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REPORT ON THE MINING POLLUTION IN NEW CALEDONIA

by

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South Pacific Commission
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SOUTH PACIFIC REGIONAL ENVIRONMENT PROGRAMME

Noumea, New Caledonia

TOPIC REVIEW

REPORT ON MINING POLLUTION IN NEW CALEDONIA

by

M. Benezit
The Director of Mines and Energy
Noumea, New Caledonia

NOTE : While the following topic review paper concerns only a single South Pacific territory, it is a territory with one of the longest continuous histories of mining activity and one of the most advanced research and control programmes. The lessons it contains concerning the environmental problems associated with mining activity and the efforts required to control them are applicable to most mining projects on high islands in the South Pacific region.

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SOUTH PACIFIC REGIONAL ENVIRONMENT PROGRAMME

REPORT ON MINING POLLUTION IN NEW CALEDONIA

by

M. Benezit
The Director of Mines and Energy

This report aims at summarising information on mining pollution collected to date by the Department of Mines. It should make it possible to define the exact extent of damage caused by mining prospection and extraction operations and thus serve as a background paper for the setting up of a coherent effective control programme.

Over the years, mining pollution phenomena have become more extensive and serious:

- new prospection and extraction techniques are associated with increasingly powerful machinery;

- more than a quarter of the mainland is covered with peridotites and therefore lends itself to mining;

- extraction centres are scattered over all the ultra-basic (peridotite) areas;

- ore is extracted at increasing depths because of depletion of the rich veins, which means that ever greater volumes of tailings must be disposed of;

- cyclones and the rugged terrane of the mining areas encourage erosion of bare surfaces and displacement of loose materials.

Our assessment of the noxious effects of mining is not without shortcomings: signs of pollution cannot always be quantified as well as one would wish since the size of the Territory and communication difficulties preclude constant and effective monitoring.

Mining pollution, actual or anticipated, is however sufficiently wide-spread for an attempt to be made to outline the situation as a whole. It now affects large numbers of people, at individual and community level, and large tracts of land, and is all the more serious as some of its effects are irreversible. In the last few years, however, some improvement has been observed. Partly as a result of government action, mining companies have been led to exercise more and more care in their operations.

Mining activity, which causes this pollution, has gone through a phase of stagnation followed by one of regression: the number of mining centres considerably decreased after the boom (1970: 24 centres, 1974: 35 centres, end of 1980: 11 centres). It can therefore be said without exageration that mining damage in New Caledonia is now, and henceforth will be far more often caused by old abandoned mines than by mines still in operation. However, for political and psychological reasons, complaints from individuals will probably not follow the same pattern.

I. LEGAL IMPLICATIONS

From the legal standpoint, mining activity is governed by exceptional legislation: despite the fact that it destroys the substance which forms its object and is detrimental to land surface conservation, mining is nevertheless encouraged in all countries for imperative reasons of State.

The legal solutions adopted are thus frequently compromise solutions.

Powers are shared between the Government and the Judiciary and the Territorial Legislation reflects this shared responsibility by making separate provisions for two types of cases of mining damage:

(a) In the case of prevention or reparation of damage the Government (Department of Mines) shall subject the miner to control and surveillance (technical and administrative monitoring) and, if necessary, shall take action itself.

However, for this action to be legal, the damage must affect or threaten public security, conservation of water resources or public thoroughfares*.

(b) In the case of repairing damage caused by mining activity to a third party or neighbouring property and in the absence of an amicable arrangement between the parties, the party which considers itself injured shall have recourse to a Court of Law and may, if the Court so orders, receive compensation corresponding to the value of the losses incurred.

Both these procedures naturally run parallel and sometimes even overlap, when both private interests and public security are jeopardised.

At all events, the Government must attempt to act as arbitrator and, for this purpose, a Mining Pollution Commission was created and made responsible in 1968 for assessing the noxious effects and damage arising from mining and in 1973 for prevention of mining damage.

Within the limits set by the Government and under the protection of mining legislation, the miner remains free to undertake whatever mining operations are necessary regardless of damage caused to third parties, provided, of course, that this damage is repaired. For this reason, he is at present simply required to declare his activities (art. 39 of Decree 220 of the Mining Resolution). Government control has been strengthened with regard to large companies which are obliged to conclude formal Agreements with the Territory.

