Enhancement on Gaseous Fluoride and Sulfur Dioxide Emission Performance of the Outer Compartments at EGA Al Taweelah Smelter Gas Treatment Center (GTC)

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Abstract

Emirates Global Aluminium (EGA) Al Taweelah smelter lines 1 and 2 (also known as Phase 1) Gas Treatment Centers (GTC) have one of the longest primary alumina airslides in the industry. Each pot line has two GTCs and each GTC has both a dry scrubber and a wet scrubber. The GTCs have 32 compartments, 16 on either side of the primary alumina storage silo, all connected by a 120 m long primary airslide. Despite the industry-accepted low levels of hydrogen fluoride (HF) and sulfur dioxide (SO_2) emissions from the stacks, process gas testing on individual compartments revealed that the outer compartments emitted elevated HF and SO_2 compared to the rest of the plant with similar results found on all four GTCs. This paper describes the unique and innovative methods used by, identified the resolve the problem to further reduce HF and SO_2 emissions.

Keywords: DX Cell Technology, potline gas treatment center (GTC), gaseous fluoride emissions from GTC, alumina conveying airslide, alumina distribution to potlines.

1. Introduction

Emirates Global Aluminium (EGA) owns and operates two smelters, the older Jebel Ali smelter in Dubai. The newer Al Taweelah smelter, is located in the Khalifa Industrial Zone Abu Dhabi approximately 80 km east of Abu Dhabi city.

Al Taweelah Phase 1 has four GTCs divided between east and west GTCs. East GTCs (5311 and 5312) are identical whereas west GTCs (5312 and 5322) are slightly different. GTC 5322 has additional two ducts connected to Hot Butt Removal (HBR) for gaseous treatment of the fumes from the hot spent anode cover. This duct has an advantage of cooling the gas stream into GTC, which leads to a lower inlet gas temperature and lower HF gaseous emissions. Therefore compared with the other three GTCs, GTC 5322 has lower HF and SO_2 emissions. Therefore for the purposes of simplicity, this paper only references the plant with the highest emissions; however the air slide is same in all four GTCs.

In addition, Al Taweelah Phase 1 GTCs are divided into “dry side” and “wet side”. The “dry side” is the traditional dry alumina scrubbing technology that is common in one form or another at most aluminium smelters in the world. The “wet side” or “wet scrubber is a SO_2 removal system that uses a total of 26,000 tonnes per hour of fresh seawater in a single pass to reduce the SO_2 emissions by approximately 90%. The spent seawater is then mixed with the blow down from the seawater cooling system for the power station, additional fresh seawater, aerated and cooled and released back into the Arabian Gulf in line with the conditions set by the Environmental Department of the Abu Dhabi Government and EGA’s lenders.

Alumina is conveyed via an approximately 100 m long air slide connected to both halves of the GTC as shown in Figure 1. The primary alumina air slide feeds the plant via 32 alumina distribution slots with the aim to distribute equal amounts of alumina to each individual mini airlift and from there to individual compartments for adsorption of the gaseous HF. In each side of half GTC, the gas flow from certain compartments tends to flow to specific fans due to the design of the outlet duct work. Physically there is no isolation between the compartments but due to the location we can say that there is.

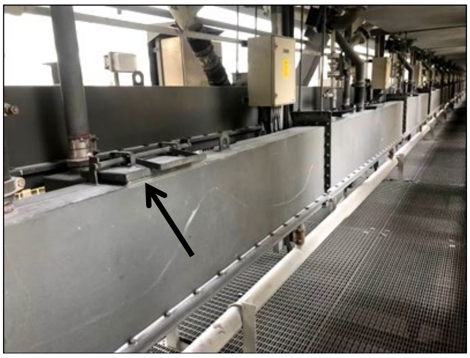

Figure 1. GTC primary alumina airslide with sampling locations.

The emission data for the last 4 years will be presented in this report in order to give a clear picture of before and after scenario. This study and trial has been undertaken on GTC 5311 with the same innovative solution applied to the other two GTCs. The alumina quality and flow ability were studied to identify the reason of elevated emission of HF and SO_2 emission in outer compartments. During the first summer in 2011, EGA observed that the gaseous fluoride and sulfur dioxide emission on the outer compartments (Fan 1 and 6) are higher compared to inner compartments.

