# The Neutralization-Flocculation-Lamella Settling (NF-LS) process in the treatment of Acid Mine Drainage (AMD) from Coal Mines in South Brazil. Comparative processes and new basis for sulphate ions removal

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## Introduction - Problems caused by Coal AMD in South Brazil

- Around 6,300 ha are polluted
- Contamination affects urban and rural areas in a large scale
- AMD causes economical problems in the region

## Introduction

AMD (coal mining): effluent formed after pyrite natural oxidation (mainly in dumped tailings)

**AMD-Characteristics:**

1. **Highly loaded solutions: $Fe^{+3}$, $Mn^{+2}$, $Al^{+3}$, $SO^{-2}_4$**
2. **High acidity**
3. **Low pH values (< 3.0)**

**Main active treatment alternatives (2004 onwards)**

- **NF-SP = Neutralization-flocculation and settling in ponds**
- **NF-LS = Neutralization-flocculation and lamelar settling**
- **NF-DAF = Neutralization-flocculation and dissolved air flotation**

**NF-SP = Neutralization flocculation and settling in ponds**

**Capão da Roça, 30 $m^3$/h-RS**

**NF-LS = Neutralization-flocculation and lamelar settling**

**Cooperminas-250 $m^3.h^{-1}$/ Criciúma-SC**

**NF-DAF = Neutralization-flocculation and Dissolved air flotation**

**Mina Esperança- 250 $m^3h^{-1}$-Criciúma-SC**

**AMD 250 $m^3$ $h^{-1}$ treatment: Technical and economical comparisons**

| Parameters | Flotation | Lamella settling |
|---|---|---|
| Loading capacity, $m^3.m^{-2}.h^{-1}$ | 9.0 | 5.0 |
| Residence time, min. | 40 | 90 |
| Operating costs, $R\$.m^{-3}$ | 1.0 | 0.5 |
| Investiment costs, $R\$.m^{-3}$ | 3.000 | 1.900 |
| Energy consumption, $kWh.m^{-3}$ | 0.7 | 0.3 |
| Total area (foot print), $m^2$ | 600 | 450 |

## Aims

**This work is a series of studies on active methods to treat AMD-acid coal mine drainage in South Brazil**

**Herein, the study shows advances on the removal of metals and sulphate ions in two AMD treatment plants**

## Main Facts and Aims

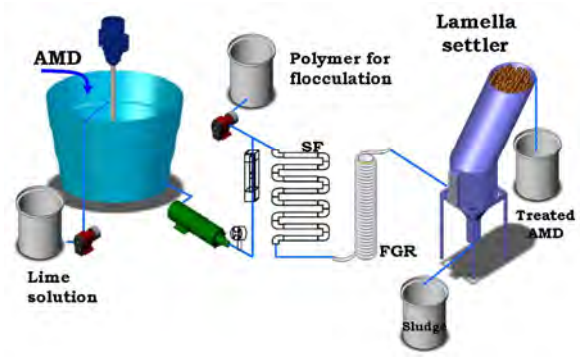
- **Case 1: AMD (SS-16 Site), 30-100 $m^3/h$, drains off from an abandoned coal mine, aside a local population suffering from water drought (especially in summer...!!)**
- **Case 2: AMD from a 30 years coal mining activity (Capão da Roça). 25000 $m^2$ of area have been used for tailings disposal. This fact has caused local contamination of the water resources**



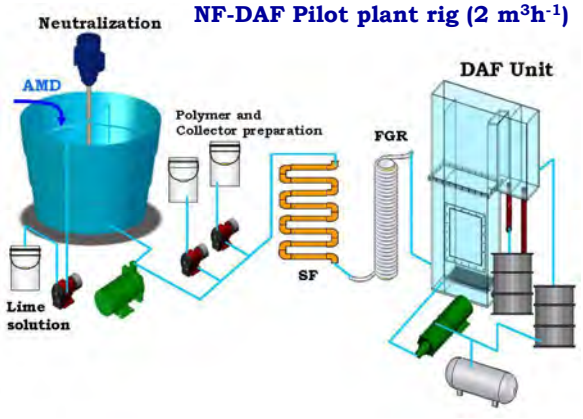
## Methods

**Neutralization with lime (ppt are formed), flocculation of the ppt with polyacrilamide and flocs separation by either flotation (FAD-dissolved air flotation) or by LS-lamelar settling**

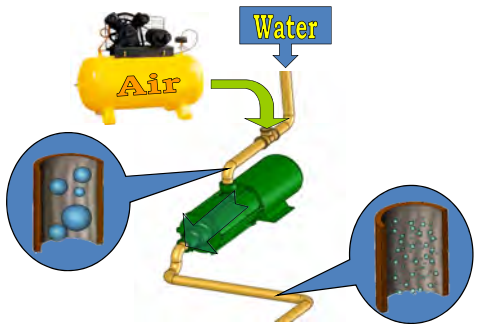
**NF-LS Pilot plant rig (2 $m^3h^{-1}$)**



