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**ATMOSPHERIC LEACHING OF A SAPROLYTIC NICKEL LATERITE  
ORE IN CHLORIDE SOLUTIONS**

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Thesis presented in partial fulfilment of the requirements  
For the degree of Master of Science in Hydrometallurgical Engineering  
In the Department of Chemical Engineering  
UNIVERSITY OF CAPE TOWN  
May 2008

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## Abstract

# ATMOSPHERIC LEACHING OF A SAPROLYTIC NICKEL LATERITE ORE IN CHLORIDE SOLUTIONS

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A hydrometallurgical process using chloride solutions for recovery of nickel from a saprolytic laterite ore was proposed by Jaguar Nickel Inc. The process claimed selective leaching of nickel over iron and magnesium, the principal impurity elements accompanying nickel in laterite ores. The selectivity was claimed to be a consequence of increased hydrogen ion activity, allowing for economic acid consumption and limited destruction of the laterite lattice. In this study the claims of the Atmospheric Chloride Acid Leach Process (hereafter referred to as the Jaguar Process) were investigated on a saprolytic laterite ore. Atmospheric leaching tests were conducted in order to test whether the claims hold for this different laterite ore. Manipulation of the hydrogen ion activity was tested using a thermodynamic model to predict HCl activity. The acid activity in the test solutions was estimated by a thermodynamic model prediction; however manipulation of the acid activity was shown not to affect nickel selectivity. In fact, the initial rate of nickel leaching was a stronger function of the acid concentration. The Jaguar Process conditions did not yield selective leaching at typical operating concentrations even under conditions of increased acid activity. Nickel contained in the serpentine mineral phase appeared to leach more quickly than the nickel contained in the iron-hydroxide mineral phase. Initial leaching rates were very fast and a mixed chemical reaction and diffusion mechanism may be controlling. Leaching was not well described by shrinking particle models and an empirical model was therefore developed.

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# ATMOSPHERIC LEACHING OF A SAPROLYTIC NICKEL LATERITE ORE IN CHLORIDE SOLUTIONS

## 1.0 Introduction

### 1.1 Nickel Production Challenges

Nickel (Ni) is an important commodity, primarily as a component of stainless steel which accounts for 67% of the volume of Ni used annually [1,2]. The 2003 Mining Annual Review for nickel [1] outlined slow growth in the global economy for 2003, but despite this, reported a 6.4% increase in world nickel demand and a 7% increase in stainless steel production. The trend of increasing stainless steel production has remained (related to industrial production and global economic growth), although secondary nickel demand through scrap markets, nickel hydride batteries, alloys and super alloys is strong. The industry is seen as a volatile one [2] and a nickel shortfall was experienced in the 1960s [3], but in the late 1990s the industry was stable with several new producers coming on-line, notably the Australian laterite projects, Bulong, Murrin Murrin and Cawse, and the high grade Voisey's Bay sulfide deposit in Canada soon to be exploited. However, new production has failed to meet committed capacity; and politics, legislation and social issues have led to delays in the Voisey's Bay development. The nickel industry was facing a significant challenge to fast-track new producers or expansions in order to avoid a nickel shortfall.

Until recently, nickel was sourced predominantly from sulfide deposits which are currently more cost-effective to process than oxide deposits (so-called laterites). However, due to the depletion of sulfide reserves, lateritic nickel deposits now constitute the largest known terrestrial source of nickel [4, 5, 6], and consequently much work is being done to improve laterite processing.

### 1.2 Nickel Laterite Ores

Nickel is found either in sulfide deposits or oxide deposits. The nickel oxide deposits are referred to as laterites and can generally be described as near-surface deposits of oxide material consisting of heterogeneous mixtures of nickeliferous hydrated iron oxides, clays and magnesium silicates formed by weathering on a geological timescale or 'lateritisation' of olivines and serpentines. The term *laterite* is derived from the Latin word for *brick earth* [7].

A common rock form of much of the earth's crust is peridotite, which consists mainly of olivine. Olivines are iron and magnesium silicates which commonly have other elements substituted into the lattice such as nickel and cobalt. During the slow weathering of the olivines and serpentines, the more soluble components of the rock are taken into solution by ground water and redeposited at greater depths which results in zones of nickel enrichment up to 20 times that of the original rock. The rock above is enriched with the less-soluble components, such as aluminium, chromium and iron. Figure 1-1 shows concentration profiles of metals in an idealised laterite deposit. In reality, laterites are poorly crystalline and extremely complex mineralogically, and can be further classified according to the general mineralogical characteristics of four zones.