While the issue was being investigated the problem disappeared on its own during the cooler months, only to return the following summer in 2012 and again repeat itself into 2013. Further investigation looking at visual changes in the plant and using a water gauge identified the airside itself was changing shape during the warmer months. The main cause was thermal expansion of the +100 m long airslide which is rigidly fixed to the plant with heavy duty 100 mm diameter drain piping at the end of the plant forcing the airsides to rise or move sideways, although the actual outcome varied from plant to plant and even end to end of each GTC. The visual and measured changes of the plant were then compared against actual process analysis to determine if these physical changes were causation or correlation.

2. Test Results

The average gaseous HF emission for GTC 5311 during the years 2014 - 2015 at sample positions Fan 1 and 6 is higher by 171 % than in sample locations in Fans 2 to 5 with similar performance in the other two GTCs. The gaseous fluoride emissions for the last 4 years are presented in Figure 2 for all Phase 1 GTCs.

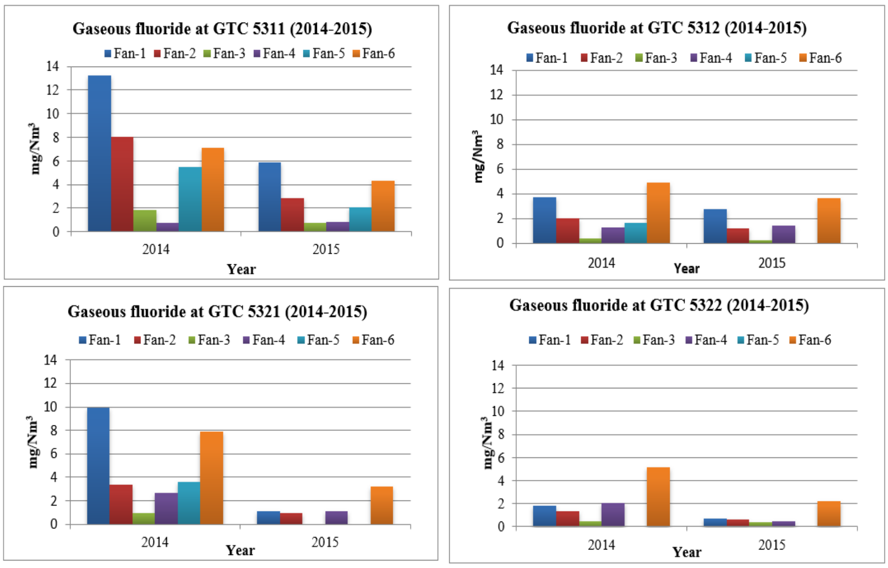

Figure 2. Gaseous fluoride (F_g) at GTC before modification.

The average sulfur dioxide emissions for 2014 - 2015 for the dry scrubber side are by 78 % higher than for wet scrubber side. The average sulfur dioxide emissions for 2014 - 2015 for the dry side of GTC 5311 at sample positions of Fan 1 and 6 is higher by 18 % than in the sample positions at Fan 2 to 5 and same performance on two other GTCs. The sulfur dioxide emission for last four years is presented in Figure 3 for all Phase1 GTCs. The exceedance on inner compartments at GTC 5312 on 2014 and 2015 are due to operation issues not related alumina distribution.

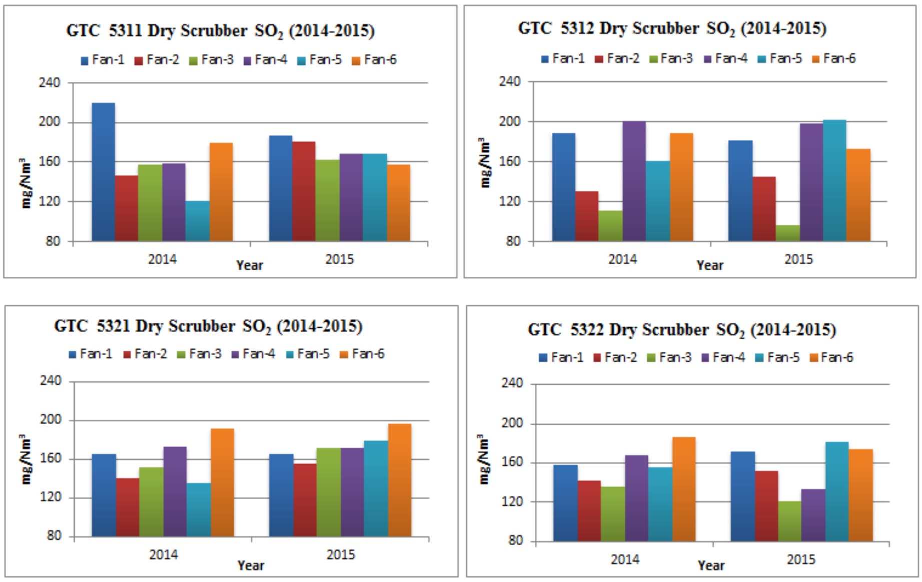

Figure 3. Sulfur Dioxide (SO_2) emission at GTC dry scrubber before modification.

