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PRELIMINARY DIAGNOSIS OF THE ENVIRONMENTAL IMPACTS CAUSED BY GOLD PROSPECTING IN ALTA FLORESTA/MT

A CASE STUDY

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CNPq CETEM

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SUMARY

1. FOREWORD

While carrying out its assignment of fostering mining activities in Brazil, the CNPq/CETEM - Center for Mineral Technology Development - since it was founded in 1978, has been seeking technological alternatives for making good use of metallic and nonmetallic minerals through research into ore dressing and extractive metallurgy. At the same time, CETEM is studying how mining activities may be carried out without damaging the environment, through research into treating effluents and solid tailings contaminated by heavy metals or toxic substances. In a broader approach, CETEM is carrying out studies for appraising and diagnosing the environmental impact caused by mineral and metallurgical activities.

The program "Environmental Technology Development", implemented at CETEM in 1989, began its activities with a project for appraising the environmental effects of gold prospecting in Poconé-MT. Multidisciplinary studies were made of the social issues involved in gold prospecting; the technological aspects of mining and of dressing gold-bearing ore; and also biogeochemical monitoring of mercury concentrations in drainage waters.

The next step in this research was to implement the project for diagnosing the environmental effects in Alta Floresta - MT, also caused by gold prospecting. In this case, the project's aims were confined to identifying and measuring the principal effects caused by harmful agents, particularly mercury contamination, silting up of drainage waters and socioeconomic factors.

Understanding the causes and the dynamics of those agents has been reserved for a later phase of specific studies. Only after these studies have been made, may modifications be suggested that could minimize the environmental impacts, and also allow long-term forecasts to be made.

CETEM's efforts to make the Alta Floresta project efficient were helped by cooperation from other institutions, since specialists were needed in the areas of medicine and biology. The importance was also recognized of state and municipal bodies on account of their knowledge acquired from research.

The following institutions took part in the project:

- CESTEH/Oswaldo Cruz Institute Foundation;
- Department of Chemistry and Biology/Federal University of Mato Grosso;
- Carlos Chagas Filho Institute of Biophysics/Federal University of Rio de Janeiro;
- Cia. Matogrossense de Mineração (METAMAT);
- Alta Floresta Municipal Authority;
- Alta Floresta Municipal Works, Town Planning and Environmental Dept., and
- Municipal Health Department.

Another item which was really important for conducting the project, was the team's full access to information from the gold mining areas. This is evidence of the gold mining community's interest in changing their image of destroyers of natural resources, to one of producers of an important part of the local economy.

Rio de Janeiro, april 30, 1992

ROBERTO C. VILLAS BÔAS

2. INTRODUCTION

The team's studies are part of an integrated plan for making a preliminary diagnosis of the environmental effects of gold prospecting in Alta Floresta-MT, being coordinated by CETEM. The field investigations were made between May and June and were complemented by data gathered in September, 1991.

Gold has been prospected in the Alta Floresta region during the past 12 years in *garimpos* (gold fields). Prospecting intensified in the mid-80's when deposits formed by minor drainage waters, or located in old drainage channels of varying sizes, were mined. In these cases, the mining method used is still hydraulic tearing down and dredging, known as *baixão* mining.

From 85/86 onward, new equipment was introduced which was able to reach the active alluvium deposits in the more abundant rivers (Teles Pires and Peixoto de Azevedo rivers). Installed on rafts, dredges with divers in the beginning, and scraper dredges more recently, were used to open new work fronts.

Gold mining, like any other mining activity, has a strongly transforming effect on the environment, and may become a source of pollution and environmental degradation, while methods for controlling mercury emission and solid tailings are not used.

The metallic mercury used in amalgamating the gold particles, which is the final stage of the ore dressing process, has caused abnormal concentrations of mercury in waterways. This has occurred principally in the Amazon region, where most of the ore mined is alluvial. The close association of these deposits with the drainage waters means that the mercury lost during the open-circuit amalgamation process, without using retorts or confining the contaminated tailings, passed into the waterways.

Through the "Environmental Technology Development" program, CETEM began its activities in this region with the purpose of diagnosing the environmental impact caused by gold prospecting.

In early February, 1991, a visit was organized to the region for a preliminary reconnaissance of the operating and environmental conditions for gold prospecting activities. The aim of this visit was, through this first contact, to provide basic conditions for gathering information and to have an idea of the infrastructure needed for starting work.

That information provided the basis for planning a diagnostic project in the region. A survey was made so that the level of contamination and the degree of silting up of the principal drainage waters of the area in question could be determined in preselected places, which might make it possible to define the region as a whole. Sites were chosen bearing in mind such factors as: the type of mineral prospecting (using scraper dredges or hydraulic tearing down) and characteristics of the affected microenvironments (abundant rivers, streams, springs and soils).

The target areas chosen for sampling included a continuous stretch of the Teles Pires river, including its more important tributaries and secondary drainage waters, where *baixão* (secondary drainage) gold fields are to be found.

Since projects in the environmental area are somewhat complex, they must be examined with the help of various sciences. The social, human health, biological, environmental geochemistry and mineral technology aspects were appraised, in an endeavor to produce the widest possible picture for understanding the gold prospecting activity. The area's economic importance is reflected directly in the municipality itself which, having been mainly a farming region, became a regional pole of support for gold prospecting in a relatively short time.

The region is part of the Southern Amazon Depression and contains varying types of habitats of real importance for the quality

of life. However, very little work has been done in this region for gathering information on the biotic and also abiotic aspects of this ecosystem.

This means that studies for those purposes are urgent, principally due to the advance and influence of man in the environment who progressively each year, through gold prospecting and farming, has been altering the ecosystem. These studies may, in the future, be the basis of an appropriate environmental policy for the region.

The participation of the various study areas was due to a pool of institutions which, with their specialties, made a decisive contribution to the work.

The following scheme was used for the work stages:

- reconnaissance visit;
- planning and logistical infrastructure;
- stage of collecting samples and field information;
- chemical analyses and results, and
- preparation of area and final reports.

3. PURPOSES

The environmental diagnosis as such, aims to provide the most accurate possible "photograph" of the situation of the gold prospecting activities in the light of issues related to the environment. Due to its diagnostic nature, this study will be of aid in implementing more thorough studies into matters related to mercury contamination and to transformations caused by such mining activities, either from the physical or social points of view.

This work will also be used as a basis for introducing technological, cultural and procedural modifications, which may minimize the impacts caused by gold prospecting.

The aim is to propose a research methodology which may be used as an interdisciplinary approach for diagnosing environmental impacts in gold prospecting regions. The idea is that CETEM should augment its capacity for assimilating knowledge, broadly and effectively, of the principal and certain individual features originating from the relationship with environment, which every gold prospecting region has.

The fact that Alta Floresta started with a colonization project concentrating on farming, and that it continued to do so until shortly after its emancipation, conflicts with the economic explosion resulting from the gold prospecting, which raised the municipality to the level of regional pole. The lack of sufficient infrastructure to meet the population's requirements gave rise to various social and economic issues, which grew as the municipality developed.

The principal component of the physical degradation of the environment in gold prospecting areas would seem to be silting up of drainage waters, caused by higher rates of erosion and sedimentation, as a direct consequence of mining and ore dressing on river beds and their environs. This study also had the purpose of estimating the levels of suspended solids and the flow of drainage waters,

which are directly related to the degree of silting.

It was also sought to provide a detailed description of productive processes used by the gold miners and how disturbance of the environment occurs.

The process and organization of gold mining work involves the use of mercury and the effects of such use. In amalgamation it is sought to determine the quantities of the ratio of metallic mercury used and gold produced. Also observed are possible points of emission of mercury into the different environmental compartments (soils, sediments, water and atmosphere).

The research was extended to a preliminary appraisal of the distribution of total concentrations of mercury in current sediments and flood plains, in an area which covers an approximately 80km stretch of the Teles Pires river, including its more important tributaries.

In view of the specific way in which mercury passes into drainage waters, in this case, as a metallic effluent of the amalgamation processes, it was decided to divide up the study of the concentrations according to the granulometry of the sediments, so as to identify possible preferential sedimentary *facies* when mercury is retained in a hydric medium.

If one is to understand the behavior of heavy metals in a hydric medium it is essential to monitor the physical-chemical parameters of the water. These variables, which are subject to seasonal variations, must be monitored throughout the year so that their variation intervals may be determined. However, as the diagnostic nature of this work required it to be done in a short period of time, it was not possible to analyze the seasonal influence on issues related to gold prospecting.

4. DESCRIPTION OF ALTA FLORESTA MUNICIPALITY

4.1 General Comments

Mention should be made of the principal forces shaping the recent development of Amazônia, which also paved the way for the occupation of northern Mato Grosso. They are:

- the essential role played by the federal government bringing, on one hand, private capital to the region through fiscal and financial incentives and, on the other hand, providing basic road, port, electric, communications infrastructure etc.;
- the predominance of factors outside the region (geopolitical and national security, the utilization of natural resources, etc.), as ways of invigorating and bringing economic, social and political modernization, and
- economic occupation of the region, although as part of the national economy, through some modern nuclei. [1]

The idea of this synthesized information is to identify the tendencies of the region being studied in the light of the integration process and to distinguish, principally, some sociopolitical and economic transformation forces prevailing there.

4.1.1 Recent events in the region's development

The construction of the BR-163 Cuiabá-Santarém highway (1971/1976) and the asphalting of the BR-364 Cuiabá-Porto Velho

[1]The "Poloamazônia" (1974) included the region in the 15 imagined poles while the "Farming pole of southeastern Amazônia" consistes of northern Mato Grosso and Goiás (now Tocantins state) and the South of Pará.

highway, meant for Mato Grosso state that the northern and western parts toward Pará State and Rondônia, respectively, were opened up for economic occupation.

For a typical economic frontier area with an enormous potential of natural resources, the construction of approach roads allied to colonization incentives, fostered a fast growth process with absorption of capital and encouraged more people to settle there.

The former State of Mato Grosso, until the 70's, had its economic growth centered in its southern region, now the State of Mato Grosso do Sul. After the state was divided in 1977, the north - now Mato Grosso - raised its participation in the GDP according to regions from 0.44% to 0.59% (1977-1980). It also accompanied the average of the Center-West region, although keeping slightly ahead, in terms of the product growth rate (source: IBGE).

The basic force that made Mato Grosso grow was the expansion of farming production integrated to the national economy via the exportation of products.[2]

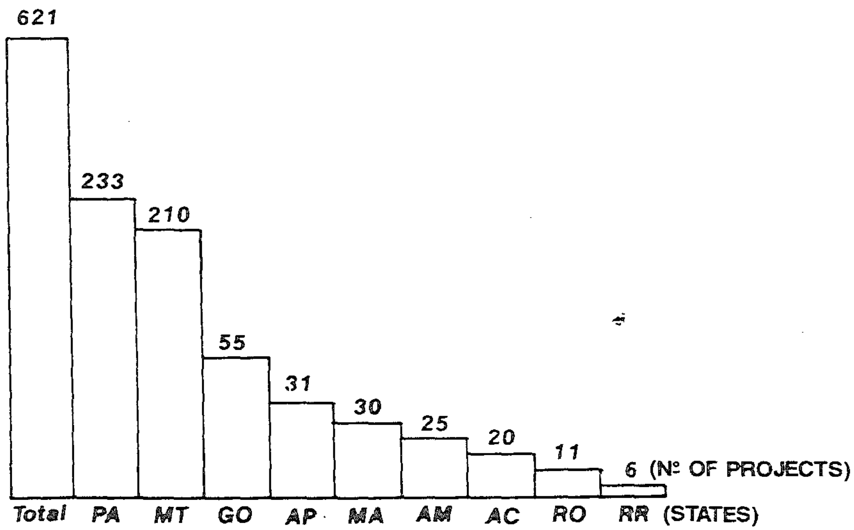
Another important indicator to be mentioned are SUDAM's investments in farming projects. It is well-known that special treatment is accorded to the entrepreneurial and capital-intensive type of farming for occupying space. Until 1985 Mato Grosso was in second place in the number of projects and volume of investments (Table 1 and Figure 1).

[2]Mato Grosso exported 55% of its production to the rest of Brazil and approximately 28% to other countries (IPEA, 1985), ranking in second place throughout all the Amazon Region, and only outdone by the State of Amazonas.

TABLE 1 - Projects approved by SUDAM during 1981/1985 (%)

STATES	1981	1982	1983	1984	1985
Pará	43.6	35.2	48.9	43.8	40.6
Mato Grosso	19.3	31.9	20.2	22.5	27.1
Amazonas	28.4	14.6	11.2	19.6	12.8
Rondônia	0.7	—	1.8	1.4	0.4
Acre	—	1.7	1.9	0.7	0.5
Roraima	0.5	1.8	1.0	1.3	0.8
Amapá	0.8	1.4	6.6	4.6	13.8
Goiás	2.9	10.5	4.0	4.2	2.5
Maranhão	3.8	2.9	4.4	1.9	1.5
TOTAL	100	100	100	100	100

Source: SUDAM/DAI/DPOI



Source: SUDAM/DAI/DPOI

FIGURE 1 - Projects approved by SUDAM (1981/1985)

This economic growth was accompanied by an appreciable increase in the population through a massive influx of migrants from southern and southeastern Brazil. In the period 1970 to 1980, the state's population growth rate was 6.6% per year, that is, three times the growth rate in the rest of the country.

The microregion of northern Mato Grosso grew 16.1% in the same period. This was the state's second highest rate, which accelerated in the 80's because of the completion of the BR-163 highway, the installation of colonization projects and the discovery of gold in the region.

What distinguished the occupation of northern Mato Grosso was colonization basically by private enterprise.[3]

The Federal Government put up for auction approximately 2 million hectares of land. This land was gradually bought by private companies which had gained experience in colonization, particularly in Paraná state.

The purpose of the colonization schemes was to absorb the population surplus of the southern and southeastern regions, caused by the considerable rate of modernization of agriculture in those areas.

These settlers or surplus workers had reasonable technical knowledge and some capital and were attracted to the frontier areas because of the available land [4] and by campaigns conducted by the colonizers. The colonizers, in their turn, were granted loans at subsidized interest rates and also reduced taxation of corporate profits.

It was mostly southerners, and particularly from Paraná, who were settlers or partners with a fair degree of capitalization.

[3]Mention should also be made of the incentives offered by the Center-West Development Program (PRODOESTE), which was part of the first National Development Plan/72-74 for the region's economic occupation.

[4]In the 70's the value of one hectare of land in Paraná was the same as three hectares in this region.

In the area of influence of the BR-163 highway, the SINOP and INDECO settlers were the principal colonizers, coming from the towns of Sinop and Alta Floresta, respectively. The basis of the colonization of both groups was 100 ha plots of land to be planted with permanent crops (coffee, cocoa, guarana and rubber trees), as well as subsistence crops.

Alta Floresta, where this study was done, originated from a colonization project of INDECO, covering an area of 800 thousand hectares acquired at federal government auctions and from a private company in southern Brazil, which owned the land adjoining the auctioned area. The urban nucleus is a regional center, as may be seen in detail in item 4.1.2.

Founded in 1976, Alta Floresta was declared a municipality in 1979. The investiture of its first administrator in 1981 was to seal its emancipation. The first election for mayor and town councillors took place in 1982 together with the first direct elections for state governor held after 1964.

The reorganization of political parties which took place in Brazil in the 1982 elections, along with the change of the two-party system, does not seem to have had much influence on the local political scene. The influence of INDECO and of its President, Ariosto da Riva, on the administrative and political process continued: "...the occupation was entirely controlled by the colonizer, also because the company's owner decided to live in his "new" town, which factor should not be underestimated." (Coy, 1989).

4.1.2 The appearance of gold prospecting and the region's new scenario

Private colonization conducted and concluded by the company Integração Desenvolvimento e Colonização - INDECO, was the force behind the physical and territorial occupation, while the Federal

Government invested in infrastructure, granted tax and financial incentives and installed farming projects with aid from SUDAM.

At first, this colonization consisted of settling farmers and rural workers with reasonable capital, on the assumption that a modern farming sector would be installed.

The changes that took place in the nation's political and economic spheres in the 80's led, in the meantime, to the emergence of a new scenario for the region which can, roughly, be described as follows:

- the expansion of gold prospecting in Amazônia caused by the price of gold, by the aggravation of the country's social problems and by the emphasis put on Serra Pelada gold fields;
- the discovery of gold alongside the Teles Pires river in 1979, and the inflow of gold prospectors coming from the Juruena gold fields and those in the south of Pará state. Their arrival was made easier by the local roads built by the colonizing company;
- difficulties faced for putting the farming sector on a steady basis, due to the unsuitability of certain crops (such as, for example, the first types of coffee), unreliable means of transporting production out and the low competitiveness of the production, which meant that labor and capital were free to go to the gold fields.

Gold mining and gold selling then began to take the upper hand in business relations, turning the town of Alta Floresta into a regional gold buying pole and supplier of support infrastructure to the gold fields, through the sale of machinery, fuels, food, air transportation, etc., as well as sundry services.

It is important to note that the farming sector did not slump, but continued coexisting alongside the gold mining activities. The farmers moved in on the gold fields as workers or owners, depending on how much capital each one had, either leaving their families behind on their ranches or overseers looking after the ranches.

In the early days of 79/80, conflicts arose between land owners and gold prospectors, besides those that took place among the prospectors themselves, vying for areas.[5]

The possibility of coexistence between agriculture and gold mining only occurred on the Alta Floresta land, which was already then organized and parceled out. The neighboring tracts of land, Paranaíta and Apiacás, both belonging to INDECO and inside the territorial bounds of Alta Floresta municipality, were taken over by the gold prospectors. The *corrutelas* [6] of the same name expanded rapidly, and became independent municipalities at the end of the 80's.

The expansion and mechanization of the gold fields caused, on one hand, the emergence of a new urban middle class, burgeoning business, a new elite and investment alternatives. On the other hand, they brought serious environmental problems - silting up of drainage waters and failure to control mercury emissions - and social problems such as violence, disputes over gold field claims, besides the collapse of the urban infrastructure.

At present one can see a relative decrease of gold mining, if compared with mining between 1980 and 1985. It is not possible to detect at the moment whether this is just a business cycle crisis. We are giving a brief summary of some important factors for gold prospecting:

[5] Just as an example, a passage has been copied below from the *Revista Opção* (May/91), on page 8 "... after gold was discovered, the town was upset by serious problems, which INDECO and Ariosto da Riva had to face. It is said that once about 20 gold prospectors staying in the *Barracão* hotel, in between swigs, drew lots to see who would kill Ariosto da Riva. Upon being told about the game, the colonizer went there and explained to the gold prospectors that he was not against gold mining provided the settlers and their land were respected, because it was they who supplied the town".

[6] Corrutelas are villages whose infrastructure is reasonable, as much in terms of support for the gold fields, as for human living conditions.

1. The impact of the economic stabilization plan (President Collor Plan I), published in March/90, on gold mining activities; the Plan's anti-inflationary measures included a price freeze, but also the prior rise of public utility tariffs (energy, fuels, etc.) by about 40%. Diesel and gasoline, which are basic input for the gold fields, were readjusted, which meant that production costs also rose.

Furthermore, the price of gold dropped immediately and only returned to its earlier level 60 days later, due to the cruzeiro/dollar monetary parity enforced by the Plan.

2. Law No. 7805 of 18/07/89, regulated by Decree No. 98,812 of 09/01/90, established new legal rules for gold prospecting, the most important of which were:

- abolition of the gold prospector's registration certificate, making the self-employed prospector's activity impracticable;
- the activity of gold prospecting was made subject to cooperative organization;
- institution of the System of Gold Mining Permission requiring licensing by the official environmental bureau. The preparation of an Environmental Impact Study/EIA would be prepared and also a Plan for Recovering Degraded Areas/PRAD.

3. Environmental pressure. The gold fields have been the subject of national and international concern and they have been blamed for: silting of rivers, land clearing, indiscriminate use of mercury, the spread of sickness, land conflicts, pressures on areas where Indians live, violence and the aggravation of social tensions.

4. The emergence of a movement in favor of development, led by the local elite, advocating the resumption of growth by boosting cattle-raising. It cannot be said that the Alta Floresta cattle-raising pole conflicts with the predominating gold mining activity or is seek-

ing to replace it. It seems, however, more of a tentative response to the region's complex socioenvironmental situation.

In spite of the factors described above, there are favorable conditions which can explain the continuity of gold mining, even in the face of adversities. These conditions are related to the low costs of dressing and extracting the ore, namely:

- alluvial ore and therefore easy to remove by hydraulic tearing down;
- no grinding stage (loose gold);
- no costs for environmental control (tailings bank, etc.);
- lost cost of land on rural properties, and
- the use of rudimentary concentrating equipment which uses cheap material for making it (wood).

4.2 Alta Floresta - Regional Center

Alta Floresta Municipality is in the north of Mato Grosso microregion (M-332/IBGE). It covers an area of 19,447 km2 and has 6 districts: Sede, Nova Bandeirante, Monte Verde, São José do Apuy, Alto Paraíso and Carlinda. It is the most important economic and administrative center in the northern part of the state, and is mostly known for its trade and services.

4.2.1 Population figures

There has been appreciable population growth in Alta Floresta, reaching a figure of 7.4% between 1980/1990. Estimates made by the Town Council indicate a population of 136,000 inhabitants (1990), of which 54% are urban and 46% rural. The predominance of urban inhabitants may be considered the result of the discovery of gold in the region (1979), leading to fast expansion of the town's commerce and services.

As to their origin, 70% of the population are from the south of Brazil, particularly Paraná.

It may be noted also that about 65% of the inhabitants are between 16 and 35 years of age, which is an extremely young population. The economically active population is, consequently, quite large, representing 65% of the total population.

4.2.2 Productive structure

The physical and economic occupation process initially planned on the basis of plots of land up to 100ha, underwent changes throughout the 80's. Today the land allocation reflects a process of concentration, that is, 13% of the owners hold 81% of the land

The stratification of ownership is illustrated in Table 2.

TABLE 2 - Stratification of Rural Ownership in Alta Floresta - 1990

AREA(ha)	% OWNERS	% LAND
5 - 20	8.6	0.1
20 - 50	27.9	1.9
50 - 100	10.6	1.6
100 - 500	39.3	14.8
over 500	13.6	81.6

Source: Estudo da Realidade em 90/91 - Alta Floresta Town Council /INCRA

As to the division into strata of rural producers, it has been noted that most of them are sharecroppers and not owners (about 46%), of which 60% have no legal contract. The land owners represent 40%, although 55% do not have their property title deeds in order. 10% of the rural producers are wage earners.

It is interesting to note, therefore, that approximately 60% (sharecroppers, wage earners, homesteaders and tenant farmers) of the rural producers do not own the land they cultivate. This fact can be put down to the aforementioned process of concentration of ownership. It should be borne in mind that on the Alta Floresta tract of land, approximately 30% of the area allocated for colonization has been actually occupied. An illustration of this is shown in the map in Figure 2 overleaf.

The municipality's economic turnover today is provided by gold mining in the gold fields. The urban nucleus has been transformed into a renderer of services and trading center, including of gold from other neighboring municipalities and from the south of Pará state.

The town has 12 securities dealers (DTVM) and 20 gold buying shops (intermediaries). The principal shops are: Goldmine, Aurium,

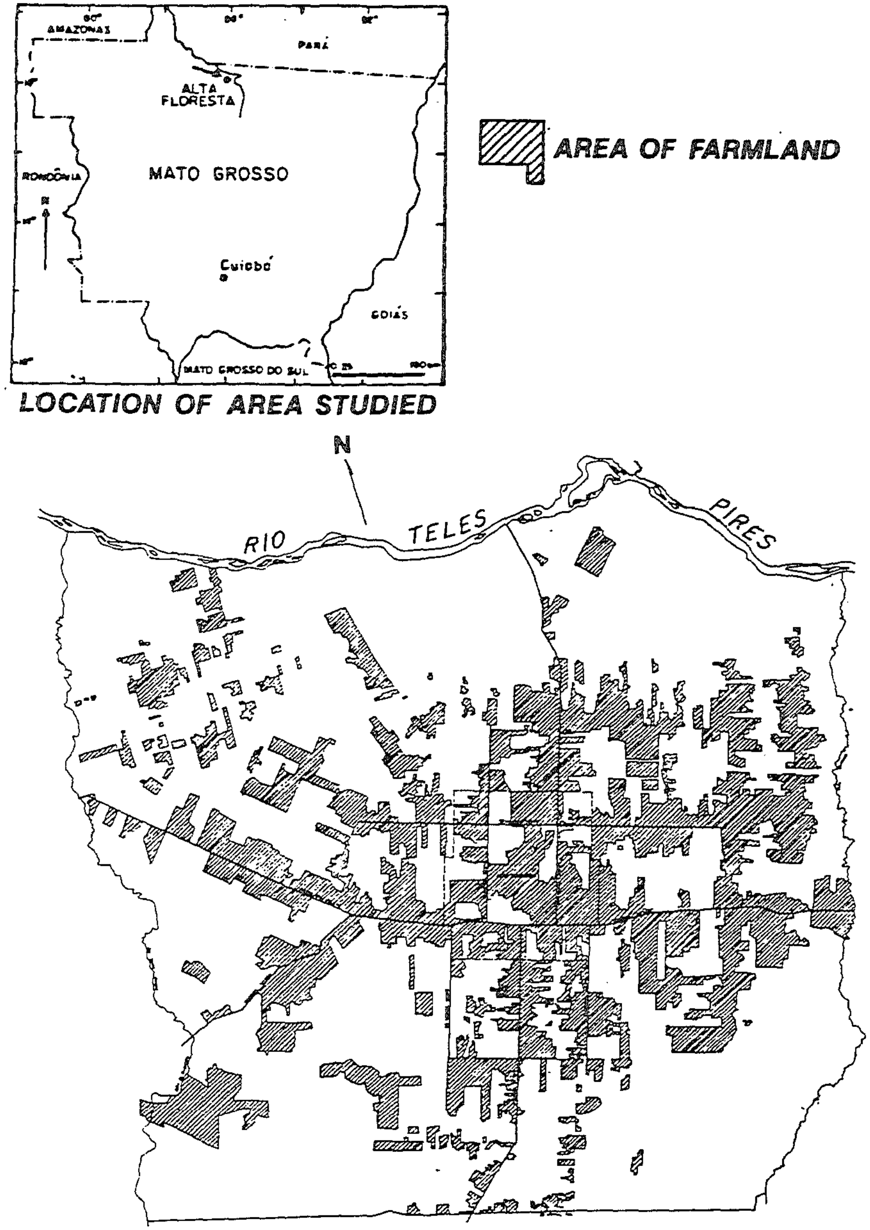


FIGURE 2 - Projection of Occupation by Farming Activities - Alta Floresta Land - Mato Grosso

Marçam, Ourozezinho and Ourominas.

Official production is estimated at 1 ton/month. (Source: Municipal Finance Department - interview).

Agricultural production prevails over perennial crops (coffee, cocoa and guaraná) in terms of planted area (63.3%). Then there are the temporary crops such as rice, maize, beans, cotton and cassava. Coffee is the main product. Table 3 lists the municipality's principal products.

TABLE 3 - Indicators of the Principal Farm Products of Alta Floresta Municipality - 1990

Crops/ Products	Area/(ha) (A)		Production/(tons) (B)		Yield (B/A)
	Nº	%	Nº	%	
Temporary Crops					
–rice	8,400	14.3	9,072	10.7	1.1
–maize	6,577	11.2	9,865	11.7	1.5
–beans (wet + dry seasons)	4,573	7.8	2,489	2.9	0.5
–cotton	600	1.0	360	4.3	0.6
–cassava	1,300	2.2	26,000	26.9	20.0
Subtotal	21,450	36.5	47,786	56.5	
Permanent Crops					
–coffee	33,906	58.0	35,748	42.2	1.1
–cocoa	2,897	4.9	1,100	1.3	0.4
–guaraná	285	0.4	29	0.03	0.1
Subtotal	37,088	63.3	36,877	43.5	
TOTAL	58,538	100	84,663	100	

Source: Estudo da Realidade em 90/91 - Alta Floresta Town Council

The rural producers extract Brazil nuts and tap latex from rubber trees to complement their activities.

Cattle-raising has been begun recently in this municipality. Basically, the herd consists of beef cattle (75%) and, in second place, dairy cattle.

The municipality has the following storage system: CASEMAT (Cia. de Armazéns Silos do Estado do Mato Grosso) and COAG (Cia. Omnina de Armazéns Gerais).

There is also the Cotia Central Cooperative which specializes in selling coffee and Agroindustrial Caiabi, belonging to the INDECO Group, which sells coffee, guarana and Brazil nuts. Comercializadora Pará also deals in the latter two products.

The temporary crops go to the regional market and for supplying local requirements due to the high freight charges. The permanent crops are exported.

Cattle products are sold to the regional market, due to the lack of cold storage plants and dairies.

The industrial sector primarily makes use of local raw materials. There are 90 companies, of which lumber, civil construction, brick and ceramic factories predominate. Other kinds of processing activity are also noted, such as companies processing rice (4), nuts (2), coffee (5), maize (Moinho Santo Antônio) and guaraná (2).

4.2.3 Production support structure

The local trade consists of approximately 1,000 establishments engaged in very varied activities. The more important are shops seeling farm equipment, products and imput, including machines and farm vehicle parts and equipment for gold prospecting, supermarkets, service stations and pharmacies.

Prominent among the very varied services are the hotel network (66 hotels), meals (38 restaurants) and medical services (8 hospitals, 4 medical posts and 6 clinical analyses laboratories).

Alta Floresta has 1 law court and 2 public registries.

.Transportation infrastructure

The municipality has regular airlines flying to Cuiabá, Santarém and Belém operated by Taba. Ten air shuttle companies also offer cargo and passenger services, mainly for the gold fields. The airport has a 1600m long asphalted runway.[7]

It also has 2 landing fields.

The roads system consists of 3,000km of unasphalted local roads, the federal highways BR-163 and BR-364 and the state highways MT-208, MT-325, MT-417, MT-320 and MT-160.

Passengers are transported by road in regular bus lines interconnecting the municipality and interstate buses going to and from Mato Grosso do Sul, Paraná, Rio Grande do Sul, Espírito Santo, Maranhão and Pará states.

.Public services infrastructure

Water is supplied by SANEMAT, although only to 30% of the population. Electric energy is produced by CEMAT's thermoelectric plant, whose maximum power is 10 MW. This plant, however, does not operate with its total capacity and the power supply is subject to cuts. It is estimated that about 15% of the demand is not met. The electric system serves the rural area inside a radius of 15km.

Municipal services such as garbage removal and town cleaning are carried out regularly. The town's garbage dump, apart from being full, was installed in an area near the springs of the streams that supply the town, which could cause their contamination. The lack of differentiated garbage collection means that the residues from the gold buying shops (melting shops) and hospitals are mixed with the others.

[7]Until 1989, Alta Floresta Airport was considered Brazil's 3rd-ranking airport in terms of number of landings and takeoffs of small planes.

The Town Council wants to install a garbage recycling plant and also allocate a new 20 ares area, with a capacity for 90ton/day, which would have a collecting main for the residues from the melting shops.

The sewerage system consists of septic tanks with sewage traps and settling ponds.

.Banks

There is a large banking system consisting of the following banks: *Banco do Brasil, Banco do Estado do Mato Grosso-BEMAT,Banco da Amazônia-BASA, CEF*-Federal Savings Bank,*Bamerindus, Bradesco, Itaú* and *Finasa.*

.Communications

The municipality is served by Telemat and is covered by the DDD/DDI system. It has 38 telexes and radio and TV broadcasting through 2 broadcasting stations *(Bandeirantes* and*SBT*), one MW and one FM radio broadcasting station. It also has a weekly newspaper (*Jornal da Cidade*) whose circulation is 3,000, two fortnightly newspapers (*Folha de Alta Floresta* and *Folha Popular*), whose circulations are 2,500 and one magazine.

The Brazilian Mail & Telegraph Company has a branch and mail boxes in the municipality.

.Education

The municipality's educational system offers vacancies ranging from preschool to high school, as well as 1 technical teacher's training course and accountancy. In 1990 the municipality had 139 schools and 10,630 students enrolled. The municipal public authority offers only elementary school education and principally attends the rural population. Table 4 gives a summary of this educational situation.

TABLE 4 - Educational System - Alta Floresta 1990

Type / Number	Municipal	State	Private	Total
Schools	123	11	5	139
Teachers (A)	165	477	60	702
Students (B)	4,161	9,175	1,294	10,630
(B:A) ratio	25.2	19.2	21.5	

Source: Estudo da Realidade em 90/91 - Alta Floresta Town Council

.Medical Services

The medical services have a reasonable amount of beds, although they are mostly run by the private sector. Of the eight existing hospitals, offering a total of 230 beds, only one is municipal, which has 30 of its own beds and 60 under an agreement with IPEMAT.

The municipality also offers good out-patient treatment in three Medical Centers and seventeen small clinics. The Public Health System, which is being given priority attention by the Town Council, attends a total of 200,000 patients per year for basic treatment.

The Municipal Hospital can only meet 30% of the real medical demand and supplementary medical care is provided by neighboring municipalities in the north of Mato Grosso and south of Pará.

The municipality's medical staff consists of 28 doctors, 21 dentists and only 5 nurses with a university education.

.Diseases and Mortality

The situation at Alta Floresta is no diferent from that prevailing in other Amazon municipalities. The health situation is typical of

underdeveloped regions, where diseases result from social and economic deficiencies (pathology of hunger and misery). Shortcomings in the sanitation infrastructure tend to make the situation worse.

Malaria is the most common sickness and the tendency is for it to increase. Malaria patients occupy approximately 60% of the hospital beds.

In 1990 SUCAM examined 16,561 laboratory slides, of which 32% were positive. Ninety percent of the diagnosed cases of malaria come from the gold fields and the remainder from farming areas.

Plasmodium falciparum represents 44% of the slides examined. This type is responsible for most of the deaths due to malaria.

In 1991, until May, 9,000 slides had been examined, meaning an increase of more than 30% in the period. Other rather common diseases are:

- tuberculosis - 35 new cases up to May, 1991. Tuberculosis is very common and is spreading alarmingly,
- leprosy - the highest rate in the state and there is a strong tendency for it to increase (there were 28 new cases up to May);
- leishmaniasis - very common and with serious consequences for the public health;
- industrial accidents, as well as violence, are major causes of death in Alta Floresta Municipality, and
- dehydration, gastroenteritis, diseases that can be prevented by vaccination, AIDS, malnutrition - common illnesses of underdevelopment are also common among the children of Alta Floresta.

Sexually transmissible diseases, infectoparasitic diseases and oral diseases complete the municipality's epidemiologic picture. Alta

Floresta and other municipalities of this reason are facing dramatic situations, threatening the population's health, such as: an outbreak of human rabies caused by vampire bats, the threat of dengue whose carrier has its natural habitat in the region and, lastly, the threat of cholera.

The comments made here are based on the team's observations and also on information received and conversations held with the municipality's Health Department officials, in which we are stressing the systematic failure to report the health situation in the gold fields and also the demand for services coming from the gold prospectors.

It is clear that priority is being given to public health because of:

- the growing participation of funds allocated to the health sector, and
- programming of public health activities and strategies prepared.

Nonetheless, the lack of planned investments in basic sanitation has been noted, which will make it impossible to change the municipality's epidemiologic status.

Also noted was a lack of sectors specializing in diagnosing and treating mercury intoxication, as well as the fact that there is no laboratory support available to make such a diagnosis.

4.2.4 Social & political structure

Of the organized political parties, the PMDB is the most important. In the 1989 elections, in an electoral college of 41,416 voters, the Mayor's party won and took 6 of the 15 Town Council seats. The party membership of the town councillors is shown in Table 5.

