IBRAM
BRAZILIAN MINING

2nd EDITION

CIRCULARITY PRACTICES
IN MINERAL SECTOR

IBRAM
MINERAÇÃO DO BRASIL

CIRCULARITY PRACTICES IN MINERAL SECTOR

2nd EDITION

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PRESENTATION

Considering population growth trends, social prosperity and energy transition for less emitting technologies, the increase of demand for minerals is inevitable. And the sector mineral, as the basis of value chains, will be increasingly required to actively participate in the challenges brought by the sustainable development agenda, in special focus on the energy transition, and to integrate with the various value chain links and help close production cycles and consumption.

A major society challenge is keeping the same life standard level to everyone, assuring reduction of waste generated. Thus, manufacturing sectors, including mining, also have to deal with such paradox. Thus, resource use efficiency and technology development to use waste are strategic and fundamental.

Mineral sector will have fundamental role at developing transition plans to circular economy, whether in local, regional or global scope, as demands for inputs to supply manufacturing processes will hardly be fully supplied by anthropogenic resource or secondary material sources.

Within this viewpoint, IBRAM releases the 2nd edition of the E-book: Circularity Practices in Mineral Sector, to foster and disseminate knowledge on mining industry in this new approach, and mainly, incentive all mineral sector to search for technological solutions that create additional value and improve environmental results in mining waste and mineral processing.

Have a nice reading!

Raul Jungmann
Chief Executive Officer

INTRODUÇÃO

Christiane Malheiros[1]
Laís Resende[2]

In traditional linear business models, minerals are extracted, processed in almost their totality, used to manufacture a product and, finally, discarded. However, these models do not are more compliant with supply chains today, which have growing demand, but with sustainability objectives and regulatory requirements increasingly more restrictive. Considering this, the circular economy emerges as a transformative approach, promoting a model sustainable development that redefines the way we consume and manage resources.

In a global context, this strategy becomes essential to mitigate environmental impacts and foster resource efficiency. Mining sector, in particular, can benefit significantly from adopting circular practices, optimizing tailings and spoil reuse, that historically represent environmental and economic challenges.

A circular economy intends to reduce waste, expand material life with the highest value possible, design products so that materials are recycled back to economy, and regenerate nature. In summary, circular economy goes way beyond recycling. In Figure 01, it is described how a manufacturing system would be, using this new economic model practices:

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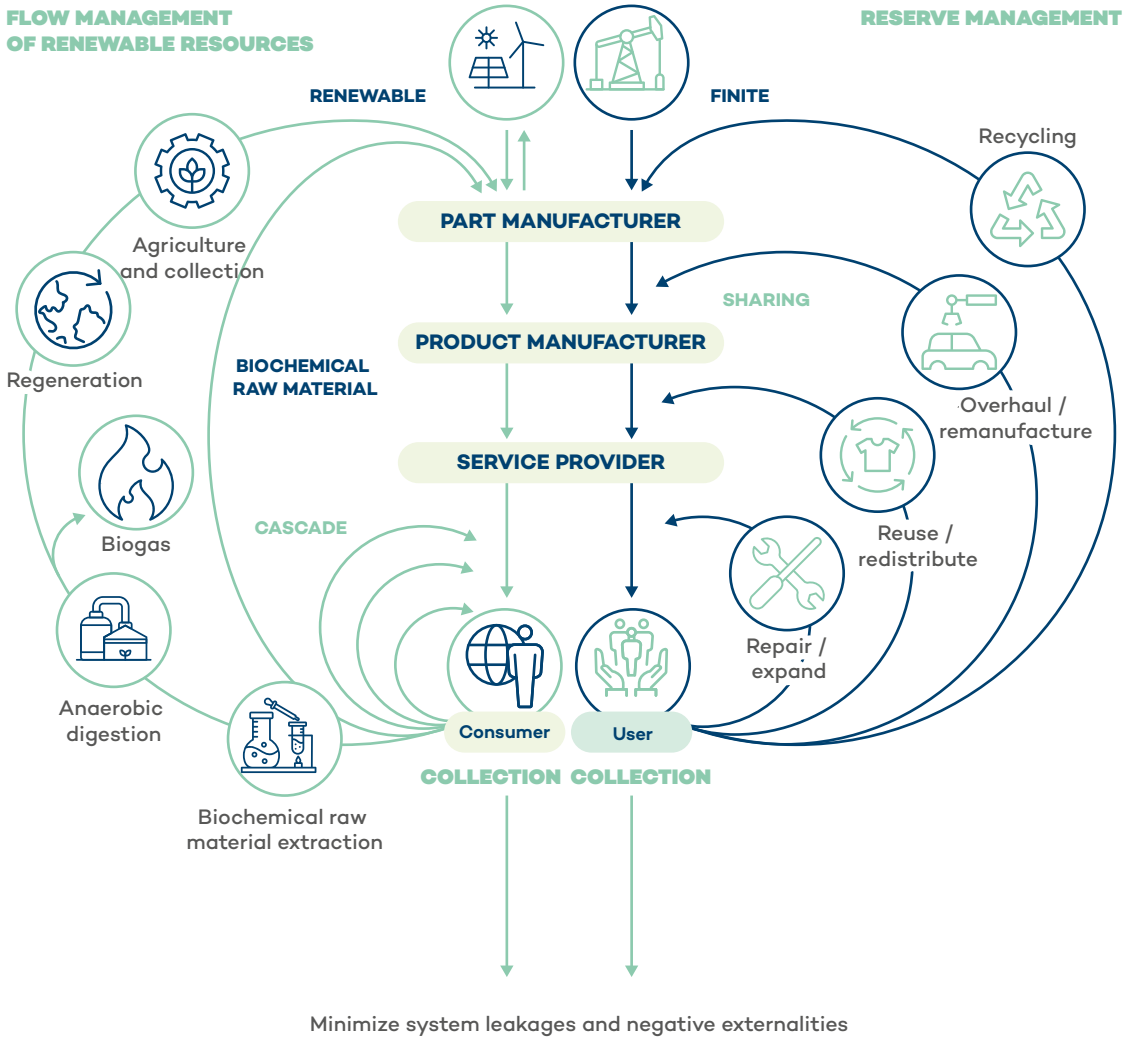
Figure 1: Circular Economy System Diagram



Source: Adapted from Ellen MacArthur Foundation, 2019

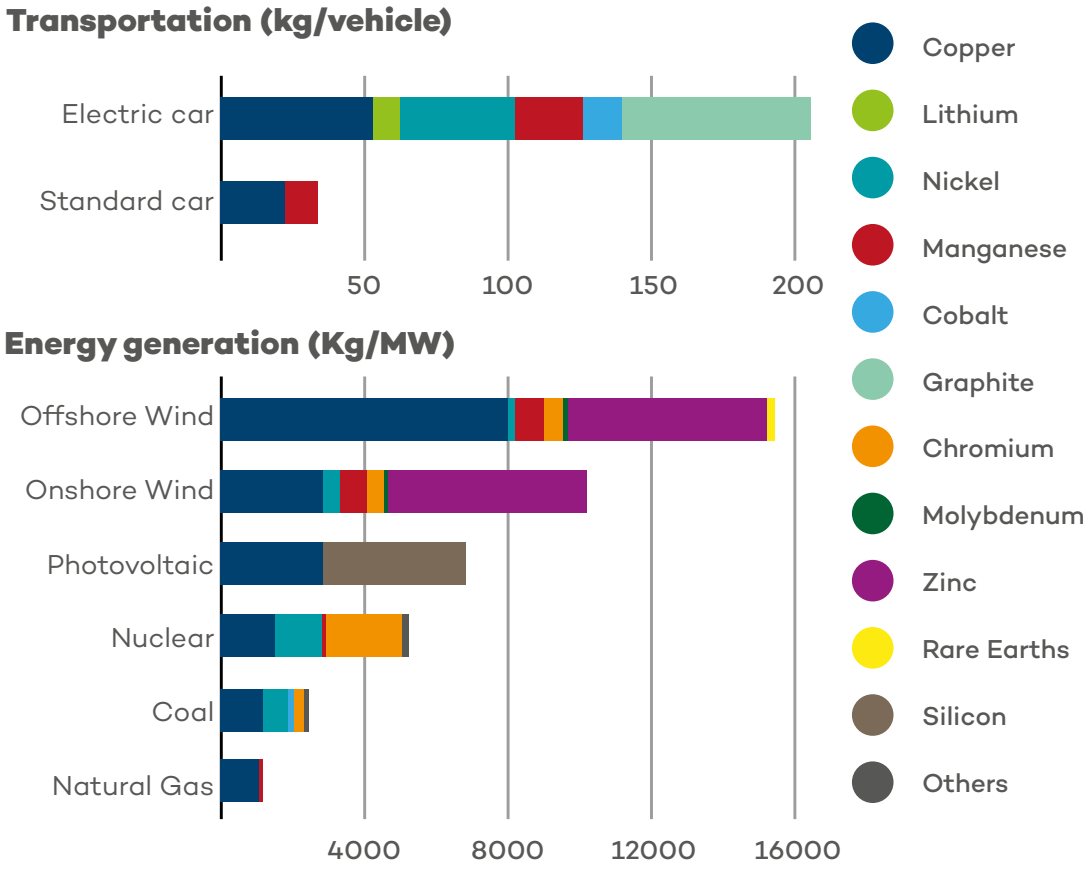
In the 1st Edition of Mineral Sector Circularity Practices, tailings and spoil reuse relevance was highlighted, as well as non-mineral waste, by mining companies, exploring the connection between sustainability and productivity in mineral sector. Emerging technologies, regulation and successful cases were introduced, that showed the potential of changing waste into valuable resources. This focus not reduces the quantity of waste generated, but also enables more sustainable mining.

In this 2nd edition, circular economy benefits specifically for mining sector will be approached, detailing the best practices and innovations that can be adopted. Main challenges that Brazil faces in tailings reuse will also be discussed, with the goal of enabling a more sustainable and productive future.

Circular economy as energy transition solution

A circular economic model can be one of the alternatives for the world to de-carbonize and reduce climate change impacts. It is known that some minerals are key components of energy transition technologies required to low carbon future. Transition minerals are natural occurrence substances, often found in rocks, optimal to be used in renewable technology. (Figure 2)

Figure 2: Critical and strategic minerals used in renewable energy technologies.



Notes: Kg=kilogram; MW=megawatt; Steel and aluminum not included. Demand was estimated from four main variables: (i) renewable insertion trends in different scenarios; (ii) sub-technology participation in each technological area; (iii) mineral intensity of each sub-technology; and, (iv) mineral intensity improvements.

Source: Adapted from IEA (IEA,2021). Available at https://ibram.org.br/wp-content/uploads/2024/07/IBRAM_MINERAIS_CRITICOS-E-ESTRATEGICOS_web.pdf

As it can be seen, such mineral demand in the future will be increasingly triggered by various energy transition technologies and will grow at rates that have never been seen before. In a scenario aligned with Paris Agreement, demand can rise 40% for copper and rare earths, 60-70% for nickel and cobalt, and almost 90% for lithium in the next two decades.

Electric vehicles are becoming the largest lithium consumers, and will be the largest nickel users by 2040. This increasing mineral dependence for economy decarbonization will present unique challenges to governments and policy makers in relation to mining market vulnerabilities, including eventual price volatility and supply safety need (IEA, 2021).

Reusing tailings and spoil that contain these critical and strategic minerals can be a more environmentally attractive alternative to solve part of decarbonization challenges. At the same time, it will reduce new mine opening requirement, as well as non-renewable natural resource extraction; tailings and spoil use will enable environmental impact reduction of new geotechnical structures and can lead to the generation of new business, recipes, and economic development.

Over the last six years, world population consumed more than 500 million tons of materials - quantity corresponding to what was consumed within all 20th century. Circular economy will help to reduce emissions at 40%, generate almost 2 million jobs, and become a market of US$ 2 to 3 billions in the next years.

Apart from being seen as a solution to environmental impact reduction, circular economy also becomes attractive in relation to its economic potential. If we started to consider circularity, not as waste management solution, but as it really is, we would have a different scenario.

Strategy: how a circular model can be implemented in different mineral sector industries

In mineral sector, there is a large variability in characteristics and volumes of tailings, spoil and non-mineral waste generated in operations. Types of tailings vary according to concentration process employed in processing stage, and also with mineral deposit characteristics, where ROM (Run of Mine) is extracted, that will supply ore treatment plants (Amaral et al., 2019).

On the other hand, spoil is linked to local geology specificity and non-mineral waste to processes and products of each industry. Due to that, there is a complexity at designing targets and/or public policies, considering solutions range according to each mineral good.

Even though there is the complexity abovementioned, a convergence point among all generating industries of different mineral and non-mineral waste types is the search for technical and business solutions that present economic feasibility and that enable the largest consumption possible of waste.

