The Toowong Process: Developing a Viable Solution for Copper's Dirty Problem

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Outline

- The context – “industry need”
- The approach – “the Core way”
- The development path – “timeline”
- The results – “success”
- The future – “next steps”

Arsenic in Global Concentrates

- Increasing concentration of arsenic in mines and concentrates feeding copper smelters
- Proximity of copper smelting to densely populated areas particularly in developing nations
- Growing costs of acceptable and safe handling, storage and disposal of arsenic
- Growing environmental concerns about arsenic toxicity and transference of liability to smelters

Arsenic in Global Concentrates cont.

- Apparent surplus of arsenic trioxide production and build-up of stockpiles
- Variation in national and site environmental limits for arsenic limits
- Normalisation of limits across developing nations defaulting to more stringent standards and requirements demanded in the West and other first world Asian countries

Current Industry Response

- Increase penalties for arsenic and other impurities
  - But this has not been as aggressive as required to change the miners approach
- Apply maximum impurity thresholds over which concentrates will not be accepted or treated
  - China now 0.5% As limit on base metal concentrates
  - Japan lower 0.3% As limit on base metal concentrates

Current Solutions

- Blend copper concentrates to meet target arsenic levels for smelters. Smelters deal with arsenic.
- Roast arsenic rich concentrates ahead of smelting the copper calcine material. Treat arsenic dusts.
- Copper metal production using leaching-SX-EW. Arsenic is fixed in the process and disposed in dedicated tailings facilities.

Alternative Solution

- Unlocking Alkaline Leaching Chemistry
  - Started development work in 2009 following review of conventional ASL approach
  - Extensive batch and continuous locked cycle testing
  - Tested a range of copper (up to 3.3% As) and nickel concentrates (0.8% As)
  - Leaches Enargite, Tennantite, Tetrahedrite, Gersdorffite
  - Recently tested other Antimony and Arsenic minerals successfully

