in the European soil).
    - The oxidized shape, the inorganic mercury (HgII) is spread in the ground by way of precipitation.
    - Within the biochemical cycle of the metal, Hg° , can be oxidized in inorganic mercury (HgII) and then methylated by biotic (bacterial methylation) or/and abiotic processes.
  - **The mercury stemming from human activities:**
    - When the ground is affected, naturally or by human being, as gold-mining activities for example in Guiana or deforestation in Brazil, particles migrate to the rivers. This inorganic mercury, in environment devoid of oxygen (water or sediments) is transformed into organic mercury, the methyl mercury (MeHg), which is ingested by fish.

Mercury in Amazonian soil (2/3)

- **The mercury introduced by the gold-mining activity :**
  - **<u>The activation of the methylation</u>**
    - The activities of gold-mining amplify the phenomenon of natural erosion and inject into the rivers the particles carrying the inorganic mercury, until then collected in the ground.
    - Every year millions of m3 of ground are transformed into muds which are rejected in the bed of rivers. The mercury of geologic origin is then remobilized. It concentrates at the surface and participates in the poisoning.
  - **<u>The rejected mercury</u>**
    - Gold diggers directly reject some elementary mercury in stream during the operations of amalgamation of gold (1,2 kg Hg for 1 kg gold). This volatile form of mercury is discharged into the atmosphere (55%) and aquatic biotopes (45%).
    - Today, many operators go back on former deposits and put back in traffic of the mercury rejected in the natural environment by their predecessors.
    - Several hundred tons were poured into the biotope of the rain forest and in concentrated zones of which some are inhabited by the Amerindians.

Mercury in Amazonian soil (3/3)

(Charlet and Boudou 2002)



Previous mercury studies (InVS 1997)

List of fish species collected in the Upper-Maroni ranked according to their relative contributions (%) to total Hg intake

Family	Species	C (carnivorous) O (omnivorous) H (herbivorous)	Wayana name	No. of fish	(Hg) muscle ng/g. dw (mean ± SD)	Percent of total flesh consumed	Percent Hg intake
Pimelodidae	Pseudoplatystoma fasciatum	C	Huluwi	1	4,700	7.5	27.02
Erythrinidae	Hoplias aimara (>1,700 g)	C	Aïmara	21	3,965 ± 1,045	7.2	22.02
Ageneiosidae	Ageneiosus brevifilis	C	Mitala	8	2,640 ± 1,332	5.5	11.12
Doradidae	Doras micropeus	O	Agonosu	18	1,167 ± 318	11.2	9.98
Serrasalmidae	Serrasamlus rhombeus	C	Piraïe	3	1,870 ± 1,000	4.5	6.43
Erythrinidae	Hoplias aimara (<1,700 g)	C	Aïmara	21	1,955 ± 925	3.5	5.19
Doradidae	Platydoras costatus	O	Hoké	11	518 ± 206	8.1	3.2
Characidae	Cynodon meionactis	C	Haïkané	16	4,407 ± 2,041	0.9	2.9
Curimatidae	Prochilodus reticulata	C	Kulumata	4	432 ± 97	7.9	2.6
Serrasalmidae	Myleus tometes	H	Coumaru	7	103 ± 122	15.9	1.25
Characidae	Astyanax	C	Yaya	5	1,040 ± 415	0.9	0.74
Loricariidae	Pseudoancistrus barbatus	O	Pële	45	155 ± 53	3	0.36

Previous mercury studies (InVS 1997)

Average daily consumption of fish flesh by Wayana family members, according to age and sex

Age group		Nb	Average daily consumption ± SD (SP*, g/day, fw)
< 1 year		**5**	**20 ± 9**
1-3 years		**14**	**47 ± 18**
3-6 years		**27**	**116 ± 69**
7-10 years		**34**	**173 ± 79**
11-14 years		**29**	**195 ± 110**
15-25 years	Men	**16**	307 ± 185
	Women	**20**	**262 ± 161**
	Total	36	**282 ± 171**
26-45 Years	Men	**27**	372 ± 193
	Women	**27**	**262 ± 138**
	Total	54	**317 ± 175**
> 45 years	Men	**19**	**162 ± 158**
	Women	**9**	**140 ± 116**
	Total	28	**155 ± 144**

* SP, standard portion

In period of abundance, the amount of fish consumed could be very high : more than 600 g/day (fresh weight) by some males adult.