Due to that, the strategy within each company will be different, however to the sector, in its totality, it will be possible to design a common path, as for instance,

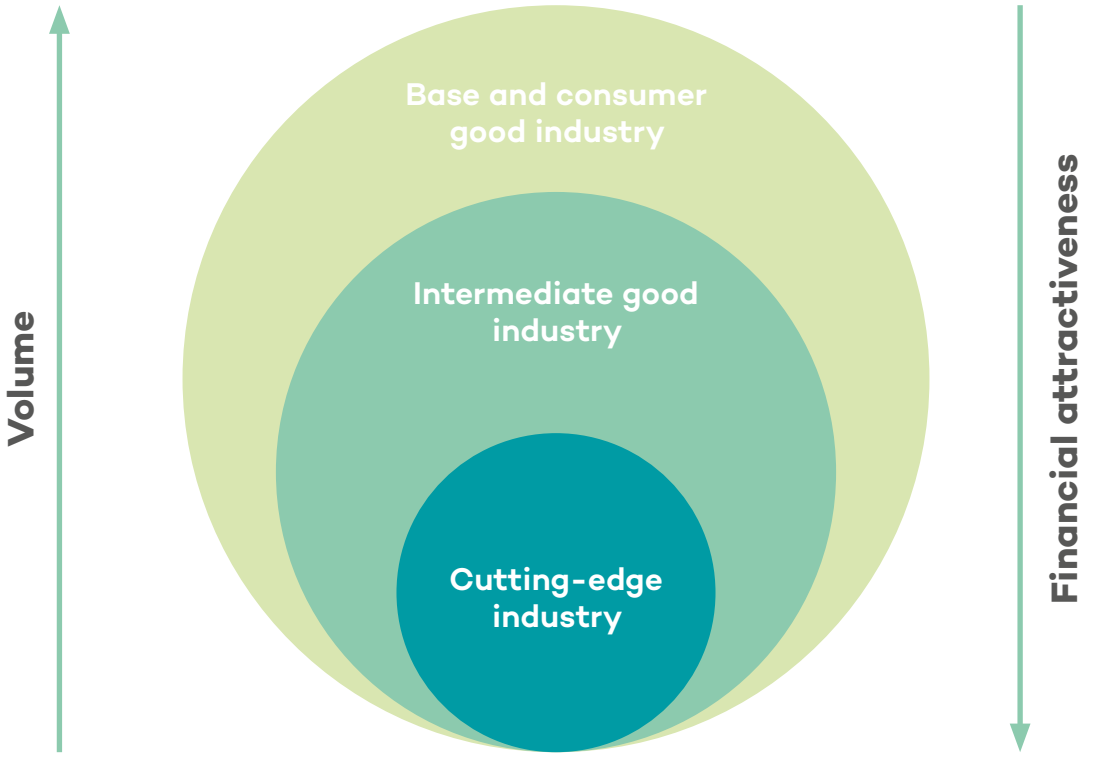
research development and support, financing and even promotion of laws and regulations that enable circular economy in such organizations.

One of assessment strategies to a new business, aiming at waste circularity, can be performed considering potential volume disposed and financial attractiveness.

Within such analysis, it is required at first to understand the technical potential of tailings, spoil and non-mineral waste. It shall be highlighted that such material reuse can be performed in different types of industries, depending on technical properties of each one of them.

There are applications that can consume a significant volume within base or consumer good industry, for instance, civil construction. However, input value in this application will have low added value. On the other hand, there will be application alternatives in sectors including cutting-edge technology industry, that can provided added value to input, however with low volume potential. In the next figure, this analysis is illustrated.

Figure 3- Circular business implementation strategy for tailings, spoil and non-mineral waste



Source: Authors, 2024

Recently, as per ISO 59004 (2023) Standard, six principles were developed to guide strategy within organizations in relation to circular economy. Such principles will guide the actions companies will adopt to create a circularity assertive program, including:

- Systemic thought: organizations adopt life cycle perspective and apply long--term approach, as they consider their impacts in environmental, social and economic systems.
- Value creation: organizations recover, retain or add value, providing efficient solutions, that enable socioeconomic and environmental value and use resources in efficient way.
- Value sharing: organizations collaborate with stakeholders along the value chain or value network in inclusive and quantitative way, for society benefit and wellbeing, through value sharing created by solution delivery.
- Resource management: organizations manage stocks and flows in sustainable way, including closing, deceleration and reduction of resource flows, enabling resource accessibility and availability for present and future generations, and reducing risks associated to virgin resource dependence.
- Resource traceability: organizations collect and keep data to enable resource traceability along their value chains and are responsible for sharing relevant information with stakeholders.
- Ecosystem resilience: organizations develop and implement practices and strategies that protect and enable resilience and regeneration of ecosystems and their biodiversity, including prevention of losses and damaging emissions, considering planet limits.

Circular economy background in Brazilian mining

Circular economy is already being implemented in different sectors. Some companies have adopted practices that promote material reuse, recycling and waste reduction. Such initiatives show that the transition to a circular model not only benefits the environment, but also triggers innovation and competitiveness.

In mining industry, tailings, spoil and non-mineral reuse background is still complex.

Despite significant developments, including new technology implementation and increasing awareness on waste management, there are significant challenges yet. The lack of an ecosystem that incentives and benefits circular product consumer; cultural resistance; high logistic and operational costs to trigger initiatives, do not enable such material reuse practices.

Brazilian mineral sector has evolved to create a fiscal, legal and tax environment that incentives circular economy.

An example is the initiative of ANM (National Mining Agency) to include circular economy and urban mining within Sustainability pillar of New Brazilian National Plan 2050. Such normative is still being developed and presents challenges and

policy guidelines, guiding governmental action (Decree no. 11.108/2022 - long--term strategic agenda).

In 2019, National Industry Confederation - CNI performed a survey to check how circular economy has been treated by industrial sector. According to this survey, more than 88% of entrepreneurs consider circular economy as very important to Brazilian economy. It was also identified that 76.5% of interviewees already adopt some circular economy practice, even though the majority still does not know that initiatives fit this concept.

In Figure 4, it is possible to check further details of this survey:

Figure 4: Main circular practices adopted

Source: CNI, 2019

As it can be seen in Figure 4, practices listed by respondents include process optimization (56.5%), circular input use (37.1%), resource recovery (24,1%), and product life extension (22,9%) in circular economy initiative adoption. In the same survey, it was identified hat main reasons that led companies to circular economy initiatives included operational efficiency (47.3%) and new business opportunity (22.6%).

Results of survey performed by IBRAM

Brazil Mining ESG (Environmental, Social and Governance) Agenda, structured by the Institute from 2019, with Letter of Commitment publication, is the advising guide of mineral sector and IBRAM itself. Such commitments and actions intend to promote a wide process ofmining evolution. This agenda provides a set of actions included in twelve sectoral commitments, that are annually measured, checked and reported to society. Figure 5 provides 12 topics covered by mineral sector ESG Agenda:

Figure: 5: Mineral sector ESG Agenda sectoral commitments

These 12 thematic groups were created to promote sustainable and social responsibility practices, aligned with global guidelines for sustainable development.

Waste Work Group (GT), in particular, plays a crucial role at the search for synergies, research support and creation of favorable ecosystem, so that mining companies can implement their waste circular economy.

In 2023, GT presented the largest associate participation number. These companies account for approximately 50% of Brazil´s mineral production, that was 2.3 billion tons (IBRAM,2024).

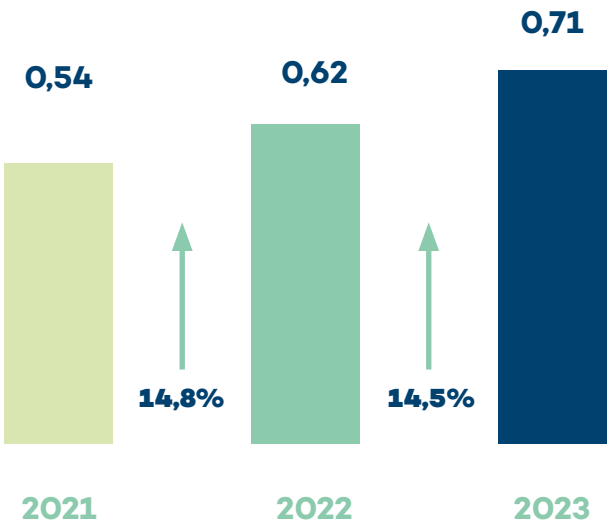
According to data reported by associate companies, approximately 4.9 million tons of non-mineral waste were generated, out of which 3.5 million tons were recycled, reprocessed and reused in 2023, with 0.71 index, according to Figure 6.

According to results assessed in mineral and non-mineral waste thematic, mining companies invested around BRL 420 million in circular economy initiatives. Still according to this survey, 27% of the companies declared they consumed tailings and spoil in circular practices, showing the relevance of circularity thematic for mining activity.

From such data, mining fundamental role can be seen in transition plan development to circular economy, whether in local, regional or global scope, and also in circularity strategy execution, as a large part of their waste is a solution, so that other industries become more sustainable, enabling decarbonization and reduction of environmental impacts.

Such practical circularity case publication, for mineral waste (tailings, spoils and co-products), and non-mineral waste, included in this 2nd Edition, is again he sector demonstration for knowledge promotion and dissemination on mining industry, in this new approach, and mainly, incentive to all mineral sector at the search for technological solutions that create additional value and improve environmental results in mining waste and mineral processing.

Figure 6: Recycling over **total non-mineral waste generation**



(Source: IBRAM 2024)

AMG BRASIL

GEOPOLYMER AND CEMENT PRODUCTION FOR CIVIL CONSTRUCTION

PROJECT

Project Title	• GEOPOLYMER AND CEMENT PRODUCTION FOR CIVIL CONSTRUCTION
Partner Institutions	**Partner Institutions:** • Study and Project Sponsor • Escalation and Technology Center - Escalab
Project Stage	**Ongoing** • (x) Product optimization • (x) Pilot prototype development • (x) Semi-industrial operation **Completed** • (x) Theoretical Modeling • (x) Lab Tests – Characterization • (x) Bench Tests – Product Development
Business Model	• ( ) Outsourcing • ( ) B2B • (x) Technology Incubation and Internal Development • ( ) Others _____
Main mineral good	• Pegmatite
Type of Tailings/ Spoil/Non-Mineral Waste	• Aluminosilicates
Volume Reused	• Estimated project volume of 2 ton/month, with production capacity increase forecast upon operation start.
New products generated	• Geopolymer and cement materials with different applications, including porcelain tile, synthetic, draining floors, interlocked floors, and high load floors.
Investment (BRL)	• 1,176,376.08

Process description

AMG BRASIL – Volta Grande Mine operates its activities in Nazareno and São Tiago municipalities, Minas Gerais, with production of tantalum/tin concentrates from pegmatitic rocks. What is more, the company also engages in feldspar production for porcelain tile and glass industry.

Through a solid commitment with sustainable practices, AMG Brasil plays a crucial role in CO2 emission reduction. Critical mineral supply enables producing green technologies and goods, that not only require less energy to operate, but also have a longer life and significant reuse and recycling potential. Such minerals contribute significantly to mitigate the emission of millions of tons of CO_2 in the atmosphere.

A clear example of sustainable practices was the creation of a new processing unit, which one of the goals was reuse tailings that were released in Dams VG 01 and VG 02 for Spodumene Concentrate production, and such dams are decharacterized nowadays. The product stood out within current production, through income increase and job creation, evidencing that good practices related to sustainable development not only reflect environmental preservation, but also economic and social development.

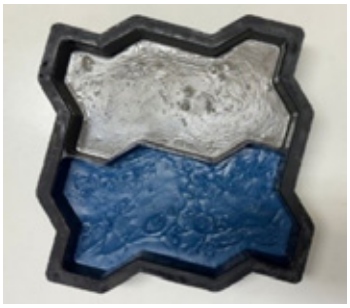
Thinking of environmental challenges related to pollutant emission, AMG has triggered studies for more sustainable studies in relation to Portland cement production. Named as future cement, geopolymer materials provide eco-efficient solution.

This new technology goal is seizing industry byproducts, to develop materials with equivalent or higher strengths than standard ones in civil construction. Such materials are comprised by aluminosilicates and activating alkaline solutions, and spodumene processing development tailings, a type of aluminosilicate, plays a crucial role in chemical reactions.

AMG Brasil proposes to use tailings generated during spodumene processing, a lithium mineral, in geopolymer production intended to civil construction sector. This project is a result of a partnership between the company and Study and Project Sponsor (FINEP), along with Ministry of Science, Technology and Innovation, with FNDCT resources, that funded, through non-reimbursable economic subsidy selection process.

In order to perform tests required, a collaboration was established between AMG Brasil and Escalation and Technology Center (Escalab), a unit of Universidade Federal de Minas Gerais (UFMG). This partnership main goal is using Escalab infrastructure and experience to develop new products to perform residual material analyses, define waste treatment strategies, operate pilot plant, produce samples and do tests, all under AMG Brasl supervision and guidance.

The first product to be tested are interlocked floors to be used for area paving in the company. Work execution projects are already ongoing. The last tests executed in trial bodies by Escalab showed that it is possible to assure high strength parts, with results above expectation. With test stage success, it is estimated that, with pilot plant, it will be possible to achieve initial production



Geopolymer interlocked floor piece.

Geopolymer floors.

of 4 ton/month of geopolymers, with expansion forecast for larger capacities in the future. Apart from interlocked floors, the use of tailings will also be studied in production of other products linked to civil construction, including: cement and coatings.

Spodumene processing development tailings usage promotes circular economy and is aligned with Sustainable Development Goals SDG 9 (Industry, Innovation and Infrastructure), SDG 11 (Responsible Cities and Communities), and SDG 12 (Responsible Consumption and Production) set forth by the UN. The project goal is increasing tailings disposal route and decreasing environment impacts, reinforcing AMG commitment with environmental, social and governance (ESG) policies.

