Characterization of a Coal Tailing Deposit for Zero Waste Mine in the Brazilian Coal Field of Santa Catarina

Juarez R. do Amaral Filho[1], Ivo André H. Schneider[1], Rejane M. C. Tubino[1]
Irineu A. S. de Brum[1], Gerson Miltzarek[1], Carlos H. Sampaio[1], Carlos H. Schneider[2]

[1]Universidade Federal do Rio Grande do Sul, Programa de Pós-Graduação em Engenharia de Minas, Metalúrgica e Materiais, Centro de Tecnologia, Av. Bento Gonçalves, 9500. Bairro Agronomia. CEP: 91501—970. Porto Alegre – RS – Brazil. juarez.amaral@ufrgs.br; ivo.andre@ufrgs.br
[2]Carbonífera Criciúma S.A. Av. Presidente Juscelino, 715. CEP: 88810—200, Criciúma – SC – Brazil: Schneider@carbocri.com.br

Abstract Brazilian coals tailings deposits demand large physical area, change the topography and generate acid mine drainage (AMD) with laden with metals. This work characterizes a typical coal tailings deposit, seeking the separation of three fractions for future reuse: a fraction of low density; a fraction of intermediate density; and a fraction of high density.The characterization included particle size analysis, dissymmetric studies, XRD, acid-base accounting tests and determination of ash and total sulphur. The results showed a size distribution of 67% coarse, 14% fine and 19% ultra-fine particles. Gravimetric concentration recovered 34.2% of the total for energy use or generation and 9.2% is a pyrite rich concentrate. The remaining material, has a lower acid generation potential by about 60% based on acid-base accounting tests.

Key Words coal tailings; coal preparation; zero waste mine, sustainability.

Introduction

Brazilian run-of-mine (ROM) coal contains high levels of impurities (rock minerals and pyrite). Thus, it requires concentration methods to reach the conventional Brazilian power station's standards, which require coals containing 43% of ash and 2.3% of sulphur. Approximately, 50—60% of the ROM material is discharged as waste in tailings deposits. It is estimated that more than 300 million tonnes of coal tailings exists in the south of Brazil, generating AMD with the well known environmental impacts and economic costs.

It is planned for the year of 2012 the start up of operation of a coal power station of circulating fluidized bed with a generation capacity of 400 MW (USITESC – Power Station of South of Santa Catarina). This plant will accept coals with 67.0% and 3.2% of ash and sulphur grades respectively, providing an opportunity for increase the global recovery of the Brazilian ROM coals and to recover part of the coal tailing deposits. With tailing processing, large quantities of coal waste would become raw material for electricity generation at USITESC while a fraction could be processed for pyrite concentration and potential manufacturing products for other industrial sectors. The pyrite concentrate could be converted to sulphuric acid, ferric coagulant, ferrous sulphide and inorganic pigments (Tveit, 2003; Wei and Viadero, 2007; Marcello et al., 2008; Vigânico, 2009; Colling, 2010). The remaining wastes, which can not be utilized will contain less sulphur, can be managed and used as a basis for studies aiming at the development of new products to be used in construction and/or agriculture. Figure 1 shows the traditional approach of Brazilian coal industries (continuous lines) and the proposed new approach presented here, reflecting the principles of sustainability (dashed lines).

This work aims to characterize a typical coal tailings deposit located in southern Brazil, dividing it into three distinct density fractions and suggesting the best applications for each one. The results are discussed in terms of the Brazilian reality and the perspectives of zero waste mine.

Methods

The waste studied was provided by Carbonífera Criciúma S.A. from the Mining Unit II (UM II) – Verdinho, Forquilhinha County, SC, Brazil. After processing ROM coal at UM II, the waste is placed at a coal tailing deposit. The deposit receives "coarses"(+2.0mm -50.8mm) and "fines"(+0,1mm - 2.0mm) waste particles as well as the sludge from the settling ponds, which are used for solid-liquid separation of process water. The estimated tailings mass in the deposit is 11 million tonnes. Figure 2 shows an upper view of the tailing deposit studied.

