Massive Recycling of Underpot Material to Pots at Sohar Aluminium Smelter

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Abstract

In modern aluminium reduction prebaked cell technology, spillage of cover bath material and alumina into the basement is still a challenge and requires appropriate management. This spillage can be controlled by improving the operation practices and implementing engineering controls. The basement material management is an important process, as the smelters are keen to reduce costs and increase production efficiencies. The appropriate cleaning of the basement material contributes to better air circulation under the pots, allowing the expected heat exchange in the pots. The controlled and levelled recycling will reduce impact on metal purity quality and the quality of the anode cover material which plays as a heat insulator for the pot and protect the anodes from air burning.

Up to 2017, Sohar Aluminium accumulated 22 000 tonnes of basement material that needed to be reintroduced into the potline. It was developed an innovative strategy to speed up the recycling rate instead of using the traditional regular introduction through the bath plant, blended in the anode cover material.

This paper describes the learnings from the accumulation of materials along the years, the planning and the equipment developed for the innovative segregation of bath and alumina from the basement material. The finer material was recycled as alumina in the Gas Treatment Center (GTC) and the coarser material in the bath plant. As a result, in 3 years, with this process, more than 10 000 tonnes of alumina were captured as cost reduction, and 10 000 tonnes of pure bath sold to the market.

Keywords: Aluminium reduction cells, Basement spillages, Alumina recycling, GTC, Potline services, Metal purity, Pure bath generation.

1. Introduction

The Sohar Aluminium plant operates a single potline of 360 cells that is divided into two rooms with AP40/42S pot design, with a metal production of 400 000 tonnes per year. It also has a carbon plant producing baked anodes and a cast house producing ingots and sows. Sohar

Aluminium has several customers in GCC, Asia and Europe and supply liquid high purity metal to four downstream partners next to the Smelter in Sohar.

Sohar Aluminium facilities include a smelter that utilizes advanced technology operated with best practices along with an owned state-of-art 1 000 MW power plant and dedicated port facility in the Sohar industrial port area.

Sohar Aluminium had 22 000 tonnes of accumulated basement material that was removed in 2017 after a line shutdown event. Accumulated basement material needed to be segregated and reintroduced into the potline as it has a great value for Sohar Aluminium and the environment. The aim was to develop an innovative strategy to recycle basement material directly in the pots, instead of using the regular single introduction though the bath plant. The regular blend in the anode cover material will be slow and would make if finer and increase variability of percentage of alumina in the material.

Figure 1. Basement material accumulated in 2017.

Aluminium electrolysis is a delicate process highly dependent on managing impurities within the cell. Basement alumina, a byproduct generated during the process itself, often contains elevated levels of iron and silicon. These impurities will dissolve in the bath and directly contaminate the metal. Once dissolved, they can significantly impact cell performance in several ways, such as:

1. Metal purity. Understanding the behavior of these impurities, particularly those with a detrimental effect like iron and silicon, is crucial for smelters to optimize their processes, especially plants with high purity metal contracts.

2. Efficiency metrics. Even small changes in anode cover material or alumina granulometry can affect current efficiency or anode effect frequency of a potline, key metrics for smelters. By effectively managing these impurities, smelters can improve cell performance, reduce emissions, and enhance the quality of the aluminum produced.

3. Emissions and GTC stability. Furthermore, recycled alumina directly in the Gas Treatment Center (GTC) can present challenges in flowability throughout the alumina circuit, including the Hyper Dense Phase System (HDPS) and air slides. The presence of fines and the potential for segregation within the recycled material can disrupt smooth flow in these systems. For the HDPS to function effectively, a consistent particle size distribution is necessary to ensure proper mixing and transportation of the alumina. Similarly, air slides rely on the proper flow characteristics of the alumina particles to function efficiently. Blockages or uneven flow caused by inconsistencies in granulometry can disrupt the entire alumina feeding process. Optimizing the granulometry of the recycled alumina and potentially implementing strategies to address segregation become crucial steps in ensuring efficient utilization of this valuable byproduct.

2. The Project

Recycling basement material at the Sohar Aluminium smelter presents significant economic and environmental advantages by capturing valuable alumina and potentially reusable bath components, the project reduced consumption of raw materials, leading to cost savings and effective waste management. Furthermore, reintroducing basement material back into the production cycle significantly minimizes liabilities: the amount of waste requiring landfill disposal, lowering disposal fees and contributing to a more sustainable operation. This approach promotes a closed-loop system within the smelter. Figure 2 illustrates a process flow for the segregation process.