Preliminary strength and compression tests

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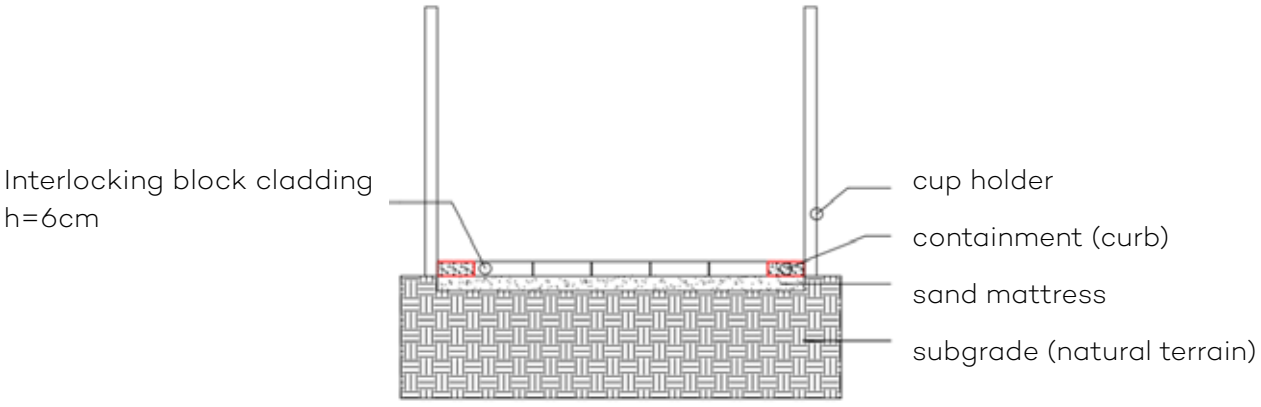


Execution project detailing - sidewalk paving/safe path.

AngloAmerican

CIRCULAR ECONOMY - TRANSFORMING TAILINGS IN SHIMS THAT PAVE PUBLIC ROADS

PROJECT

Project Title	• CIRCULAR ECONOMY - TRANSFORMING TAILINGS IN SHIMS THAT PAVE PUBLIC ROADS
Partner Institutions	• O Rei do Bloco e Prefabricados • Transportadora Vila LTDA • Construtora Terraço
Project Stage	**Completed** • (x) Theoretical Modeling • (x) Lab Tests – Characterization • (x) Bench Tests – Product Development
Business Model	• ( ) Outsourcing • ( ) B2B • (x) Technology Incubation and Internal Development • ( ) Others _____
Main mineral good/	• Sandy tailings originated from iron ore processing.
Type of Tailings/ Spoil/Non-Mineral Waste	• Iron ore processing flotation tailings, with similar characteristics to fine sand.
Volume Reused	• Around 2,500 tons of tailings.
New products generated	• The material is being used in ship production for rural road paving and also in full replacement of sand used in settlement (“sealing sand”).
Investment (BRL)	• So far, around BRL 1.2 million were invested

Process description

In order to enable the project and assure that shims presented the characteristics required to usage, Anglo American did pilot tests for interlocked block manufacturing (pavers), varying sand replacement contents for tailings in the following percentages:

- 50% (T50), 60% (T60), 75% (T75) and 100% (T100).

For comparative effects, a reference trace (REF) was also produced, i.e., without using tailings.

Due to results achieved, it was verified that trace T50, i.e., with 50% replacement of river sand for sandy tailings, complied with minimum requirements provided in NBR 9781 (ABNT, 2013). For T50, it was used the following concrete trace (in volume):

1:2:2:1 (cement:sandy tailings:sand:crushed stone 0)

Figures 1, 2 and 3 (page x) evidence concrete consistence and part of part production process.

From results achieved, it is concluded that, thus, flotation tailings usage as partial replacement to sand is technically feasible, and it also presents higher mechanical behavior, as higher compression strength up to 62%, compared to standard shims.

Finally, it is possible to infer, from the results achieved, that flotation tailings use as alternative aggregate provides longer durability to pavement, and it is an economically and environmentally beneficial option.

Figures below provide results achieved to T50 and REF

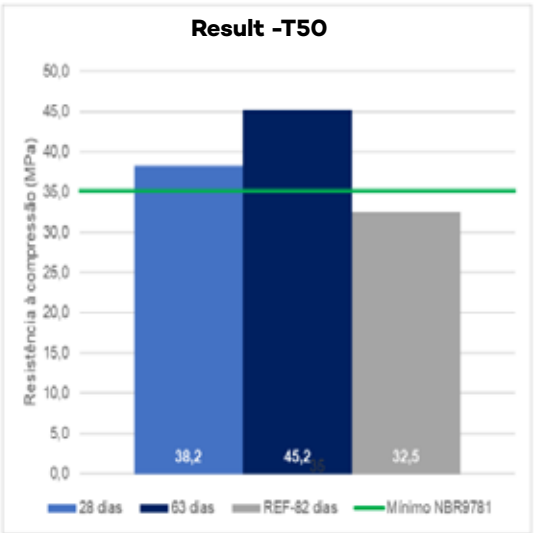


Figure 3 • Compression resistance of the mixture with 50% sand replacement (T50). compared to the normative effect and the result obtained for the reference mixture (REF).

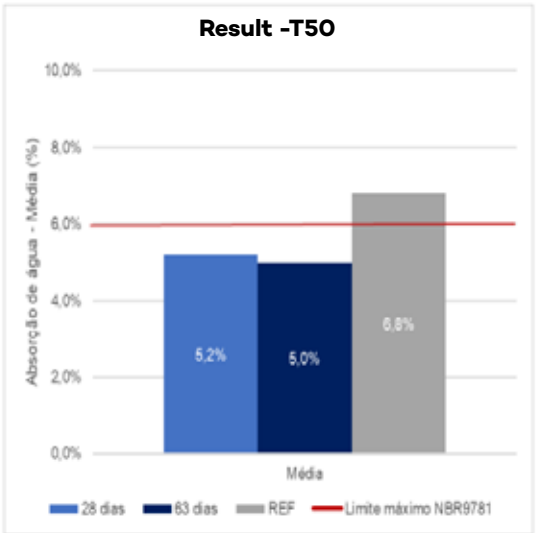


Figure 4 • Average water absorption of the mix with 50% sand replacement (T50), compared to the normative requirement and result obtained for the reference mix (REF).

Figure 1

Figure 2

Figure 3

In iron ore processing, two main types of tailings area generated (with similar characteristics as fine sand), and muddy tailings, even finer granulometry material, and with higher iron percentage in its constitution.

In order to provide a better destination to filter flotation tailings, pilot tests were performed to manufacture interlocked blocks (shims), varying sand replacement contents for tailings with different percentages, until it was seen that sand river 50% replacement for sandy tailings complies with minimum requirements provided by NBR 9781 (ABNT 2013), for shim manufacturing.

From results achieved, it is concluded that, thus, flotation tailings usage as partial replacement to sand is technically feasible, and it also presents higher mechanical behavior, as higher compression strength up to 62%, due to tailings characteristics (especially by Fe presence in composition).

After positive results, the partner company **O Rei do Bloco e Prefabricados**, with headquarters in Serro city, started production of he first 230,000 shims, that were donated to Alvorada de Minas municipality, for section sidewalk construction corresponding to "Zé do Mato" road, that gives access to Itapanhoacanga District.

In parallel, with support of **Transportadora Vila e da Construtora Terraço**, around 2,000 tons of tailings were submitted directly to the same work, and used in block settlement to replace the sand.

Later, there was also the donation of 50.,000 shims to Serro municipality, and 12,820 to Conceição do Mato Dentro municipality, all located in MG.

It shall be highlighted that usage of shims produced with dam tailings provided higher durability to pavement, and it is also an economically and environmentally beneficial option.

Process gains include:

- Natural resource consumption reduction - as there is no need to mine sand;
- Tailings pile volume reduction;
- Economic advantages: reduces small aggregate acquisition by manufacturer / eliminates sand acquisition while installing shims
- Technological base new material production possibility - taboo break in relation to tailings use as lower material to river sand. Literature results point out paver advantages using iron ore processing tailings, as for instance: higher abrasion, compression strength and lower water and porosity absorption. I.e., it enables producing more resistant and durable parts;
- Local supplier attraction and development for such pre-cast production;

Apart from environmental and economic advantages, it also contributes to the pillar "Prosperous Communities", of our Sustainable Mining Plan, under two aspects: concrete pre-cast manufacturing is performed with local supplier (Serro). What is ore, products will be used to local road paving, improving user comfort. The goal is starting by the road that connects MG010 to Itapanhoacanga (Alvorada de Minas) and expand in the future to another access roads to communities within undertaking surroundings that require improvements.

Shims donated to Itapanhoacanga road work

ANGLOGOLD ASHANTI

PROJECT

- SPOIL AND TAILINGS USAGE FOR WALL AND FLOOR COATING
- SPOIL AND TAILINGS USAGE FOR PAVING AND INPUTS FOR ASPHALT INDUSTRY
- SPOIL USAGE FOR AGGREGATE REPLACEMENT
- SULPHURIC ACID PRODUCTION FROM AU CONCENTRATE
- CONCRETE SPOIL AND TAILINGS USAGE PROJECT
- LOW CONTENT IRON ORE
- AU TAILINGS REPROCESSING
- FERTILIZER

ANGLOGOLD ASHANTI

Project Title	• SPOIL AND TAILINGS USAGE FOR WALL AND FLOOR COATING
Partner Institutions	• CEFET-MG • Dacapo • EMP • Jasmmin
Project Stage	**Ongoing** • (x) Surveys/Bench/Pilot/Semi-industrial
Business Model	• ( ) Outsourcing • ( ) B2B • (x) Technology Incubation and Internal Development • ( ) Others _____
Main mineral good	• Wall and floor coating production from flotation/ leaching spoil and tailings
Type of Tailings/ Spoil/Non-Mineral Waste	• Tailings are comprised by quartz, carbonates, chlorite and minerals of mine group • Spoil contains quartz, chlorite, carbonates, organic matter and mica group minerals.
Volume Reused	• For this initiative, the estimate is reusing 200 kg of tailings and 500 kg of spoil monthly
New products generated	• Wall and floor coating products
Investment (BRL)	• start: approximately 360 thousand reais

Process description

Overall, raw material preparation stages include crushing and classification for spoil case

Dry tailings and spoil are added to preparation, along with coating preparation raw material.

ANGLOGOLD ASHANTI

Project Title	• SPOIL AND TAILINGS USAGE FOR PAVING AND INPUTS FOR ASPHALT INDUSTRY
Partner Institutions	• CEFET-MG • EMP • Jasmmin
Project Stage	**Ongoing** • (x) Product optimization • (x) Pilot prototype development • (x) Semi-industrial operation
Business Model	• ( ) Outsourcing • ( ) B2B • (x) Technology Incubation and Internal Development • ( ) Others _____
Main mineral good	• Binder paving and production in asphalt industries with flotation/leaching tailings and spoil.
Type of Tailings/ Spoil/Non-Mineral Waste	• Tailings are comprised by quartz, carbonates, chlorite and minerals of mine group • Spoil contains quartz, chlorite, carbonates, organic matter and mica group minerals.
Volume Reused	• For this initiative, the estimate is reusing 100 of tons of tailings and 300 tons of spoil monthly
New products generated	• Road paving and aggregate to asphalt industry
Investment (BRL)	• initial approximately 550 thousand reais

Process description

Overall, they include aggregate replacement to road paving and binders used in asphalt production.

ANGLOGOLD ASHANTI

Project Title	• SPOIL USAGE FOR AGGREGATE REPLACEMENT
Partner Institutions	• CEFET-MG • EMP • Jasmmin
Project Stage	**Ongoing** • (x) Product optimization • (x) Pilot prototype development • (x) Semi-industrial operation
Business Model	• ( ) Outsourcing • ( ) B2B • (x) Technology Incubation and Internal Development • ( ) Others _____
Main mineral good	• Civil work aggregate spoil usage
Type of Tailings/ Spoil/Non-Mineral Waste	• Spoil contains quartz, chlorite, carbonates, organic matter and mica group minerals.
Volume Reused	• For this initiative, the estimate is reusing 600 of tons of spoil monthly
New products generated	• Different types of civil construction aggregate.
Investment (BRL)	• initial approximately 300 thousand reais

Process description

Overall, spoil will be submitted to classification and can generate different products, from cracked rock to crushed stone powder.

ANGLOGOLD ASHANTI

Project Title	• SULPHURIC ACID PRODUCTION FROM AU CONCENTRATE
Partner Institutions	• N/A
Project Stage	**Completed** • (x) Theoretical Modeling • (x) Lab Tests – Characterization • (x) Bench Tests – Product Development
Business Model	• ( ) Outsourcing • ( ) B2B • (x) Technology Incubation and Internal Development • ( ) Others _____
Main mineral good	• Sulphuric acid production from Au concentrate
Type of Tailings/ Spoil/Non-Mineral Waste	• Au concentrate has high sulphide content, and due to treatment, it can be converted into sulphuric acid
Volume Reused	• For this initiative, 11 kt tons of sulphuric acid are produced a month
New products generated	• Sulphuric acid
Investment (BRL)	• approximately BRL 30M, with Queiroz plant return

Process description

Overall, Au concentrate undergoes roasting stage, and in this stage, sulphides are converted into oxides. Gas generation, S-rich, is transformed in sulphuric acid.

