MERCURY IN BRAZIL AS RESULT OF GARIMPO OPERATIONS

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ABSTRACT

The formidable impacts caused by mercury usage in industrial activities, be it in chemical factories or energy production, as it is inherent in coals used in thermal power plants, and in agriculture as part of herbicides compounds are all well documented in the literature. As well teeth amalgams are an old concern, recently revived in the scientific literature.

From the end of the 80's onwards the extraction of gold in rain forest areas and wetlands, in the form of **garimpo** operations, are receiving increased attention from scientists and public planners.

The purposes of this paper is to situate the problems caused by **garimpo** extractions which utilize mercury in Brazil advancing some interaction effects of such utilization within the ecosystems and population health, as well as present some solutions to date to deal with such a problem and, last but not least pointing out some of the still pending problems.

INTRODUCTION

Etymologically, **garimpo** is a Brazilian word quite utilized during colonial times, meaning the working of gold, diamonds and emeralds mines, by a **garimpeiro**, that is a person with practical skills but without the formal licensing of the legal authority, thus illegally performing such extractions. Or, as stated in the Royal Decree dated of march, 26, 1731" *o nome com se apelida neste país aos que mineram furtivamente as terras diamantinas e que assim são chamados por viverem escondidos pelas grimpas das serras"* or, translating," the name given in this country to those outlaws miners that mines the lands of Diamantina, being thus called due to the fact that they live in" grimpas" on the hills" .

Throughout times it became synonim of small, artisan type, operations, as contrasted to industrial mining.

By the end of the 80's however, due to the paramount extraction of gold in the amazon region, the word also means informal mining, in the sense that the size of the operations might be small or large, but always semi-outlawed or totally outlawed, since the legal authorities did not produced a legal framework on time to accommodate all the several particularities of the said operations. For details on the terms being utilized to describe gold extraction activities, the reader has to refer to VEIGA(1997).

Notwithstanding, **garimpo** is the best terms for such activity worldwide, whenever the following facts are present:

- Gold is extracted as free gold or alluvial gold;
- Such extractions are in rainforest areas and tropical wetlands;
- The exploitation is performed under no legal framework, either mining or environmentally;
- Normally no formal working links exist between the players in the **garimpo.**

GOLD GARIMPO IN BRAZIL

The map (MARCONDES, 1996) that follows illustrates in unquestionable manner the scattering of **garimpos** throughout the Brazilian territory, the reason being purely geological, since in tropical precambrian areas the presence of secondary compounds is favored, gold not being an exemption, except for the case of not occurring as a compound, but rather as the metal itself !

Garimpo in primary sources, as those of massive sulfides are unknown for gold in the country, and those occurring as quartz veins,in modern times, are quite rare, although sometimes seen.

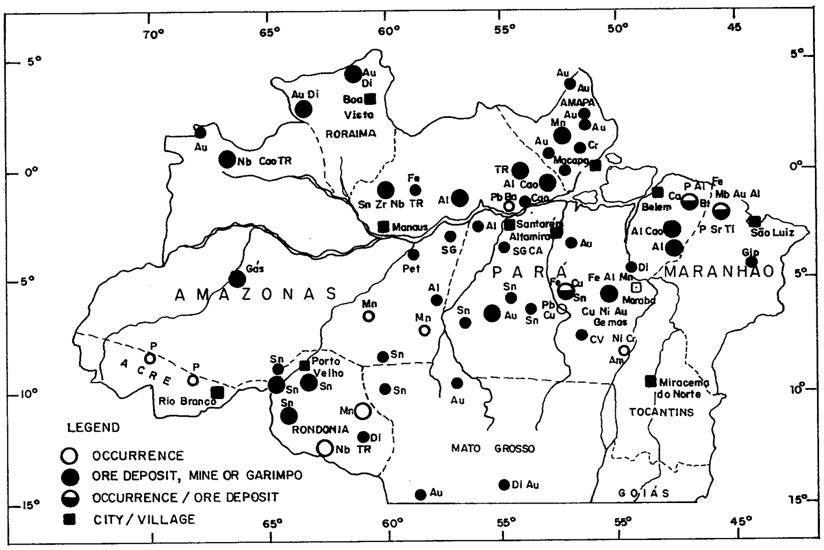


Figure 1 – Mineral Resources of the Brazilian Amazon

One of the typical characteristics of the **garimpos**, in the golden ages of the 80's and 90's, due the very favorable selling price of gold ingots, was their mobility, in such a way that the authorities always issued some kind of legal bill, after the site of operation has being occupied, overnight, by thousands of **garimpeiros**, arriving from all places.

Thus, the following table brings the areas, so called, reserved areas to the **garimpagem** and the substance that was allowed to be **garimpada**, as published by DNPM in 1994, and still pretty much the same.

