

## STANDARDS FOR MINING ACTIVITIES AND ENVIRONMENT

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### ABSTRACT

The increasing society's consciousness regarding industrial activities is causing environmental pressure in the legislation of the majority of industrialized parts of the world. Environmental protection and waste disposal are topics of ever-growing significance. Removal of toxic metals from aqueous solutions and wastewater streams has become a problem of increasing importance worldwide as a result of that perception. Concerning the mining industry, one of the majors problems is the control of the contamination by runoff water. The neutralization and chemical treatments are applied almost universally to precipitate out the dissolved metals present in the streams. In this work standards are presented for the treatment of contaminated wastewater in the Brazilian mining industry.

**Key words:** Effluents, standards, environmental,

## INTRODUCTION

In many aspects mining activities are considered harmful to the environment. In some cases, this is strictly reality, but more and more one can feel a better level of conscientiousness towards the protection of the working environment, with its preservation for future generations, and a better control of environmental harm.

The need for standardization of industrial activities is undeniable. Besides granting better productivity, companies seek international quality certificates for their products and more presently, they also pursue certificates of environmental friendliness, attesting world recognition for their efforts to preserve the environment they act upon.

Following this trend of environmental quality certification the ABNT – Associação Brasileira de Normas Técnicas (the Brazilian Association of Technical Standards) grouped renowned professionals on mining activities, to foster the preparation of standards for environmental damage control. These studies generated twelve new standards so far, described in table 01.

Table 01

| <b>ABNT – ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS<br/>ABNT – THE BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS</b>  |                                  |
|---|----------------------------------|
| <b>TITLE</b>  | <b>STANDARD NUMBER</b>           |
| Caracterização de Cargas Poluidoras na Mineração<br>Valuation of Polluting Loads Generated in Mining – Procedure  | NBR 12649:1992<br>NBR 12649:1992 |
| Elaboração e Apresentação de Projeto de Disposição de Rejeitos de Beneficiamento, em Barramento, em Mineração.<br>Design of Tailing Dams – Guidelines for Preparation and Presentation Format | NBR 13028:1993<br>NBR 13028:1993 |
| Elaboração e Apresentação de Projeto de Disposição de Estéril em Pilha, em Mineração.<br>Design of Mining Waste Dumps – Guidelines for Preparation and Presentation Format                    | NBR 13029:1993<br>NBR 13029:1993 |
| Elaboração e Apresentação de Projeto de Reabilitação de Áreas Degradadas pela Mineração<br>Rehabilitation Guidelines for Surface Mined Lands  | NBR13030:1999<br>NBR 13030:1999  |
| Cianeto – Processos de Destruição em Efluentes de Mineração<br>Cyanide – Processes for Cyanide Destruction in Mining Effluents  | NBR 13744:1996<br>NBR 13744:1996 |
| Arsênio – Processos de Remoção em Efluentes de Mineração<br>Arsenic – Removal Process in Mining Effluents   | NBR 14062:1998<br>NBR 14062:1998 |

| <b>ABNT – ASSOCIAÇÃO BRASILEIRA DE NORMAS TÉCNICAS<br/>ABNT – THE BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS</b>                |                                  |
|---|----------------------------------|
| <b>TITLE</b>  | <b>STANDARD NUMBER</b>           |
| Óleos e Graxas – Processos de Tratamento em Efluentes de Mineração<br>Oil and Grease – Processes of Treatment in Mining Effluents | NBR 14063:1998<br>NBR 14063:1998 |
| Sulfetos – Processos de Tratamento em Efluentes de Mineração<br>Sulfides – Process of Treatment in Mining Effluents               | NBR 14247:1998<br>NBR 14247:1998 |
| Bário Solúvel – Processos de Remoção em Efluentes de Mineração<br>Soluble Barium – Removal Processes in Mining Effluents          | NBR 14343:1999<br>NBR 14343:1999 |
| Zinco – Processos de Tratamento em Efluentes Líquidos<br>Zinc – Removal Processes in Effluents                                    | NBR 14569:2000<br>NBR 14569:2000 |
| Cádmio – Processos de Tratamento em Efluentes Líquidos<br>Cadmium – Removal Processes in Effluents                                | NBR 14571:2000<br>NBR 14571:2000 |
| Chumbo – Processos de Tratamento em Efluentes Líquidos<br>Lead – Removal Processes in Effluents                                   | NBR 14572:2000<br>NBR 14572:2000 |

Eight standards presented here are summarized below, and their complete texts are available at the ABNT – Associação Brasileira de Normas Técnicas, in Delegacias Estaduais of the ABNT.