At GTC 5311 average of sulfur dioxide emission on wet scrubber side on 2014 - 2015 at stack 1 and 6 is higher by 19 % than at stacks 2 - 5 and it is the same on two other GTCs. The sulfur dioxide emission for last four years is presented in Figure 4 for all Phase1 GTCs. The test is conducted on a few stacks per year, not at all stacks, at individual GTC to be representative of the performance of that GTC. Although the performance of individual stacks is different, it purely depends on sulfur dioxide reaction.

The compartments don't feed specific fans, rather they are drafted into a common manifold from which the all three fans all draw from, however due to the layout, certain compartments will be dominate in certain fans. Such as compartments 13 to 16 makes up the bulk of the gas drawn by fan number 3.

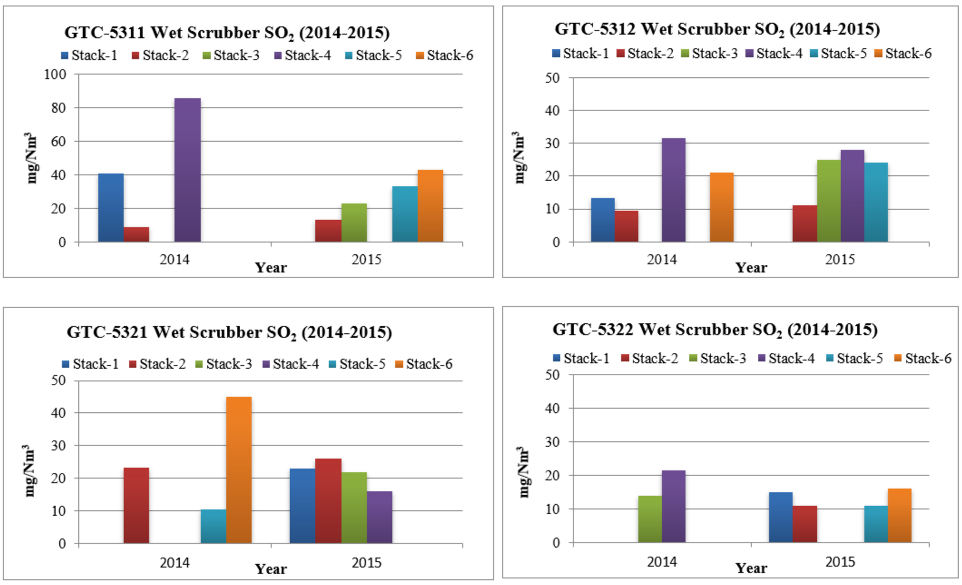

Figure 4. Sulfur dioxide (SO_2) emission at GTC Wet scrubber before modification.

3. PSD of Primary Alumina

The physical properties of primary alumina, i.e., Particle Size Distribution (PSD), in particular the amount of – 45 µm impact on the efficiency of HF adsorption as more surface area means more adsorption. Finer alumina has more surface area and therefore more opportunities for adsorption and hence increased scrubbing efficiency. A primary alumina sample was taken from three different locations along the primary alumina air slide, one sample from first and last compartment on each GTC half as well as one sample from the center for -45 % PSD analyses. The analysis demonstrated that the fines are lost from the alumina as it moves along the airslide towards the end.

We collected secondary alumina sample from one of the GTC for fluorine percentage and PSD analyses. This is to see the concept of the fine alumina with high adsorption of HF. It is clearly seen from the Table 1 that in the finer alumina the F% increased which means high adsorption rate on fine alumina compared to the courser alumina.

Table 1. PSD% and fluorine % in secondary alumina.

PSD%	% Fluorine
+150 µm	0.55
-150 µm + 75 µm	0.88
-75 µm + 45 µm	1.71
-45 µm	3.52

At 3.52 % fluoride, the ability for the fines alumina to effectively scrub more HF from the gases is compromised and more than double the average of 1.8 to 2.0 % fluorination.

4. Alumina Flowability

To understand the alumina flowability, two measurements were taken. The first measurement was undertaken by collecting three alumina samples at the same location of PSD study and tested by funnel flow shown in Figure 5. It was found that the flowability of alumina on the inner section of the air slide was slower than when compared to the samples taken at the ends of the airslide. This indicates that the alumina is finer at the ends of the airslide when compared to the inner sections of the airslide.