AREA	ORE	STATE	COUNTY
Carnaíba	Emerald	Bahia	Pindobaçu
Rio Madeira I	Gold	Rondonia	Porto Velho
Alto Coité	Diamond	Mato Grosso	Poxoreu
Rio Madeira II	Gold	Rondonia	Porto Velho
São Tomé	Pegmatites	R. G. Norte	Lages
J. do Serido	Pegmatites	R. G. Norte & Paraíba	Juazeirinho
Zé Vermelho	Gold	Mato Grosso	Alta Floresta
Cabeças	Gold	Mato Grosso	Alta Floresta
P. de Azevedo	Gold	Mato Grosso	Peixoto Azevedo
Tapajós	Gold	Pará	Itaituba
Cumaru	Gold	Pará	S. Felix Xingú
Tepequem	Diamond&Gold	Roraima	Boa Vista
S. Terezinha	Emerald	Goiás	Sta. Terezinha
S. Pelada	Gold	Pará	Curianópolis
Rio Jurema	Gold	Mato Grosso	Alta Floresta
Minas	Several	Minas Gerais	Vários

Of these the largest areas are Tapajós, in the Itaituba county, with 2.874.500 ha; Minas Gerais, in the counties of Diamantina/Monjolos/ Gouveia/Dantas/Bocaiuva, with 1.178.375 ha;Peixoto de Azevedo, with 657.550 ha ; Alta Floresta, totaling 171.000 ha ; Cumarú, in the county of São Felix do Xingú, with 95.145 ha , etc... just to give an account of the sizes we are mentioning.

Therefore, due to the given reality of the **garimpo** existence, bills were passed in the house of representatives in order to provide a legal structure for the activity, these being Bill of Law 7805/89, dated 20/06/1989, followed by Federal Decree 9812, dated 04/01/1990.

As for gold, the Brazilian **garimpos** may be grouped in five main classes:

1.- Manual: quite rudimentary;

2.- Semi-mechanized: where the rocks at the river bottom are sucked via hoses manually driven by divers and powered by Diesel motors up to 32 HP;

3.- Drags: the same as above except that the hoses are thus conducted by mechanical hoisting and no divers exist;

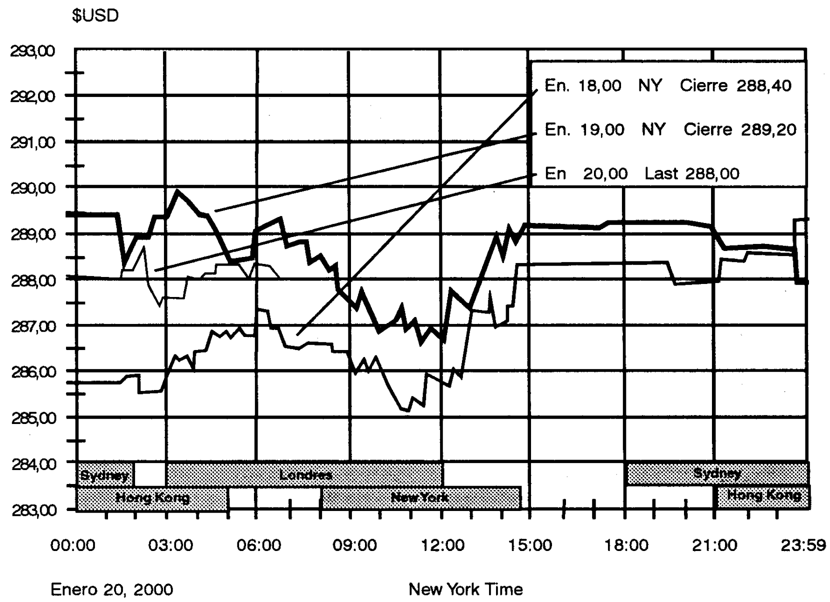
4.- Hydraulic: hydraulic loosening of the waste rock; as well caterpillars and trucks might be seen, instead of the hydraulic monitors;

5.- Primary Ore: in quartz veins.

The National Department of Mineral Production, herein denominated DNPM, yearly issues the publication SUMÁRIO MINERAL BRASILEIRO, and quite regularly the most complete ANUÁRIO MINERAL BRASILEIRO, both bringing all of the most important statistics in the mineral arena in the country. They shows the extraordinary decrease in **garimpo** gold production from the nineties onwards, due to the very low selling price of the troy once. Some analysts affirm that only at a US$ 400.00 per once troy will bring back **garimpo** production in larger scale, besides the fact that, according to MARON (1999), after the Kandir Bill in 1996, that allowed less taxation of primary and semi-manufactured Brazilian products, the largest part of the Brazilian gold is being exported as such, since that part of gold that goes into the domestic market is quite taxed!!

For an overview of some of the legal, economical and social problems of **garimpos** the reader is invited to consult MIRANDA et al. (1997)(SED 38); for an overall account of the mineral economic facts related to gold, please seek http://www.dnpm.gov.br.

An interesting feature of gold price fluctuations , however , is given by this graph , recently published by PANORAMA MINERO (January 2000) shown the variations of gold prices within a 24 hours period, in Sydney, Hong Kong , London and New York , accordingly to NY Time.



