

TRACING MERCURY IN THE AMAZON

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1. Introduction

Mercury in large quantities discarded and dispersed in the Amazon environment-. It is not easy for us to form a concrete image about it. The major reason may certainly be the overwhelming scale of nature there containing an endless green carpet of dense forests and the Amazon River that spreads like an ocean with numerous tributaries flowing into it. When I heard of mercury pollution in the region nearly a decade ago, my first reaction was to crack a joke imprudently. I said that most of the quantities of mercury must be purified by Mother Nature and be brought into the Atlantic Ocean; at the worst, slightly polluted shrimps caught in the mouth of the river might possibly be exported and eventually tasted by the Japanese. Actually, however, things are not so simple as they appear. It now seems unlikely that the whimsical mercury will dissipate away from the Amazon. On the contrary, mercury is being accumulated in some fishes in the form of organic mercury. Recently there is even a report that sick men are found among the so-called Garimpeiro, who complain of nerve troubles. They say that the possibility of mercury poisoning cannot be denied although it is yet to be proved epidemiologically.

It is less than 10 years now since it became known that a vast amount of virgin forests was being lost year after year because of the slash-and-burn method of agriculture in the Amazon causing the fear of a decline in the oxygen supply source for the world. At that time the LANDSAT satellite was releasing images depicting scars on the face of the earth as if caused by skewering. Overall, however, the Amazon still remains a treacherous green region and at a glance, one can hardly believe that mercury pollution is extending and accumulating. In reality, however, danger is already there for the ecological system.

Now, let's briefly look back upon the past. In 1970s, tin mining was brisk in Rondonia, a western part of the Amazon. Then in 1980s, a Serra Pelada gold mine

was discovered on a worldwide scale just on the east side of the famous Carajas iron mine located in the eastern area of the Amazon. Thus the Amazon suddenly became a huge gold field and attracted swarms of miners called Garimpeiro. The total number was said to be 300,000 or 500,000. The quantity of gold that has been produced in the region for the last 20 years is estimated to be roughly 1,500 tons or more, although accurate statistical values are unavailable. Most of the gold was mined at Garimpo and extracted through the amalgamation process.

Ores like gold dust are mined at open-air or underground pits and are taken out. Then foreign substances are removed from the ores by using a sluice or by panning to bring about a high grade concentrate of gold. Further, metallic mercury is added to it to make gold amalgam, which is to be burnt in the field to become coarse gold or sponge. Garimpeiro is a general term of laborers engaged in the work and mines are called Garimpo. To perform the work, heavy equipment and power are sometimes utilized, but most of the mining there basically depends on manpower and is a primitive one as such. Currently, at large-scale mines, the world trend is toward the cyanide process and the carbon-in-pulp process instead of using mercury. Nevertheless, the amalgamation process is suited for small-scale, individual style operations. Collection of gold is easy by this process, so it is still prevalent over the world to result in pollution by mining.

It was five years ago that technical collaboration from Japan was requested for "Centro de Estudo e Análise de Mercúrio para a Amazônia" (Amazon Center for Mercury Analysis and Studies). Meanwhile, in a field survey conducted last year, the Mercury Analyzer PM-2 and its peripheral instruments developed by Nippon Instruments Corporation (NIC) displayed high performance as expected. It has been verified that they can play a leading role in monitoring mercury pollution for the time ahead. The report here is intended to deal with the progress of this project,