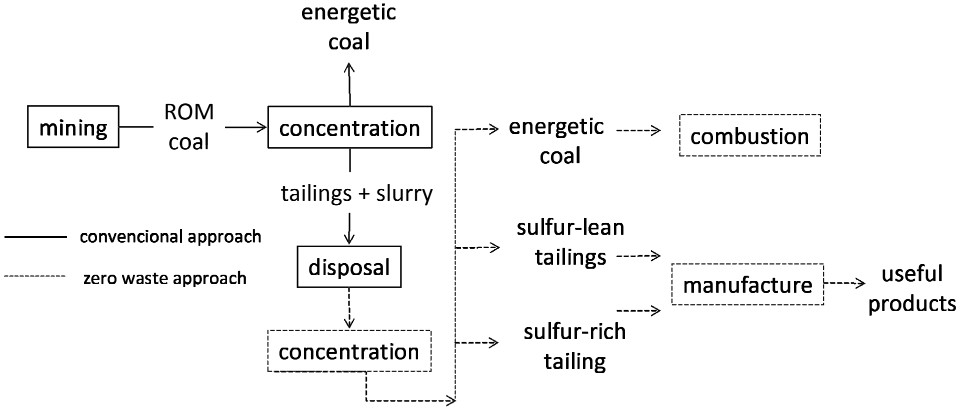

Figure 1 *Traditional approach and proposed approach to management of mining waste*

Samples were collected from four drill holes in the waste deposit. The samples were mixed, quartered, and manually separated in order to segregate the "particles" from the "sludge". The particles were screened to separate the "coarse" fraction (-50.8mm + 2.0mm), the "fine" fraction (-2.0mm +0.1mm). The material passing through the sieve of 0.1 mm was joined with the sludge fraction. The "coarse" and "fine" fractions were submitted to a laboratory for dense medium processing aiming to float the fraction based on their relative densities of 1.5 – 1.7 – 2.0 – 2.2 – 2.4 – 2.8 and the sunk on 2.8. These tests allowed drawing densimetric curves and thereby obtaining mass recovery in any particular density. After the float-sink assays the fractions were characterized in terms of total sulphur and ash contents.

Additional analyses were carried by x ray diffraction (XRD) to assess the mineralogical composition. The acid–base accounting (ABA), as described by Sobek et al (1978), was carried out to determine the net acidity generation potential.

Results

After manual separation, screening and characterization of the fractions, the results indicated that through the processes of mineral tailings concentration it is possible to obtain 3 different-sized fractions. A fraction with size -50.8mm +2.0mm, that can be obtained by jigging, a fraction with size -2.0mm +0.1mm, that can be concentrated in the fines circuit (spirals, tables, cyclones),

Figure 2 *Upper view of tailings deposit of Mining Unit II – Verdinho – Criciúma S.A.*

***Table 1** Analytical results of the mining waste studied*

relative density	size (mm)	sulphur (%)	ash (%)	mass (%)	XRD results*	possible products
- 2.3	+ 2.0 - 50.8	2.3	60.8	8.4	gypsum; kaolinite; quartz	energetic coal
	+ 0.1 - 2.0	3.3	60.5	6.8	gypsum; jarosite; quartz	
+ 2.3 – 2.8	+ 2.0 - 50.8	1.8	87.7	50.8	quartz; plagioclase	construction; ceramic; stonemeal; backfill
	+ 0.1 - 2.0	2.8	87.7	5.8	gypsum; quartz	
+ 2.8	+ 2.0 - 50.8	38.0	66.4	7.8	quartz; pyrite	sulphuric acid, ferric coagulant, ferrous sulphide, ferric oxide nonoparticles; inorganic pigments
	+ 0.1 - 2.0	17.8	76.2	1.4	quartz; pyrite	
N/D	- 0.1	3.1	67.6	19.0	gypsum; quartz	energetic coal

*major minerals

and a fraction less than 0.1mm, called "slurry". The particle size analysis showed the following distribution by weight: 67% "coarse" particles (-50.8mm +2.0mm), 14% "fine" particles (-2.0mm +0.1mm) and 19% "slurry" (-0.1mm).

Sink-float tests allowed to separate the "coarse"particles (-50.8mm +2.0mm) and the "fine" particles (-2.0mm +0.1 mm) fractions in 3 different-densimetric fractions (Table 1). In Table 1 their mineralogical components and the possible products are presented for each fraction.

The amount of "coarse" and "fine" particles with densities under 2.3 was determined as 8.4% and 6.8%, respectively. These fractions fulfil the energetic specification of the future power station of USITESC. They can also be blended with the "slurry" (- 0.1mm) reaching the USITESC operational standards of 67% ash and 3.2% sulphur. In this case, the "blend" ("coarse", "fine" and "slurry"), in theory, would become 64.5% ash and 3.1% sulphur, recovering up to an estimated 34.2% of the whole tailing deposit.

