New Bauxite - Testing Protocol

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Abstract

The Rusal Aughinish Alumina (AAL) refinery is located on Aughinish Island, on the southern shore of the Shannon Estuary 33 kilometres west of Limerick city in the South West of Ireland. The plant, which commenced operation in 1983, has a current production capability of 1.99mt/yr. It sources bauxite predominantly from Guinea, Brazil and Guyana and uses the Bayer process to produce Alumina. The refinery functions with an accredited Safety Management System (ISRS), Environmental Management system (ISO14001), Quality Management System (ISO9001) and Energy Management system (ISO50001). The AAL Research Group established a protocol for the evaluation of new bauxite supplies. The protocol is used to identify potential issues with processing a new bauxite at AAL or other refineries. It includes a review of the materials handling and slurry properties, alumina extraction at high and low temperature, mud settling and the impurities balance. This paper outlines the steps in the protocol and how the results have matched performance of the bauxites at refinery scale.

Keywords: Alumina refinery, Bauxite testing.

1. Introduction

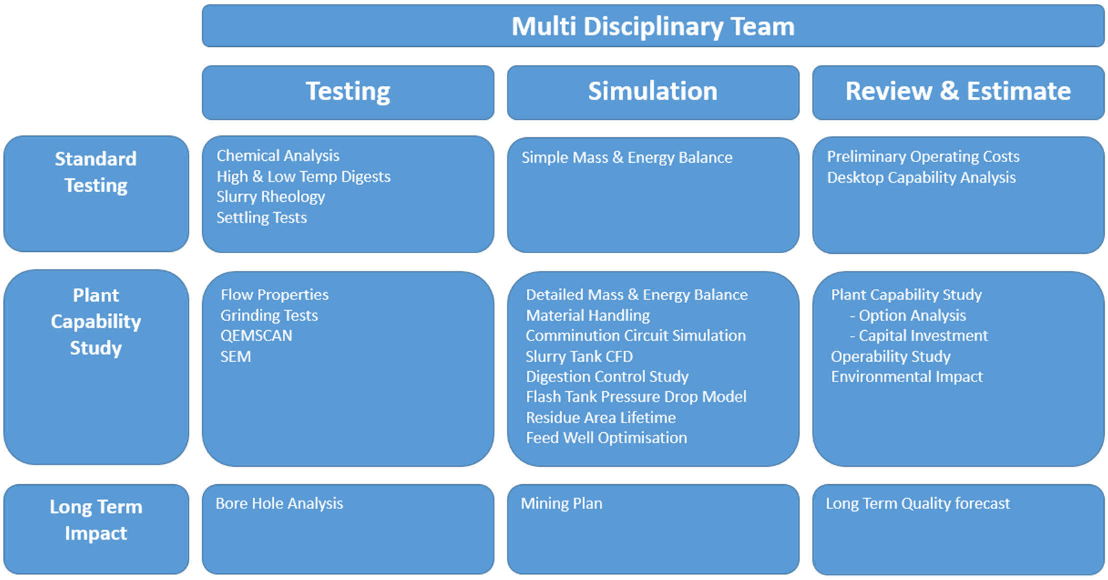
The AAL refinery was commissioned in 1983 and designed to process a specific blend of dried bauxite.

Over the years, the refinery has seen significant increases in production through innovative debottlenecking projects. In recent years, due to decreasing bauxite quality and increasing cost, AAL Research Group have developed test protocols to evaluate alternative bauxite supplies. The protocols introduce a systematic and comprehensive approach to evaluating a new bauxite blend through Test Work, Simulation, Reviews and Economic Estimation.

AAL also support other refineries in the Rusal group with Bauxite testing.

2. Bauxite Testing Protocol

The bauxite testing protocol starts with standard tests and then moves to more specific tests to understand the impact on the refinery. An overview of the bauxite testing protocol is shown in Figure 1.