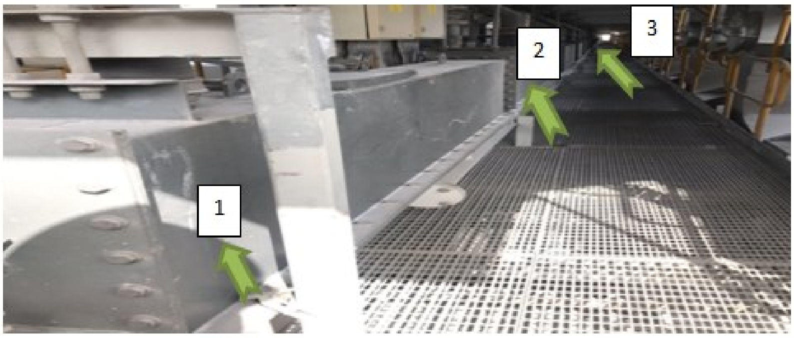

Figure 5. GTC primary alumina airslide sample locations.

The second measurement undertaken was measuring the mini airlift compartment filling time by using a stop watch. It was observed that the outer compartments numbers 1, 2, 3 and 32 are taking up to 187 % longer compared to the inner compartments numbers 4 to 14 and 18 to 31 as shown in Figure 6. This means that the alumina quantity at that particular location is lower than at other locations.

Additionally compartments 15 and 16 also have lower alumina flow rates, however as these compartments are also fed the recycled fines alumina from the airlift, the gas flow in this location is slightly lower and cooler, the emissions from these compartments is well within the target limits.

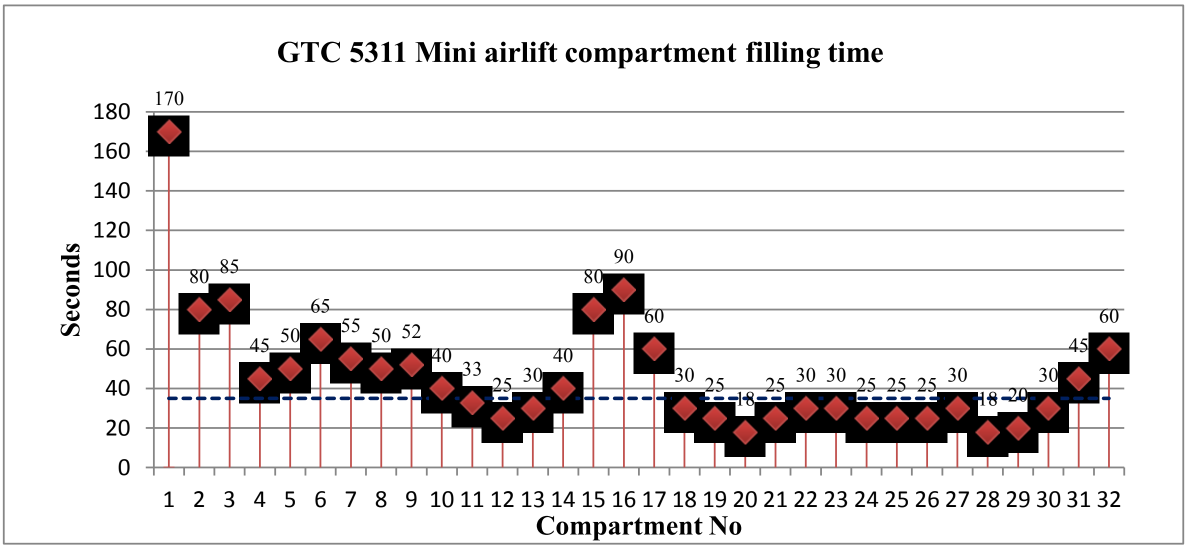

Figure 6. GTC 5311 Mini airlift compartment filling time.

5. The Problem

After undertaking different measurements such as PSD of alumina and alumina flowability, we concluded that there is misalignment of the primary alumina air slide beyond the tolerance of the alumina distribution variance as the outer compartments received less alumina than the inner compartments. Additionally, due to the distortion of air slide and aeration process to convey the alumina along the air slide, the inner compartments get finer alumina with the alumina steadily becoming more course as it moves towards the end of the primary airslide. The entire -20 µm fraction of the alumina is lost before reaching the last compartment numbers 30-32 and approximately 50% of the total -45 µm fraction is also lost at the same location as shown in Figures 7 and 8. In addition to that the SO_2 emission also reduced due to less alumina as demonstrated before in [1].