ANGLOGOLD ASHANTI

Project Title	• PROJECT CONCRETE SPOIL AND TAILINGS USAGE PROJECT
Partner Institutions	• CEFET-MG • EMP • Jasmmin
Project Stage	**Ongoing** • (x) Product optimization • (x) Pilot prototype development • (x) Semi-industrial operation
Business Model	• ( ) Outsourcing • ( ) B2B • (x) Technology Incubation and Internal Development • ( ) Others _____
Main mineral good	• Standard and self-compacting concrete production with traces of tailings and/or spoil
Type of Tailings/ Spoil/Non-Mineral Waste	• Tailings are comprised by quartz, carbonates, chlorite and minerals of mica group • Spoil contains quartz, chlorite, carbonates, organic matter and mica group minerals.
Volume Reused	• For this initiative, the initial estimate is reusing 100 t of tailings and 300 t of spoil monthly
New products generated	• Standard and self-compacting concretes
Investment (BRL)	• approximately 360 thousand reais

Process description

Overall, they include raw preparation stages with crushing and classification for spoil case.

Dry tailings and spoil are added to concrete preparation as a replacement to cement and small aggregate up to 20%.

ANGLOGOLD ASHANTI

Project Title	• LOW CONTENT IRON ORE
Partner Institutions	• N/A
Project Stage	**Ongoing** • (x) Product optimization • (x) Pilot prototype development • (x) Semi-industrial operation
Business Model	• ( ) Outsourcing • ( ) B2B • (x) Technology Incubation and Internal Development • ( ) Others _____
Main mineral good	• Low content iron ore production from calcined Au tailings
Type of Tailings/ Spoil/Non-Mineral Waste	• Tailings are comprised by hematite.
Volume Reused	• For this initiative, the initial estimate is reusing 100 Mt of tailings annually
New products generated	• Low content iron ore
Investiment (BRL)	• initially BRL 100,000

Process description

Overall, sulphide Au concentrate, upon calcined and leached, generates hematite-rich tailings. Process consists of Fe richening by magnetic separation and shim generation.

ANGLOGOLD ASHANTI

Project Title	• AU TAILINGS REPROCESSING
Partner Institutions	• N/A
Project Stage	**Ongoing** • (x) Product optimization • (x) Pilot prototype development • (x) Semi-industrial operation
Business Model	• ( ) Outsourcing • ( ) B2B • (x) Technology Incubation and Internal Development • ( ) Others _____
Main mineral good	• Au production from dam tailings
Type of Tailings/ Spoil/Non-Mineral Waste	• Tailings are comprised by quartz, carbonates, chlorite and minerals of mica group • Au associated to quartz and sulphides
Volume Reused	• For this initiative, the initial estimate is reusing 3 MMt of tailings
New products generated	• Tailings reprocessed Au
Investment (BRL)	• initially 30 thousand reais

Process description

Overall, studies point out direct leaching of tailings deposited in dams already disabled. What is more, such leaching tailings will be reused as input in projects that use waste as civil industry co-products.

COCORUTO

ANGLOGOLD ASHANTI

Project Title	• FERTILIZER
Partner Institutions	• Campo Análises
Project Stage	**Ongoing** • (x) Product optimization • (x) Pilot prototype development • (x) Semi-industrial operation
Business Model	• ( ) Outsourcing • ( ) B2B • (x) Technology Incubation and Internal Development • ( ) Others _____
Main mineral good/	• Limestone powder production from spoil
Type of Tailings/ Spoil/Non-Mineral Waste	• Spoil contains carbonates, quartz, chlorite, organic matter and mica group minerals.
Volume Reused	• For this initiative, the initial estimate is reusing 100 t of spoil monthly
New products generated	• Limestone powder
Investment (BRL) (BRL)	• initially BRL 28,000

Process description

Overall, some lithologies of Serra Grande mine / Goiás are rich in dolomite. The project consists of seizing Au treatment waste of these lithologies and limestone powder generation. The work is in metal mobility test validation stage of product generated.

ArcelorMittal

REVIVESCER PROJECT –
CERÂMICA USSU

PROJECT

Project Title	• REVIVESCER PROJECT – CERÂMICA USSU
Partner Institutions	• ArcelorMittal – Mineração Serra Azul • Fundação ArcelorMittal • State Culture Incentive Law, by means of AIC / SABIC institution
Project Stage	• ( ) Ongoing • (x) **Completed**
Business Model	• ( ) Outsourcing • ( ) B2B • ( ) Technology Incubation and Internal Development • (x) Others: Community Collective / Income Generation
Main mineral good	• Utility handicraft ceramic production with usage of ArcelorMittal Mineração Serra Azul tailings.
Type of Tailings/ Spoil/Non-Mineral Waste	• Ceramic composition: bentonite, calcium carbonate, kaolin, quartz, feldspar and clay, with addition of dry mining tailings.
Volume Reused	• For each 100 g of clay, 10 g of dry mining tailings are added. Another quantities and uses of tailings in ceramic production are being studied. Ceramic pieces can have different weights, according to size. In project production, they are currently between 200 g and 600 g.
New products generated	• Utility ceramic for culinary use and decoration.
Investment (BRL)	• BRL 700,000.00

Process description

ArcelorMittal intends to contribute positively in communities it operates, and that means listening attentively to understand people expectations and dialog for partnership building.

"Revivescer Project – Creative Ceramic Lab" is a sociocultural initiative for community economy promotion, from qualification at production of utility ceramic handicraft pieces and entrepreneurship. Starting in June, 2023 in a space provided by ArcelorMittal, called Community Home, through applying direct investment and with sponsorship via Culture Incentive Law (LEIC), the project services Itatiaiuçu inhabitants, with the following goals:

- Education action led by community;
- Community undertaking opportunity that enables development and economic diversification;
- Sustainability from autonomy and waste reuse, including mining tailings.
- Collaborative and artistic process for work and income generation;

Raw material (minerals)

USSU Collective (members)

Dry spoil preparation

Mass preparation

Thus, the project has played a crucial role in community development and strengthening. Students received several technical process qualifications, and at present they have production autonomy.

Manufacturing process is fully handicraft, starting by mass preparation with addition of minerals, mining tailings and water. A humid mass is formed, which is stored in indoor space, and with ventilation for natural drying. This is a fundamental stage to piece quality.

In manual modeling process, participants rely on some instruments to give form and finishing, where they use a lot of creativity to give personality to pieces. After this stage, burning process starts, using appropriate and safe electric furnace to activity and people, reaching high temperatures of 1,200 grades approximately.

Mining tailings use application in this project, even in small proportions, has the goal of following world market trends, placing sustainability in product concept

Manual modeling

Peças em exposição

to add value to ceramic, from visibility to community and collective undertaking.

As project develops, participants have built their own brand, by means of participative process. Nowadays, Cerâmica USSU is a community collective formed mostly by women, that search for autonomy, job and income, and that bets on a valuable future to the group and community itself, making it more equitable, resilient and prosperous.

BAMIN

GARBAGE CIRCUIT

PROJECT

BAMIN

Project Title	• GARBAGE CIRCUIT
Partner Institutions	• Caetité Municipality • Rio Energy
Project Stage	**Ongoing** • (x) Product optimization • (x) Pilot prototype development • (x) Semi-industrial operation
Business Model	• ( ) Outsourcing • ( ) B2B • ( ) Technology Incubation and Internal Development • (x) Others: Cooperativism/Income Generation originated from collective collection in Caetité and Licínio de Almeida/BA municipalities.
Alvo produzido	• Recyclable waste (paper, plastic, metal and glass), organic manure and humus.
Tipo do Rejeito/ estéril/ Resíduo não minerais	• N/A
Volume	• 3,500 tons of recyclable waste.
New products generated	• Organic manure.
Investment (BRL):	• January/2020 to June/2024 investment performed of approximately BRL 1,470,466 (one million and four hundred and seventy thousand and four hundred and sixty-six reais); • Annual investment in 2023 (Jan-Dec) of approximately BRL 338,000 (three hundred and thirty-eight thousand reais).

Process description

Garbage Circuit project is BAMIN social and environmental initiative, which main purpose is changing lives from business opportunities by solid waste management (selective collection and composting), with direct participation of recyclable material collectors organized in cooperatives.

Main project goals include promoting sustainable economic and inclusive growth, full and productive job, providing decent work to everyone; building resilient infrastructures, promoting inclusive and environmental actions, and fostering innovation; and assuring sustainable production and consumption patterns.

The project has stood out due to innovative character since its conception, creating a true circuit involving several actors, where the search for the goal is making the connection between every action performed, selective collection, environmental education composting process, organic vegetable garden and earthworm culture. Each process is not treated individually, and integrated actions and transversality are a determining factor for sustainability and success of this social initiative.

The project promoted social insertion of Collectors that worked in Caetité municipality dump yard, and is fruit of his initiative, recyclable material cooperative members are structured and organized in a cooperative named COOPERCICLI comprised by 19 men and 10 women, stimulating circular economy, job generation, and new value chain growth.

COOPERCICLI participate of 2nd Selection Process of National Health Foundation – FUNASA in July/2022, and it was awarded, achieving the classification of first (1st) Northeastern cooperative, and third (3rd) place overall in Brazil, as per Opinion no. 85/2022/DIESP-BA/SUEST-BA. Cooperative won an award corresponding to the amount of BRL 510 thousand for equipment acquisition. This resource enabled the acquisition of a new cargo lift, a new truck and a new press.

BAMIN celebrates Coopercicli action acknowledgment, established by Garbage Circuit project cooperative partnership, representing positive result achievement validation for the environment, and mainly human being dignity, providing wellbeing to benefited people..

CALCIUM CARBONATE CO-PRODUCT USE IN BAUXITE PROCESSING

PROJECT

Project Title	• CALCIUM CARBONATE CO-PRODUCT USE IN BAUXITE PROCESSING
Partner Institutions	• N/A
Project Stage	**Ongoing** • (x) Product optimization • (x) Pilot prototype development • (x) Semi-industrial operation
Business Model	• ( ) Outsourcing • ( ) B2B • (x) Technology Incubation and Internal Development • ( ) Others _____
Main mineral good	• Bauxite
Type of Tailings/ Spoil/Non-Mineral Waste	• With the goal of reducing its bauxite waste dam water volume , located in Alumínio/ SP municipality, a water treatment route was developed, that passes through a decarbonation process, and this water can thus be reused in refinery. This product generates a co-product, calcium carbonate.
Volume Reused	• 720 t/year
New products generated	• N/A
Investment (BRL)	• CAPEX investment was not required to project implementation.

Process description

CBA alumina refinery, located in the city of Alumínio-SP, produces every year approximately 730 thousand tons of calcined aluminum oxide. Bauxite waste generated in this process is drained before being conditioned in dry form in waste dam. Water achieved in this flow is rich in caustic soda, and thus, it is returned to alumina refinery reuse. This water also has sodium carbonate, due to sodium hydroxide carbonation. To remove sodium carbonate, a double change reaction with calcium hydroxide is required. This procedure generates calcium carbonate, which is precipitated and removed from the system by means of press filters.

Calcium carbonate generate has alkaline characteristics, with 12.1 pH and can be used to assist in various processes that require acidity correction.

In bauxite processing, ore is comminuted in crushers (primary and secondary) of toothed roll, and terminated by means of scrubbing. Next, it is classified in vibrating sieves (primary and secondary) of linear motion, with 0.8 mm cut.

Tailings before and after carbonate usage

Bauxite retained is our product, and passing material follows to dam as tailings. Due to acidic nature of aluminum ore, tailings pH is around 5.5, resulting in water superficial tension that prevents colloidal particle decanting. That also keeps reservoir with high turbidity. To enable colloid decanting in dam, we used gel lime to correct water pH, enabling dam water clarification.

Calcium carbonate generated in process

Calcium carbonate dosage with bauxite

Bauxite washed in sieving stage

To correct tailings pH early, we started adding calcium carbonate to processing development, along with ROM bauxite supplied in station. Apart from complying with its pH correction function, calcium carbonate also improved washing efficiency. Its basic nature acted as detergent agent, enabling detachment between particles and below 0.8 mm particle runoff through classification sieves, and as a consequence, improving sieve classification and draining.

As a result, final production presented higher quality in relation to reactive silica content (contaminant). During six months of industrial tests, we have achieved improvement in reactive silica content, due to planned production, comparing difference between result achieve in station, we have reduced the gap between 2023 and 2024 for reactive silica, and we started to see seizable alumina gap reduction, indicating a gain in process, also reflected in washing efficiency, process indicator that increased in last six months accrued.

These results will have positive impact in general refinery performance, reducing caustic soda consumption, benefit in cost avoided. What is more, the material has improved operational manipulation, with low adhesion to chutes, conveyor belts, shovel loader dump boxes, trucks and wagons. The effect expected was also efficient in Miraí tailings dam water pH stabilization, keeping clarified water within standards required to return to environment, with pH between 6 and 9 and turbidity below 100 NTU, not requiring dosages in Water Treatment Plant - ETA, thus it works only smart quality controller.

In summary, it is an initiative linked to circularity that enables using alumina production process waste, generation several improvements in bauxite production and concentration processes, including processed ore reactive silica reduction and consequent input use reduction in refinement stage. Apart form a series of environmental benefits, including reduction of wear, fuel, ore motions, and mainly Miraí dam water quality, with the best fauna occupation within now clarified pond surroundings.