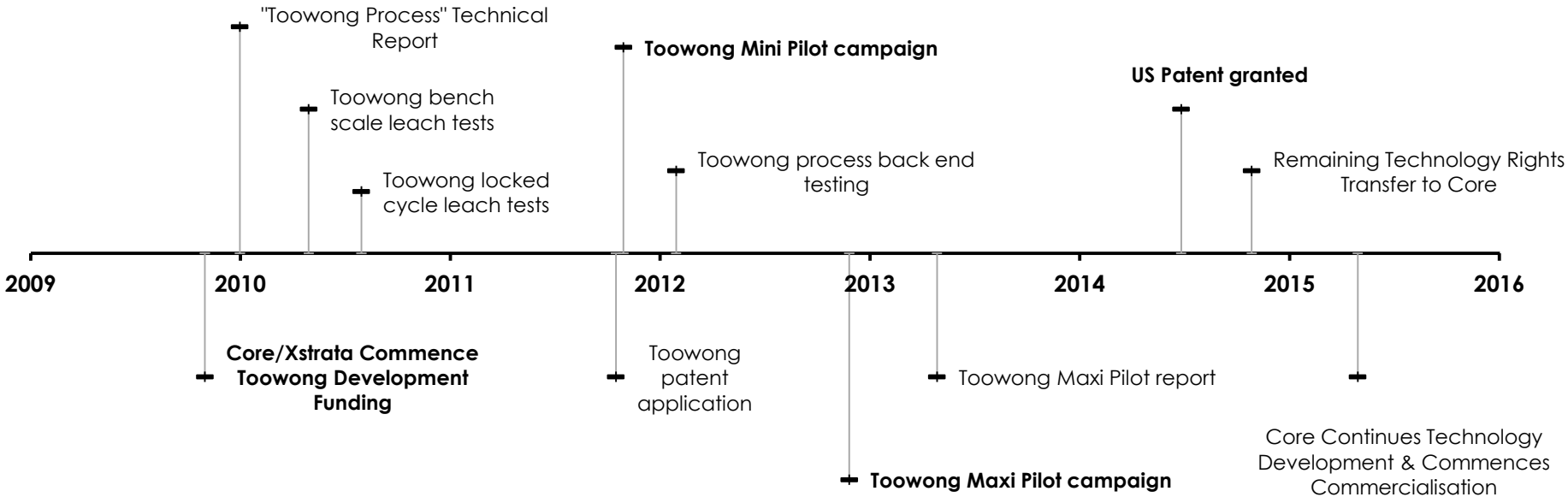
From Chemistry to Process

- Key milestones on the development path
  - Review previous patents and work
  - Understand reaction chemistry
    - Strong analytical chemistry capability, sulphur chemistry, arsenic speciation and caustic soda measurement and control
  - Focus on process model and ultimate process control
    - Develop process model early to understand recycles
    - Develop analytical methods early to provide fast assays for the real world plant
  - Focus on techno-economic studies
    - Review unit operation practicalities and economics early

From Process to Pilot (and Beyond)

- Core's approach
  - Process driven by minerals and chemistry
  - Robust unit operation testing in batch and locked cycle mode ahead of piloting
  - Variability testing ahead of pilot – "no surprises"
  - Strong/timely analytical support for pilot
  - Smaller pilots, driven by industry and smarts
  - Process modelling, including dynamic modelling
  - Staged approach, maximum de-risking at each stage
  - "One shot", no second chances to provide client with deliverables

Toowong Process Development



Mini Pilot Plant - Overview

- Successfully completed in November 2011
- Primary Leach Circuit Tested over 4 weeks, to confirm leach chemistry
- 15 kg/day Copper Concentrate treated (10ml/min slurry feed)

Results

- Leach Feed 1.1% As
- Leach Residue 0.05 to 0.10% As
- 90 to 95% Arsenic removed