Multi Disciplinary Team

	Testing	Simulation	Review & Estimate
Standard Testing	Chemical Analysis High & Low Temp Digests Slurry Rheology Settling Tests	Simple Mass & Energy Balance	Preliminary Operating Costs Desktop Capability Analysis
Plant Capability Study	Flow Properties Grinding Tests QEMSCAN SEM	Detailed Mass & Energy Balance Material Handling Comminution Circuit Simulation Slurry Tank CFD Digestion Control Study Flash Tank Pressure Drop Model Residue Area Lifetime Feed Well Optimisation	Plant Capability Study - Option Analysis - Capital Investment Operability Study Environmental Impact
Long Term Impact	Bore Hole Analysis	Mining Plan	Long Term Quality forecast

Figure 1. Bauxite Testing Protocol.

2.1. Standard Testing

The starting point to evaluate a new bauxite is the standard test stage. The standard tests include chemical analysis, slurry rheology, bomb/autoclave digest and settling tests. This first level of testing allows a quick screening of the bauxite. The test data is recorded and gives a simple comparison of the various bauxite types.

The tests provide enough information to develop a simple mass and energy balance. A desktop capability analysis and a preliminary economic model are then developed and this allows an initial screening of the economic viability and production rate capability.

2.2. Plant Capability Testing

The plant capability tests provide the detailed information required for the plant capability study. These tests include but are not limited to flow properties, grinding tests, digestion studies and QEMSCAN.

Simulations are then used to predict the impact that the change in bauxite supply will have on the refinery. The simulations incorporate many years of operating experience and allow the engineer to objectively and comprehensively evaluate a new bauxite supply.

The testing and simulation work carried out as part of the plant capability study allow a detailed plant capability study to be prepared. This study is carried out by a multi-disciplinary team who can accurately evaluate the impact on refinery equipment. The study includes an option analysis and capital requirement for the options. The environmental impact of the proposed options are also reviewed at this stage.

2.3. Long Term Impact

In parallel to the plant capability study, the long term impact of the new bauxite supply is evaluated. This includes reviews of mining plans and quality forecast of the mine.

The information from this review is used in the plant capability study to evaluate future capacity limitations.

3. Plant Capability Study

The plant capability study utilizes an experienced multi-disciplinary team to predict the impact of a change in bauxite supply on the refinery. The outcome of the study is an economic review of the feasibility of processing the bauxite including the required capital investment.

This team select and perform the required test work which is then used in the simulations. The testing and simulations carried out are not standard and depend on the properties of the bauxite. A large emphasis is placed on this stage as correct evaluation will lead to the overall lowest cost solution and reduce the risk.

Some examples of the test and simulations are detailed below.

3.1. Materials Handling

Bauxite handling systems differ in design according to bulk properties such as moisture and flow characteristics. Discrete Element Modeling (DEM) of materials handling systems has been developed to identify the capacity of the existing equipment and to look at potential future debottlenecks.

In Figure 2, the difference between a dry and wet bauxite can be see for the given configuration. In the case of dry bauxite the material passes freely through the chute. On the other hand the wet bauxite very quickly starts to hold up material on the walls. This hold up will eventually compact and lead to a blockage.