TABLE 5 - Political Party Membership - Alta Floresta 1990

Municipality	Mayor's Party	Composition of Town Council	N° of Voters
Alta Floresta	PMDB	6 PMDB, 2 PRN, 1 PFL, 1 PDT, 1 PL, 1 PDC e 3 independent	41,416

The municipality and the region have 2 state deputies and one federal deputy elected on the basis of what is called the *Nortão*, who are: Leonildo Menin, Romoaldo Junior and João Teixeira.

Some regional hopes have been detected coming from the community itself and from professional politicians to the effect that this unit of the federative system should be modified and a new territorial division be made. According to this motion submitted by Federal Deputy João Teixeira, a new state would be created, including the northern Mato Grosso microregion and part of the south of Pará state.

If this new state came to be, the representation in the National Congress (Chamber of Deputies and Senate) would be enlarged, which would allow greater bargaining power in getting federal funds for the region.

This idea, however, does not interest the colonizer Ariosto da Riva, nor the local elite leaders, whose relationship with the State Governor and with the Federal Government seems to be sufficient to deal with regionalist claims at the moment.

At this point, some brief comments would be appropriate. Until the 1988 Constitution was enacted, during what is known as the New Republic, dependence on funds coming from the Federal Government ended by turning governors and mayors into mere transmission links for policies devised in Brasília. The political and financial centralization made it necessary to adapt the way of conducting politics. The Federal Government party also became the Mayors' party, since they needed funds.

President Collor visited Alta Floresta in May, 1991, to declare his support for the region. This support was expressed in adherence to the project prepared by the elite leaders which aims to reduce the region's dependence on gold production. The project has the basic purpose of turning Alta Floresta into a cattle-raising pole. It would be up to the Federal Government to make funds available for:

- building the Apiacás hydroelectric plant (22MW), providing constant energy for agroindustry;
- asphalting the unpaved stretch of the MT-320 highway, as well as local roads, making it easier to take production out of the region;
- allocating funds from SUDAM for building a cold storage plant - FRIGONORTE.

The rural workers and small land owners feel they are being excluded from the region's development project. In the words of the Alta Floresta Rural Workers Union, there is no support for small production, for selling, for regularizing land ownership and, in addition, cattle-raising is only feasible on very large tracts of land. Nonetheless, a possibility is glimpsed of adherence to this project in that they identify the gold fields as the main cause of the failure of agriculture. Accordingly, the elimination or reduction of gold prospecting could mean "saving the crop". (sic)

It is interesting to note the absence, in the local authority's speeches of gold prospecting as a social and economic reality. No sign was found of governmental programs for this activity.

In the Town Council, although there are councillors who have been or are engaged in gold producing activities, there is no formal connection with gold prospecting.

The municipality's Constitution adheres to the legal spirit in the Federal and State Constitutions on the subject of gold prospecting.[8]

However, nothing practical has resulted from this idea.

In the "Estudo da Realidade em 90/91", a paper prepared by the Town Council, the following may be read: "Regarding gold prospecting, which causes harm to the environment, although it is not so alarming for the region. It is a necessary evil, because if it were not for gold prospecting, the region would not have developed."

The Gold Prospectors Union of the State of Mato Grosso-SINGAMAT/USAGAL - has a union branch in Alta Floresta.

There are organized professional associations in Alta Floresta - for both employers and workers. Examples are the Rural Producers Union, the Alta Floresta Breeders Association-ACAF, the Shop Owners Club-CDL, the Rural Workers Union, etc.

There are also 150 organized rural community associations and 100 subcommunity associations. These associations work to safeguard the interests of the inhabitants, making efforts to have claims for necessary infrastructure attended: medical clinics, schools, transportation. Some are run like small town halls, managing social programs together with the corresponding local departments.

The municipality also has social welfare organizations, such as the Rotary Club, Lions Club and APAE (Association for Handicapped Children).

The State bodies represented in the municipality are EMATER/MT and INDEA/MT.

Federal bodies working in the municipality are:

[8] "The Municipality will encourage the organization of the gold prospecting activity into cooperatives, considering protection of the environment and the economic and social welfare of the gold prospectors."
Article 186, Section XVI of the Environment. Constitution of the Municipality of Alta Floresta - MT, 05/04/1990.

- a branch of IBAMA (former IBDF) (Environmental Institute), which grants permits for felling trees and selling lumber;

- CEPLAC, supplying aid to cocoa planters, and

- a branch of the Federal Revenue Service, which collects Financial Transactions Tax levied on gold buying and selling transactions.

4.2.5 Physiographical aspects

.Geology

The study area is located on proterozoic terrane where the rocks are between 1860 and 1110 million years old and are represented by the Xingú Complex, Uatuma Group, Beneficente Group and Caiabís group (see stratigraphic table).

In the northern part of the area, the terrane belongs to the Iriri Formation (Uatuma Group) represented by intermediate-acid volcanic rocks. In the middle part are alkaline Canamã rocks (Caiabís Group) and sedimentary rocks of the Beneficiente Group. Both are well exposed at the junction of the Cristalino and Teles Pires rivers. To the south rocks of the Xingu Complex predominate. This is a polymetamorphic unit whose very transformed and deformed rocks do not, in the field, show lithotypes that allow them to be separated into subunits.

The granitic masses, called Teles Pires (Uatuma Group), are scattered in the form of stocks in the center-northern part. The pile is covered by recent alluvia and eluvial-colluvial caps consisting of unconsolidated gravel, sand, silt and clay.

ERA	AGE (in million years)	LITHOSTRATIGRAPHY		LITHOLOGIES
CENOZOIC	—	—		UNCONSOLIDATED GRAVEL, SAND, SILT AND CLAY
UPPER PRE-CAMBRIAN	1100	CAIABIS GROUP	ALKALINES CANAMÃ	ALKALISYENITES, TRACHYTE AND PHONOLITE
	—	GROUP BENEFICIENTE		SANDSTONES, ARKOSES, SILTS, SCHISTS
	1550	GROUP UATUMA	T. PIRES GRANITES	GRANITES
	1550 to 1700		IRIRI FORMATION	RHYOLITES, ANDESITES, ASSOCIATED SEDIMENTARY ROCKS
MIDDLE TO UPPER PRECAMBRIAN	1680 to 1860	XINGU COMPLEX		MIGMATITES, GNEISSES, AMPHIBOLITES, GRANITE

Source: Radambrasil, 1980

FIGURE 3 - Simplified Table of the Stratigraphy of the Study Area

.Geomorphology

The region's most interesting geomorphologic features, either due to their many varied aspects, or to the way they help us to understand their geology, are the Apiacás Plateau (Residual Plateaus of the north of Mato Grosso) and the Interplateau Depression of Southern Amazônia.

The Apiacás Plateau is a large and singular complex of elongated relief, laid out in an ESE-WNW direction, according to structural alignments. It shows geomorphic features shaped principally into a broad belt of folded and faulted rocks of the Beneficiente Group and volcanic rocks of the Iriri Formation.

In terms of structure, the relief corresponds to a topographically high syncline and structured level stretches with scarps adapted to faults which predominantly mark the geomorphologic contact with the Southern Amazônia Depression.

In terms of height, the crests with their residual tablelike shape, are on the same level as the others of plateaus of Southern Amazônia, at around 450m.

The plateau divides the waters between the basins of the Teles Pires and Juruena rivers, where the Teles Pires has as its main tributaries, in this geomorphic unit, the Cristalino and São Benedito rivers.

The vegetation consists of Open Forest and Savanna/Forest in the contacts with depressions.

The Interplateau Depression of Southern Amazônia is the largest geomorphologic unit of the area and comprises the regional floor of the relief, at an altitude of between 200m and 300m. The most striking feature of this depression is the strong dissection of the relief, in a mostly convex shape, which leveled the different structures through successive erosive phases. However, the geological framework is perceived through many forms of relief which show adaptation to faulting and folding. The structures are topographically inverted and disguised by the strong erosion to which they have been submitted, resulting in forms of relief that have been dissected, lowered and leveled out by hierarchic drainage, following the dendritic pattern. Principal drainage waters: Peixoto de Azevedo and its tributary streams, Nhandu, Rochedo, Carlinda, Paranaíta and Apiacás.

According to Sioli (1974), the Amazonian rivers can be classified according to the geological and pedological characteristics of the terranes through which they run. The author therefore suggests that the region's hydrography should be compartmentalized into three type of rivers: "black waters", "light waters" and "white waters".

The rivers that have "black waters" contain a high concentration of dissolved organic substances and low turbidity (e.g. the Negro river), while the "white water" rivers carry a large quantity of suspended solids (e.g. the Madeira river).

The Teles Pires river, whose bed runs along a strongly shaped and dissected relief, has a low potential for supplying suspended solids and is therefore a river which has "light waters" of an olive green hue.

The "light water" rivers have low turbidity and contain deposits of clayey sediments, principally downstream of waterfalls and rapids. Sand is the basic ingredient of their sedimentation and for this reason they have many beaches and sand bars.

.Climate

The climate in the Alta Floresta region is hot, damp and tropical, with high average temperatures (23°C and 26°C) throughout the year. The maximum daily temperatures are 34°C to 37°C. Temperatures close on 40°C are often recorded and there is abundant rainfall (IBGE, 1986). According to information received from CINDACTA 1, in the last two years the average temperatures have oscillated between 22°C (June/89) and 27.6°C (Nov/89). Records of annual rainfall have shown values of 1,820.6 and 1,733.5 mm, respectively. There are two clearly defined climatic seasons: a dry winter, with a short three (3) month dry period - May, June and July; and a rainy summer. The hottest months are in the spring-summer (September-April) which coincide with the season when there is most rainfall.

Dry mists are frequent (mainly between August and October), caused by the deliberate burning of pastures (so that the grass will sprout evenly) and of natural vegetation cut down (to provide new areas for farming).

5. PRESENTATION OF REPORTS PER AREA OF STUDY

5.1 Social Sciences

It is very difficult to estimate the amount of gold fields and gold miners within the scope of this study.

According to the Gold Miners Union of the State of Mato Grosso-SINGAMAT, there are 163 gold mines, of which 57 are in Alta Floresta, 34 in Paranaíta and 72 in Apiacás. The estimated number of gold miners is 10,000.

It is important to stress that each productive unit (pair of machines) is, strictly speaking, a gold mine, regardless of the generic name they may have in the group of units located in the same geographical space. Accordingly, the Cabeça, Serrinha, Piauí or Planeta mines, and so many other names, correspond to gold miners' *fofocas*. In other words, a group of productive units working on exploiting the same site.

Everything leads us to believe, therefore, that using the criterion of a productive unit and not that of identifying the geographical space, one could arrive at a much higher number of gold mines.

Regarding raft mining, information gathered during field reconnaissance indicate the existence of 160 machines operating in the region's rivers.

The Cooperativa de Extração Mineral Paranaíta Ltda- COOPAR, the only active cooperative whose headquarters are in Alta Floresta, states that it has 61 members, all of whom run raft businesses, and estimates that 100 machines exist. These figures could mean that around 1000 persons are involved.

Research into legal regulations - gold mining permits - does not throw light on the matter, since 90% of the gold mines operate without any regulation. (Source: SINGAMAT).

Classifying the gold miner is even more complex.

Law 7805 of 18.07.89 abolished the system requiring a gold miner to register and instituted the system of gold mining permission. Although, implicitly, the gold miner continues to be an individual worker, the law recommends the organization of cooperatives as a way of *"socioeconomic advancement of gold miners and preserving the environment"*.

Laura Barreto (CETEM, 1989) made the following comments in her paper on this subject:

"The new regulation in fact does not contain a basic concept imparting order to gold mining, resulting in contradictions. Just as an example: the transitory, mobile and random tendency prevails because of the type of minable deposits; consequently, there are countless formalities to be fulfilled for legalizing the activity which will result in a complex and slow bureaucratic merry-go-round which conflicts with the conception of gold mining as a risk activity and a simplified system of turning minerals to good account (system of mining permission). An attempt is made to put the two systems on the same standing, in terms of duties and rights, although gold prospecting is submitted to the economic and productive logic of organized mining, forgetting that it is a different system."

SINGAMAT maintains that legislation made free gold prospecting and the independent gold prospector illegal and also did not define who is the gold prospector and who is the gold mining entrepreneur. It seeks to regulate the matter by proposing a "Gold Prospector's Statute" which would define gold prospectors as those who extract mineral substances on the following bases:

- on a cooperative basis;
- as a family business, without permanent employees;
- working in association, without permanent employees;

- wage-earning work;
- self-employed and individual work, and
- rendering services, in return for remuneration of any kind.

The Statute distinguishes the category of "miner" as a private individual or company which engages in the activity of mineral exploitation with paid assistance of prospectors on a permanent basis.

Accordingly, it could be said that the gold prospector category is subject, at the least, to contradictory interpretations.

In real life, however, gold field workers, raft operators, small prospectors or entrepreneurs, are considered prospectors (*garimpeiros*) because of the similar nature of the deposits worked: alluvial, eluvial and colluvial gold.

As a consequence, it is felt that only a census in the region would be capable of providing a description lending itself to generalizations. Meanwhile, an attempt will be made to round up some of the makings of labor relations prevailing in the region's gold fields.

5.1.1 Labor relations

The principal features of the region's gold fields are:

- unlimited exploration of space, allowing free access which is done by rafts in rivers;
- prospecting in secondary drainages (*baixões*) involving two situations: free access when the land has no title deed, or has no "owner"; access through payment of a kind of rent to the land owner or homesteader.

In the case of rental, SINGAMAT usually takes part in the negotiations suggesting the use of a standard contract for an indefinite

period. The commission paid to the land owner is monthly an amounts to approximately 10% of the gold production. This percentage varies according to the production achieved.

The gold fields are reached by road (most of the *baixões*) and by boat (generally for prospecting in rivers).

The nearest one could get to a scheme for the gold fields is that which distinguishes the owners of production instruments from non-owners. This is because the figure of the self-employed gold prospector, carrying his rudimentary production instruments in search of gold, the manual gold miner, is disappearing.

Therefore, the owners of the production instruments would be: the gold field entrepreneurs (owners of rafts with or without scraper dredges, or of various machine pairs) and the small prospectors (owner of one or a maximum of two machine pairs).

The entrepreneurs and the small prospectors pay the production expenses, that is: diesel oil, gasoline, repairing machines, food and, when necessary, paying rent to the land owner.

Non-owners are gold field workers, operators and other additional categories, such as an administrator or manager, cook or canteen owner.

The workers receive a percentage for each *despescagem* of the gold, usually done at intervals of 1 to 12 days. This percentage varies 7% to 10% in the *baixão* gold fields and from 4 to 5% in the raft operated gold fields. Under this working system the higher the productivity the more money is earned. The working conditions are hazardous and have no support in law. These workers consider themselves *percenters*. Figure 4 A and B shows a fairly accurate scheme of the above.

RAFT GOLD MINING

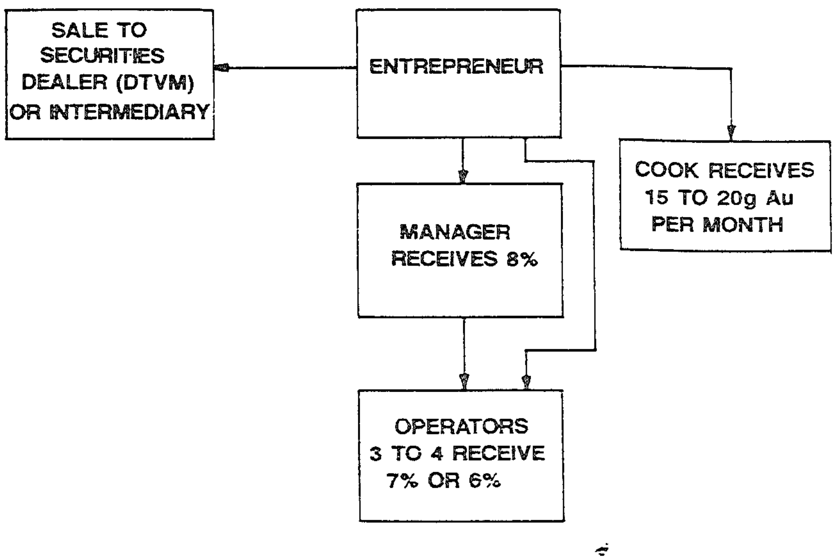


FIGURE 4A - Scheme showing the principal characteristics and labor relations in the gold fields.

Baixão GOLD FIELDS

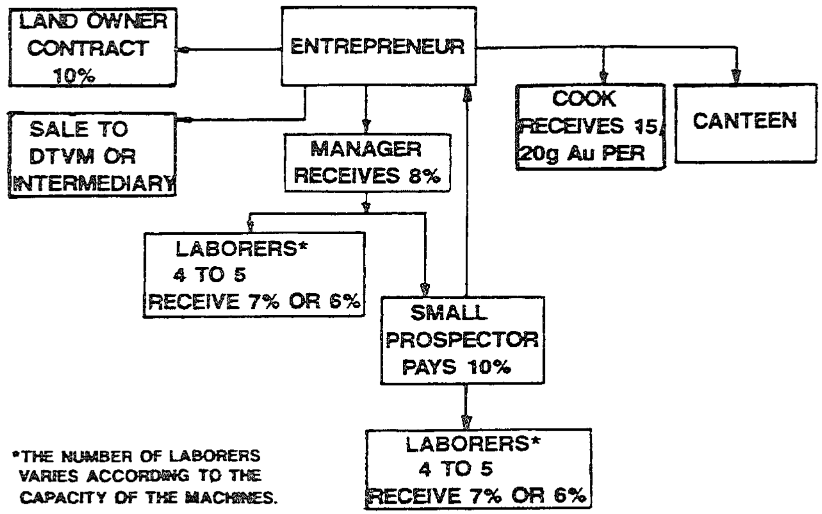


FIGURE 4B - Scheme showing the principal characteristics and labor relations in the gold fields.

The gold field laborers are usually from northeastern Brazil or from Maranhão state. Some manage to accumulate enough capital to buy a pair of machines, becoming small prospectors.

SINGAMAT represents the gold field laborers and, at times, the small prospector. It has a union official in Alta Floresta and an employee in Apiacás and Paranaíta. It carries out membership campaigns and estimates that 40% of the prospectors/gold field laborers are members. However, its infrastructure is somewhat unreliable for attending its members.

The rule in Law 7805/89 ordering the prospectors to organize themselves into cooperatives does not seem to have worked in the region.

In 1990, after the legal regulation, 4 cooperatives were formed, identified through their federal tax numbers (CGC/Ministry of Finance): Regional Cooperative of Prospectors of Alta Floresta, Cooperative of Prospectors of Juruena, Cooperative of Prospectors of São Benedito and the Paranaíta Mineral Extraction Cooperative - COOPAR. Of these, only the latter has a known address and members list.

In an interview with the president of COOPAR, who supports the idea of cooperatives, and had experience in farming cooperatives in Paraná, it was possible to understand the difficulties involved. The main drawback among them is the lack of interest shown by entrepreneurs who have become members just to comply with the law.

COOPAR brings together the raft gold fields entrepreneurs and seeks to offers services which make membership attractive, such as: supplying input, centralized gold sales in order to get a better price in the market, the preparation of a common environmental impact study.

This solution, which was thought of for rationalizing gold

prospecting, and included in COOPAR's reasoning, has not produced practical results. The introduction of a corporate model capable of permitting fulfillment of mining, environmental and labor legislation, has come up against the specific characteristics of gold prospecting - the fast and maximized appropriation of the wealth coming from this exhaustible mineral.

According to SINGAMAT, Alta Floresta has the following gold fields:

ALTA FLORESTA GOLD FIELDS

1 - SERRINHA
2 - CÉU AZUL
3 - 3º LESTE
4 - 4º LESTE
5 - LINHA 14
6 - ROCHEDO
7 - GROTA DA MALÁRIA
8 - ILHA DO TELES PIRES
9 - ILHA DA PRINCESA
10 - ZÉ BIGODE
11 - PISTA NOVA
12 - PISTA DO CABEÇA
13 - MOLHA BÊBADO
14 - DOMBOROSQUE
15 - TELES PIRES
16 - PONTAL
17 - SEQUEIRO DO RATO
18 - MOGNO
19 - PISTA DO CUIABANO
20 - BARRA DO ROCHEDO
21 - JAMIN 1,2,3
22 - TRIÂNGULO
23 - NHANDÚ
24 - TIRA CALÇA
25 - ESTRADA "D" e "C"
26 - SEGUNDA LESTE
27 - PIUM
28 - CAJUEIRO
29 - CASTANHEIRA
30 - LAPISQUE
31 - AMARAL
31 - ESTRADAS A.B.C.D.E.F
33 - METRALHAS
34 - LINHA 17
35 - GROTA DA PEDACEIRA
36 - PIOVESAN
37 - SANTA HELENA
38 - PLACA DA COCA
39 - ZANETE
40 - OUROLÂNDIA
41 - PISTA DO PADEIRO
42 - NAVAIR
43 - SÃO BENEDITO
44 - YAMACHITA
45 - RASTEIRA
46 - 12,5 MOGNO
47 - PISTA DO GOIANO
48 - CORRENTÃO
49 - JAPONÊS
50 - 4 PONTES
51 - DANIEL
52 - CRISTALINA
53 - GROTA SÊCA
54 - LINHA 15
55 - ESTRADA ESTE
56 - JEICÍ
57 - GROTA RICA

5.2 Mineral Technology

The main purpose of including the mineral technology area in this report was to provide a detailed description of the productive processes used in the gold fields and how disturbances of the environment occur.

Some target areas were chosen for gathering data (Figure 5) which represented the types of gold fields, principally from the point of view of extraction and dumping of tailings. With regard to amalgamation, an attempt was made to estimate the ratio of metallic mercury used and gold produced, also observing possible points where mercury was passing into the environmental compartments (sediments and atmosphere).

5.2.1 Types of gold-bearing deposits

The presence of gold in the area being studied is essentially associated with alluvial-colluvial coverings, which will be discussed further on according to the prospecting methods currently used, that is, the *baixão* type (hydraulic tearing down) and in abundant rivers (using rafts).

Gold prospecting in the channels of abundant rivers of northern Mato Grosso is done using dredges and divers, scraper dredges and scrapers. Prospecting is usually concentrated approximately 1m to 3m under the river bed. The deposits are alluvial and, therefore, secondary where the gold is concentrated by physical processes, particularly after erosion and reworking of ore-bearing rocks or rocks from other deposits (Berbet, 1988). These deposits may be classified into three types:

- <u>active bed</u>, lying inside the actual channel of the river, and exposed to natural obstacles (river crossings, waterfalls, rapids,

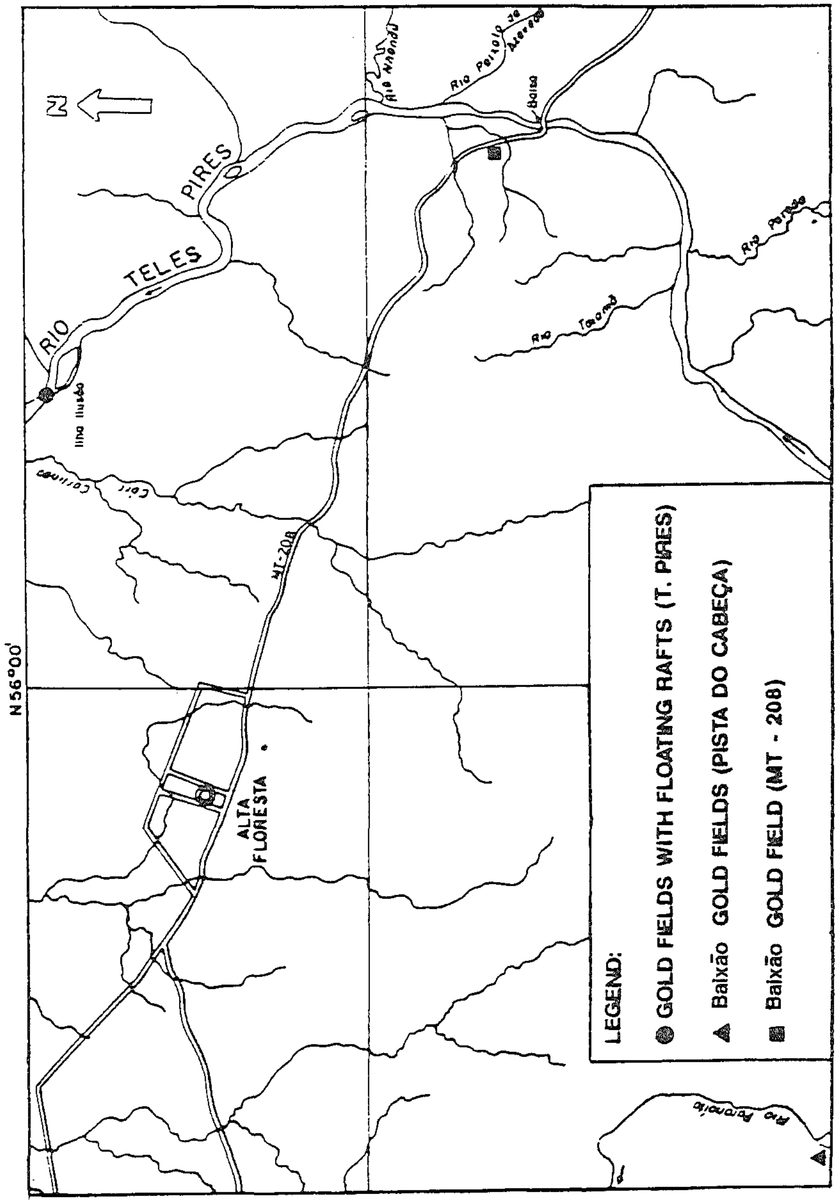


FIGURE 5 - Map Showing Sites of *Baixão* and Raft Gold Fields of the Teles Pires River which were studied and commented.

curves and meanders);

- alluvial plain, formed by the deposit of loads of suspended matter, caused by lesser down slope and lateral migration of its bed, with a consequent drop in transport energy; and
- terraces at levels which correspond to the old active bed deposits, inserted between flood clays in abandoned meanders and paleovalleys (MINEROPAR, 1985; Sept. 1986).

The deposits often consist of gravel, sand and silt/clay, in the natural order of settling, with variable levels of consolidation. They may be defined as immature and badly selected sediments of varying colors, although mostly greenish-grey. Not uncommonly they show signs of laterization with the development of ferruginous concretions found covering the pile.

In stratigraphic terms, this pile is formed by a fine, basal conglomerate level, at time discontinuous, lying on the basement complex, containing fine gravels and abundant clayey-sandy matrix. Immediately above it are coarse to fine sands with the presence of clay of varying thickness. The top is virtually clayey-sandy, usually rich in organic matter and about 50cm thick (Sept. 1986).

On the active beds the gravel fraction tends to be well rounded, with the presence or not of small stones. The sands are well washed and, therefore, free of clay, while there is an appreciable amount of clays to be found in the alluvial deposits, in the form of layers inserted between the sands and gravels.

In the *baixões*, most of the deposits are similar to those of the abundant rivers, while the origin, that is, active bed, alluvial plane and terraces. They really vary considerably as to size, since the *baixões* are distinguished preferentially by prospecting in lower class drainage waters (streams, forest waterways, holes in river banks...).

5.2.2 Description of mining methods

The principal areas where the dredges operate are the Teles Pires and Peixoto de Azevedo rivers.

On the Teles Pires river the mining limits for floating rafts are set at the top by a ferruginous carapace - a conglomerate formed by pebbles (matrix) and iron oxide (cement) - which covers the alluvium, and at the bottom by a rock known locally as *lagrese* or *lagresia*. By moving the raft forward and sideways the operator manages to prospect all the surface area of the alluvium.

In the *baixão* gold fields, the limits run from the soil to the rock, known locally as the *laje*. The material is torn down in blocks and the volume is according to the height.

.*Baixão* gold fields

Water for tearing down is taken directly from the drainage waters, or from those waters to a tank and then to the mining front. The pumps used are generally 3" diameter for delivery/suction with a stationary, internal combustion (diesel) engine. These pumps feed a jet nozzle whose high pressure tears down the material. The same motor breaks up the material and helps to transport the pulp to the dredge. During the tearing down the engine begins to work at a lower topographical level than the water intake, which also helps keep up the nozzle pressure.

The pulp is transported to a *poço* (pit) where it is discharged to the concentrator trough. Along this route material is classified approximately above 2", and sorted by hand using a pitchfork. The engine's rotation speed is controlled so that the dredge works the greatest possible time with a pulp dilution of approximately 50% solids in volume.

There is no actual control of this dilution. It is simply noticed when the pump is unable to pump properly. Another point to be noted is that when working the gold field, there is no control equipment, meaning that the operator's visual attention must be relied upon.

There are usually three or possibly four persons involved in this process. The operators work at the mining front, sorting the material and controlling the delivery to the trough. The fourth and possible operator works with a pickax helping to tear down and separating the solid lumps. The most in demand among the operators for his work is whoever works on the dredge which fees the trough. With his feet at the suction intake, he tries not to let the coarser material enter (greater than the dredge's delivery capacity), tries to maintain the pulp dilution as stable as possible and tries to work so that there will be no delivery interruptions (temporary lack of material coming from the mining front). The dredge works below the topographical level of the trough and the piping often gets blocked; hence, it is sought to work with the equipment as close as possible and with the delivery line as straight as possible. Four inch discharge delivery/suction dredges are used (Figure 6).

.Raft Gold Fields

On the floating rafts the mining front is on the river bed, which makes the mining method more simple operationally (only one person controls the operation), although more difficult because the torn down material is under water (the experience of each operator is depended upon).

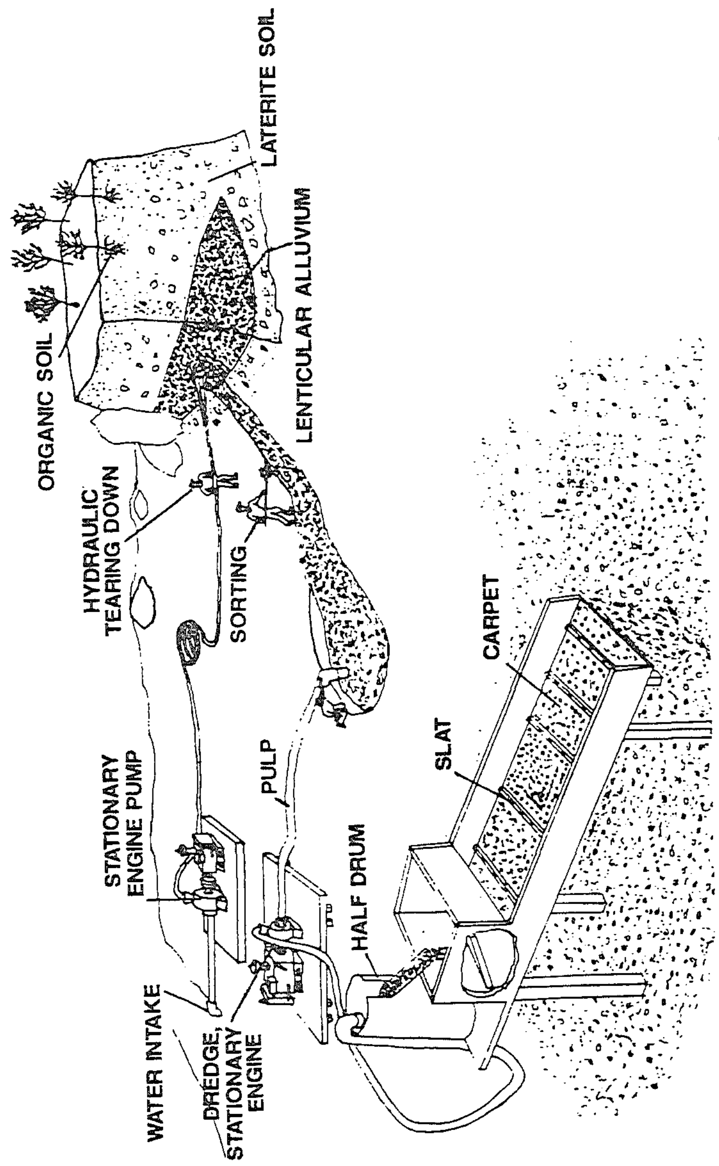


FIGURE 6 - Layout of *baixão* gold field showing the water intake, hydraulic tearing down, dredging, concentration and dispersion of tailings.

The dredges used on the Teles Pires river are of the 8" suction/delivery kind. 3 or 4 operators work on the dredges. They work in shifts, taking turns among themselves, so that they not only do the mining, but also the concentration and gold recovery. The operator controls the mining through a panel which activates a hydraulic assembly. This assembly adjusts the height of the dredge's suction admission, the rotary movement of the *abacaxi* and the forward movement of the raft in the anchorage.

The *abacaxi* is a scraper weighing approximately 20kg consisting of a 1/2" diameter hardware housing and pieces of springs used in the suspension assembly of trucks. These ends of these pieces stick out around the housing. They have two purposes: to break open the hard ferruginous carapace which covers the alluvium and to make the raft move sideways. This sideways movement is achieved when the *abacaxi* scraper touches the river bed. If the pressure is high, it tends to break the ferruginous carapace and dredges the alluvium. This pressure is relieved by moving the steel height-adjusting cable. The *abacaxi* is located at the dredge's suction admission and its housing is pierced to allow suction (Figure 7). Another mining parameter the operator uses is to control the quantity of gold contained in the feed using a bowl at the trough admission.

When a blockage occurs or it is necessary to prime the dredge, a 4" auxiliary suction/delivery pump is operated (pulley system). On the delivery line there is a curvature leading into the dredge through a hose (polymer) so that the suction admission may be moved vertically. Once dredging has begun, constant stoppages are confined only to changing the raft's position.

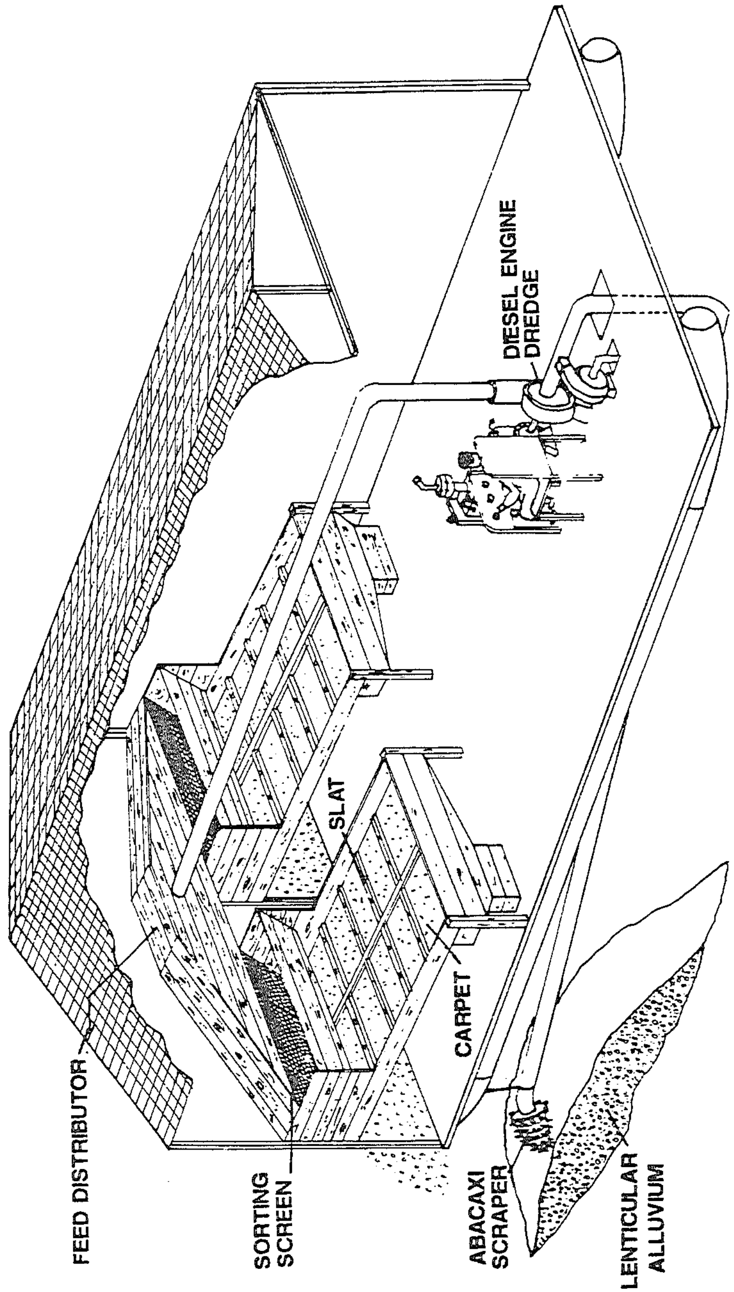


FIGURE 7 - Layout of installations of a raft and scraper dredge and concentration details.