As regards reparation for damages to third parties, articles 33 (B-2°) and 34 of this mining decree of 13 November 1954 stipulate:

Article 33 (B - 2° - para. 3)

Whenever land occupation for mining purposes deprives the title-deed holder or traditional owner (in the case of community-owned lands) for more than one year of the use of his land or if, after mining activity has ceased, the land is no longer suitable for cultivation, the traditional owners or deed holders may demand that the land be purchased by the miner. Any area of land that is very seriously or extensively damaged or degraded must be purchased, if the traditional owner or deed holder so requires. The land to be bought is always estimated at double its pre-occupation value.

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* Measures taken in application of Articles 40 of the mining decree of 13 November 1954 and 212 of the mining resolution dated 22 August 1959.

Article 34

The mining claim holder or authorised operator is required to make good any superficial damage he may have caused by his operations. In this case, however, compensation only amounts to the exact value of the damaged sustained.

II. CAUSES AND FORMS OF POLLUTION

1. NATURAL CONDITIONS

Nickel deposits are located in the upper portions of mountain masses, generally at altitudes of between 500 and 1,000 metres.

These mountains are extremely rugged with :

- a crest that is relatively narrow and has a fairly marked divide. Flat or depressed areas are rare, which means that there are few natural sites for *in situ* disposal of failings.

- very steep sides right to the foot of the mountains, easily exceeding the angle of the natural slope of the piles of ore and waste materials. Tracks and roads are difficult to establish and loose materials cannot stay in place.

Local climatic factors aggravate the topographical problems.

If we recall that annual rainfall in France is around 700 mm, the rainfall pattern in New Caledonia can most eloquently be illustrated by the following figures:

- 500 mm of rain fell in 24 hours at the Camp des Sapins (Thio) during the cyclone "Alison", but up to 650 mm/day had already been recorded on other occasions.

- Rainfall of 50 mm within a quarter of an hour is not exceptional.

This naturally has consequences on the flow of streams; severe floods occuring only a few hours after such heavy rains and subsiding almost as quickly.

In the mining areas, drainage basins are small and extremely steep. When calculating the size of antipollution structures, it is wise to provide for water drainage at a rate of 23 m^3/second/km^2, corresponding to a rainfall of 100 mm/hour with a runoff ratio of 0.7.

In such climatic conditions considerable erosion obviously occurs. Measurements taken by ORSTOM in the Dumbea Basin (a non mining area) have shown natural erosion to be over 100 tons/km^2/year.

2. MINES

These are usually open-cast, single-exit mines on horizontal terraces (or "benches") 5 to 10 metres high.

The surface laterites (overburden) are scraped off with power shovels and bulldozers and carried in trucks to an authorised disposal site (dump).

The same is done with the primary waste (barren boulders) which is removed directly at the mining surface.

The rough ore is carried by truck to a rotating screen (trommel). The fine marketable ore is then carried by truck or belt conveyor to the sea and the secondary (tailings) waste is also dumped in an authorised disposal area.

Nickel deposits in New Caledonia have two main features that affect the environment:

1 - The waste ore ratio varies considerably from one deposit to another, and in the same deposit as mining proceeds, but is normally around 2.1:1 with the following composition:

- Laterites (overburden)	0.8
- Primary waste (barren boulders)	1
- Secondary waste (tailings)	0.30
	2.10

In the last few years, for an average production of 6 million tonnes of ore, 13 million tonnes of waste have been dumped annually.

Furthermore, since the ore layer is not very thick, large areas are stripped each year for mining and associated operations (roads, storage platforms). An estimated 22 hectares are stripped for a production of 1 million tonnes.

3. DIFFERENT FORMS OF POLLUTION

In no particular order of importance, they are as follows:

- destruction of the plant cover
- red colouring of streams and changes in their flow patterns
- dust

- displacement of solid materials
- cuts in the natural mountain
- changes in soils and plant species.

(a) Destruction of the plant cover

Mining areas are almost always covered with scraggy shrubs; forests are rare.

In itself the disappearance of this vegetation is a source of considerable concern but there is now some hope of re-establishing a plant cover on tailings that are not too stony.

(b) Red colouring of streams and changes in their flow pattern

Streams turn red in colour as a result of erosion of the stripped zones where the soils laid bare are generally more vulnerable than the surface hardpan. These zones moreover have a high water retention capacity because of their slighter slope and greater thickness of weathered materials. The streams flowing down from the mining areas are affected in two ways:

. Volume of water: flow rates are reduced and in dry weather may dwindle to nothing (water supply problems); in heavy rains runoff is, on the other hand, increased.

