# THE TREATMENT AND DISPOSAL OF MINE WATER AT NEVES CORVO MINE

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## INTRODUCTION

SOMINCOR, SOCIEDADE MINEIRA DE NEVES CORVO, S.A., from its inception has considered the protection of the environment of the area to be fundamental. Water resources in areas such as the Baixo Alentejo are extremely important and therefore received a large amount of attention during the planning stages of the Neves Corvo Mine.

In any underground mining operation a "draw down" of the water table in the area is inevitable, and this drainage, together with the water introduced for industrial purposes, has to be removed from underground and disposed of. The possible influence of this product on the Oeiras River was the starting point for the design of treatment facilities. The river was studied from a physical-chemical point of view, and laboratory treatment tests were carried out to determine the required treatment route necessary to allow discharge of underground water to the Oeiras River, whilst minimising change to the physical-chemical characteristics.

## OEIRAS RIVER

The Oeiras river is a small tributary of the Guadiana river. Its waters are mainly used for irrigation, cattle watering and as a support for fish life. During the dry season the flow is very much reduced and only some deeper areas remain where the fish survive. The analysis performed concluded that whilst the water of the River Oeiras is relatively mineralised and hard, it is not contaminated from a physical-chemical point of view.

Table 1. presents values of the results of the analysis before the development of the mining enterprise.

A considerable length of the Oeiras river was studied, and the results shown in the Table 1, are average values which characterize the water immediately upstream and downstream of the area where the treated water from underground is now discharged.

CHARACTERISTICS OF MINE WATER

There is a great deal of information on mine water quality from sulphidic underground mining operations. The quality of the mine water depends upon numerous factors including:

- physical characteristics of the ore
- net acid generating potential
- groundwater characteristics
- backfill practice
- mining practice
- age of the mine
- variability and mineralogy of the mined ore

The Neves Corvo Mine extracts high grade cupriferous sulphide ore from the base of a massive sulphide ore body, consisting mainly of pyrite . This massive sulphide lense is situated in a volcanic sedimentary series of tuffs, shales and greywackes. Mine water pumped to surface is currently alkaline, being influenced by carbonates in the host rocks, but primarily from cement residues from the backfilling process. It is expected, however, that this alkalinity will be reversed at some point in the mine's life, and that this acidity will produce a corresponding increase in heavy metals and solids in suspension.

This quality deterioration of the Mine Water will be caused by a combination of several effects; a reduction in infiltration as the water table continues to lower, the increasing mineral contact area produced by mining and water percolation through backfill, a propotion of which is pyrite.

Early estimates of pumping requirements were as high as 600 $m^3$ per hour, these were produced following the first intersection of the orebody, where the highly fractured nature of the sulphide lenses produced an aquifer effect, and large flows for an extended period resulted.

Design of the undergound facilities was therefore undertaken on this basis, further investigation as to the potential final requirements being impossible during this development phase, as the temporary pumping arrangements were operating close to capacity.

Following the commisssioning of the permanent installations in May 1988. several more ore intersections were mined at the lowest possible elevation to induce a lowering of the groundwater table in the sulphides. Groundwater has since stabilised between 150 and 170 $m^3$ per hour, a slight seasonal effect being observed.

Groundwater, however, only accounts for approximately 60% of the 250 $m^3$ pumped from the Mine, a further 27% being introduced as part of the Mining process, i.e., dust supression when drilling, cleaning, etc.. Backfilling, which involves the hydraulic transport of sand, coarse fraction mill tailings, and cement accounts for the 13% balance, an average 30 $m^3$ per hour.

Backfilling however only takes place over approximately 50 hours per week these periods being at very high flow rates of slurried material.

The flow rate, typically 200 tonnes solids with 90 $m^3$ water per hour, currently dominates the chemical and physical characteristics of mine water reporting back to the underground treatment and settlement facilities, extended periods producing high flows with high solids content and very alkaline conditions.

## MINE WATER TREATMENT UNDERGROUND

To handle large quantities of mine water efficiently over large pumped heads (600 m at Neves Corvo) it is necessary first to remove as much of the solid content as possible. Failure to do this results in unacceptable pump wear, producing dramatic reductions in efficient pumping and energy consumption. Several methods are in use world wide, including, simple gravity sumps, circular rake type thickeners and the Lamella Thickener, it is this type of machine that is installed underground at Neves Corvo.