Previous studies (BRGM* 2005)

- **Muscle mercury concentration of Aïmara (piscivorous fish) (2005)**

Length of fish Aïmara	[38 - 55 cm]		]55 - 80 cm]	
Sites	**N**	**Average. Conc.**	**N**	**Average. Conc.**
Litani river (upper Antecume Pata)	7	0,49	4	1,102
Antecume Pata	9	0,572		
Tampok river	6	0,628	4	0,891
Waki & Tampok river	6	0,487	9	0,666

(Report BRGM – University Bordeaux 1/CNRS - 2007)

Aïmara

Hoplias aimara

*BRGM = France's leading public institution involved in the Earth Science field for the sustainable management of natural resources and surface and subsurface risks

Previous mercury studies (1997 and 2005)

- **Mercury concentration of hair in Amerindians for Antecume Pata, Taluwen/Twenké and Cayode villages**

  - **10,6 µg/g** (n=235) **in 1997** (InVS* source)

  - **12,2 µg/g** (n=130) **in 2005** (InVS source)

- **Results** (InVS source - 1997) :

  The results confirm mercury exposure of the Wayana population related to a diet rich in fish, which are relatively highly contaminated for certain species (up to 1.62 mg/kg fresh weight or 8.1 mg/kg dry weight in skeletal muscle).

  The results from hair samples showed that 57% of the Amerindian people had Hg levels above the World Health Organization (WHO) safety limit (10 µg/g); all those over 1 year old had a Hg intake greater than the WHO safety limit (200 µg MeHg/week for a 60 kg male).

  The neurologic examination and neurobehavioral development tests revealed significant links between impregnation levels in the children and the presence of some neurologic and behavioral deficits (with reduced peripheral visual field profiles, reduced color discrimination capacities, and reduced performance in psychomotor and neuropsychologic tests).

*InVS = French Institute for Public Health Surveillance

Previous mercury studies by Bordeaux University (2008)

Feeding mice with diets containing mercury-contaminated fish flesh from French Guiana: a model for the mercurial intoxication of the Wayana Amerindians

In 2005, 84% of Wayana Amerindians living in the upper part of the Maroni River in French Guiana presented a hair mercury concentration exceeding the limit set up by the World Health Organization (10 µg/g). To determine whether this mercurial contamination was harmful, mice have been fed diets prepared by incorporation of mercury-polluted fish from French Guiana.

Methods :

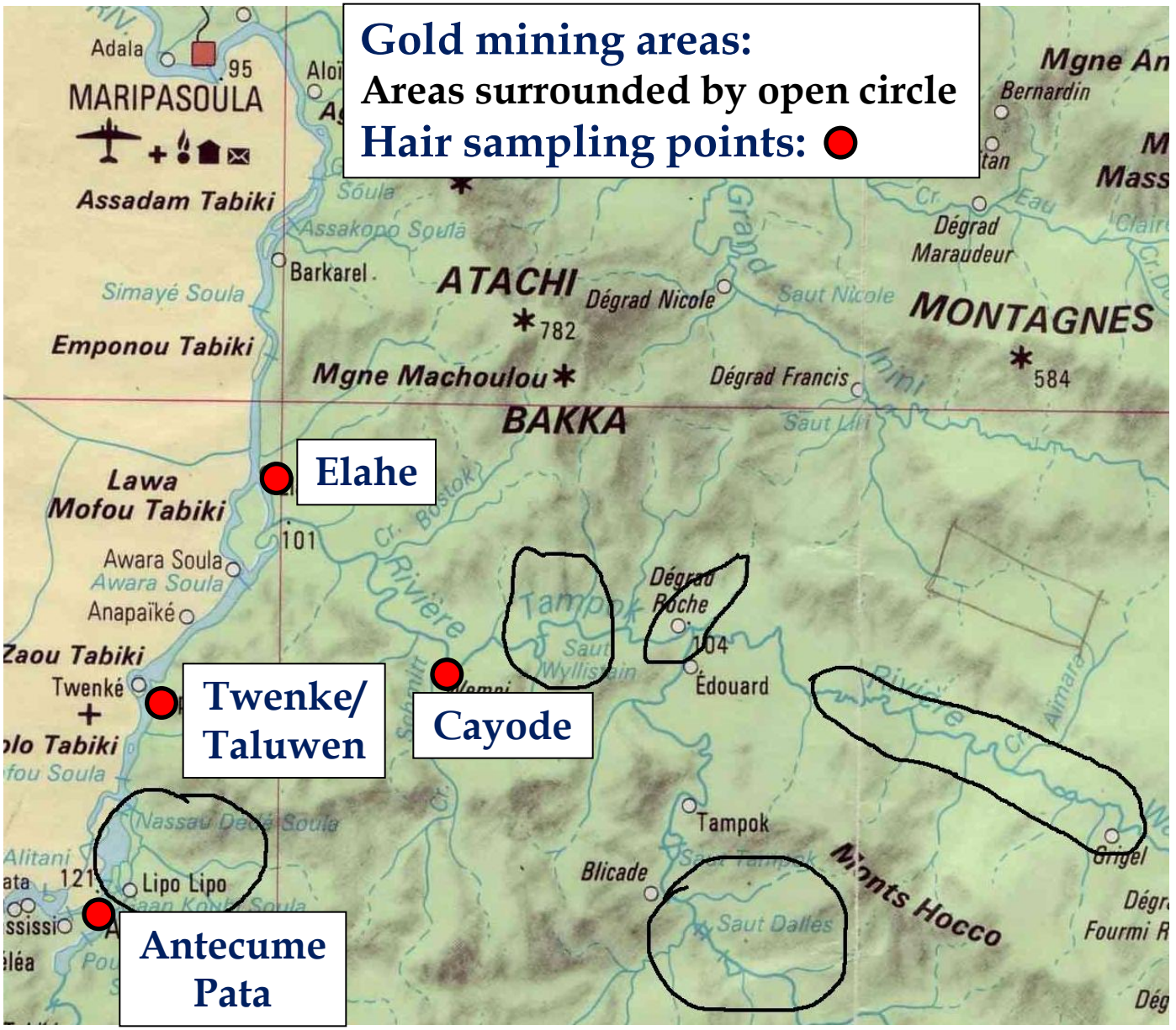
Four diets containing 0, 0.1, 1, and 7.5% fish flesh, representing 0, 5, 62, and 520 ng methylmercury per g, respectively, were given to four groups of mice for a month. The lowest fish regimen led to a mercurial contamination pressure of 1 ng mercury per day per g of body weight, which is precisely that affecting the Wayana Amerindians.