Therefore EGA determined that the higher HF and SO_2 emissions from the outer compartments was due to a combination of lower alumina flow due to the distortion of the airslide from thermal expansion and lower concentration of alumina fines being fed into the same outer compartments.

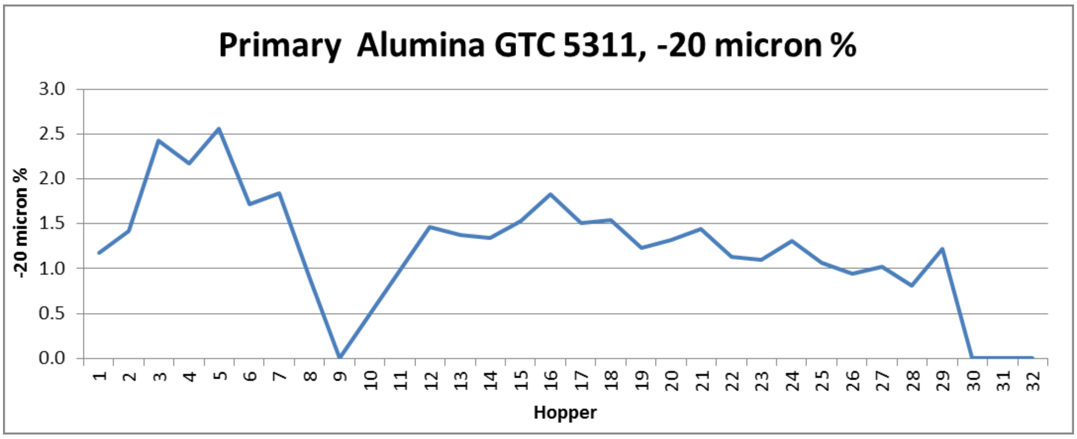

Figure 7. Primary Alumina PSD -20 µm %.

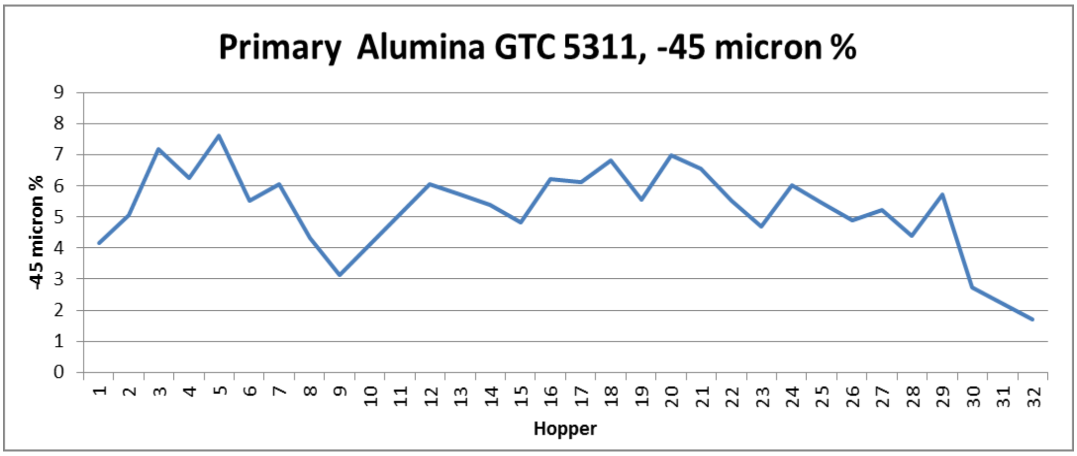

Figure 8. Primary Alumina PSD -45 µm %.

6. Innovative Solution

After identifying the root causes for the elevated emissions in outer compartments through several measurements an innovative solution was identified to resolve the issue. The solution involved increasing the air slide feeding slot, from which alumina flows from primary air slide to the mini air lift to the outer compartments where it is affected by distortion. The slot width was increased from 6 mm to 15 mm carefully using an angle grinder while protecting the aeration pad from sparks on the first and last four hoppers after several trials by testing the mini airlift compartment filling time as shown in Figure 9.

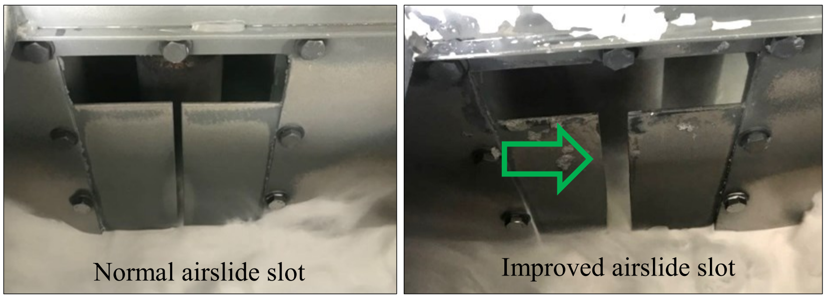

Figure 9. Showing the airslide modification.