The success of the recycling project hinges on an effective segregation process. Techniques like screening, gravity separation, or magnetic separation can be employed to isolate alumina, metallic materials, and other non-metallic fractions from the basement material. Recovered alumina can then be reintroduced into the potline after proper screening and classification to meet the desired particle size range through various operations. Depending on the characteristic (granulometry and degree of contamination) of the segregated bath, this can be reused as a fraction of the Anode Cover Material (ACM). That was the case for Sohar Aluminium. This circular process of reintroducing this segregated bath will in the long term reduce plant needs to procure externally bath as raw material.

The direct use of basement material in the bath plant presents some operational challenges. The presence of fines in the basement material can increase the overall level of fine particles in the ACM. This can lead to day-to-day variations in the ACM composition and flowability, making more difficulty the control of free alumina content within the ACM. Maintaining a consistent free alumina level in the ACM is crucial for optimal cell performance. Therefore, while some bath components from the segregated material might be treatable and reusable, their reintroduction likely requires additional processing steps to ensure they meet the necessary specifications for the cover bath.

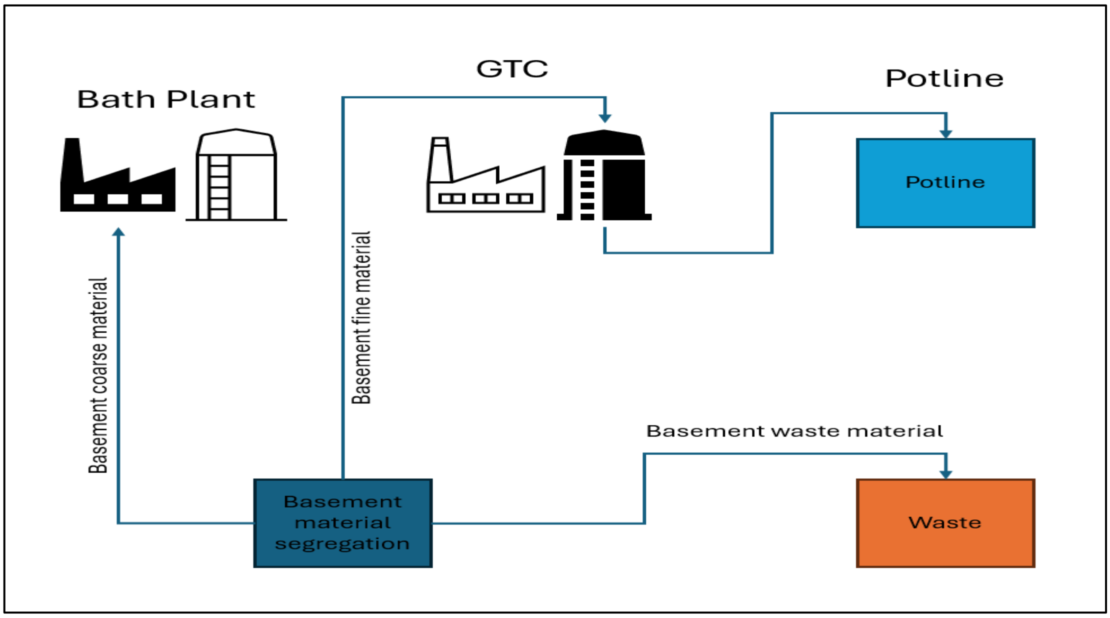


Figure 2. Simplified newly process flow for basement material.

The Sohar Aluminium basement recycling project stands as evidence of the company's commitment to reach sustainable operations. By implementing this innovative approach, the project unlocks significant economic and environmental benefits through effective segregation and characterization of basement material, delivering consistence and recovering valuable alumina and bath from the potline basement. In essence, the project fosters a closed-loop system within the smelter, maximizing use of resources, improving waste management, and significantly reducing production costs.