Results (Universite de Bordeaux 1 – CNRS UMR 5805) :

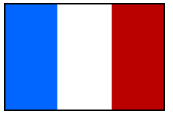
The expression of several genes was modified with mercury intoxication in liver, kidneys, and hippocampus, even at the lowest tested fish regimen. A net genetic response could be observed for mercury concentrations accumulated within tissues as weak as 0.15 ppm in the liver, 1.4 ppm in the kidneys, and 0.4 ppm in the hippocampus. This last value is in the range of the mercury concentrations found in the brains of chronically exposed patients in the Minamata region or in brains from heavy fish consumers. Mitochondrial respiratory rates showed a 35–40% decrease in respiration for the three contaminated mice groups. In the muscles of mice fed the lightest fish-containing diet, cytochrome *c* oxidase activity was decreased to 45% of that of the control muscles. When mice behavior was assessed in a cross maze, those fed the lowest and mid-level fish-containing diets developed higher anxiety state behaviors compared to mice fed with control diet.

Gold mining areas and hair sampling points

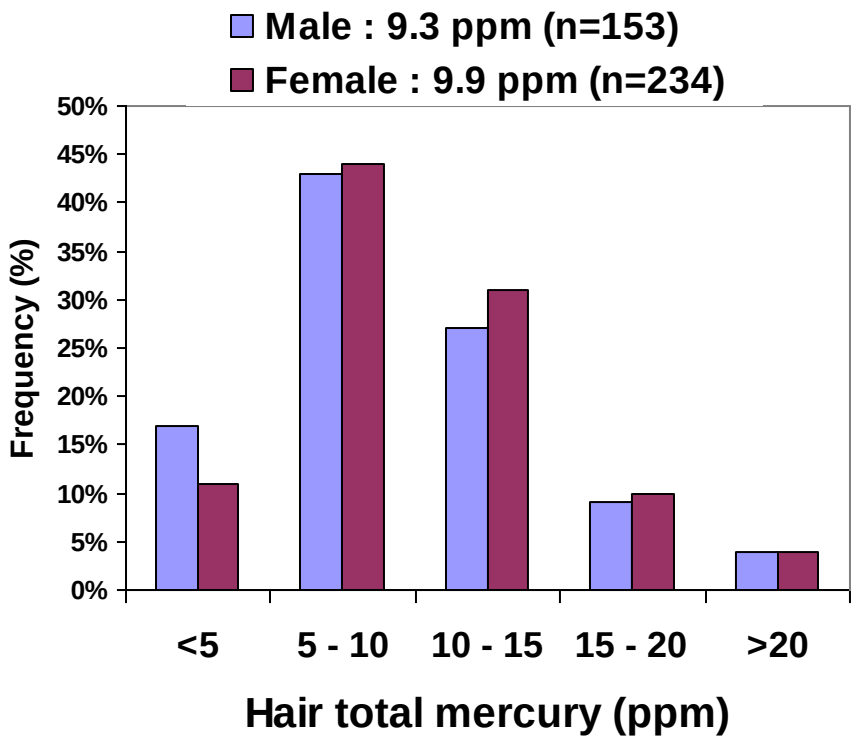
Suriname (former Dutch Guiana)