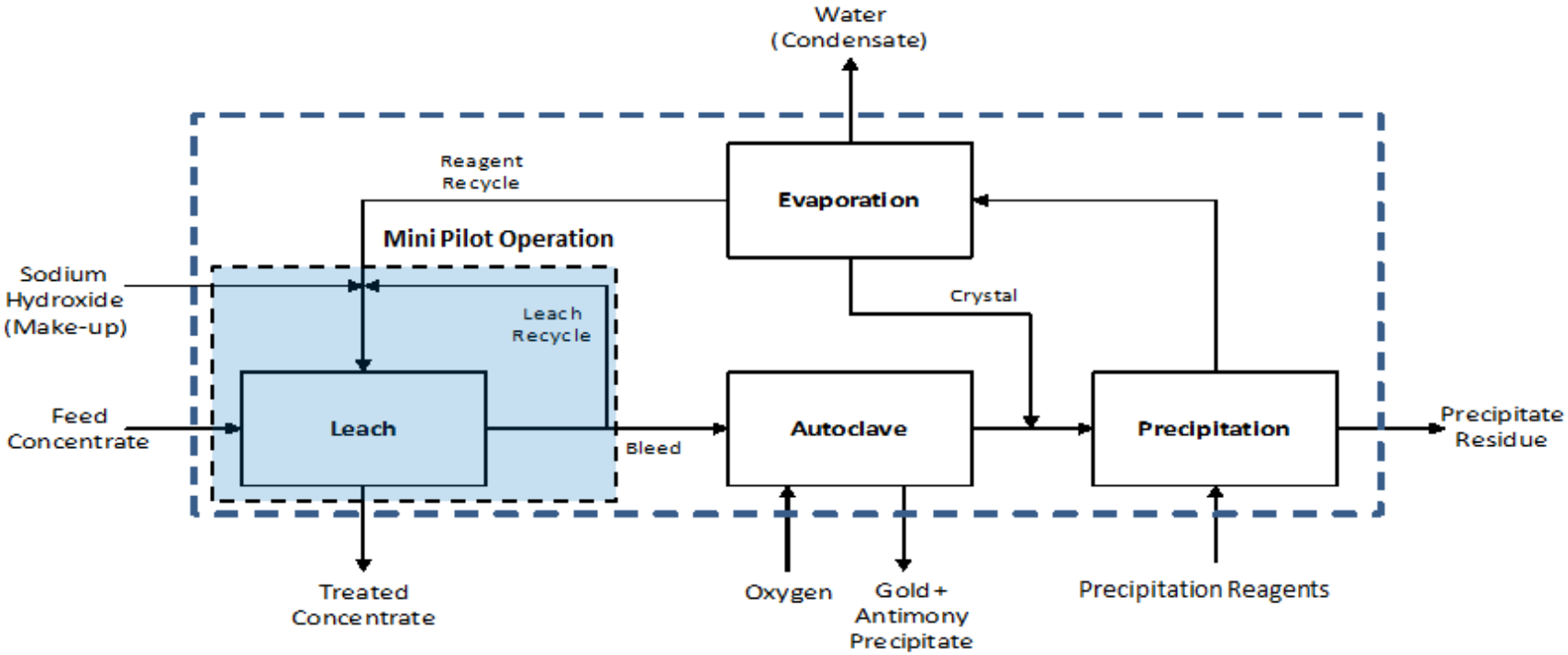
Mini Pilot Plant - Objectives

Objectives:

- Confirm Leach Operation without Sulphide Addition ✓
- Confirm Caustic Consumption ✓
- Leach Residue Stability and Filterability ✓
- Provide Samples for Further Downstream Testwork ✓