THE MERCURY PROBLEM

In rainforest areas and tropical wetlands, whenever a situation as the one aforementioned arises, mercury originates from gold extraction, **garimpo**, operation, both in the form of elemental mercury, used to amalgam gold, and mercury vapor, either elemental or oxidized, originated from the burning of the amalgam, thus liberating gold and mercury, as well. Such mercury compounds will then be released to the environment, carelessly, due to the very fragile legal framework in which such operations are carried out, not to mention the law enforcement alone, into rivers, into soils or just into the atmosphere.

For a complete account of the several unit operations carried out at gold **garimpos** sites in Brazil, please see FERNANDES et al. (1991), FARID et al.(1992), RODRIGUES et al.(1994), RODRIGUES FILHO (1995,1996), DA SILVA et al. (1996), BRAGA and ARAÚJO (1995), ARAÚJO and SANTOS,(1995) and VILLAS BOAS (1997).

The environmental problems associated to the presence of mercury in the environment, being it in a liquid, ionic, or vapor form are all well documented in the literature, for instance D'ITRI (1990), CÂMARA (1993), PECORA (1970), amongst others (5th I.C. on Hg, 1999). However, no alternative route to Hg amalgamation is in effect, and processes as cyanidization, a problem in itself, oil or wax agglomeration, halide extraction, etc. neither compete economically nor are suitable for **garimpagem**, see CRAMER(1990)!

FERGUSSON(1990) lists some of the alkyl derivatives of the heavy metals relevant to the mercury environmental geochemistry and chemistry, the interests being in the toxicity of such compounds and the fact that methylation does occur for many of the heavy metal elements.

Methylation represents the transfer of a methyl group from one compound to another, the process occurring biologically or abiotically. Bacteria and fungi so far reported to methylate Hg, As, Se,Te,Pb,Cd,Tl and In, are usually aerobic, exception being clotridium sp and methanobacterium which are anaerobic.

There is good evidence for biomethylation of mercury, arsenic, selenium and tellurium; however there are doubts regarding that of the other heavy metals.

In 1964 the cobalt complex ion (CH3Co(CN)5)3-, which is the model for vitamin B12 was show to methylate mercury. WOOD(1968) suggested that the methylating agent associated with methane-producing bacteria was methylcobalamin, i.e. the methyl derivative of vitamin B12, where the CN- group is replaced by CH3-.

On the other hand, methylation by non-enzymatic MeCoB12 may be treated as abiotic, except that the reagent itself is produced biotically and may be re-methylated biotically. The two main abiotic methylation processes are transmethylation, and to a lesser degree photochemical.

Several features of the chemistry of mercury facilitate its existence in organo-species and is quite important to consider when dealing with the mercury problem in tropical estuaries, not to mention the aforementioned role of the vitamin B12 as a methylating agent, sometimes not taken into account even by scientists visiting **garimpo** areas !!

One of these features is that both Hg^{2+} and CH_3Hg^+ are soft acids and bond pretty well to soft bases such as S^{2-} and SH^-, the cation being large and polarizable, and because of the positive charge, in itself a good polarizing cation with tendency to constitutes covalent bonds. The Hg-C bond, though not that thermodinamically strong (60 to 120 kJ/mole) is stronger that Hg-O bonds, therefore persisting in the environment.

Bacteria that might be associated with mercury methylation are located in the bottom of sediment rivers, estuaries and the oceans, besides the intestines and feces, soils and yeast, the factors that influences their methylating action being temperature, Hg and bacteria concentrations, redox conditions, pH, type of soil, type of sediment, sulphide concentrations.

Methylmercury accounts for circa 0.1 to 1.5 % of the total mercury in sediments, and around 2% of the total in sea water, but in fish it accounts for over 80% of the total. It is not clear, however, if the CH_3Hg^+ is taken in by the fish from the water or formed within the fish, or both.

The changing chemistry of mercury was already pointed out by RENUKA(1993) and it is always a point of concern among those who are devoted to the study of mercury and mercury compounds.

In Brazil, remediation procedures for exhausted gold ores, however carrying mercury were tried, and an electroxidation method was introduced in **garimpo** sites in order to reclaim mercury from tailings as described by SANTOS E SOBRAL (1998). A discussion will be given in a later section of this paper to this process.

The rationale behind the several research project conducted throughout the major **garimpo** areas in Brazil was to seek answer for the following questions:

What is the fate of mercury into the environment ?

Is there any alternative reagent to mercury that is competitive with it?

How to avoid environmental damage from these operations and from mercury ?

At the beginning of the 90's, the Brazilian House of Representatives decided to seriously look upon the mercury problem in garimpos and commissioned CETEM – Center for Minerals Technology – of the Brazilian Research Council – to perform a four year program for that matter, utilizing all available resources in the country or outside the country.

Several links were thus established between CETEM all of the other institutions that were interested in mercury, from several viewpoints, namely, mining, reclamation, health, environment, ecology, legislation, social structure, economy, etc...