3. Project Phases – Waste Elimination and Basement Cleaning, Material Segregation and Fine Material Introduction in the Alumina System

Sohar Aluminium has implemented a multi-phased approach to optimize basement material recycling and segregation, enhancing resource recovery, operational efficiency, and safety. Here's a breakdown of the key phases:

Phase 1: Basement cleaning and storage

Before: Basement cleaned time to time with inefficient storage in open areas in bulk or in big bags, leading to material contamination, losses of volume and quality and requiring extra labour and handling to recycle. Pots with excess material accumulated in the basement, affecting pot heat transfer and heat balance.

After: Basement continually cleaned with optimization of storage areas. A vibro screen machine is used to segregate basement material in different granulometry and characteristics. Pots basement constantly clean.

Phase 2: Segregation based on utilization

Before: A single fraction of basement material recycled in the bath plant with challenges to maintain a consistent quality of the ACM: Recipe, granulometry, free-alumina content and contaminants levels. Potroom complains about finer ACM and difficulties to maintain a good cover of anodes.

After: Segregation of three materials:

Fine Material (< 0.8 mm): 65 %. Primarily alumina and fine bath, directed to the potline after size screening.

Coarse Material (0.8 mm - 25 mm): 30 %. Bath material suitable for the bath plant use. An additional screen of 4 mm was used to improve the separation efficiency.

Scrap (> 25 mm): 5 %. Material classified as waste.

Phase 3: Fine material introduction in the alumina system

Before: 100 % of basement material collected directed to bath plant, added as a fraction to produce the ACM

After: Segregated materials are directed for optimal use: fine material (alumina with fine bath) to the potline and coarse material (bath) to the bath plant, added as a fraction to produce ACM.

3.1 Phase 1 - Addressing Inefficiencies

The basement cleaning was not levelled, and most of time, occurring preferentially at and around a pot during its change out. A not clear vision of the importance of this material also led to a serious accumulation under the pots. Figure 3 is an example of excess materials accumulated in the basement, clean basement and handling equipment.

Figure 3. Before and after - basement with excess material (left), clean basement (middle) and handling equipment (right).

Previously, the cover mix material was stored in big bags directly exposed to sunlight (Figure 4). Over time, this exposure caused the material to agglomerate and became difficult to handle, creating challenges for processing. Forklifts, bucket loaders, and manual labour were all required to remove the big bags and any large debris associated with them. Additionally, the mixed basement material was simply piled in a central location.

Figure 4. Before (left) and after introduction of vibrator machine (right).

To this point, a controlled and efficient approach was implemented. A key improvement involved the installation of a vibro screen machine. This screening was designed for multiple size options, allowing the Sohar Aluminium process team to analyse and test some options. By controlling the material's consistency, the screen contributed to smoother operation and enhanced the control of quality within the operations. The final sizes for segregation came after the process team define the requirements for potline and bath plant.

3.2 Phase 2 - Segregation Based on Utilization

<u>Fines: 65 % of basement material</u>

The fine material segregated has primarily alumina which is recycled replacing the fluorinated alumina. This material can be used directly in the pots but need to have adequate granulometry to keep smooth operation of conveyors and pot feeders. The size of the screen selected was 0.8 mm, same as the GTC fluorinated alumina vibrating screen. Around 65 % of basement is considered fine material (< 0.8 mm).

The Figure 5 shows the results of granulometry and chemical analysis for the fine material with roughly 55 % fluorinated alumina and 45 % fine bath. The fine bath will impact on the liquid bath level control in the pots.

Very important to note that this fraction has 2 400 ppm of Si, which will impact the metal purity. The significant percentage of Si and the percentage of bath are the main reason that most of the smelters have restrictions to recycle basement material internally. The next section will discuss the challenges and countermeasures used by SA for continuous utilization.

Fine	Fe	Si	Total Al2O3	Total Bath	AlF3	CaF2	BD(gm/cc)	Size(%)					
	ppm	ppm	%	%	%	%	%	>20 mm	>14 mm	>3.15 mm	>0.200 mm	>0.075 mm	<0.075 mm
Basement-1	1769	2340	53.90	44.39	12.62	3.22	1.30	0	0	0	23.9	38.7	37.5
Basement-2	1605	2232	55.83	42.49	12.96	3.17	1.30	0	0	0	22.9	37.5	39.6
Basement-3	2255	2713	51.81	46.38	12.26	3.50	1.31	0	0	0	27.0	40.2	32.8
Basement-4	1709	2259	55.08	43.25	12.93	3.22	1.28	0	0	0	22.2	43.4	34.4
Average	1835	2386	54.16	44.13	12.69	3.28	1.30	0	0	0	24.0	39.9	36.1

Figure 5. Physical and chemical analysis of basement fine material in Sohar Aluminium.