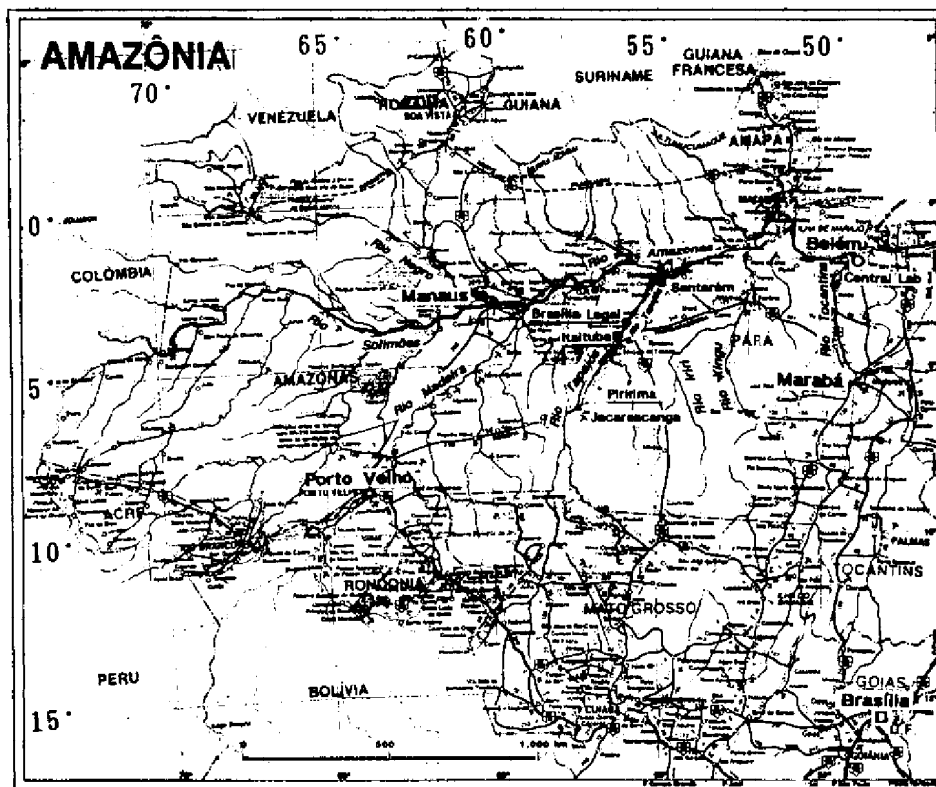
while spotlighting the birth of the PM-2. But I will not touch on the geochemical and environmental analysis of the survey result because the present stage is hardly the moment.

2. Mercury Pollution in the Amazon and Its Survey Techniques

The Amazon region in Brazil occupies 5 million km², about 60 percent of its land, with a population of about 15 millions, which is only 3 people per km² in terms of density. (The area called the Amazon district is at about 11°S Lat. and northward, as shown in the attached map.) This region is covered by thick forests and is characterized by a tropical rain forest climate over a vast, complex basin. The Amazon is known to be a region where globally important, diverse forms of life exist. And they are sensitive to human activities.

The geological features of this region are complicated incorporating economically important resources. So far, large primary and secondary mineral deposits have been discovered including manganese, bauxite, copper, tin and gold in addition to iron ores on a worldwide scale. A number of enterprises are

participating in the development of such enormous underground resources, and a great number of Garimpeiro at a 200,000 to 300,000 level are engaged in gold mining. Further, more than a million of laborers are supporting them. Gold mining by Garimpeiro is primitive. In particular, out of mercury spent in large quantities for extraction of gold, only 20 to 30 percent of them is recycled. The rest is discharged in the environment. Thus far, over 1,000 tons of mercury have been dumped around the river and about the same quantity or more of mercury have been released into the atmosphere in the form of gas and dispersed. They will fall down on the ground again by rainfall covering wide areas. The total amount of them is estimated to be 3,000 to 4,000 tons in terms of metallic mercury. The present survey is aimed to seize the current status of environmental pollution caused by the mercury discharged from the Garimpo mine and to examine a monitoring system designed for estimation of the future effects. Since, however, the present-day knowledge of the physical, chemical and biochemical behaviors of mercury artificially dispersed in the realm of nature is still insufficient and much has to be known yet. It is



Brazilian Amazon Region

therefore necessary to refer to and study well the research achievements in other fields concerning the dispersion of mercury and conversion of its chemical form.

In the natural world, many of metal deposits, of hot water type deposits in particular, are accompanied by a mercury dispersion halo in the circumference of the mineral body. In view of the fact that such halos are distributed comparatively locally, an investigation method has been established in which mercury in the soil or rock is treated as an indicator element. Also known is a mercury dispersion which relates to metamorphic areas in a geothermal region or which is accompanied by a spurt of hot water or vapor. Accordingly, survey of the dispersion halo of mercury is regarded as an effective means of investigating layers that store the terrestrial heat.

The mercury concentrations in uncontaminated areas of the Amazon are estimated to be 0.1 to 0.5 ppm in rock, 0.3 to 0.5 ppm in soil and 0.00003 to 0.0002 ppm in river water. For the mercury discharged from the Garimpo mine, the urgent problem is to know in what form it has infiltrated into the Amazon's background and dispersed. Detriments to the health by mercury pollution are reported in some areas. But so far as the survey by DNPM/CETEM (to be referred to later) for the past several years is concerned, not so remarkably fearful solutions have been recognized about riverbed deposits, fish, etc. Because the relevant information is little and fragmentary, one cannot assume the whole picture. It is possible that part of the mercury thrown out into the natural world will be sooner or later methylated. The current status of the mercury dispersion should therefore be investigated thoroughly to enable future estimation as well.