. Quality of water: water takes on a reddish colour as in the case of erosion, but far more so as the leached surfaces are more extensive.

(c) Dust

Whenever there is a spell of dry weather, a lot of dust is produced by mining operations, especially the haulage trucks.

Up on the mine, this dust is detrimental to workers' health and security.

Down in the plains, it affects dwellings and farms. Pasture lands become less fertile 100 to 200 m on either side of the road and cattle shun this area.

However, these problems disappear as soon as the rains fall or when mining activity ceases.

(d) Displacement by water of solid materials

Water running over loose earth becomes loaded with solid materials. The diameter of the materials varies with the slope and flow rate. Fine particles are always carried down even if the larger ones stay in place.

When boulders are set in motion, they roll down the mountain side but are rarely transported very far on the flats. They generally remain entrenched in the channel bed which they partly fill, causing the stream to become wider, shallower and slower flowing. The action of transported boulders sometimes causes a mini canyon to be formed in the soft B horizon of the piedmont. As a result, the piedmont slope is destabilised.

Embankments, bridges and culverts located in the immediate vicinity of the mining area can be affected by deposits resulting from this displacement, and their efficiency suffers in consequence.

Small particles are always carried much further, often as far as the estuary.

A tiny fraction of them does settle on the channel bed where the gradient is not too steep but their thickness is insignificant upstream from the zone of tidal influence.

A larger part settles on the flood plains when the flood waters go down.

A single flood can result in deposits of several centimetres on the flats.

Lastly, a final part reaches the estuary where it can constitute deposits up to 1 metre thick because of alternating currents in the tidal zone and floculation which occurs upon encounter with salt water.

Experience has shown that sea currents do not transport these materials very far, that the shorelines affected are mainly mangrove swamps and that there are no visible deposits beyond 3 metres in depth.

Apart from some cases of reddish water in catchments, deposits of solid materials remain the most crucial problem at present.

(e) Cuts in the natural mountain

These are deep linear or contour excavations of varying size, such as roads, drilling platforms, mining benches.

These works often give rise to heavy erosion, either by their sole presence which breaks the natural balance of the land or because they channel surface runoff into torrential streams which flow outside the formed beds.

(f) Changes in soils and plant species

Climatic, edaphic and biodynamic conditions make the spontaneous recolonisation of mined areas extremely difficult. Twenty or thirty years after cessation of all activity, a mining site is often still completely bare of vegetation. The edaphic medium in mining areas is always unfavourable for plant growth. Vegetation in these areas is remarkable for its slow growth and lack of vigour, and the number of species which recolonise the abandoned mines remains quite small.

On the polluted alluvial plains, the Ca/Mg imbalance inflicted on the soil causes its fertility to diminish steadily in proportion to the thickness of the deposits. Damage appears to be ascribable more to reduced photosynthesis and respiration in the leaves that became coated with laterites during floods rather than to mineral deficiency or toxicity problems. However, when alluvial deposits are particularly thick, a reduction in organic matter and nutritive element content can give rise to plant malnutrition and a slowing down of growth. The most productive plants then tend to die out and be replaced by hardy, ubiquitous species that are low-yielding or of no agricultural value whatsoever.

III. THE HAZARDS - AND MEASURES TAKEN TO OBVIATE THEM

The damage caused by pollution seems now to have become irreversible. There is good reason therefore to fear that new mining activities undertaken in not yet degraded areas, will cause similar damage. Added problems of a special type may also occur:

- Destruction of unique plant species
- Degradation of particularly vulnerable zones (shorelines, seabeds).

Before examining some special cases, let us briefly examine the general measures taken by the authorities to reduce the risk of new environmental damage to a reasonable level compatible with continuing mining activity:

. Creation of a Commission responsible for the control of mining pollution as per order of the Secretary-General of the Territory (letter No. 10-77/SGAD/AG dated 16 February 1973). This Commission took over from the "Commission responsible for assessing problems and damage caused by mining activity" (created by Resolution No. 68-373/CG dated 11 July 1968).

The first Commission had proved ineffective for control purposes since it was not entitled to intervene until the damage had actually occurred. In its new form the Commission for mining pollution control inspects future mining sites before any work is started and lays down technical regulations for the prevention of excessive pollution on the surrounding area.