Figure 10 demonstrates the mini airlift compartment filling time at GTC 5311 after modification. It’s clearly demonstrates the lower filling time by as much as 50% on outer compartments compared with inner compartments.

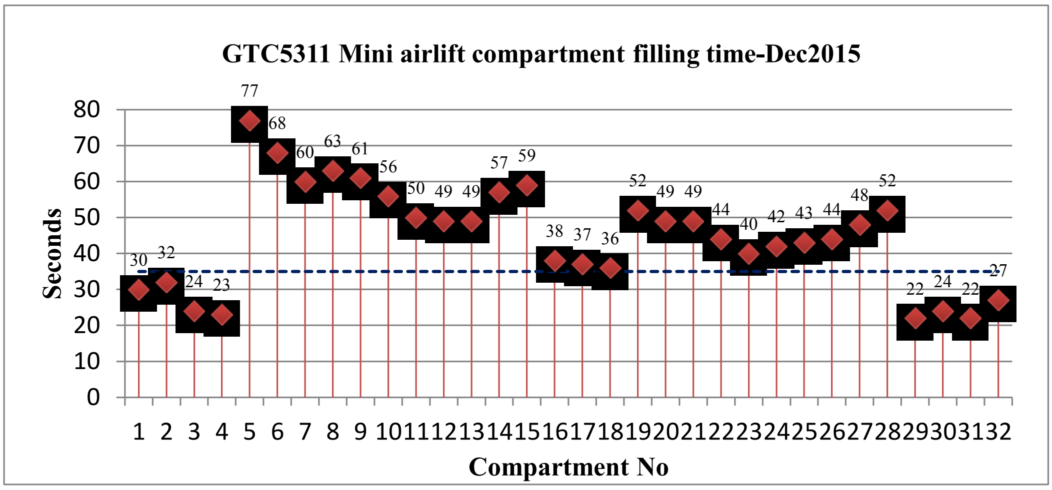

Figure 10. GTC 5311 Mini airlift compartment filling time (December 2015).

7. Environmental Benefits

After the modifications for GTC 5311 completed during December 2015, the HF emissions from the dry scrubber reduced by 93 % from the outer compartments measured at fans 1 and 6 as shown in Figure 11.

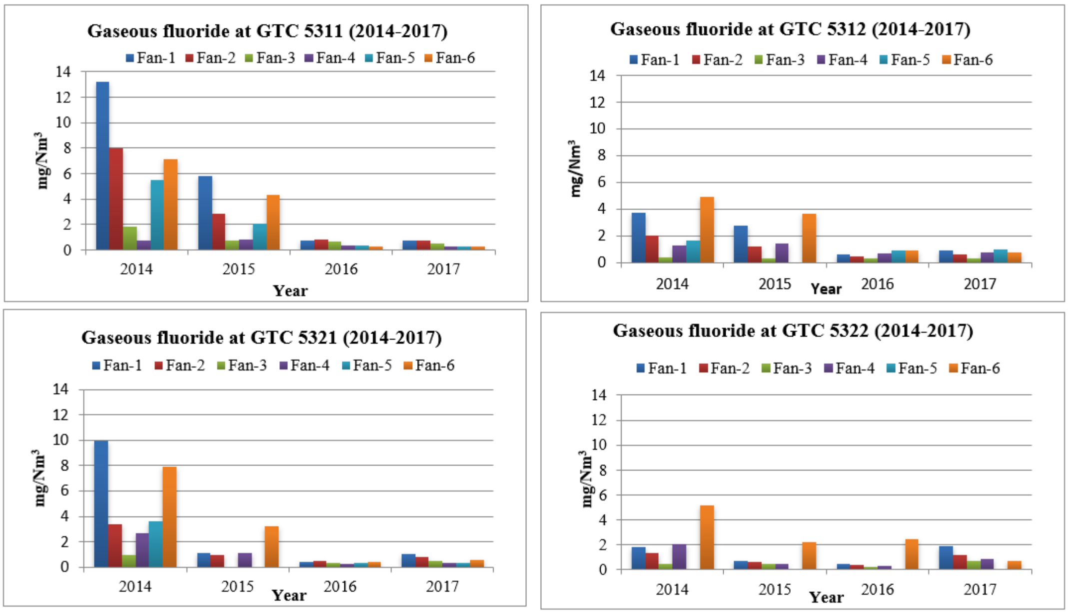

Figure 11. Gaseous fluoride (F_g) at GTC before and after modification.