Figure 6. Fine material output from segregation machine (< 0.8 mm).

<u>Coarse: 30 % of basement material</u>
The coarser material segregated from 0.8 mm to 25 mm is sent to the bath plant for ACM production. This granulometry was selected based on current bath plant control limits as per customer specification.

Figure 7. Coarser material split in two fractions to facilitate processing. Size 0.8–4 mm material segregated (left) and size 4–25 mm (right).

To avoid the vibro screening getting clogged time to time, an extra screen of 4 mm was installed, avoiding excess fine material directly in the coarse material. This separation increased the efficiency of the screening process, but the two fractions are mixed back again and sent to the bath plant for processing ACM.

Scrap (5 %)
Scrap material defined as any coarse material above 25 mm and deal with it as waste. This material has bath, aluminium, refractory, wood and carbon pieces.

Figure 8. Scrap material output from screening process (> 25 mm).

3.3 Phase 3 - Fine Material Introduction in the Alumina System

After the screening of raw basement material, the fine material is filled in big bags and transported to the GTC courtyard for further processing. A fluidized bin controls the material flow as the bulk bag is opened inside, allowing the material to seamlessly flow into a bucket elevator.

The bucket elevator, equipped with variable speed control, precisely regulates the rate of basement fine material introduction based on demand. The elevator connects to an air slide conveyor, which merges the basement material stream with the existing GTC fluorinated alumina stream (flowing at a rate of 44 t/h). This combined stream is then fed to a fluorinated alumina air lift conveyor.

Figure 9. Bin (left) and bucket elevator (right) to introduce basement fine material to fluorinated alumina stream.

Before reaching the fluorinated alumina silo, the output from the air lift conveyor is directed through existing vibrating screens. The GTC system utilizes two vibrating screens, with one operating as a primary unit and the other serving as a standby. However, when processing basement fine material, both screens operate simultaneously to ensure rigorous quality control. To prevent oversized particles from passing through the screens and compromising the final product, the preventive maintenance frequency for these screens has been increased to a proactive level. This approach facilitates a homogeneous mixing of basement fine material (introduced at a rate of 2 t/h) with the GTC fluorinated alumina stream. This allows the effective utilization of recovered basement material using the existing production flow without impact on regular operation.

4. The Challenges for Basement Material Segregation

The newly implemented basement material screening, characterization and recycling at Sohar Aluminium offers a significant leap in efficiency. However, an effective recycling of basement material for optimal performance presents some challenges.

Sohar has a standard configuration that delivers alumina directly from storage silos to individual pots using low-pressure fluidization technology. The typical equipment for alumina conveying has a feed system from silos to pot rooms, a horizontal distribution system feeding pot sections, pot air slides with isolators for pot hoppers, and a dedicated feed system for a single 90-pot section.

Although the vibrating screen material remove > 0.8 mm, the basement fine material still may contain a wide range of particle sizes. Particles below 0.8 mm still can potentially impact the alumina transportation system and the pot feeding process. If a coarser material batch happens and concentrates in some pots, pots performance can be impacted.

Another challenge arises from potential build-up within the distribution system. The distribution system has cycles to remove coarse material build-up in the lower velocity points. However, these cycles might still not be sufficient to avoid finer particles adhering on the system walls or settle in specific locations within the horizontal distribution system. This uneven distribution can lead to inconsistencies in the alumina delivered to the pots. Additionally, the system utilizes ventilation cyclones to capture particles from the fluidizing air, with reintroduction into the alumina stream. While this approach aims to minimize waste, finer particles could not be captured in the cyclones and circulate within the system. This recirculation could lead to an increase of fines in the overall alumina feedstock.

The optimization of the ducts cleaning cycle could also be explored to more effectively remove unwanted material from the entire distribution system. Finally, investigating the efficiency of the ventilation cyclones and potentially exploring additional filtration techniques could minimize the recirculation of fines within the system (HDPS).

By assessing these potential segregation challenges, Sohar Aluminium ensured a more consistent and optimal quality of alumina delivered to the pots, potentially leading to no adverse effects on cell performance and overall production efficiency when recycling basement fine material with up to 55 % alumina.