. Establishment of Protected Areas: the purpose of these is to guarantee the quality of the public drinking water supply and, in general, to ensure the conservation of nature and, in particular, forests.

Protected areas established to date are of two types:

- those resulting from the mining decree dated 13 November 1954 (articles 8 and 31) which forbids mining prospection and operations or strictly controls them in certain areas.

- those resulting from application of non-mining regulations on the protection of water catchments or afforested reserves, which prohibit any polluting activity. This second type of protected areas was not at all coordinated with mining legislation, and respect of them is not legally enforceable with regard to miners.

On 1st January 1981, there were 22 protected areas of the first type covering 334,071 hectares.

There are many more protected areas of the second type (virtually one per municipal district and many special ones) but they cover a smaller total surface. A map showing the boundaries of protected areas of the first type has been attached to give an idea of their extent in relation to the whole of the Territory.

. Research on the natural environment and changes brought about by mining activities

This is a programme set up jointly by government departments and ORSTOM.

It has been described in detail in Section VII.

. Reafforestation trials:

Erosion of denuded zones and displacement by water of earth and rocky tailings resulting from mining operations constitute the chief cause of environmental degradation.

An effective way of controlling this degradation is by replanting of a tree cover, first on the tailing and later possibly on the benches of mines that are no longer in operation.

The first trials were undertaken on laterites in the south of the island in March 1971 by the Centre Technique Forestier Tropical (Tropical Forestry Centre) CTFT at the request of the COFIMPAC Company (INCO-BRGM).

A further trial was set up, also in the south, by the PENAMAX Company in November 1973.

In February 1974, ORSTOM on behalf of SLN did a trial planting of a tree cover on old tailings at the Poro Mining Centre. CTFT took over from ORSTOM in February 1978.

Initial practical conclusions that can be drawn from these trials are set out in Section VII.

In addition to the regulations and research efforts just described, the authorities have been urging mining contractors to develop techniques for reducing the impact of mining pollution. Techniques that effectively stabilise waste materials and arrest washing away are briefly described below:

1 - Stabilisation of waste materials

(a) Choice of disposal site. Criteria for choosing a waste dump are the existence of a depression whose downhill opening, if there is one, can be easily sealed off. The drainage basin of the chosen site must be as small as possible so that the dump can be easily waterproofed. Naturally, no permanent spring or stream should flow through the site and the chosen zone must first have been thoroughly surveyed to ensure that no exploitable nickel deposit will be sterilised by the dump. Where a deposit is shown to exist, its exploitation should be envisaged allowing the site to be utilised later as a dump.

Sites chosen on the above criteria often necessitate trucking of waste materials over quite a long distance and therefore a choice must be made between economic constraints (haulage cost) and the advantages of possible sites.

(b) Construction of seal. The seal is to prevent materials from moving downhill, under their own weight where there is a steep slope or pushed by the runoff waters that can never be entirely obviated.

The seal is generally built of large rocks; it must be sufficiently massive to withstand the pressure of the waste materials. However, the pressure is fairly small because of the relatively strong cohesion of lateritic waste.

In order to increase the utilisable storage height without having to construct a very large structure (width and volume increasing rapidly with height) the seal can be built as a series of steps at an angle smaller than that of the natural slope.

(c) Waterproofing is aimed at reducing runoff in the dump, since water running through the waste can cause a serious landslide and in any case always leads to pollution of streams.

Runoff water is diverted through a channel built right around the site and discharged downhill from the seal into a settling dam (described further on).

(d) Waste disposal (grading and compacting): the laterite overburden and tailings are trucked to the dump and a bulldozer is used to spread out the heaps of waste material. Generally the compacting effect of trucks and heavy equipment rolling over the lateritic materials is sufficient to give them adequate cohesion. In some cases however specific compacting has proved necessary, its purpose being to increase the cohesion and stability of the lateritic mass and thus to be able to store a greater volume in a given site (through buildup to a greater height).

Increased cohesion of the laterites in addition helps to prevent washing away. Water seepage through the compacted waste is much reduced and provision of rock fill drains (at the base of the dump and on some intermediary contours) facilitate water discharge without affecting the stability of the mass. The end objective is to artificially recreate the consistency of laterites in their natural location.

The laterites to be compacted are spread out in layers about 30 cm thick. If their water content is significantly higher than what is acceptable for obtaining optimum compaction (Procter optimum), the material is allowed about half a day to dry off. The most suitable compacting equipment is the self-propelling smooth-banded compactor.