CBMM

- REFRACTORY BRICK WASTE RECOVERY
- ROUTE DEVELOPMENT FOR MAGNETITE PRODUCTION FROM TAILINGS OF PYROCHLORE PROCESSING.
- PROCESS ROUTE DEVELOPMENT FOR BARITE CONCENTRATE PRODUCTION, FROM TAILINGS OF PYROCHLORE CONCENTRATION STAGE

PROJECT

Project Title:	• REFRACTORY BRICK WASTE RECOVERY
Partner Institutions:	• RHI Magnesita
Project Stage:	**Completed** • (x) Theoretical Modeling • (x) Lab Tests – Characterization • (x) Bench Tests – Product Development
Business Model:	• (x) Outsourcing • ( ) B2B • ( ) Technology Incubation and Internal Development • ( ) Others _____
Main mineral good: **Main mineral good:**	• N/A
Type of Tailings/ Spoil/Non-Mineral Waste	• Refractory bricks
Volume Reused:	• 923.60 t (reference 2023)
New products generated:	• Refractory Bricks
Investment (BRL)	• BRL 0 (existing infrastructure used) • Cost around BRL 120 thousand / year with operation (brick recovery)

Process description:

Refractory waste generated in CBMM Special Alloy Department is recovered internally and through correct handling, cleaning and classification, returned to RHI Magnesita as high quality and performance secondary raw material to be reinserted in manufacturing process. At present, such materials recovered and reprocessed are returned to national market.

In 2023, with the recovery of 923.60 tons of refractory waste generated and recovered in CBMM, reduction of approximately 1,460 tons of emissions of CO2and in process of RHI Magnesita occurred.

As a next step in this circularity work, RHI Magnesita technical team, along with CBMM, is working at “green brick” supply development and feasibility in national market, produced from insertion of secondary raw material also recovered by the Company.

Recovered refractory brick photo

Reused refractory brick photo

Project Title:	• ROUTE DEVELOPMENT FOR MAGNETITE PRODUCTION FROM TAILINGS OF PYROCHLORE PROCESSING.
Partner Institutions:	• N/A
Project Stage:	**Completed** • (x) Theoretical Modeling • (x) Lab Tests – Characterization • (x) Bench Tests – Product Development
Business Model:	• ( ) Outsourcing • ( ) B2B • (x) Technology Incubation and Internal Development • ( ) Others _____
Main mineral good:	• Pyrochlore
Type of Tailings/ Spoil/Non-Mineral Waste	• Pyrochlore processing development magnetic tailings, comprised by hematite and magnetite mainly.
Volume Reused:	• 920,148 t (reference 2023)
New products generated:	• Iron ore
Investment (BRL)	• BRL 852 thousand in 2023

Process description

Magnetic tailings generated through magnetic separation, where magnetic fraction follows to a stage of cycloning for contaminant reduction, material with >60% Fe is then drained for later marketing.

Magnetic tailings cycloning.

Project Title	• PROCESS ROUTE DEVELOPMENT FOR BARITE CONCENTRATE PRODUCTION, FROM TAILINGS OF PYROCHLORE CONCENTRATION STAGE
Partner Institutions	• N/A
Project Stage:	**Completed** • (x) Theoretical Modeling • (x) Lab Tests – Characterization • (x) Bench Tests – Product Development
Business Model:	• ( ) Outsourcing • ( ) B2B • (x) Technology Incubation and Internal Development • ( ) Others _____
Main mineral good:	• Pyrochlore
Type of Tailings/ Spoil/Non-Mineral Waste	• Barite concentrate is originated from flotation tailings, comprised by hematite, goethite, barite, and others.
Volume Reused:	• 35,496 t (reference 2023)
New products generated:	• Barite concentrate
Investment (BRL)	• More than BRL 2.61 million were invested i 2023, to reach 40% higher production capacity, resulting in 42 thousand tons a year.

Process description:

Barite concentration process in CBMM is performed from tailings processing of niobium concentration stage. Part of flotation stage end tailings is thickened in hydrocyclones for later conditioning and direct flotation of barite in flotation columns. Product with > 85% $BaSO_4$ is drained for later marketing, as barite concentrate.

Vista do circuito de flotação para concentração de barita.

J. Mendes

- MINING SAND REUSE PRODUCT DEVELOPMENT: BRASIL´S FIRST ENVIRONMENTAL EDUCATION CENTER BUILT WITH MINING TAILINGS.
- TECHNOLOGY APPLIED TO ORGANIC WASTE TRANSFORMATION IN ORGANIC MATTER

PROJECT

J. Mendes

Project Title:	• MINING SAND REUSE PRODUCT DEVELOPMENT: BRASIL´S FIRST ENVIRONMENTAL EDUCATION CENTER BUILT WITH MINING TAILINGS.
Partner Institutions	• Isobloco; • Congonhas Municipality
Project Stage:	**Completed** • (x) Theoretical Modeling • (x) Lab Tests – Characterization • (x) Bench Tests – Product Development
Business Model:	• (x) Outsourcing • ( ) B2B • ( ) Technology Incubation and Internal Development • ( ) Others _____
Main mineral good/	• N/A
Type of Tailings/ Spoil/Non-Mineral Waste	• 85% of tailings (mining sand) and 15% of rock powder.
Volume Reused	• 9,068 kg
New products generated	• Nanocellular concrete (product) and pre-cast (products).
Investment (BRL)	• BRL 292,700.00

Process description

Grupo J. Mendes, developed, jointly with Isobloco (company focused on nanocellular concrete, located in Marechal Deodoro – AL), iron ore tailings incorporation project (mining sand – tailings originated form magnetic separation process) of J. Mendes in standard formulation, which main challenge was creating nanocellular concrete (product) and pre-cast (byproducts), using the maximum tailings possible, keeping Isobloco standard formulation mechanical strength (at least 3 Mpa for sealing blocks), and preserving manufacturing cost relation, and too much additization makes the product expensive.

Upon several tests and lab trials promoted by Alagoas SENAI, general goal has been achieved successfully, resulting in Isobloco EcoMining line, with 85% dosage of mining tailings (mining sand) and 15% of rock powder, and it is chosen as optimal formulation for block and slab development, to build Brazil´s first environmental education center made of mining tailings, located in Congonhas/MG, in Cachoeira Ecological Park - space granted by Congonhas/MG Municipality, in partnership with J. Mendes.

Congonhas/MG Environmental Education Center has three (3) Modular Isobox modules, in 6.00m x 2.55m x 2.75m (LxWxH) dimensions, each module weighing between 10 tons and 12 tons. Modular Isobox consists of a module in containerformat, with vertical and horizontal sealing in Isobloco System 10 walls (10x30x60cm blocks); floor slab in Modular Isolaje System 7x30 (7x30x60cm stone slabs); and lining in Modular Isolaje System 7x60 (7x60x30cm stone slabs), achieving final composition, as shown in the following prototype:

Total mining sand consumed to sealing production was nine thousand and sixty-eight kilograms (9,068 kg) ,out of this total, for Isobloco 10 production, four thousand, seven hundred and fifty-two kilograms (4,752 kg) were consumed of tailings, and for Modular Isolaje 7 production, four thousand, three hundred and sixteen kilograms (4,316 kg) were consumed.

On May 28, 2024, Environmental Education Center was delivered to Congonhas/MG Municipality (according to the photo below).

Apart from the project delivered, Isobloco mobile factory implementation is being studied, where it is estimated that tailings consumption expectation (mining sand) of a mobile factory is 12 tons/shift (twelve tons per work shift). Considering twenty-two (22) days worked in a single shift, there would be 264 tons/month (two hundred and sixty-four tons a month).

Reiterating that nanocellular concrete production can happen within at most 2 shifts (not considering a third shift only for paver production for secondary road and sidewalk paving), totaling 528 tons/month (five hundred and twenty-eight tons of tailings a month), operating at maximum capacity. In relation to annual consumption: 3,160 tons/year/shift (three thousand, one hundred and eight tons of tailings a year, for each work shift). In case maximum 2-shift production capacity is reached, year total would be 6,336 tons/year.

Project advantages include:

Cost Cutting: CCI – Isobloco Cellular Concrete 85% of tailings (mining sand) and 15% of rock powder, produced through tailings originated from Ferro+, has equivalent cost to concrete made with natural sand, providing an economic solution without compromising quality;

- Sustainability: aligned SDG, CCI contributes to CO_2 emission reduction, decreases water consumption up to 60%, and promotes remain and industrial waste reuse, enabling circular economy;

- Innovation and Efficiency: CCI is ideal to Social Interest Housing (HIS), and other applications that demand high performance in thermoacoustic insulation, fire-break, anti-humidity, anti-mould and execution quickness and convenience.

J. Mendes

Project Title	• TECHNOLOGY APPLIED TO ORGANIC WASTE TRANSFORMATION IN ORGANIC MATTER
Partner Institutions	• Piracema – MG Municipality; • EMATER Piracema – MG.
Project Stage:	• ( ) Ongoing • (x) **Completed**
Business Model	• ( ) Outsourcing • ( ) B2B • (x) Technology Incubation and Internal Development • ( ) Others _____
Main mineral good	• N/A
Type of Tailings/ Spoil/Non-Mineral Waste	• (indicate main minerals or substances that comprise tailings/spoil produced or non-mineral waste) • Organic waste originated from mess room.
Volume Reused	• N/A
New products generated	• Organic matter (produced in J. Mendes mining sites, through industrial electric composter)
Investment (BRL)	• Grupo J. Mendes: BRL 516,279.00 (Total value) • Ferro+ Mineração: BRL 311,279.00 • JMN Mineração: BRL 205,000.00

Process description

Organic waste generated in mining sites of Grupo J. Mendes (Ferro+ and JMN Mineração), is classified in waste type to be forwarded to landfills. Thinking of possibilities and impacts that organic waste can cause, Ferro+ and JMN Mineração, aim at providing environmentally adequate disposal to such waste, changing it in organic matter.

To do that, market search was performed on technological and efficient solutions for organic waste transformation,where employees are not exposed to risks, and waste can be reused, in compliance with three sustainability pillars (economic, social and environmental).

Based on such assumptions, an electric composter made by Topema Innovations was identified. It has two lines, for residences and industries, and industrial line equipment has three categories, 30 kg, 100 kg and 300 kg.

Thus, for compliance with Ferro+, it was chosen to purchase equipment that supports 300 kg, and for JMN, two composters were acquired, that support 100 kg/each. Both pieces of equipment characteristic is waste processing time, that ranges between 6 and 18 h, depending on how organic waste is presented. Considering liquid quantity in waste, the machine takes longer to process.

In the following images, it is possible to notice before waste being

Before

After

processed, and after waste processed and transformed into organic matter.

Thus, feasibility study was performed, and it was identified hat, in the long-term, the equipment provides financial gains to the company, and it also forwards organic waste to landfills, and this is a very relevant environmental gain. Social gains include social and environmental activities promoted with municipalities, internally, and agricultural sectors, where organic matter analysis was performed, and product donation and disclosure events were promoted, as provided in the following images.

lundin mining

- REUSE OF TAILINGS, MINERAL WASTE OF COPPER CONCENTRATE PRODUCTION PROCESS OF LUNDIN MINING FOR AGRICULTURAL REMINERALIZER GENERATION
- TECHNOSOL PRODUCTION FOR MINE CLOSING PURPOSES

PROJECT

lundin mining

Project Title	• REUSE OF TAILINGS, MINERAL WASTE OF COPPER CONCENTRATE PRODUCTION PROCESS OF LUNDIN MINING FOR AGRICULTURAL REMINERALIZER GENERATION
Partner Institutions	• Technical support of Mineragro, that is a private agronomic research company specialized in the topic and that has partnership with UnB, Embrapa, UFG, Unesp and IFMS.
Project Stage:	• ( ) Ongoing • (x) **Completed**
Business Model	• ( ) Outsourcing • ( ) B2B • ( ) Technology Incubation and Internal Development • (x) Others: Business to consumer, through operation assignment to some fertilizer manufacturer partner.
Main mineral good	• Mica schist remineralizer categorized as silicate agromineral.
Type of Tailings/ Spoil/Non-Mineral Waste	• Tailings, copper concentrate production process mineral waste of Lundin Mining categorized as silicate agromineral.
Volume Reused	• Business plan developed by Lundin Mining in 2024 foresees annual marketing potential of 2 million tons of product in alternative use as soil remineralizer.
New products generated	• Mica schist agricultural remineralizer, product approved by MAPA - Ministry of Agriculture, Cattle Raising and Supply.
Investment (BRL)	• 1,451,746.25

Process description

Lundin Mining, considering its ESG values, searches for alternatives to use the tailings, considering mainly Goiás state mid-northern region economy, which, among others, has agricultural call. At present, Lundin Mining operation located in Alto Horizonte, Goiás, generates around 24 million tons of tailings a year.

Tailings, copper concentrate production process mineral waste of Lundin Mining is categorized by MAPA - Ministry of Agriculture, Cattle Raising and Supply, as soil remineralizer silicate agromineral. Brazil imports currently 85% of agricultural fertilizers. National Fertilization Plan target is producing 50% internally by 2050. In this scenario, remineralizer contribution potential cannot be neglected. Today, the country uses 3 million tons/year of agricultural remineralizers. The expectation is achieving 75 million tons/year by 2050.