Another challenge is the high presence of bath in the fine material to be recycled as alumina. The material with 45 % of bath goes directly to the pot liquid bath and will increase the bath level of the pots. Strategy, monitoring and countermeasures used are detailed in the next section.

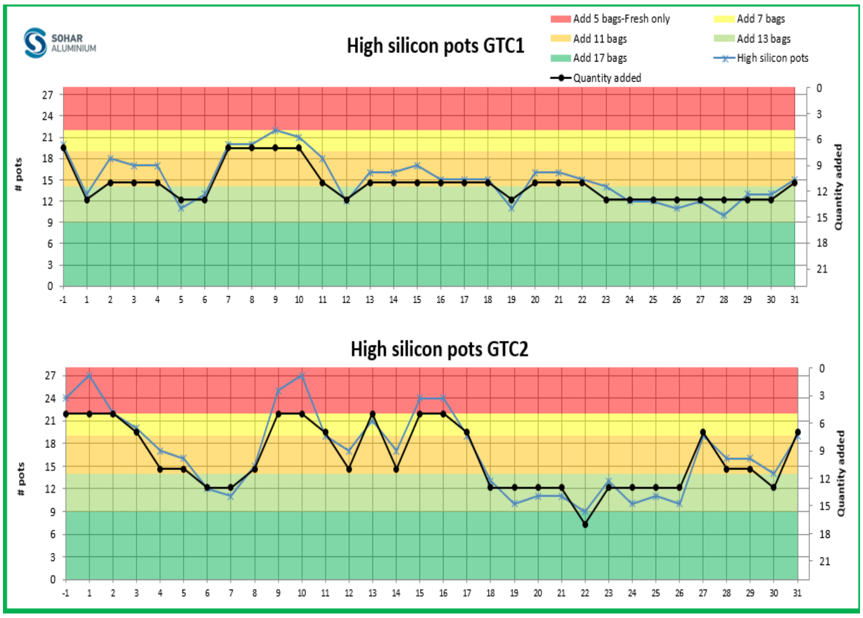
5. Quality Control in Potline Process and GTC Process

5.1 Pots Quality Control

The integration of basement fine material with the existing GTC fluorinated alumina stream offers economic and resource recovery advantages. However, potential drawbacks related to alumina contamination and uneven distribution of impurities require careful consideration. The primary concern lies in the composition of basement fine material. While it contains around 55 % alumina, the remaining 45 % consists of fine bath material and impurities. Introducing this material could potentially contaminate the standard fluorinated alumina used in the potline, negatively impacting the metal purity.

To mitigate this risk, a multi-pronged strategy was implemented:

- Comprehensive Material Analysis: Samples of the basement fine material were collected and analysed in a laboratory to gain a thorough understanding of its exact composition before introducing it to the pots. This analysis identified key elements that could potentially influence pot metal purity, like Fe and Si. Figure 5 above shows the analysis results.
- Using silicon content in the pot metal analysis as a KPI (Key Performance Indicator) for process control. The existing hyper dense phase system (HDPS) used to convey fluorinated alumina to the potline presents a distribution challenge. The central section of the HDPS distributes alumina for two groups of 45 pots each within a room. It's noted that impurities from the basement fine material affect more the pots closer to the HPDS branches, and less impact on pots located at the end of the HDPS branches. With this, the first 10 pots at the beginning of each branch typically show higher Si, see Figure 11. The pots at the middle shows Si values approximately 70 ppm more than the pots at the end of the distribution branches. Higher or lower number of pots with high silicon (>800 ppm) content will determine the need to adjust the feed rate of the basement fine material through the GTC system. Figure 10 illustrates the strategy to target less pots with high Si, and more big bags recycled. By constantly monitoring pots with high silicon levels, operators can ensure operations as expected without jeopardizing the potline metal quality.



Silicon pots	Basement feeding (Bags)
0-9	17
10-14	13
15-19	11
20-22	7
>22	5

Figure 10. Number of silicon pots in a month period and standard for # bags to recycle according to number of pots with high silicon.