To learn the actual conditions of mercury dispersion, the generally conceivable method is to investigate the distribution of the total amount of mercury and its possible variations by detailed sampling using established statistical techniques along with chemical analysis. But the objects of sampling are so diverse including the atmosphere, water, river deposits, soil, plants, fish and human body samples. Therefore, from the aspects of time and cost, it appears impossible to implement proper sampling over such a vast polluted region. Surveys conducted so far tell that it is difficult to grasp the mercury distribution to extract anomalous areas.

The mercury dispersed in the atmosphere will precipitate and move as a smog, and will fall down onto the earth by rainfall. Then applied with more intense sunlight, the mercury will be vaporized and dispersed into the atmosphere again. The mercury will also move away by water flow. Regarding a cyclic sequence of the mercury behavior near the ground surface, its outline can be known through the mercury concentrations in the atmosphere, soil and soil gas. Among them, the mercury concentrations in the atmosphere and soil gas are easily measurable with the PM-2. When attachments are utilized, water analysis can be made also. Since, moreover, data can be known at each measurement point, the obtained data can serve for succeeding measurements. In short, it is possible to screen and mesh those areas that need in-depth investigation.

3. Backdrop of Conducting Surveys

Aware of the need for emergency measures to prevent mercury mining pollution in the Amazon basin, the Brazilian Government called on Japan for technical cooperation (1989). But the request was not complied with immediately. Some time later, negotiations were also made for assistance from Germany and a loan from the World Bank, but they resulted in failure.

Since 1973, I have been engaged in work associated with Brazil and have made tours to the Amazon several times for resource surveys and inspections. From these experiences, I have gained some level of knowledge about the environmental and geographical features of that region, being strongly attracted to the nature there at the same time. For the mercury problem, the DNPM under the MME is in charge and I have had a long acquaintance with the DNPM head. About a decade ago, he was in the midst of worry about how to cope with the problem. I therefore made a proposal to him. I pointed out that coupled with the environmental survey, data collection on the distribution of resources must be made to design an appropriate development system with stress laid on the prevention of mining pollution. As a matter of technical cooperation from Japan, my proposal was to conduct the feasibility study of such a development system by picking up several model areas centered on the midstream basin of the Tapajós River. The aim was modernization of the mining technology in order to uproot the cause of mercury pollution. In response, the DNPM requested cooperation for the "Project of Environmental Monitoring of Garimpo Mining Areas in the Brazilian Amazon Region". Unfortunately,

however, no appreciable progress was made. The reasons were that Japan feared that a reform of the Garimpo mining could involve a change of the Brazilian social system and that the point at issue was environmental pollution due to the chemical element mercury (allergy to “Minamata” mercury in Japan). A feeling of “awe” toward the Amazon might be mingled, too.

In the meantime, in 1990, the NIRE started research of mercury analysis (ITIT) jointly with the DNPM (completed in 1993). Also, the Japanese Government established a training center for prevention of mining pollution (CECOPOMIN) at the DNPM/Sao Paulo branch as a matter of the project system technical cooperation. For the purpose, five experts were dispatched from Japan together with equipment and materials for training of technicians (completed in 1996). In 1993, the DNPM changed the substance of its pending request to “Centro de Estude e Anàlise de Mercúrio para a Amazônia” for environmental monitoring. Its idea was to induce Japan to extend a similar project system technical cooperation to Brazil. But in view of possible competition with the above training center, the case was handled by individually arranging the dispatch of experts, offering of equipment and acceptance of trainees. However, unlike the project system technical cooperation where everything is planned and implemented over the span of five years under a consistent philosophy, individual arrangements are all on the yearly basis. It is therefore difficult to tackle things in an affordable manner, and all the more so in the present case involving lots of problems to study and overcome. Against such a backdrop, I was dispatched from JICA, Japan in 1994 as a geochemistry specialist. Together with analytical experts, we examined the present status of mercury pollution survey in Brazil as well as the relevant research setups at the government and university level there. We then mapped out a master plan (5-year plan) for the mercury pollution monitoring survey. Although I was dispatched on the individual basis, the project itself must proceed under a consistent philosophy, and so I asked external research engineers engaged in mercury pollution to join our project so that techniques to be employed by us can be as comprehensive and universal as possible. At the same time, we reexamined the list of equipment and materials to be brought from Japan and made its renewal. Initially I thought of taking with me the NIC's PM-1A to apply it to an environmental measurement test but my plan was not realized. Later

on, I also gave up the use of a system to collect airborne substances for atmosphere observation, which I intended to offer to Brazil together with the PM-1A. What then followed was switchover from the initially planned system to a new system such that the measuring device itself is mounted inside a balloon so that measurement of mercury concentrations and data storage can be made at the optional altitude by remote control. The development of a new model PM-2 was started accordingly. Thus, owing to these circumstances, the preparation of other sampling equipment was also delayed to result in postponement of our pilot survey for monitoring until fiscal 1996.