All major research organizations in the field participate in such a program, plus government institutions dealing with the mining and environmental issues, plus the **garimpeiros** unions, these institutions being:

- Research: CETEM, UFRJ, UFPa, UFF, FIOCRUZ, EVANDRO CHAGAS, UFMT.
- Federal government: MME, MMA, DNPM, IBAMA.
- State government: METAMAT, SEICOM/Pa.
- County government: Prefeitura de Poconé, Prefeitura de Alta Floresta, Prefeitura de Itaituba.
- Unions: Sindicato Nacional dos **Garimpeiros** da Amazonia, Sindicato dos **Garimpeiros** de Itaituba.

And the task was to answer the aforementioned questions plus some others that throughout the research path were discovered to be of significance to the final goal.

THE PARTICULATE MATTER

Besides mercury, the release of particulate matter coming from earth-moving also contributes to the deleterious effects on the biota and health. Physical impacts on the environment coming from mining activities are related to the release of particulate into rivers, lakes oceans and the air.

These,as known, interact with the environment and may substantially alter the biota. Little is known of such effect when associated with heavy metals cations, mercury included; later, we shall discuss in more detail some satellite photos taken of particulate carrying mercury in the upper atmosphere.

If one utilizes the partition coefficients (Kd’s) as proposed by DUURSMA(1994),the partitioning of the contaminants may thus be determined, between the several compartments of interest, i.e. water, sediment, particulate and biota, hence furnishing useful empirical data in determining the percent distribution between dissolved and particulate matter, accumulation in organisms, etc.. and a very intriguing fact is that a newly contaminated tropical estuary might be a sink for a long period, afterwards becoming a source as equilibrium is attained faster that in temperate climates.

A very extensive program, named CAMGA-TAPAJOS, monitoring the **garimpos** at the Rio Tapajos area was conducted by SEICOM/Pa(1992) and the following table may be inferred.

Environmental impacts derived from extraction and concentration techniques for gold recovery in Rio Tapajós, as related to particulate matter

<table>
<tr><th colspan="2">Causes</th><th>Physical and/or Chemical</th><th>Biological</th><th>Antropic</th></tr>
<tr><td rowspan="5">EXTRACTION</td><td rowspan="5">CONCENTRATION</td><td>erosion/increasing suspended load</td><td rowspan="2">changes in ecological habitats</td><td>damaging fishing activities</td></tr>
<tr><td>changes in color, turbidity and other organoleptic water properties</td><td>increase in water treatment costs</td></tr>
<tr><td>silting-out and changes in river courses</td><td rowspan="3">changes in ecological habitats</td><td>losses of natural resources</td></tr>
<tr><td>water pollution (soaps and oils)</td><td>endemic diseases</td></tr>
<tr><td></td><td>losses of natural resources</td></tr>
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SOME DATA COLLECTION OF INTEREST

Some relevant physical chemical data collected, are herein summarized, in order to present the kind of problems that are found in **garimpos**. We tried not to be exhaustive, for that matter see Proceedings of the 5th I.C. on Hg as a Global Pollutant, but just present data that are quite representative of the overall posed problem and that we were directly involved.

a)Background and sediment mercury concentrations, measurements in local air, gold shops and urban areas were made, as well as Au/Hg ratio, and the content of mercury in processed tailings determined.

These measurements and determinations were reported in the literature, see VILLAS BÔAS (1997), VEIGA et al. (1991), RODRIGUES FILHO and MADDOCK (1997), FARID (1992), BRAGA and ARAÚJO (1995), and ARAUJO and SANTOS (1995), all from CETEM. Tables 1 and 2 summarize these findings.

Table 1 - Mercury concentrations in sediments, air, gold shops and tailings

Area	**Mercury[a]**					
	Background (ppm)	Sediments Cn/Bn[b]	Air ($\mu g/m^3$)	Gold Shops ($\mu g/m^3$)	Au/Hg	Tailings (ppm)
Poconé	~ 0.10	1.5 to 24	0.14-1.68	~ 100	1:1.5	1 - 25
Alta Floresta	~ 0.07	1.5 to 48	up to 5.8	up to 41	1:1.5	5 - 134
Itaituba	~ 0.15	1.5 to 24	up to 6.6	$>$ 9.9	N.A.	47

[a] concentration from several field samples.

[b] Cn/Bn accounts for the ratio between the concentration of Hg in the -74μm fraction and the background value of Hg in the same fraction.

Table 2 - Field results for Peixoto de Azevedo [c].

Source	Hg input kg/month	Recovery kg/month	Total Losses kg/month	Losses to Air kg/month	Losses to Water kg/month
Garimpo do Melado	16	3.20	12.8	7.7	5.1

[c] BRAGA and ARAÚJO, 1995.

Several other important data on soil, sediments and water were collected, analyzed and presented elsewhere (LACERDA, 1992, 1994, 1996, 1997; RODRIGUES FILHO,1994; FARID, 1992; TUMPLING et al, 1995; MUELLER, 1996), among others.