Met All Objectives

Mini Pilot Plant - Flowsheet

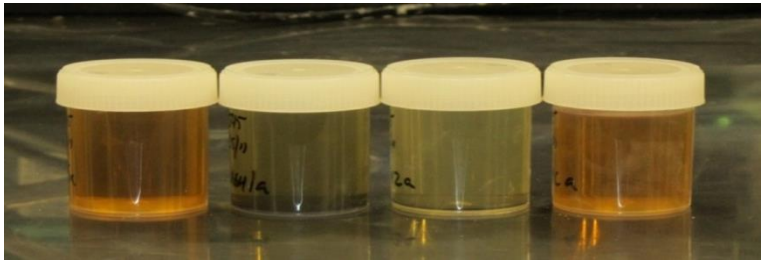


Mini Pilot Plant - Operation

November 2011

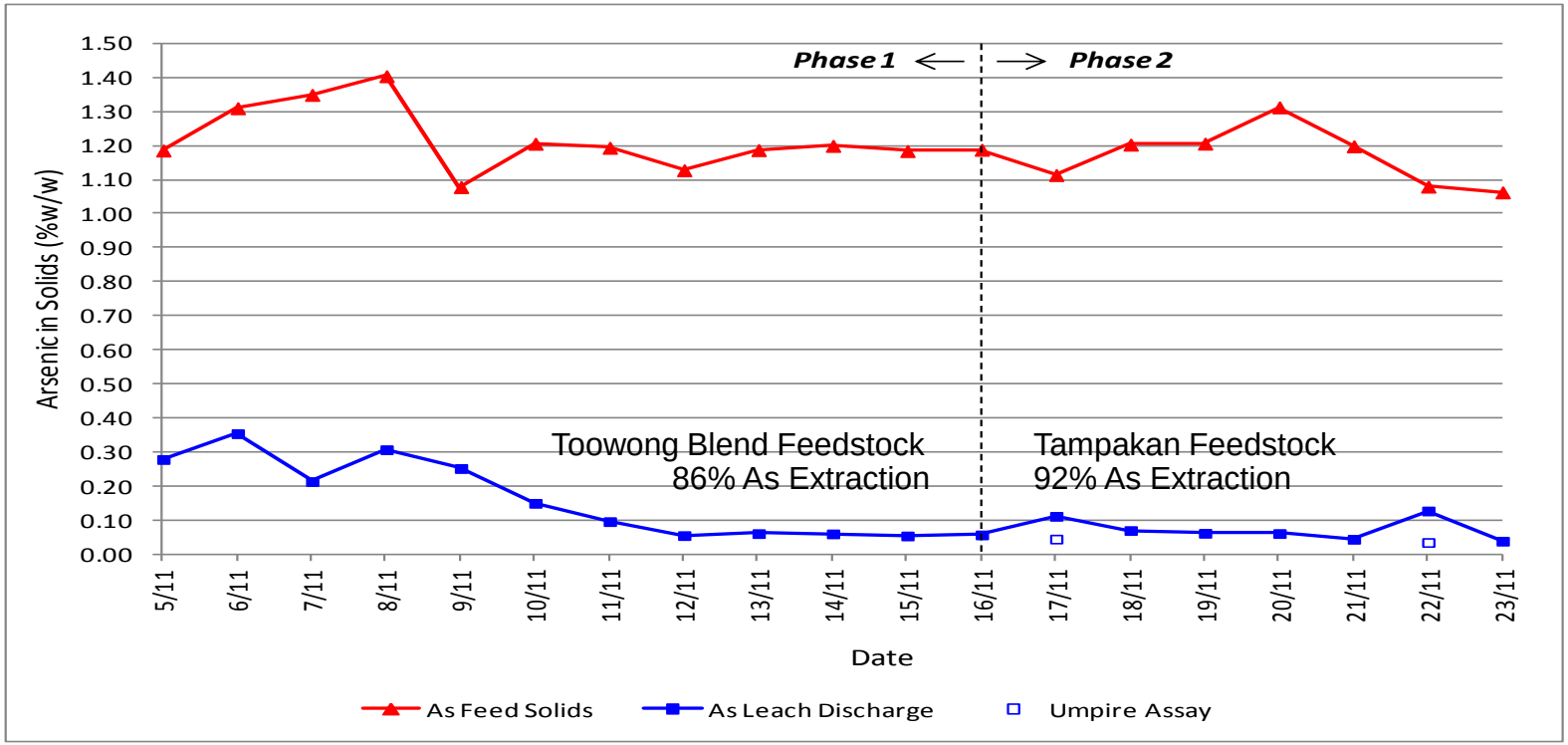
Leach Circuit

Leach Residue Filtration



Leach Solutions

Mini Pilot Plant - Results