4. Two Governments' Organs concerned with Promotion of the Project and Respective Fields in Charge

Project designation:

CENTER FOR MERCURY STUDIES AND ANALYSIS IN THE BRAZILIAN AMAZON

a) Brazil side

1) Executing organ (C/P): MME, DNPM/Brasilia head bureau

(Coordination): DNPM, DMCAM to make general control

(Central Labo. I: equipment): DNPM/Belem branch bureau; DNPM/Itaituba branch office
Central Labo. II shall be installed at DNPM branch bureau to primarily take charge of analysis for environmental samples.

2) Organ for technical cooperation

(Central Labo. II: engineers assignment): Evandro Chagas Research Institute (IEC/Belem)

By entering into an agreement with DNPM, IEC shall primarily take charge of preparing samples related to the human body as well as analysis and epidemiological study of them to make the most of the IEC characteristics as a tropical disease research laboratory. This time, part of analytical equipment, e.g. a gas chromatograph and an atomic absorption analyzer shall be installed in its analysis room.

(Engineers assignment and analysis):

By entering into an agreement with DNPM, CETEM shall cooperate for monitoring.

CETEM has been investigating mercury pollution since 1989. In connection with this project, a gas chromatograph, an atomic absorption analyzer, etc. shall be installed in its analysis room. (Technical cooperation): Cooperation from Universidade Federal (UF) at Rio de Janeiro, Brasilia and Para

b) Japan side

1) In charge of general control: Ministry of Foreign Affairs, Economic Cooperation Bureau, Technical Cooperation Division

2) Executing organ:

(Dispatch of specialists): JICA, Expert Assignment Division, 2nd Expert Assignment Department

(Procurement of equipment and materials): JICA, Expert Assignment Division, 2nd and 3rd Expert Assignment Departments, Procurement Division; JICS

(At site): JICA Brazilian office (Brasilia headquarters, Belem branch)

3) Ministry & agency in charge:

(Geochemistry): Ministry of International Trade and Industry, International Trade Policy Bureau, Economic Cooperation Department, Technical Cooperation Division, Environmental Protection and Industrial Location Bureau, Mine Safety Division

(Analysis): Environment Agency, Environmental Office of Overseas Environmental Cooperation

5. Study of Mercury Dispersion in the Amazon Region

The mercury polluted region ranges widely, covering the atmosphere, ground and water spheres, but most closely related with the human life are likely to be:

(1) Pollution around Garimpo affecting the atmosphere, soil, river water, river bottom deposits and fish:

Caused by extra metallic mercury dumping, mercury evaporation, and mercury gas due to amalgam combustion.

(2) Ambient atmosphere of gold purchase places and precious ornament processing places as well as soil pollution:

Caused by refinement of amalgam and sponge.

Mercury discharged from its generation source through dispersion, draining and waste disposal causes pollution of the atmosphere, water and soil. The pollution befalls even to living things. Mercury is also propagated and transferred via space. Such pollution may be classified into a type of flow like flowing water and smoke, and a type of accumulation, e.g. in soil, sludge and living things. In the latter case, two instances may be considered further. One is mere deposition as a residue and the other is concentration in organisms. A huge amount of moisture on the surface of a humid ground is volatilized and dispersed by intense sunlight and returns to the atmosphere. That active ascending current is fanned by a northeast trade wind and is blown against the Andes to cause rainfall in the inland Amazon. The initial moisture will thus return to the ground again. About a half of those rainfalls is said to be circulating water. Is mercury unrelated to such behavior of water?

From the result of surveys thus far conducted, the quantity of mercury discarded into the environment is estimated to be 1.3 to 4.0 kg per 1 kg of gold produced at Garimpo mines. The reason why there is such a wide difference in the numeric value may probably be different levels of mercury handling techniques involved. According to the DNPM statistics, the average quantity of discharged mercury at 800 Garimpo mines is 1.7 kg. It is surmised that out of the discharged mercury, 50 to 60 percent was dispersed in the atmosphere by amalgam combustion, and 5 percent by evaporation. It is also surmised that 50 to 60 percent was discharged during amalgam making process, and 5 to 10 percent in the form of metal in the mercury recovery process. There is a report, moreover, that the quantities of mercury discarded in the atmosphere can reach 65 to 83 percent of the total. Anyway, there is a good reason to believe that most of the primarily discarded mercury has dispersed in the atmosphere.