5.2.3 Description of dressing methods

Ore dressing is similar in both kinds of gold fields. Concentration is done in a sloping trough and the differences lie in the production, equipment capacity and the grain size of the processed material.

The ore pulp is concentrated on the carpets and trough obstructions. The *despescagem* [9] varies according to the capacity of the equipment.

Depending on the material, the *baixão* gold miner takes around 7 to 12 days to conclude the *despescagem*, which usually takes place after an average block of 4 x 10 x 10 (height, length and width in meters) has been torn down. In gold fields where *pára-quedas* [10] (feed distributors) are used, the concentrated material is removed at shorter intervals (2 or 3 times between *despescagem* of the carpets). On the rafts each *despescagem* takes 1 day (from 18 to 20 hours actually worked), while in some cases the last stretch of carpets is only *despescada* after 30 days.

Due to the irregularities caused by mining interruptions, feeding the troughs is discontinuous and the pulp dilution and production level vary a great deal.

5.2.3.1 Description of feed material

.*Baixão* gold fields

The feed material is mined from the ground level down to a depth limit of approximately 5 to 8m. It consists of reddish to white soil covering a layer of gravel.

[9] *Despescagem* is the name given locally to the work of removing the concentrate from the feed distributor, carpets and the trough itself.
[10] *Pára-quedas* is the name given to a drum or box placed at the feed point, which is used for stopping turbulence.

According to the miners, the largest concentrations of gold are in the gravel belt. The grain size of the feed material is up to 2 inches. In some gold fields the solid material not yet torn down is separated for crushing and subsequent dressing.

The dilution of the feed pulp, measured in the field, may vary up to 60% solids in weight with an average of 30%. Four grain size ranges were analyzed: +3 1/2. +28, +150 and -150#. The percentages found are in Table 6.

TABLE 6 - Grain size distribution of feed

GRAIN SIZE RANGE (#)	FEED (%)			
	MINIMUM	-	MAXIMUM	AVERAGE
+3 1/2	6.86	-	43.20	23.87
-3 1/2 + 28	21.57	-	66.18	39.54
-28 + 150	12.41	-	39.60	22.76
-150	10.69	-	17.30	13.84

In a single gold field the presence was noted of primary material associated with the quartz vein at some depth. In this case the primary material is stored separately and is crushed in a hammer crusher and concentrated in a separate trough. It should be noted that this material had a high gold content (30.2g Au/ton) in sampling of the feed, although the size of the occurrence is not known.

In other *baixão* gold fields visited the feed was sampled and the concentrator trough tailings showed relatively low gold contents (Table 7) and, as is characteristic in alluvia, most of the gold was retained above 150# (Table 8).

TABLE 7 - Gold content in the feed and tailings of troughs

BAIXÃO GOLD FIELDS	FEED (ppm Au)	TAILINGS (ppm Au)
A	0.29	0.09
B	0.44	1.31
C	0.37	0.20

TABLE 8 - Distribution of gold in ranges of grain sizes of the trough feed

GRAIN SIZE RANGE (#)	FEED (% Au)		
	GOLD FIELD A	GOLD FIELD B	GOLD FIELD C
+28	11.6	43.1	48.1
–28 +150	63.6	35.4	5.2
–150	24.8	21.6	46.7

.Raft gold fields

The materials used for feeding the rafts are active alluvia from the bed of the Teles Pires river. The dredged material is classified by the operators according to its coloring. There are five types of material: white, yellow, cream, greenish-brown and green. According to the operators, the yellow and cream materials contain the most gold.

The material fed into the raft is sorted for grain size in 1/4" screens. The upper material is discarded directly on the river bed.

The tailings are unloaded onto the river bed closest to the middle of the raft. Since the dredge suction is further down, after this point part of the coarse material, which settles quickly, is again sucked up for dressing. Of the rafts visited, only one of them has its suction admission located in front of the tailings discarding point, near the mooring system.

The dilution of the pulp on the rafts varies from 5 to 31.5% of solids in weight and an average of 10.8%. Three grain size ranges were analyzed: +28, +150 and -150#. Table 9 shows the values of those retained in each range:

TABLE 9 - Distribution of feed according to grain size

GRAIN SIZE RANGE (#)	FEED (%)			
	MINIMUM	–	MAXIMUM	AVERAGE
+28	8.45	–	32.06	20.08
-28 +150	61.97	–	90.26	77.12
-150	1.29	–	5.97	2.81

The low gold contents found in the feed from the gold fields on floating rafts are equivalent to those from the *baixão* gold field (Table 10).

TABLE 10 - Gold content in feed, tailings and concentrate of troughs

MINING ON FLOATING RAFTS	FEED (ppm Au)	TAILINGS (ppm Au)	CONCENTRATE (ppm Au)
E	0.20	0.33	—
F	0.06	0.17	68.00
G	1.00	0.75	1,050.00
H	3.70	0.25	1,640.00

What can be noted in the samplings of products from the concentration plant of the gold fields is that, due to the occurrence of the nugget effect [11] and of operation without control of parameters such as dilution (% of solids in the pulp), rate of solids fed,

[11] The nugget effect is the interference which the heterogeneous distribution of rough gold causes in chemical analyses. To avoid this effect, it would be necessary to collect a much bigger sample than usual for the laboratory analysis methods.

gold content in the feed and granulometry, any calculation whose purpose is the metallurgical balance of the gold in the installation becomes unfeasible.

5.2.3.2 Description of Equipment

The concentrator troughs used in both the gold fields are simple devices, easily built, inexpensive to maintain and require a low investment. They are usually made of wood and slope down lengthwise. The ore pulp is fed into the upper part and drops through gravity. The wooden floor of the trough is lined with removable carpets fastened by wooden slats in which the gold concentrates. These wooden slats (*taliscas*) are also used as concentration riffles. In some cases these slats may be combined with interwoven polymer or metal screens laid over the carpet. These screens are sometimes used instead of the wooden slats.

In the *baixão* gold fields, the dimensions (length, width and height) of the troughs varies from 1.30 x 0.70 x 0.15 to 2.45 x 1.10 x 0.25m. Often 2 sets of troughs are used for dressing. In this case, the upper trough is slightly smaller than the lower trough. The slope of the troughs of the *baixão* gold fields can be as much as 14°, although 7° is the usual. Some gold fields use a drum before where the material enters the trough; these are called *pára-quedas* and are used to break the speed of the pulp flow and concentrate gold particles with a coarser grain size. The wooden slats (*taliscas*) are positioned at 15cm to 50cm intervals.

On the rafts the dredge always feeds one pair of troughs of a much larger size: 4.30 x 3.15 x 0.20 up to 5.30 x 3.30 x 0.30m. The slope of the troughs may be as much as 7°, although 5° is the usual. The feed may be distributed to both the troughs through a division in the piping, or through a baffle plate at the end of the dredge's delivery piping. The wooden slats are positioned at 70cm intervals. Due to the considerable width of the trough, 1 or 2 slats

positioned lengthwise are installed.

.*Baixão* gold fields

In the *baixão* gold fields it is necessary to use water for hydraulic tearing down (jet nozzle) and a dredge for feeding the trough. This requires the use of internal combustion engines (diesel) which drive the pump and dredge.

Generally, 3" suction and discharge pumps are used for hydraulic tearing down. The pumps and engines are of various types and brands, while the most common power of the engines is 11 h.p. The pumps are coupled so as to make discharge easier.

The same applies to the dredges. The suction/delivery diameter is 4" and the most common engine power is 27 h.p. All the engines are started by hand. The jet nozzle engine works at a constant rotation while the dredge engine has operator-controlled rotation. The dredge and stationary engine assembly are mounted on a wooden plank supported by 200 liter barrels; this is to ensure that the assembly floats if the mining front fills with water and also makes transportation easier (Figure 6).

.Raft gold fields

The floating rafts are basically wood structures supported on a deck and held up by 2 metal floats. The rafts usually measure 14 x 8 x 5m (length, width and height), the troughs occupy the front part side by side and the mooring structure is positioned at the rear. In the middle are the dredge and engine - the latter for moving the dredge and the raft (Figure 7). Along the sides are the bathroom, kitchen, deposit/tools and access to the second deck. On the upper deck are bedrooms and sometimes a small patio.

The raft engine is usually a 6 cylinder diesel MWM and the gear boxes are of various types and brands. The gear boxes drive a hydraulic assembly and dredge at 120kgf/cm2 and 1,800 rpm, respectively. The dredges are 8" suction /discharge delivery and almost all are Hefpel dredges. On the suction piping, before the dredge itself, there is a 4" suction/discharge auxiliary pump for priming and/or unblocking the dredge. The hydraulic assembly is controlled by 3 rods. The first drives the hydraulics of the steel mooring cable (1/2"), allowing the raft to move lengthwise. The second drives the pump which revolves the *abacaxi* scraper - located at the front of the raft between the troughs, enabling the alluvion to be reached. The third drives the hydraulics of the steel cable (5/8") which regulates the height of the dredge's suction piping, where the *abacaxi* is located. The hydraulic drive pumps can be of the MAB or MAE type.

The rafts have a diesel generator set which can produce up to 18kVA, although 3kVA is usual. Electric energy is obtained through these generator sets for operating light bulbs, a water pump (cleaning, supplying the raft) and a weld grinder.

The rafts are shifred crosswise by moving the *abacaxi* scraper touching the river bed and lengthwise by activating the steel mooring cable (Figure 8). When it is necessary to move the raft beyond the anchorage point - 120m long mooring cable - it is taken by a boat which is positioned in front of it between the floats, driving it with a 25 or 40 h.p. engine.

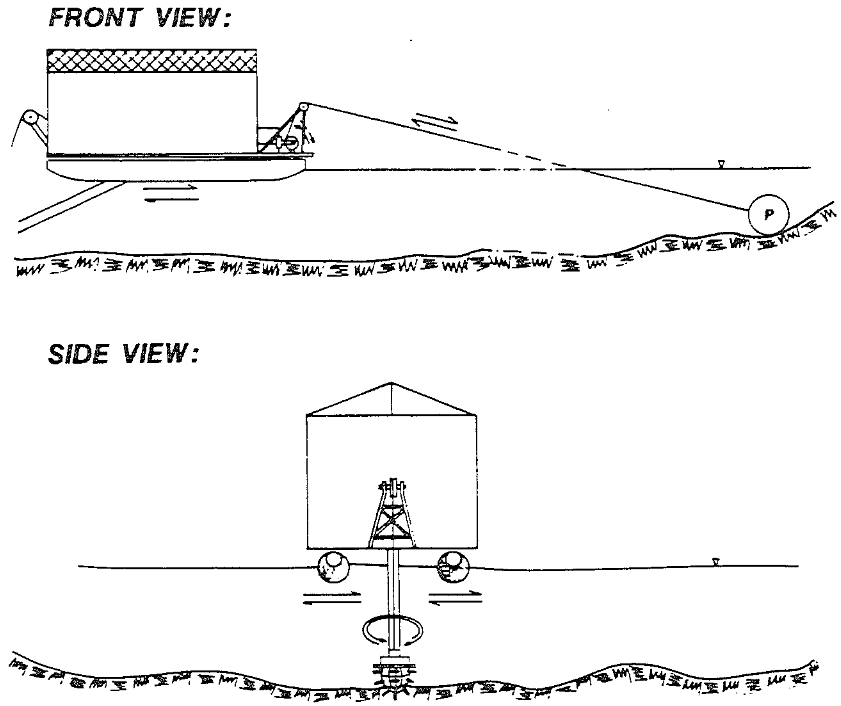


FIGURE 8 - Scheme for front and sideways motion of rafts during mining

5.2.4 Appraisal of amalgamation processes

During the field phase, it is possible to closely accompany the amalgamation stages in some *baixão* gold fields and on floating rafts on the Teles Pires river. In the gold fields visited, it was noted that very little care was taken when handling mercury - in the amalgamation and amalgam burning phases - and also in containment of contaminated tailings.

5.2.4.1 Description of Methods

The material coming from the gravity concentration, done in sloping troughs (*cobra fumando* or *caixa garimpeira*) is collected at intervals of 1 to 12 days, and forms what is called concentrate or resumo. This material is recovered through a process called *despescagem* and consists of removing the concentrate retained in the trough, on carpets and in the *fervedouro*.[12]

The separation of the amalgam and excess mercury from the other minerals is done directly in a gold washing pan or in a bowl.[13]

. *Baixão* gold fields

In the *baixão* gold fields the amalgamation method is similar to that used on floating rafts, although the main difference is that it is all done by hand.

After removal, the concentrate is mixed with the metallic mercury in drums and transferred for separation in washing pans or bowls. The amalgam separation and excess mercury added is done mostly

[12] A drum placed at the system entry for moderating the turbulence or a "half length" trough placed also at the beginning of the equipment to which clean water is also fed.

[13] A container used locally which differs from the washing pan mainly due to its shape - polar cap - and smaller size.

in natural drainage water or water catchment dams for hydraulic tearing down. This explains the contamination found in the material fed to the trough of one of the gold fields (1.24ppm Hg) which used the same dam for amalgamation and for impounding water.

Cases of gold fields were seen where mercury was added to the *fervedouros* in order to produce amalgamation beforehand. Occasionally, the mercury may be added in the concentration trough itself. This procedure was not observed in the field, but was known through gold miners' hearsay.

The surplus added mercury is filtered through pieces of cotton cloth and the filtered material may be reused in future amalgamation operations. The mercury is cleaned with soap powder or detergent after some recyclings in the amalgamation process, so as to improve the recovery. In the *baixão* gold fields visited, the amalgam was burned in the open air, without using any environmental or occupational safety equipment. The amalgamation process in *baixão* gold fields is illustrated in Figure 9.

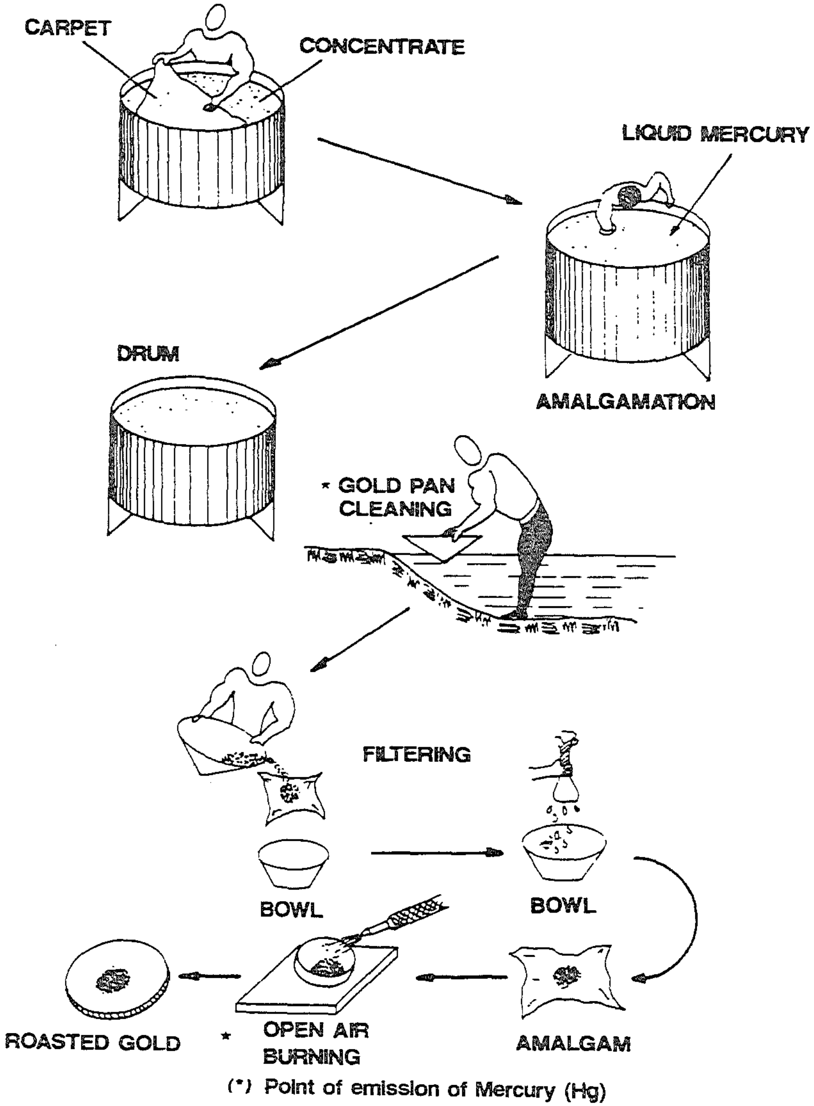


FIGURE 9 - Amalgamation in *baixão* gold fields

. Raft gold fields

In three floating raft gold fields of the Teles Pires river the amalgamation stage (weighing and detailed description) was systematically accompanied. During this accompaniment, it was sought to measure the quantity upon entry, departing to the environment and possible recycling of the mercury during the process. This was not possible on other rafts and only a verbal description of the operation was obtained. The following observations may be made based on the information obtained:

- the metallic mercury/gravity concentrate ratios were between approximately 1:400 and 1:100;
- discarding of contaminated tailings - and a content varying from 5 to 134ppm Hg - coming from amalgamation, was not controlled at all and poured directly into the trough from the river;
- the mercury obtained in the filtering stage represents, on average, 80% of the mercury used at the start, and
- the ratios between the gold produced by the three gold fields and the mercury lost to the environment were 1:1.32, 1:1.45 and 1:1.47.

Figure 10 shows the process of amalgamation on rafts.

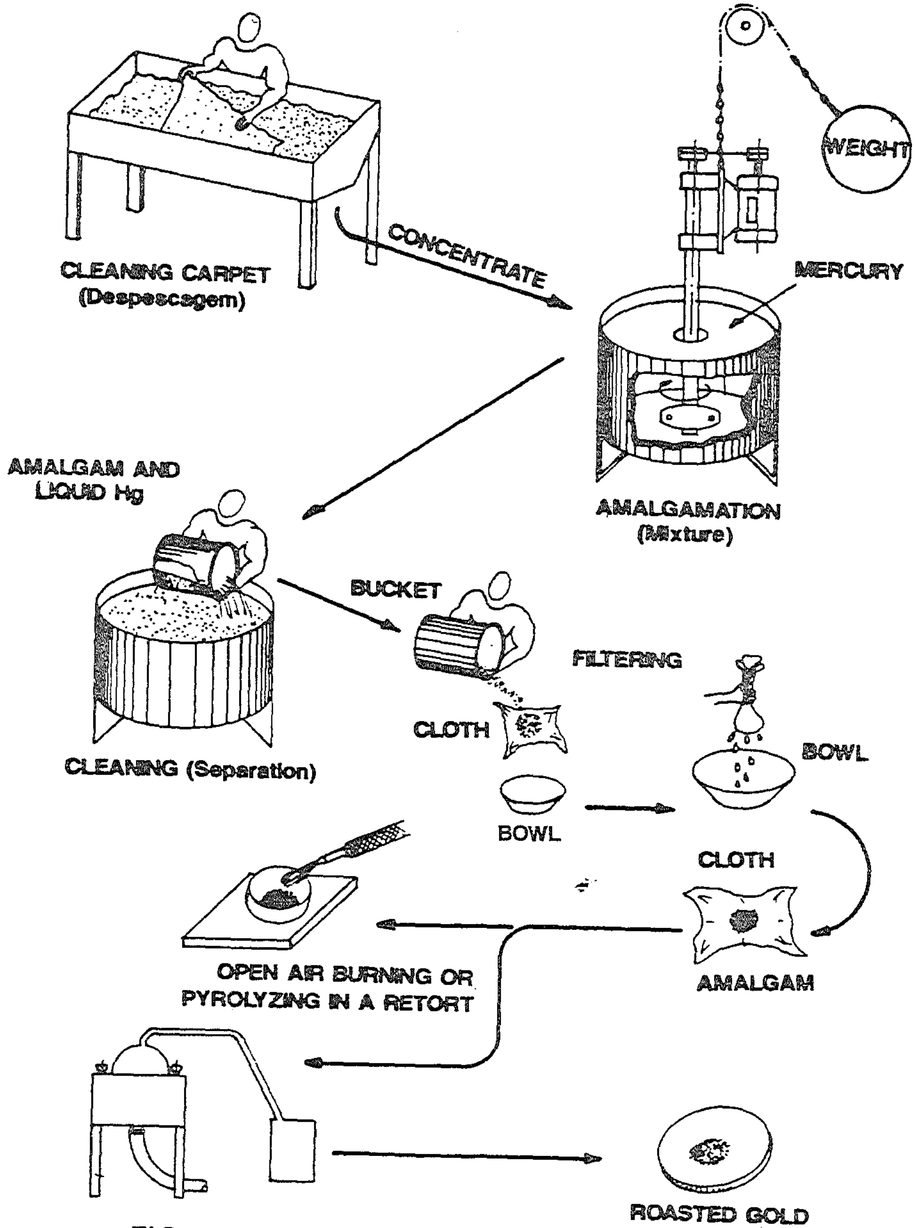


FIGURE 10 - Amalgamation on floating rafts

The floating raft operating sites are crowded and successive operations go on for years. This means that the bottom sediments of these places are very contaminated, which can be proved by the mercury contamination found when sampling the feed and trough concentrate of the rafts (Table 11).

TABLE 11 - Concentration of dispensed mercury on floating rafts

GOLD FIELDS ON FLOATING RAFTS	FEED (ppm Hg)	CONCENTRATE (ppm Hg)	AMALGAMATION TAILINGS (ppm Hg)
E	0.41	*	*
F	2.34	5.25	4.95
G	0.42	28.00	89.50
H	0.64	16.40	174.84

* not determined

5.2.4.2 Emission of mercury into the environment

During observation and measurements made in *baixão* gold fields and on floating rafts on the Teles Pires river, it was found on most occasions that no care was taken to control the emission of mercury into the environment, either to the atmospheric compartment (during burning), or into drainage waters (through sediments). Similarly, the operators are entirely exposed while burning the amalgam. The use of retorts is not customary and the place where the systematic burning is done is unsuitable. Even kitchen stoves from the gold fields are used.

In one case only, it was noted that the contaminated material, tailings and material coming from amalgamation, were put in plastic bags in order to avoid direct discarding into drainage waters. This would be effective in the case of floating rafts but, from what could be discovered, this process needs more disclosure by the cooperative which started it. It should also be noted that this method is futile if steps are not taken to avoid solids overflowing during the amalgam separation phase. In a laboratory analysis, these solids carried out by overflowing had a mercury content of 5ppm and were discarded directly into the river.

The amalgamation operations which were accompanied showed relatively small quantities of added mercury for the mass of concentrate obtained (1:400 to 1:100, when between 1:50 to 1:20 is usual). This clearly means less amalgamation ability, which was proved while accompanying a second stage carried out with the tailings of the first stage, when quite an expressive recovery of gold was achieved. This second operation consisted of amalgamation done in a rather unconventional or at least curious way, because the mercury was added to the dry tailings and the separation was done through the action of air by blowing and fanning. The amount of mercury added at the beginning of the amalgamation process interferes only with the ability of the process, and is not important as far as the environment is concerned. From the environmental point of view, what is important is controlling mercury emissions, either in the burning phase or through flushing in solid and liquid tailings.

Regarding the addition of mercury in the concentration phase, it must be stressed that this method is entirely ineffective as far as the amalgamation process is concerned - the ability is related to the proportion of mercury/ concentrate and to the contact time of the mixture - and poses a high environmental risk because it allows contamination of practically all the primary tailings. Another point to be considered is that, since no ways exist of containing these solid primary tailings, this contamination is followed by large-scale dispersion of the mercury into the environment, because these deposits of contaminated tailings are closely associated with the drainage waters.

In the *baixão* or floating raft gold fields, a major factor of dispersion of mercury into the environment is the stage of amalgam burning without using retorts because after volatilization, the amalgam may affect large areas through the atmosphere, including those where the gold fields are only influenced indirectly.

As to the proportion of mercury emitted during the amalgam burning stage, this reaches between 70 and 75% of the mercury lost into the environment. The other losses are due to contamination of solid tailings (20 to 25%) and to the refining in the gold buying shops (0.5 to 5%).

5.2.5 Appraisal of distribution, dispersion and silting up by solid tailings

The gold fields of the Alta Floresta region are, as explained earlier, distinguished by the fact that they mine alluvia in drainage waters or near them (active or inactive). The method of disposal of the concentration process tailings is, in the case of the floating rafts, directly into the rivers or else the tailings may reach drainage waters, as in the case of the floating rafts. By gathering information it was sought to establish a prior estimate of the quantities of these solids which silt up and cause transformations in the physical and chemical characteristics of such drainage waters.

. <u>Silting up by mining the bed of drainage waters using floating rafts</u>

After dressing the alluvial material, the concentration tailings are poured directly into the waterway. The sideways movements of the rafts while extracting, causes the material to be revolved all along the extent of a cross section of the river.

Considering the water in the middle flows faster and that it slows down toward the river banks, the quantity of material which is deposited alongside the rivers is consequently larger.

This differentiated settling, due to the specific characteristics of the drainage waters, causes silting up which at first changes the natural outlines of the river channel and affects the capacity and ability of transporting suspended solids.

The scraper rafts called *escarilanças* wash materials located outside the river bed, causing a mechanical tearing down of the river banks. This results in the formation of backwaters where the work front is located and the river banks and environs are then bereft of their original plant covering. The tailings of this process accumulate in banks alongside the river, appearing when the water level is low. They are known locally as *arroto*.

An analysis of the effect of silting up in the channel of drainage waters must take into consideration its transportation capacity and ability. Capacity means the amount of suspended solid mass (mg/l) which particular drainage waters can transport in terms of their flow, and ability to the size of the solids transported in terms of the water's kinetic energy.

The flow speed allied to the existence of obstacles - islands, rocky outcroppings, curves, etc -, which cause interruptions in the water flow, are factors that give rise to the appearance of turbulence, and variations in the flow speed are associated with such turbulence.

This increase of kinetic energy is accompanied by an increase in the transportation ability of the drainage waters, resulting in erosion processes. Similarly, a drop in speed results in silting due to less ability.

When the river bed is suction dredged the shape of the channel is continually altered, resulting in hollows in the floor. Comparatively speaking, these hollows are macroscopic furrows which upset the dynamics of the water flow and result in new points of silting or erosion.

The Teles Pires river contains islands and, at some points, rapids which affect the settling of suspended solids. Measurements of suspended solids were evaluated along the waterway, and an increase was noted just below the point where the raft tailings are discarded. Since the dredges work together, and even side by side, a point was established further below for measuring suspended solids in the water, so as to consider the array of suspended solid materials of the rafts together, showing a growth in comparison with the measurement made before (38mg/l) and right after (174mg/l) the work area of the rafts.

.Silting up by mining in *baixão* areas

In the *baixão* gold fields the dressing tailings are poured onto land right by the trough outlet and drop by gravity according to the land topography. As this topography is generally flat, the discarded tailings cover large areas and sometimes neighboring drainage waters.

Attempts to contain the solid material through river barriers are principally aimed at avoiding the tailings reaching present and future mining fronts. These river barriers consist of plastic sheeting containing sand and coarse quartz, held up by interwoven wooden stakes and leaves.

The dredges produce up to 25ton/h and without feed control (much variation in the pulp dilution). The water used in the dressing process is not recycled and, therefore, there is much dispersion of solid matter because of the topography. The tailings are laid out in a fan shape which gradually gets bigger in size and with time, starting from the trough disposal point. This means that a gently sloping wide radius cone takes shape. The finer the grain size of the material, the more transportation occurs and the farther away it settles.

The dressing tailings can be processed again. Generally, this is done 2 or 3 times, depending on the quantity of gold recovered earlier. This means that the miner can return the material to the place which had been the mining front, or possibly discard it alongside or even in the drainage waters which, when reached by the tailings, then contain high levels of suspended solids which can be as much as 4,000mg/l.

5.2.6 Methodology

The methodology used for achieving results may be divided into: sampling, preparation of samples and analysis.

The samples collected by the mineral technology area are: feed, tailings and trough concentrate and amalgamation tailings. Due to the lack of geological knowledge of the deposit being mined and since alluvial deposits were involved, it is hard to determine the precision of the samples, taking into consideration the quantity of material dressed.

The great variation of material flow in the concentrator troughs (including feed interruptions), suggest that material should be collected at random; however, half an hour's interval of operation was noted between the fractions which form the feed and trough tailings samples.

Approximately 20 samplings of feed and tailings pulp dilution were carried out for each gold field visited, although no strict time interval was respected.

.Sampling methodology

The feed and trough tailings samples were collected simultaneously through basins and transferred to large containers (70 liters). After filling the containers, the samples were flocculated in an acid medium, the liquid phase drained, the solid phase packed in plastic bags and the bags were then sealed.

The samples of feed and tailings from the floating rafts, after

a granulometric analysis, were blended for chemical analysis. For analyzing the mercury in the feed material, all the gold fields had their grain size ranges integrated in percentages so as to arrive at a single fraction for the laboratory.

Small quantities of samples of trough concentrate and amalgamation tailings samples were collected at various points of the settling tank of the *despescagem* material. After amalgamation, the material was cleaned and the tailings formed by overflowing. The tailings were collected at 30 second intervals in plastic bags and poured off naturally. The floating matter was then removed and the solid phase incorporated to the sample. These materials were similarly packed in sealed plastic bags.

According to Richards, when no more thorough knowledge is available on a goldbearing ore to be studied, the sampling should be done with a large mass of material. Due to the difficulties of obtaining such a large quantity, it was decided to carry out more selective sampling, in order to achieve the best possible representative amount.

.Methodology of preparing samples

In the field laboratory in Alta Floresta, the samples of the trough concentrate and amalgamation tailings were dried at ambient temperature in plastic or metal containers. They were then weighed and packed in sealed plastic bags.

The feed and trough tailings samples were classified by hand using a wet method. The meshes used for screening the materials from the *baixão* gold field were 3 1/2, 28 and 150#, while for the floating rafts only 28 and 150#, because the latter are classified beforehand in static 1/4" diameter screens. They were then weighed and packed in sealed plastic bags.

.Analytical methodology

At CETEM, each sample was homogenized in an elongated pile and a fraction of approximately 100g was taken from it. These fractions were then pulverized in disc grinders down to -150#. The +3 1/2# fraction was kept in the records and not sent for chemical analysis.

When they were pulverized, the samples were separated into three groups: for assaying gold, mercury and gold/mercury, and the batches were sent separately. In this way, through the cleaning done in the grinder between one sample and another, it was sought to minimize contamination among the samples.

The gold was fire-assayed and all the assaying was done using atomic absorption spectrophotometry.

5.2.7 Estimate of costs

The costs involved in operating the gold fields are as varied as possible. Locating the gold fields and investing in infrastructure weigh the most in such costs.

The *baixão* gold fields can produce *corrutelas*, which are villages whose infrastructure is reasonable, as much in terms of support for the gold fields as for human living conditions. On the other hand, on the floating rafts it is necessary for the laborers to stay aboard and the distance between the mining site and the town is usually the most expensive item, because nearly all the provisions must be transported.

In the case of the floating rafts an investment is sometimes made in a second raft which is used as a mechanical workshop, kitchen and storage place for food and provisions. In *baixão* gold fields situated in isolated places, such an investment is necessary, although it is

not usually needed when near villages.

Expenses with maintaining a raft are higher than in a gold field where hydraulic tearing down takes place, although the gold production is higher. The rafts have a generator set for nocturnal work, which is not entirely necessary in *baixão* gold fields. Keeping the laborer in the gold fields involves heavy costs for such small-scale activities.

The wages of laborers and personnel involved are directly related to production. Usually, a fixed percentage is received based on the gold production. In the *baixão* gold fields, the operators receive 30% of the total produced to be divided equally among themselves (3 or 4 persons); on the rafts this amount is 4 or 5% for each operator and the presence of a foreman is common, who gets 8%. The others receive a fixed wage. The number of people is as large as the gold field needs (cooks, mechanics, etc).

Due to the wear and tear on the equipment (an *abacaxi* may have a useful life of 1 day, a dredge housing only 4 days, for example), the replacement of parts becomes a very expensive item for the gold fields, besides affecting production - stoppages. From this point of view, it is important to have stocks. The gold fields also lack preventive maintenance.

There is a need for one vehicle (1/2 or 1 ton cargo capacity) in the gold fields for transportation (fuel, provisions, parts, etc) at least at weekly intervals. This variable may be daily, and the distance between the mining and a trading post is significant in terms of expenses.

According to the miners, a floating raft becomes profitable when it exceeds the range of 50 to 70g Au per *despescagem*. While in the *baixão* gold fields this range is 40 to 50g of Au.

These figures mean a total monthly production equivalent to approximately 1,000g of gold for the rafts and 300g for the *baixão* gold fields (the figure for *baixão* gold fields is very variable, as is their size).

In this region, although the price of input is in cruzeiros, it is often converted into grams of gold. According to the miners, it is easier to appraise costs for maintaining and investing in gold fields - a floating raft's sale price varies from 3 to 5kg of Au, depending on its condition.

Any appraisal in terms of costs must be specific for each gold field, due to the possibility of the most varied mistakes being made. It may be said that during the field work the activity was profitable, according to the miners, but that the profit did not meet the desired expectations, that is, there is no profit because of the volume of investments required.

5.2.8 Discussion and treatment of data

The data obtained in the field refer to the granulometric composition of the products; pulp dilution; chemical assaying of gold and mercury in the samples; geometric data and specifications of equipment; mining and dressing methods; evaluation of amalgamation processes and the emission of mercury into the environment.

The chemical analyses revealed mercury contents in the samples from concentrator trough feed (0.41 to 2.34ppm). The facts that were possibly responsible for this dispersion are cleaning of amalgamated material in water catchment tanks used for hydraulic tearing down, the use of process equipment (trough and *fervedouro*) as amalgamation containers, burning amalgam in the open air and discarding amalgamation tailings in a random manner (*baixão*) and directly into drainage waters (floating raft).

The gold assaying, as much as per ranges as per integration, of feed and concentrator trough tailings, showed irregularities of con-

tents - the tailings reached the point of showing in chemical assaying more gold than the feed - which therefore makes it unfeasible to set up a metallurgical balance. The trough concentrates (only rafts) showed contents between 68 and 1640ppm, revealing a directly relationship with the respective figures for feed and tailings.

Dressing involves factors that affect the gravity concentration, that is, erratic feed varying in quantity, much variation in the pulp dilution and material with a coarse grain size which is unsuited to the equipment's capacity. The granulometric curves in percentages of feed and tailings are very close to each other, when one considers the average among the gold fields studied. This shows the good sampling/grain size characteristic ratio.

Regarding pulp dilution, taking into account the sampling average, similarly close figures were noted for the feed and trough tailings in sampling in the various gold fields. Even when the figures are close, a slight variation is noted for granulometry and large variation for pulp dilution throughout the operation. When the process is resumed after a stoppage, the pulp dilution and the flow speed are high, causing swirling in the trough (slats and/or screens) which may cause flushing of already concentrated gold particles.