## **STANDARDS**

### **NBR 12649 – Valuation of polluting loads generated in mining**

This Standard comprises 26 spreadsheets, one for each of the most economically important minerals occurring in Brazil. Each step of the respective mining activity is covered, from extraction to subsequent treatment, including supporting activities. Simulating a situation in which no controlling measure is taken, the potential environmental modifications are tabulated, in form of alterations in the physicochemical parameters of water quality. Upon this knowledge of the polluting potential of mining activities, one can better plan on measures for the diminishment of environmental harm.

The minerals covered on the spreadsheets are the following, described in table 02:

Table 02:

| <b>Minerals Covered on The Spreadsheets</b> |          |
|---|----------|
| Chrisotile Asbestos                         | Chromite |
| Sand  | Fluorite |

|   |                        |
|---|------------------------|
| Clay  | Bituminous Schist/Coal |
| <b>Minerals Covered on The Spreadsheets</b> |                        |
| Bauxite                                     | Magnesite              |
| Limestone                                   | Iron Ore               |
| Coal – Open-Pit Mine                        | Niobium                |
| Coal – Underground Mine                     | Nickel                 |
| Primary Cassiterite                         | Primary Gold           |
| Secondary - Cassiterite                     | Secondary Gold         |
| Kaolin                                      | Phosphate Rock         |
| Copper-Gold                                 | Rock Salt              |
| Primary Cooper                              | Turf/Peat              |
| Sulfo-Oxidized Plumb                        | Secondary Zinc         |

The NBR 12649 prompted the ABNT (Brazilian Association for Technical Standardization) to produce eleven other related standards, covering the suitable methods for pollution control in mining activities.

### **NBR 13028 – Design of tailing dams – Guidelines for preparation and presentation format – Procedure**

The technologies referring to the design, construction and maintenance of earth, concrete and other types of dams are well known worldwide. They were basically developed for hydropower generation, irrigation, and human consumption and for maintaining river flowing rates.

It would be however unnecessary to develop new standards and procedures that would not add anything new to the already accepted norms.

Nevertheless, in the mining industry there are a vast number of informally constructed tailing dams that do not adhere to the correct technical standards. This is the result of shortsighted designs that only pursue low capital costs without necessarily taking into account the high safety standards required nowadays.

As metallurgical recoveries increase, process tailings are finer and unstable, behaving like a high-density liquid when liberated from its confinements in the event of failure of the retaining dam. This will result in catastrophic consequences to the safety of people downstream and to the environment.

It is of paramount importance that the legislation makes provision for the proper allocation of technology that maximizes safety and also minimizes the cost of the enterprise.

Currently, when planning tailings disposal, traditional methods such as tailing dams are by far the most common approach even though there may be other options to be considered that could minimize the environmental impacts and safety aspects. It is important that this subject is extensively discussed among various professionals and specialists in order to cover all the possible alternatives of tailings disposal.

Nowadays there is a shortage of action particularly with regard to improving metallurgical recovery of processing plants, increasing the thickness of the tailings, proper techniques of tailings disposal in dams, pre-thickening and backfiring of mined out areas. Also, the use of new technologies such as intensive reduction of fines via electrometallurgical methods can contribute to the minimization of fines to be discarded.

At a moment, traditional tailing dams are more accepted and considered more cost effective than other alternatives due to its widely spread technology, but its pitfalls lies on the improper attitude of irresponsible professionals that have an erroneous perception of considering only the short term benefits.

The purpose of the NBR 13028 standard is to offer to entrepreneurs, their designers, and contractors a set of valuable information in order to assist them in their decision making process, considering all the technical economical implications of the enterprise.