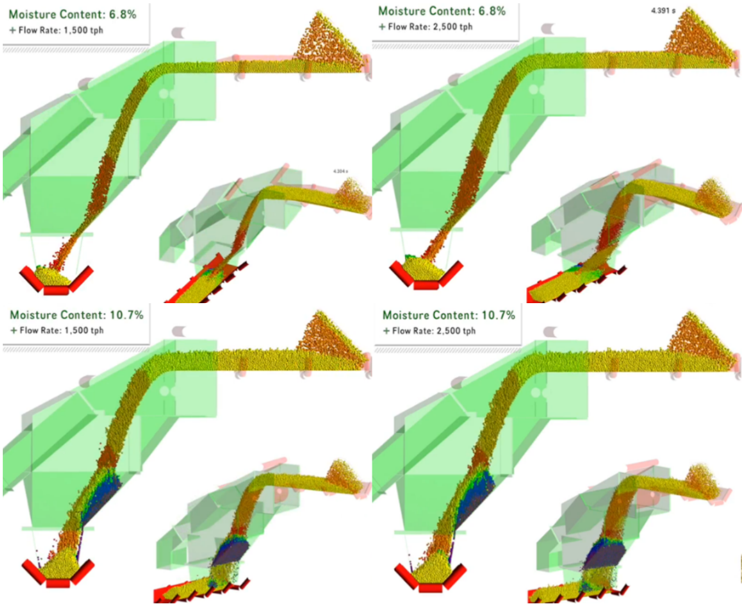


Figure 2. DEM modelling of transfer chute for dry and wet bauxite.

3.2. Slump Testing

Conveying systems in refineries differ, with different designs of hoppers, chutes, transfer systems, crushing, and conveying. The detailed flow modelling allows these difference to be quantified but at times a simple and quick evaluation is required.

The slump tests gives a simple visual impression of how the bauxite will handle under gentle compaction. In Figure 3 it can be clearly seen that a slight increase in moisture content can lead to material holding up in hoppers. The material with the increased moisture content led to blockages in the process.

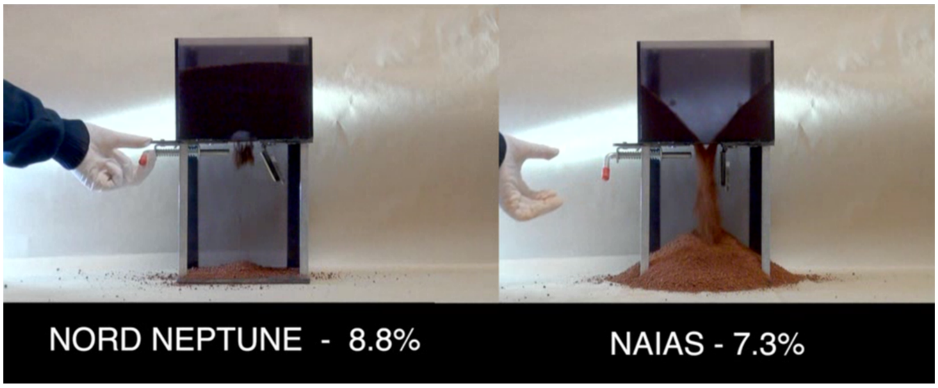


Figure 3. Small increase in moisture impacts of flowability.

3.3. Wobbler Simulation

Refinery comminution circuits vary and some include a wobbler and a hammer mill. The wobbler allows smaller material to bypass the crusher and the larger rocks to be transported to the crusher. The crusher is running at a rate much higher than design and any further increase in coarse material to the crusher will result in a choked system.

The particle size distribution (PSD) of the bauxite arriving at a refinery is a function of the mining technique and this needs consideration when evaluating a new bauxite. In one particular bauxite evaluation, a change to strip mining reduced the top size of material but the median size remained similar.

Discrete Element Modelling (DEM) is used to understand how the wobbler performs under different throughputs with different size distributions.

Figure 4 shows the bauxite passing over the wobbler bars. The output of the model showed that some of the material with size less than the wobbler gap travels along the surface of the bauxite into the crusher.

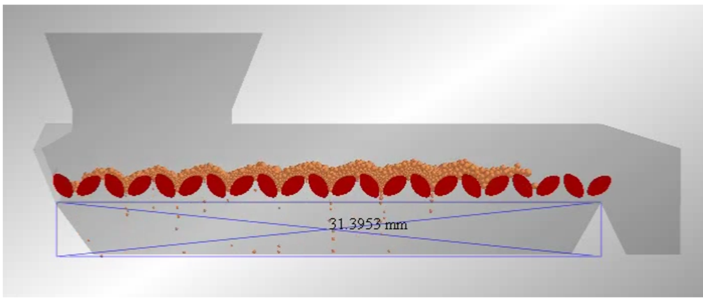


Figure 4. Snapshot of model showing bauxite layer on the wobbler bars.