All mining of a mineral deposit requires planning to be done beforehand, however little. In the case of the Alta Floresta gold fields there is no planning. Instead parameters obtained experimentally are used. Consequently, the material may possibly be mined and, depending on the acknowledged inefficiency of the concentration equipment, be processed again. This operation of reprocessing material already dressed causes greater dispersion of the solid tailings and may even make new mining fronts impracticable. The lack of any control over depositing the primary tailings produced, causes economic losses because of the dilution of relatively high contents in practically depleted tailings and environmental losses because of the large area covered by such tailings and consequent silting up of drainage waters. Regarding the floating rafts, a detailed survey of the emission of solid tailings, associated with the capacity of the equipment and a survey of the hydraulic conditions of the drainage waters where they operate, could lead to a forecast of the level of silting and consequent establishing of parameters, such as the number of rafts and the distance between them, which could minimize the impact.

5.3 Environmental Geochemistry

5.3.1 Objectives

.Distribution of mercury in sediments and water

The chief aim of the Environmental Geochemistry research was to make a preliminary evaluation of the distribution of total mercury concentrations in silt caused by currents, on flood plains and in water, in an area of about 80km of the Teles Pires river, taking in its more important tributaries.

In view of the specific nature of mercury emission to drainage waters, in this particular case, as effluent in metallic form from the amalgamation processes, it was decided to make a divided study of the concentrations in relation to the grain size of the sediments, in order to identify possible sedimentary facies preferred for retaining mercury in a hydric medium.

At the same time it was sought to determine the predominant mineralogical species which compose the granulometric fractions of the silts, for the purpose not only of collecting data for appraising the potential for adsorbing mercury in such species, but also to recognize minerals that might contain abnormal mercury concentrations in their crystalline structure (iron sulphides and iron and manganese oxides, etc.).

The sediments deposited on flood plains are true historical records of the environmental conditions prevailing at the time when they settled. It is hoped to find out from these samples about the time evolution of the levels of mercury contamination of these environments.

In order to determine the background levels of mercury in sediments of the Alta Floresta region, the Cristalino river was chosen, whose course contains no gold mining activities at all.

.Distribution of mercury on urban soils

Considering the large amount of gold buying shops in the town of Alta Floresta, numbering about 30, which trade in a large part of the gold production from northern Mato Grosso and from southern Pará, it may be estimated that sizable amounts of mercury have been emitted to the atmosphere over the past 12 years through amalgam burning. As a way of understanding the dispersion of the mercury produced in this process, a regular sampling mesh was carried out of, the surface soils (0-10cm), covering an area of approximately $3.4km^2$.

The intention to track down the mercury precipitated into the town's soil aiming, above all, to evaluate the time of residence of the vaporized metal in an atmospheric medium.

Inside the sampling mesh, 10 points were chosen for collecting soil at a depth of 30cm, for the purpose of evaluating the mercury's potential for vertical remobilization in the soils. This soil belt also corresponds to the interval used as a substratum (organic soil) for planting vegetables in urban areas.

.Hydrochemical definition

In order to understand the behavior of heavy metals in a hydric medium it is essential to accompany the physical-chemical parameters of the water, that is, pH, Eh, electric conductivity and temperature. Since these variables are subject to seasonal variations, they must be monitored throughout the year, so that there intervals of variation may be known. In this study the field stages considered not only a period at the beginning of the dry season, in May, but also a period at extreme dryness, in September, when the water level of the Teles Pires river had dropped about 2.5m in comparison with May.

The idea was to provide data for interpreting the thermodynamic equilibrium of the mercury in the environments studied.

.Preliminary evaluation of the degree of silting up of drainage waters

The principal component of the physical degradation of the environment in gold mining areas would appear to be the silting up of drainage waters, caused by a rise in erosion and sedimentation rates. This would be a consequence of mining and mineral dressing activities on river beds and their environs. The purpose of this study was to estimate the levels of suspended solids and the flow of the drainage waters, whose rates are directly related to the degree of silting up.

5.3.2 Sampling methodology

.Sampling of soils

It was sought to understand the dispersion dynamics of the mercury produced when amalgamated gold was scorched by the gold buying shops, through detection of the reach of abnormal mercury concentrations precipitated into the soils.

130 samples were collected (1 per station) from a regular mesh of approximately 100 x 300m, covering an area of about $3.4km^2$, inside the urban perimeter of Alta Floresta municipality. The samples were collected on the surface (depth of $\leq$ 10cm), in compound form, where each station corresponded to 4 different points in an approximate area of $100m^2$ (10 x 10m).

The collection stations were set up on sites less subject to the alterations caused by civil works such as paving or grading of roads. The idea was to sample soils from vacant lots, back yards, and in areas reserved for pedestrians (sidewalks).

10 samples were also collected at strategic stations using a hand-operated shell auger at depth spacing of 10 to 30cm, to determine the potential of the mercury's vertical remobilization.

Around 30 gold buying shops were identified, chosen from the central region of the sampling mesh.

.Sampling of sediments

.*Baixões*

In the gold fields where gold-bearing ore (alluvial/colluvial) is prospected along small and medium-sized drainage waters or in paleochannels of larger drainage waters, using hydraulic tearing down and pulp dredging into concentrator troughs - known as *baixão* gold fields - sampling was done in the tailings *leques* (fans) and in the current sediments themselves.

Samples were collected in the tailings *leques* by radial distribution and depth levels, from the concentrator trough, where the material is discarded, up to a distance of approximately 50m and at depths never more than 1 meter. The trough tailings are the principal cause of silting up, since they are piled along the banks of the drainage waters without effort made to contain them.

In the drainage waters affected by gold mining, samples of current sediments and suspended sediments were collected both up and downstream of the mining fronts. The purpose of this was not only to determine gradients of mercury concentration, but also to determine the variation in the rates of suspended solids of the drainage waters.

Near the headwaters of streams it was sought to identify areas in which there was no anthropic action, where mercury concentrations in the sediments should reflect their background level.

Four areas were studied - Gleba do Triângulo, Pista do Cabeça (2) and Garimpo do Cearázinho - using sampling instruments such as: a hand-operated shell auger, a hoe (current sediments and tailings) and a QM filtering kit (suspended sediments $> 0.45\mu m$), using 47mm diameter Millipore filters.

.Teles Pires river and tributaries

The sampling campaign along the Teles Pires river and its tributaries was carried out on a continuous stretch of its middle course, which in recent years was intensely prospected by scraper dredges and dredges with divers. This stretch of the river also receives contributions from areas where *baixão* gold mining has taken place, through the tributaries: Peixoto de Azevedo, Nhandu, and the Rochedo, Carlinda, Triângulo, Dois Irmãos and Taxista, streams.

It was sought to sample current sediments (recent), sediments of flood plains (recent and not sorecent) and suspended sediments, in places chosen by interpreting satellite images and from information gathered from the local population, such as background details on the activity and location of old raft concentration points (*fofocas*).

The samples of current sediments were collected using a 0.5 liter capacity Petersen bottom-finder, covering cross sections of the river, composed ideally of three points - right bank, left bank and middle. In some cases, no collecting was done because the sediments were very compacted, or there were cobblestones and/or rocky substratum.

The samples of flood plain sediments were collected together with the cross section, in the form of vertical profiles, where each interval of depth represented not only a period of the settling cycle, but also a particular sedimentary facies (organic, clayey or sandy). The investigation in these environments reached a maximum depth of 30cm, while the more frequent sampling intervals were 0 to 1cm, 1 to 5cm and 5 to 10cm.

The sampling points of suspended sediments were located preferably at the same points where current sediments were collected. The water was filtered in situ using a QM filtering kit fitted with 47mm 0.45μm porosity Millipore filters and a hand-operated vacuum pump. An average of 0.5 liter of water volume was filtered at each point.

Estimating the average flow rates of the drainage waters was done using a General Oceanics winder current meter, a tapeline and satellite image. The latter was used to estimate the width of the Teles Pires river in the places investigated.

5.3.3 Methodology of preparation and analysis

.Preparation

The soil and sediment samples were chilled ($\sim 0^{o}$C) after collection to preserve their original characteristics, followed by wet screening (28, 65, 100 and 200#), so as to make a divided study of the mercury concentrations.

In the case of the soil samples, this method was only used for 10 samples, since it was expected that there would be a real accumulation of mercury in the fraction $< 200\#(< 74\mu m)$, since the presence of the metal would be in a form with more interactive power (atmospheric contribution). The other soil samples were dry screened using only 200#.

Before forwarding the samples for laboratory analysis, they were dried at ambient temperature ($\leq 40^{o}$C) in a place sheltered by plastic sheeting. They were dried a second time in an oven in this Center's laboratory at 50^{o}C.

The first analytical results received showed that in fact significant mercury concentrations in soil were found in the fraction smaller

than 74μm. Those results indicated also that, in the sediments, the fractions larger than 74μm, showed concentrations very similar to each other. This led the team to process the other samples by indiscriminately pulverizing the fractions that were larger than 74μm, using a porcelain grinder.

The screens used are made of a stainless steel hoop and mesh.

The water samples were collected in polyethylene bottles (1.5 liter) and acidified with HCl concentrate in the proportion of 2ml of acid for each liter of water.

The samples of suspended sediments were collected through vacuum filtering using a 0.45μm pore cellulose membrane.

.Analysis

In a portion of dry sample (2g) deionized water and nitromuriatic acid are added, heating it to 60^{o}C in a double boiler. After cooling, deionized water and 5% permanganate of potassium are added. Leave the sample in a double boiler at 60^{o}C. Neutralize the excess $KMnO_4$ with 12% hydroxylamine hydrochlorate, increase the volume and proceed with reading (Malm et alli, 1989).

Readings were carried out using a CG, model CG7000 MAX 8 atomic absorption device with hydride generation (cold vapor).

Part of the soil analyses and the water analyses were done by Geolab, a laboratory belonging to Geosol-Geologia e Sondagem Ltda. The water samples were filtered beforehand using a 0.45μm pore cellulose membrane.

The physical-chemical parameter were determined in loco using specific DIGIMED, models DMPH-PV and CD-2P pH, Eh and conductivity meters.

The percentage of fire loss (FL) of the sediment samples (fraction

<74μm) was determined through the loss of mass in a muffle furnace at 700°C for one hour, caused by the elimination of organic matter and of water molecules belonging to the structure of clay minerals and hydroxides.

The concentration of organic matter (OM) in sediments were found using the method described by Peech et alli (1947), which is based on oxidation of the organic matter by $K_2Cr_2O_7$ 1.0N and H_2SO_4 concentrate, followed by titration with 0.5N ferrous sulfate.

5.3.4 Presentation of Results

.Distribution of mercury in urban soils

The mercury concentrations found in the soils (fraction $< 74\mu$m) of the town of Alta Floresta, showed a clear predominance of abnormal values, caused by mercury emission via the atmosphere from the gold buying shops. The lowest content found was 0.05ppm and the highest was 4.10ppm. The average content was about 0.23ppm.

If we consider the average natural content of mercury found in soils, of 0.10ppm (Bowen, 1979; Wedepohl, 1968), it is noted that only 20% of the samples showed natural concentrations ($<$ 0.10ppm), of which 54% belong to the interval 0.10 to 0.20ppm, 15% were 0.20 to 0.30ppm and 11% had values higher than 0.30ppm.

The superficial contamination of the soils mostly occurs in the vicinities of the gold buying shops. This indicates that part of the vaporized mercury precipitates quickly. High anomalies ($>$ 1.0ppm) were noted at up to 600 meters distance from the sources, while lesser anomalies (between 0.10 and 0.20ppm) were found up to 1,000 meters away. These anomalies may be related to old sites of gold buying shops, which it is known moved towards the town center, or else, to atmospheric dispersion itself.

The chart showing curves of constant mercury contents included in this study, shows an interpolation of the values found, whereas its configuration was established from grouping the data into intervals of mercury concentration.

In order to understand the mechanisms responsible for the dispersion/precipitation of the metal, meteorological data were collected from the Alta Floresta station (CINDACTA I - Min. of Aeronautics) referring to the past 4 years (the station was installed in 1987).

It was noted that, as shown in Figure 11 and 12, in this period there are two prevailing wind directions, as much in the dry seasons as in the rainy seasons, namely: 20° and 115° in the dry seasons (from May to August) and 30° and 280° in the rainy seasons (from September to April).

Another detail noted from the constant contents curves is the dispersion of the mercury found in the soils in two preferential directions, the origin being the gold buying shops: east and southwest. These directions coincide with those recorded for winds in the rainy seasons, indicating that, as expected, the rains are principally responsible for the precipitation of atmospheric mercury. During the dry seasons, the mercury can travel long distances due to the increase of its residence time in the atmosphere.

According to information received from the municipal finance department, the town of Alta Floresta traded in the past 12 years about 1 ton of gold per month. According to an evaluation made by Farid et alli (1991), going by samplings in gold fields at Poconé-MT, the gold which reaches the buying shops contains an average of 5% mercury. Based on these figures, it can be estimated that approximately 7 tons of mercury were transported to the environment through final burning of gold sold in the town, since equipment (hoods) capable of recovering the vaporized mercury is not used.

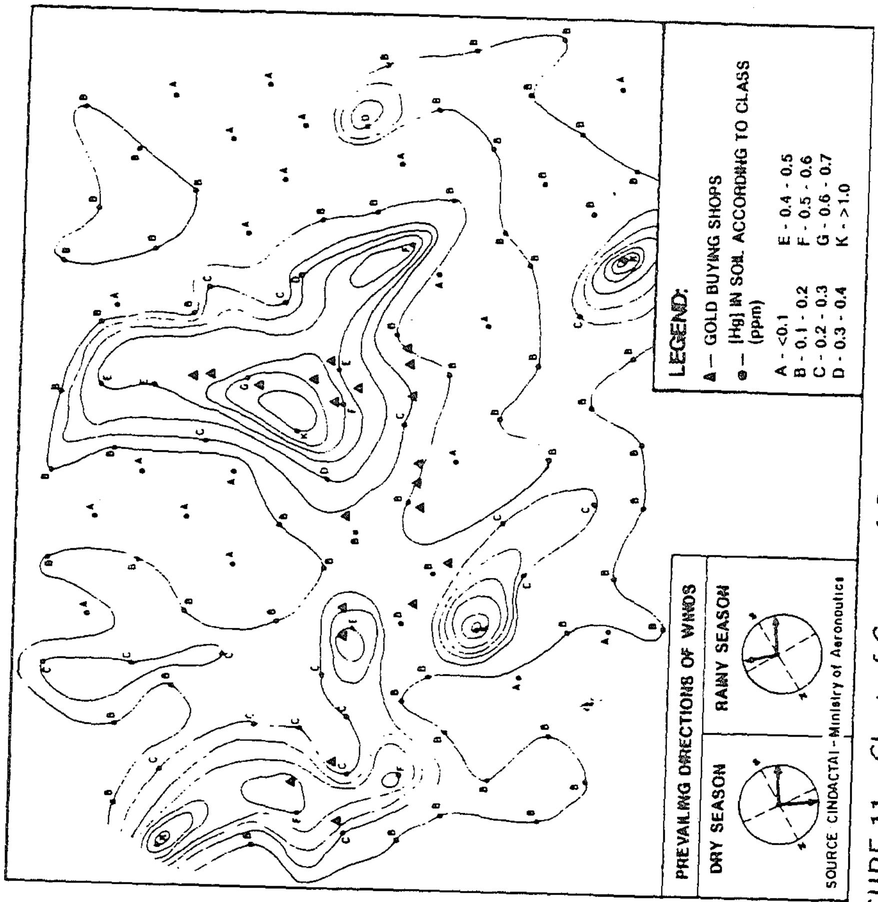


FIGURE 11 - Chart of Curves of Constant Contents of Hg in Urban Soils

LEGEND:

○ A-1, B-2...SOIL SAMPLING POINT (depth: 0 to 10cm)

● A-2, B-5...SOIL SAMPLING POINT (depth: 20 to 30cm)

△ S-1, S-2...LOCATION OF GOLD BUYING SHOPS

- S-1 - METAIS SOARES
- S-2 - MARSAM
- S-3 - METAL SANTOS
- S-4 - MARSAM
- S-5 - MARSAM
- S-6 - OURO STIPP, GOLDMINE E CARAJÁS METAIS
- S-7 - MIDAS OUROTEC
- S-8 - OURO MIL
- S-9 - AMARAL OURIVESSARIA E STYLOS METAIS
- S-10 - CARVALHO METAIS
- S-11 - CABEÇA METAIS
- S-12 - HÉLIO METAIS
- S-13 - SANTA MARIA METAIS
- S-14 - RANGEL METAIS
- S-15 - OURIVESSARIA
- S-16 - MIL METAIS, OUROMINAS, MN OURO E MARSAM
- S-17 - AURIUM
- S-18 - DÓLLAR, VALMAR
- S-19 - OUROCAR, RICCO METAIS
- S-20 - OUROZEZINHO
- S-21 - PURIMIL
- S-22 - REFINO DE OURO
- S-23 - CASA DO FRANCISCO ANDRÉ

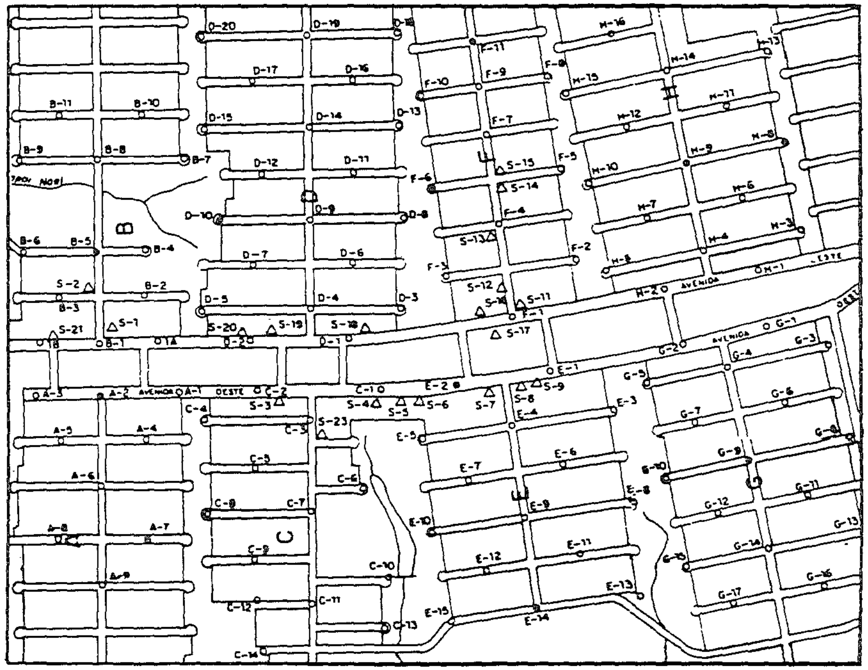


FIGURE 12 - Map of Locations of Soil Sampling Points

From the results found in soils, it may be estimated that 70 to 140kg of anthropogenic mercury are retained on the surface horizon of the sampled area, using the average content of 0.23ppm and deducting the concentration assumed as a background level of 0.10ppm.

The results found in 10 samples collected in a subsurface interval of 10 to 30cm, indicated low vertical remobilization of the mercury, because only two samples showed abnormal concentrations (0.22 and 0.52ppm). Those samples contained between 20 and 30% of silt-clay fraction (< 200#), while the others had between 50 and 70% of that fraction. This shows that the vertical distribution of the mercury concentrations in the soils directly depends on their permeability.

Based on these observations, it may be seen that only between 1 and 2% of the mercury transported to the atmosphere are associated with soils included in the sampling mesh, that is, 98 to 99% of the vaporized mercury reaches more distant areas. This is largely due to the fact that there is more gold mining in the dry season, when the mining fronts are not inundated by the free ground water and when the metal in vapor form, under low rainfall conditions, stays longer in the atmosphere. Allied to this is the surface flow of heavy rainfall into the drainage waters, which can transport the mercury in soluble form (ionic).

Jenne (1970) confirms that metallic mercury emitted to the atmosphere returns to the soil environment mainly when it rains, although dry precipitation can occur when the metal is associated with particles suspended in the atmosphere.

According to Sidgwick (1950), metallic atmospheric mercury can be oxidized through ultraviolet solar radiation, forming the ions Hg^{+2} and $Hg_2{}^{+2}$. The ion $Hg_2{}^{+2}$ under aqueous conditions would have a strong tendency to dissociation according to the reaction $Hg_2{}^{+2} \rightarrow Hg^o + Hg^{+2}$. Presumably, according to the author, then

the formation of mercury chloride ($HgCl_2$) would occur, a compound highly soluble in water, 69g/l at 25°C (in Jenne, 1970). The intensity of the oxidation reaction of the Hg^o in the atmosphere, which is difficult to estimate, can be indicated by the presence of mercury dissolved in waters.

The ionic mercury coming from the atmosphere therefore becomes widely available to methylation processes. Jernelov and Lann (1973), basing themselves on data collected in lake and estuary environments in Sweden, revealed that 90-99% of the mercury detected in aquatic organisms is in methylated form.

Bisogni and Lawrence (1975) established a model with the variables that are conditions of the kinetics of mercury methylation, showing that:

- microbian methylation of mercury can occur under aerobic and anaerobic conditions;
- methylation conditions depend on the growth rate or metabolic activity of bacteria and fungi, and on concentrations of mercuric ion (Hg^{+2});
- the predominant product of microbian methylation in a neutral pH is monomethylmercury, and
- higher methylation rates occur under aerobic conditions for a certain concentration of mercuric ion and for a referred rate of metabolic activity (in Forstner and Wittman, 1981).

.Description of sediments and rocks

Some examples of sediments and rocks that are representative of the region, making up a total of 17 samples, were submitted to mineralogic definition through optical microscopy and X-ray diffractometry, and chemical analysis, though optical emission spectrography. The purpose of those tests was to identify not only the basic minerology of the region's rocks, but also the various elements which might interact with the mercury in the various phases of its geochemical cycle, allowing better understanding of its dynamics in connection with gold mining activities.

The analyses of sediments made resulted in the identification of the predominant presence of kaolinite and quartz and in the confirmation of impregnations in the clay minerals of hydrated oxide of iron. This confirmation is of great importance since the clay minerals as much as the iron hydroxides can interact with mercury, adsorbing it physically and/or chemically.

Only in one of the sediment samples (TP-11.2) was the presence of clay minerals not detected. This sample, however, is rich in amphibole and is of the typical greenish coloring, commonly referred to by the gold miners as *lagrese* or *lagresia.*

The semiquantitative chemical analyses showed the presence of large amounts of Fe in all the samples, that is, 10% or more, except for two which contained 3% (BX-10A) and 7% (TP-22) respectively. As to Mn, also contained in all the samples, the contents were low and did not exceed 0.2%, with the exception of a sample with 2% (TP-11.2).

As far as the rocks are concerned, besides all the granite family - widely exposed in the area - and some localized sequences of phyllites/schists (Pista do Cabeça region) - easily recognized in the field, examples were identified of amphibolitic gnaisses, diabases and tourmalites. Except for the tourmalite, the remaining samples show an advanced stage of alteration.

The fact that sulphided minerals were not identified in the region, either in rocks or in sediments, means that the existence is unlikely of abnormal concentrations of the metal, caused by the remobilization of lithogenic mercury.

According to Mitra (1986), the metallogeny of mercury is associated with sulphided deposits of Cu-Pb-Zn, together with Ag, Sb,

Te, etc.

.Hydrochemical definition

The physical-chemical parameters, pH, Eh, conductivity and temperature of the various drainage waters studied were defined for the purpose of identifying the field of stability of the mercury. During May and June (beginning of low water mark), the waters have a slightly acid to neutral pH, varying from 5.40 to 7.33. It was noted that in drainage waters where *baixão* gold mining occurred, BX notation, the waters were more acid that in the Teles Pires river and its tributaries. This is due probably to the proportionally greater influence, in smaller drainage waters, of the horizon of the humic soil when releasing organic substances capable of reducing the pH values (humic acids).

The oxyreduction potential (Eh) of the run-off waters showed variations from 49 up to 330mV. The average value of 173mV, however, indicates a condition of neutrality in relation to oxidation of the mercury. The highest value found (330mV) was detected in water coming from the concentration trough of the gold field, showing that the turbulence in those places, or even in natural river rapids, is a factor causing the Eh to rise.

The stability diagram (pH-Eh) of the mercury shows that for the values found in the area, the stable form of the metal in a hydric medium is Hg^o (Figure 13).

It was also found that seasonal changes may significantly alter the physical-chemical parameters, when the drainage waters receive the impact of the gold fields.

During September this medium was considerably acidified at points TP-3, BX-14, BX-15 and BX-16 (Table 12). At the points where the influence of gold mining activity is negligible or non-

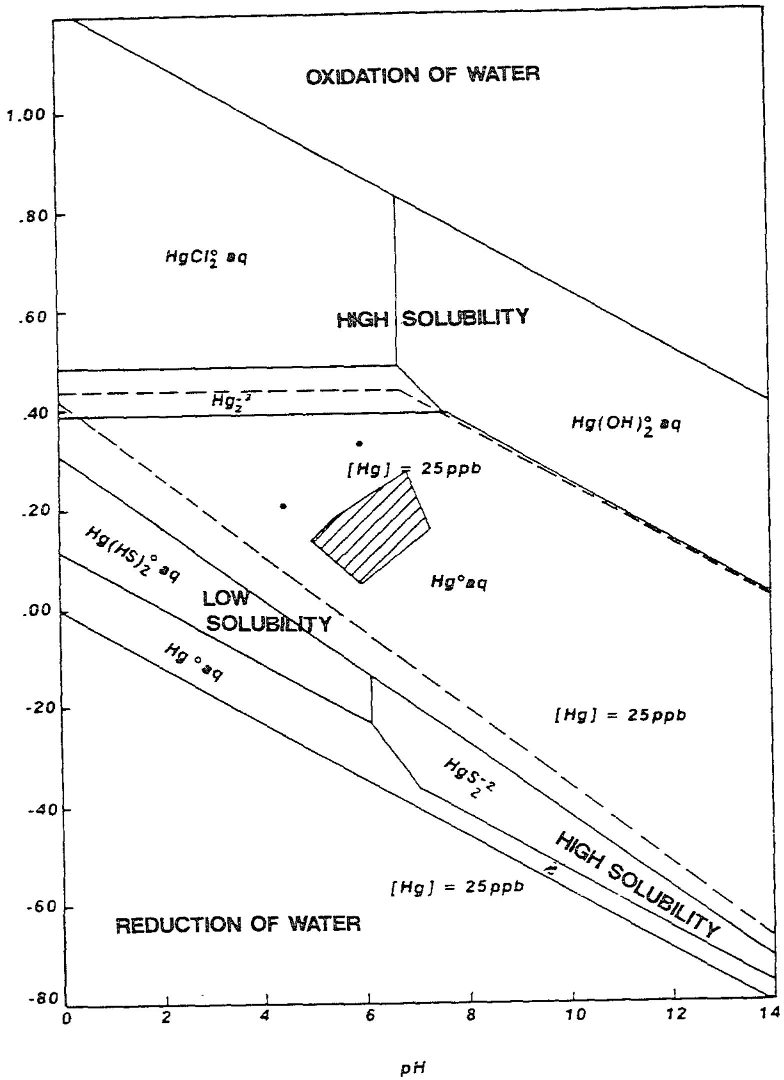


FIGURE 13 - Field of stability of mercury species at 25°C, 1atm. Includes 36ppm Cl, 96ppm S as sulphate. The shaded area indicates various investigations made in this work. Source: USGS 1970.

existent, it was noted that such conditions continue practically unchanged (Teles Pires river upstream, Cristalino river and Carlinda stream).

TABLE 12 - Definition of Physical-Chemical Parameters

PLACE-STATION	MAY/JUNE pH	MAY/JUNE Eh (mV)	MAY/JUNE COND. (μS/cm)	MAY/JUNE TEMP. (°C)	SEPTEMBER pH	SEPTEMBER Eh (mV)
Teles Pires river – TP-1	6.30	142	13.6	26	—	—
Teles Pires river – TP-1.4	6.48	165	18.7	25	—	—
Teles Pires river – TP-3	6.57	173	18.5	28	5.0	140
Teles Pires river – TP-2	6.90	245	19.2	26	—	—
Teles Pires river – TP-4.1	6.88	273	18.6	26	—	—
Teles Pires river – TP-4.2	6.46	231	15.6	26	—	—
Rochedo river – TP-6	6.50	175	180	24	—	—
Rochedo river – TP-8	6.71	199	15.9	27	—	—
Carlinda stream – TP-12	6.62	165	33	24	—	—
Carlinda stream – TP-18	7.33	159	17.7	27	—	—
Cristalino river – TP-28	6.50	137	22	25	6.60	168
Teles Pires river – TP-20	6.22	153	16	27	—	—
Peixoto de Azevedo river – TP-21	6.74	160	18	26	—	—
Nhandu river – TP-24	6.05	173	18	25	—	—
Teles Pires river – TP-27	—	—	—	—	6.60	210
Teles Pires river – TP-31	—	—	—	—	5.0	140
Taxista stream – BX-1	5.92	330	84	26	—	—
Paranaíta river – BX-5	5.70	139	25	26	—	—
Paranaíta river – BX-6	6.28	165	25	25	—	—
Paranaíta river – BX-7	5.95	49	46	27	—	—
Paranaíta river – BX-7A	5.79	155	35	29	—	—
Paranaíta river – BX-8	5.93	178	9.9	25	—	—
Triângulo stream – BX-10	6.04	182	29	25	—	—
Tributário Triângulo – BX-11	5.40	184	18	27	—	—
Triângulo stream – BX-12	5.40	184	18	24	—	—
Carlinda stream – BX-13	6.62	135	29	23	7.10	188
Triângulo stream – BX-14	6.51	101	24	25	5.98	199
Triângulo stream – BX-14A	5.75	177	15	24	—	—
Taxista stream – BX-15	6.49	179	21	26	4.40	218
Triângulo stream – BX-16	6.69	163	33	27	5.85	198
Dois Irmãos stream – BX-17	6.62	168	33	23	—	—

At the TP-3 station (Teles Pires river) it was noted that under extreme low water mark conditions, besides the drop in the pH, there was a substantial alteration in the water coloring, changing from reddish-yellow (May/June) to greenish-grey. This phenomenon can be explained according to the pH-Eh stability diagram of the iron (Drever, 1982). In this diagram we can see the stability of the Fe^{+3}, in the form of $Fe(OH)_3$ or Fe_2O_3, for pH and Eh conditions found in May/June. In September, however, these values indicated the stability of Fe^{+2}_{aq}., which would originate from the desorption of the iron from the suspended particles.

The low conductivity values found in the area, expressing a small concentration of dissolved salts, favor the solubilization of heavy metals. Forstner & Wittman (1981) report the inverse ratio between the values of salinity and of concentration of metals dissolved in water.

.Distribution of mercury in sediments

The transportation of mercury into the hydric medium can occur directly as a liquid effluent, or indirectly, through precipitation of the vaporized mercury during amalgam burning. The liquid metallic mercury, because of its high density (13.5), tends to concentrate in current sediments, while vaporized metallic mercury disperses in the atmosphere, where its precipitation depends on climatic conditions, that is, temperature, wind strength and rain.

Investigations were made into mercury concentrations, dividing up the aquatic environment into 3 microenvironments containing flood plain sediments, current sediments and water, respectively. In order to get a better definition of the distribution of mercury in the area studied, it was further subdivided into 8 subareas, of which 6 referred to areas near the places being prospected by scraper dredges (Teles Pires river and tributaries) and 2 corresponded to the places where the prospecting is done exclusively by *baixão* gold mining (streams, river bank holes and paleochannels). The location of the sampling points, arranged in cross sections of the river, is shown in Figure 14.

.Subarea I (Peixoto de Azevedo river)

This subarea comprises the area where the impact caused by silting up is most observed. The clear disfigurement of its banks

DIVISION BY SUBAREAS

I	II	III	IV	V	VI
TP-21 1	TP-20 1	TP-8	TP-24	TP-13A	TP-1 4
TP-21 2	TP-20 2	TP-8 4A	TP-24 1	TP-13B	TP-2
TP-22	TP-20.3	TP-8 4B	(Rio Nhandu)	TP-18 2	TP-3 1
TP-22 1	TP-25	TP-9 1	TP-6	TP-18 3	TP-3 2
TP-23 A	TP-25 2	TP-15 1	TP-6 1	(Rio Teles Pires)	TP-3 3
TP-23 B_1	TP-25.3	TP-15 2	TP-7		TP-3 4A
TP-23 B_2	TP-25 4A	TP-16	(Rio Rochedo)		TP-3 4B
TP-23 C	TP-25 4B	TP-17	TP-12A		TP-3 5A
(Rio Peixoto de Azevedo)	TP-25 5	TP-17 1	TP-12B		TP-3 5B
	TP-25 6A	(Rio Teles Pires)	(Corr Corlindo)		TP-4 2
	TP-25 6B		TP-28		TP-4 3
	TP-25.6C		TP-29		TP-31
	TP-26 1A		TP-30		TP-32
	TP-26 1B		(Rio Cristalino)		(Rio Teles Pires)
	TP-26 2				
	TP-27				
	(Rio Teles Pires)				

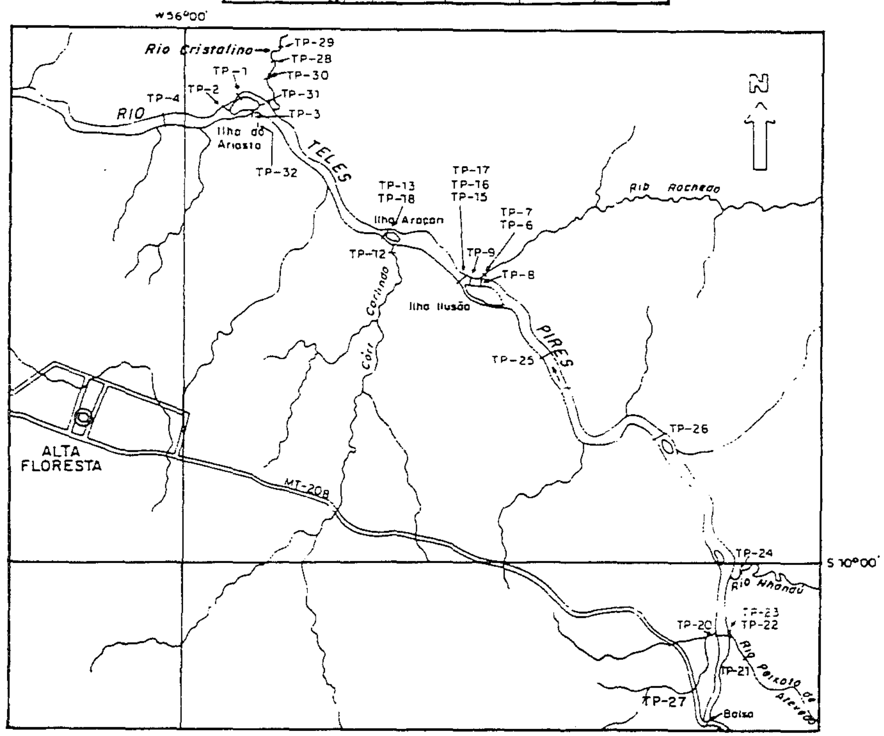


FIGURE 14 - Map of Locations of Sampling Points - Teles Pires River and Tributaries

and bed, caused as much by the action of the scraper dredges as by the use of the hydraulic tearing down method, is borne out by the rate of suspended solids in its waters, which is about 30 times higher than the rate found in the Teles Pires river - TP-27 - upstream of the areas affected by the gold mining (Table 13). The solid flow of suspended matter of the Peixoto de Azevedo river, which can be evaluated according to the data on flow and on concentration of suspended solids, is approximately 255ton/h. The water is the typical reddish-yellow of drainage waters that run through laterite soils, where there are plenty of oxides and iron hydroxide.