6. Pilot Survey for Monitoring Project

(1) Orientation for the survey

This survey was a preliminary one to select effective means suitable for the monitoring survey of mercury pollution in the Amazon region. Its aim was therefore to find out proper measures with attention paid to the following points. In the survey conducted in 1996, emphasis was laid on tests of the Mercury Analyzer PM-2. Sampling of river water and riverbed deposits

was also made carefully using various equipment. Detailed investigations were made in particular about a lake carrying resident water by the Tapajós riverside, since the lake's environment was feared to have something to do with methylation. An investigation plan was also made for mercury pollution of fish of a catfish family living on the riverbed, but this plan was not materialized. It is a matter of course that the investigation activity in a region like the Amazon River area is decisively dependent on the performance of a boat that is utilizable.

a) Operations at Garimpo mines, the major generation source of pollution, are quite unstable. They are distributed over a broad range as far as 65,000 km² in the midstream region of the Tapajós River alone. These mines, totaling 100 or so, are diversified in scale, and they have been operating for the past 30 years or more as the pollution source. Even today, mercury is irregularly generated from many and unspecified Garimpo mines and it is difficult to determine the major sources.

b) Because the evaporation and dispersion of mercury take place broadly via the atmosphere, rain water, river, soil, vegetable, fish, etc., sampling and analysis by statistical techniques would require an enormous amount of samples that are too much to handle. Screening by any means is indispensable.

c) A virtually unexplored virgin forest zone is the object of investigation.

(2) Technical study of the measurement method of mercury concentrations in the atmosphere

While the PM-1A allows direct measurement of mercury concentrations in the atmosphere and soil gas near the ground midair sampling is necessary for measurement of the atmosphere high up in the sky. According to our initial plan, a long Teflon fluoro-resin tube for sampling would be pulled up together with a balloon, and at each of the prescribed altitudes a ground pump connected to the tube would be run to induce the midair atmosphere to the PM-1A for mercury concentration analysis. However, upon making thorough technical examinations of this method along with related experiments, we found out the following.

a) The pipe should exceed 200 m in length. Even if Teflon is used as the pipe material, more than 50

percent mercury loss is likely due to its adhesion to the pipe inner wall, etc. Moreover, this mercury adsorption rate is variable in addition to the difficulty of cleaning the pipe interior.

b) Time loss is great. Namely, for each measurement, regardless of whether the pipe length is 30 m or 210 m, for instance, full exchange of the sample gas within the pipe is necessary. The required time is considered to be 10 minutes or so per measurement location including the time for purge and changeover.

c) Handling is not easy. The pipe for sampling needs to be fixed and unfixed to and from the mooring cable at an appropriate interval in the course of ascending and descending.

Finally, in consideration of the much peculiar physical and chemical properties of mercury, it was decided to load a balloon with a mercury measuring device and thereby to conduct in situ measurement of the mercury concentration in the atmosphere at different altitudes in steps of 30m up to 210m in maximum. The problem was that the PM-1A was too heavy to be loaded onto a balloon making necessary a 40 percent increase in the balloon capacity compared with PM-2. Moreover, the available balloon had none of data logger and remote control functions, not to mention a facility for atmosphere temperature and wind velocity recording. Remodeling to incorporate these functions was found considerably difficult, and therefore the development of a new device capable of meeting the above requirements was taken up. For details of the newly developed Mercury Analyzer PM-2, the reader may refer to the specifications available from NIC, its manufacturer. The balloon for use was a Kitoon (Kite balloon) type of 85 m³ capacity using helium gas. The winch was newly designed and made out.