3.4. Comminution Circuit Simulation

New Bauxite supplies often bring with them a lower extractable alumina content which leads to an increase in the specific bauxite tonnage. The increased tonnage in turn results in an increase in the average throughput through the mills. This throughput increase is further compounded when a mill is offline for maintenance resulting in the throughput of the remaining mills far exceeding the design capacity.

AAL have developed detailed models of the comminution circuit to allow accurate prediction of the comminution circuit performance. The models have been developed by means of laboratory testing, plant surveys on the existing mills and computer simulation.

The simulations allow the grind size to be evaluated with a new bauxite supply and the associated wear rate in downstream equipment can then be estimated.

When bottlenecks are identified, the simulations are used to evaluate options to debottleneck the comminution circuit. Initially the simulations were used to model a change in the mills from open circuit to closed circuit grinding. The simulations showed that such a change would exceed the hydraulic limit of the mills and therefore, this is not a feasible option.

Sensitivity analysis on the mills showed the significance of the feed size on the resulting grind size. This resulted in an increased focus on the dry bauxite crushing. As an initial step, technology was installed to continuously monitor the product size exiting the crusher. This measurement is now used to manage maintenance plans and has resulted in a step reduction in feed size to the mill. In figure 5 the images show the crushed bauxite before and after a crusher overhaul. A 30% reduction in the P80 is observed which significantly improved the comminution circuit performance.

Future debottlenecking in this comminution circuit continues to focus on dry grinding as this offers the most economical means of achieving the desired grind size from the mill and managing wear rates downstream.

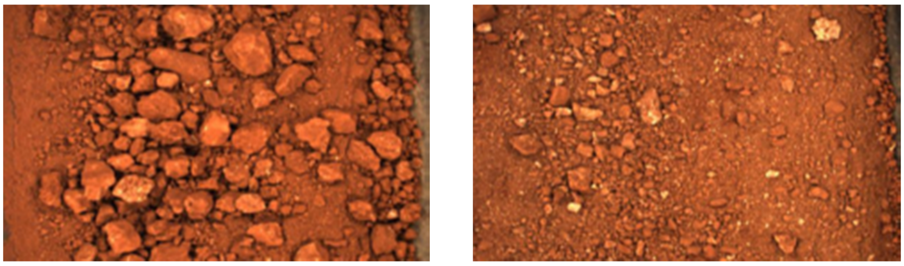


Figure 5. Coarse (left) and Fine (right) product from the crusher.

3.5. Slurry Rheology

The process of desilicating bauxite can lead to a significant increase in bauxite slurry viscosity. The impact of this increase can be accurately modeled by means of laboratory testing and Computational Fluid Dynamics (CFD) modelling. The modelling is then validated by means of comparison against the power draw observed on the agitator.

The CFD images shown in Figure 6 illustrate the impact on the tank mixing with different bauxite blends. The images show the viscosity profile in the tank and it can be seen that at a ratio of 1:1 the tank is very poorly mixed with zones of highly viscous material.

The blend of material was then varied and the model output compared to the power available on the agitator. It was estimated that a blend of 3:1 was within the capabilities of the tank agitator prior to testing on full scale. Refinery scale testing has subsequently confirmed this.