Maxi Pilot Plant - Overview

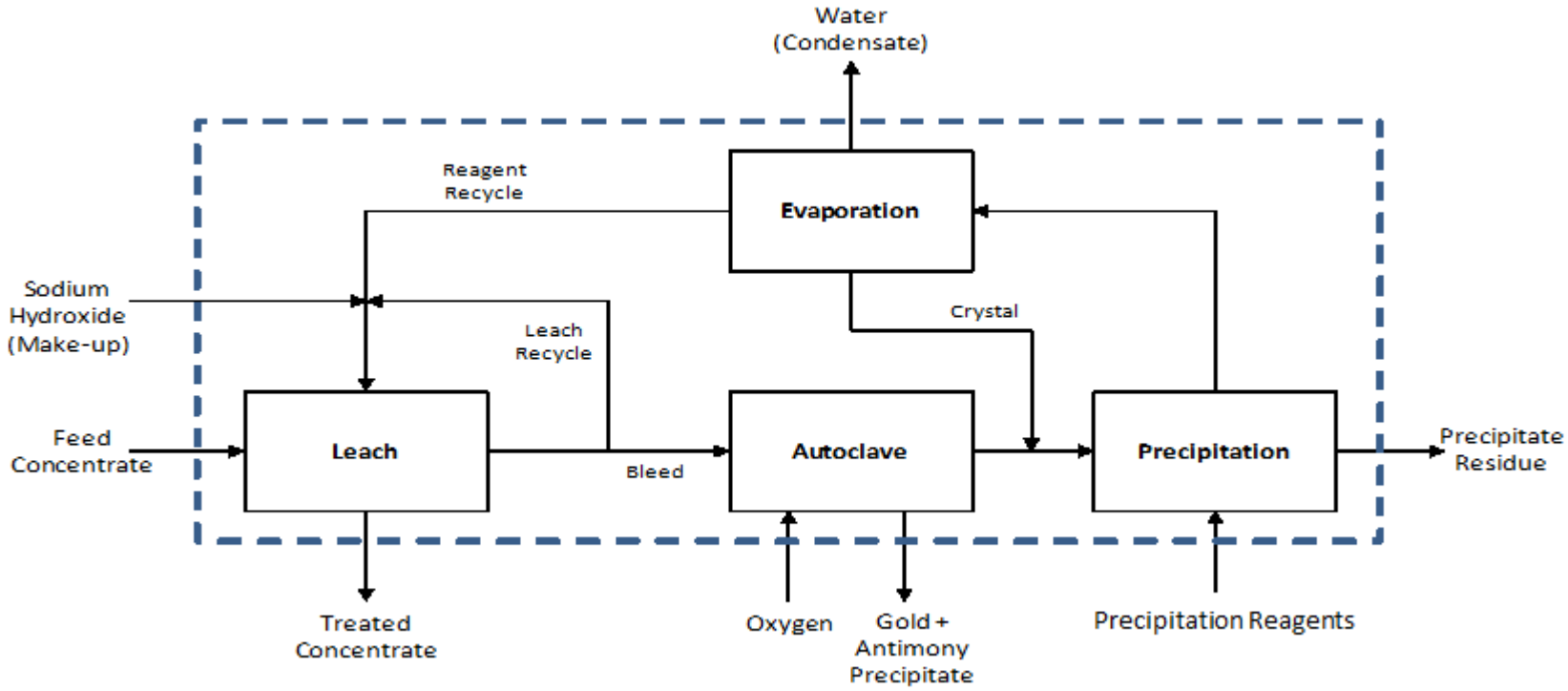
- Ran from 19th Nov - 21st Dec 2012
- Major $4.5m integrated pilot campaign employing over 60 personnel
- ~53 kg/day Copper Concentrate treated
  - 11 days, Toowong Blend
  - 23 days, Tampakan Composite