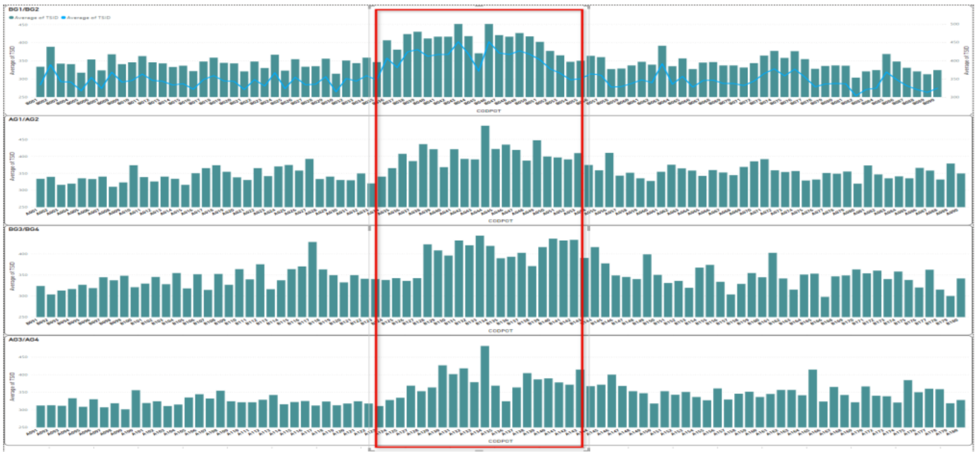


Figure 11. Distribution of Si content in groups on 90 pots.

5.2 HDPS Performance Control

Basement fine material comes with heavier particles (bath particles) which are less fluidizable and settle in the fluidising pad, causing accumulation in lower speed positions, and can cause blockage and transportation interruption. Those particles settle at the beginning of each branch in central HDPS and manual cleaning is required in the first 3 HDPS sections from each branch. Manual cleaning was required when bubble pressure at the far end of the HDPS goes to ZERO plus the level switch indicates low alumina level. Weekly manual cleaning was required.

To address this distribution challenge, additional control was required to accommodate the new operation with basement fine material:

- Daily HDPS flushing done to remove the deposits and minimise the accumulation.
- Increased bubble pressure set point to get extra vertical flow.
- Introduced horizontal air to push material toward end of each branch.

All above actions, see Figure 12, helped to keep HDPS performing as normal and reduced manual cleaning from weekly to quarterly.

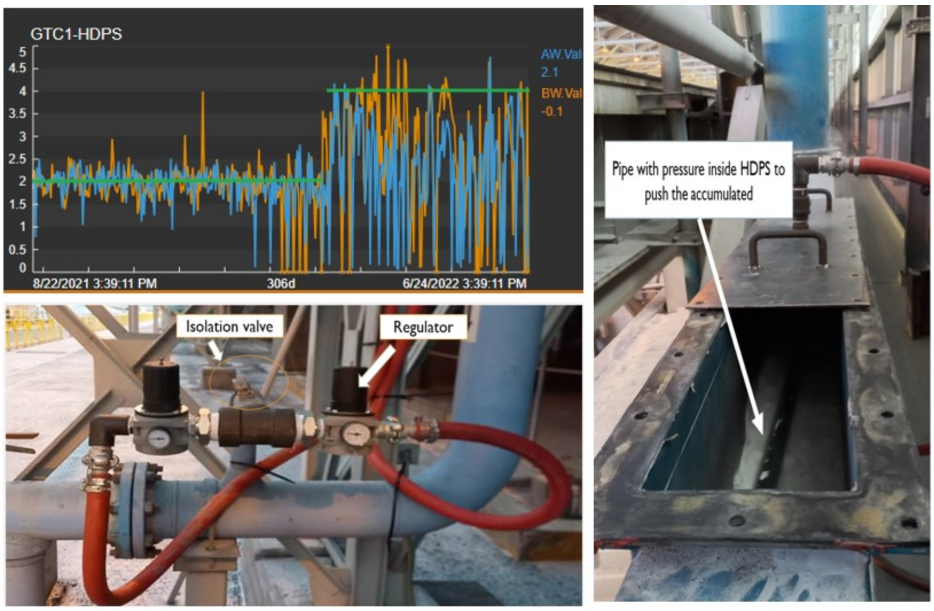


Figure 12. Flushing, higher bubble pressure and new horizontal air system.