It was also noted that the mercury concentrations or the total samples showed anomalous values, with rates 1.5 to 20 times higher than the value found in one of the samples (0.27ppm), which must represent a content which approaches the background level of that subarea (Table 13).

The locations of the sampling points, according to their positions in each cross section, are shown in Figure 15.

Figure 15 shows the chart of mercury contents found in current and flood plain sediments, correlating the concentrations found in the +200# and -200# fractions. It can be seen that all the sediments samples have very high values in the +200# fraction, which can be converted into a linear function whose angular coefficient is greater than 1. This indicates that the metal is found principally in metallic form, and is only slightly prone to interactive processes with sediment particles.

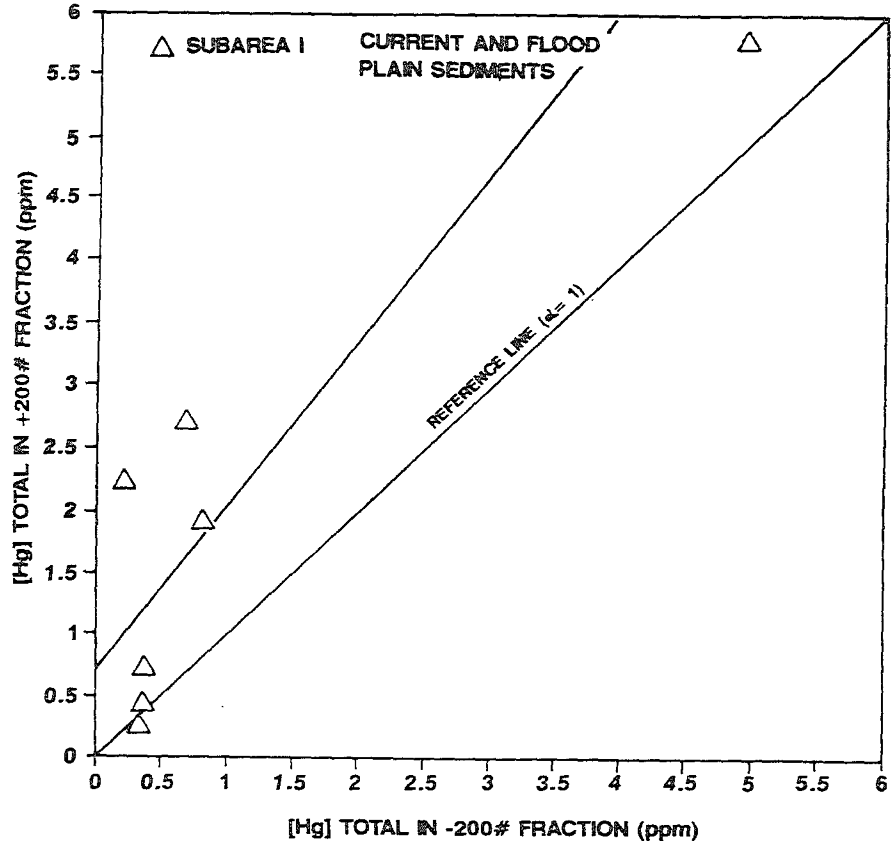


FIGURE 15 - Correlation between [Hg] in the +200#and -200#fractions

TABLE 13 - Subarea I - Peixoto de Azevedo river

STATION	TSS[a] (mg/l)	FLOW (m^3/s)
TP-21.1*	125	~ 570
TP-21.2	125	~ 570
TP-22**	—	—
TP-22.1	125	~ 570
TP-23.A	125	~ 570
TP-23.B1	125	~ 570
TP-23.B2	125	~ 570
TP-23.C	125	~ 570

STATION	-200# Fraction				+200# Fraction	TOTAL
	% Weight	[Hg] (ppm)	%[b] O.M.	%(c) F.L.	[Hg] (ppm)	[Hg] (ppm)
TP-21.1*	4	11.5	—	—	0.22	0.67
TP-21.2	22	0.32	—	—	0.25	0.27
TP-22**	66	4.92	2.9	7.5	5.77	5.24
TP-22.1	72	0.38	4.2	7.8	0.43	0.39
TP-23.A	35	0.36	4.2	5.4	0.71	0.59
TP-23.B1	62	0.21	0.6	6.0	2.24	0.98
TP-23.B2	45	0.66	1.1	6.1	2.70	1.78
TP-23.C	0	0.80	—	—	1.92	1.70

* trough tailings; ** flood plain sediments.

(a) total suspended solids; (b) organic matter; (c) fire loss.

.Subarea II - (Teles Pires river)

Subarea II contains 4 sediment collection stations upstream of the tributary of the Peixoto de Azevedo river, while the other stations are located downstream (see Figure 4).

In the upstream stretch, station TP-20, the color of the Teles Pires river is greenish, suggesting a low concentration of suspended inorganic sediments. Even so, the concentration of suspended solids, of 33mg/l, indicates a condition similar to that of subarea VI, where the water is reddish-yellow. Therefore, the difference in color must be related to the absence of iron hydroxides in the suspended particled matter, of that stretch of subarea II, which receives contributions from small streams where *baixão* gold mining takes place. In those streams the marked presence was noted of a kaolinite matrix, giving the water a milky color.

At the TP-27 station no gold mining is going on in the river, which is confirmed by the low concentration of suspended solids (4.0mg/l).

In the downstream stretch, the Teles Pires river transports 54mg/l, where the increase of suspended solids is due to the influence of the Peixoto de Azevedo river.

Figure 16 shows a chart of mercury concentrations in the sediments, comparing the +200#and -200#fractions. Two distinct distribution patterns are noted in these samples. One, formed by a straight line whose angular coefficient (α) is more than 1, indicating preferential accumulation in the fraction +200# of Hg^o. The other, represented by the straightline $\alpha<1$, may mean a greater availability of mercury for adsorption to occur in the high specific surface particles, or else the simple retention as micropulverized Hg^o. Therefore, mercury preferentially associated with the -200#fraction could have either undergone remobilization (allochthonous) in the form of soluble or particled Hg^{+2}, or be deposited in the form of microdroplets derived from the amalgamation tailings of the rafts.

Also in that subarea anomalous concentrations of mercury were found in all the total samples, with values 1.3 to 9.5 times higher than the minimum content of 0.21ppm. The maximum concentration noted was 2.04ppm (Table 14).

The Teles Pires river at the station upstream of the areas affected - TP-27 - showed a low mercury concentration in the water, $<$ 0.2ppb. This rate is lower than those found in the water of the Madeira river, of up to 0.46ppb (Lacerda et alli, 1987).

TABLE 14 - Subarea II - Teles Pires river

STATION	TSS[a] (mg/l)	FLOW (m^3/s)
TP-20.1	33	~ 1270
TP-20.2	33	~ 1270
TP-20.3	33	~ 1270
TP-25	54	~ 1900
TP-25.2*	—	—
TP-25.3	54	~ 1900
TP-25.4A	54	~ 1900
TP-25.4B	54	~ 1900
TP-25.5	54	~ 1900
TP-25.6A*	—	—
TP-25.6B*	—	—
TP-25.6C*	—	—
TP-26.1A	—	—
TP-26.1B	—	—
TP-26A	—	—
TP-27	4	~ 1200

STATION	-200# Fraction				+ 200# Fraction	TOTAL
	% Weight	[Hg] (ppm)	%[b] O.M.	%[c] F.L.	[Hg] (ppm)	[Hg] (ppm)
TP-20.1	0	—	—	—	1.88	1.88
TP-20.2	0	—	—	—	2.04	2.04
TP-20.3	35	0.90	—	—	1.55	1.33
TP-25	70	0.55	—	—	0.80	0.63
TP-25.2*	73	1.52	12	19.9	1.26	1.43
TP-25.3	20	4.01	—	—	0.62	1.30
TP-25.4A	2	1.24	—	—	0.32	0.34
TP-25.4B	5	0.97	—	—	0.25	0.29
TP-25.5	47	1.17	2.6	8.2	0.49	0.81
TP-25.6A*	93	1.61	2.3	9.7	1.14	1.58
TP-25.6B*	79	1.01	4.9	11.4	1.88	1.20
TP-25.6C*	32	0.26	—	—	0.23	0.24
TP-26.1A	56	0.49	4.1	9.2	0.63	0.55
TP-26.1B	5	1.24	—	—	0.16	0.21
TP-26A	0	—	—	—	0.10	0.10
TP-27	2	0.41	—	—	0.15	0.16

* flood plain sediments.

(a) total suspended solids; (b) organic matter; (c) fire loss.

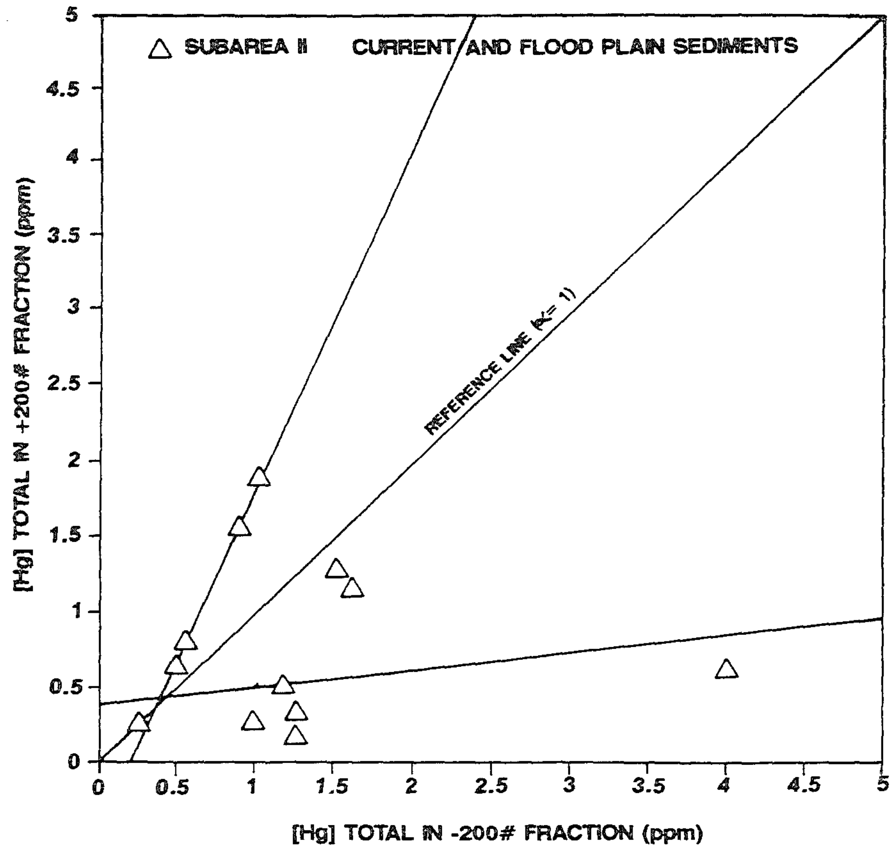


FIGURE 16 - Correlation between [Hg] in the +200#and -200#fractions

In subarea III there was a substantial reduction of the concentration of suspended solids (38mg/l), indicating that a large part of the solid load coming from the Peixoto de Azevedo river was deposited in the stretch immediately upstream, contributing toward its silting up.

Similar to subarea II, the mercury concentrations in the sediments show two patterns of granulometric distribution. The samples with larger contents in the -200#fraction are found principally in the raft tailings banks, which even form small islands due to the accumulation of reworked gravel. In these places one would expect an accumulating of the polluting metal in the +200# fraction, due to the closeness of the emitting source. However, the high permeability of these materials can increase the percolation of the mercury between the grains, allowing it to be retained by fine sediments (Table 15).

TABLE 15 - Subarea III - Teles Pires river

STATION	TSS[a] (mg/l)	FLOW (m^3/s)
TP-8	38	~ 2000
TP-8.4A*	—	—
TP-8.4B*	—	—
TP-9.1**	—	—
TP-15.1	—	—
TP-15.2	—	—
TP-16	—	—
TP-17**	—	—
TP-17.1**	—	—

STATION	-200# Fraction				+200# Fraction	TOTAL
	% Weight	[Hg] (ppm)	%[b] O.M.	%[c] F.L.	[Hg] (ppm)	[Hg] (ppm)
TP-8	32	0.84	—	—	0.57	0.66
TP-8.4A*	29	0.74	3.8	9.8	1.02	0.94
TP-8.4B*	9	19	—	—	1.85	3.39
TP-9.1**	2	12.4	—	—	0.37	0.61
TP-15.1	0	—	—	—	3.11	3.11
TP-15.2	0	—	—	—	2.30	2.30
TP-16	0	—	—	—	2.71	2.71
TP-17**	0.5	6.35	—	—	0.43	0.46
TP-17.1**	0	—	—	—	0.19	0.19

* flood plain sediments ** raft tailings.

(a) total suspended solids; (b) organic matter; (c) fire loss.

The mercury concentrations in the total samples varied from 0.19 to 3.39ppm, with an average of 2.00ppm. The highest value

corresponds to a sediment lying under (5 to 10cm) the clay level of a flood plain, formed by well selected sand with intercalations of levels rich in organic matter. The fine (organic) fraction showed 19ppm of mercury, indicating that these substances retained the polluting metal more efficiently.

Similar to subareas II and III, in subarea V anomalous concentrations of mercury were found in the total samples of sediments, varying from 0.32 to 1.00ppm, with an average of 0.73ppm (Table 16). It was also noted that the metal was associated as much with the +200#fraction, in some cases, as with the -200#fraction, in others (Figure 17).

TABLE 16 - Subarea V - Teles Pires river

STATION	TSS[a] (mg/l)	FLOW (m^3/s)
TP-13A*	—	—
TP-13B*	—	—
TP-18.2	52	~ 2140
TP-18.3	52	~ 2140

STATION	-200# Fraction				+200# Fraction	TOTAL
	% Weight	[Hg] (ppm)	%[b] O.M.	%[c] F.L.	[Hg] (ppm)	[Hg] (ppm)
TP-13A*	47	0.52	—	—	0.88	0.71
TP-13B*	52	1.07	8.6	16.8	0.69	0.89
TP-18.2	44	0.32	—	—	0.33	0.32
TP-18.3	71	1.06	3.6	11.2	0.85	1.00

* flood plain sediments

(a) total suspended solids; (b) organic matter; (c) fire loss.

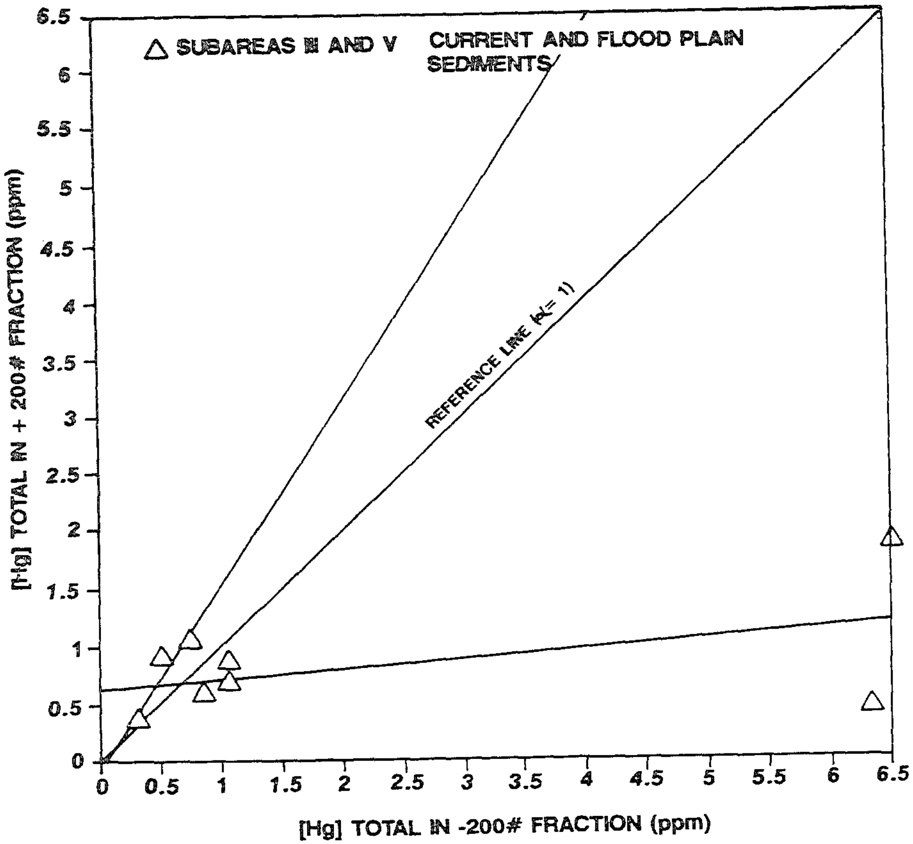


FIGURE 17 - Correlation between [Hg] in the +200#and -200#fractions

In subarea V a new increase was detected in the concentration of suspended solids, from 38mg/l (subarea III) to 52mg/l. This increase occurred exactly at a far off site about 8km downstream of the area where there had been a *fofoca* of 11 scraper dredges, showing that a solid suspended load, remobilized during the dredging work, can cover long distances.

From the values of concentration of suspended solids and of flow, a suspended solids flow (SSF) was found in the various places sam-

pled of the Teles Pires river. A longitudinal profile (downstream direction) shows a variation of the SSF rates (Figure 18).

Regarding the area which was presumably not affected by the gold mining (TP-27), an enormous rise in the SSF value was noted, from 18ton/h to 150ton/h and reaching 400ton/h after the confluence of the Peixoto de Azevedo river. The increase of up to 22 times in the SSF value reflects the accelerated process of physical degradation caused by silting up of the drainage waters exposed to alluvial gold mining.

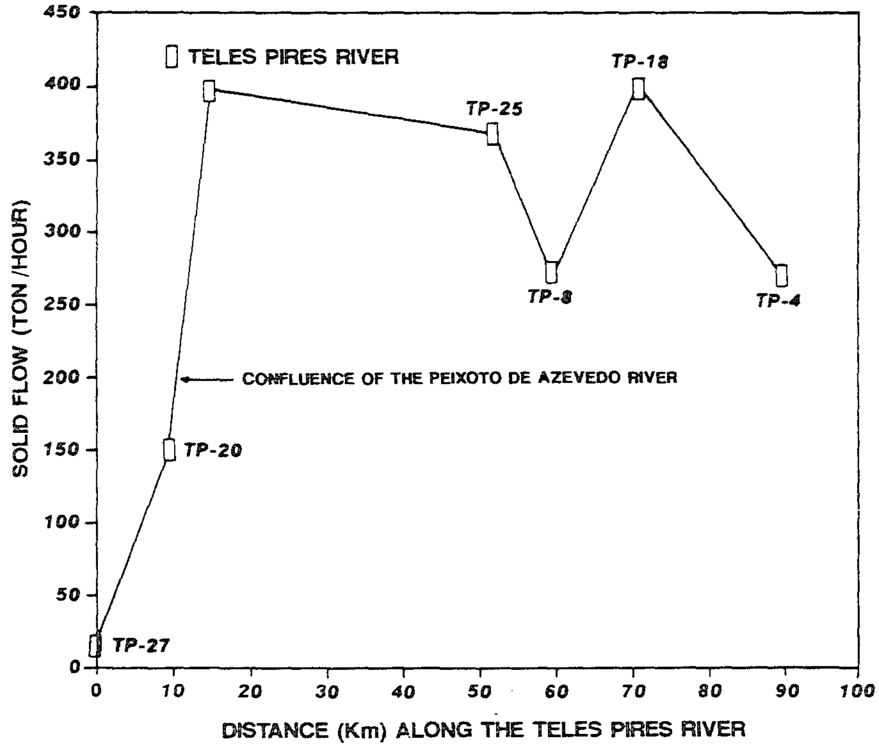


FIGURE 18 - Longitudinal variation of the rates of suspended solids flow

. Subarea IV - (Nhandu river, ribeirão Rochedo, Carlinda streams and Cristalino river)

These tributaries receive contributions from the *baixão* gold fields located in their sub-basins, with the exception of the Cristalino river. The Nhandu river, apparently, is the most affected drainage of this subarea, showing the highest values, as much for concentration of suspended solids as for concentration of Hg in sediments.

Considering the long distance that separates the sampling points in these drainage waters (near the confluence with the Teles Pires)

TABLE 17 - Subarea IV - Nhandu river, Rochedo and Carlinda streams, and Cristalino river.

STATION	TSS[a] (mg/l)	FLOW (m^3/s)
TP-24 (Nhandu)	27	~ 120
TP-24.1* (Nhandu)	—	—
TP-6 (Rochedo)	20	~ 90
TP-6.1 (Rochedo)	20	~ 90
TP-7 (Rochedo)	20	~ 90
TP-12A (Carl.)	15	~ 80
TP-12B (Carl.)	15	~ 80
TP-28 (Crist.)	8	~ 190
TP-28A (Crist.)	8	~ 190
TP-29 (Crist.)	8	~ 190
TP-30A (Crist.)	8	~ 190
TP-30B (Crist.)	8	~ 190

STATION	-200# Fraction				+200# Fraction	TOTAL
	% Weight	[Hg] (ppm)	%[b] O.M.	%[c] F.L.	[Hg] (ppm)	[Hg] (ppm)
TP-24 (Nhandu)	44	0.41	0.0	5.6	0.19	0.28
TP-24.1* (Nhandu)	87	3.02	3.6	7.9	3.75	3.11
TP-6 (Rochedo)	54	0.74	3.1	7.5	0.41	0.59
TP-6.1 (Rochedo)	7	0.49	—	—	0.27	0.29
TP-7 (Rochedo)	29	1.00	—	—	0.21	0.44
TP-12A (Carl.)	0	—	—	—	0.78	0.78
TP-12B (Carl.)	7	1.07	—	—	0.44	0.48
TP-28 (Crist.)	0	—	—	—	0.05	0.05
TP-28A (Crist.)	0	—	—	—	0.07	0.07
TP-29 (Crist.)	7	0.08	—	—	0.08	0.08
TP-30A (Crist.)	0	—	—	—	0.05	0.05
TP-30B (Crist.)	5	0.24	—	—	0.11	0.12

* flood plain sediments

(a) total suspended solids; (b) organic matter; (c) fire loss.

river) from the places where *baixão* gold mining has occurred, and also, the low flow energy which is a characteristic of these tributaries, it may be reckoned that it will be hard for the metallic mercury emitted in the gold fields to reach the sampling points transported by flushing.

Another feature noted in these drainage waters is the preferential retention of the mercury in the -200#fraction, showing its availability for adsorption to occur and, consequently, transportation through the fine particulate matter. This makes it possible to maintain that part of the heavy metal present in these drainages is in a form capable of transportation, via suspended sediments, to the Teles Pires river (Figure 19).

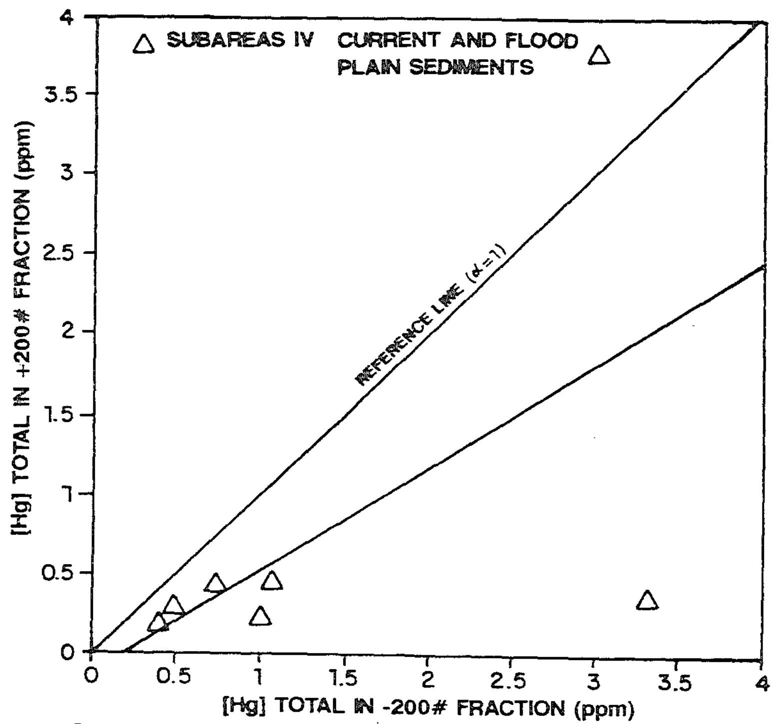


FIGURE 19 - Correlation between [Hg] in the +200#and -200#fractions

Concentrations of Hg in these sediments vary from 0.28 to 3.11ppm, the average being 0.85ppm.

The Cristalino river, which is free of gold mining activity, showed low concentrations of mercury in the sediments and in the water. In the sediments the total concentrations had an average of 0.07ppm, indicating a background value of mercury close to that found in the unaffected drainage waters of the region of Poconé-MT, of 0.04 to 0.06ppm (Lacerda et alli, 1991c).

The mercury concentration found in the water of the Cristalino river, <0.2ppb, despite the greater detection limit of the method used, is compatible with values attributed to the uncontaminated Amazon rivers, <0.04ppb (Pfeiffer et alli, 1991).

. Subarea VI - Teles Pires river

On this stretch of the Teles Pires river, very far downstream of the area studied, were very active, scraper dredges, according to the local population. Confirming this information, almost all the samples of sediments analyzed showed clearly greater concentrations of mercury in the -200#fraction. In Figure 20 the line of angular coefficient less than one expresses the strong association of the mercury with the silt-clay fraction, showing its more interactive form and, therefore, subject to transportation by adsorption to fine sediments.

Hence, it may be assumed that the mercury found in this subarea has an essentially allochthonous nature, that is, it originated from adjacent or more distant areas.

The origin of this polluting metal, which has greater interactive power, must be related principally to the atmospheric emission caused in the gold fields themselves by amalgam burning, since the vaporized mercury can return to the drainage basin in soluble form (Hg^{+2}). The Hg^{o} emitted directly to the drainage waters finds physical-chemical conditions which favor its stability, showing that

it does not play a major part in the solid-liquid interaction processes.

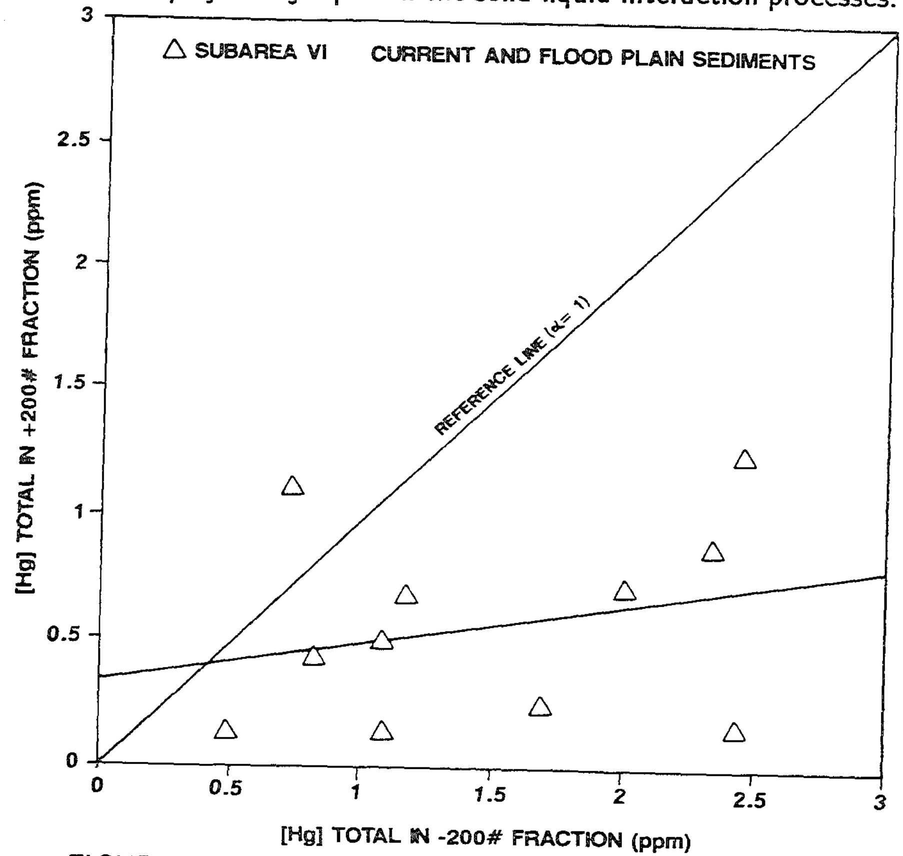


FIGURE 20 - Correlation between [Hg] in the +200# and -200#fractions

Lacerda and Salomons (1991b) also attribute the low mobility of the metallic mercury to the occurrence of the metal associated with different grain sizes of sediments in the drainage affected by gold fields in Cumaru, Pará.

Also, in this subarea, the concentration of mercury detected in the water, sample TP-31, was below the detection limit of the analytical method used, that is, <0.2ppb.

TABLE 18 - Subarea VI - Teles Pires river

STATION	TSS[a] (mg/l)	FLOW (m^3/s)
TP-1.4	28	~ 2300
TP-2	29	~ 2300
TP-3.1	33	—
TP-3.2	33	—
TP-3.3	33	—
TP-3.4A*	—	—
TP-3.4B*	—	—
TP-3.5A*	—	—
TP-3.5B*	—	—
TP-4.2	33	~ 2300
TP-4.3	33	~ 2300
TP-32	—	—
TP-32A	—	—
TP-32B	—	—

STATION	-200# Fraction				+200# Fraction	TOTAL
	%Weight	[Hg] (ppm)	%[b] O.M.	%[c] F.L.	[Hg] (ppm)	[Hg] (ppm)
TP-1.4	73	0.72	2.8	9.5	1.10	0.82
TP-2	53	1.17	—	—	0.68	0.94
TP-3.1	12	1.09	—	—	0.13	0.25
TP-3.2	79	2.45	3.2	11.5	1.24	2.20
TP-3.3	33	1.08	4.4	10.3	0.49	0.70
TP-3.4A*	47	2.33	2.5	8.0	0.87	1.57
TP-3.4B*	30	0.49	2.1	7.5	0.13	0.24
TP-3.5A*	41	1.99	3.7	10.1	0.71	1.24
TP-3.5B*	0.8	2.43	—	—	0.16	0.18
TP-4.2	19	1.69	—	—	0.25	0.52
TP-4.3	61	0.82	2.5	8.1	0.42	0.68
TP-32	—	0.64	—	—	< 0.05	0.28
TP-32A	—	0.08	—	—	0.05	0.06
TP-32B	—	0.13	—	—	0.08	0.09

* flood plain sediments

(a) total suspended solids; (b) organic matter; (c) fire loss.

It was also possible to find a direct correlation between the mercury concentrations of the -200#fraction and the percentage of fire loss (FL) in the samples of sediments which have mercury enrichment in the silt-clay fraction. While the FL test reflects the concentrations of organic matter, clay minerals and hydroxides, it may be deduced that the polluting metal has been adsorbed to that group of substances (see Figure 21).

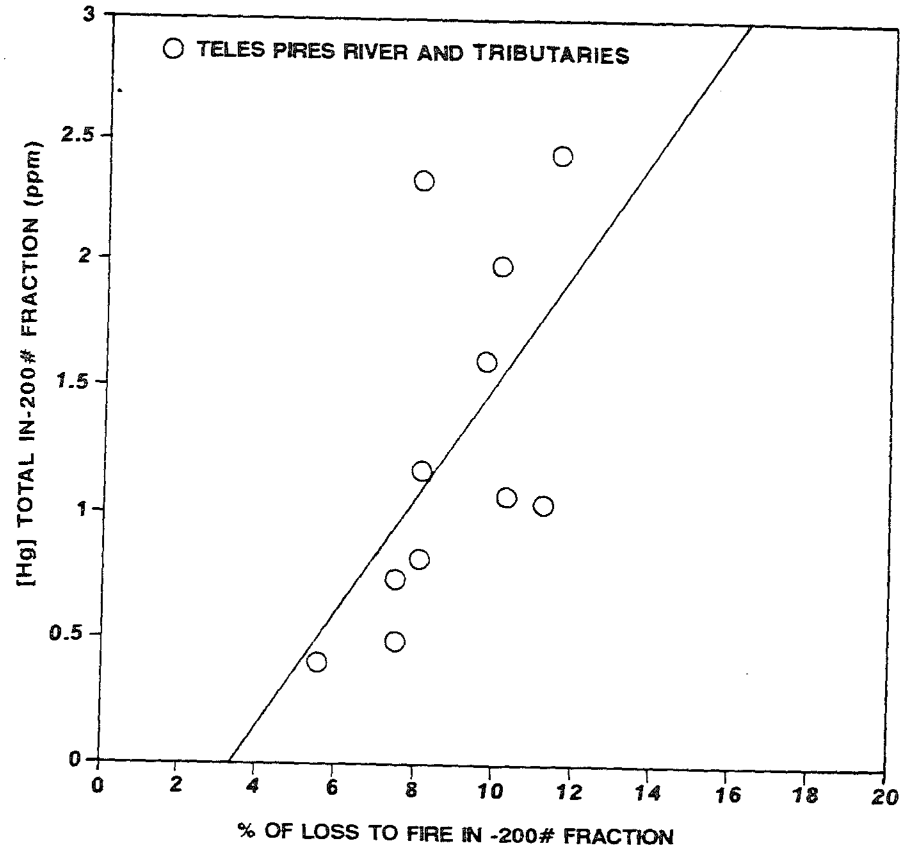


FIGURE 21 - Correlation between [Hg] in the -200#fraction and percentage of loss to fire.

For the purpose of specifying the level of participation of each substance in the adsorption phenomenon, an analysis was made of the organic matter content in the same samples, belonging to subareas IV and VI, where there had been mercury enrichment in the silt-clay fraction. Figure 22 shows results which also evidence a direct correlation between the mercury concentrations in the -200#fraction and the percentage of organic matter.

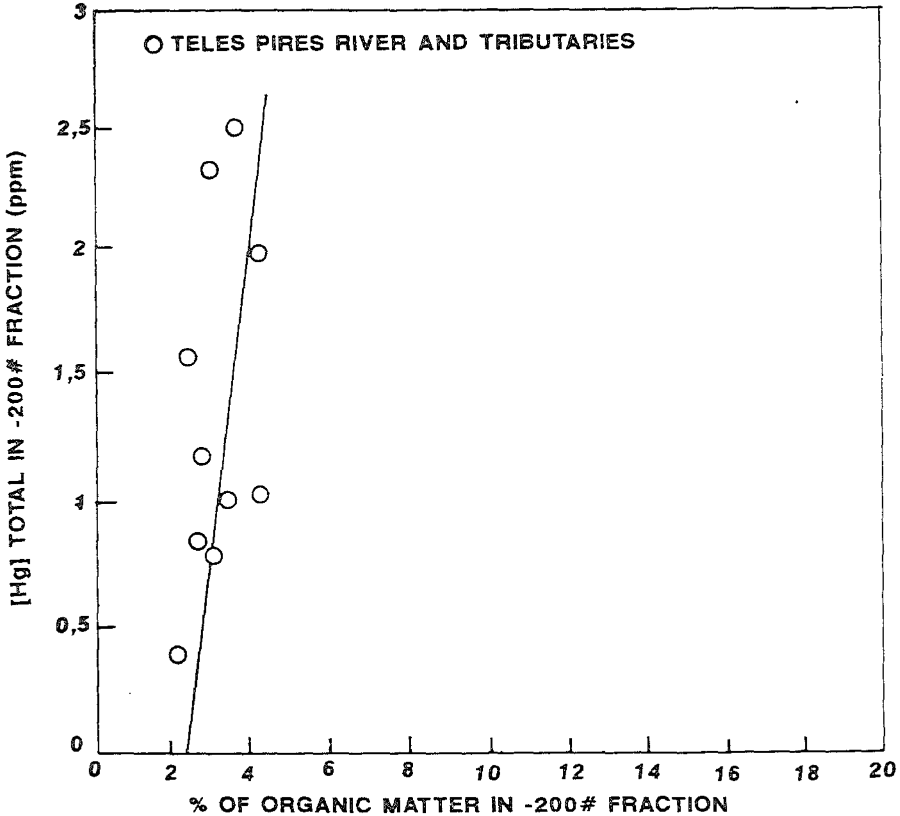


FIGURE 22 - Correlation between [Hg] in the -200#fraction and percentage of organic matter.