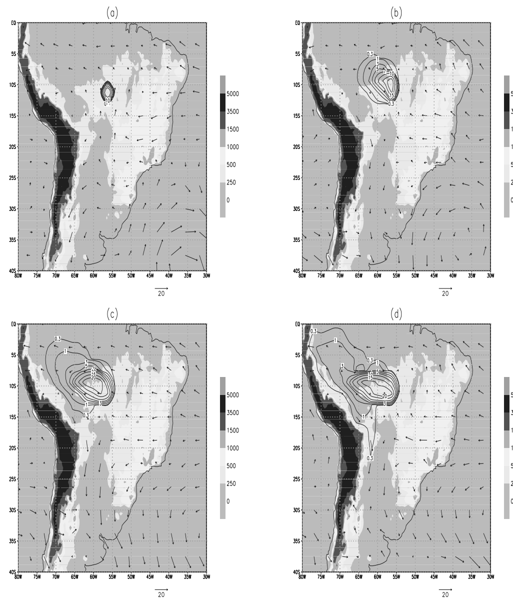
Also data on the health status of the living community were collected an reported elsewhere (CAMARA,1993; TOBAR, 1996; HACON, 1996), among others trying to establish correlation between mercury poisoning among the local population, including the **garimpeiros**, and eating habits, concurrence of diseases, and inhalation of mercury vapor. These subjects are also present still today in several papers of this 5th I.C.

b) Mercury dispersion in Alta Floresta: later in 1996, another grant, via PADCT enabled CETEM to coordinate an effort involving several other institutions, some of the already mentioned and some new ones, as INPE, the National Institute of Space Research, and USP through the Institute of Physic, dealing with mercury measurements in the atmosphere in the region of Alta Floresta. The findings of such a project were published elsewhere, see COELHO (1997).

Some interesting features emerged from the data shown in the figures (Apud NOBRE et al. 1996) regarding the atmospheric dispersion of contaminants, after 7 days from the emission, at the level 925 hPa, from a source with constant intensity, active for 5 days, beginning in 20/08/95 and located in Alta Floresta. At the seventh day, it can be observed that the dispersion was directed to the west as well as to the north and south directions, certainly due to the effect produced by the Andes, as a geographical barrier. Thus, in a few days, contaminants such as mercury, emitted from the Alta Floresta region, may deposit in relatively distant hydrological basins. A look at the satellite photos due show the extraordinary, predicted, mobility of air parcels carrying mercury aerosols throughout the atmosphere, with pre andine, caribean and even at the La Plata estuary consequences ! SILVA FILHO et al., (1999), discusse the mercury distribution in surface soils in central amazon.

c)Accredited analytical procedures, for total mercury, were used for soils, and water, see WILKEN,(1991); PADBERG, (1991), and air emissions in Alta Floresta, via denuders, as discussed by MARINS (1996), or via CVAAS and PIXE for the particulate, see HACON et al(1995); ARTAXO (1996) and GERAB (1996). The results for sampling of the gold shops ambient showed that the major part of the mercury associate to the particulate, coming from the hoods is in the gross fraction of the aerosol; however, an important fraction of mercury is within the fine particulate, thus facilitating its transport together with the ”queimada” aerosol; about half of the mercury associate to the particulate is non-volatile, being strongly attached to the particles, see FERNANDES et al (1996).

Also, a biomonitor, i.e. *Tillandsia usneoides*, a bromeliad for atmospheric mercury was tested (MALM et al., 1996) showing promising results at a comparatively low cost, although some advocates that, FONSECA et al (1999), its use is indicated only to areas where Hg concentration are higher that 5ug/m3 of air; also interesting other discussions are available such as SCHWUGER et al.(1999); KVIETKUS et al (1999); GUIMARAES et al.,(1999); CECILIO et al.(1999); PINTO et al.(1999); MAURO et al. (1999) amongst others; methylmercury determinations, were conducted at the Instituto de Biofísica of UFRJ, as shown by PFEIFER et al. (1991) and much later on, via the guidance of AKAGI (1996), and HORVAT (1997), CETEM was able to perform them MELAMED (1999).



Mercury dispersion in Alta Floresta, considering a constant source of emission of 3.5 units initiated at 20/08/95. (a) first day; (b) second day; (c) seventh day; (d) ninth day after the beginning of the emission.(APUD NOBRE et al, 1996)

SOLUTIONS FOUND

Problems with mercury release in **garimpo** are well widespread in the Pacific Rim, Latin America and Africa requiring the conception, design and implementation of adequate methods for mercury utilization, monitoring and mitigation.

The solutions to the problem of mercury usage were divided into two classes:

- in those areas where the problem already exists
- future avoidance of the problem

In order to tackle both, the local involvement of the community is a must (in Brazil it is quite common to find, besides labor and employee unions, Rotary's and Lion's Clubs that act as facilitators). Nobel Prize HOFFMAN (1995), presented the methodological approach that we utilized in those already mentioned areas. Such methodology takes into account the fact that the samples we were collecting involved people living in communities; therefore a historical context of that particular community, a social profile of that community, a description of the political power underlying that community. And the legal aspects of the extraction activities and the environmental concerns of that community were established and analyzed by social researchers, see BARRETO (1991); BARRETO et al.(1996); PORTELA(1991); BARBOSA and LOBATO (1992) and MENEZES (1996).