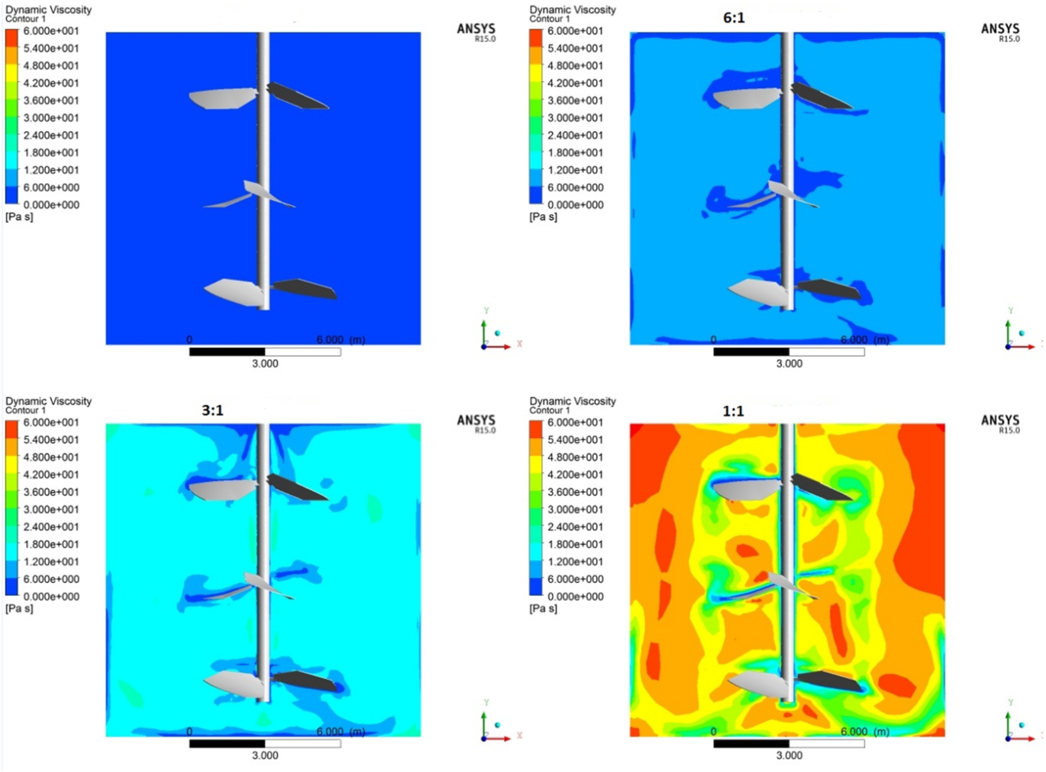


Figure 6. Slurry tank modelling.

3.6. Flash Train Pressure Drop Model

The multi-effect flash evaporation unit typically seen in Bayer refineries consists of a series interconnected flash vessels. The liquid underflows the flash tank to the next flash tank and the steam is condensed in heat exchangers.

When considering a new bauxite supply the impact on the energy balance is evaluated and in turn the impact on the flash tank pressure profile. This evaluation is done by means of a pressure driven flash tank model integrated into the existing mass and energy balance.

The evaluation tool, which was developed in house by AAL engineers, simultaneously solves the mass and energy balance and the 2 phase pressure drop equations. This allows the engineer to predict the pressure profile for each of the operating scenarios. This methodology is outlined in Figure 7.

In a recent bauxite evaluation the optimum blend resulted in a reduction in energy input into high temperature digestion. This reduction in energy resulted in a variation in pressure profile and this results in excessive wear rates and a reduction in energy recovery.

The tool that was developed allows the engineer to alter the pressure profile under a number of different operating scenarios including when flash tanks are bypassed.