It is therefore clear that the organic matter plays an important part in the responsibility for transporting mercury in a hydric medium.

By subtracting from the fire loss (FL) percentage, the percentage of organic matter, the concentration of clay minerals and hydroxide in the sediments analyzed (-200#fraction) can be found. Figure 23 shows the same direct correlation between the mercury concentrations in the silty-clay fraction and the percentage of clay minerals and hydroxides, indicating that the adsorption and transportation of

mercury also occur associated with the surface of these secondary minerals.

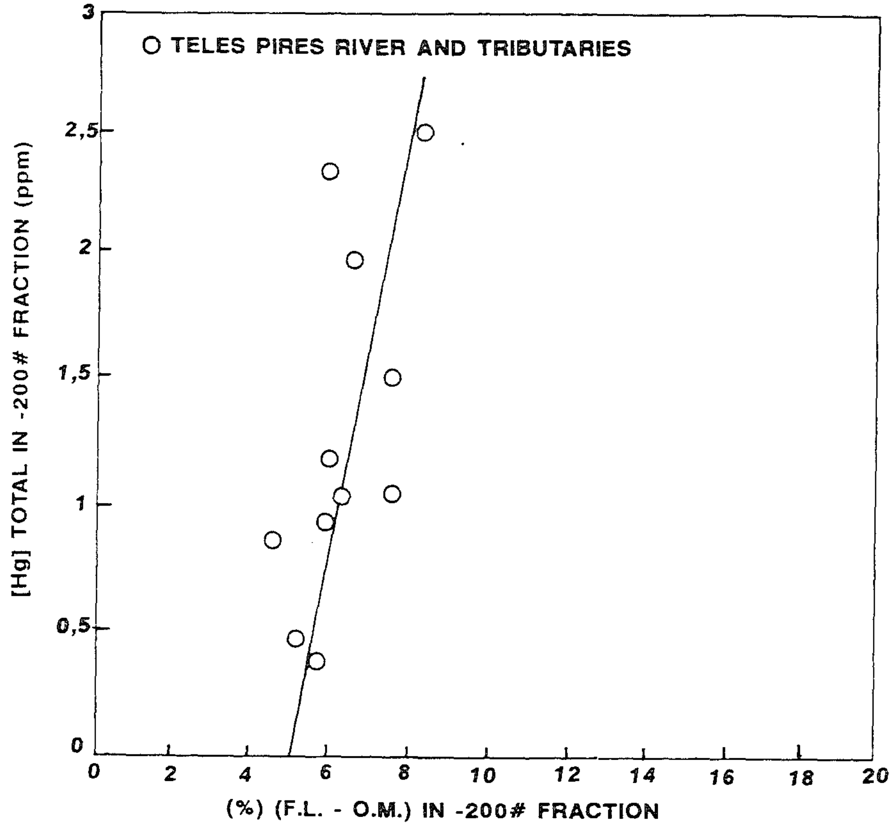


FIGURE 23 - Correlation between [Hg] in the -200#fraction and percentage of (F.L. - O.M.).

In spite of the evidence provided, confirmation of these hypotheses calls for a selective approach regarding the mercury carrying geochemical phases, specifying the Hg concentrations associated with each phase (exchangeable, oxidizable, reducible and residual). These studies should be contemplated during the course of this research, since they may offer important data in an evaluation of the actual availability of the mercury for biological incorporation.

.Subarea VII (Gleba do Triângulo)

This subarea, which lies approximately 60km southeast of the municipal headquarters, contains minor perennial drainage waters such as the Taxista, Triângulo and Dois Irmãos streams, etc. - all of which are tributaries of the Teles Pires river. The main gold fields of this subarea are in these streams, where sampling was done at various points, as shown in Figure 24. At all the points sampled, anomalous mercury contents were found. The total concentration levels varied from 0.25 to 4.05ppm (average 0.76ppm), which shows that they are way above the generic background value for sediments (0.19ppm a-ccording to Bowen, 1979; Wedepohl, 1968). This background value seems to be compatible with the minimum concentrations found.

The value of 4.05ppm, which is 5 times higher than average and 20 times the background level, can be explained because of the direct use of mercury in the trough coupled to the grinder. This is used in exceptional cases when there is the presence of hard agglomerates, at times, quartz veins, enriched with gold. However, even though it is used in exceptional cases, there is nothing to prevent the highly contaminated tailings produced, from which this sample was taken, entering into contact with the others, allowing flushing and dispersal of the mercury. This is the consequence of the lack of any concern about containing it. Incidentally, this is the way all the tailings are treated.

As to the way mercury is handled in these places, there is certainly waste, as much in the panning and amalgam operations - an empirical process - as in the burning in open circuits, which con-

DIVISION INTO SUBAREAS			
GLEBA DO TRIÂNGULO		PISTA DO CABEÇA	
BX-1	BX-13	BX-3.1	BX-7.1A
BX-2	BX-14	BX-3.1A	BX-7.1B
BX-9.1B	BX-14A	BX-3.2A	BX-7.2A
BX-9.2A	BX-15	BX-3.2B	BX-7.2B
BX-9.2B	BX-16	BX-3.3A	BX-8
BX-9.3A	BX-16A	BX-3.3B	
BX-9.3B	BX-17A	BX-3.3C	
BX-9.4	BX-17B	BX-4	
BX-10		BX-5	
BX-10A		BX-6	
BX-10B			
BX-11			
BX-12			

W56°00'

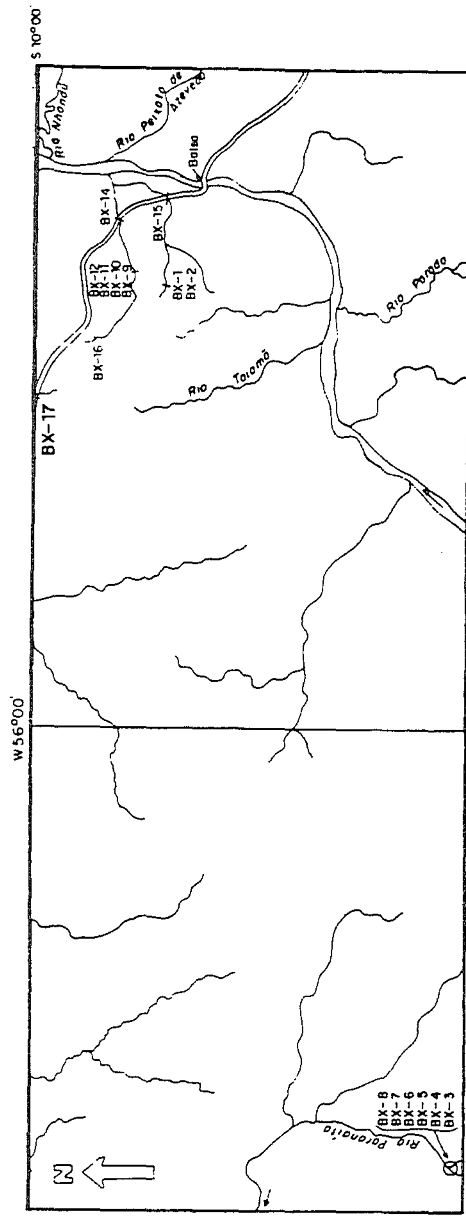


FIGURE 24 - Map of Locations of Sampling Points - *Baixão* Gold Fields

tributes a great deal to the proliferation of contaminated points. Accordingly, it was sought to determine the availability of the mercury, as much in the current sediments as in the trough tailings sediments.

The results of the chemical analyses are in Table 19.

TABLE 19 - Subarea VII - Gleba do Triângulo.

STATION	TSS (mg/l)	Weight Total	Flow m^3/s	Concentration Hg(ppm) > 200#	< 200#	Total	% (O.M.)	% (F.L.)
Trough tailings								
BX-1	–	33.3	–	0.70	0.50	0.63	–	–
BX-2	–	42.2	–	4.05	—	4.05	–	–
BX-9.1B	–	22.0	–	0.28	0.48	0.38	–	–
BX-9.2A	–	36.6	–	0.31	0.15	0.25	–	–
BX-9.2B	–	35.1	–	0.45	0.28	0.42	–	–
BX-9.3A	–	59.3	–	0.53	0.13	0.30	–	–
BX-9.3B	–	22.7	–	0.44	0.20	0.39	–	–
BX-9.4	–	83.8	–	0.62	0.20	0.27	–	–
Current sediments								
BX-10A	–	92.9	–	1.38	0.32	0.39	–	–
BX-10B	–	46.1	–	0.57	0.23	0.41	3.7	9.9
BX-14	–	36.7	–	0.93	0.35	0.72	–	–
BX-15	–	35.6	–	0.62	0.48	0.56	6.3	13.9
BX-16	–	9.0	–	0.52	1.40	0.60	–	–
BX-16A	–	29.6	–	1.43	1.71	1.51	–	–
BX-17A	–	39.1	–	0.45	1.10	0.70	–	–
BX-17B	–	72.7	–	1.09	0.30	0.52	–	–
BX-14'	–	–	–	< 0.05	0.15	0.11	–	–
BX-15'	–	–	–	0.18	0.11	0.15	–	–

It can be seen that the concentration of mercury in the sediment is greater in the coarser fractions, that is, fractions above 200#. This is found principally in the trough tailings. The mercury concentration is greater in the current sediments than in the trough tailings. The physical-chemical conditions prevailing in this environment indicate little variation of the slightly acid pH, and low redox (Eh) potential.

Taking these variables into account, it may be said that the heavy metal is found principally in metallic form and is of predominantly

anthropogenic origin, due to the degree of the anomalies.

The sediments are essentially quartzose sand with disseminated clay (kaolinite) and incipient participation of organic matter. Even if the physical-chemical conditions of the environment do not directly favor the oxidation of the metallic mercury, the mercury may, however, be adsorbed by the clay minerals as from oxidation in the atmosphere of the vaporized Hg^o. According to Mitra (1986), this adsorption is maximized when the pH is about 6.

In this way the mercury is likely to be adsorbed by the clay minerals, either through the ion exchange or by physical adsorption through the specific surface of the components of the sediments; kaolinite has 10 to $50m^2/g$ (SILVA et alli, 1991).

As to the extent that mercury is used in the troughs, it was found, and this is supported by data, that there is little and restricted use. On the other hand, the panning and amalgamation done frequently near the drainage waters, may be the reason for the higher concentration in the current sediments. Due to the small flow of the drainage waters and the high density of the mercury ($13.6g/cm^3$), aspects which hinder its horizontal mobility, it could be said that the mercury is near where it is being used. Regarding vertical migration, this may be disguised as a result of the reworking of the materials by other gold miners.

With regard to mercury concentrations in the waters of the above-mentioned drainages, levels were found oscillating from 3.2 to 4.6ppb. For the value attributed to uncontaminated Amazon rivers, which is only 0.04ppb, according to Pfeiffer et alli (1991), these values indicate that the drainage waters in question are very contaminated, that is, the rates found are approximately 100 times higher than in natural Amazon rivers. This contamination becomes more important if we compare the values found in this study with those found in the Madeira river, <0.04 - 0.46ppb (Lacerda et alli, 1987) and Tapajós river, <0.01-0.01ppb (Padberg, 1990). However, mention should be made of the greater dilution of the mercury in the rivers concerned. The origin of the mercury detected in the water samples must be related to the atmospheric emission that occurred in the gold fields themselves, during the amalgam burning.

Another aspect which is a cause for anxiety is the advanced state of silting up of their drainage waters. The courses have been altered according to the gold mining requirements and river bank vegetation has been destroyed. At certain points, the rate of suspended solids is so excessive (2,021.43mg/l) that the river discharge has a muddy consistency and minimum fluidity. The suspended load is essentially composed of kaolinite (alteration of feldspars found in abundance in the area's predominating granitic rocks) and, at times, the active water surface does not have a depth of more than 20cm.

.Subarea VIII (*Pista do Cabeça - Baixão*)

This subarea, which lies approximately 70km southwest of the municipal headquarters, forms a sub-basin of the Teles Pires river, in which its biggest landmarks are the Paranaíta river and the Molha Bêbado stream. Samples were collected in the places called Garimpo do Jonas, Garimpo do Sr. Miguel and Fazenda Santa Cecília.

Similar to the Gleba do Triângulo, in all the places sampled the anomalous presence of mercury was found. Even in places whose information collected earlier had pointed to a total lack of gold mining activities, anomalous mercury levels were found. The values found, with total concentration in the sample, oscillated between 0.19 and 1.32ppm (average of 0.43ppm), while 66.7% of the samples showed less than average values.

The same aspects noted in the Gleba do Triângulo, regarding the way in which the mercury was handled and the treatment of tailings, can be applied to this subarea.

The analytical results are in Table 20.

TABLE 20 - Subarea VIII - *Pista do Cabeça.*

STATION	TSS (mg/l)	Weight Total	Flow (m^3/s)	Concentration [Hg](ppm) >200#	<200#	Total
Trough tailings						
BX-3.1	274.2	27.7	–	0.27	0.46	0.32
BX-3.1A	274.2	44.0	–	0.28	—	0.28
BX-3.2A	274.2	42.9	–	0.40	0.30	0.36
BX-3.2B	274.2	51.1	–	0.58	0.47	0.55
BX-7.1A	–	12.6	–	0.25	0.81	0.32
BX-7.1B	–	14.8	–	0.09	0.68	0.19
BX-7.2A	–	10.9	–	0.23	0.69	0.28
BX-7.2B	–	9.3	–	0.22	0.71	0.26
Current sediments						
BX-4	4,208.00	50.6	–	0.41	0.47	0.44
BX-5	1,839.00	27.1	2.01	0.24	0.79	0.46
BX-6	471.60	35.9	1.03	0.33	0.55	0.41
BX-8	5.47	54.1	0.34	1.66	1.02	1.32

According to the results contained in Table 20, it can be seen that, unlike the Gleba do Triângulo, the biggest concentration of mercury is in the finer fractions, that is, fractions less than 200#. The concentration in the current sediments still prevails over the concentration in the trough tailings, although there is only a slight difference.

Since the sediments have compositions similar to those of the previous subarea, that is, quartzose sand and kaolinitic clay, the greater participation of organic matter is apparent as one of the factors causing the higher concentration of mercury in the fractions smaller than 200#(possibly due to adsorption).

The presence of iron hydroxides, principally in the form of limonite, is well known in the region. Although its distribution in outcropping is very erratic, the hydrated iron oxide is disseminated in the current sediments and impregnated in the clay minerals. Hence, it is important to stress that the iron hydroxides as much as the clay minerals and organic matter, working individually or concurrently, are very active components in the mercury adsorption.

Small semi-abandoned ponds are frequently found in the gold field areas, where the vegetation is going through various stages of decomposition. This fosters bacterial activity, the growth of fungi and the formation of humic acids, resulting in a reducer environment.

The organic matter, through the various forms of interaction with metallic ions in these types of environments, is capable of reducing the ionic mercury which may be present to the metallic state, or of causing its precipitation in the form of sulphides, thereby restricting its mobility (Jenne, E.,A., 1970; SILVA et alli, 1991).

Notwithstanding this, there is also the possibility of the bacteria and fungi causing the methylation of the Hg^{2+}, increasing its bioavailability and expanding its distribution (Mitra, S.; 1986).

As to environmental degradation in general terms, since this area is active most of the time and has the greatest population concentration, the effects are proportionally greater. Most of the drainage waters are very silted up. At certain points (Molha Bêbado stream), the level of suspended solids has reached 4208mg/l, which corresponds to more than 750 times the level found in the head waters of the Paranaíta river (5.5mg/l) of which the Molha Bêbado stream is a tributary.

5.4 Biology

Biology plays an important role in diagnosing the impacts of a pollutant or an activity that transforms environmental conditions, since it studies living beings as much from the taxonomic as from the ecological point of view.

During this study it was sought to:

- provide basic hydrological information, principally from the physical and chemical points of view of the water;
- describe the environments studied;
- assess the quality of algae existing in the drainage system;
- detect the presence and assimilation of mercury by aquatic organisms, represented by fishes, mollusks, macrophytes and algae, and
- to use, if possible, these organisms as indicators of the presence and level of mercury in the environment.

The lotic systems (running waters) show peculiarities in relation to the lakes, or lentic systems, as far as the dynamic factor of the water body is concerned. The water speed does not permit a stable balance of substances, as observed in lakes. Even if the physical-chemical processes are identical to the flow dynamics, it causes in the rivers a horizontal seasonality and in the lakes a vertical stratification (Schafer, 1984).

In its various intensities, the current creates such harsh conditions for the organisms that inhabit it, that special adaptations are necessary for them to live under such conditions.

The physiological processes of the organisms of a community are influenced by the variation of environmental factors. At present, these factors are principally altered as a result of man's activities. As mentioned earlier, in this study the biology area will analyze the possible impacts of the gold mining activity, particularly related to the silting up of drainage waters by solid tailings and by mercury emission.

Among the different metals that are potentially toxic for the environment, mercury has intrinsic characteristics which maximize its toxicity. It is the only one of these metals which undergoes biomagnification. Its transfer to trophic chains is accelerated through the periodic reproduction of phytoplanktons (Figure 25).

The principal nonoccupational way for mercury to enter human beings is by their eating contaminated fish. The process of incorporation to fishes depends, however, on the availability of methylmercury in the medium. This is the most toxic form of mercury, whose solubility in lipids is sometimes 100 times more than metallic mercury (Lacerda, 1990).

After the stage of amalgamation and amalgam burning, the mercury that reaches the drainage waters can be transported by:

- incorporation to the current sediments, where it can be removed and adsorbed by fine suspended particles (Lacerda, 1990), and
- solubilized or complexed current to the low molecular weight organic compounds (Lindberg & Harris).

When it is transported by incorporation to current sediments, the mercury does not move so fast, which means that it can contaminate adjacent areas.

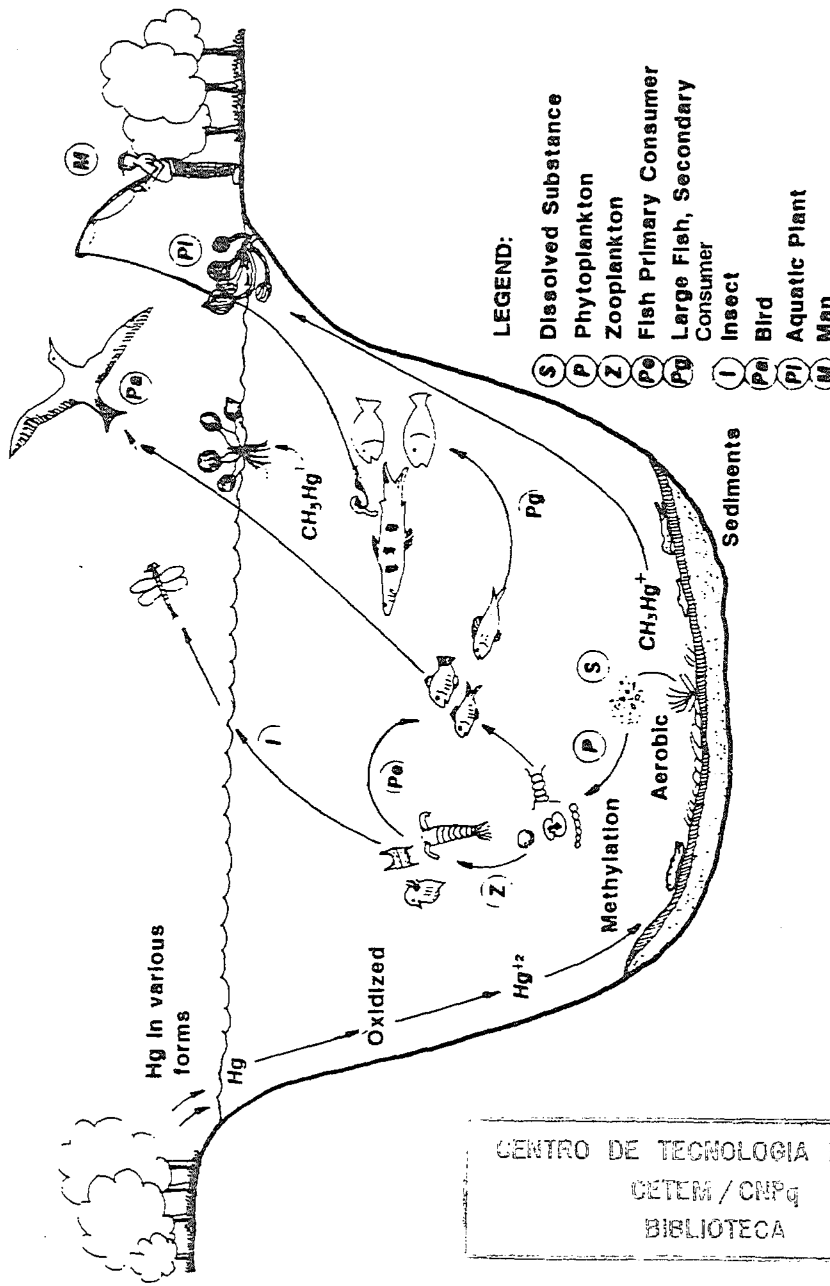


FIGURE 25 - Bioaccumulation of methylmercury in the Biota.

"According to data provided by Martinelli et alli, in a lake on the Solimões river, near the mouth of the Madeira river, about 100km downstream of the main gold mining area on the Madeira river, high concentrations of mercury were found in fishes, thereby indicating an enormous potential for mercury to be transported by rivers and streams" (in: Lacerda, 1990).

This transported mercury can reach living aquatic beings through the continuous passage of water to the organism in the breathing process, facilitating the penetration of mercury or other toxic substances directly into the circulatory system and immediately into the body.

Regarding the silting up of drainage waters by suspended solids, the alterations can cause the death of aquatic organisms. In the case of fishes, death is caused by the obstruction of the gills (respiratory system), resulting from the deposition of sediments. Another alteration is the low primary production (photosynthesis) caused by less light penetrating.

Environments where there is intense bacterial activity, allied to high temperatures and concentrations of organic substrate, cause the biological transformation of the mercury, thereby being responsible for the high levels of methylmercury in fishes.

According to Pinto, R. (1987), *Eichhornia crassipes* has a depolluting action, since its fasciculated root retains the suspended particulate matter and can thus absorb heavy metals as much as organic particles.

5.4.1 Physiography of area

The area in question is located on what is known as the Southern Amazonia Depression, between the latitudes 9°30' - 10°8'10" and longitudes 50° 27'15" - 55°30' (Figure 26). The altitude varies from

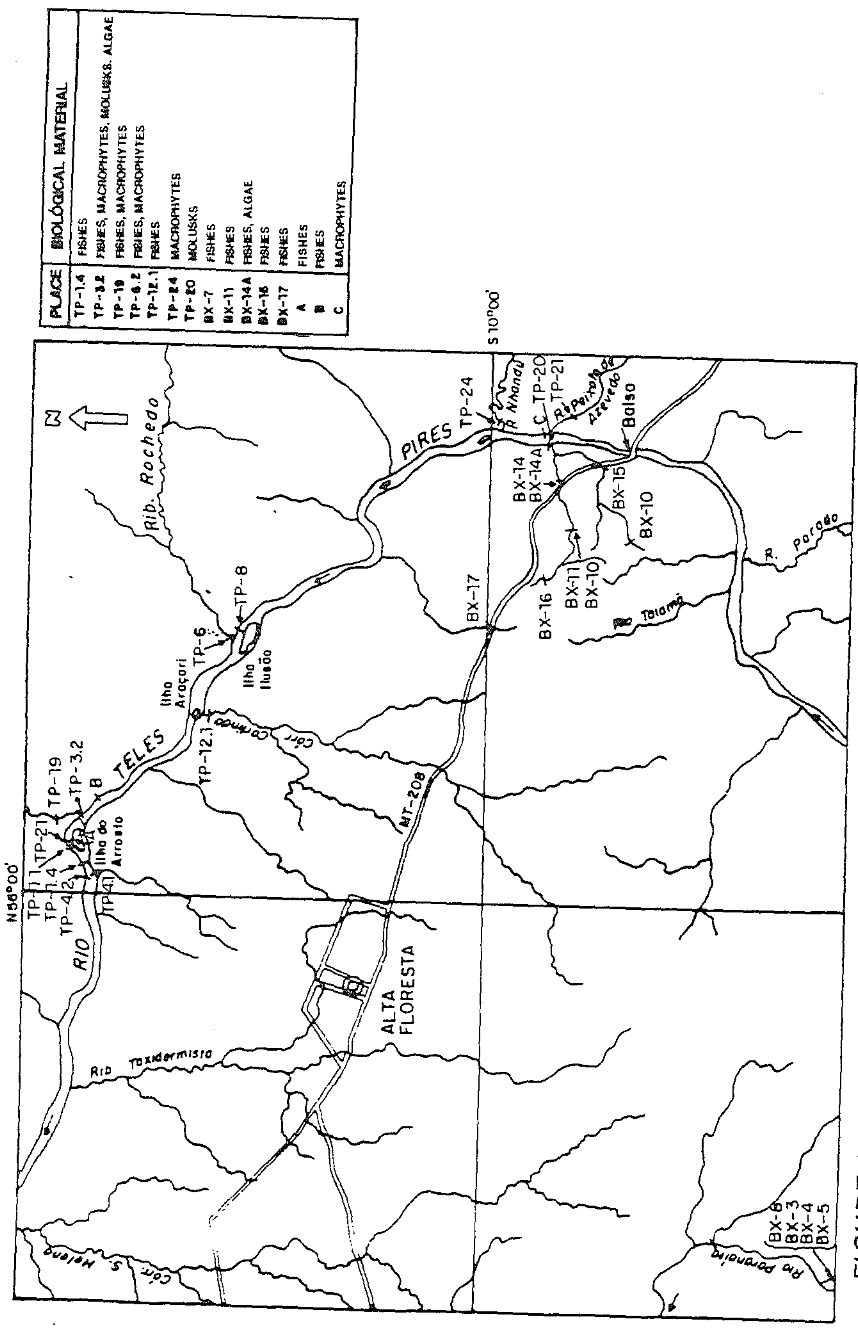


FIGURE 26 - Map of Distribution of Biological Sampling Points

200 to 300m.

The region of the Teles Pires river has several important tributaries in its drainage waters, such as Peixoto de Azevedo, Nhandu, Cristalino, Paranaíta rivers; Rochedo and Carlinda streams.

The climate is tropical, hot and humid, with temperatures oscillating between 24 and 40°C. The annual average rainfall is between 2500 and 2750mm. The vegetation is included in the Tropical Rain Forests associations.

5.4.2 Description of study stations

.Teles Pires river

In this river the studies were done on the stretch lying between the place called Porto de Areia and immediately upstream of the mouth of the Peixoto de Azevedo river.

Its waters in this stretch are muddy and contain large amounts of suspended matter, coming principally from gold mining activities on its bed or on the bed and flood plains of some of its tributaries.

In places where backwaters have formed, and there is a consequent reduction of kinetic energy in the water, the accumulation of clays rich in organic matter was noted. In these places it was possible to collect macrophytes, algae and periphyton. The mollusks and fishes were collected principally where there were beaches.

It is important to bear in mind that, upstream of the mouth of the Peixoto de Azevedo river, the Teles Pires river has clearly transparent waters, greenish in color because of the presence of organic matter and probably nanoplanktons.

.Peixoto de Azevedo river

The Peixoto de Azevedo river is noteworthy because, in the study area, it is the largest contributor of suspended solids to the Teles Pires. Gold prospecting in this river has made its waters muddy, reddish in color and in some places its course has undergone several changes because of the accumulation of solid tailings.

In this environment the aquatic life has been almost entirely destroyed and, in spite of countless attempts to catch fishes, mollusks and macrophytes, it was not possible to collect biological samples.

An interesting fact is the occurrence of innumerable turtles at the confluence with the Teles Pires river.

.Nhandu river

A winding river with turbid water. Its banks are protected against erosion by abundant vegetation, consisting of medium-sized forest growth. Judging by appearance, it has not been affected by gold mining and the suspended matter consists of organic debris. The sediment on its bed is clayey, grey and rich in organic matter. During the dry season, decomposition has the effect of releasing large quantities of humic substances.

In places where backwaters have formed, aquatic plants are growing.

.Rochedo stream

Its waters are semiturbid and contain suspended solids, indicating the presence of gold mining. On its bed, which is composed of silt-clay layers, traces of diesel oil were seen.

A small river where backwaters have formed favoring the growth of aquatic plants. It was noted in these backwaters that if the layer of sediments is touched, gases are released; however much effort was made to catch fishes and mollusks, only macrophytes were caught.

.Carlinda stream

Its waters are very dark and rocky outcropping appears at some points. The flood basins adjacent to the river channel release gases in large quantities during the low water period. In the stretch studied, the presence of aquatic macrophytes or mollusks was not noted and only fishes were caught.

.Cristalino river

Its waters are typical of "black waters", that is, they are very dark, very transparent and contain sediments formed by sand and many leaves. There is accelerated decomposition, which may be noted from the intense release of humic substances. This also explains the dark coloring of the water.

Its course shows some areas of rocky outcropping appearing like rapids and large stretches of backwaters. There is lush vegetation along its banks, whose leaves during flood periods are carried to the river bed (allochthonous matter), helping to replace nutrients.

Clean water entering from this river dilutes the load of suspended solids in the Teles Pires river.

The Cristalino river probably plays an important role in predatory activities, mainly for diurnal fishes which could feed preferentially in this river, due to the abundant food and good visibility for catching prey. The Teles Pires river, due to its great turbidity, can be used as a refuge. This being so, one must consider the very probable migration of fishes in the area of confluence of the two rivers.

.Region of the Paranaíta river and Triângulo stream

Baixão gold fields predominate in these areas, located in small drainages (hollows in river banks, forest waterways and small streams), where hydraulic tearing down and subsequent pulp pumping is done.

As a result of this process, the load of solids incorporated results in drastic modifications of the river's natural course. This is occurring in the Paranaíta river, Molha Bêbado, Triângulo, Dois Irmãos and Taxista streams.

The consequence of this type of environment is the extermination of many aquatic organisms, leaving only those which are more resistant to such transformations. The aquatic organisms can take refuge in small tributaries or in artificial lakes (dams), which also has consequences, because it reduces the area of the habitat, increases competition for space and food and can cause reproductive isolation.

5.4.3 Materials and methods

During the field phase samples were collected of biological materials (macrophytes, phytoplanktons, fishes and mollusks) and the water's physical and chemical parameters were measured, at 24 stations located in the system of drainage waters of the Teles Pires river.

On the Teles Pires river 6 sampling stations are allocated downstream and 1 upstream of the confluence with the Peixoto de Azevedo river. The other stations are located on tributaries of the Teles Pires river.

5.4.3.1 Hydrochemical variables

.Water Temperature

The water temperature was determined using a straight thermometer with a scale of -10°C to 110°C, for obtaining data from the surface and points on the bottom.

.Water Transparency

This was determined by lowering a Secchi disk vertically into the water and reading it until it disappeared from sight, which indicates the river's luminosity zone.

.Coefficient of vertical attenuation

This was determined by reading the Secchi disk, and calculated using the formula described by Kink (1986).

$Kc = \frac{9}{Zds}$ where:

Kc = coefficient of attenuation; 9 = constant; Zds = reading the Secchi disk in meters.

.Suspended matter

This method is based on filtering an aliquot of a liquid sample of a known volume (v). The filters used (AP - 45mm, 47μm - Millipore) are previously dried at 50°C for 2 hours. They are then weighed and numbered (Initial Weight - IW). After filtering the material with a hand-operated vacuum pump (Nalgene - 3psi), the retained matter was dried at 50°C for 2 hours and weighed (FW). All the drying and weighing phases of the filters were carried out in CETEM's laboratory.

In order to avoid interference from the loss of matter from the filter, the method used above was used. Distilled water was used in the filtering.

The calculations followed the formula described by Teixeira & Kutner (1962) and Tundisi (1969).

$M_s(mg/l) = \frac{(P_f - I_w)}{v} x (10)^3$ N.B. weight in grams and volume in liters.

.pH

The pH measurement was done by a direct reading, using a pH meter (Digimed - model DMPH - PV).

.Dissolved Oxygen

After pouring the liquid sample into an amber bottle, 2ml were added of a solution of manganous sulphide and 2ml of an alkaline azide, the bottle was then closed and shaken. With this fixing the sample reacts and forms a precipitate of manganous hydroxide at the bottom of the bottle with approximately 1/3 of its volume.

Following this, 2ml of potassium fluoride and 2ml of concentrated sulphuric acid were added, the bottle was closed and the sample shaken until the precipitate of hydroxide dissolved. An aliquot of 25ml was transferred to the titration bottle and 3 drops of the starch indicator were added, shaking the bottle. For titration a solution of sodium thiosulphate is used, dripping it and shaking until the blue turning point becomes colorless.

When determining the dissolved oxygen a Politest model OD - ref. 33010.00.00 kit was used, according to the method of CETESB - L5 164 and AWWA-218B. This technique was based on a method suggested by Winkler (1988) and modified by Pomeroy & Kinschmann (1945).

.Percentage of saturation of dissolved oxygen

The percentage of saturation is a function of dissolved oxygen, of the temperature and of pressure of where it was collected, which helps to compare with results from other regions.

The percentage of saturation for an obtained value of dissolved oxygen *(mg/l)*, is found through the following formula:

$\%Sat = \frac{A.100}{y.C_F}$ where:

A - Oxygen of the titrated sample; y - Solubility of the O_2 in water at the sample temperature; C_F - Altitude correction factor.

5.4.3.2 Chlorophyll "a" and phaeophytin

After pouring the liquid sample into ordinary bottles, 250ml of the sample was filtered in a dark ambient in glass fiber filters (Schleicher & Schull-SS, mod. GS-92, 0.45μm), with a replica, then packed in aluminum paper and stored with silica gel in a freezer (-10°C). Procedure described by Vollenwaider (1972).

.Extraction

Each filter was steeped in a porcelain mortar in a dark place, using acetone at 90% as a cold solvent, until the filter was completely dissolved.

The steeped sample was centrifuged at 3000rpm for 15 minutes, the floating material was put in a 10ml measuring flask and completed with acetone at 90%.

.Reading

The readings of chlorophyll "a" and phaeophytin were carried

out in a spectrophotometer on the wavelengths 663 and 750nm. For the phaeophytin, 2 drops of hydrochloric acid (HCl) at 0.01N were added.

5.4.3.3 Biological samples

.Phytoplankton

For the algae study the material was collected by hand using cloth netting for phytoplankton, with a mesh aperture of 20μm. After passing the netting over the surface and at a depth of 30cm of the water mass, the material was put into transparent glass bottles and was fixed and preserved with a *transeau* solution prepared as instructed by Bicudo & Bicudo (1970:18), in the proportion of 1:1 with water from the environment.

The material obtained was analyzed in the Phycology Laboratory of the Federal University of Mato Grosso, using a binocular optical microscope with phase contrast and fitted with a light chamber. *Batracospermum sp.* and *Cyanophycea filamentosa* were also collected. Both were washed in running water to remove all the sediments. These samples were then packed in plastic bags and frozen for Hg analysis. These algae fasten themselves to substrates (tree trunks and branches) just under the surface of the water and on the river banks.