Results were then discussed in several meetings with local community involvement, utilizing in this communication procedure all the available social entities that were stakeholders for that problem, i.e., the Lyons and Rotary Clubs, the Unions, both worker" and bosses" and societal commitments were reached in other to mitigate the problems associated with Hg releases.

These commitments involved:

- the understanding of the problem
- the will to commit community efforts in dealing with it
- to gather all the stakeholders involved in the discussions and to reach a consensus approach (those that favored the procedures and those that didn't)
- once the consensus was reached the following solutions to mitigate the problems were established a)closed circuit utilization of mercury in the concentration/amalgamation steps; b) burning of the amalgam in retorts in the field, and use of fume hoods in gold dealers' shops; and c) confinement of processed material in specially build settling ponds.
- these measures were taken both for the present operations and proposed to avoid future problems.
- for the present operations, after sampling the levels of mercury, risk areas were assessed, isolated and remediation measures

were performed, regarding mercury fixation and/or recovery as below.

Immobilization of hg

Mercury can be fixed by sulphur in polysulphides. This method, however, which can be utilized for the inactivation of Hg in solid masses, has been criticized on the grounds of the equilibrium constants for the several Hg-S bonds. No field tests were conducted, but a quite interesting paper on the subject is that of BENOIT et al. (1999).

However, laboratory testing was performed utilizing polysulphide solutions, obtained from a mixture of sulphur flowers and soda ash, i.e., commercial grade sulphur and sodium hydroxide. The results, although looking promising could not be numerically assessed, in terms of the actual degree of fixation, (we are talking of sites containing below 10 ppm of total mercury) due to the still difficulty in analyzing HgS below 1 ppm, as shown by WILKEN and ALLEGRA (1991).

Recovery of Hg

Whenever possible, mercury has to be recovered. One method tested by CETEM is that of electrooxidation (SOUSA, 1991;VEIGA et al., 1991; SOBRAL and SANTOS, 1995). Its main feature is generation of hypochlorite ions by oxidation of chloride ions to elemental chlorine that in a aqueous media results in hypochlorite. Such a process may be viewed as an electrolytic segregation process, because small amounts of NaCl are intermixed with the resulting residue (“ ore”) in an aqueous pulp that is electrolyzed. The general reactions may be written as:

$$\mathrm{Hg} + 2\mathrm{ClO}^- + 4\mathrm{Cl}^- + 2\mathrm{H_2O} \Leftrightarrow \mathrm{Cl_2} + \mathrm{HgCl_4^{2-}} + 4\mathrm{OH}^- \qquad (1)$$

and

$$2\mathrm{Au} + 7\mathrm{NaCl} + \mathrm{NaClO_3} + 3\mathrm{H_2O} \Leftrightarrow 2\mathrm{NaAuCl_4} + 6\mathrm{NaOH} \qquad (2)$$

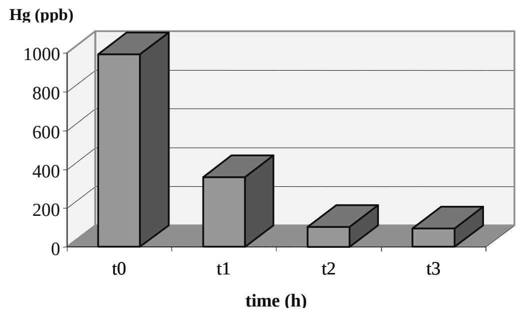
the dissolved gold being electrowon jointly with mercury.

Mercury recovery from tailings was conducted by installing and electro oxidation pilot demonstration unit in which up to 92% Hg recovery was achieved for a 6 h electrolysis time, in a 100 g/L NaCl solution, with an average energy consumption of 177 kWh/t, at pH 6-7, from tailings containing 6.8 mg/kg of Hg, producing a final solid material with 0.5 mg/kg of Hg. The dissolution of mercury may be viewed as:

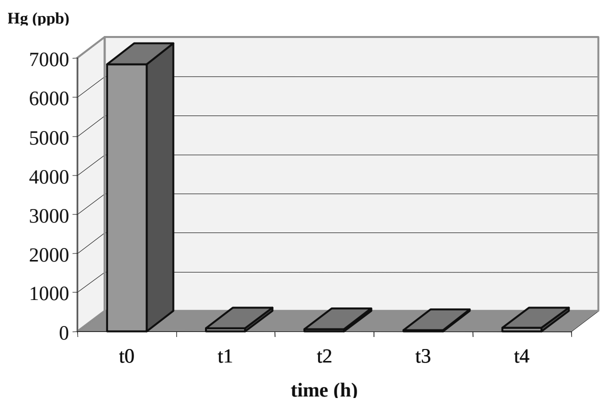
$$2NaOCl + Hg^{0} + 4HCl \rightarrow 2Na^{+} + HgCl_4^{2-} + 2H_2O + Cl_2 \qquad (3)$$

and mercury being deposited as elemental mercury.