Another fraction that can be recovered is the pyritic fraction, with density below 2.8. The "coarse" and "fine" particles contribute with 7.8% and 1.4% of the weight, given a total of 9.2%. The material with about 35% sulphur, with a pyrite concentration of about 65%, could be processed to produce sulphuric acid, ferric sulphate, ferrous sulphate, and pigments.

Considering the separation of the energetic and the pyritic fractions, the total waste mass could be reduced by 43.4% (4,774,000 tonnes). The remaining material 56.6% (6,226,000 tonnes) are lower in pyrite and less aggressive to the environment. The "coarse" and "fine" particles with the density in between 2.3 and 2.8 correspond to 50.8% and 5.8% of the deposit. This material would have considerably minor sulphur content, with a less acid generation potential. The total sulphur content of the deposit would decrease from 5.2% to 1.9%. The results of the acid base accounting tests showed initial values from -162.5 kg $CaCO_3$/t (whole deposit) and final values of -62.5 kg $CaCO_3$/t. The result is a reduction in acidity generation and concentration of metals in the AMD, deducting costs substantially in the effluent treatment plant, wich probably will operate with a better environmental performance. Also, investigations could be initiated in order to reuse the material, for instance: construction, production of ceramics, and agriculture (stonemeal).

It should be considered that, nowadays, the carboniferous region of Santa Catarina Brazil, by means of the industries, government, and research institutions, are engaged to recover all the pollution provided by decades of coal exploration. The main efforts have been carried out to treat the AMD and to recover degraded areas. However, we consider that part of the solution is to provide a useful destination to the coal tailings, considering the principles of sustainable development and zero waste mine (Benzazoua et al, 2008; Hesketh et al, 2010; Menezes et al, 2010). The region presents a diversified economy, including agriculture, ceramics industry, and textile industry, therefore showing an eminent market for products development to be marketed so as to help the economic and social development within a regional context.

Conclusions

This approach brings a new outlook to tailings management in the Brazilian coal-based industries. The study showed that it is possible to decrease or even eliminate the environmental liabilities of coal tailing deposits by means of Research, Development and Innovation (R&D&I). The coal companies can diversify their production, and, even after decommission of the mining exploration, continues their activities processing the coal wastes. The products include energetic fractions, materials for civil construction, and incomes for the chemical industry. The benefits are both to the regional economy and to the environment.

Acknowledgements

The authors thank Cape Breton University for hosting the IMWA 2010. The authors are also grateful for the financial support extended by CNPq and the Brazilian "Coal Network" for this research.

References

Benzaazoua M, Bussière B, Demers I, Aubertin M, Fried E, Blier A (2008) Integrated mine tailings management by combining environmental desulphurization and cemented paste backfill: Application to mine Doyon, Quebec, Canada. Minerals Engineering 21: 330–340.

Colling AV (2010) Oxidação da Pirita por Via Bacteriana em Rejeitos de Carvão. M.Sc. Dissertation. Universidade Federal do Rio Grande do Sul.

Hesketh AH, Broadhurst JL, Harrison STL (2010) Mitigating the generation of acid mine drainage from copper sulfide tailings impoundments in perpetuity: A case study for an integrated management strategy. Minerals Engineering 23: 225–229.

Marcello RR, Galato S, Petersona M, Riellac HG, Bernardina AM (2008) Inorganic pigments made from the recycling of coal mine drainage treatment sludge. Journal of Environmental Management 88: 1280–1284

Menezes JCSS, Silva RA, Arce IS, Schneider IAH (2010) Production of a poly-alumino-iron sulphate coagulant by chemical precipitation of a coal mining acid drainage. Minerals Engineering 23: 249–251.

Tveit TM (2003) A simulation model of a sulphuric acid production process as an integrated part of an energy system. Simulation Modelling Practice and Theory 11: 585–596

Viganico EM (2009) Produção de Sulfato Ferroso a Partir de Rejeitos de carvão. M.Sc. Dissertation. Universidade Federal do Rio Grande do Sul.

Wei X, Viadero RC (2007) Synthesis of magnetite nanoparticles with ferric iron recovered from acid mine drainage: implications for environmental engineering. Colloids and Surfaces, A, Physicochemical Engineering Aspects 294: 280–286.

Sobek A, Schuller W, Freeman J, Smith R (1978) Field and Laboratory Methods Applicable to Overburdens and Minesoils. U.S. Environmental Protection Agency, EPA-600/2-78-054, Cincinnati.