From such understandings, researches have been performed with technical support of Mineragro, that is a private agronomic research company specialized in the topic and that has partnership with UnB, Embrapa, UFG, Unesp and IFMS. Upon performing experiments in controlled environment, vegetation house, and seeing promising , soy planting was performed, crop 2021/2022, by using remineralizer in a 900-hectare experimental station for agronomic efficiency tests in Ipameria - GO municipality.

Soy harvest results confirmed the promising expectations. Main nutrients provided by remineralizer include potassium and copper. Potassium is one of the most required nutrients by plants, only behind nitrogen. This nutrient regulates plant nutrient translocation. It enables carbohydrate transportation and storage. It increments nitrogen absorption and protein synthesis. It also acts providing ripening to fruits and grain filling.

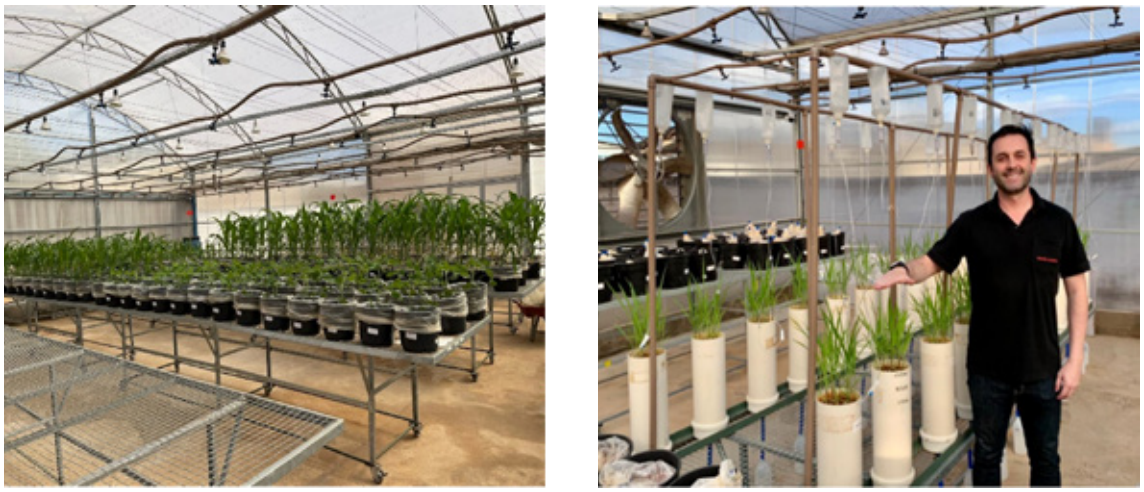


Figure 1: Initial tests with the use of remineralizer in controlled environment. Photo credit: Lundin Mining.

Figure 2 - Soy planting with the use of remineralizer in ergonomic efficiency Experimental Station. Photo credit: Mineragro.

Average planting productivity with remineralizer use originated from Lunding Mining tailings achieved 82.5 bags/ha, higher performance than the area planted with market benchmark remineralizer, and area planted without any remineralizer application. Another significant productivity indicators include number of plants per hectare and weight of a thousand seeds (PMS), also presenting higher performance.

After soy harvest, sorghum planting was performed in the same location, and off-season crop started in the firs week of August, 2022. In 2024, the third year in a row was completed, considering soy planting in crop and sorghum in off-crop. In three years, considering 2021/2022, 2022/2023 e 2023/2024 crops, harvest results were satisfactory.

Still during the second semester of 2022, Lundin Mining formally requested product approval before MAPA - Ministry of Agriculture, Cattle Raising and Supply, the body that regulates the topic. In January, 2023, the product was officially acknowledged by MAPA as a new soil remineralizer, i.e., it presents soil quality improvement and agronomic efficiency, not causing damages to the environment.

Figure 3 – Remineralizer loading in dam area and product usage in experimental planting in operation scale in agronomic efficiency Experimental Station.
Photo credit: Lundin Mining.

Due to product approval before MAPA, Lundin Mining. has developed, with KPMG technical support, the business plan within the second semester of 2023, and first semester of 2024. Business Plan foresees annual marketing potential of 2 million tons of the product as soil remineralizer. An acting radius of up to 500 km was identified, considering the demand of various different agrosilvicultural cultures, divided into 3 regions, local, regional and macro-regional, reaching other states, apart from Goiás. The strategy to start commercial production includes operation assignment to some fertilizer manufacturer partner. Product market arrival to the market is 1 to 2 years.

Finally, tailings use as source of raw material for agricultural remineralizer production has been seen as a promising tool for circular economy promotion, and it also denotes being one of the possible answers to increasing challenge for the mining sector to find technical alternatives and tailings buildup in dams.

Figure 4: Off-season 2022 sorghum experimental planting with remineralizer use. Photo credit: Mineragro.

Figure 5: Experimental planting harvest in operational scale using soil remineralizer.
Photo credit: Lundin Mining.

lundin mining

Project Title	• TECHNOSOL PRODUCTION FOR MINE CLOSING PURPOSES
Partner Institutions	• Technical support of Mineragro, that is a private agronomic research company specialized in the topic and that has partnership with UnB, Embrapa, UFG, Unesp and IFMS.
Project Stage:	• (x) **Ongoing** • ( ) Completed
Business Model	• ( ) Outsourcing • ( ) B2B • (x) Technology Incubation and Internal Development • (x) Others _____
Main mineral good/	• Technosol is a new soil class acknowledged by FAO (Food and Agricultural Organization of the United Nations), originated from copper concentrate processing tailings.
Type of Tailings/ Spoil/Non-Mineral Waste	• Tailings, copper concentrate production process mineral waste of Lundin Mining categorized as silicate agromineral.
Volume Reused	• The study foresees reuse of 2750000 tons of tailings for the creation of Technosols to be used, as alternative use, in Lundin Mining spoil pile closing activities.
New products generated	• Technosol is a new soil class acknowledged by FAO (Food and Agricultural Organization of the United Nations).
Investment (BRL)	• 412,000.00

Process description

All mining and processing development generates piles of rock spoil, as well as tailings. In Chapada, 47 million tons of spoils are moved, and 24 million tons of tailings are generated a year.

Spoil pile recovery planning after operational activity closure is extremely important and must be performed during such structure installation and operation stages. Lundin Mining, committed with its ESG values and responsible mining management system, is investing in tailings alternative use researches, and in studies aiming a spoil pile rehabilitation.

Thus, Lundin Mining relied on technical support to Mineragro, partner research company of Embrapa, UnB, UFG, Unesp and IFMS, to enable tailings usage as artificial soil formation material, also know as technosol, to be used in spoil pile vegetation, as soil achievement is one of the main challenges to such structure rehabilitation.

Technosol concept usage stored in tailings piles or dam stands out as a promising alternative for soil conservation not impacted yet by anthropic activities. By using this technique, dams and piles can be returned to the environment, being an environmental recovery support, providing basic conditions to reestablish vegetable species, and forming quality soils, whether to agricultural or forestry production, promoting carbon fixation, among other possibilities. Thus, Technosol is a new soil class acknowledged by FAO (Food and Agricultural Organization of the United Nations).

So, researches, using many different technosols, that are mixes of tailings and soils, started in a vegetation house controlled environment. Initial results, with brachiaria growing, confirmed promising expectations. After the activities in vegetation house, Lundin Mining took the decision to install and test an experiment in a spoil pile located in its operations in Alto Horizonte, Goiás municipality.

Spoil pile experiment installation located in Lundin Mining.

Photo credit: Lundin Mining.

This field stage goal was assessing technosol mix proportions, aiming at covering spoil piles, in response to brachiaria productivity. 3 different technosol concentrations were assessed, apart from control treatment with 100% of Savanna biome natural soil.

Field experiment development between October, 2022 and January, 2023.
Photo credit: Lundin Mining.

Brachiaria choice for spoil pile revegetation goal was providing future uses of this structure aimed at agriculture and cattle raising. One of main economic activities in Goiás state. After 60 days of hydroseeding, parameters assessed to determine brachiaria use feasibility with technosol included MSPA - Overhead Part Dry Mass, number of bunch grasses per hectare, soil coverage percentage, and soil temperature.

Productivity of around 5,196 kg/ha of MSPA – Overhead Part Dry Mass was achieved. This productivity result can be considered satisfactory, considering that other Savanna biome studies, with red lateritic soil containing adequate fertility found results of 2,855 and 3,063 kg/ha. Technosol usage has been proven favorable as a substrate for coverage vegetation establishment to mining, spoil pile operational structure closing. Every parameter has presented good results and economic feasibility.

Technosols have improved soil quality, not damaging the environment, providing good fertility, better microbial and vegetable activity.

The experiment evidences that technosol use as enabled soil conservation and preservation, decreasing the pressure for new preserved soil borrow areas, for spoil pile sustainable closing and recovery purposes.

Technosol created from tailings was a feasible alternative to spoil pile rehabilitation, aiming a future use of such structures aimed at Goiás state main production sector, agribusiness. A clear example of support to circular economy and ESG practice.

First field assessment held in April, 2023.

Photo credit: Lundin Mining.

Second field assessment held in May, 2024.

Photo credit: Lundin Mining.

Mosaic® Fertilizantes

BASICA PRO

SUSTAINABLE PACKAGING

PROJECT

Project Title	• BASICA PRO
Partner Institutions	• N/A
Project Stage:	• ( ) Ongoing • (x) **Completed**
Business Model	• ( ) Outsourcing • ( ) B2B • (x) Technology Incubation and Internal Development • ( ) Others _____
Main mineral good	• Complex Mineral Fertilizer achieved through fluosilicic acid neutralization with lime and limestone.
Type of Tailings/ Spoil/Non-Mineral Waste	• Fluosilicic acid
Volume Reused	• 40 thousand tons of fluosilicic acid, residual component generated in soluble phosphate fertilizer manufacturing.
New products generated	• Soil conditioner, with silicon (Si) and calcium (Ca) contents, it can be applied in soil preparation and sugar cane ratoons, assuring nutritional complement to sugar cane plantation and triggering phosphate fertilizing.
Investment (BRL)	• Around US$ 10 million for production process plant adaptation and construction.

Process description

Annually, Uberaba Industrial Complex produces around 40,000 tons of fluosilicic acid. Out of this volume produced, around 20 to 25% is disposed and neutralized in Liquid Effluent Treatment Plant, generating waste upon treatment.

This process has a high operational cost, due to limestone and lime consumption need for neutralization, apart from the requirement of drying yard adaptation, storage space, and dredging operation of such waste.

Due to that, the company has developed a new product called Basica PRO, achieved by fluosilicic acid direct neutralization with quicklime, producing added agronomic value and increasing natural resource life cycle. Today, around 20 thousands tons of Basica PRO / year are produced.

The company uses limestone consumption technical index (t limestone/m³ disposed water) in ETEL (Liquid Effluent Treatment Plant) of UBA 3 (Uberaba Unit 03) as calculation base and reduction accounting of gases issued. The project is part of the company Global Net-Zero, with target by 2040.

As results, it shall be highlighted waste generation significant reduction of treatment ponds, of such pond dredging operations. What is more, there was also reduction of solid dragging risk to water resources, and also of costs with treatment pond waste drying yard.

Project Title	• SUSTAINABLE PACKAGING
Partner Institutions	• Yatto, Zaraplast, Grupo Embrasa, Tectextil, Teixeira Textil e Braskem.
Project Stage:	• (x) **Ongoing** • ( ) Completed
Business Model	• ( ) Outsourcing • ( ) B2B • (x) Technology Incubation and Internal Development - Technology application pioneering (joint initiative with packaging supplier and resin manufacturer) • ( ) Others
Main mineral good	• N/A
Type of Tailings/ Spoil/Non-Mineral Waste	• Standard packaging (big bags and bagging), i.e., polypropylene and polyethylene waste
Volume Reused	• So far, the project has reused 70 tons of packaging.
New products generated	• All material originated from reverse logistic is used in new packaging manufacturing, at 50% virgin raw material and 50% recycled raw material proportion. • So far, we have dispatched more than 1,000,000 packagings with such characteristic.
Investment (BRL)	• In order to be part of this process, no cash investment was required to Mosaic, as it used its operational structure, including human and material resources.

Process description

Mosaic project has been conceived through a partnership with Zaraplast and Braskem, when the first agribusiness packaging was launched, containing 30% of Braskem post-consumption polypropylene resin (PCR), converted into packaging by Zaraplast.

As a second stage, a partnership with Yatto started, a startup specialized in reverse logistic and circular economy, and our suppliers (Embrasa, Tectextil e Teixeira Textil and Zaraplast), in order to create a solid ratification, certification and audit structure of this process, to assure reverse logistic and circular economy chain.