A series of pilot plant runs were conducted in the location of Rio do Rato, Itaituba. The results of this field campaign are given below (SANTOS & SOBRAL, 1995).



Mercury concentration in the residue during electroleaching, i_a = 0.8 A/dm^2; 49.1 g NaCl/dm^3; 17 mL HCl; time 4 h; 1550 rpm.



Mercury concentration in the residue during electroleaching, i_a = 0.8 A/dm^2; 49.1 g NaCl/dm^3; 25 mL HCl; time 4h; 1550 rpm

Others

Other more obvious, and common senses solutions and measures were found and implemented, such as:

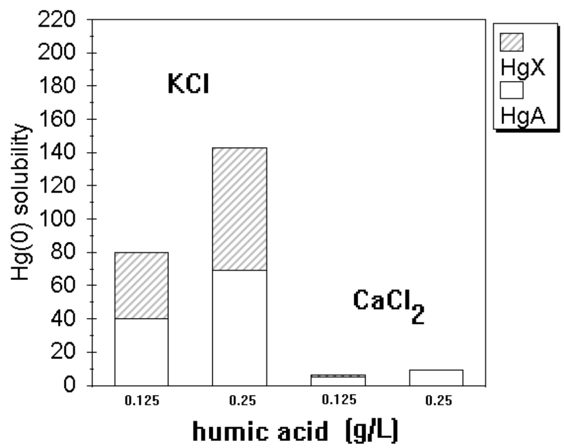
- no spilling of mercury during the amalgam phase, being a matter of mercury management throughout the process
- use of amalgamation vessels
- processing of the ore in close-circuit
- use of retorts in order to collect the mercury vapors
- use of fume hoods at the gold shops

Also an overall manual on how to process alluvial gold ores and manipulate mercury safely was issued (CETEM, 1994;1995; DNPM, 1996). Also, an overall account of part of this experiences are available,see SADEK et al. (1999).

MERCURY IN PRESENCE OF HUMIC ACIDS

The importance of the study of the mechanisms through which humic acids interacts/reacts with mercury compounds were stressed by MELAMED et al. (1997); VILLAS BÔAS et al. (1997) and, among others, VARSHAL (1999).

Tests utilizing Ca to revert the effect of humic acid on the enhancement of Hg^0 solubility, MELAMED and VILLAS BÔAS (1998), show that the increased solubility of Hg^0 due to the *Aldrich* humic acid was reverted in the presence of Ca. The need to verify such an amendment, and the possible development of this technology in the presence of natural organic acids MELAMED et al. (1999) is a must. Interestingly, the data shown in indicate that Ca prevents the dissolution of Hg^0 rather than a competitive complexation mechanism.



PENDING PROBLEMS

Pollution Limits: in order to assess if a substance, or compound, is effectively deleterious to animal health and or to the environment its past usage records are reviewed and reassessed. It also may be tested in simulation experiments on living organisms. Analytical and instrumental methodologies are to be available for lower detection limits, otherwise temporary lower detection limits are fixed. Tests driven under simulation conditions have to be standardized or via consensus. These are very important to inform on individual risks and the lowest observed adverse effect level., as well, but how to conduct this in the amazon ?

Compartments: the interactions between pollutants, environment and compartments are to be carefully assessed and speciation techniques are becoming a must in order to define the toxicity of the substance or compound, see for this matter, COQUERY et al. (1999).

Responsabilities: in fixing the lower and upper limits of pollution; they are not JUST a technical responsability; they are a POLYTICAL responsability that will include, besides technical evaluation, an economical evaluation and their social consequences (health, education, employment). Here lies a very intriguing problem since in the majority of rain forest areas, **garimpo** activities are considered to be illegal, what difficult quite a bit its willingness to collaborate in environmental and health matters, or, as in the case o Brazil its legalization procedures are so cumbersome that, in fact, the great majority just remains illegal. At the 5th. IC. several papers dealed with the threats to public health and, eventual, responsabilities (PIVETTA et al., 1999; PASOOS et al., 1999; HACON et al, 1999; SANTOS et al., 1999;VASCONCELLOS et al. 1999;GRADJEAN et al., 1999;JESUS et al., 1999; MATTOS et al. 1999; SANTA ROSA et al., 1999;TAVARES et al., 1999; MIEKELEY et al. 1999;MERGLER et al. 1999; GUAN et al., 1999; DESCHAMPS et al. 1999;OLIVERO et al. 1999; TUCEK et al. 1999). Also, several papers presents views on educational programs and, eventual, responsabilities (KLIGERMAN et al., 1999; CAMARA et al., 1999;DESCHAMPS et al., 1999; DAVIDSON and VEIGA, 1999;GUERRIER et al., 1999;VEIGA et al. 1999; WHEATLEY, 1999; SHAMLAYE, 1999;); at the industry level(KINDBOM and MUNTHE, 1999 ; GUSTAFSSON, 1999)