LAMELLA THICKENER

The Lamella Thickener is a simple gravity settling device that utilises a stack of closely spaced inclined plates to clarify and thickenen a wide range of slurries and liquors, whilst occupying as little as one tenth of the space required by a conventional basin type thickener of equal capacity. Settling in a Lamella Thickener occurs both by hindered and unhindered modes and slurry is induced to flow between parallel plates separated commonly by 50 mm. Plates are arranged in stacks, and in order that they be self cleaning, they are normally inclined between 45° and 55° to the horizontal.

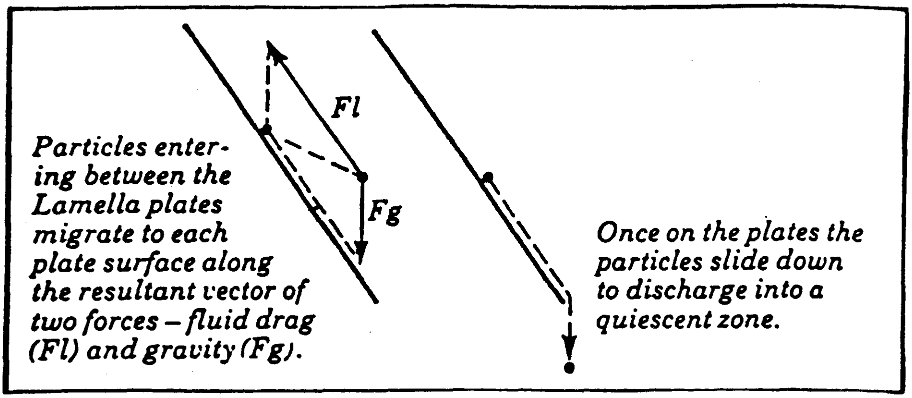



Fig. 1

Somincor installed a Sala C.L.T. 600 Lamella Thickener with 600 $m^2$ area based on the following criteria:-

Inlet Mine Water Flow Criteria

| | |
|---|---|
| Maximum | 600 $m^3$/hr |
| Average | 415 $m^3$/hr |
| Minimum | 195 $m^3$/hr |

Solids

| | |
|---|---|
| Solid Content Average | 1.5 g/l |
| Solid Content Maximum | 6.0 g/l |
| Solid Specific Gravity | 2.8 - 4.3 |

Overflow Water Criteria

| | | |
|---|---|---|
| Solid Content Normal | 0.04 g/l | |
| Solid Size Normal | 30% | 3.5μ |
| | 80% | 10 μ |
| | 99% | 20 μ |
| Solids Specific Gravity | 2.8 - 4.3 | |

Water make, from all three sources, gravitates to the haulage level where it is transported in an open ditch to the Lamella Thickener, (Fig. 2) passing through a normally non-operational gravity sump. This sump was constructed as part of the temporary arrangements and is utilised now only during periods of Lamella maintenance. In the Lamella chamber the flow, of between 150 $m^3$ and 310 $m^3$ per hour, depending on mining activity and backfill status, passes through two stages of "trash screening" before being dosed with Allied Magnafloc 338 polymer at dosage rates between 1.0 gm/$m^3$ and 2.0 gm/$m^3$, again depending on the quantity of solids arriving, itself a function of backfilling activity.

Backfilling, as stated, is currently the major influence on water quality arriving at the Lamella. Backfill at Neves Corvo is carried out by hydraulically placing mixtures of alluvial sand, coarse fraction + 20µ mill tailings and cement. Details of backfill are:-

| Constituent | Range | Typical |
|---|---|---|
| Sand Weight | 75% - 90% | 85% Solid |
| Coarse Mill Tailings Weight | 20% - 5% | 10% Solid |
| Cement Weight | 20% - 0% | 5% Solid |
| Water Weight | 50% - 20% | 30% Mixture |

Solids arrival at the Lamella is therefore a function of which mixture is being utilised, the position in the mine at which backfilling is taking place, and the stage of the filling cycle. Water is removed both by percolation to a drainage system of perforated pipes and geotextile and by decantation. Decantation becomes progressively more important towards the end of the fill cycle in a stope, as the volume available for settlement before decant is obviously becoming less and less progressively, with a corresponding increase in the solids transported over the decant weir.

Typical solids content entering the Lamella Thickener are, 16 grams per litre during backfilling and 3.2 grams per litre without backfill, and typical figures for the overflow product to the clean water pumps are 0.069 with backfill operational and 0.020 grams per litre at other times, 0.035 average.