Post-consumption resin (PCR) usage not only minimizes non-renewable source consumption, but also contributes to the environment, as it enables emission reduction of CO2, water and other natural resources at 14% and 18%, correspondingly.

nexa

- JAROSITE INDUSTRIAL APPLICATION DEVELOPMENT
- AGRICULTURAL INPUTS

PROJECT

Project Title	• JAROSITE INDUSTRIAL APPLICATION DEVELOPMENT
Partner Institutions	• Geeco Materiais e Engenharia (Startup) • UFMG – Universidade Federal de Minas Gerais • UNA – Centro Universitário • WEG Tintas
Project Stage:	• (x) **Ongoing** • ( ) Completed
Business Model	• ( ) Outsourcing • ( ) B2B • (x) Technology Incubation and Internal Development • ( ) Others
Main mineral good	• Paint, cement additive and ecological brick production raw material.
Type of Tailings/ Spoil/Non-Mineral Waste	• Jarosite ($(NH_4)Fe_3(SO_4)_2(OH)_6$) is a metallurgical waste produced in Nexa site zinc refineries. Iron removal stage through ammonium sulphate addition, that occurs to purify the electrolyte that will be forwarded to metallic zinc production in electro recovery.
Volume Reused	• First yeas: 7 kt/year • Third year forward: 30 to 40 kt/year
New products generated	• Industrial paint pigment production input • Concrete production cement additives. • Ecological bricks (geopolymers)
Investment (BRL)	• 4 M BRL, 50% consideration of FINEP and partnership with WEG Tintas – Non-reimbursable funding • 500 k BRL, with 50% consideration of FAPEMIG – Non-reimbursable funding

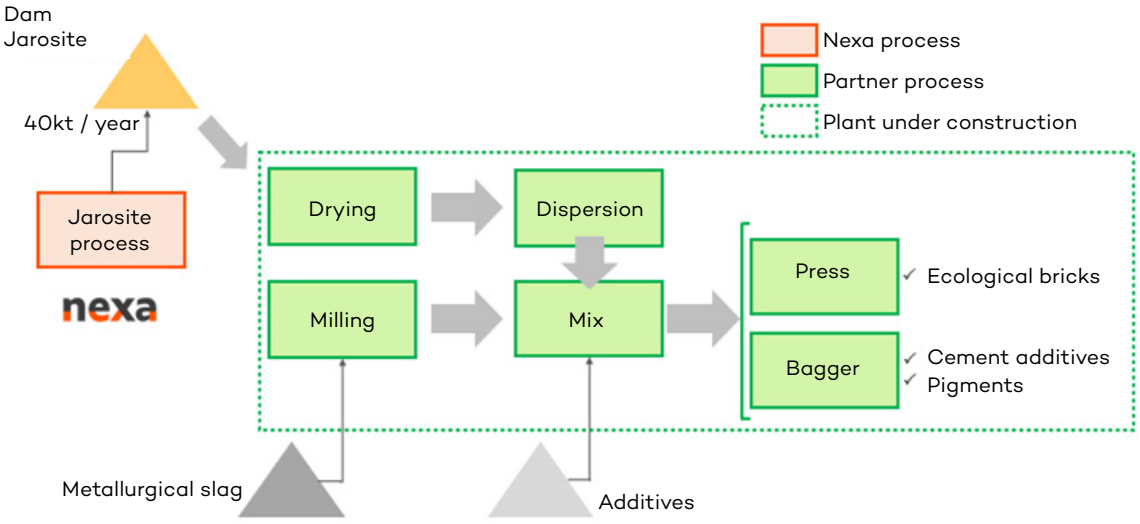
Process description

Jarosite, end tailings of Nexa Juiz de Fora site zinc refinery, is currently stored in dams.

With the goal of forwarding this material as raw material for other industries, process routes have been developed in order to service 3 markets.

Jarosite undergoes drying stage, then it is dispersed. To this material, it is added metallurgical milled slag and other additives, to achieve the formulation required in each application.

In one of the specific routes, generated product is still taken to a new mix stage with aggregates, cement and water, for ecological block production by pressing. In other two routes (cement additives and pigments), the product is marketed bagged.



Jarosite disposal macro flow chart

Project Title	• AGRICULTURAL INPUTS
Partner Institutions	• Tecnogreen – Universidade de São Paulo • CIT Senai • Geeco Materiais e Engenharia
Project Stage:	• (x) **Ongoing** • ( ) Completed
Business Model	• (x) Outsourcing • ( ) B2B • (x) Technology Incubation and Internal Development • ( ) Others: _____
Main mineral good	• Calcined limestone for use as soil acidity corrective and micronutrient supply
Type of Tailings/ Spoil/Non-Mineral Waste	• Waste achieved from willemite ore mineral processing (zinc) with dolomitic fitting rock. Material comprised by dolomite, hematite, quartz, willemite, galena. The material results from willemite flotation, arranged currently in pile.
Volume Reused	• Up to 200 thousand tons a year (volume foreseen)
New products generated	• Dolomite for use as agricultural limestone - soil corrective
Investment (BRL)	• 8 M BRL, with 50% funded by FINEP (non-reimbursable funding) • + 400 M BRL with Embrapii funding

Process description

Ebb tailings processing technological route will use the material generated in sunken in zinc flotation stage, that will be submitted to draining stage, and then, it follows to calcination. Calcination occurs in conditions that have been set forth in some metal removal tests, so that agricultural product specification is achieved, according to MAPA (Ministry of Agriculture, Cattle Raising and Supply) standards.

SAMARCO

APRENDER PARA EVOLUIR E TRANSFORMAR

- PURIFICATION ROAD PAVING WITH SANDY TAILINGS BLOCKS
- MILLING BODY SCRAP RECYCLING (MUNAS)
- SANDY TAILINGS USAGE IN DAM DECHARACTERIZATION WORKS

PROJECT

Project Title	• PURIFICATION ROAD PAVING WITH SANDY TAILINGS BLOCKS
Partner Institutions	• SAMARCO, UFOP/EMBRAPII, UNISTEIN, Ouro Preto Municipality, Mariana Municipality.
Project Stage	• ( ) Ongoing • (x) **Completed**
Business Model	• ( ) Outsourcing • (x) B2B • ( ) Technology Incubation and Internal Development • ( ) Others: _____
Main mineral good	• Iron ore
Type of Tailings/ Spoil/Non-Mineral Waste	• Sandy tailings generated in iron ore concentration plant flotation process, comprised predominantly by quartz and hematite
Volume Reused	• 1.1 thousand tons to Purificação Road paving
New products generated	• Interlocked and curb paving blocks
Investment (BRL)	• Project with UFOP/EMBRAPII – BRL 1,392,604, 50% invested by Samarco • Purificação Road works - BRL 73 million

Process description

Purificação Road (OP-10) interconnects Antônio Pereira district to Morro de São João in Ouro Preto municipality headquarters. Through this road, Antônio Pereira district population now has direct access to the headquarters, around 8 km, in spite of crossing almost 30 km in another section that, necessarily, passed through Mariana municipality. The new road was open on November 17, 2023.

The project executed 7.5 km sidewalk, 5 km with interlocked blocks (16 faces with 11 x 22 x 08 cm dimensions) produced with sandy tailings. Apart from blocks, curbs were also manufactured using Samarco sandy tailings, all produced by UNISTEIN, in Pedro Leopoldo, from filtered sandy tailings (collected in Samarco Germano filtering plant output).

Tailings percentage in relation to total fine aggregate consumption was 32.32%. Around 28 thousand m² of interlocked floor were installed and almost 7 km of curb. To manufacture such concrete artifacts, approximately 1.1 thousand tons of tailings were consumed.

Purificação Road sidewalk works

Purificação Road sidewalk works

Implementation of blocks made of sandy tailings

The initiative was part of the project developed in partnership with EMBRAPII Sustainable Mining Unit, of Universidade Federal de Ouro Preto (UFOP Escola de Minas), to perform researches on new ways of using iron ore sandy tailings in civil construction manufacturing chain.

Through technological development, the project has social and environmental and socioeconomic bias, as it promotes circular economy and creates social positive impact. Solutions were searched not only to mining, but also especially to society, from a bridge between technologies and the market. The interaction between industry, university and Government present in project is a "triple helix" model example, that aims at promoting economic development, by means of innovation and entrepreneurship, and that strengthens innovation ecosystem.

Blocos feitos de rejeito arenoso

Paving was foreseen in constraint 57 of LOC (Corrective Operational License) of Samarco and complied with a demand of COMATRI (Ouro Preto Municipal Council for Cultural and Natural Estate Preservation).

Purificação Road Opening

Project Title	• MILLING BODY SCRAP RECYCLING (MUNAS)
Partner Institutions	• SAMARCO, MAGOTTEAUX, MIDES
Project Stage	**Ongoing** • (x) Product optimization • (x) Pilot prototype development • (x) Semi-industrial operation
Business Model	• ( ) Outsourcing • (x) B2B • ( ) Technology Incubation and Internal Development • ( ) Others: _____
Main mineral good	• Iron ore
Type of Tailings/ Spoil/Non-Mineral Waste	• High chrome steel milling body scrap (munas)
Volume Reused	• 126 tons
New products generated	• High chrome mill ball • Mill coating
Investment (BRL)	• N/A

Process description

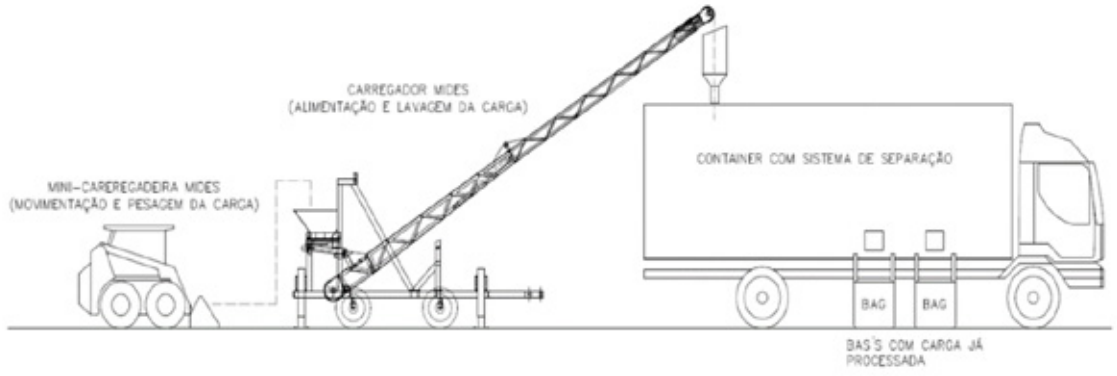
The solution proposed is milling body recycling (munas) containing impurities (including over size and ore powder waste) originated of SAMARCO Concentrator II secondary milling.

Ball mills used steel balls that move inside hem to fragment iron ore. Balls have varied diameters to maximize ore milling efficiency, and such process is performed by attrition, compression and impact of particles against balls. Milling goal is releasing mineral species, preparing the material to subsequent processes and reducing ore granulometry. That enables that the material reaches the specific size required to processes including flotation, ore pipeline transportation and pelletization.

Muna scrap is transported to cleaning, segregation and classification by an expert company. Upon scrap washing, separation is performed through a magnetic process to remove any unwanted metallic fragments. The container with separation system can recycle up to 12 tons of munas per hour and remove up to 98% of ore powder.

Muna scrap with impurities

clean nail scrap



Classification process

Milling body recycling requires less energy than the production of new ones from iron ore, generating reduction of greenhouse gas emissions and preventing mineral extraction, preserving then finite resources.

It is estimated that such scrap recycling can save around 75% of energy compared to primary production, and it is fundamental to sustainability and circular economy.

With recycling and cleaning, the scrap can be reindustrialized, returning as material to manufacture new milling balls. This process can result in 20 to 25% cost-cutting at new material purchase.

This initiative reassures SAMARCO commitment to adopt sustainable practices in its processes.

Mides cleaning process

Project Title	• SANDY TAILINGS USAGE IN DAM DECHARACTERIZATION WORKS
Partner Institutions	• SAMARCO, BVP Engenharia
Project Stage	• (x) **Ongoing** • ( ) Completed
Business Model	• ( ) Outsourcing • (x) B2B • ( ) Technology Incubation and Internal Development • ( ) Others: _____
Main mineral good	• iron ore
Tipo do Rejeito/ estéril/Resíduo não minerais	• Sandy tailings generated in iron ore concentration plant flotation process, comprised predominantly by quartz and hematite.
Volume Reused	• 8.9 million tons between 2021 and 2023. • 2.2 million tons up to May, 2024, equivalent to more than 68% of sandy tailings use generated in iron ore concentration process.
New products generated	• Sandy tailings usage as material to correct reservoir topographic grid and geotechnical structure reinforcement shoulder.
Investment (BRL)	• 316 million.

Process description

Germano Dam and Germano Digging Drained Piling are two SAMARCO priority projects. In January, 2024, Germano Digging Drained Piling structure no longer presented dam characteristics and was no longer included in dam concept. This achievement occurred upon reinforcement shoulder implementation, reservoir conformation (eliminating pond formation) and monitoring system implementation. Upon this intense work completion, public agency technical audits evidenced compliance with decharacterization process requirements. An advanced stage was also achieved in decharacterization project of Germano

Dam, with 75% of works performed by December, 2023. Final term to such structure decharacterization, foreseen in commitment term with public agencies is May, 2029.

One of dam decharacterization process stages is eliminating all water buildup in dam reservoir. Thus, **a major part of sandy tailings** produced in iron ore concentration process, that would be forwarded to tailings and spoil disposal pile (PDER), **was used as base material for reservoir topographic grid correction base material**.

Upon such correction, all water flow will be forwarded to superficial drainage system, eliminating thus all water buildup in Germano Digging reservoir. Such tailings have also been used at other structure decharacterization, including Germano Dam Saddle dykes, assuring: structure

Reservoir reconformation with compacted sandy tailings and superficial drainage system implementation.

long-term stability, all Fundão Valley internal drainage and elimination of reservoir upstream Axis 01 Dyke.