### **NBR 13744 – Cyanides – Processes for cyanide destruction in mining effluents.**

The knowledge of the chemical behavior and stability of the cyanide ion in aqueous solution is of particular importance to the gold-processing industry as both process control the detoxification of tailing solutions. The mechanisms involved in the reaction of the cyanide ion in aqueous solution can be complex.

The cyanides in the effluent of metallurgic plants that use the cyanadation process can be classified in five categories as: free Cyanide, simple Compounds, weak complexes, moderately strong weak complexes and strong complexes.

In values below pH 7 essentially all free cyanides are present in the HCN form. The values of pH=9.36, concentrations of HCN and CN<sup>-</sup> are equal. At pH lower than 9,36 and 20 °C HCN predominate, being 69.6 % at pH 9. In 8 values of pH the concentration is of 95.8 % of HCN and more than 99 % at pH 7. It is well known that the HCN can be removed of the solution for volatilization and has been influenced for factors as: temperature, value of pH, superficial area of the interface and the concentration of the present species in the solution.

The salts simple cyanide is soluble in water, being the alkaline resultant solution that had hydrolysis and the solubility of composites varies with the value of pH and the temperature. The cyanides of heavy metals are soluble in solutions of cyanides of potassium and sodium, producing its respective salts complexes. Íons complex formed in accordance with depends on the complexation degree the concentration, and availability of present, former cyanide: Cu(CN)<sup>-</sup>, Cu(CN)<sup>2-</sup>, Cu(CN)<sup>2-</sup><sub>3</sub> and Cu(N)<sup>3-</sup><sub>4</sub>. In general, the complex ion is more steady than the original one and with outgrowth lesser composition its dissociation that is influenced by the factors of value of pH and the average concentration of the complex ion. Already it was studied that if a complex of cyanide of one determined metal is introduced in a different solution containing other metallic íons, can occur a metal substitution in the complex, with formation of a more steady complex. The substituted metal of this form precipitates as one cyanide insoluble, hydroxide or carbonate.

The toxicity of composites of cyanide is directly related to its dissociation or ionization in water solution, producing cyanide exempts (CN)<sup>-</sup> and hydrolysis the HCN. With this, of toxicity big the composites cyanide are those that are of high solubility in water or either the simple composites: NaCN, KCN, Ca(CN)<sub>2</sub>, Hg(CN)<sub>2</sub>.

Some processes of degradation and removal of cyanide in industrials effluents that are used, considered and developed exist. The choice of the process most viable depends on each case and some on factors to the effluent one are taken in account: Concentration of cyanide and the physicist-chemistry composition of the effluent, the parameters allowed for the legislation, nature, place of handling and discarding in the environment.

Methods for the removal of cyanide: natural degradation, oxidation processes, acidification/volatilization/regeneration (AVR), adsorption processes, electrolytic processes, conversion to less toxic species in solution, precipitation of insoluble metal cyanides, biological treatment, high-temperature hydrolysis.

## **REMOVAL OF METALS IN MINING EFFLUENTS**

The increase in mining activities coupled with greater environmental awareness has produced renewed interest in the developing of standard processes for the treatment of mine waters. The wastewater treatments selected have to produce an effluent compatible with the receiving system (lakes, rivers or groundwater).

The production of metals usually utilize ores containing one or more of the desired metals. Others minerals such as oxides, carbonates, silicates, sulfates, and sulfides are also present in the ore. For the production of metals the pyrometallurgical or the hydrometallurgical processes are used. Specifically in hydrometallurgical process liquid effluents are generated. Heavy metals are usually present in hydrometallurgical wastewaters. The control of contamination of the receiving systems by the heavy metals is one of the main problems in the mining industry. Neutralization and other chemical treatments to precipitate the dissolved metals are now practiced almost universally.

The standards procedures presented in the following sections describe the processes of treatment to these metals in effluents. The majority of processes are based in chemical precipitation. In these methods reagents are added to produce a specific compound whose solubility is very low under these conditions. Therefore a solid phase is produced immediately. Precipitation is carried out under strict conditions in order to selectively remove the undesirable metals from the solution. A precipitation process should be conducted within a certain pH range because precipitates may re-dissolved outside this range. Besides it also should be conducted at an optimum temperature since most precipitates are more soluble in hot than in cold solutions.