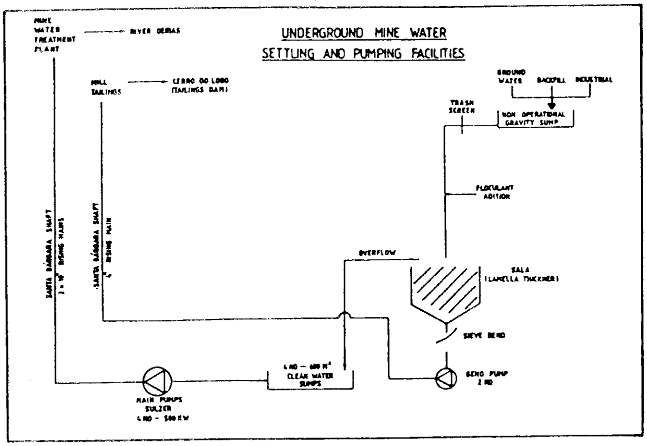
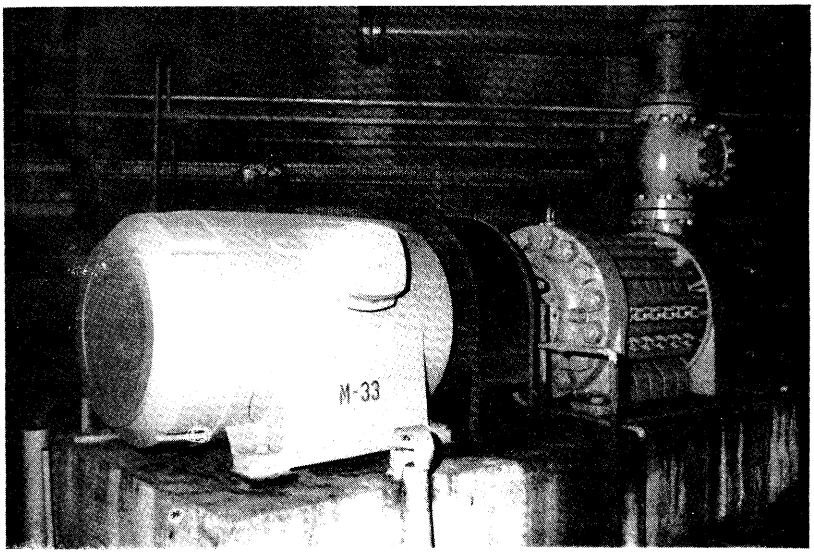


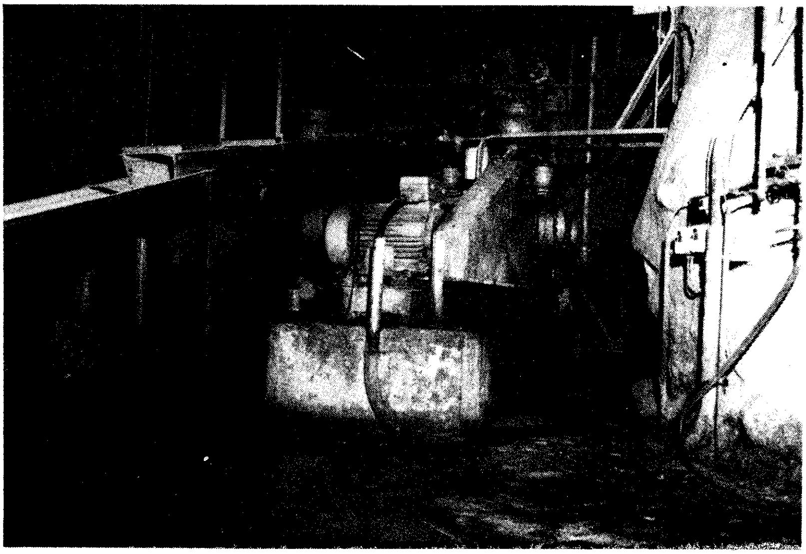

Fig. 2

The Lamella overflow product is run in to one of three clean water basins, and from there is pumped to the surface Mine Water Treatment Plant, via 10" Rising Mains in the Sta. Bárbara Shaft by means of the clean water pump station, where 4 No. 500 KW six stage Sulzer Pumps are installed. The fact that the first pump rebuild since commissioning has recently be carried out, following some 12000 hours of operation, provides evidence as to the efficiency of these settling arrangements.