(3) Pilot survey in 1996

This survey, which also incorporated a training plan for DNPM engineers, was carried out at three sites-itaituba city, Piririma Rato River, and Brasilia Legal Curi Lake. Described below is mainly the real aspect of atmosphere and soil gas measurement with the PM-2.

i) Transportation of equipment

For a 1,000km air route from Belém to Itaituba, the surveyors took two packages containing the PM-2 basic unit, accessories and a computer weighing



P. 1 Instructions given on PM-2 by Mr. Hoshino, NIC at DNPM/Itaituba.



P. 2 Gold purchase places on both sides of the road. The Tapajós River lies beyond the road.

about 70kg in total by a commercial flight. The rest of heavy items weighing about 2 tons in total comprised three packages of the balloon main body, mat sheets, stakes, etc. weighing 250 kg, three winches weighing 400 kg, and other mining equipment. Transportation by ship would naturally have been needed in an ordinary case taking 3 to 4 days. Actually, as we were pressed for time, we took them by air with cooperation extended by Brazilian air force. Regarding 60 helium gas cylinders about 3 tons in weight, they were transported over 1,000 km of waterway between Belém and Santarém, followed by 300 km of overland travel on a truck.

From Itaituba to Piririma, both the personnel and the PM-2 were taken by air taxi (170 km, 40 min) while the balloon and other heavy items were transported on a truck (50 km) and further on a motor boat (250 km). For a 60 km route between Itaituba and Brazilia Legar, the personnel traveled together with all equipment by a large boat, which afterward anchored on the shore of the Tapajós River. We used this boat as our base and started the survey.

The experiences we got from a chain of these transportations can serve as a precious reference for our future monitoring plans.

ii) The number of the surveyors was eight who came from DNPM, CETEM and IEC. In addition, there were seven supporting engineers.

iii) For operation of the PM-2 and the balloon, Mr. Hoshino of NIC gave us a lecture (P. 1) as well as practical training.



P. 3 Gold refining work at a gold purchase place in Itaituba.

iv) For the power supply for the winch, a portable generator (200 V, 2 kW) was used.

1) Survey of Itaituba City

Itaituba City is the center of Garimpo mining along the Tapajós River, a tributary of the Amazon River, with a population of 100,000 odd people. In the city there are many gold purchase places, large and small, totaling 30 (P. 2). At these gold purchase places, lumps of amalgam once burnt at Garimpo are burnt again for refinement (P. 3), and thereby gold is quantified and purchased. Regarding the mercury vapor discharged on the occasion, large purchase stores usually recover the mercury by setting up a



P. 4 Preparations for flying a balloon, at Itaituba.



P. 5 The ascending balloon with PM-2 suspended, at Itaituba.

cooling tower; nevertheless, a large part of the mercury is discharged into the atmosphere.

a) Measurement of midair mercury concentration with the PM-2

After borrowing a ground owned by the army and located at the western outskirts of Itaituba City, we flew the balloon and carried out the atmosphere observation. The site was about 1.5 km west of the urban district center and was roughly on the leeward. We kept away from a curious crowd attracted to flying of that colorful balloon. Fortunately, soldiers were on guard for us, so we could moor the balloon under no apprehension (?).

At the time of the first test measurement while the balloon was descending, we encountered an unexpected happening. There suddenly occurred a thundershower and the balloon was furiously fanned by the strong wind. By the combined efforts of 7 to 8 people, we barely managed to secure the balloon with a mooring net, all of us being wet to the skin. An iron pipe framed tent prepared by the army collapsed, too. It appeared likely that the maximum instantaneous wind velocity was 20 m/sec or more. Such a sudden



P. 6 The moored balloon, at Itaituba.

gust of wind was hardly imaginable in view of a breeze blowing at 1 to 2 m/sec just before that. And its onrush was so fast. From then on, we made it a rule to conduct the balloon observation only in the forenoon and to perform measurement during the balloon ascending. By the way, no lightning arrester was equipped to the balloon.

Thus, measurement was made during the balloon ascending at different altitudes in steps of 30 m up to 240 m in maximum. This means that there were nine measurement points. The required time was about three hours including the time for preparatory work (P. 4) such as base mat laying, helium gas feeding (approx. 12 to 13 gas cylinders), measurement itself (P 5), and balloon mooring (P. 6). Another one hour must be taken into account if all of the balloon, base mat, etc. should be pulled out. After leaving the moored balloon as it was for ten days, the quantity of gas required for replenishment was about a half of the cylinder capacity.

The mercury concentration, atmosphere temperature and wind velocity at each altitude were measured by remote control and the date and hour was put. The data readable on the display was stored in memory for subsequent printout. For the direction of a wind, the direction of the balloon was measured from the ground.

Earlier, a certain research report said that a mercury smog may not rise so high. We relied on it and set up the maximum altitude for measurement accordingly. But from the result of our measurement on that occasion, we could not verify its truth. Rather, we suspect that the mercury smog can go higher up in the sky, Next time, we would very much like to aim at higher altitude as possible up to, say, 500 m while adequately providing against sudden changes of the

weather condition like a thundershower and a gust of wind.