The following factors determine the choice of a precipitant: (a) economic; (b) easiness to be separate the precipitates; and (c) low solubility.

In mining activities the presence of minerals containing heavy metals, as either main or secondary minerals, requires a standardization of the process of their removal from effluents because the dissolved metals are considered harmful to the environment. The next topics discuss the standardization of the removal processes of arsenic, barium, cadmium, zinc and lead.

### **NBR – 14062. Arsenic – Removal processes in mining effluents.**

Arsenic is one of the most problematic impurities in the metallurgical industry and is a common element in the natural environment and is frequently a significant component in gold deposits. It is used in large quantities in the manufacture of glass to eliminate a green color caused by impurities of iron compounds. A typical charge in a glass furnace contains 0.5 percent of arsenic trioxide and certain arsenic compounds, such as galliumarsenide (GaAs), are used as semiconductors, as a laser material, wood preservation, and agricultural chemicals.

The chemical forms of arsenic consist of trivalent and pentavalent inorganic and organic compounds. In drink water although combinations of all forms are possible, it can be reasonably assumed that the pentavalent inorganic form is the most prevalent.

Arsenic occurs at relatively high levels in sulfide minerals of copper and iron. The most common mineral associations in order of frequency are: quartz, carbonates, pyrite, arsenopyrite, sphalerite, galena, pyrrhotite, realgar, orpiment, chalcopyrite, stibnite, sulphosalts, tellurides, haematite...

Chemically, arsenic is an intermediate element between metals and nonmetals. Its properties lie, in general, in the middle of the series formed by the family of the elements nitrogen, phosphorus, arsenic, antimony and bismuth and the arsenic ranks about 52<sup>nd</sup> in natural abundance among the elements in crystal rocks.

Arsenic extraction and immobilization from hydrometallurgical solutions and effluents is usually achieved by a means of ferric arsenate precipitation, as amorphous high Fe (III): As (V) sludges by lime neutralization of these often acidic solutions.

Sulfide ores oxidation is well known generated free acidity (low pH) and the liberation of trace metals, including arsenic and is also soluble in some high pH conditions along with manganese, zinc, chromium, nickel, selenium, vanadium and uranium.

Available technologies for arsenic treatment:

**Co-precipitation**

Alum coagulation  
Iron coagulation  
Lime softening

**Sorption techniques**

Activated alumina  
Iron coated sand  
Iron exchange resin

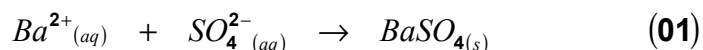
**Membrane techniques**

Reverse Osmosis  
Electrodialysis

Several methods of active water treatment for arsenic removal are potentially available to the mining industry. Such methods involve chemical precipitation; sorption and reverse osmosis but arsenic removal by chemical precipitation with Fe<sup>2+</sup> and Fe<sup>3+</sup> is considered as most effective and commonly used.

**NRB 14343:1999 - Soluble Barium - Removal process in mining effluents containing**

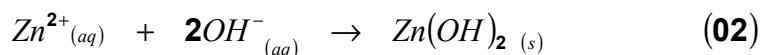
The process of soluble barium removal from effluents and wastewater is based in the solubility of barium sulfate, which forms a precipitate in aqueous solutions. The effluent or wastewaters containing soluble barium are submitted to a treatment, which consists in the addition of salts containing the sulfate anion. The pH of the effluent must be controlled for the optimization barium sulfate precipitation (equation 01).



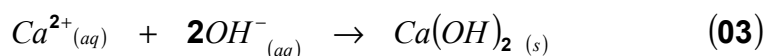
The final effluent, groundwater and receiving system must be monitored permanently for barium and sulfate because there is a compromise between the levels of barium and sulfate allowable in the effluents. The barium background must be considered in the final levels of the metal in the treated effluent.