**NF-DAF Pilot plant rig (2 $m^3h^{-1}$)**

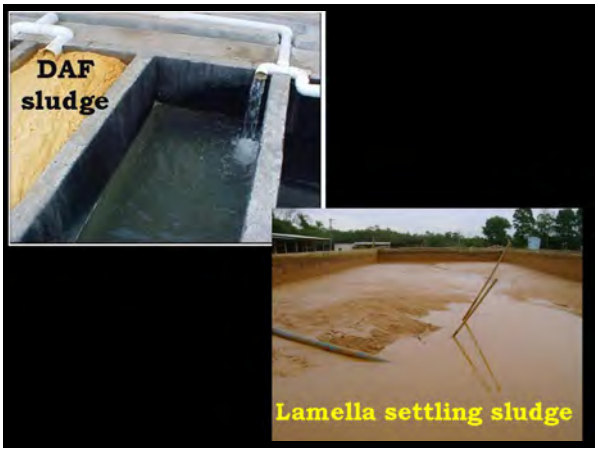



**Multiphase (water/air) pump for microbubble generation BGB®-2007**




## Results

**Both AMD treatment techniques showed similar efficiencies (removal of metal ions > 90 %) but the separation by lamella settling presented advantages, namely less reagents, lower power requirements and process simplicity**




| Parameters | Treated AMD-Averaged values ($mg.L^{-1}$) | Emission Standards Limits in Brazil ($mg.L^{-1}$) |
|---|---|---|
| Mn | 2.0 or 0.6 | 1.0 |
| Fe | 1.4 | 15.0 |
| Ba | 0.02 | 5.0 |
| B | 0.07 | 5.0 |
| Cd | <0.002 | 0.2 |
| Pb | 0.02 | 0.5 |
| Cr | 0.005 | 0.5 |
| Cu | 0.1 | 1.0 |
| Hg | <0.0002 | 0.01 |
| Ni | 0.15 | 2.0 |
| Zn | 0.61 | 5.0 |

| Parameters | Treated AMD-Averaged values ($mg.L^{-1}$) | Emission limits in Brazil ($mg.L^{-1}$) |
|---|---|---|
| pH | 7.0 or 9.0 | 5.0-9.0 |
| Color, Hazen | 13 | - |
| Turbidity, NTU | 0.7 | - |
| Surface Tension, $mNm^{-1}$ | 71 | - |
| Conductivity, $\mu Scm^{-1}$ | 1290 | - |
| TOC, $mgL^{-1}$ | 0.6 | - |
| Hardness, $mgL^{-1}$ de $CaCO_3$ | 368 | - |
| Dissolved Solids, $mgL^{-1}$ | 1114 | - |
| $SO_4^{-2}$, $mgL^{-1}$ | 1622 | - |
| Al, $mgL^{-1}$ | 1 | - |

## Case 2. AMD - Capão da Roça



**In this Case 2 (AMD 2), the removal of sulphate ions was studied additionally by co-precipitation of the anion with aluminum bearing salts followed by flocculation and separation of flocs formed by lamella settling (PFLS) at pH 4.5**

**AMD (Case 2) treated by PFLS, at pH 4.5 – PAC:$SO_4^{-2}$ ratio = 5:1**

| Parameters (mg/L) | Treated AMD |
|---|---|
| $SO_4^{-2}$ | 570 |
| $Cl^-$ | 1250 |
| $Al^{+3}$ | 15.8 |
| $Mn^{+2}$ | 2.1 |
| $Fe^{+3}$ | 0.3 |

**Initial Sulphate Ions = 1900 mg.$L^{-1}$**

## Conclusions

**Treated (AMD) water by NF-LS was nearly free of heavy metals ions, namely, Fe, Al, Mn; low solids content, making it useable for irrigation, and other purposes**

**Today the approximate operating costs for AMD treatment removing metals ions and sulphate ions are around 0.4 US$.$m^{-3}$ and 2.5 US$.$m^{-3}$, respectively**

**The costs might be reduced recycling elements (like aluminum) from sludge generated by the processes**

## Alternatives for water reuse

**(According to Brazilian Law)**

1. **Urban**
2. **Agricultural and forestry**
3. **Environmental**
4. **Industrial**
5. **Aquaculture**

## Acknowledgements

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UFRGS Universidade Federal do Rio Grande do Sul
COPELMI Mineração Ltda.
SIECESC
REDE CARVÃO

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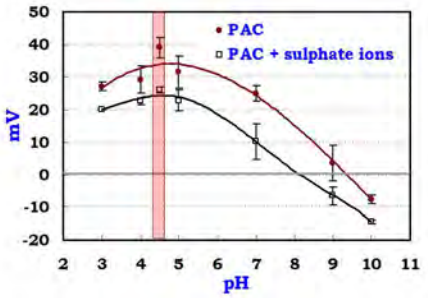
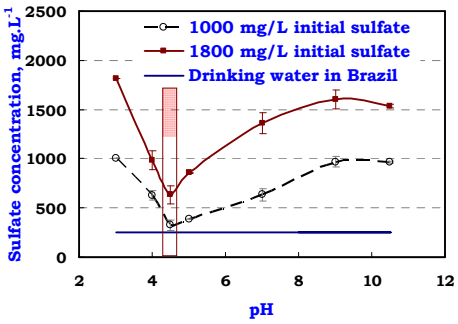
## Zeta potential of aluminum colloids




**Mechanisms of adsorption and complexation**

## Sulphate ions removal at pH 4.5




### Organic and biological contaminants

| Parameters | Unit | AMD | Treated AMD |
|---|---|---|---|
| OBD 5 days | mg/l | N.D. | N.D. |
| Phenols | mg/l | N.D. | 0.002 |
| Surfactants | mg/l | N.D. | 0.016 |
| Grease and Oils | mg/l | N.D. | N.D. |
| N.M.P. Fecal Coli | N.M.P./100 ml | N.D. | N.D. |
| N.M.P. Total Colis | N.M.P./100 ml | 2,0 | N.D. |

**ND = Not Determined (below detection limit)**