We came to notice some minor improvements to be made for handling, such as a simpler way of suspending the PM-2 to the balloon, prevention of heavy rolling due to a strong midair wind (adjustment of suspension rope), and simplified installation of the tail to the balloon. Nevertheless, the measurements with the PM-2 went on very smoothly and the device never became wrong over the duration of one month and a half in continuing measurement by moving. It is compact enough, lightweight and easy to operate. It endured a long distance via the routes of air, land and water, and withstood repeated shocks in transit and reloading. It remained in order throughout even under sudden changes of weather and high temperatures exceeding 40°C.

NIC has already accomplished assembling of the GPS into the PM-2, and examinations are under way to mount a satellite communication system on it in the future.

Table 1 shows an example of the measurement result of mercury concentrations in the atmosphere.

b) Measurement of soil gas mercury concentrations in Itaituba urban district

The city is about 5.5 km from south to north and extends about 6.0 km east and west. On the south edge lies the Tapajós River and gold purchase places

gather alongside the river. Upon conducting measurement per 300 m x 200 m density unit, wide variations of the mercury concentration were detected to the extent of 20 to 330 ng/m³ around the area of densely gathered gold purchase places. The concentration lowered to 20 ng/m³ in areas away from about 1 km from the urban district center and decreased further to 10 ng/m³ in the surrounding areas 3 to 5 km away. Around the houses dealing with precious ornament processing, however, 100 to 150 ng/m³ concentrations were measured locally. The concentration in the atmosphere near the ground surface was 2 to 3 ng/m³.

Measurement of the soil gas mercury concentration was made twice at each measuring point in order to avoid the effect of local contaminations, and the 2nd numeric value was adopted, respectively. Since these measuring points were subjected to direct sunlight where the temperature could rise beyond 50°C, we used a parasol for the PM-2 and packer. It was found possible to carry out about 15 to 20 measurements in one day.

The survey has proved that measurement of the soil gas mercury concentration can be performed efficiently with the PM-2.

c) Measurement of the mercury concentration in air inside gold purchase places

The mercury concentration in air inside stores provided with modern facilities including a mercury

Table 1. Mercury concentrations in the atmosphere up in the sky of Itaituba City.

		(Position) GPS: Lat. 04°17'00" S, Long. 56°00'03" W								
	Height	0	30	60	90	120	150	180	210	240
1st time	Hg (ng/m ³)	5.5	6.25	2.5	—	6.00	—	10.3	1.50	—
	Wind director (°)	90~120								
8/13	Vel. (m/s)	1.7	5.5	5.3	—	3.0	—	5.0	4.4	—
	Height	0	30	60	90	120	150	180	210	240
2nd time	Hg (ng/m ³)	5.0	3.75	3.25	9.50	4.75	3.00	2.75	2.50	13.8
	Wind director (°)	70	90	90	70	50	40	50	50	50
8/23	Vel. (m/s)	0.4	0.7	1.2	0.7	1.1	0.7	1.0	0.5	1.8
	Temp. (°C)	31.9	31.1	31.4	31.1	30.8	30.8	30.6	30.3	30.4

recovering unit was 4 to 6 mg/m³, while the concentration inside poorly equipped stores attained to astonishing 200 to 6,450 mg/m³. In the latter case, if the PM-2 were run for one minute, the amount of mercury gas inhaled into the device would be 50 times its maximum range and several million times in terms of the minimum indication unit to result in contamination of the piping. Therefore a syringe was used to collect air (10 ml) for measurement and analysis with the PM-2. Nevertheless, the contamination was notable and took a few days for cleaning. In such a case if the tygon tube used as a joint is replaced, cleaning may be made by applying a purge for a few times. Anyway it seems advisable not to use the PM-2 in such highly polluted places.

d) Mercury pollution in DNPM office The mercury concentration in air in office rooms frequented by many people were found invariably high at a 200 to 500 ng/m³ level. It was 50 ng/m³ in an inner bedroom connected by a corridor. A similar tendency was noticed in other places, thus suggesting the need for proper measures against mercury pollution for a place of pretreatment of monitoring samples as well as for the analysis room. It is important to keep the footwear and clothes of men entering the room from mercury contamination. It is also necessary to pay close attention to ventilation of the indoor air. In this respect, one effective measure is to conduct pretreatment and analysis in an isolated monitoring ship.