French Guiana



Hair mercury concentration in the upper part of Maroni (2004-2008)



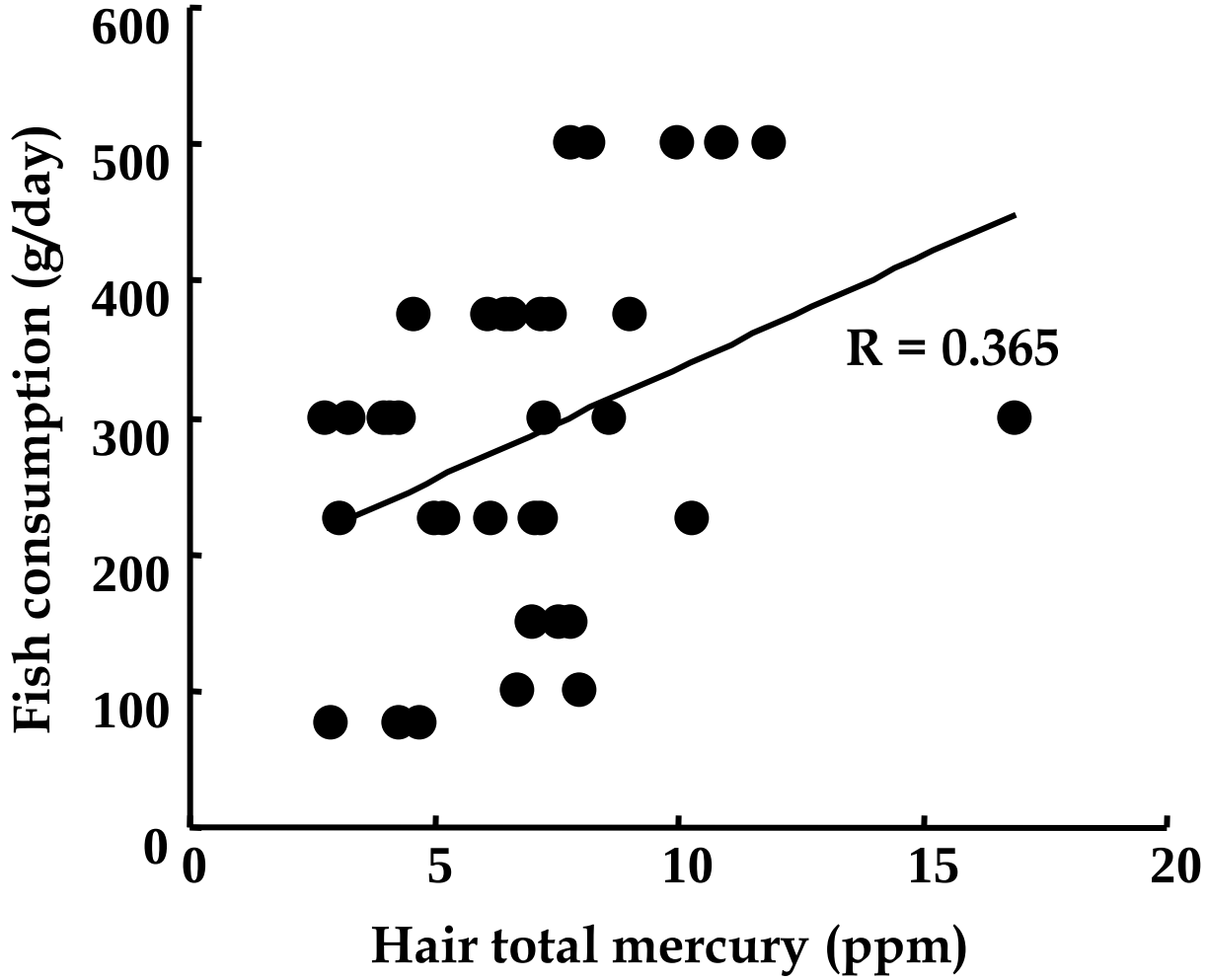
ppm	F		M	
<5	27	11%	27	17%
5 - 10	102	44%	66	43%
10 - 15	72	31%	41	27%
15 - 20	23	10%	13	9%
>20	10	4%	6	4%

The ratio of methylmercury was about 95.9% (>10 ppm, n=52).
Hair methylmercury is an indicator of internal exposure to mercury, indicating ingested mercury from food not but other external exposure.