This compaction method was developed by the Société Le Nickel and is being used in the Kouaoua (Méa) and Thio (Kongouhaou) mines operated by this company. The outer slop of the waste dump is protected against erosion by hard-surfacing with stones. On the lowest contour a 2% counter-slope is made to prevent too much surface runoff flowing along the base of the dump slope.

Reafforestation trials on stabilised mining waste were set up two years ago. The results have been encouraging both on an old conventional waste dump and on a modern compacted dump.

2) Interception of river - transported materials

(a) Filtering dams

Wherever there is a waste dump, whether or not it is compacted and whatever protective measures have been taken on the site (sealing, water-proofing) the surface flow from the dump will inevitably be slightly red. To prevent this runoff from badly polluting streams right down to the sea, filtering retaining dams have been developed. These are smallish structures built right across the stream bed, generally at an altitude where the latter is still very narrow and in a reasonably flat quiet reach, with large and medium-sized rocks so as to keep the structure fairly porous. The Water seeps through such a dam slowly part of the load carried in suspension will be precipitated. Some sedimentation already occurs upstream from the dam, due to a marked slowing down of the current.

The main unknown factor in this type of structure is the time it will take for the "filter" to become clogged and completely watertight. When this occurs an overflow has to be provided.

The cost of such a dam ranges from 0.5 to 3 million CFP francs.

(b) Settling dams

On wide, heavily polluted streams construction of filtering dams is not feasible, for flow-rates are so high and variable that the structure would eventually be washed away.

On large stream therefore proper heavy dams need to be constructed, watertight with a side overflow for periods of high flow. The foundations and lateral anchorage, as well as the overflow, must be carefully designed. Such a project can only be worked out by an engineering firm or department must be implemented under strict specialist control. If the dam is not perfectly watertight, fissures or cracks will eventually jeopardise its stability.

The cost of this type of dam ranges from 5 to 15 million CFP francs according to the size of the stream.

When combined with a natural earth bank at the lowest boundary of the mine and a channel to direct surface runoff towards the settling dams, these measures reduce pollution to a minimum and for the time being there is not much more to be done. Already at this stage the effect of anti-pollution measures on production costs is considerable.

* * *

The procedures described above are now applied, at least partially, on all active mining sites. However, as was pointed out earlier, there are many more old abandoned mines than active mines in New Caledonia at present. The construction of settling dams is the only feasible solution in the latter case since most, if not all, loose waste materials are already well on their way to the sea. Maintenance of these dams is fairly complicated. A permanent solution to the problem is to revegetate degraded areas, both the depleted mine benches and the waste dumps, in order to hold the earth down. Replanting trials undertaken are part of an ongoing programme that will be described further on.

IV. THE DIFFERENCE BETWEEN OLD AND NEW MINES

One clear indicator of the difference is the number of complaints received over the years. Very rare before 1965, complaints were frequent from 1965 to 1972. Since 1972 only two serious complaints have been recorded, both in 1976.

In 1977 the Department of Public Works issued a warning concerning silting by mining waste at certain bridges on territorial highway No. 1.

In 1978 a Thio cattle farmer reported abnormal cattle mortality in his herds, but this could not be with certainty ascribed to pollution of his pastures, although the latter was an observed fact.

In 1979 and 1980 no significant problem was reported.

It must be pointed out that rainfall in 1977 and 1978 was much below average and that only two cyclones occurred during this period, Marion and Bob which, moreover, hardly affected the mining districts.

The action taken since 1973 by the mining pollution control Commission thus appears to have been effective, and miners seem at last to have become aware that it is in their best interest to prevent damage rather than have to pay damages to people living in the area, and sometimes be compelled to close down their mines.

Another explanation for the reduction of mining pollution since 1974 is the significant decrease in production which occurred after the 1970 and 1971 boom years. The subsequent slump caused many small mining centres to cease operations and production to be confined to about fifteen large centres.

The table hereunder shows the pattern of changes between 1960 and 1980:

YEARS	Number of active mining centres	Annual production
1960	31	2.3 million tonnes
1965	22	2.6 " "
1970	24	7.0 " "
1971	54	7.7 " "
1972	40	5.5 " "
1973	34	5.8 " "
1974	35	7.0 " "
1975	36	6.7 " "
1976	31	5.9 " "
1977	27	5.8 " "
1978	11	3.2 " "
1979	12	4.3 " "
1980	11	4.6 " "

75% of the total tonnage to date was produced after 1965 and 38% of this tonnage between 1965 and 1972.