5.3 Sampling for Fluoride Analysis and Alumina Quality Control

The original sampling point within the HDPS, located after the basement material became susceptible to contamination. Daily samples collected from this point (meant to analyse % fluoride adsorbed in alumina and GTC performance on emissions) became unreliable due to the presence of basement material impurities. Key parameters like percentages of F, Si, and Fe were significantly impacted, masking the true quality of the fresh alumina reacted.

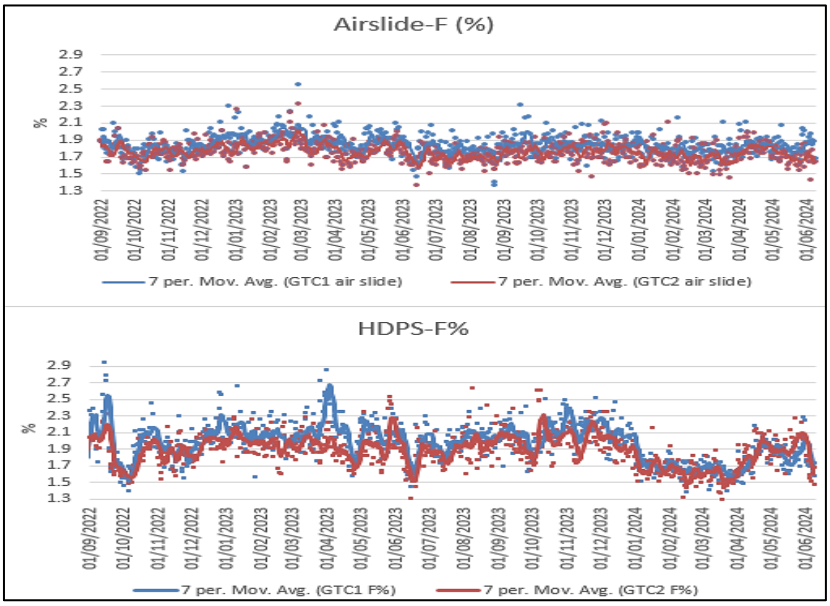


Figure 13. Fluorine percentage in alumina samples before (top) and after (below) basement material addition.

To overcome this hurdle, a new daily sampling strategy was implemented. Samples are now collected from the air slide located upstream from the basement material introduction point. This new location provides a crucial advantage: the collected samples represent the pure fluorinated alumina quality and GTC performance before any contamination occurs. By analysing samples from this new location, process engineers can accurately assess the true quality of the base alumina and the effectiveness of the GTC system. The HDPS samples, while still collected, now provide a clear picture of the impact of basement fine material on the alumina stream just before it reaches the pots.

This two-pronged approach ensures a more precise understanding of both the base alumina quality and the overall effectiveness of the GTC system, even with the introduction of basement fine material, ultimately allowing for better control and optimization of the integration process.

6. Project Benefits and Conclusions

This project was a technical, operational and success story. Sohar Aluminum's innovative project for recycling basement material has yielded significant environmental, quality, and financial benefits.

- Environmental Wins:
  - ✓ Recycled hazardous waste, minimizing landfill impact and promoting sustainability.
  - ✓ Created a cleaner and safer work environment by removing accumulated material.

- Quality Enhancements:

- ✓ Established a consistent cover mix with reduced fines, leading to improved potline anode cover with anode air burn reduction.

- Financial Advantages:
  - ✓ Basement fine material's higher fluorine percentage content further enhanced the reduction fluoride consumption. Figure 14 shows the fluoride consumption throughout the years at SA.
  - ✓ Effective material utilization translates to substantial cost avoided with landfill.