The algae play an important role in extensive primary production, that is, in oxygenating the environment. Due to their abundance and wide distribution in different aquatic environments, taxonomic identification of them is essential. This identification is shown in Table 21.

TABLE 21 - List of algae found.

A	B	C	D
Micrasterias sp (25) *Closterium* sp_1 *Cosmarium* sp_2 *(10)* *Cosmarium* sp_3 *Desmidium sp* *Euastrum* sp_1 *(4)* *Euastrum* sp_2 *Xanthidium sp* *Euastrum* sp_3 *Desmidium* sp_2 *Gonatozygon pilosum* *Anabaena sp* *Navicula* sp_1 *(15)* *Pinnularia* sp_1 *Actinotaerium sp* *Navicula* sp_2 *Oscillatoria sp* *Scenedesmus sp (3)* *Eunotia sp* *Aphanizonema sp* *Surirella sp* *Cosmarium* sp_1 *(8)* *Staurastrum sp* *Desmidium grevilli (5) (Kütz.) De Bary* *Closterium* sp_2 *Desmidium swartzii* *Pinnularia* sp_2 *(4)*	*Phacus* sp_1 *Navicula sp* *Phacus* sp_2 *Surirella (2)* *Eunotia sp* *Cymbella sp*	*Eunotia sp* *Cyanophyceae filamentosa (4)*	*Nitzischia sp (4)* *Closterium sp* *Staurastrum sp (2)* *Aplanocapsa* *Trachelomonas sp* *Staurastrum* sp_2 *Surirella sp (3)* *Navicula sp* *Eunotia sp (3)* *Cymbella sp* *Navicula* sp_2 *(2)* *Staurastrum sp3* *Actinotaenium sp*

E	F	G	H
Cyanophyceae sp (4)	*Batracospermun sp* *Closterium sp (4)* *Actinotaenium sp (4)* *Cosmarium* *Navicula sp* *Eunotia (12)* *Navicula flexuosa* *Cyanophyceae* *Eunotia flexuosa* *Navicula* sp_2 *Gomphonema sp* *Bulbochaete sp*	*Staurastrum* sp_1 *Staurastrum* sp_2 *Pinnularia sp (3)* *Actinotaenium sp* *Eunotia sp (2)* *Coelastrum sp* *Microcystis* *Eunotia curvata (2)* *Staurastrum* sp_3	*Desmidium sp* *Euglena sp* *Staurastrum sp* *Navicula sp* *Actinotaenium* sp_1 *Closterium sp* *Gonatozygon-pilosum* *Actinotaenium sp* *Cosmarium sp* *Eunotia sp*

I	J	L
Navicula sp *Actinotaenium sp* *Staurastrum* *Cosmarium sp* *Mougeotia sp* *Desmidium sp* *Eunotia* *Nitzischia sp*	*Synedra sp (10)* *Aulacoseira herzogii* *Gomphonema sp (1)* *Staurastrum sp* *Scenedesmus sp* *Frustulia sp* *Surirella sp (2)* *Staurastrum* sp_1 *Eunotia sp (2)* *Closterium sp (3)* *Cyanophyceae* *Actinotaenium sp (4)* *Staurastrum margaritaceum (Ehr.) Ralfs* *Zygenema sp* *Eunotia* sp_2 *Scenedesmus quadriculata* *Surirella* sp_2 *Navicula* sp_1 *(6)* *Navicula* sp_2 *Dictyosphaerium pulchellum Wood (8)*	*Microspora sp* *Synedra sp (15)* *Eutonia* *Navicula sp* *Gomphonema (2)* *Surirella (2)* *Cosmarium* *Lyngbya* *Cosmarium (4)* *Frustulia sp (3)*

SITES:

A. Lake near the Triângulo stream

B. Peixoto river

C. Nhandu river

D. Rochedo river

E. Paranaíta river

F. Tributary of the Triângulo stream

G. Carlinda stream

H. Triângulo stream, near the Alta Floresta-Peixoto highway

I. Dois Irmãos stream

J. Teles Pires river above Alto Peixoto

L. Teles Pires river near Ilha do Ariosto

(*) the figures in brackets refer to the quantity of algae found when analyzing the 8 slides of each site.

.Macrophytes

Examples of macrophytes were collected by hand, washed in running water while removing all sediments and then the plants were grouped into young, adult and aging. The parts were separated into root, petiole, leaf, stolons, etc. (Figure 27). The samples were cleaned again under running water and packed in plastic bags for subsequent freezing and chemical analysis. In the chemistry laboratory of the Federal University of Mato Grosso, they were dried in an oven at 40°C.

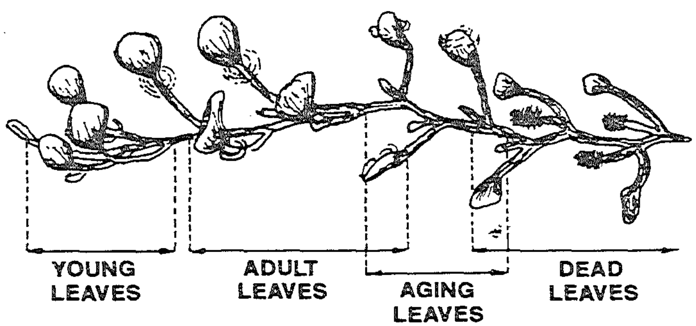


FIGURE 27 - A branch of *Eichhornia azurea* Kunth and its different stages of development, according to SCHWARZBOLD, A. 1990

.Mollusks

The samples were collected by hand on the banks of the Teles Pires river. Later they were measured with a pachymeter and the organic part was separated from the carapace. The material was also dissected into musculature and intestine for later Hg analysis. In order to make a better analysis, the mollusks were grouped into ranges of carapace length. The taxonomic identification was done in the Zoology Department of the National Museum in Rio de Janeiro. The batch was registered under No. Col. Mol. MNRJ 6202.

.Ichthyofauna

The fishes were caught with a No. 3 circular fishing net and a fishhook. They were measured for weight, height and standard length (Figure 28). After being dissected, the musculature and liver were packed separately and frozen in plastic bags for later mercury analysis.

Taxonomic identification was done comparing the materials found with what exists in specialized literature. Basically, classic works were used: Britski, 1983; Gery, 1977; Goulding, 1980 and Fowler, 1954.

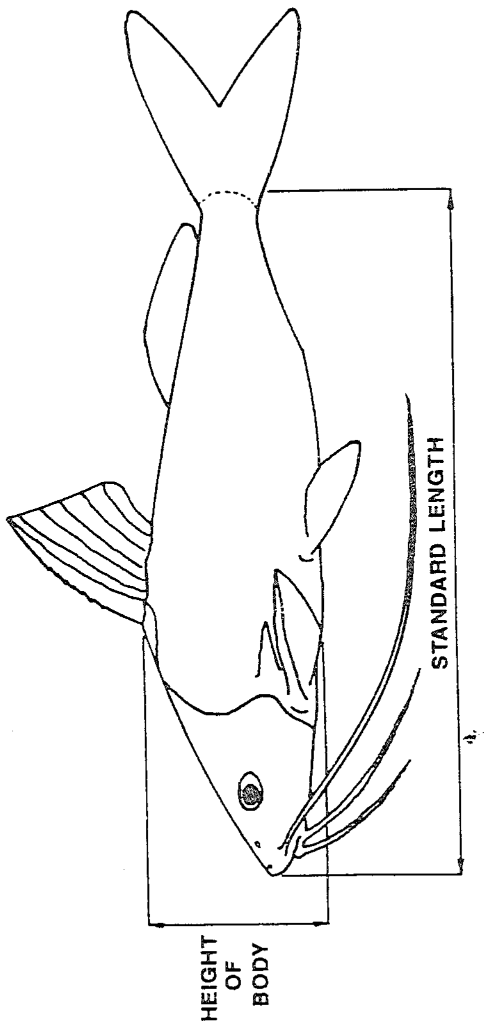


FIGURE 28 - Diagram of the measurements of fishes

5.4.3.4 Mercury analysis method

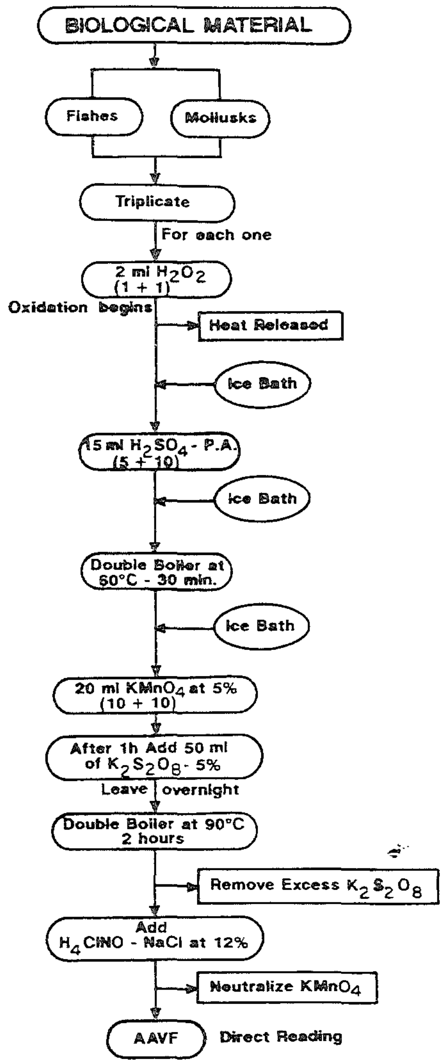
Beforehand, all the glass equipment used in the mercury analyses went through a decontamination process using Extran detergent, nitric acid at 10% and distilled-deionized water, during 24 hours.

The equipment (scalpel, knife, spatula, scissors and others) used for preparing the biological samples, were duly decontaminated following the procedure mentioned above.

After drying, the macrophytes and algae were ground up in a blade mill, while the fishes and mollusks were ground up in an electric processor and in a porcelain mortar, and packed again.

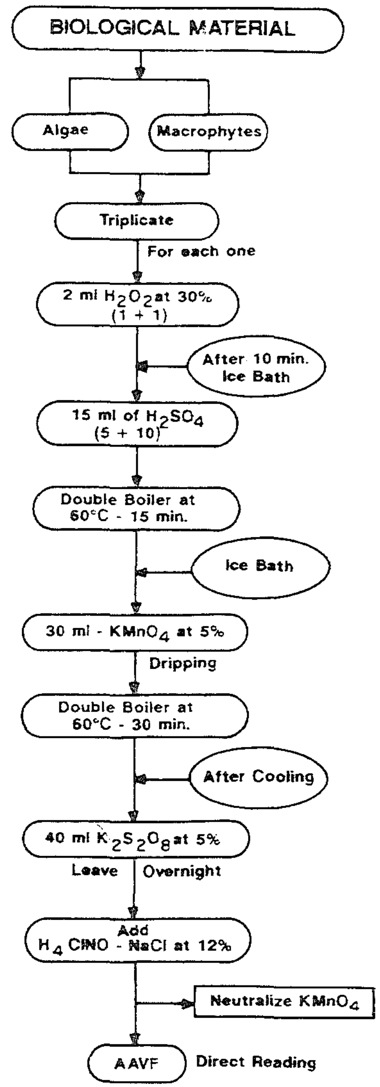
All the samples were homogenized and triple aliquots were taken from them at random using an analytical balance. A sample of fish musculature (*Hoplias molabaricus*) was kept for intralaboratory analysis control.

For the procedures followed when analyzing the concentration of mercury in the biological samples, the method of oxidation and reading in an atomic absorption spectrophotometer was used, according to techniques modified by Malm et alli (1989). The mercury analyses of the biological material were carried out in the Analytical Chemistry Laboratory of the Chemistry Department of the Federal University of Mato Grosso, under the supervision of Prof. Dr. Edinaldo Costa e Silva and his staff. The routine of the chemical analyses of the biological material is shown in Figures 29-A and 29-B.



N.B. First neutralize the placebo so as to have an idea for the samples.

FIGURE 29-A - Description of the routine followed for the chemical analysis of mercury in biological samples.



N.B. First neutralize the placebo so as to have an idea for the samples.

FIGURE 29-B. Description of the routine followed for the chemical analysis of mercury in biological samples.

5.4.4 Presentation of physical and chemical results

The following values were found for suspended solid matter, measurements of the concentration of dissolved oxygen, temperature and water transparency in the various environments studied (Table 22).

TABLE 22 - Physical and chemical parameters of the water

Place/Station	Depth(m)	Time	Temper. Air	Temper. H_2O
Teles Pires river TP-1.1	0.00	9:20	28.0	27.5
Teles Pires river	3.20	*	*	26.10
Teles Pires river TP-1.4	0.00	10:30	25.0	25.0
Teles Pires river TP-2.1	0.00	14:45	31.0	26.5
Teles Pires river TP-3.2	0.00	15:00	31.5	28.0
Teles Pires river TP-4.1	0.00	15:20	30.0	26.5
Teles Pires river TP-4.2	0.00	16:00	28.5	26.5
Above Peixoto river TP-20	0.00	10:05	*	*
Peixoto river TP-21.1	0.00	10:30	*	*
Nhandu river TP-24	0.00	1	*	*
Rochedo stream TP-6.1	0.00	11:05	26.5	24.0
	3.50	*	*	24.0
On Teles Pires river near the rochedo stream TP-8.0	0.00	12:18	30.0	27.0
Carlinda stream TP-12.1	0.00	15:40	27.0	24.5
	2.70	*	*	23.5
Cristalino river TP-19	0.00	*	*	*
Tailings pond				
Paranaíta river Bx.3	0.00	13:05	*	*
Molha Bêbado river Bx.4	0.00	13:40	*	*
Paranaíta river Bx.5	0.00	14:10	*	*
Headwaters of the Paranaíta river Bx.8	0.00	*	*	*
Triângulo stream Bx.10	0.00	*	*	*
Triângulo stream near road Bx.14	0.00	11:00	*	*
Tributary of the Triângulo stream Bx.14A	0.00	11:30	*	*
Lake near Triângulo stream Bx.11	0.00	*	*	*
Taxista river Bx.15	0.00	14:00	*	*
Spring of the Triângulo stream Bx.16	0.00	15:00	*	*
Dois Irmãos stream Bx.17	0.00	16:00	28.0	23

TABLE 22 - Physical and chemical parameters of the water (continuation)

Place/Station	O_2Diss.	Chlorophyll a	Phaeophytyn	% Oxygen saturation	pH
Teles Pires river TP-1.1	7.0	0.549	0.91	85.8	6.3
Teles Pires river	5.0	*	*	59.8	*
Teles Pires river TP-1.4	5.0	0.0	0.0	58.7	6.48
Teles Pires river TP-2.1	5.0	*	*	60.22	6.9
Teles Pires river TP-3.2	5.0	*	*	61.8	6.6
Teles Pires river TP-4.1	6.0	*	*	72.3	6.88
Teles Pires river TP-4.2	*	*	*	*	6.46
Above Peixoto river TP-20	7.0	0.55	0.91	*	6.22
Peixoto river TP-21.1	6.5 (1)	0.0	0.0	*	6.74
Nhandu river TP-24	6.0	0.0	0.0	*	6.05
Rochedo stream TP-6.1	7.5	*	*	86.5	6.5
	7.0	*	*	80.7	*
On Teles Pires river near the Rochedo stream TP-8.0	*	*	*	*	*
Carlinda near TP-12.1	6.0	0.0	0.0	69.8	6.62
	6.0	*	*	68.5	7.06
Cristalino near TP-19	4.0	*	*	*	6.5
Tailings pond					
Paranaíta river Bx.3	7.0 (1)	*	*	*	6.45
Molha Bêbado stream Bx.4	2.5	*	*	*	6.34
Paranaíta river Bx.5	7.0 (1)	*	*	*	5.7
Headwaters of the Paranaíta river Bx.8	*	*	*	*	5.93
Triângulo stream Bx.10	*	*	*	*	6.04
Triângulo stream near road Bx.14	5.0	0.5	0.9	*	6.51
Tributary of the Triângulo stream Bx.14A	4.0	*	*	*	5.75
Lake near Triângulo stream Bx.11	*	*	*	*	5.4
Taxista river Bx.15	7.0 (1)	*	*	*	6.49
Spring of the Triângulo stream Bx.16	8.0	*	*	*	6.69
Dois Irmãos stream Bx.17	6.0 (1)	*	*	*	6.62

TABLE 22 - Physical and chemical parameters of the water (continuation)

Place/station	Secchi disk (m)	Coef. length(m)	Susp. matter mg/l	Max. depth (m)
Teles Pires river TP-1.1	0.32	28.1	28.4	3.5
Teles Pires river		28.4	146	*
Teles Pires river TP-1.4	0.42	21.4	*	3.0
Teles Pires river TP-2.1	0.35	25.7	28.6	5.0
Teles Pires river TP-3.2	0.35	25.7	32.8	2.6
Teles Pires river TP-4.1	0.38	23.7	29.6	10.0
Teles Pires river TP-4.2	0.43	20.9	36.4	8.0
Above Peixoto river TP-20	0.45	20.0	33.9	2.10
Peixoto river TP-21.1	0.11	*	116.9	7.0
Nhandu river TP-24	*	*	27.45	3.6
Rochedo stream TP-6.1	0.58	15.5	19.8	3.8
On Teles Pires river near the Rochedo stream TP-8.0	0.35	25.7	37.8	5.0
Carlinda stream TP12.1	1.00	6.62	14.8	3.0
Cristalino river TP-19	*	*	*	3.5 - 4.0
Tailings pond				
Paranaíta river Bx.3	0.08	112.5	183.95	*
Molha Bêbado stream Bx.4	0.00	*	5774.0	*
Paranaíta river Bx.5	0.05	180.0	1865.4	*
Headwaters of the Paranaíta river Bx.8	*	*	5.5	*
Triângulo stream Bx.10	*	*	2.021.4	*
Triângulo stream near road Bx.14	0.05	180.0	1.107.5	*
Tributary Triângulo stream Bx.14A	0.90	10.0	15.8	1.20
Lake near Triângulo stream Bx.11	*	*	9.6	*
Taxista stream Bx.15	0.05	180.0	342.0	0.6
Spring of the Triângulo stream Bx.16	0.5	18	6.4	*
Dois Irmãos stream Bx.17	0.25	36.0	65.5	*

* - not determined.

(1) Due to the large amount of suspended matter, these dissolved oxygen results may have distorted values.

These are the parameters that relate more directly to the phytoplanktons community and, consequently, to all the aquatic life.

.Teles Pires river

In the area studied, the Teles Pires river receives the largest load of suspended matter from the Peixoto de Azevedo river. These

solids are diluted along its course as they receive the waters of the Nhandu, Rochedo, Carlinda and Cristalino tributaries and also undergo sedimenting, which causes Teles Pires river bed to silt up.

This has been proved by measurements made at 6 stations downstream of the confluence with the Peixoto de Azevedo river, where the water transparency values vary from 0.32 - 0.43m and the rate of suspended matter from 37.8 - 28.4 mg/l. The dissolved oxygen values varied from 5.0 - 7.0mg/l. The 5mg/l value represents a low rate of primary production, because of the small variety and quantity of phytoplanktons found downstream of the Peixoto de Azevedo river, since there is very little light penetrating the water column.

Upstream of the mouth of the Peixoto de Azevedo river, the water transparency value is 0.45m and the concentration of dissolved 02 is 7.0mg/l, evidencing a larger variety of algae in comparison with the previous situation.

.Peixoto de Azevedo river

The load rate of suspended solids is high (116.9mg/l), which entails low levels of water transparency, drastically reducing the photic zone (0.11m).

As a result of the low light penetration, there was a reduction of the variety and quantity of phytoplanktons.

In this system probably the biggest contribution to oxygenation of the water comes from other sources, such as turbulence and direct diffusion from the air/water surface.

.Nhandu river

This river shows a high concentration of suspended solids (27.45mg/l), which is equivalent to the value found in the Teles Pires river, although probably consisting of organic debris.

In the backwater areas, macrophytes are abundant (*Eichhornia azurea*), and a periphytic community has formed (algae growing on a substrate), which plays an important part in releasing dissolved oxygen (6.0mg/l), through primary production. In the analyses of phytoplankton material, only one *Eunotia sp.* was found.

.Rochedo stream

This river has semitransparent waters and the suspended matter (19.8mg/l) consists basically of organic debris which have little effect on the transparency of the water (0.58m).

The concentration of dissolved oxygen does not vary in depth. The water column is homogenized in the rivers, since they are always moving.

Regarding the analysis of the phytoplankton material, a reasonable variety of algae was found, where Diatoms and Desmids predominate.

.Carlinda stream

The suspended matter (14.8mg/l) consists of organic debris and probably nanoplanktons, which are responsible for the greenish-grey color of the water.

Light penetrates through practically all the water column, evidenced by the Secchi disk reading of 1.0m with 15% luminosity and 1% luminosity at total depth (2.70m).

Even considering this transparency, the variety and quantity of phytoplanktons are low. On the other hand, the concentration of dissolved oxygen is relatively high (6.0mg/l). Probably, this oxygenation is due to the production of nanoplanktons and in a small part due to the release and direct diffusion of the air/water surface caused by movement.

.Molha Bêbado stream

This is at present at an advanced stage of silting up, since during the period when it was studied, its bed had $\pm$ 0.5m depth and 5.774mg/l of suspended matter originating from gold mining activity. No light penetrates (0.0m).

The concentration of dissolved oxygen was 2.5mg/l and no kind of alga was found. Oxygenation of the water depends on the process of O_2 release by the movement and direct diffusion of the air/water interface.

.Paranaíta river

The Paranaíta river in the area studied receives from its Molha Bêbado tributary a large amount of suspended solids at a rate of 5.774mg/l. Upstream of this confluence the rate is 1.865mg/l of suspended solids. It is at an advanced stage of silting up.

The transparency of the water was 0.05m and the dissolved oxygen concentration was 7.0mg/l.

While analyzing the phytoplankton, only one species of *Cyanophycea filamentosa* was found. This is justified by the low light penetration, because of the large amount of suspended solids brought directly from the gold fields.

.Triângulo stream near road (BX.14)

The suspended matter in this stream resulted in a rate of 1,107mg/l, with a water transparency of 0.05m, 5.0mg/l of dissolved oxygen and a small variety and quantity of algas.

This tributary (BX.14A) where there is no gold mining, is black and transparent. The suspended matter (15.8mg/l) consists of organic debris. The concentration of dissolved oxygen is 4.0mg/l and is possibly due to the high rate of decomposition.

The algal material contains a large population of *Batracospermum sp.* (Rodoficea), and a variety of associated diatoms in its structure.

The lake (BX.11) near the Triângulo stream, has black, transparent, limpid water. The value of the suspended matter was 9.6mg/l. There was more variety of algas in this place, thereby justifying the large population of herbivorous fishes (*Anostomidae*).

This environment is going through an active process of decomposition with abundant release of nutrients, which causes a large quantity of algas to associate with the sediment.

.<u>Dois Irmãos stream</u>

This stream has a rate of 65.5mg/l of solid suspended particles, which is the reason for the low water transparency (0.25m).

As a consequence of the very little light penetration, there were reduced and less varied phytoplanktons. The rate of dissolved oxygen concentration was 6.0mg. This depends on first diffusion from the air/water surface, since its waters are semistagnant and the primary production is possibly very low.

5.4.5 Results of mercury analyses

.<u>Mollusks</u>

The mollusks were collected only on the bed of the Teles Pires river at places where the flow dynamics allow the formation of beaches. The sampled stations are near Ariosto island and upstream of the confluence with the Peixoto de Azevedo river.

TABLE 23 - Hg concentration in the mollusk *Hemisinus tuberculatus* (Spix, 1827) in different classes of sizes.

A - Place: Teles Pires river – near Ariosto island

SIZE (cm)	QUANTITY	Hg CONCENTRATION (ppm)	
		MUSCLE	INTESTINE
1 ↔ 2	11	0.27±0.01	*
2 ↔ 3	43	0.25±0.01	0.32±0.01
3 ↔ 4	65	0.17±0.01	0.29±0.01

B - Place: Teles Pires river – near the confluence with the Peixoto de Azevedo

SIZE (cm)	QUANTITY	Hg CONCENTRATION (ppm)	
		MUSCLE	INTESTINE
1 ↔ 2	23	0.17±0.01	1.15±0.04
2 ↔ 3	57	0.23±0.01	1.11±0.01
3 ↔ 4	05	0.63±0.02	0.80±0.03

* - insufficient mass

In the samples from the Teles Pires river and near Ariosto island (Table 23-A), the intestine analysis showed the highest mercury content (0.39 ± 0.01ppm) in the 3-4cm size range and the lowest concentration between 2-3cm (0.32 ± 0.01ppm). The musculature analysis showed the lowest value (0.17 ± 0.01ppm) in the 3-4cm range and the highest value between 1-2cm (0.27 ± 0.01ppm).

The samples of mollusks that showed the highest mercury content were collected at the station upstream of the confluence with the Peixoto de Azevedo river (Table 23-B), where the concentrations were distributed in *Hemisinus tuberculatus.* In the intestine it was 0.80 ± 0.03ppm in the 3-4cm sizes and 1.15 ± 0.04ppm in the 1-2cm range. The biggest concentration of mercury in musculature was 0.63 ± 0.02ppm between 3-4cm. These results exceed the maximum mercury value for aquatic organisms, which is 0.05ppm (WHO, 1978).

It must be pointed out that in the mollusk *Hemisinus tuberculatus*, the highest mercury content is in the intestine. Since mollusks act as filters and are herbivorous, the concentration of mercury in the musculature is small. Perhaps this concentration depends on the trophic chain.

A comparison between the Hg dosages in the intestine and musculature of the mollusks is shown in the chart in Figure 30.

The mollusk *Ampullaria usularum* (Table 24) shows 0.15 $\pm$ 0.02ppm of mercury in the intestine, and 0.04 $\pm$ 0.01ppm for the musculature.

TABLE 24 - Concentration of mercury in the mollusk *Ampullaria usularum*

Place: Ariosto island

SIZE (cm)	QUANTITY	Hg CONCENTRATION (ppm)	
		MUSCLE	INTESTINE
2.6	1	0.04±0.01	0.15±0.02

. Macrophytes

From all the places studied only the aquatic macrophytes *Eichhornia azurea* and *Eichhornia crassipes* were brought from the rivers: Teles Pires, Cristalino, Nhandu and Rochedo. All the samples had low mercury concentration levels.

Eichhornia azurea (Table 25) had a concentration of mercury principally in the aging and adult parts.

The macrophytes from the Nhandu river had a bigger concentration than in other rivers studied (0.35 $\pm$ 0.01ppm on the aging leaves and 0.24 $\pm$ 0.04ppm on the also aging root). This species fixes itself to the bottom sediment and on the river banks; since the aging parts are almost always entirely submerged in the water, there is a direct relationship between plant/sediment and plant/ water.

No mercury was detected in the macrophytes from the Cristalino river.

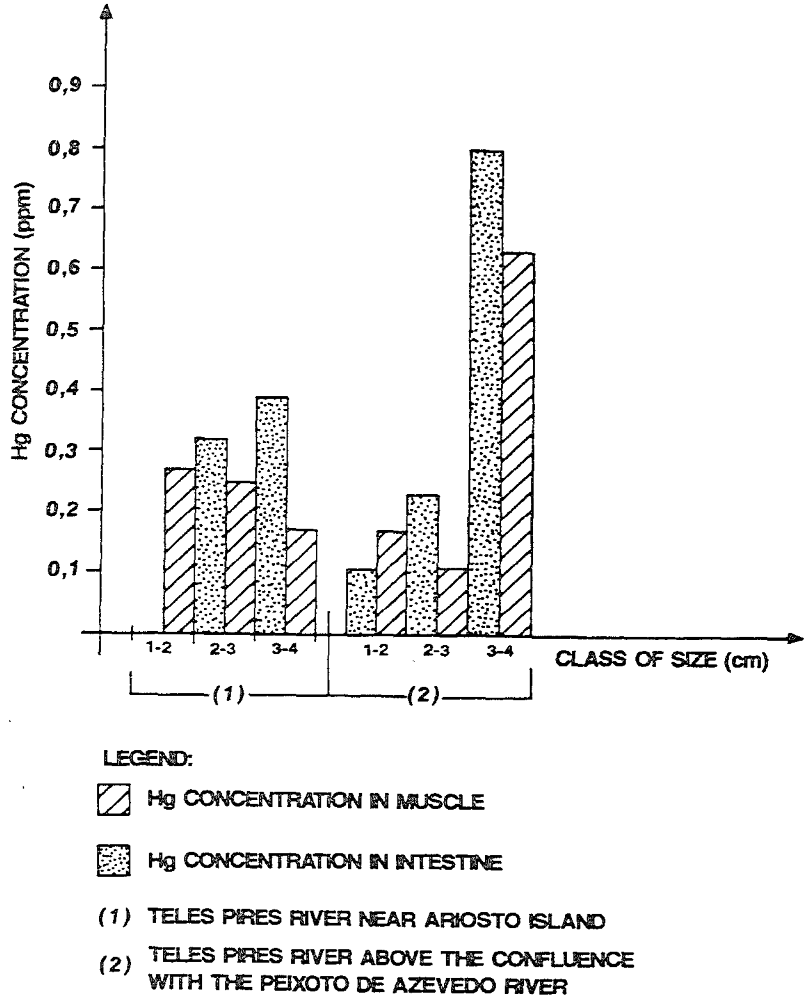


FIGURE 30 - Comparison between the Hg distribution in the musculature and intestine of mollusks

TABLE 25 - Concentration of mercury (ppm) in *Eichhornia azurea* (Sw.) Kunth

PLACE	YOUNG LEAF	ADULT LEAF	AGING LEAF	ADULT ROOT
Teles Pires river	N.D.	N.D.	0.06±0.01	0.37±0.02
Cristalino river	N.D.	N.D.	N.D.	N.D.
Telles Pires river 4km from the confluence with the Peixoto de Azevedo river	N.D.	N.D.	0.15±0.01	*
Nhandu river	N.D.	N.D.	0.35±0.01	*

PLACE	AGING ROOT	ADULT PETIOLE	AGING PETIOLE	STOLONS
Teles Pires river	0.04±0.01	0.14±0.03	N.D.	*
Cristalino river	N.D.	N.D.	N.D.	*
Telles Pires river 4km from the confluence with the Peixoto de Azevedo river	0.26±0.02	N.D.	0.15± 0.01	0.15± 0.01
Nhandu river	0.24±0.04	N.D.	*	N.D.

Eichhornia crassipes (Table 26) shows very much lower mercury contents than in the species mentioned earlier.

Generally speaking, the mercury concentration values were low, although relatively higher in the younger parts. Probably, this higher value in the younger part is related to the high metabolism, due to the growth phase during which a larger quantity of substances is used.

TABLE 26 - Concentration of mercury (ppm) in *Eichhornia crassipes* (Mart.) Solms

PLACE	ADULT BULB	YOUNG BULB	AGING BULB	YOUNG LEAF	ADULT LEAF
Rochedo stream	N.D.	N.D.	0.04±0.01	0.32±0.01	N.D.

PLACE	AGING LEAF	YOUNG ROOT	AGING ROOT	YOUNG PETIOLE	AGING PETIOLE
Rochedo stream	0.12±0.05	0.12±0.01	0.08±0.01	N.D.	N.D.

N.B: N.D. - Not detected up to the equipment limit (< 0.03ppm Hg)
* insufficient mass for analysis.

. Algae

No mercury concentrations were found in *Batracospermum* sp (Table 27). This result also applies to associated algas in their structure.

Cyanophycea filamentosa shows a high mercury content (0.66 ± 0.08ppm). This result includes its periphyton.

Probably, because the structure of the cellular wall of this *Cyanophycea* is more simple than those of the *Batracospermum* and macrophytes, there is a possibility of more assimilation of mercury in its organism.

TABLE 27 - Concentration of mercury (ppm) in Algas

Place	Spacies	Diameter µm	Hg Concentration
Teles Pires river Near Ariosto island Tributary of the Triângulo stream	Cianoficea filamentosa	10	0.66 ± 0.08
	Batraco-spermum sp	8 p/célula	N.D.

N.D. - not detected up to the equipment limit (<0.03ppm Hg).

.Fishes

Of all the fishes studied (Table 28), the species which showed the highest concentration of mercury was *Paulicea sp* (Jaú), caught in the Cristalino river, with a mercury content in the musculature of 0.90 ± 0.04ppm, while in the liver the level was 1.08 ± 0.09ppm. The high concentration of mercury in the liver is related to the size of the organism and indicates that the principal means of entry is through the trophic chain. This content exceeds the maximum limit as much for uncontaminated environments as for human food

(WHO, 1978). Since it is a carnivorous species, a migrant and inhabits river rapids, it is difficult to justify that this bioaccumulation is occurring in the Cristalino or Teles Pires rivers.

Analyzing the same species, although caught in the Teles Pires river, the level of mercury concentration in the liver was high, showing a value of 0.71 $\pm$ 0.08ppm and in the musculature 0.43 $\pm$ 0.02ppm.

It is important to stress that the Cristalino river shows signs of being an environment containing much microbial activity.

In the lake formed on Ariosto Island (flood plain), the mercury values distributed in fishes were low, varying from 0.05 $\pm$ 0.01 to 0.13 $\pm$ 0.02 for the liver and 0.05 $\pm$ 0.01 to 0.15 $\pm$ 0.01 for musculature.

In the rivers which are affected by *baixão* gold mining, usually the values of mercury concentration in the fishes were low, without reaching 0.2ppm of mercury. The highest value was in the species *Bryconops cf. caudomatulatus* (Bicudinho), which was 0.14 $\pm$ 0.01ppm, found in the Aguas Brancas river.

According to verbal information, gold prospecting took place in the headwaters of the Triangulo stream about a year ago.

The fishes caught in the Aguas Brancas river's waters, which are clean, showed sediments deposited in their gills. This indicates that these fishes must have migrated from the Paranaíta river, which has muddy waters.

One of the chief consequences of *baixão* gold mining is the high rate of suspended solids, which can cause the deposition of solids in the gills and also the mass slaughter of fishes through asphyxia.