Maxi Pilot Plant - Objectives

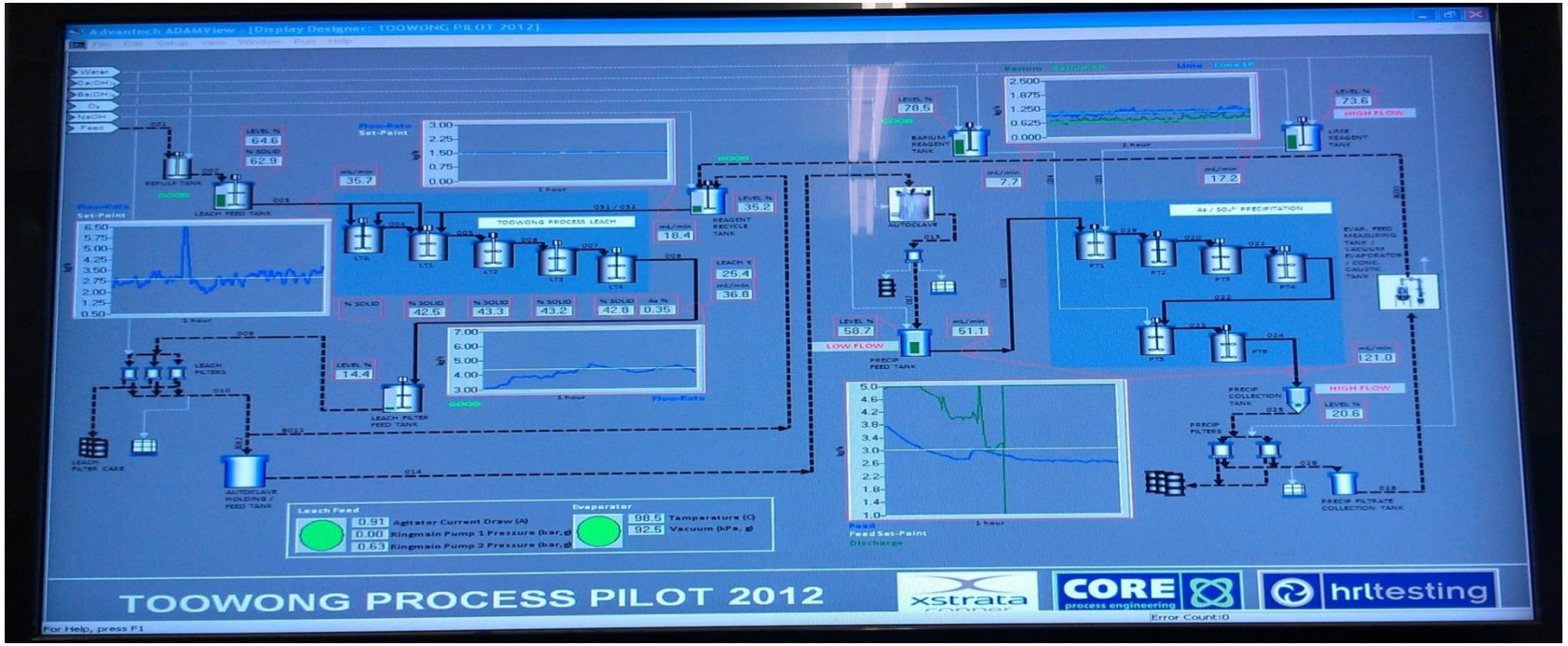
Objectives:

- Checking for no fatal flaws in the process
  - Due to operation time ✓
  - Due to integration of leach and recycle loops ✓
- Achieve the following technical targets
  - <0.1 %w/w As in treated concentrate ✓
  - Demonstrate that arsenic and sulphate can be removed to a residue ✓
  - Demonstrate that any gold solubilised in the leach can be recovered ✓
  - Demonstrate impurity accumulation in leach residue did not impact on smelter acceptability ✓
- Generate arsenic precipitate for future arsenic fixation work ✓
- Generate design specifications to support future capital and operating cost studies ✓

Maxi Pilot Plant - Flowsheet



Maxi Pilot Plant - Operation



Live Process Monitoring (Temperature, Pressure, Mass Flow, Tank Level, Current Draw)

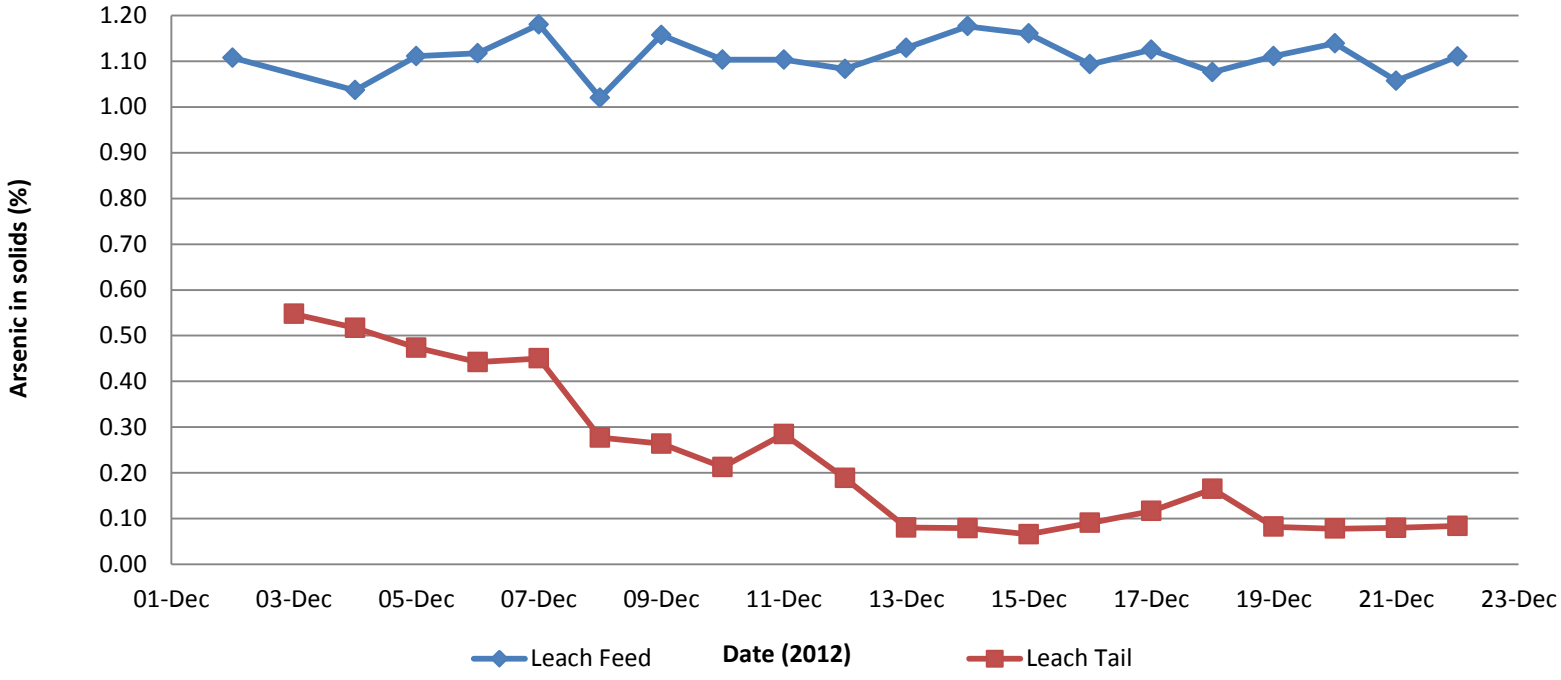
Maxi Pilot Plant - Results

- Key results:

		Toowong Blend			Tampakan Concentrate		
	Units	Feed	Product	Extracted	Feed	Product	Extracted
As	%	1.11	0.11	90%	1.12	0.09	92%
Sb	%	0.06	0.01	78%	0.08	0.01	85%
Si	%	3.15	2.63	18%	4.70	3.36	28%
Au	g/t	2.42	2.12	12%	7.54	7.53	0%

  - 0.09% arsenic in treated concentrate over the final 10 days of testing Tampakan concentrate (average)
  - >90% arsenic extraction over the final 10 days of testing (average)
  - Minimal gold extraction

Maxi Pilot Plant - Results



Maxi Pilot Plant - Results

Reagent Requirements:

Reagent	Units	Pilot Additions
Sodium Hydroxide (NaOH)	kg/t feed	11 - 13
Sodium Sulphide ($Na_2S.xH_2O$)	kg/t feed	0 - 15
Precipitation Reagents	kg/t feed	40 - 60

Funding and IP

- Core Resources and Xstrata Funded Development
- Provisional Patent lodged in October 2011
- Core Resources now owns IP, rights reverted to Core in November 2014
- USA patent granted in July 2014
- AusIndustry “Accelerating Commercialisation” grant awarded in April 2016
- Core continues to fund patent protection activities

Benefits of Toowong Process

Key Process Differences

Toowong	ASL
Nil/Low Sulphide Addition	High Sulphide Addition
0 to 15 kg/t	100 to 150 kg/t
0 to US$7.5/t conc	US$50 to $75/t conc
Low Poly Sulphides	High Poly Sulphides
Low Sulphate Bleed	High Sulphate Bleed
Low Gold Dissolution	High Gold Dissolution

Next Steps for the Technology

- Appoint Delivery Partner for the Technology
- Accelerate Commercialisation Activities with Grant Support
  - Engineering studies and further development work
- Core is now ready to grant an initial Licence to an early adopter of the Toowong Process and assist to advance the development of the Project
  - Could be an Antimony Project or Copper Project (to remove arsenic)

Next Steps for the Technology cont.

- Core will also commit to contributing technical assistance to the Project including:
  - Considerable proprietary IP and know-how relating to the analytical techniques, reagent and metal recovery as well as residue stabilisation process
  - Extensive hands-on experience in the design, construction, commissioning and operations of complex mining projects across the Core Group
  - Access to its metallurgical laboratory and other technical resources

Acknowledgements

- Core would like thanks its client and dedicated staff, that were involved in the development of the Toowong Process from testwork to piloting to achieving recognition in the recent Australian Innovation awards.
- Core would also like to thank AusIndustry for recently providing an accelerating commercialisation grant to support the Toowong Process commercialisation.

Questions?