Fish Species: once methyl mercury is formed it goes via the food chain reaching higher concentrations in fish species that are located at the top of the aquatic food chain, due to biomagnification effect through throfic levels. The amazon area is the richest worldwide in fish species; what is the threshold figure for every fish specie regarding mercury level concentrations in order to assess if such a fish is" intoxicated" with it ?And,then, what about RfD for methyl mercury ? See, for instance, quite interesting discussions on RfD for methyl mercury (SCHOENY et al., 1999; CASTILHOS and BIDONE, 1999); several reported measurements in the brazilian amazon (KEHRING and MALM, 1999;BRABO et al., 1999;MORAIS et al.,1999);NAKAZONO et al., 1999; SANTOS et al., 1999; LIMA et al., 1999: REOULET et al., 1999), in the wetlands (PINTO et al., 1999), the role of selenium (BARBOSA et al., 1999). The need of differential guidelines for permissible mercury levels in water, depending upon the fact that such a water, and fish species,is in a tropical or non-tropical area (RIBEIRO et al., 1999).

Sinergisms: in Nature quite rarely 2 + 2 is equal 4 ! Therefore, a better understanding of the several interplays between the many physical, chemical and bio variables that affect a given speciation mechanism within a given compartment is still lacking Not to mention in health, for instance, when trying to detect if a given symptom derives from mercuarialism or, on the other hand, say, malaria (TOBAR, 1996); Some papers are important in this regard (SILBERGELD;et al.,1999.; STRICKLAND et al., 1999). Also of interest is" a holistic approach to mercury liberation and its toxicity" (GHOMSHEI et al., 1999).

Mathematical Models: well always a problem, this we all know since. they intend to represent/simulate a complex system through certain number of compartments that interact with each other; here again, synergisms !Therefore, mathematical models, before utilized, have to be thoroughly understood.Some discussions on the use of models are clarifying (ROULEAU and PELLETIER, 1999; BENOIT et al., 1999).

Geo and Biogeochemistry of Hg: the geo and biogeochemistry of heavy metals in general is still a very much open question and that of mercury is not an exemption. Very intriguing questions as the role of the presence of other metal species as regard mercury accumulation in soils are still to be answered As for tropical soils the always present iron (VEIGA, 1993; RODRIGUES FILHO, 1995; LACERDA, 1996) needs more research (see ZEIDEMANN et al., 1999; FOSTIER et al. 1999,; RIBEIRO Jr. Et al. 1999 at this 5th. I.C.). Quite useful papers are,on this matter, on the role of total Hg, methyl Hg and Hg(II) (BAILEY et al., 1999; HINES et al., 1999).; on the origin of mercury in amazon soils, anthropogenic or natural ?,(MILLER et al., 1999)

Decomissioning: borrowed from the nuclear industry this term means what to do after mine closure, as regard the mine site itself, the environment surrounding the mine site, the living community etc. This subject, as taken for the **garimpo** areas spread out through Latin America, the Pacific Rim and Africa is, again, a completely open question; no valid decommissioning methodology and procedure has been established as yet. Several papers dealing, in one or another form, with such subject are , (VEIZAGA and BOURGOIN, 1999;MACHADO, 1999; PESTANA and LECHLER, 1999; SOUZA et al., 1999;ARAUJO NET, 1999;BERMUDEZ and VEIGA, 1999) on gold extraction; others on mercury extraction (RYTUBA, 1999; KIM et al., 1999; COVELLI et al., 1999) and, yet some quite relevant for guideline establishments (LAPERDINA, 1999; ASHLEY, 1999; QU, 1999; WHYTE and KIRCHNER, 1999).

Sustainable Development: well this is a very interesting issue, since we are discussing, at this talk, mercury and sustainability; but, again, such.an issue requires some framework to start with, not to mention the, unbelievable, war striking in Europe. Well, this apart, sustainability of some dangerous pollutant has to be brought either by banning it or managing its use. At our findings, throughout these campaign experiences that we reported in this talk, we found mercury sustainable IF some measures were taken; these measures were already exposed earlier in this talk, and all of them needed a strong commitment of the communities involved as well as local authorities. However this is not a solution overall accepted. At this 5th IC. Some very interesting papers on this are available (GUSTAFSSON and REIN, 1999); REIN and FIN, 1999; REIN, 1999; ANDREWS and SWAIN, 1999; PONCE et al. 1999; PILGRIM et al. 1999); a paper on appropriate treatments for surplus and waste mercury" (ANSCOMBE, 1999) that is very appropriate since the US Stockpile was responsible some years ago for the release (selling) of large quantity of mercury flasks ! A paper proposing a network to look at the impacts of global warming and the cycling of mercury (REUTHER, 1999) And, last but not least, an intriguing paper (REYES and GALVAN, 1999) on the economics of mercury pollution and its negative externality !!