As the alumina distribution is now improved to the outer compartments, the SO_2 emissions in the dry and wet scrubbers were reduced by 32 % and 63 %, respectively as shown in Figures 12 and 13.

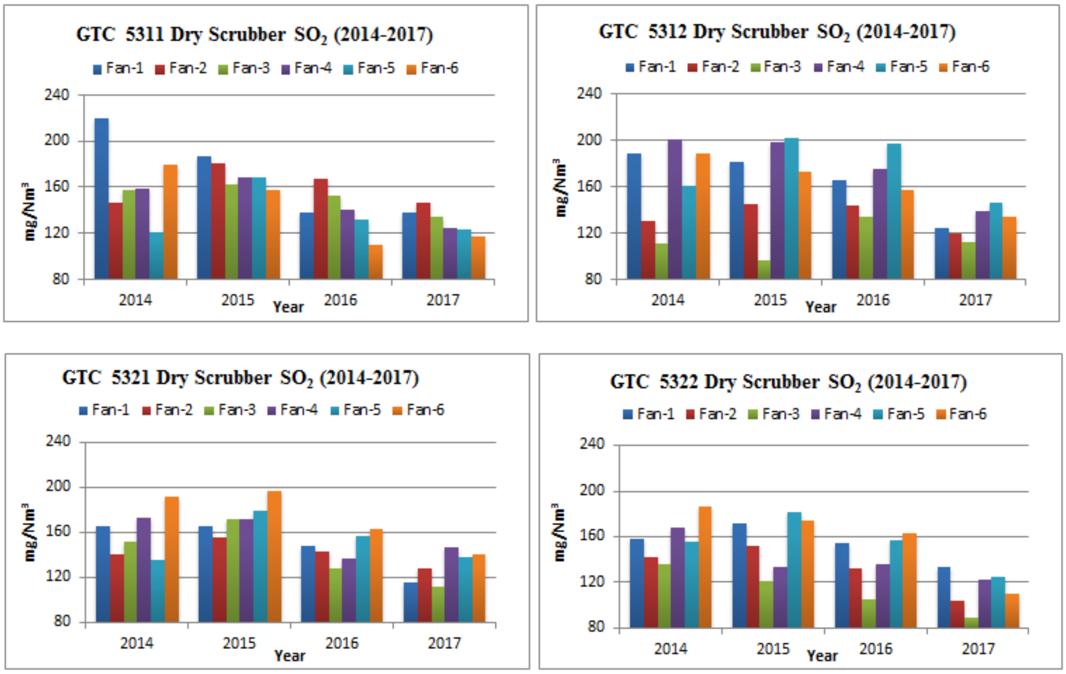

Figure 12. Sulfur Dioxide (SO_2) emission at GTC Dry scrubber before and after modification.