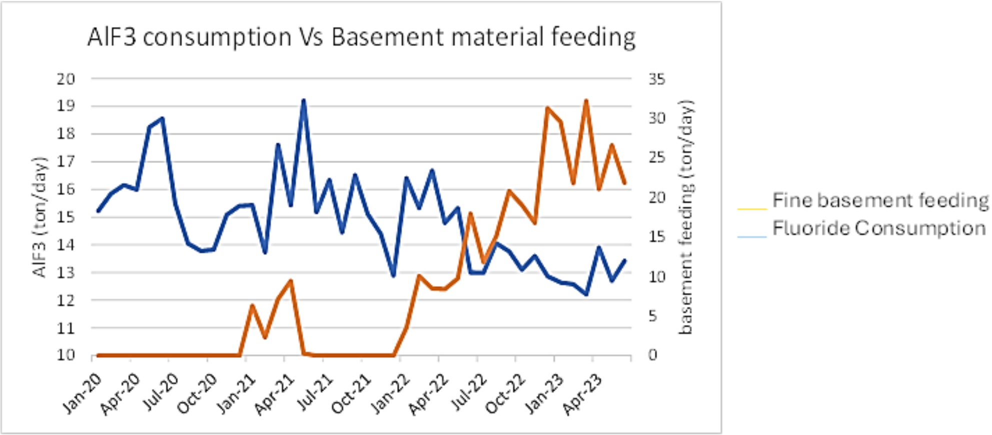


Figure 14. Reduction of fluoride consumption at SA with use of fine basement material.

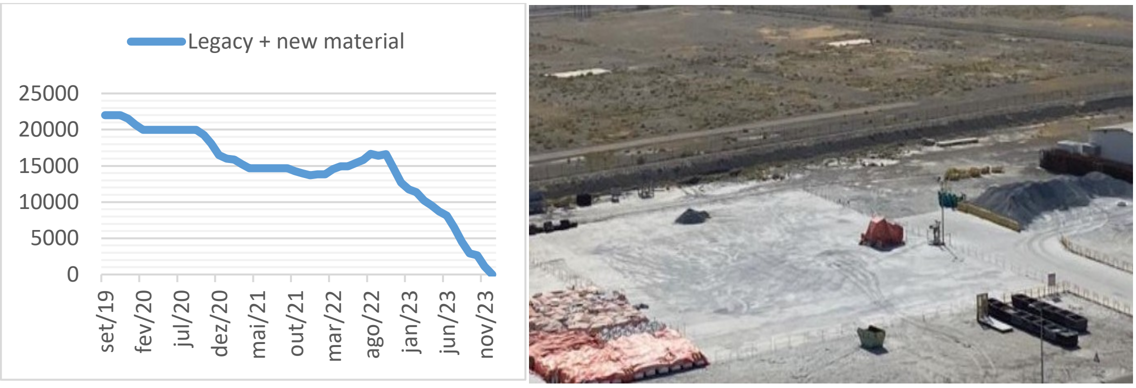


Figure 15. Basement material inventory (t) and current storing area.

It was captured 2.5 million USD in value with reduction in alumina and fluoride consumption. In addition, not considered here, approximately 5 000 tonnes of pure bath was sold, because of excess bath generation in the pots. Another value not captured here is the avoided cost with land fields. Figure 16 illustrates the benefits.

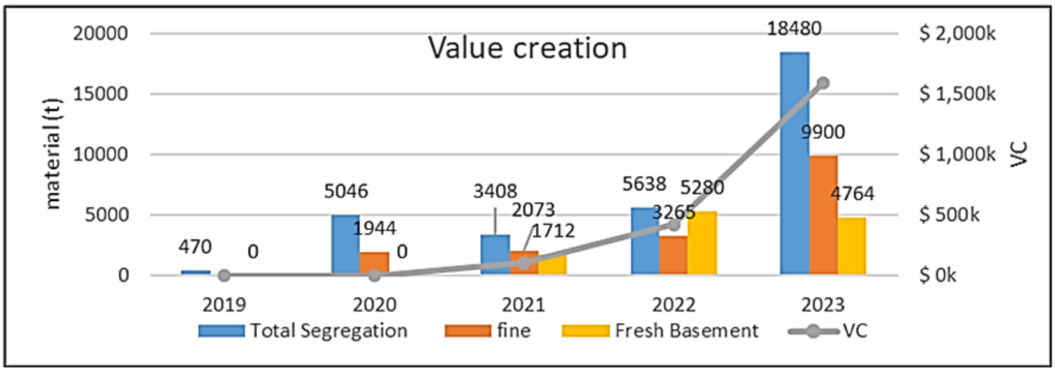


Figure 16. Value creation over project period.

This project exemplifies a comprehensive approach to basement material recycling, encompassing both under-pot material and fresh material for cover mix control. The new system ensures quality control, operational efficiency, and proactive maintenance. Sohar Aluminum's success serves as a model for the aluminum industry, demonstrating how responsible recycling contributes to a sustainable and cost-effective future.

The inadequate management of the underpot material can be a huge problem for smelters. If well managed this material turs an important effort to improve cost and efficiency in the operations.

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