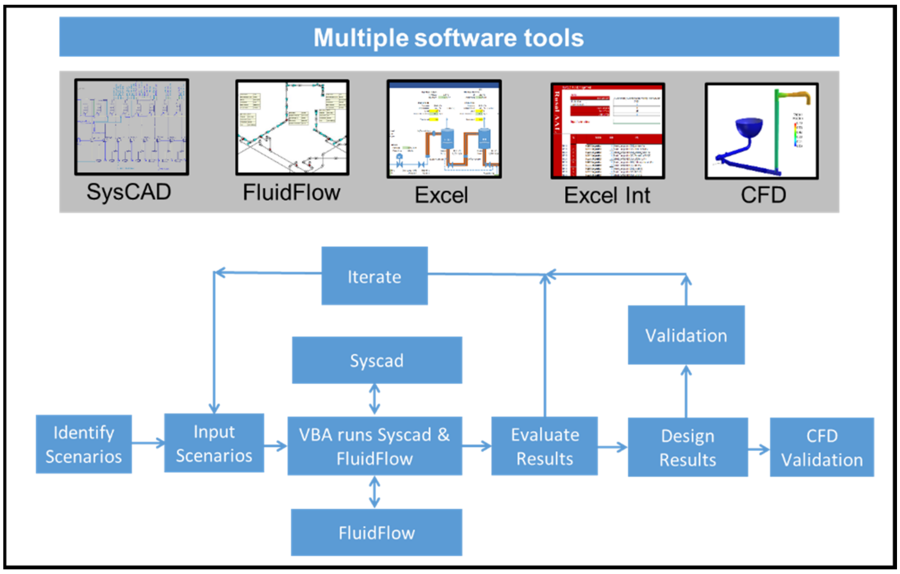


Figure 7. Orifice sizing methodology.

3.7. Organic Balance

The AAL refinery is designed to operate an oxalate-free precipitation circuit and operates under certain process conditions to maintain the same. The balance between oxalate formation and oxalate removal is key to preventing the formation of solid phase oxalate in the precipitation circuit.

The standard tests give the first level of detail required to understand the oxalate balance with a new bauxite. The borehole samples are also used to give an indication of how the organics content will vary in future years.

The results of the test can be incorporated into the validated plant mass and energy balance and required oxalate removal capacity predicted.

3.8. Inorganics Balance

The sulphate, carbonate and chloride impurities are removed from the process as part of desilication reactions that take place in digestion. In Figure 8 the cage structure that is formed is illustrated.

The standard tests provide sufficient information to incorporate these impurities into the plant mass balance. The silica content of the bauxite is also known at this stage and will allow the impact on the refinery to be assessed.

AAL currently operate with a sweetening bauxite with a moderately high silica content. This sweetening bauxite plays a major role in the removal of inorganic impurities and maintaining the balance.

In a recent bauxite evaluation, an alternative low silica sweetening bauxite was investigated. The plant mass balance, which incorporates models developed by Peter Smith of CSIRO (Commonwealth Scientific and Industrial Research Organisation), was used to understand the requirement when operating with this particular bauxite. The modelling results were used to identify the options to process this bauxite and the capital requirements.

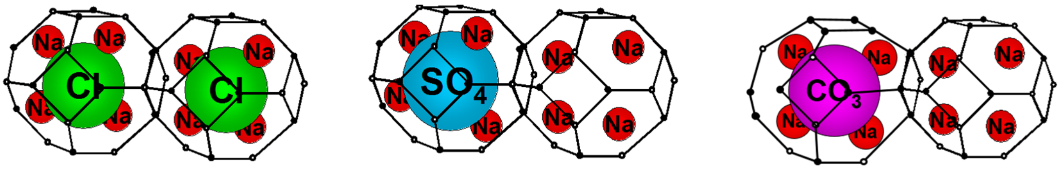


Figure 8. Carbonate, sulphate and chlorides trapped in cage structure.

4. Bauxite Testing Flowchart

The flowchart in Figure 9 below shows the iterative nature of the testing protocol. The standard testing is generally performed on all bauxite samples while the detailed testing will depend on the results of standard tests and capability studies.