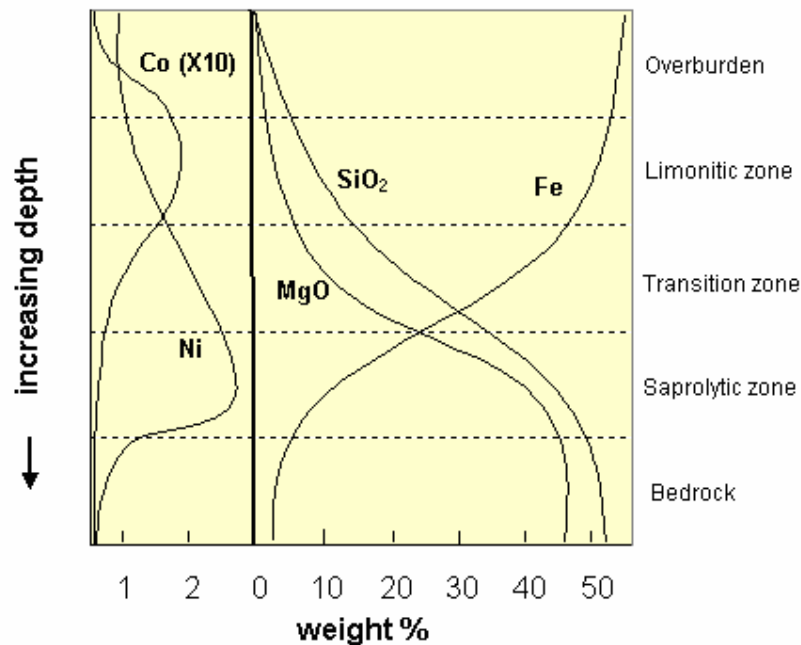


Figure 1-1: Chemical concentration profile at different depths in an idealised laterite deposit (after Berezowsky [4] and Monhemius [8])

The depleted top layer, or overburden, consists mainly of barren hydrated iron oxides. The limonitic zone is comprised mainly of goethite with some nickel associated with the hydrated iron hydroxides. The transition zone is a mixture of the limonitic-type ore, with intermediate values of nickel, iron and magnesium, and the deeper saprophytic zone which consists mainly of magnesium silicates with high levels of nickel enrichment. The limonitic zone is more mineralogically and chemically homogeneous than the saprophytic ore and is also of finer particle size (at least 50%  $-10\ \mu\text{m}$ ) [3]. Details of laterite characteristics have been presented in many studies [4, 8-13].

Ores are often blended to yield roughly constant nickel grade, however even blended laterite ores of constant chemical composition can lead to significant variations in processing behaviour, as was demonstrated by Canterford [14] in his study of samples of blended feed to the Yabula refinery (Queensland, Australia). This variation in behaviour is directly related to mineralogical variations. The feed at the Yabula plant contains nickel in almost all of the minerals making up the ore, but the nickel content of each mineral varies widely. It was found that nickel was more readily extracted from silicate (saprolyte) ores than from limonitic ores and those samples with lower iron content generally gave scattered leaching results due to the different reactivities of the nickel-bearing minerals. Thus even with the same chemical composition, there are differences in behaviour. This will be true to a greater or lesser extent for all laterite ores.

This study focuses on one laterite sample obtained from Barro Alto in South America. The sample is categorised on site as “Western Type Ore (WTO) acido” which is a saprolytic ore.

### **1.3 Laterite Ore Processing**

The primary hurdle in processing laterite ores is that no specific nickel-bearing mineral exists which can be concentrated by existing technologies such as flotation, magnetic separation or gravity concentration. The recovery of lateritic nickel takes place via two general routes: a pyrometallurgical route (smelting) or a hydrometallurgical route (leaching) or sometimes a combination of these. The most important factors in economic laterite processing are acid consumption and energy requirements. Pyrometallurgical processing is most appropriate when applied to saprolytic ores due to the presence of ideal slag-forming material ( $\text{SiO}_2$  and  $\text{MgO}$ ); low iron (allowing for realistic energy usage); and high nickel grade. Hydrometallurgical processing is more suited to material with a low Mg/Fe ratio (increasing magnesium increases acid consumption) and consequently low nickel grade. Although many hydrometallurgical processes exist for the treatment of laterites, all with advantages and disadvantages, no one standard process has been adopted. This is a reflection on the unique mineralogical qualities of the oxide ore bodies.