Hair mercury concentration in each village (2004-2009)

Village	Sex	No. of subjects	Total hair mercury (ppm, min-max)
Cayode	male	108	9.9 (2.9 – 26.4)
	female	138	10.9 (1.6 – 26.6)
Twenke/Taluwen	male	29	8.7 (2.1 - 21.2)
	female	67	8.4 (2.0 – 17.9)
Antecume Pata	male	4	5.9 (3.2 – 9.4)
	female	13	11.3 (4.3 – 20.0)
Elahe	male	12	8.2 (2.5 – 14.9)
	female	16	6.1 (3.1 – 9.4)
Total	male	153	9.4 (2.3 – 26.4)
	female	234	9.9 (1.6 – 26.6)

Correlation between hair mercury concentration and fish consumption in Cayode and Twenke/Taluwen village (2008)



Hair mercury concentration in Cayode village

(2004 - 2009)

Children	Nb	Mini Hg (µg/g)	Maxi Hg (µg/g)	Average Hg (µg/g)	> 10 µg/g (threshold WHO)*	% Nb> WHO	> 4,4 µg/g (threshold EFSA)	% Nb> EFSA*
Cayode 2004	13	7,38	**21,97**	**11,51**	6	46	13	**100**
Cayode 2005	16	6,42	**26,6**	**12,41**	12	75	16	**100**
Cayode 2006	22	3	**13**	**8,91**	9	41	19	87
Cayode 2007	15	3,4	**14,3**	**8,33**	5	33	13	87
Cayode 2008	17	4,3	**25,5**	**9,16**	5	29	16	94
Cayode 2009	20	4,7	**24,6**	**11,92**	13	65	20	**100**

*EFSA = European Food Safety Authority *WHO = World Health Organization

Adults	Nb	Mini Hg (µg/g)	Maxi Hg (µg/g)	Average Hg (µg/g)	> 10 µg/g (threshold WHO)	% Nb> WHO	> 4,4 µg/g (threshold EFSA)	% Nb> EFSA*
Cayode 2004	24	6,4	**21,13**	**12,81**	18	75	24	**100**
Cayode 2005	16	6,59	**25,82**	**13,1**	10	62	16	**100**
Cayode 2006	17	4,3	**13,5**	**11,76**	10	59	16	95
Cayode 2007	9	6,5	**20,7**	**11,84**	6	66	9	**100**
Cayode 2008	12	4,6	**20,7**	**11,45**	8	66	12	**100**
Cayode 2009	5	11,4	**21,9**	**16,56**	5	**100**	5	**100**

Hair mercury concentration in Cayode village (2004 - 2009)

Results :

- In the village of Cayode on the Tampoc river, 60% of the adults has a mercury level above the old safety limit determined by WHO (10 µg/g) and 100 % with the EFSA standard (4.4 µg/g).
- We observed an increase in the mercury concentration among young children almost certainly due to contamination during their gestation and the breast-fed period. 100% of them has a level above the EFSA safety limit (4.4 µg/g).
- Figures translate the very strong relation between the level of poisoning and the importance of the gold mining activity upstream to the studied villages.
- The game being rare in the gold-mining areas, the populations has to increase their consumption of fish, their main source of protein, what has the effect of increasing their poisoning level.
- The level of mercury went down in 2006 further to a campaign of sensitization with a video in reference to Minamata disease introduced in villages.

Fishes in the upper part of Maroni

[Piscivorous species]

Aïmara
Hoplias aimara

Piraïe
Serrasalmus rhombes

Mitala
Ageneiosus brevifilis

[Omnivorous species]

Huluwi
Pseudoplatystoma fasciatum

Fishes in the upper part of Maroni

[Benthivorous species]