### **NBR 14569:2000 - Zinc – Removal Process in Effluents**

The removal of the zinc as zinc hydroxide from effluents and aqueous solutions can be achieved through the addition of specific reagents to produce an insoluble compound. The precipitant can be sodium or potassium hydroxide or high calcium quicklime. In this process, known as hydrolysis, an uncharged species is formed. The precipitation of a hydrolytic product is favored by adding OH<sup>-</sup> ions, which react with H<sup>+</sup> ions shifting the equilibrium of equation (02) to the right:



When calcium quicklime is used a parallel reaction occurs (equation 03):



A flocculation must be added to assist the solids decantation. The optimum pH is near 9.0. The precipitates formed - zinc and calcium hydroxide - can be separated from the solution through thickening processes.

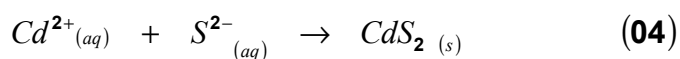
This process advantages are its high efficiency, easy control at ambient temperature. There are to do periodical maintenance in system for to removal the incrustations and scaling.

### **NBR 14571:2000 - Cadmium – Removal Process in Effluents**

The principal natural occurrence of cadmium is in zinc ores, as the sulfide greenockite.

Cadmium and other metals are removing from effluents and aqueous solutions in the form of insoluble sulfides. Soluble metals in aqueous solutions and effluents, such as zinc, nickel, cobalt, copper, cadmium and lead are precipitated as sulfides when their concentration in the solution is low. For this reason the process is extremely used, as purification in the effluents and the most common precipitating agents used is sodium sulfide and ammonium sulfide.

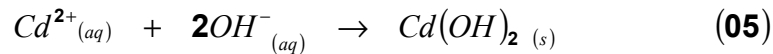
The extremely low solubility of metals sulfides is utilized to precipitate metals from aqueous solutions. Basically, sodium sulfite is used as the precipitation agent. The principle of process can be described by the following equations (04)



The cadmium sulfite can be removed by filtration, and the pH-value has to be controlled.



Other process also used of the removal of the effluents is the precipitation of hydroxides. Under certain conditions of pH, temperature and concentrations of cadmium in solution leads the cadmium to precipitate. The process can be represented by equation (05)



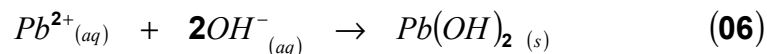
The advantages of these two processes are its high efficiency, easy control, word ambient temperature and economical technology. The residues that contain cadmium sulfite and cadmium hydroxides need the adequate disposal site that has to be control forever.

### **NBR 14572:2000 - Lead – Removal Process in Effluents**

The principal lead mineral is the sulfite, galena. Galena is frequently accompanied by sulfites of zinc and iron.

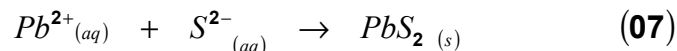
The presence of lead in effluents and wastewater is hazardous and it has to be removal. In this standard (NBR 14572:2000 – Lead - Removal process in Effluents) is described three processes of lead removal with precipitants: (a) high calcium quicklime to forms hydroxides; (b) sulfite precipitating agents, and (c) sulfate precipitating agents.

In the hydroxide process an alkaline lead hydroxide is obtained after addition of the high calcium quicklime (CaO). As the lead hydroxide is insoluble, it is precipitated (equation 06)

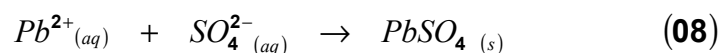


The precipitation should be conducted within a certain pH range – the optimum pH is near 9.0- because with over pH =12 Pb(OH)2 forms Pb(OH) 2- 4 which has amphoteros characteristics.

When is utilized sulfite as precipitating agent is needed high rate of agitation and the solution together with a seed is gone in the vessel for about 3 hours. This is the equation (07):



When is used sulfate as precipitating agent, usually sodium sulfate, lead is precipitated. Continuous agitation and the solution together with a seed is left in the vessel for about 3 hours to permit the formation of lead sulfate (equation 08)



The advantages of these three processes are its elevated efficiency, easy control, word ambient temperature and economical technology. The residues containing lead hydroxides, lead sulfite and lead sulfate are very hazardous. The disposal of the residues needs of the adequate site with permanent monitored of the final effluents, groundwater and receiving system.

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