SULZER PUMP

Lamella Thickener underflow product, passes,at up to 45% solids, over a "sieve bend" wet screen, which removes any remaining tramp material, into a steel sump ahead of the mud pumping stage. Water is added here to produce a product that is up to 25% solids solids by weight. This product is then pumped by one of two Geho 2PM 600 HD "piston in oil" diaphragm type pumps, to surface. This mud product is pumped directly to the Copper Concentrator tailings pumps, and thereby passes directly to the Cerro do Lobo Tailings Depository, with the tailings from the Concentrator.



GEHO MUD PUMP

SURFACE MINE WATER TREATMENT PLANT

In addition to underground "clean water" pumping directly, the surface Treatment Plant also deals with small quantities of "run off" from stockpile areas,these are arranged to collect in a pluvial water dam and are pumped when necessary to the Treatment Plant.

At the time of the design of the Treatment Plant no legislation existed in Portugal in respect of criteria for effluent discharge in to the environment, consequently Somincor decided to design the plant to meet the forthcoming EEC Directives on Surface water, these are listed in Table 2.

Laboratory testing was undertaken of a pilot scheme where a pH of 9 was considered to precipitate heavy metals and, with the addition of a non- ionic polyelectrolite flocculant, help to settle the remaining solids.

The installation was sized at an average of 350 cubic metres per hour, 100 mg/l of iron as dissolved solids and 40 mg/l of suspended solids. Mine Water together with "run-off" enters to an agitated tank where lime is added if required.

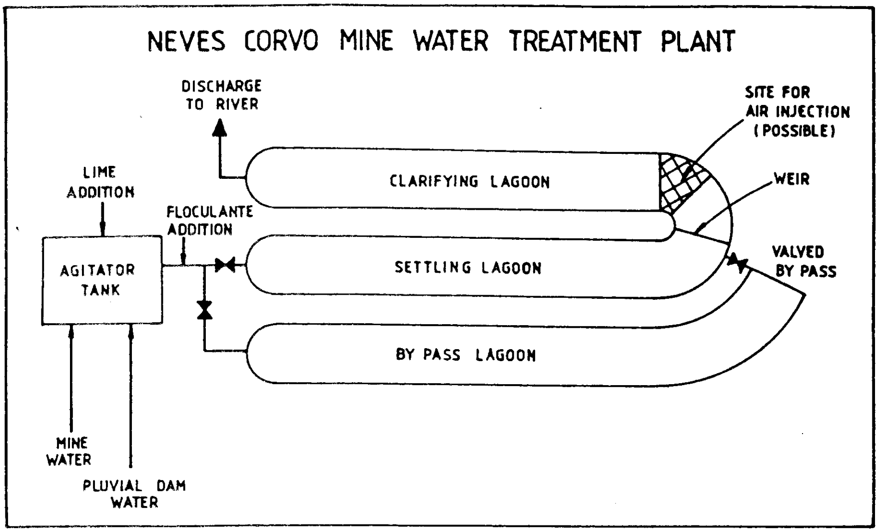
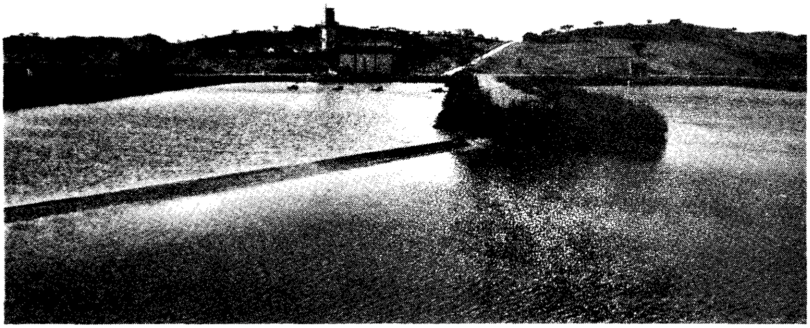



Fig. 3

The tank has a volume of 101.25 cubic metres and is dimensioned to provide a contact time of 15 minutes. On leaving the "lime tank" the water is dosed with polyelectrolyte before passing to the settling lagoons.

Flocculante addition is controled by "jar tests" of incoming product.

Two settlement lagoons in series are provided; the primary lagoon has a volume of 14 500 cubic metres and a surface area of 5400 $m^2$ with a depth of 4.25 m, and was designed on the basis of storage for one year deposition of settled solids. The secondary clarification lagoon was designed on a 48 hour retention time, having a volume of 16 500 $m^3$.