The core of hydrometallurgical processes for laterite treatment is the leaching unit operation. Excellent metal recovery is achievable through the application of a simple atmospheric leach; however laterite ores are comprised mainly of magnesium and iron silicates and, once in the leach solution, selective recovery of nickel then poses a problem. Due to its presence in so many minerals, iron management is well developed in hydrometallurgy and pressure leaching can be used to precipitate iron. Magnesium, however, is less easily managed as increased magnesium leaching leads to excessive consumption of acid, rendering many processes uneconomical. Current hydrometallurgical processes in use or proposed have

been developed to minimise the negative effect of these two major gangue elements. Section 2.1 outlines and discusses selected hydrometallurgical laterite processes.

#### 1.4 Hydrochloric Acid as a Lixiviant

Leaching is commonly carried out in sulfuric acid solutions. However, chloride solutions can be advantageous due to:

- weaker association of the proton with chloride ions compared to sulfate ions which results in a more aggressive leaching medium;
- increased leaching kinetics resulting in smaller leaching vessels (for a fixed ore input) and lower operating temperatures making leaching under pressure unnecessary;
- operation under a wide range of oxidising conditions and acidity.

Disadvantages of chloride solutions which have stifled commercialisation of chloride-based processes are:

- the corrosive nature of the solutions and the corresponding materials of construction constraints. However, advances have been made in this regard and corrosive chloride solutions can now be safely handled so that their advantages may be exploited;
- the inability to use limestone as a neutralising agent [10] and
- the difficulty with economically recycling HCl; some advances have been made with metal chloride pyrohydrolysis [10], but this route remains energy-intensive and therefore expensive to operate.

A large number of chloride leaching processes have been investigated and developed, most of them limited to laboratory scale. The advantages of chloride systems, mentioned above, result from the following solution chemical properties:

- Stable *metal chloro-complex* formation, the stability of which is reflected in thermodynamic stability constants. For most metals, the chloro-complex is more stable than the corresponding sulfate complex [15], which could be indicative of the need for milder leaching conditions and subsequently easier metal separations.
- Increased *metal chloride solubilities*. All metal chlorides, except AgCl, are more soluble than their corresponding metal sulfates and this property can lead to more efficient separations. However, if the concentration of free chloride in a solution is increased, metal chloro-complex solubility decreases due to the common ion effect. This is used in the Falconbridge Matte Leach Process whereby  $\text{NiCl}_2 \cdot 2\text{H}_2\text{O}$  is precipitated by the addition of HCl to the solution [16].

- Changed *redox properties* of some metal ions in chloride solutions. Chlorine can oxidise all metals in a chloride environment. This forms the basis of platinum group metal processing. Another application is the use of Cu(II) as an oxidising agent in strong chloride solutions. The high stability of Cu(I) affects the Cu chemistry and Cu(II) becomes a relatively strong oxidising agent, comparable to ferric ion [16].

The key parameter linked to the above is the species activity. Activity coefficients are generally not unity in hydrometallurgical systems. Except for very dilute (ideal) solutions, the activities of ions and salts differ significantly from their readily measurable concentrations. An example of this effect in chloride solutions is shown in Figure 1-2, from which it can be seen that the proton activity is enhanced at increased acid concentration in the presence of added  $MgCl_2$ . Increasing the temperature dampens this effect to a small degree. From the figure, a 2 M HCl solution experiences an approximate three times increase in proton activity on addition of 1 M  $MgCl_2$ .

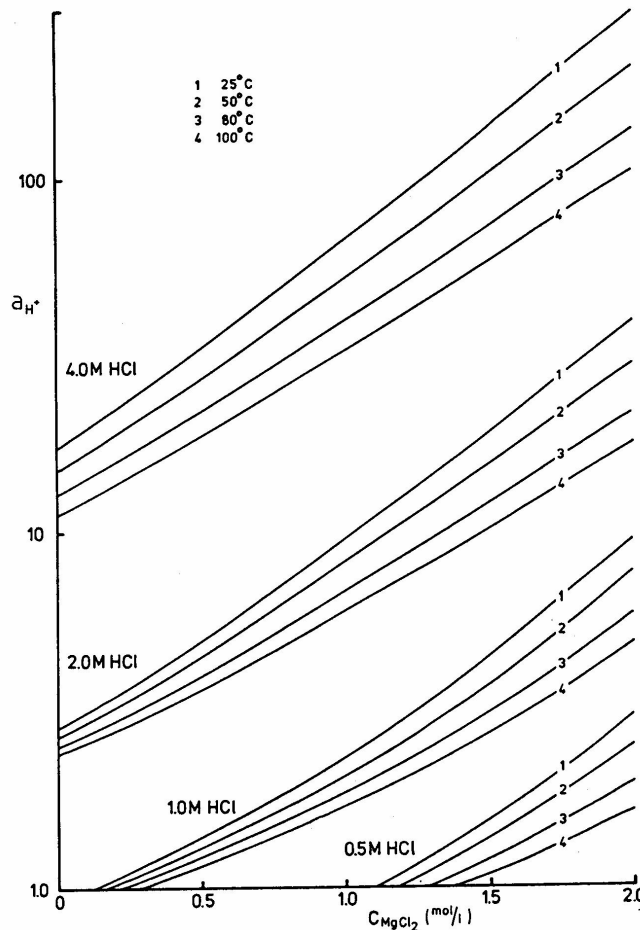


Figure 1-2: Deviation of proton activity from unity for solutions of HCl and  $MgCl_2$  (Jansz [17])