TABLE 28 - Concentrations of mercury in fishes of the Teles Pires river and its tributaries

Place: Cristalino river

SPECIES	FEEDING HABIT	STANDARD LENGHT (cm)	HEIGHT (cm)	WEIGHT (g)	Hg CONCENTRATION ppm MUSCLE	LIVER
Paulicea sp	Carnivorous	61.0	9.0	4,089.	0.90±0.04	1.08±0.09
Brycon sp	Omnivorous	48.0	16.0	2,723.	0.1±0.01	0.12±0.02
Brycon sp	Omnivorous	18.4	6.8	147.5	0.09±0.01	*

Place: Teles Pires river

SPECIES	FEEDING HABIT	STANDARD LENGHT (cm)	HEIGHT (cm)	WEIGHT (g)	Hg CONCENTRATION ppm MUSCLE	LIVER
Pseudoplatystoma sp	Carnivorous	69.0	6.0	3,095.0	0.28±0.01	0.51±0.01
Hemisorubim sp	Carnivorous	39.0	5.0	685.5	0.39±0.01	0.65±0.03
Serrasalmus cf.	Carnivorous	4(17.0↔26.0)	17.0↔26.0	138.6↔546.0	0.19±0.03	0.19±0.01
rhoumbeus		4(5.6↔15.5)	14.0↔15.5	73.6↔138.6	0.18±0.01	
Hypostomus sp	Forager	12.5	2.0	34.6	0.03±0.01	
Paulicea sp	Carnivorous	58.5	13.5	3,755.4	0.43±0.02	0.71±0.08

Place: Águas Brancas river (mouth of Parnaíta river)

SPECIES	FEEDING HABIT	STANDARD LENGHT (cm)	HEIGHT (cm)	WEIGHT (g)	Hg CONCENTRATION ppm MUSCLE	LIVER
Astyanax sp_1	Forager	20(5.4↔6.9)	2.15↔2.8	208.65	0.04±0.01	*
		18(7.0↔ 10.05)	0.4↔2.8	247.9	0.03±0.01	*
Myleus sp	Herbivorous	19(3.8↔4.0)	2.6↔30.0	46.0	0.02±0.01	*
Curimata sp_2	Hylophagous	6(6.5↔9.5)	2.3↔3.3	118.8 v	0.03±0.01	*
Pimelodus sp	Carnivorous	2(8.3 e 9.4)	1.5 e 1.7	15.8	0.12±0.01	*
Loricariidae	Bottom feeder	15.0	3.7	107.4	0.02±0.01	*
Bryconops cf.						
caudomatulatos	Botton feeder	6(7.3↔7.9)	2.0↔2.2	47.3	0.14± 0.01	*
Sarrasalums	Carnivorous	2(5.5 e 5.5)	12.5 e 2.3	5.8	0.06±0.01	*
elongatus						

Place: Laker near the Triângulo river

SPECIES	FEEDING HABIT	STANDARD LENGHT (cm)	HEIGHT (cm)	WEIGHT (g)	Hg CONCENTRATION ppm MUSCLE	LIVER
Anostomidae	Omnivorous	19.9	5.5	207.2	0.06±0.01	*
Geophagus sp	Bottom feeder	4(5.1↔9.9)	(2.4↔4.0)	92.1	0.13±0.011	*
Erythrinus erytrinus	Carnivorous	2(9.8 e 10.5)	(2.3 e 2.6)	47.5	0.24±0.03	*

Place: Dois Irmãos stream

Rhamdia sp	Carnivorous	12.7	2.3	33.1	0.12±0.01	*
Pimelodus blodii	Carnivorous	4(7.4↔8.3)	1.8↔2.0	35.5	0.09±0.02	*
Astyanax sp_1	Forager	4(6.8↔12.0)	2.7↔13.3	60.7	0.06±0.01	*
Serrasalmus clongatus	Carnivorous	7.9	3.9	76.4	0.06±0.01	*
Anostomidae	Omnivorous	12.3	3.7	50.4	0.09±0.02	*

Place: Ribeirão Rochedo

Myleus sp	Herbivorous	2(4.9 e 5.5)	(3.3 e 3.3)	19.8	0.03±0.01	*
Astyanax sp_2	Forager	2(6.2 e 6.4)	(3.0 e 3.1)		0.05±0.01	*
Pimelodus sp	Carnivorous	3(10.6↔12.2)	(2.5↔2.9)	85.8	0.12±0.01	*

Place: Headwaters of the Triânguloriver

Geophagus sp	Bottom feeder	2(6.5 e 7.3)	3.0 e 3.1	31.8	0.02±0.01	*

Place: Carlinda river

Myleus sp	Herbivorous	2(8.6 e 9.5)	56 e 4.6	54.5	0.07±0.01	*
Anostomidae	Herbivorous	2(10.0 e 10.3)	2.9 e 2.8	53.1	0.18±0.01	*
Bryconops sp	Forager	11.2	2.2	17.0	0.09±0.01	*
Loricariidae	Bottom feeder	5.8	1.2	8.1	0.11±0.02	*

Place: Tributary of the Triângulo river

Erytrinidae	Carnivorous	25.8	6.2	352.9	0.19±0.02	*
Anostomidae	Omnivorous	18.0	4.9	129.4	0.19±0.01	*
Chilodus sp	Hylophagous	14(7.3↔10.1)	2.6↔3.8	234.8	0.08±0.01	*

Place: Lake on Ariosto island

Cichla ocellaris		4(15.1↔21.7)	4.4↔6.3	445.8	0.05±0.01	*
	Ichthyophagous	9(23.3↔26.1)	6.6↔7.3	2465.1	0.05±0.01	0.05±0.01
Hoplias malabaricus		3(24.3↔26.7)	5.5↔7.0	1285.3	0.15±0.01	0.07±0.01
	Ichthyophagous	3(28.6↔31.6)	6.7↔7.2	1994.7	0.14±0.01	0.13±0.02

Place: Flood plain – Laker near the Teles Pires river – Fazenda Geraldo

Hoplias mala baricus	Carnivorous Ichthyophagous	29.5	5.5	410	0.11±0.01	*

* - insuffcient mass for analysis

5.5 Medical Area

· Workers in Gold-buying Shops - A Case Study of Occupational Health

5.5.1 Background information

There are different ways in which mercury, in its differing chemical forms, enters the human organism and is metabolized. Eating food with high mercury levels and inhaling contaminated air in a working environment or in public, are the principal ways which contribute toward increasing a population's exposure to mercury compounds.

Biological monitoring has been widely used in occupational health to prevent the occurrence of adverse effects and as an indicator of exposure, when the ratio between internal and external exposure is known. However, this information is not sufficient for appraising the risk to human health in a populational group.

Urine is the most common indicator used for determining occupational exposure to mercury vapors. The levels of mercury in the urine are used as an indicator of exposure after a latency period of 6 months to 1 year. The kidneys store inorganic mercury, which will be reflected in the mercury levels of the urine.

Several studies have evidenced the correlation between the mercury levels in the working environment and the concentration of mercury in the urine.

After exposure has ceased, the mercury levels in the urine get progressively lower. The ratio of mercury in the air and mercury in the urine in individuals exposed for a long period of time have shown a ratio of 1:2 - 2:5 (WHO, 1980).

5.5.2 Gold-buying shops

The gold-buying shops are the principal target of our investigations. In the town center of Alta Floresta there are 32 shops doing business, of which 20 are intermediaries and 12 deal is securities. This activity, together with 8 banks, concentrate most of the region's economic resources.

The melting in gold-buying shops of gold burned beforehand in the gold fields, is one of the final stages of the gold production. When mercury is burned at high temperatures it volatilizes. The gold solidifies and mercury vapors are eliminated into the atmosphere. This stage eliminates from 1 to 7% of the mercury, since the rest had already been eliminated by burning in the gold fields.

It was found that hoods were being used, in this process, which to some extent reduce the risk of occupational exposure to mercury vapors. However, it was found that these vapors are discharged directly into the outside atmosphere, exposing the community near the gold-buying shops to the mercury vapors. However, samples of mercury in the air of the outside environment were not analyzed.

5.5.3 Methodology

.Target area and sample

Our target was the workers in the gold-buying shops, consisting as much of those who are directly exposed to mercury vapors - through melting roasted gold - as those who do administrative work, although on the same work site. Specimen collection began at the end of May.

Of the 32 gold-buying shops, the 5 main shops chosen according to the volume of their buying were contemplated. Thirty employees

were interviewed (questionnaires attached) and 17 urine specimens were obtained.

The limited number of cases recovered prevented subsamples from being prepared for analyses corresponding to each roasting shop.

The individuals who took part in the sampling (17) were grouped into:

a. direct occupational exposure - melters (M);
b. indirect occupational exposure - the administrative staff and others who share the same physical space (A).

The members of the two chosen groups have an exposure time of more than 6 months. Of the 8 hours work per day, melting the roasted gold continuously occupies at least 5 hours, making up a weekly total of 28 hours during which direct exposure to mercury vapors occurs.

.Collecting urine specimens

Sterilized plastic bottles were furnished. These bottles were numbered according to the questionnaire identification. The interviewed persons were asked to collect about 200ml of the first urine passed on the following day, discarding the first spurt and, as soon as the urine had been collected, to put it in a refrigerator until the specimens had been taken in at approximately 9 a.m. on the same day on which they were collected.

After the specimens had been sent for by the Health Department, they were taken to the Alta Floresta Project Laboratory at the Environmental Department of the Town Council and stored in a freezer at -10°C. Fifteen days later they were forwarded by CETEM to the Carlos Chagas Biophysics Institute at the Federal University of Rio de Janeiro for mercury analysis. They were kept at a low temperature during transportation.

.Urine analysis

The methodology used, according to information received from the Institute for chemical analysis of mercury in the urine specimens, basically consisted of:

. digestion

- for 5ml of urine 10ml of the mixture 1:1 of H_2SO_4 : HNO_3 are added;
- the specimens are put in a double boiler for 30 minutes at an average temperature of 55°C;
- after being cooled in an ice bath, 10ml of $KMnO_4$ at 5% are added to the specimens and left to rest for approximately 12 hours; and
- the excess oxidizing agents are neutralized using hydrochlorate of hydroxylamine (H_4ClNO-NaCl) 12% and the volume is completed up to 50ml with distilled/deionized water.

. reading

- After digestion, the specimens are sent for reading the Hg contents through atomic absorption spectrophotometry, using the hydrides generation technique.

Information on the analytical method used was supplied by the Biophysics Laboratory.

5.5.4 Discussion of results

Table 29 lists the principal characteristics of the persons interviewed.

TABLE 29 - Principal characteristics of the group of workers exposed through their work to mercury vapors in gold-buying shops - Alta Floresta, May,1991.

Identification number	Gold Buying Shop	Sex	Age	Group **	Time in Activity	Symptoms described	Mercury Concentration in Urine (μg/l)±(SD)
3	A	M	29	M	15 m	none	14.75±5.3
14	B	M	38	M	10 years	amnesia metallic taste	15.0±1.5
1*	A	M	29	M	7 years	nervousness pains in hands and feet irritability altered gait and diarrhea	17.3±4.8
11	C	F	20	A	4 years	none	18.8±3.8
5	C	F	35	A	11 years	none	26.8±3.0
22	A	M	30	A	7 m	eyesight problems. irritability	27.0±6.9
2	D	M	29	M	6 years	none	27.3±3.9
8	C	M	29	M	4 years	none	37.8±6.2
10	B	M	23	A	4 years	none	39.2±3.3
6	C	M	20	M	6 years	none	48.9±8.9
9	C	M	22	M	6 years	none	60.3±4.2
15	E	M	33	A	10 years	irritability. altered gait	63.4±4.1
20	E	M	28	M	18 m	nervousness. drowsiness. eyesight problems metallic taste	83.5±34.4
13	B	M	22	M	24 m	eyesight problems	85.5±2.9
21	D	M	30	M	12 m	irritability	85.9±9.7
7	C	M	28	M	24 m	nervouness. eyesight problems. irritability	116.7±2.9
21	E	M	24	M	13 m	irritability. alterered gait	159.9±4.4

* Individual with a history of acute mercury intoxication, internment and treatment, caused by the same activity; ** Group to which they belong.

M = Melters A = Administrative

The mercury concentration levels in the urine are 14.75μg/l to 159.9μg/l, while 76.5% of the cases studied show levels higher than 20μg/l, accepted in literature as normal for someone working with mercury.

In the first group, <20μg/l, individual number 1, with levels of 17.3μg/l and the symptoms described, is an exception, because he has already been interned and treated for acute mercury intoxication caused by the same sort of activity.

After treatment and staying away temporarily, he went back to being a melter.

The administrative staff, in two of the three cases considered, showed concentration levels of 26μg/l, which was higher than other cases of melters whose had been on the job for the same time.

After level 60.3μg/l, all the individuals studied showed the symptoms referred to, which are typical of mercury poisoning.

Table 30 shows the values for individual gold-buying shops. Even considering the lack of statistical significance, due to the number of cases, expressive differences draw attention to possible differential exposure values, which could be the consequence of technological characteristics of the hoods or the type of work.

TABLE 30 - Average concentration of number of specimens in μg/l, according to the gold-buying shop.

SHOP	μg/l	Nº OF CASES
A	19.8	3
B	46.6	3
C	51.5	6
D	56.4	2
E	102.2	3

The five shops chosen are those that do the most gold-buying business.

5.6 Chemistry

The purpose of this study is to provide details of the field laboratory's activities, as from its installation and until the preparation of samples, their analysis and the methodology used.

5.6.1 Installing the laboratory

A room was assigned to the research team on the premises of the Municipal Department of the Environment & Public Works. Wooden benches were made, electric energy and lighting points were installed, as well as a sink with running water.

A survey was made of glassware, reagents and equipment for the Alta Floresta Project. Glassware for general use (beakers, test tubes, pipettes, etc.) and specific items for mercury analysis (kits), reagents for general use (acids, chloroform, sodium hydroxide, etc.) and for specific use (hydrochlorate of hydroxylamine, dithizon and potassium permanganate), as well as equipment like a water deionizer, magnetic stirrer and Bunsen burner, among others.

Part of this material was taken from the Poconé Project and part direct from CETEM/DQI.

5.6.2 Preparation of samples

The samples were collected by the biology (fishes, mollusks and macrophytes), geochemistry (soils and sediments) and ore dressing teams (amalgamation tailings, feed and trough tailings and concentrate).

.Sediments and Soils

The wet samples collected were dried in a covered area so as to avoid direct sunlight. In the field care was taken handling the samples, to avoid their contamination. Of the 131 soil samples, 10 were chosen for wet screening and granulometric analysis using screens of 28, 65, 100 and 200#. Screening was done by hand in plastic bowls. The remaining samples were dry screened in the same meshes and the -200#fractions were separated for analysis.

The samples sent to CETEM were wet screened in the same fractions described above and dried in ovens at 50°C. The +28#fraction was discarded and the other fractions were pulverized to -200#in a porcelain mortar and sent for chemical analysis.

.Macrophytes, Fishes and Mollusks

After collection, the macrophytes were washed in running water and separated into root, petioles, leaves, stolon, etc. Fishes and mollusks were dissected and the musculature, intestine and liver ground up.

5.6.3 Chemical Analysis - Methodology

.Sediments, Soils and Biological Matter

Deionized water and nitromuriatic acid are added to an aliquot of dry sample, heating it to 60°C in a double boiler. After cooling, deionized water and potassium permanganate at 5% are added. Leave in the double boiler at 60°C. Neutralize the excess $KMnO_4$ with hydrochlorate of hydroxylamine 12%, complete the volume and read. The sediment samples were analyzed in the laboratories of CETEM (DQI) and GEOSOL (GEOLAB). The soil analyses were done by Geolab, the laboratory belonging to Geosol-Geologia

e Sondagem Ltda, and the samples of fishes, mollusks and macrophytes were analyzed at the Federal University of Mato Grosso, in the Chemistry Department. All the methodologies adhered to modified techniques of Malm et alli (1989).

5.6.4 Comments

When analyses are made in environmental projects, care must be taken when preparing the samples, considering that normally, such projects are carried out in places far from the headquarters of the research center or institution. A mistaken interpretation of any information may mean a return to the collection site, at much expense. Below are some of the precautions necessary for preparing and analyzing environmental samples with trace and ultratrace levels:

. in the field:

- freeze the sample after collection (this is essential in the case of methylmercury);
- store in an amber glass container (rubber bottle stoppers absorb mercury);
- collect samples using plastic or porcelain tools (spade, spatula);
- do not dry, or dry at a low temperature;
- avoid pulverizing (if possible);
- if necessary, after drying, grind in a mortar made of porcelain, agate or a material which does not react with the elements to be analyzed;
- between one pulverization and another, wash the pulverizer with alcohol (if possible), rinse with quartz, discard the first pulverization of the samples and only use the second pulverization for chemical analysis.

. in the laboratory:

- use a laminar flow hood;
- use a filter in air conditioning for dust and vapors;
- open the samples with pure reagents (lacking Hg and heavy metals);
- make several placebos;
- decontaminate glassware with extra-strength detergents, acid and water;
- use distilled/deionized water;
- do not keep the samples in plastic bottles after opening (case of Hg);
- if dilution is necessary, take care;
- use class A glassware (quality and precision);
- care taken optimizing the equipment is important, as are standards and calibration reagents;
- the analytical method (opening the sample) must be followed very closely, from weighing until reading;
- care with the good condition of the components of the atomic absorption equipment is essential; for example, the hollow cathode bulb at the end of its useful life, as well as a very big variation in signal emission, can cause reading errors;
- use standards of sample control for solving these problems;
- make double analyses, interlaboratory analyses, and
- the Millipore paper filters contain mercury (ppb level) in an irregular manner, where the concentration varies from paper to paper. A way of eliminating or at least minimizing this problem is to make several placebos (more than 5), and find their average. The sodium mass (after using the filters) is usually small (near to 0.001g), which results in a very considerable error in the outcome for small placebo variations.

6. RESEARCH METHODOLOGY

Due to the lack of a specific methodological model for diagnosing the environmental impacts in gold mining areas, it was decided to prepare methodology which would consider the more important environmental variables of this activity.

The procedure followed consisting of a multidisciplinary approach which, based on the special features of gold mining, would produce a set of basic information for understanding gold mining and its association with the environment.

For preparing this methodology, experience gained by CETEM during its environmental studies in the gold fields of Poconé-MT was used as a reference, in addition to academic studies from other institutions.

There are some special circumstances of the kind of organization of the gold mine which makes it an unique mineral activity. These circumstances require the various sciences that study it to adapt their classic approaches to problems.

The adaptations are necessary because of such factors as:

- lack of official information on the activity, which results in extrapolation of data obtained in the field;
- difficulty in making a quantitative appraisal of emissions of solid tailings (silting up) and of mercury (contamination);
- the transient nature of gold mining, related to alluvial deposits which, normally, are widely dispersed;
- technological adaptations and specific procedures for each gold field, and
- lack of interest and erroneous information on aspects of environmental preservation, which results in faulty procedures, although in some cases they are easily reversible.

The method of approach to the gold field was the most associated possible action among the various areas of study, during the field stages and when discussing results. The aim of this procedure was greater integration and exchange of information among the professionals involved, seeking the most varied and complete comprehension possible.

Figure 31 shows a diagram where the basic objectives of the areas of study participating in this project are interrelated. It also shows the tangent points where each specialty receives and provides information to the others.

When analyzing the diagram, examples may be given of some of the principal associations between the specialties, such as:

- a description of the geological and physiographic aspects helps in appraising the impacts caused by gold mining;
- appraising mercury losses during the amalgamation process is important for discussing the results obtained by the geochemical, biological and medical areas when tracking down contamination by mercury, and
- assessment of the degree of mercury contamination in the biota helps in understanding the distribution of mercury tracked by geochemistry in the areas influenced by the gold fields.

The joint action of the teams in the field, choosing the same gold fields and areas for gathering data, contributed toward obtaining possible correlated results.

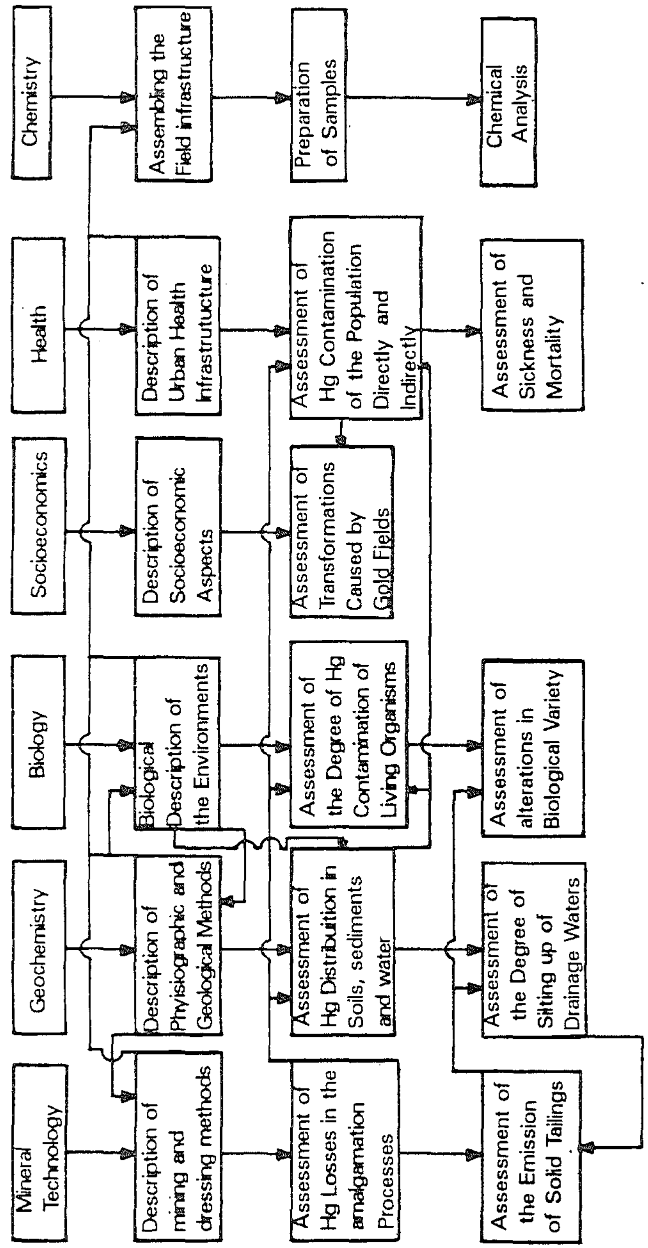


FIGURE 31 - Diagram of associations between the various specialties.

7. CONCLUSIONS AND INTERDISCIPLINARY ANALYSIS OF RESULTS

The gold mining activity in Alta Floresta, Mato Grosso, causes environmental impacts, in that the principal characteristic of its extraction is based on random mining of the ore and on dispersal of solid tailings and of mercury directly to the drainage waters.

Apart from the physical impacts caused by the activity, the inflow of people results in the public services being unable to meet the demand generated by the rapid growth of the population. The direct effect of this imbalance is deterioration of the quality of the Government's attention to the population (Chapter 5.1).

The silting up caused by the *baixão* gold fields can lead to radical changes in the natural course of the secondary drainages, because the mined reserves and the discarding of solid tailings are closely involved with the rivers, sending to them a high rate of suspended solids. This additional load of solids causes an increase in turbidity of the waters, thereby reducing the photic zone (light penetration), and only very resistant wildlife and vegetation manage to overcome this hardship (Chapter 5.4).

In the larger drainages the effect of the incorporation of solids to the water body can be attenuated by the volume of water present. We must consider, however, that these drainage waters where the floating raft gold fields operate - principally the Teles Pires and Peixoto de Azevedo rivers - mine relatively larger amounts of material, if the raft is considered a productive unit. The Teles Pires river is also the final depository of the loads of suspended solids produced by the *baixão* gold fields and carried to their tributaries (Chapter 5.3).

The amalgamation processes, in both types of gold field, do not have control and occupational or environmental protection mechanisms/equipment. The fact that this process does not have a closed circuit causes the dispersion of the mercury to the environment. This dispersion becomes even greater when the mercury in the amalgamation tailings returns through the process of repassing through the primary concentration circuit (Chapter 5.2).

It is essential that much wider use be made of retorts in the phase of the first burning of the amalgam, because this is responsible for the emission of about 75% of the mercury transported to the environment. The mercury emitted during the burning phase undergoes dispersion into the atmosphere, the dynamics of which are little known, and may spread out over long distances. The aggravating circumstance involved in the high percentage of atmospheric emission lies in the evidence found in sediments and water to the effect that the vaporized Hg has greater chemical reactivity, causing increases in the distribution, dispersal and bioavailability of the metal.

Another point of emission of mercury in volatile form are the gold-buying shops which, besides dispersing the metal through the atmosphere, cause it to precipitate into urban soils (Chapter 5.3). Among the group of workers of the gold-buying shops, the mercury dosage in their urine points to a situation of risk to health which tends to affect principally the melters, although employees doing other jobs, but sharing the same working environment, may show concentration levels higher than normal. The symptoms mentioned appear after $63 \mu g/l$ of mercury concentration in urine and coincide with the classic symptomatology. The disparities in the average levels of concentrations found in the various roasting shops seem to indicate differential levels of exposure (Chapter 5.5).

The values found for mercury dosage in biological samples in *baixão* gold fields show that there is a minor process of metallic mercury transportation, restricted more to the panning and amalgamation sites.

The results of this study indicate bioaccumulation of mercury in the trophic chain, with greater contamination of carnivorous fishes which are also more used for human food (jaú, pintado and matrinchã), varying from 0.03 to 0.90ppm Hg in the musculature to 0.12 to 1.08ppm Hg in the liver. This exceeds the maximum limit for fishes set by the WHO (0.05ppm of mercury). There is a clear need for intensifying studies in groups of mollusks and algae, associated with analyses by speciation (determination of organomercurial substances). These organisms are more fixed in a particular place and are therefore less likely to migrate than fishes. Hence it is practicable to use them as bioindicators of heavy metal contamination (Chapter 5.4).

The prospects of studies to be made by CETEM in the area of assessing the environmental impacts, and developing processes and procedures for minimizing such impacts caused by gold fields, have found fertile ground in Alta Floresta-MT, as much from the point of view of the complexity of the local activity, as from that of the need to give support to an extractive activity which is of the utmost importance to the local economy.

Some parts noted in the productive process of the local gold fields can be mentioned as points which could undergo simple changes which, in a relatively short time, could bring environmental benefits.

Some measures for reducing the dispersion of mercury in the environment could be adopted which are, briefly:

1. wider use of retorts in the amalgam burning phase in the gold fields, by making the gold miners aware of the importance of using such equipment for environmental protection and for safeguarding the gold miners themselves;
2. encouraging the use of retorts which have simplified construction designs and which can be used in all the gold fields;
3. the gold-buying shops should begin using hoods with an exhaust and system for retaining the vaporized mercury in a filter, which would mean that both inside and outside the shops would be free from mercury contamination;
4. confining the amalgamation tailings which have been contaminated by residual mercury and which were pulverized during the process, in small dams lined with plastic sheeting or a clay covering. these contaminated materials represent, when mixed with other tailings, the principal direct means of contamination of drainage waters, and
5. avoiding methods used in the gold fields which lead to the use of mercury in such stages as mining or ore dressing, which do not in any way increase the efficiency of the amalgamation process and aggravate the problems of mercury dispersing through drainage waters.

Regarding the silting up of drainage waters, measures for controlling the emission of solids must be accompanied by a more extensive study of the region's hydrographical system, as well as the locating of gold-bearing deposits in relation to the system.

While a more thorough study is not made for building dams, steps should be taken to stop as much as possible the discarding of trough tailings along the river banks. This would avoid their being discharged directly into the drainage waters, which get choked up by their inability to carry the suspended solid matter.

In the case of prospecting gold-bearing deposits under river beds - using floating rafts - it is even more complicated to indicate measures that could minimize the environmental impacts. Perhaps it might be possible to determine the number of rafts which are allowed to work a certain stretch of the river, based on studies made for determining the hydrodynamic properties of river channels as regards sedimentation.

For the floating rafts the amalgamation processes should take the same precautions recommended for handling mercury, both in the amalgam burning phase and in containing the contaminated tailings.

The impacts caused by the gold fields on the socioeconomic structure and which have led to the collapse of public services, such as health, safety, sanitation, etc, can be lessened by:

- recognition of the activity's social importance and its inclusion in the municipality's economy;
- investments in planning gold mining using the 'garimpo' method;
- assimilation of the demand produced by the gold mining community, adapting the Government's infrastructure (in number and quality), considering that this community produces wealth, and
- after this sort of activity as a venture with rights has been recognized, to make people aware of the obligation to preserve their environment, through specific standards and rules which take into account the special circumstances of gold mining by such prospectors.

A study of ore dressing processes and mining methods may bring benefits such as water recirculation, increased efficiency in recovering gold and a resulting augmented profitability, preservation and more advantage taken of gold-bearing deposits.

The environmental disturbances occurring in the region call for a long-term plan for monitoring the effects of mercury contamination and of silting up of drainage waters.

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APPENDIX

INTERVIEW FORM MEDICAL AREA SUBPROJECT: PRELIMINARY DIAGNOSIS OF HEALTH OF PERSONS EXPOSED TO MERCURY - INSTRUMENT FOR GATHERING DATA - ALTA FLORESTA - MATO GROSSO - MAY, 1991

Number:.............Where interviewed:.............

Date:....../....../...... Informant's address:.........

Samples delivered? Urine: Yes ( ) No ( ) Hair: Yes ( ) No ( )

1. IDENTIFICATION DETAILS:

1.1 Name:............................

1.2 Sex: 1 - Male ( ) 2 - Female ( ) 1.3 Age:.... 1.4 Where born:....

1.5 How long in Alta Floresta (months):...............

1.6 Where do you work? Gold fields ( ) Roasting shop ( ).... Other ( )....

2. OCCUPATION:

2.1 What is your job?......... 2.1.1 Company's name:...............

2.1.2 Company's principal activity:...............

2.1.3 Other activities of the company where you work:.........

2.1.4 How many people work in the company?...............

2.2 What type of work do you do in the company?...............

2.2.1 What are your working hours? (how many hours/day?)..........

How many days/week?........ How many months/year?..........

2.2.2 How long have you been working in this job?..........

2.2.3 What do you do in the months when you don't work?..... Where?.....

2.3. OCCUPATIONAL/MIGRATIONAL BACKGROUND

YEAR/AGE	PLACE: (states, cities, others)	OCCUPATIONAL DETAILS	IF ANY, Type of exposure to mercury

2.4 Have you worked with mercury in the past 6 months:

( ) Yes ( ) No. In what way?..... How many hours/day?......

How long?...... How much of mercury do you use per day?.......

3. SICKNESS DETAILS:

Code: 1. Yes. 2. No. 3. Don't know. 4. Not applicable.

CURRENT DATA:

3.1 Do you have any health problem at present? ( )

If so, what sort of health problem?.....

3.2 Are you taking any treatment? ( ).........

If so, what treatment?..........

3.3 Have you been absent from work due to health problems this year? ( )

If so, what sort of health problem?......

3.4 Have you suffered any employment-related accident in the past 12 months? ( ) How many? ( ) How did the most serious happen?........

3.5 Have you suffered any accident going from your home to work or vice versa?

How many? ( ) What accidents? ( )

3.6 Do you have or have you had any health problem caused by work? ( ) If so, what problem (s)?

3.7 In your opinion, what in your work can cause illness?....

3.8 Have you had malaria? ( ) 3.8.1 If so, how many times? ( )

3.8.2 What kind of treatment did you have?.....

3.8.3 Which medicines did you take?.........

4. Personal Details:

4.1 How much do you weigh?.... 4.2 How tall are you?.... Other information:....

5. SPECIFIC SICKNESS DETAILS FOR MERCURY:

Code: 1. Yes. 2. No. 3. Don't know. 4. Not applicable.

5.1 Do you have ( ) or have you had ( ) any health problem which may have been caused by mercury? ( ) Yes ( ) No. What problem?.....

5.2 Have you had any kind of treatment? Yes ( ) No ( )

With whom?.... How was the treatment?.....

5.2.2 Did you take any kind of medicine? Yes ( ) No ( ). Which medicine?....

5.3 Have you already been absent from work due to health problems related to mercury? Yes ( ) No ( ). 5.3.1 For how long?.....

5.3.2 Who recommended your absence?.....

5.4 Have you had any nervous problem? Yes ( ) No ( )

5.5 Do you often have:

Hand tremors ( )	Metallic taste ( )
Face tremors ( )	Insomnia ( )
Leg tremors ( )	Altered gait ( )
Nervousness ( )	Tingling or burning of skin ( )
Irritability ( )	Drowsiness ( )
Eyesight problem ( )	Moodiness ( )
Depression ( )	Others:.........

5.6 Did this nervous problem arise or did it get worse after you began working with mercury? ( )

5.7 Have you been to a doctor because of this nervous problem? ( )

5.8 Do you have or have you had any kidney problems? ( ) If so, what?.....

5.9 Did this kidney problem arise or did it get worse after you began working with mercury? ( )

5.10 Was this kidney problem identified by a doctor? ( )

5.11 Do you have or have you had any skin lesion caused by mercury? ( )

what kind of lesion?....

5.12 Do you have any scar or trace of those lesions? ( )

5.13 Do you hear well? ( )

6. SMOKING AND DRINKING ALCOHOL

6.1 Do you smoke? Yes ( ) No ( ). How many per day? ( ) For how long? ( )

Have you smoked in the past? Yes ( ) No ( ) How many per day? ( ) When did you stop? ( )

6.2 Which types of alcoholic beverage do you usually drink?

( ) Doesn't drink ( ) beer ( ) wine

( ) spirits (sugar cane liquor, vodka, alcohol...) ( ) others ( ) unable to say

6.3 Have you at any time felt you should reduce the quantity of alcoholic drink or stop drinking? ( ) doesn't drink ( ) yes ( ) no

6.4 Do you feel annoyed with yourself about the way you drink alcoholic beverages? ( ) doesn't drink ( ) yes ( ) no

6.5 Do you usually have an alcoholic drink in the morning to alleviate nervousness or a hangover? ( ) doesn't drink ( ) yes ( ) no

7. FAMILY COMPOSITION

Code: 1. Yes.. 2. No. 3. Don't know. 4. Not applicable.

7.1 Do you live with your family? ( ) Yes ( ) No

7.1.1 Who lives with you (of your family)? (Name, sex, age, kinship)

7.1.2 If you don't live with your family, where does your family live?

7.2 Do you work where you live with your family? ( ) Yes ( ) No

7.3 How long?

7.3.1 Do you have children? ( ) Yes ( ) No. If so, how many?

7.4 Is your wife pregnant? ( ) Yes ( ) No

7.4.1 If so, how many months?

7.4.2 Does any child have a health problem? Since birth?

7.4.2.1 If so, what problem? 7.4.3 Have you ever lost a child?

8. BRIEF INFORMATION ON LIVING CONDITIONS

8.1 Monthly earnings: Up to minimum salary ( ) 1 to 3 min. salaries ( ) 3 to 5 min. salaries ( ) above 5 min. salaries ( )

8.2 Education: ( ) illiterate ( ) did not complete elementary school ( ) completed elementary school or more. Last year when exams passed:

8.3 When you are ill where do you seek medical care?

8.4 What is your house like (type of wall, roof, etc)?

8.5 Does your house have: ( ) piped water ( ) connected to sewage mains or septic tank

8.6 What do you usually eat for breakfast, lunch and dinner?

9. FISH CONSUMPTION

Local varieties

1. Tambaqui	14. Mapara	27. Pirarara
2. Curimata	15. Filhote	28. Acará
3. Jatuarana	16. Pintado	29. Piraíba
4. Pacu	17. Pirarucu	30. Jaú
5. Dourado	18. Pescada	31. Bacu
6. Jaraqui	19. Carapara	32. Aruana
7. Branquinha	20. Liso	33. Piranha
8. Tucunaré	21. Traíra	34. Others (say which):
9. Sardinha	22. Piramutaba	....
10. Pirapitinga	23. Bodo	....
11. Cubiu	24. Acari	....
12. Mandi	25. Piau	....
13. Surubim	26. Cara	....

9.1 Do you eat fish? ( ) 9.2 How often?......

9.2.1 Consumption per species in decreasing order: Fishes most consumed in the

summer:........ Fishes most consumed in the winter:........

9.3 Summer

9.3.1 Weekly frequency of consumption in the summer: Every day ( ) 3 - 5 days/week ( ) 1 - 3 days/week ( ) 3 times/week ( )

9.3.2 Daily frequency of consumption in the summer: Three times a day ( ) Twice a day ( ) Once a day ( )

9.4 Winter

9.4.1 Weekly frequency of consumption in the winter: Every day ( ) 3 - 5 days/week ( ) 1 - 3 days/week ( ) 3 times/week ( ) once a week ( ) twice a month ( )

9.4.2 Daily frequency of consumption in the winter: Three times a day ( ) Twice a day ( ) Once a day ( )

9.5 Origin

9.5.1 Origin of fish in the summer: Local ( ) Regional ( ) Don't know, bought ( )

9.5.2 Origin of fish in the winter: Local ( ) Regional ( ) Don't know, bought ( )

9.6 Way in which fish is acquired in the summer: Caught ( ) Bought ( ) Exchanged ( ) Given ( ) Others......

9.6.1 Way in which fish is acquired in the winter: Caught ( ) Bought ( ) Given ( ) Others......

9.7 Which fish did you eat this week?....

9.8 How many kilos of fish does your family eat per week?....

9.9 How many kilos of fish does your family eat per day?....

9.10 How is the fish prepared:....

Interviewer's Comments:....

Interviewer's signature:....