SURFACE TREATMENT PLANT
(Lagoons 1 and 2)

A third lagoon is provided to allow by-pass of the main lagoon when it becomes full and requires cleaning, this lagoon has a volume of 2400 $m^3$. In practice however it has proven more efficient to pump deposited solids from the settlement lagoon to this third lagoon and to dispose of them from there. This system has the advantage of utilising the larger volume of the primary lagoon for the the whole of the time. A Toyo 400 submersible mud pump has been successfully utilised for this duty, cleaning occupying some 3 to 4 days each six months.

The design of the Treatment Plant also includes a small suport building for preparation and dosage of reagents together with a storage facility for 20 tonnes of lime.

Following the 48 hour clarification period in the secondary lagoon the mine water is passed directly in to the Oeiras river. Recent measurements however of oxygen levels in the river, being 100% Mine Water in this dry Summer period indicate the need for oxygenation of the water prior to discharge and experimental work has been undertaken to determine the best method to be applied. Somincor intend to introduce a trial phase of direct air injection in to the treated water as it passes from the primary in to the secondary lagoons, a low pressure blower being utilised for this purpose injecting air at the lagoon base level through a grid of HDPE pipes. Somincor's Environmental Department have the responsibility for monitoring quality and samples are taken twice daily and analysed for pH suspended solids conductivity and clarity. Samples are also taken on a regular basis and analysed for all qualities indicated in Tables 1 and 3.

This analyses are carried out at the Somincor Central Laboratory.

As can been seen from tables 3 and 4, the change from a alkaline to an acid product from underground has not yet taken place and apart from isolated occassions lime dosing has not been required. However, cement addition to backfill is currently being reduced and a change in the regime may be seen in the near future.

All other aspects of the installation are functioning well, however, as reference to tables 3 and 4 will show. Reference again to Table 2 will illustrate clearly the effectiveness of the planning and investigation carried at the project stage at Neves Corvo.

**TABLE 1**

**EXTRACT FROM PRE DISCHARGE STUDY**

**CHARACTERISTICS OEIRAS RIVER**

**NOV 82 - MAY 92**

| PARAMETER | UNITIES | A-DO-NEVES (UPSTREAM THE DISCHARGE) | | MALHÃO LARGO (DOWNSTREAM THE DISCHARGE) | |
|---|---|---|---|---|---|
| | | AVERAGE VALUE | MAXIMUM VALUE | AVERAGE VALUE | MAXIMUM VALUE |
| TEMPERATURE | | | | | |
| Ambient | (0°C) | 16.3 | 19.0 | 16.3 | 18.0 |
| Sample | (0°C) | 14.3 | 18.0 | 14.3 | 18.0 |
| pH (25°C) | | 7.9 | 8.7 | 8.1 | 8.7 |
| CONDUCTIVITY | (µS/cm-25°C) | 302.5 | 390.0 | 502.5 | 900.0 |
| SOLIDS | | | | | |
| Total Suspended | (mg/l) | 14.2 | 25.0 | 22.8 | 51.4 |
| Total Dissolved | (mg/l) | 205.3 | 253.0 | 301.6 | 469.0 |
| ALKALINITY | (CaCO3 mg/l) | 51.3 | 71.0 | 94.0 | 166.0 |
| TOTAL HARDNESS | (CaCO3 mg/l) | 94.0 | 141.0 | 129.3 | 218.0 |
| CALCIUM HARDNESS | (CaCO3 mg/l) | 45.0 | 61.0 | 58.5 | 90.0 |
| FLUORIDE | (mg/l F) | not mentioned | not mentioned | not mentioned | not mentioned |
| CHLORIDES | (mg/l Cl) | 48.3 | 65.0 | 78.0 | 143.0 |
| PHOSPHATES | (mg/l PO4) | 0.15 | 0.16 | 0.18 | 0.20 |
| SULPHATES | (mg/l SO4) | 31.5 | 41.00 | 38.25 | 56.0 |
| NITRITES | (mg/l NO2) | 0.01 | 0.04 | 0.07 | 0.14 |
| NITRATES | (mg/l NO3) | 5.59 | 22.00 | 4.18 | 15.00 |
| NITROGEN AMONIA | (mg/l) | 0.17 | 0.32 | 0.17 | 0.27 |
| ORGANIC NITROGEN | (mg/l) | 0.12 | 0.19 | 0.11 | 0.15 |
| TOTAL PHOSPHORUS | (mg/l) | 0.17 | 0.30 | 1.04 | 2.40 |
| DISSOLVED 02 | (mg 02/l) | 10.4 | 12.7 | 10.5 | 14.1 |
| CBO5 (02 mg/l) | (mg 02/l) | 2.3 | 2.8 | 1.6 | 2.0 |
| CB90 (02 mg/l) | (mg 02/l) | 19.3 | 25.0 | 20.5 | 36.0 |
| COT (02 mg/l) | (mg Cl) | 8.8 | 11.0 | 9.8 | 13.0 |
| OXIDABILITY PERMANGANATE MODIFIC. ac. 10 min eb. | (mg 02/l) | 3.4 | 4.8 | 3.5 | 4.7 |
| ARSENIC | (ppb) | 41.24 | 10.0 | 5.5 | 10.0 |
| LEAD | (ppb) | 5.10 | 135.4 | 44.78 | 139.5 |
| COPPER | (ppb) | 340.3 | 8.40 | 3.99 | 5.50 |
| IRON | (ppb) | 28.8 | 631.2 | 296.3 | 460.9 |
| MANGANESE | (ppb) | 0.54 | 62.2 | 30.5 | 47.5 |
| MERCURY | (ppb) | 48.77 | 1.32 | 0.09 | 0.19 |
| ZINC | (ppb) | 9.20 | 70.63 | 59.15 | 96.43 |
| NICKEL | (ppb) | | 15.01 | 13.0 | 17.80 |

