Summary and Conclusions

I. Bauxite residue facts

Depending on bauxite quality and process parameters, some 1 to 3 tonne of residue is produced per tonne alumina at a disposal cost of some 2-10 US$/t dry residue. Mining of lower grade bauxites will increase the residue factor. Global annual dry residue production is about 120 Million tonnes, increasing at a rate of about 10% per year.

Only a few percent of the annual residue production is currently being used, mainly in cement & ceramics, in agriculture, as land fill covering or road and embankment construction. The remainder is largely stored (wet or dry) on land and added to the 2.7 billion tonnes of residue that is already stored. The economic feasible distance of residue transportation from refinery to potential users is proportional to the cost of storage and the realised value of the residue.

Residue has a fine particle size (typically 90% < 75 µm, 50% < 10 µm) and hence substantial leaching potential. However, investigations have shown that the residue solids from the Ajka refinery incident in October 2010 don't present a respiratory threat.

Untreated fresh bauxite residue slurry is highly alkaline, typical pH 12.5 to 13. Due to chemical reactions the pH bounces back after initial neutralisation, although weathering over decades reduces pH to ≈ 10. A method was presented to rapidly predict long-term residual alkalinity or acid neutralising capacity using a buffer system.

In addition to compounds, such as desilication product (DSP) and tricalcium aluminate (TCA) that are formed during the Bayer process, the residue contains oxides and minerals that were present in the original bauxite. Due to the extraction of alumina from bauxite, the concentration of many compounds in the residue has roughly doubled. The potential toxicity and usefulness of the compounds depend on their concentration and their mineralogy.

Key residue issues are:

- Potential failure of residue retaining dams, groundwater contamination (older storage areas are normally not lined), dusting at storage areas and sustainability of closed storage areas.
- The large volume of residue that has to be stored leads to the search for large scale utilisation of residue as a feed stock with the ultimate goal of achieving a zero waste solution.

II. Actions for dealing with residue topics – Refineries

Each refinery operates in a unique context, resulting in specific risks, needs and opportunities. Below list presents actions for dealing with bauxite residue.

1) Reduce pH. Where possible, reduce the pH before storage or at the residue storage area by mud farming, the latter enabling atmospheric carbonation. The pH of the residue stored in a deposit should preferably be below 11.5; whilst this is technically feasible, significant costs are normally involved. Neutralisation technologies can include: flue gas desulphurisation, CO_2 capture (injection in residue slurry and/or through mud farming), addition of acid or gypsum, or mixing with sea water or brine.
2) Apply Dry Storage. The Best Available Technology for new residue storage is Dry Storage (hence this is not applicable for legacy and existing storage areas). Dry Storage involves an initial slurry dewatering step, also reducing soluble soda losses with the disposed residue.

   Dewatering technologies are:

   a) Modern flocculants in combination with up-to-date deep thickeners producing underflow slurry with 45-55 wt% moisture.
   b) Vacuum drum filters producing a filter cake with a moisture content of 35-50 wt%.
   c) Filter presses and Hi Bar filters producing a dry filter cake with a moisture content of 24-30 wt%.

Dry Storage technologies are:

a) Dry Stacking:
High density residue slurry (see a. and b. above) is pumped to the storage area and deposited in thin layers. A layer is allowed to consolidate and dry by natural evaporation before successive layers are deposited to form a stack. The smooth surface slope and the angle of deposition allow rainwater to run off. The storage area is under-drained to improve residue consolidation and to avoid water leakage to the underground. Water reclaimed from the storage area is pumped back to the plant or treated and discharged to the environment.

b) Dry Disposal:
Dry filter cake (see c. above) is transported by truck or conveyor belt to the storage area for spreading by earth moving equipment. The storage area is under-drained to avoid water leakage to the underground. Water reclaimed from the storage area is pumped back to the plant or neutralised and discharged to the environment.

Dry Stacking and Dry Disposal on an under-drained storage area result in stable residue deposits with a final moisture content of about 25 wt%.

3) Rehabilitate full Dry Storage areas and treat water before discharge. In the absence of top soil, the addition of gypsum, compost, manure, sewage sludge and fly ash have shown to lower pH and electrical conductivity and to effectively promote vegetation with locally suitable species. Water discharges are collected for further processing as required.

4) Develop methods for utilisation of residue as valuable feed stock, leading to a zero waste solution.

A. There are opportunities to extract valuable components from the residue

Examples are: residual Gibbsite and caustic soda, trace elements such as Sc, Y, etc. These opportunities do not substantially reduce the amount of residue.

B. Make products that incorporate bauxite residue as input material

Pre-treatment, such as dewatering and neutralisation, is needed for certain applications.
Technically possible applications include the use of bauxite residue:

- In agriculture for retention of water and nutrients (possibly pre-treated with for example sea water/brine, gypsum, etc).
- In civil construction such as storage embankment (possibly mixed with other compounds such as fly ash) and road foundations or in landfill site covering.
- In iron and steel metallurgy as component of the agglomerate charge or as a bentonite substitute in pelletizing for iron smelting feed.
- As raw meal input for Portland cement clinker production (3 - 5 wt% bauxite residue).
- As an almost impermeable seal for storage of industrial waste.
- In ceramic applications for roofing tile, pavement tiles and brick production (30-40 wt% bauxite residue) depending on additional materials (firing required).
- After de-watering (and possibly calcination) as pozzolanic material in cement (up to 30 wt% bauxite residue) for concrete applications and end-products (tiles, building blocks etc).
- As a geopolymer for building materials or immobilisation/stabilisation of problematic waste. Adding other materials, such as fly-ash, may be needed as Si- and Al- inputs. (process at room temperature)
- As a component in natural fibre reinforced polymer composites for the fabrication of building products (such as doors, tiles, partition walls etc).
- As a catalyst for iron/iron oxide catalyzed reactions e.g. hydrocarbon cracking and production of carbon nanotubes
- As a sorbent and coagulant for treatment of waste streams such as acidic waste, mining waste communal waste, CO_2 sequestration, etc.

Some of the above technologies are industrially mature, whilst others are emerging technologies.

III. Recommendations

1) The aluminium industry should be more active in informing the outside world about the positive qualities and opportunities of bauxite residue, such as its long lasting acid neutralising capacity, its pozzolanic and agricultural features and the occurrence of valuable trace elements.
2) The aluminium industry should be more pro-active in clarifying recurring issues that create a negative image of bauxite residue by promoting related scientific research. Whilst untreated highly caustic bauxite residue slurry is harmful, there is no evidence that dry bauxite residue is hazardous although its non-hazardous nature must be scientifically proven on a case by case basis. Potential exposure to bauxite residue differs from site to site and realistic studies of population exposure should be carried out, compared with reference conditions to which the population is normally exposed and the results should be made public.
3) The aluminium industry should involve potential users, technology suppliers, relevant R&D institutions and government agencies to seek opportunities to work together in the further development of specific applications for (large scale) utilisation of bauxite residue. This applies both to new technologies as well as technologies that are currently being developed. Representatives of producers can join forces to develop pre-competitive projects.
4) The round table session did not reach a shared conclusion regarding the role of government regulation to solve the issues related to bauxite residue. Positions ranged from “the industry is in the best position to address bauxite residue issues” to “without more stringent legislation progress will be insignificant”.