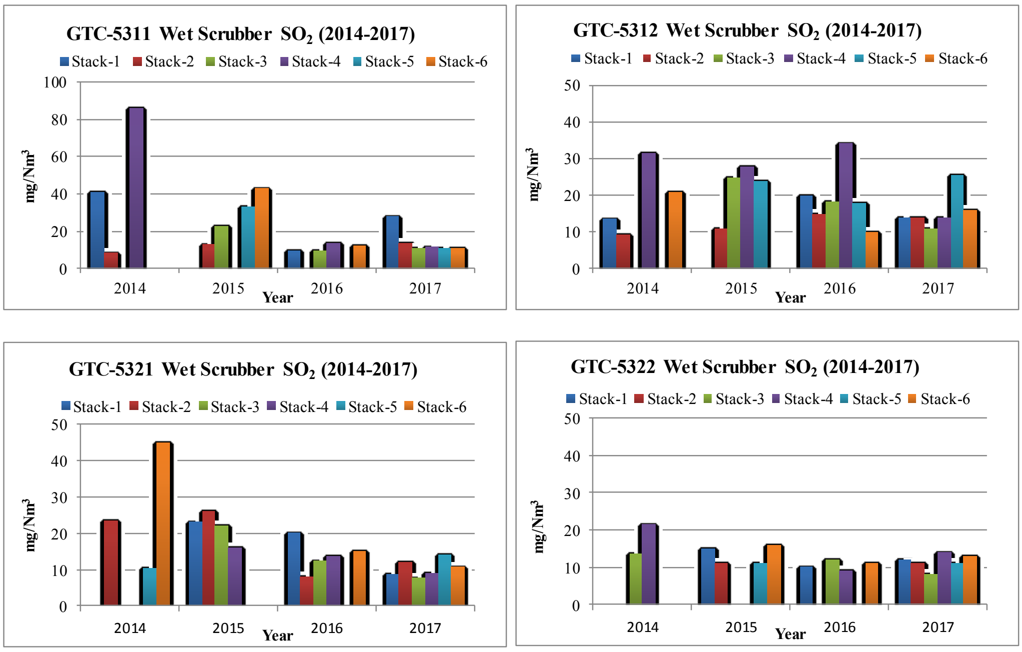

Figure 13. Sulfur Dioxide (SO_2) emission at GTC Wet scrubber before and after modification.

The large improvement in SO_2 scrubbing on the dry scrubber side is due to the SO_2 molecules being adsorbed weakly to sites on the alumina particle surface. A very small amount of SO_2 may react to form sulfates on the surface and these are strongly bound as seen in the Figure 14. However if HF is present or presented afterwards, it will displace SO_2 from alumina surface. The temporal break-through behavior at different fluoride (F) and sulfur (S) loading has been measured by Dando and Lindsay [2].

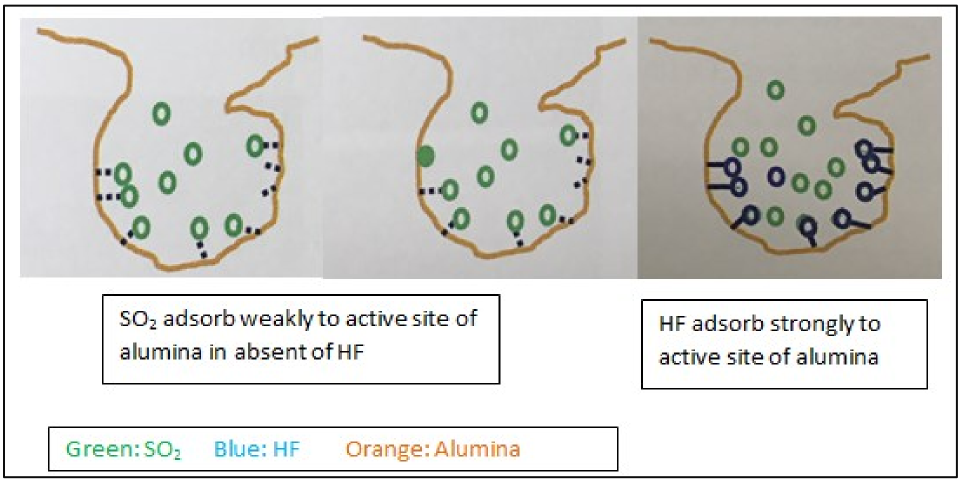

Figure 14. SO_2 adsorption on Alumina active site in absent of HF [2].

8. Cost Benefits

The financial advantage of reducing the HF emissions from the GTC stacks has contributed to reducing the overall aluminum fluoride (AlF_3) consumption. Table 2 demonstrates the theoretical AlF_3 consumption before and after the modification. The actual AlF_3 data are not considered since they are affected by other factors related to the pot performance and primary alumina chemistry.

Table 2. Theoretical AlF_3 consumption, before and after the modification per GTC.

Year	HF (mg/Nm^3)	HF (kg/t Al)	AlF_3 (kg/t Al)	AlF_3 cost (USD$/y)
2014 - 2015	7.6	0.58	0.93	213 211
2016 - 2017	0.5	0.04	0.06	15 533
Benefits	**7.1**	**0.55**	**0.87**	**197 678**

As the figures in Table 2 indicate, the cost savings are considerable: USD$ 200 000 y per GTC, which is USD$ 600 000 /y for all three GTCs in Phase1.

9. Conclusion

Using this innovative method and the human resources available on site, EGA Al Taweelah smelter has found environmental benefits as well as a cost effective solution to reduce AlF_3 consumption demonstrating that relatively small, low cost improvements on large plants can lead to significant benefits: A saving of 600 000 $ per year and a reduction of 93 % in gaseous fluoride emissions from the dry scrubber side and 63 % of SO_2 emission from the wet scrubber.

10. References

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2- Stephan Broek et al., TMS Course for Control of potline scrubber & fugitive emissions for aluminium smelters course, Abu Dhabi, UAE, May 2018.