In concentrated solutions, thermodynamic properties are difficult to predict. However, quantifying non-ideality is important as it governs chemical species equilibria and activities.

Activity coefficients vary from unity due to the interaction of solution species with each other and the solvent. Thus if one has a knowledge of the species activity, one can anticipate which species will predominate and how such species would influence kinetic processes, for example, leaching.

Activity coefficient models allow for the prediction of species activity in real solutions. The classical models for concentrated solutions are the Pitzer [18] and Meissner [19] models. The former is based on an expression for the excess Gibbs energy of the solution, which consists of an extended Debye-Hückel term and virial expansion terms, whilst the Meissner model is a simpler (less parameterised) empirical model based on phenomenological ionic strength dependence of the activity coefficient. The measurement and prediction of proton activity is discussed further in Section 2.2.

One laterite process, using hydrochloric acid, was proposed by (what was then known as) Jaguar Nickel Inc. [20, 21]. In context with other available technologies for nickel recovery from laterite ores, the Jaguar Process showed potential advantages worthy of further investigation.

The Jaguar Process utilised an atmospheric leach in HCl and  $MgCl_2$  which Jaguar Nickel claimed offered a certain amount of selectivity between nickel and the major gangue elements, magnesium and iron. According to Jaguar Nickel, the selectivity is based on the thermodynamic properties of mixtures of HCl and  $MgCl_2$ .  $MgCl_2$  has a high hydration number, and due to the resultant reduced water activity, magnesium leaching is claimed to be suppressed while nickel, which complexes more easily in solution, is leached. It is proposed that iron in solution is hydrolysed due to the low water activity, provided chloride levels are maintained low enough to avoid  $FeCl_4^-$  formation. A further claimed advantage is reduced acid consumption resulting from the selective leaching, which comes as a consequence of the use of strong brines to leach the laterite (as illustrated in Figure 1-2). [20, 21]

## **1.5 Scope and Objectives of this Study**

Anglo American plc is involved in the development of alternative processing technologies at its research facility, Anglo Research (AR), a division of Anglo Operations Limited. The Technology Business Unit at AR was tasked to review alternative technologies for the beneficiation of nickel laterites; this project initially involved some scouting test work, with the overall objective to identify/develop an attractive alternative technology for treating laterite ores. This study forms part of this larger undertaking.

The Jaguar Process was one of the processes under investigation by AR and the interesting solution chemistry effects appeared to offer significant process advantages. However, testwork information published was less than thorough and it was deemed necessary to investigate the nature of leach solutions used in the Jaguar Process in order to further judge the process claims.

This study focussed on the selectivity claim of the Jaguar Process leach and whether it could be repeated. Due to the complexity of the solution characteristics, this study also aimed at understanding the reasons behind the observed effects. This investigation comprised of two objectives:

- **Objective 1:** To establish if the selectivity achieved in the Jaguar Process was repeatable on a different laterite ore.
- **Objective 2:** To investigate fundamental reasons for the observed leaching behaviour.

Objective 1 was investigated using atmospheric batch leach tests, limited to one type of laterite ore. Various solution conditions were tested and the resultant selectivity calculated.

Objective 2 was investigated in three focus areas:

- solution thermodynamics
- laterite mineralogy
- leaching kinetics

Jaguar Nickel used the thermodynamic properties of strong brine solutions to explain their selective Ni leaching – manipulation of the water and hydrogen ion activities was seen as key, although not explicitly measured, and the hydration number of  $\text{MgCl}_2$  was also seen as a key solution property. The Jaguar Process included manipulation of Fe precipitation in the leach, counter-current leaching, and other aspects not considered in this study. In this study, hydrogen ion activity is investigated in order to obtain actual (real) *pH values* for the solution conditions tested. In order to obtain accurate measurements, a solution chemistry model, the Pitzer-Hydration (P-H) model, was developed at AR [22] to, besides thermodynamics, incorporate hydration theory. This study makes use of the P-H Model but does not attempt to evaluate the derivation thereof or review the supporting theory.