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TABLE 2

COMPARISON OF UPSTREAM, DOWNSTREAM

DISCHARGE WITH GUIDELINES

JAN - DEC 1989

| | | A-DO-NEVES (UPSTREAM THE DISCHARGE) | TREATED EFFLUENT | MALHÁO LARGO (DOWNSTREAM THE DISCHARGE) | GENERAL RULES OF WASTEWATER DISCHARGE |
|---|---|---|---|---|---|
| PARAMETER | UNITIES | AVERAGE VALUE | AVERAGE VALUE | AVERAGE VALUE | PERMISSIBLE MAXIMUM VALUE (2) |
| pH (25°C) | | 7.7 | 9.1 | 7.2 | 6.0 - 9.0 |
| CONDUCTIVITY | (μS/cm-25°C) | 314.8 | 2 114.2 | 881.0 | not mentioned |
| SOLIDS | | | | | |
| TOTAL SUSPENDED | (mg/l) | 8.4 | | 3.7 | 60 |
| TOTAL DISSOLVED | (mg/l) | 250.2 | 1 642.3 | 663.7 | not mentioned |
| TOTAL HARDNESS | (°F) | 29.1 | 147.6 | 68.2 | not mentioned |
| CHLORIDES | (mg/l) | 50.6 | 352.2 | 123.8 | not mentioned |
| PHOSPHATES | (μg/l) | 61.1 | 41.8 | 75.9 | not mentioned |
| SULPHATES | (mg/l) | 11.5 | 504.2 | 193.3 | 2 000 |
| SULPHIDES | (mg/l S) | 0.182 | 0.0 | 0.10 | 1 |
| NINITRES | (mg/l NO2) | 0.017 | 1.0 | 2.24 | not mentioned |
| NITRATES | (mg/l NO3) | 0.736 | 16.8 | 12.20 | 50 |
| NITROGEN AMONIA | (mg/l NH4) | 0.13 | 4.5 | 0.99 | 10 |
| TOTAL NITROGEN | (mg/l N) | 2.14 | 6.4 | 3.59 | 15 |
| TOTAL PHOSPHORUS | (μg/l P) | 81.0 | 125.7 | 42.0 | 10 000 |
| CBO5 | (mg/l O2) | 1 | 5.70 | 1.38 | 40 |
| C90 | (mg/l O2) | | | | 150 |
| OXIDABILITY (PERMANGANATE MOFIFIC.) ac. 10 min. eb | (mg/l O2) | 2.45 | 13.50 | 2.67 | not mentioned |
| PHENOLIC COMPOUNDS | (μg/l C5H5OH) | 2.9 | 4.4 | 1.53 | 500 |
| AENONIC SURFACTANT | (LAS mg/l) | 0.1264 | 0.22 | 0.09 | 2 |
| BREASES AND OILS | (mg/l) | 0.138 | 0.19 | 0.10 | 15 |
| HIDROCARBONS | (mg crisenol/l | 3.676 | 4.2 | 3.15 | 1 |
| MERCURY | (μg/l Hg) | 0.14 | 0.3 | 0.22 | 50 |
| COPPER | (μg/l Cu) | 2.83 | 305.8 | 35.03 | 1 000 |
| LEAD | (μg/l Pb) | 1.08 | 2.0 | 1.23 | 1 000 |
| IRON | (μg/l Fe) | 525.20 | 324.9 | 333.90 | 2 000 |
| MANGANESE | (μg/l Mn) | 47.75 | 416.5 | 204.95 | 2 000 |
| TOTAL CHROMIUM | (μg/l Cr) | 1.41 | 8.9 | 5.93 | 2 000 |
| CADMIUM | (μg/l Cd) | 2.92 | 7.3 | 4.35 | 200 |
| ZINC | (μg/l Zn) | 17.50 | 636.0 | 302.5 | 5 000 |
| NICKEL | (μg/l Ni) | 2.17 | 10.0 | 3.01 | 2 000 |
| ARSENIC | (μg/l As) | 15 | 192.0 | 16.00 | 1 000 |
| CALCIUM | (mg/l Ca) | 13.30 | 195.3 | 74.60 | not mentioned |
| MAGNESIUM | (mg/l Mg) | 11.80 | 26.8 | 17.00 | not mentioned |
| POTASSIUM | (mg/l K) | 6.80 | 36.6 | 18.60 | not mentioned |
| SODIUM | (mg/l Na) | 27.90 | 253.3 | 100.80 | not mentioned |