It can be asserted that, with a very few exceptions, no mine nowadays constitutes a serious pollution hazard.

The very strict measures that mining operators are now obliged to take are very largely a consequence of the damages caused by past mining operations.

While, with the newly developed techniques, it is possible today to exploit a mine with only minimal damage to the natural environment, there is nothing, or virtually nothing to be done about pollution from previous mining sites. The waste from these old mines has already been carried far down creeks and rivers loading the beds and spreading out over low-lying lands when floods occur.

Apart from the, occasionally very high, compensatory payments that mining operators have had to make to owners of polluted riverside lands, no action has yet been initiated to try and restore these lands to the stage where they can once again be used for agricultural and pastoral purposes.

One of the main difficulties lies in the fact that responsibility is very hard to apportion, as sharing it out on the basis of the tonnage produced takes into account neither the waste/ore ratio and hence the total volume of waste dumped, nor where or how disposal was effected, some dumps holding the waste materials much better than others. In addition to this, the whereabouts of many former mining operators is now unknown which makes any project based on their financial contribution unfeasible. Preliminary studies for and implementation of such projects will therefore most likely have to be financed by the government, at a time where revenue from mining activity is dwindling!

* * *

V. THE EFFECT OF FUTURE MINES

The list of future mining operations, whose impact on the environment must be evaluated as from now, is as follows:

. The Kopeto B2 deposit

The Kopeto B2 mine is located north of Nepoui, on the Pouembout side of the Kopeto mountain and should be operational in the coming years.

The Pouembout valley, a predominantly agricultural district, has up till now remained free of any mining pollution. One can easily understand the concern farmers in the district are feeling when one sees what mining has done to the Thio, Houailou and Poya valleys.

A very strict mining procedure based on maintaining a natural earth embankment downhill from any excavation has been developed for this particular deposit in cooperation with the Department of Mines and the pollution control commission. Dumping of waste will be done on the Rivière Salée (Salty River) side of the mountain, with all possible precautions. A settling dam on the Rivière Salée will round off this anti-pollution system. Pollution in the Pouembout valley should therefore be kept minimal.

. The Northern Districts Project

It is planned to establish a nickel smelting plant in the Koumac area, taking the ore from the Tiebaghi plateau. The slopes of this plateau are as yet virtually free of mining pollution and the planned production of 2 million tonnes of ore per year and of 30,000 tonnes of refined metal definitely represents a serious threat to the environment, not only on land but also in the lagoon waters.

As this project is only at the preliminary study stage, there is still time enough before implementation to find acceptable solutions and to compel the operators of the industry to protect the natural features in this district.

VI. COST OF ANTIPOLLUTION MEASURES

It is difficult to cost antipollution measures because totally effective and adequate methods are rarely applied. For the time being, the only company capable of applying the full set of available pollution control techniques is the Société Le Nickel.

The only measures the small miners in general are taking is to haul tailings to a dumping site that is more or less well sealed on its downhill side but rarely waterproofed with channels.

The following cost estimates are based on miners' records. All cost figures are per tonne of marketable ore produced:

- carrying waste to a dump: 50 to 70 CFP francs/T.
- construction of a small rock embankment at the base of the dump: 10 to 20 francs/T.
- carrying of laterites, waterproofing of dump sites, construction of a seal downhill and compacting: 75 to 100 francs/T.

These costs do not include redemption of equipment.

As a result of these measures, production cost (pre-tax) of one tonne of ore will increase by 5 to 10% according to whether the protective procedures aim at minimum or maximum protection.

In the case of the small mining operations, the increase in production cost would probably be around 5%.

These costs were calculated from figures for the year 1977. In the past much less was done to combat pollution and the increase per tonne as a result of control measures was certainly much lower.

However, to the expense of control measures taken must be added the compensatory sums miners have had to pay out to inhabitants of pollution-damaged areas. This aspect of the problem is far from insignificant.

On some occasions the territory has received compensation, in the form of works carried out by mining operators to rebuild deteriorated roads, which is "repair" rather than "reparation".