2) Survey at Piririma

Piririma is about 170km to the south of Itaituba and is located 40km upstream of the Rato River, a tributary of the Tapajós River. It is one of Garimpo mines where there is a camp. It is situated at the north end of the designated region of Tapajós Garimpo mining.

There we carried out the following-atmosphere measurement with the PM-2 hung by the balloon, measurement of soil gas around the camp, and investigations of flowing water, deposits, fish and collection of test samples for a mercury pollution survey of the Rato River.

The result shows that the mercury concentration in the atmosphere was 1 to 3 ng/m³ and the corresponding value in soil gas was generally 5 to 15 ng/m³ and 48 ng/m³ in maximum.

3) Survey at Brasilia Legal



P.7 Taking out helium gas cylinders from the mother boat, a pasture at the entrance of Lake Curi.



P.8 Mercury measurement in midair atmosphere above the pasture at the entrance of Lake Curi; a tiny PM-2 can be seen.

There is a small village called Brasilia Legal about 60km downstream of the Tapajós River from Itaituba. For the survey on that occasion, we used a boat of 50 tons or so as our mother boat. It was one used locally as a passenger boat. A total of 15 people including 8 surveyors plus a pilot, cook, etc. went on board. The boat towed two small motor boats to provide for an inland survey. We cast anchor at the entrance of a pasture spreading along the riverside (P. 7) and conducted investigations of the atmosphere (P. 8). The balloon observation utilizing the posture turned out to be quite efficient, since a broad flat ground could be used without leveling work and since we did not need to bother about interference from outside. Our survey mission happened to be timed with the dry season, so we expected little rainfall. We therefore gathered rain water with a sheet (3x3 m) set up on the ground at a corner of the balloon base. We had to recover the water as soon as possible for fear of contamination by dust mixing; on the top of that, we

had to protect what little water we had from being stolen by oxen and horses in the pasture.

What should be considered for future monitoring in the Amazon where overland access is extremely difficult is that it needs enormous money to set up observation spots on the ground. There is a limit about it. What matters also is possible mercury pollution within the facility and installation. In contrast, utilization of a developed waterway can substantially extend the sphere of action while saving costs. The ship to serve as the base can be isolated, too, thus offering a measure against pollution as well. As for boats locally procured, however, their engines and other machines are inferior and frequently cause troubles. The boats are exposed to the open air with no partition like a window or wall. Makeshift curtains made of vinyl sheet are too powerless to resist thunderstorms and swarms of insects that attack every day. Even taking a meal is difficult, not to mention proper measures against malaria. Pretreatment of collected samples cannot be made, either. The most effective way is therefore to load measuring devices on a mother boat sufficiently equipped to compete with hostile environments of the Amazon and to conduct atmosphere observations by utilizing pastures scattering in many places.

7. Concluding Remarks

In July 1992, a treaty to prevent global warming was signed at “The United Nations Conference on Environments and Development” (global summit). Also adopted on the occasion were “Statement of Principles for Forests” and “Convention of Biological Diversity”. A number of problems involved in the Amazon were pointed out at the conference. Brazil's anguish deepened as the principal party concerned, being surrounded by loud voices of apprehensions for the effect of mercury on the ecological system, and the threat of Minamata disease in particular. The voices

were raised against the backdrop of the world's urge to protect tropical rain forests.

Regarding mercury pollution surveys, the EU also has been proceeding on the relevant project since 1994. It is a three-year plan in cooperation with Para State Government. Incorporated in the plan is setting up of a mercury analysis room at three places including Santarem. These setups are aimed at epidemiological survey of mercury, education of workers engaged in mining & industry and fishery, and establishment of clean mining technologies. In addition, researches of mercury pollution are under way by the concerted efforts of CETEM, São Paulo University and other research institutions.

Because of its past history, Japan's technical cooperation is under the fixed gaze of nations and organizations the world over regardless of its form and scale. Now through the pilot survey conducted last year, the newly developed PM-2 has proved that mercury concentrations in midair atmosphere and in soil gas can easily be measured with it. As such, this device offers a powerful tool for the promotion of mercury pollution monitoring.

In retrospect, the contrast existing there in front of us was extreme indeed. That is, moving around in pursuit of a trace amount of mercury in the harsh and wild Amazon. And the high precision measurement called for in very rough surroundings.

My strong feeling is that we should proceed on surveys while coping with severe natural environments and securing the minimum comfort of engineers involved, their safety and health. I sincerely hope that from this year onward the monitoring survey of mercury pollution may fully get going, where the survey team will take waterway on a monitoring mother boat, thus shifting its life base from one place to another in the jungles of the Amazon.