TABLE 3

AVERAGE RESULTS JAN - JUN 1990

MINE WATER ENTERING THE TREATMENT PLANT

| PARAMETERS | JAN | FEB | MARCH | APRIL | MAY | JUNE |
|---|---|---|---|---|---|---|
| pH | 9.5 | 11.2 | 10.6 | 9.8 | 9.3 | 10.6 |
| Solids (mg/L) Suspended | 212 | 146 | 226 | 206 | 100 | 195 |
| Solids (mg/L) Dissolved | 1550 | 1853 | 1512 | 1746 | 2126 | 1995 |
| Oxygen (%) Dissolved | -- | -- | -- | 73 | 56 | 39 |
| Arsenic (mg/L) | 0.432 | -- | 0.307 | 0.060 | 0.054 | 0.098 |
| Copper (mg/L) | 7.644 | 2.470 | 2.992 | 4.700 | 2.880 | 1.430 |
| Iron (mg/L) | 27.512 | 7.685 | 10.792 | 14.400 | 13.515 | 10.060 |
| Mercury (mg/L) | 0.0005 | -- | 0.0011 | 0.0005 | 0.0009 | 0.0013 |
| Zinc (mg/L) | 6.710 | 1.710 | 3.640 | 4.000 | 2.221 | 3.720 |

TABLE 4

AVERAGE RESULTS JAN- JUN 1990

TREATED MINE WATER ENTERING OEIRAS RIVER

| PARAMETERS | JAN | FEB | MARCH | APRIL | MAY | JUNE |
|---|---|---|---|---|---|---|
| pH | 9.6 | 10.9 | 9.7 | 8.7 | 7.8 | 7.8 |
| Solids (mg/L) Suspended | 9.0 | 24.2 | 6.0 | 8.2 | 3.1 | 6.4 |
| Solids (mg/L) Dissolved | 1338 | 1353 | 1335 | 1383 | 1762 | 1607 |
| Oxygen (%) Dissolved | 60.8 | 65.0 | 87.0 | 68.1 | 62.8 | 60.4 |
| Arsenic (mg/L) | 0.0063 | 0.0073 | 0.0300 | 0.0043 | 0.0081 | 0.0195 |
| Copper (mg/L) | 1.129 | 0.050 | 0.163 | 0.053 | 0.075 | 0.070 |
| Iron (mg/L) | 0.435 | 0.105 | 0.247 | 0.200 | 0.030 | 0.080 |
| Mercury (mg/L) | 0.0007 | 0.0005 | 0.0008 | 0.0008 | 0.0014 | 0.0022 |
| Zinc (mg/L) | 0.069 | 0.015 | 0.084 | 0.085 | 0.062 | 0.018 |