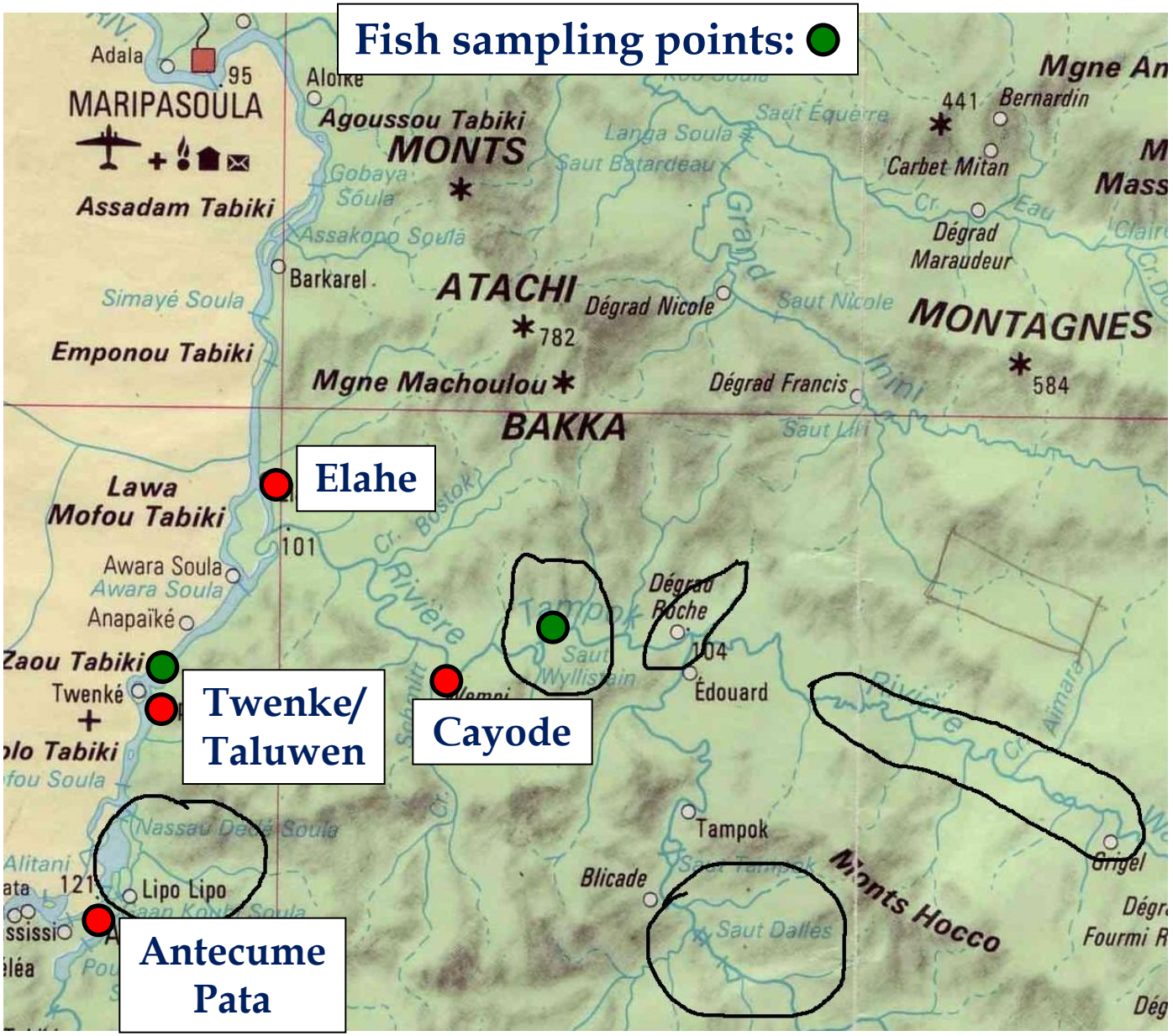
Agonosu
Doras cainatus

Yaya
Astyanax bimaculatus

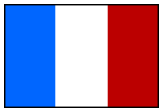
Hoké
Platydoras costatus

Fish Sampling points

Suriname (former Dutch Guiana)



French Guiana



Mercury concentration of fish flesh in the upper part of Maroni (2009)

Name of fish	No. of fish	Total mercury in muscle (ppm in wet weight, min-max)
Huluwi	6	0.33 (0.24-0.44)
Piraïe/Pene	3	0.40 (0.34-0.46)
Hoké	1	0.32
Mitala	1	0.18
Agonosu	1	0.11
Otululu/Opi/Yaya	1	0.18