In some cases damage caused was neither repaired nor compensated because the victims were reluctant to go beyond an attempt at amicable settlement. For instance the territory never instituted legal proceedings against miners for pollution of streams, although the silting up of river beds in the mining areas has been a very significant phenomenon, one that has serious consequences in periods of heavy rain. To restore the drainage capacity of some of the affected rivers (the Thio and the Dothio rivers for example), would require large-scale and very costly work.

V. THE EFFECT OF FUTURE MINES

As we saw earlier, mining operators are trialling various techniques (dams, compaction...) designed to control pollution. The effectiveness of these techniques is now a well-established fact so that one can no longer really speak of trials and trialling, the only aspect of the work needing further monitoring being the stability of the protective stuctures and possible changes. Though not final, qualitative and quantitatives results are now available.

On the other hand, as regards re-afforestation and the effect of pollution on fauna, flora, and especially the agricultural potential, many unknown factors remain to be elucidated.

1) Reafforestation trials

At the initiative of a private mining concern planting trials were undertaken by the CTFT on mining soils in the Plaine des Lacs.

In the same area two other companies from 1973 onwards funded a comprehensive study of tree species lending themselves to reafforestation on lateritic soils, and of erosion. This study was also conducted by the CTFT.

In 1975 ORSTOM started planting trials on a tailings dump in the central mountain range (Poro). These were taken over in 1978 by the CTFC which carried them to completion and concurrently planted a new trial plot at the Camp des Sapins (Ouenghi).

Initial results: we now know what tree species to plant to hold the soil, both on the southern laterites and on the peridotites in the mountain range. We also know how to produce high-quality plants of all these species in the nursery.

Planting techniques are well run-in.

Unknown factors remaining: Trials for the establishment of a grass cover have not been very successful and selection of suitable species will need to be undertaken.

Though we know which tree species develop most quickly, we do not know which live longest. Another vast domain of investigation that has not yet been broached is what to do with the old mine benches. These denuded and eroding terraces cover a far larger surface area than the tailing dumps. They have one advantage in that vehicles and equipment can operate on them fairly easily, but they also have the enormous disadvantage of offering very little loose earth and virtually none at all where intense leaching has occured.

2) A costly but necessary programme

Much effort is still needed and once solutions to the problems pending have been found, funds will have to be obtained to progress from the trial stage to large-scale rehabilitation of polluted areas. The task to be accomplished is so enormous that government action will be absolutely necessary concurrently with private initiatives, but it is of course part and parcel of development planning and will be a necessary prerequisite to the launching of certain agricultural development operations. This is why a comprehensive control programme with well-designed objectives and separate funding will need to be set up.

The objectives of such a programme could be as follows:

- Reafforestation: a) continuation of CTFT trials for selection and nursery production of tree species. New trials on various types of soils and under various climatic conditions. Planting trials on abandoned mine benches where there is enough loose soil.

b) systematic planting on laterite overburden and tailing dumps where reafforestation can reasonably be expected to succeed. Systematic planting on abandoned mine benches where trials have given positive results.

- Dredging of rivers: Such an operation could be contemplated for streams where silting is very bad and gives rise to extensive destructive flooding.

- Applied research programme conducted jointly by government departments and ORSTOM: As required by the programme outlined above.

- Setting up of a measuring network: Precise figures are necessary, notably on the degree of water pollution (rivers and lagoon), for orienting pollution control works. A measuring network is an essential tool for monitoring changes in the degree of pollution district by district and detecting new sources of pollution.

  The network would include devices for measuring turbidity and flow of rivers, and turbidity and possibly sedimentary deposits in the lagoon.

The pollution control programme would thus have practical objectives (industrial-scale works) as well as scientific objectives the value of which should not be overlooked. Obviously it cannot be entirely funded by the polluters themselves, according to the principle "who pollutes shall pay". Many operators who in the past caused extensive pollution are now not to be found and if only for this reason financial support from the government will be necessary.

It would seem appropriate to constitute a special fund supplied partly by FIDES research grants (DGRST, ORSTOM, CNEXO, etc...) and partly from the territorial budget and by the mining operators. The machinery set up in France to finance the rehabilitation of former quarries could serve as a model for operators' contribution to the fund. The latter could for instance provide the equipment necessary for reafforestation or dredging teams, while the Territory could earmark for these activities a fraction of the revenue derived from taxes on mining and metal processing activities.

A detailed budget cannot of course be drawn up until the various departments and organisations concerned have established a precise calendar for the works to be undertaken and costed them.

Signed THE DIRECTOR OF MINES AND ENERGY

M. BENEZIT