From a technical viewpoint, SAMARCO advanced knowledge on such tailings geotechnical characteristics and their variability provides assurance that the structure is being implemented according to project assumptions and criteria. Another sandy tailings usage benefits include:

- tailings usage as material to correct reservoir topographic grid and reinforcement shoulder of geotechnical structures reinforces SAMARCO circularity and sustainability character;
- tailings used are homogeneous material, enabling day-by-day workability;
- tailings used present outstanding workability results in rainy periods;
- SAMARCO high knowledge in sandy tailing behavior (predictability);
- sandy tailings are materials with better permeability to conduct water flow until internal drainage;
- Tailings and Spoil Disposal Pile life expansion (Alegria do Sul PDER);

Reservoir reconformation with compacted sandy tailings and superficial drainage system implementation.

VALE

SUSTAINABLE SAND PROGRAM

SUSTAINABLE SUPPRESSOR

PROJECT

Project Title	• SUSTAINABLE SAND PROGRAM
Partner Institutions	• The University of Queensland, UNEP, University of Geneva, UFMG, CEFET, UNIFEI, IPT, CDTN, UFOP, among others, and Agera.
Project Stage	• ( ) Ongoing • (x) **Completed**
Business Model	• ( ) Researches/bench • ( ) Industrial scale research • ( ) Outsourcing • ( ) B2B • ( ) Technology Incubation and Internal Development • (x) Marketing/donation
Main mineral good	• Sand
Type of Tailings/ Spoil/Non-Mineral Waste	• Quartz and hematite
Volume Reused	• Around 2.1 million tons of sand were reused, originated from iron ore tailings. The expectation is achieving 2.8 million tons in total moved by 2025
New products generated	• Concretes, Pavements, Pre-Cast, Mortar, Ceramic, Sleepers, among others.
Investment (BRL)	

Process description

Sustainable Sand started being produced by Vale in 2021, after seven years of research, as a replacement of the sand extracted from the environment. Since then, around 2.1 million tons of product have already been forwarded to civil construction sector and highway paving projects.

In 2023, Vale created a business vehicle dedicated to trigger sustainable sand business in Brazil. The company in question is named Agera and its headquarters are located in Nova Lima (MG). The startup establishment is strongly linked to Vale strategy of promoting circular mining, which means strengthening circular economy concepts in mining, associating economic development to natural resource better use.

Agera receives sand produced from treatment of tailings generated by Vale iron ore operations in the state, and promotes marketing and distribution. The new company also has as a mission improving researches and/or developing new solutions by using this sand.

Sustainable Sand started being produced by Vale in 2021, after seven years of research, as a replacement of the sand extracted from the environment. Since then, around 2.1 million tons of product have already been forwarded to civil construction sector and highway paving projects.

Agera has seven customer service and material stock points in Minas Gerais and Espírito Santo. For material logistic, the company keeps contract with seven highway carriers and three railway freight providers. The company services currently more than 80 manufacturing sites of seven segments (concrete mixing plants, pre-cast, mortar, artifacts, cement industries, texturized paints and pavements), and is investing in research to expanding operation to other applications, including red ceramic.

Type 01 sand produced in Brucutu mine

HOW IS SUSTAINABLE SAND MADE?

Iron ore humid processing, that is used currently in less than 30% of Vale production, generates tailings, that can be arranged in dams or piles. Such tailings are comprised basically of silica, main sand component, and iron oxides. It is a non-toxic material, that in its processing is submitted only to physical processes.

Sustainable Sand is considered iron ore production process co-product. The novelty introduced by Vale is that, in concentration stage, such process byproduct is processed again, until reaching the quality required to become commercial use sand. In traditional method, this material would become tailings and would be forwarded to dams or piles. Each ton of sand produced represents one ton less of tailings generated.

SUSTAINABLE SAND BENEFITS

In Brasil, around 330 million tons of sand are used annually in civil construction and industrial process segments. Natural sand extraction, originated from river beds, often exceeds natural replacement rate, and can cause irreversible environmental impacts. With Sustainable Sand production, it is possible to perform 100% circular extraction, transforming a material that would be disposed in several products in benefit of the society, not compromising biodiversity.

What is more, Sustainable Sand generates more profitability to civil construction and industry market, and the process assures greater control and quality of end product, avoiding material waste and reworks during works. Also in concrete production, Sustainable Sand enables reducing cement consumption and CO_2 emissions.

In 2022, The University of Queensland and University of Geneva disseminated a study that confirms that the sand originated from iron ore production process can enable solving two relevant environmental questions, as sand predatory extraction is attenuated, and mining tailings generation is reduced. The study had Vale participation, that granted its Sustainable Sand samples, so that universities performed an independent material analysis and donated US$ 1 million to support researcher work.

Project Title	• SUSTAINABLE SUPPRESSOR
Partner Institutions	• Universidade Federal do Espírito Santo (UFES) • IQX - Inove Qualyx Tecnologias Sustentáveis de Apoio à Empresas Ltda • Biosolvit – Soluções em Biotecnologia S.A.
Project Stage	• (x) **Em implantação / escala** • ( ) Completed
Business Model	• ( ) Outsourcing • ( ) B2B • ( ) Technology Incubation and Internal Development • (x) Others: Open innovation with sub-licensing and technology transfer concept
Main mineral good	• Iron ore, coal and sand particulate matter suppression application (piles, wagons and unpaved roads)
Type of Tailings/ Spoil/Non-Mineral Waste	• Post-consumption PET (polyethylene terephthalate) plastic recycling
Volume Reused	• 550 tons of PET plastic recycled a year, from 2026
New products generated	• PET plastic recycling-base particulate material suppressor to control Vale operation particulate material emission control, as in railway loadings, material storage piles and unpaved access roads.
Investment (BRL)	

Process description

Sustainable suppressor development from PET (polyethylene terephthalate) polymer recycling started in 2008, with Universidade Federal do Espírito Santo (UFES), innovating to create PET depolymerization process. This method involves an alkaline hydrolysis chemical reaction to break polymer chains and enable material recycling.

In 2013, with the purpose of operating its input chain in a more sustainable way, Vale saw the opportunity of associating this process in research and development activities, with the goal of developing new dust suppression mechanisms, reinforcing its commitment with knowledge development aimed at he environment and society. And thus, Scientific and Technological Partnership Agreement was established between VALE and UFES, with the goal of developing, jointly via technical and financial collaboration between parties, post-consumption plastic-base particulate material suppressors, so that they could be applied in iron ore, sand and coal piles, in non-dietary bulk railway transportation and in unpaved access roads.

From joint activities performed by means of partnership, it was deposited, in co-ownership between Vale and UFES,

Sustainable Suppressor

Sustainable Suppressor being applied in Tubarão site (Vitoria/ES)

Sustainable Suppressor being applied in unpaved roads in Mariana/MG Complex

Sustainable Suppressor being applied in iron ore train wagons in Brucutu/MG

patent BR1020140298703 in 2015, which goal is protecting research and development process results that generated "Sustainable Suppressor".

Sustainable Suppressor production starts with a physical stage that is comprised by: (i) plastic waste selection comprised by post-consumption PET (PETpc) from selective collection; (ii) removal of material parts different than PETpc from plastic waste (including, for instance, lid and bottle bottom); (iii) washing and drying; (iv) fragment size milling and uniformity in form of flakes; and (v) flake micronization.

After this process physical stage, Sustainable Suppressor achievement chemical process starts. At first, PET plastic depolimerization reaction occurs through alkaline hydrolysis. After depolimerization and oligomer achievement, the material undergoes a dilution process, and later structuring additives are added to assure viscosity, density and resistance properties of protection film provided by Sustainable Suppressor upon application in storage piles, wagon loadings or unpaved access roads. This chemical method grants to Sustainable Suppressor its biodegradable property, enabling environment decomposition in only 18 days, without releasing toxins or causing microplastic dispersion. PET molecules

Recycling of collectors from Vitória/ES

are fragmented and what is left is carbon, nitrogen, oxygen, and a little hydrogen.

To enable Sustainable Suppressor large scale production, Vale chose a business model that also brought open innovation concept, and with the purpose of changing the future jointly, and searched in Brazilian innovation ecosystem skills and agility required to escalation, and IQX and Biosolvit stood out. In this model, Vale foster Brazilian innovation ecosystem and develops startup / provider by means of sub-licensing and technology transfer.

What is more, this model introduces another innovation: PET supply chain traceability concept as Sustainable Suppressor raw material (Social PET), directing and fostering direct purchase from associations and local collectors. It is important to Vale, as it enables work and income fostering of associations and collectors within their operation regions.

Not only the new Sustainable Suppressor assures environmental control efficiency, but also has the potential of removing from the environment up to 25 millions of PET bottles post-consumption a year.

Apart from using PET bottles, Sustainable Suppressor production process has the capacity of seizing another lower recyclability materials, including PET plastic present in trays and bottles of all colors, like energy drink black bottles, currently disposed in landfills.

In June, 2024, Biosolvit, one of the startups selected to be Vale´s supplier in this project, open the first Sustainable Suppressor production plant, exclusively to Vale, located in Cariacica/ES. And, with social PET concept, production in this plant impacts positively 12 collector associations in Greater Vitória/ES, benefiting directly 580 collectors and their families, and approximately 60

thousand people benefited directly with selective collection.

In order to enable PET supply to comply with first plant production in Cariacica, Vale developed Reciclo project from 2021 to 2023, with the goal of fostering and increasing PET recycling in these 12 associations.

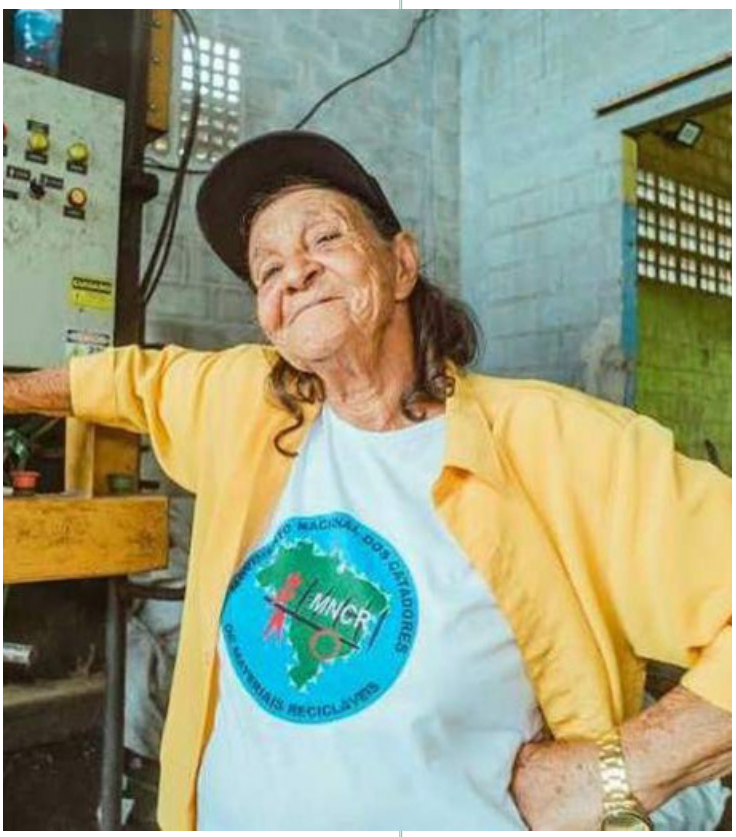
Reciclo project worked at post-consumption PET plastic catchment increase, population environmental education on the need to implement circular economy, and recyclable material collector training and awareness raising. Reciclo Project is a transformation and valuing benchmark of recyclable collectors in Espírito Santo territory, with income increment of up to 57% increase in PET plastic collection index increase of up to 77%.

Even though such impacts are released to the first plant, this suppressor has a significant potential to expand and be applied globally in various industries, apart from mining, including civil construction, ironworks and others that generate particulate matters in their operations.

Sustainable Suppressor is an example of shared value, as it offers benefits to different society sectors: result of strategic collaboration with university, preserves environmental control efficiency and or quality, is biodegradable, prevents that millions of bottles change into waste and generates income to recyclable material collectors. Thus, Vale enables social and economic condition improvement in the communities it operates.

"Our work has improved a lot with Reciclo Project. We have come from the dump yard, and today we are working with dignity and acknowledgment"

Luzenita Meireles, Acamarp founder



Sustainable Suppressor incorporates several principles, gathering ESG concepts, shared value creation, circular economy, university-company partnership, open innovation, positive territorial impact and cost-cutting.

At present, Sustainable Suppressor is in commercial implementation stage in Vale operations in all their application potentials mentioned (piles, wagons, and unpaved access roads).

Manuela, ACAMARP associate and vice-president of REUNES (Espírito Santo United Collector Solidarity Economy Network)

"Between 2021 and the end of 2022, we have experienced several TRANSFORMATIONS.

We have left a deplorable state that we were at, and today we have more support, with partnerships, supporters of our cause, and we have managed to find several friends in the mean time.

Our great metamorphosis, we were caterpillars, nowadays we are inside the cocoon, ready to achieve our major goal. We at ACAMARP, are thankful to Vale and all our partners, as without you none of that would happen"

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