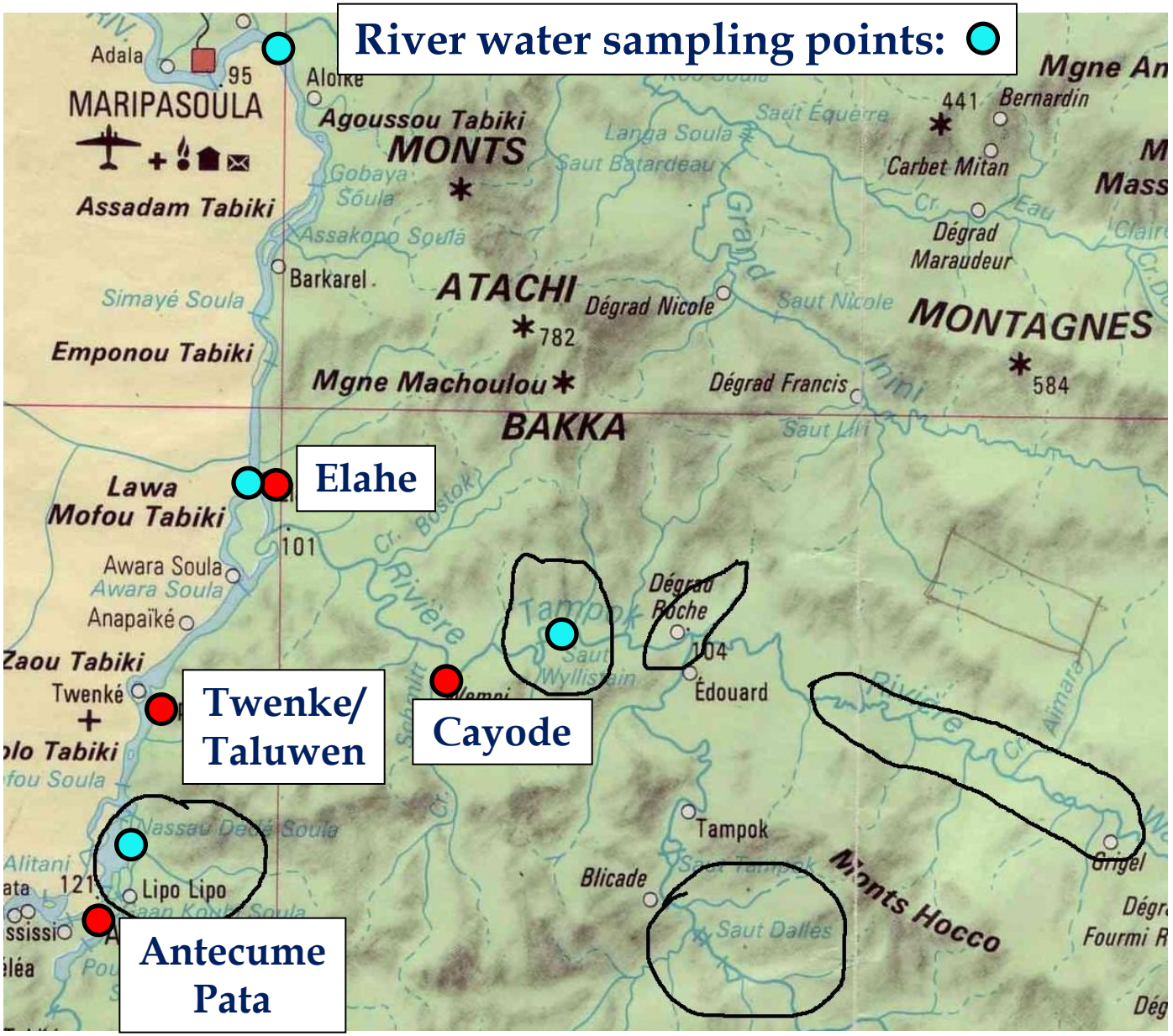
Huluwi

Piraïe

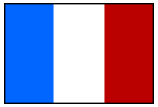
Yaya etc.

River water Sampling points

Suriname (former Dutch Guiana)



French Guiana



Mercury concentration of river water In the upper part of Maroni (2009)