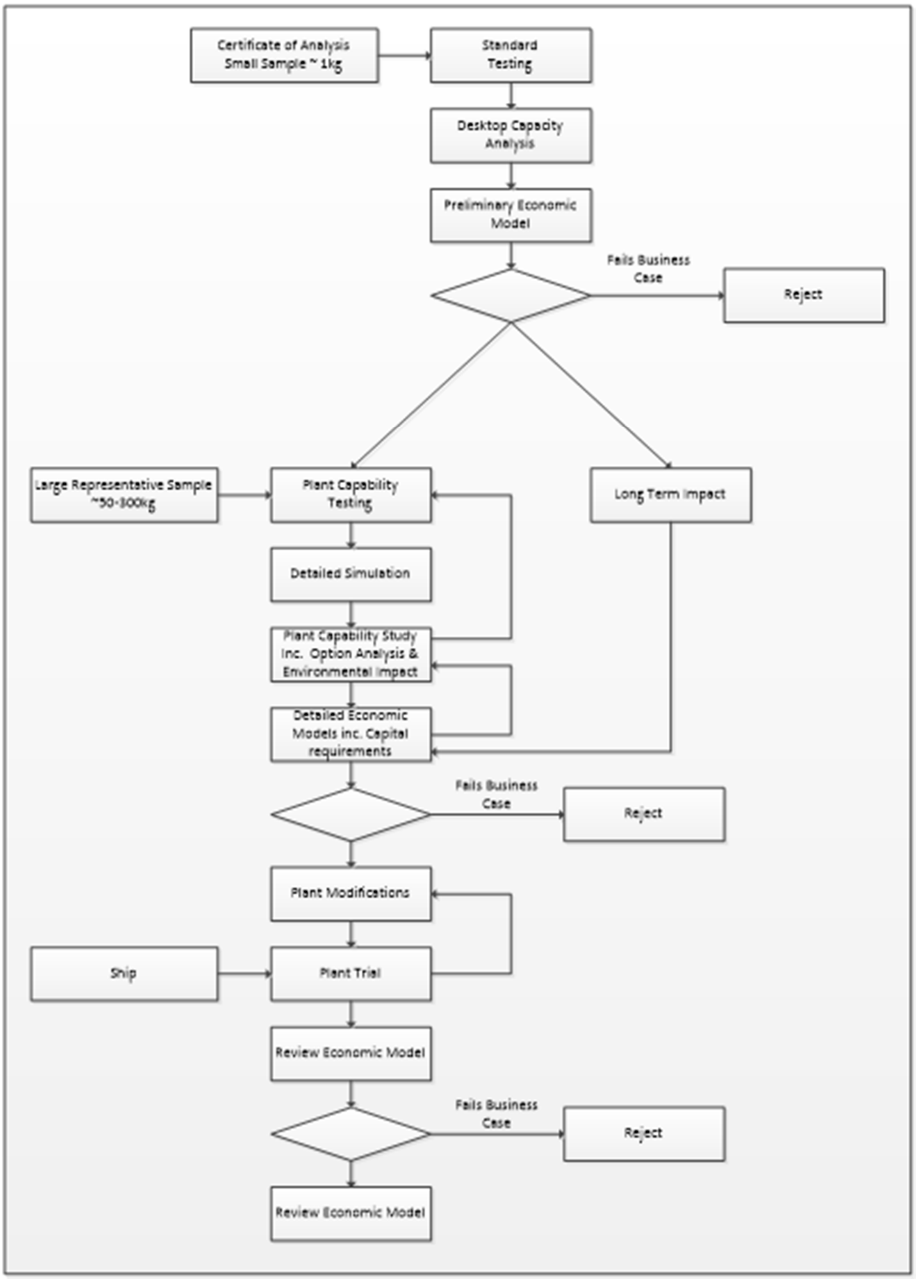


Figure 9. Bauxite Testing Flowchart.

5. Conclusions

The success of the bauxite testing protocol is in the utilization of an experienced multi-functional team capable of accurately simulating and evaluating the impact of a new bauxite supply. At AAL the study is led by the Research Group who are located on site and integrated with the operations team.

Laboratory testing is carried out by the Research laboratory analysts which allows for prompt and correct interpretation of the results and ensures the accuracy. The AAL Research Group also have the expertise onsite to develop the various simulation required for a successful evaluation. An experienced operations team allows the practical feasibility of options to be evaluated.

In addition to this in house capability, AAL utilizes external resources such as the University of Limerick. This ensures that the Research Group remain up to date with testing, modeling and simulation techniques.