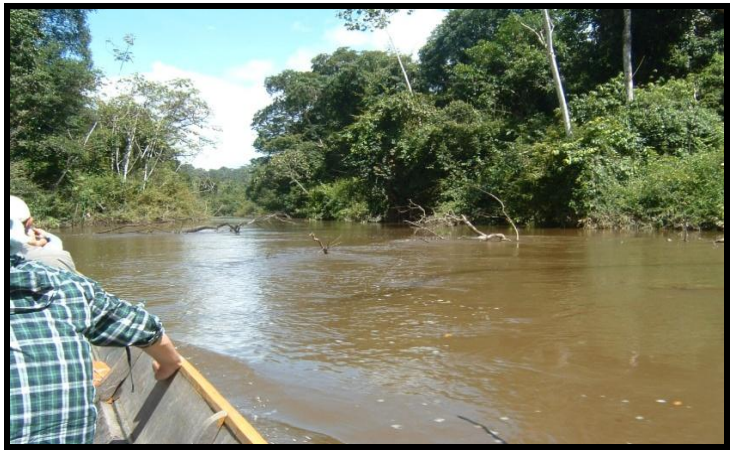
Near Maripasoula

T-Hg: 13.3 ppt MeHg: 0.07 ppt

Near Elahe

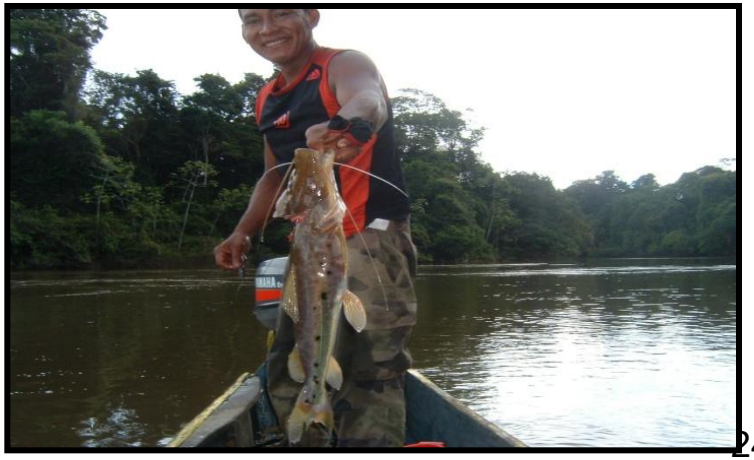
T-Hg: 3.3 ppt MeHg: 0.09 ppt

Near Antecume Pata



T-Hg: 5.8 ppt MeHg: 0.09 ppt

Near Cayode



T-Hg: 3.9 ppt MeHg: 0.07 ppt

Conclusion

In this study, we investigated the mercury concentration of hair in Amerindians in the upper part of the Maroni River for 6-years from 2004 to 2009. The average concentration of hair mercury showed remarkably high value at 9.4 ppm for male and 9.9 ppm for female respectively. In 2008, we performed the investigation of fish consumption in Cayode and Twenke/Taluwen as mercury-polluted villages. The correlation between the hair mercury concentration and fish consumption in Amerindians was significantly. Furthermore, the mercury concentration of the polluted fishes and river water in the upper Maroni river were measured in 2009. The mercury concentration in fish flesh and river water concentrations were also high.

These results indicate that the high concentration of hair mercury in Amerindians ascribed to the consumption of mercury-polluted fish by gold-mining even now.

Coworkers

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• Solidarity Guiana – Analysis of the poisoning of Amerindian people in French Guiana (2004-2009)

• BRGM – Rapport régional du mercure dans les sédiments et les poissons dans les six fleuves de Guyane (BRGM/RP-55965-FR – 2007)

• Université de Bordeaux - CNRS UMR 5805 - NIMD - INSERM - Jean-Paul Bourdineaud, Nadège Bellance, Giovani Bénard, Daniel Brèthes, Masatake Fujimura, Patrice Gonzalez, Aline Marighetto, Régine Maury-Brachet, Cécile Mormède, Vanessa Pédron, Jean-Nicolas Philippin, Rodrigue Rossignol, William Rostène, Masumi Sawada and Muriel Laclau (Feeding mice with diets containing mercury-contaminated fish flesh from French Guiana: a model for the mercurial intoxication of the Wayana Amerindians) (2008)

Investigation of human and environmental exposure to mercury in the upper part of Maroni, French Guiana, from 2004 to 2009

Jean-Pierre Harvard

Upper part of Maroni, French Guiana, has been known a mercury-polluted area induced by gold-mining. Some reports have mentioned that the mercury concentration of hair in Amerindians who lived in the polluted area showed high value. However, there has been no reports post-2002. In this study, we investigated the mercury concentration of hair in Amerindians for 6-years from 2004 to 2009 in the upper part of Maroni including Cayode, Twenke/Taluwen, Antecume Pata and Elahe villages. Hair samples of 387 inhabitants were taken (male: 153, female: 234). The average concentration of hair mercury showed remarkably high value (male: 9.4 ppm, female: 9.9 ppm). In 2008, we performed the investigation of fish consumption for 37 subjects in Cayode and Twenke/Taluwen village. The correlation between the hair mercury concentration and fish consumption in Amerindians showed significance. Furthermore, the mercury concentration of the polluted fishes and river water in the upper part of Maroni river were measured in 2009. The muscle mercury concentration of Huluwi, Piraïe and Hoké fish, which were usually eaten by Amerindians, were remarkably high. The average mercury concentrations were 0.33, 0.40 and 0.35 ppm in wet weight, respectively. The total mercury concentrations of river water were at 3.9 ppb near Cayode village, 5.8 ppb near Twenke/Taluwen and Antecume Pata village, and 3.3 ppb near Elahe village respectively. These results indicate that the high concentration of hair mercury in Amerindians is ascribed to the consumption of mercury-polluted fish by

gold-mining even now.