*A mineralogical analysis* was included in order to establish if leaching of different mineral phases was important.

A preliminary *kinetic study* was conducted to establish what factors affect Ni leaching and whether hydrogen ion activity or concentration has a greater effect.

These three focus areas contribute to a more fundamental understanding of the leaching system, but also raised many areas for further study and by no means constitute an exhaustive study – the aim of this study was to investigate repeatability of the Jaguar Process and to look at the system in more detail than had been done before.

Downstream purification and separation of nickel and cobalt from the leach liquor is achieved using unit operations such as solvent extraction and precipitation. Flett [23] has reviewed the chemistry of Ni-Co separation and concludes that solvent extraction is the most advantageous and many studies on solvent extraction in laterite processing have been done [24-28]. Unit operations which incorporate reagent (acid) recycle are important for economic viability. Although downstream processing forms a crucial part of the overall process development, it does not form part of the current investigation.

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## 2.0 Literature Review

The leaching processes developed for treating laterite ores, numerous and mostly ore-dependent, are briefly examined first. It is against this background of the search for more cost-effective methods that the Jaguar Process was developed and is reviewed here. What follows is a look at solution thermodynamics and the tools available for evaluating the species activity of interest. Other studies linking species activities to leaching behaviour are presented as well as an introduction to kinetic modelling methods.

### 2.1 Laterite Processing

By the late 1960s it was recognised that sulfide nickel deposits were being depleted, giving oxide deposits greater attention as sources of nickel [4, 6, 13, 29]. Many hydrometallurgical routes, sometimes combined with pre-roasting were developed and selected ones are reviewed here. Boldt and Queneau [7] have reviewed these and other processing routes in considerable detail. Kerfoot and Weir [30] reviewed the extractive metallurgy of nickel (and cobalt) as did Han and Meng [31] who included leaching behaviour. For the 1996 Nickel Commodity Meeting, Anthony and Flett [32] summarised the state of nickel extractive metallurgy with Berezowsky [4] focussing on laterite processing. Several other reviews of laterite processing have been published [6, 8, 9, 33].

Smelting of laterite ores produces either ferronickel alloy or matte which can be subsequently processed, but this is best suited to saprolytic-type ores due to the presence of suitable slag-forming minerals, such as silica, making up 50% of the saprolytic laterites. A pyrometallurgical route is favoured for ores of high nickel grade, low iron grade and where low cost electrical power is available [34]. Pyrometallurgical processes are not considered further in this study and, consequently, the leaching routes covered apply mainly to limonitic laterites.

#### 2.1.1. Laterite leaching with ammonia and sulfuric acid

Hydrometallurgical laterite processing was developed for the limonitic ores that were too high in iron and too low in nickel to be economically smelted to ferronickel.

The Caron process, developed in the 1920s and in operation at Nicaro, Cuba since the 1940s, involves pre-roasting of the limonitic ore to reduce the nickel and cobalt into the metallic state. Subsequent leaching in an ammoniacal ammonium carbonate solution under oxidising conditions results in the selective dissolution of Ni and Co as ammine complexes. The roasting is the most critical step and a slow heating rate (5°C per minute) is essential. The slow rate ensures the bulk of the Ni is reduced before amorphous magnesium silicate

re-crystallises at about 750°C incorporating unreduced Ni, preventing its later leaching. About 10% of the Fe is also reduced. The stable ammonium complex formation by Ni and Co in the leach solution prevents hydrolysis under the high pH (about 10) conditions. The Fe initially dissolves as ferrous ammine complexes, but is readily oxidised and precipitates as ferric hydroxide reporting to the leach residue. Along with this selective leach advantage further advantages are that leaching reagents can be recycled and that corrosion problems in ammoniacal systems are minimal [8].

Certain improvements were made to the Caron process by Sherrit Gordon, Freeport and others, and are reviewed elsewhere [8, 33, 35]. Enhanced Ni reduction is obtained by chloride and sulfur addition, however this was not successful when implemented at the Yabula refinery, a Caron-type process. BHP Biliton's (Queensland Nickel's at the time) Yabula refinery, Australia, established in 1974, imports laterite ore from Indonesia and New Caledonia since its original feed ore reserves were depleted. A novel ammoniacal solvent extraction plant was later installed as well as a nickel oxide product reduction stage which led to a larger suite of final nickel products [3]. Ammoniacal ammonium sulfate instead of carbonate has also been used for the leach. However, the improvements still render the process applicable to low Mg ore only due to Ni losses in magnesium silicate formation during roasting and ammonium losses due to mixed magnesium ammonium carbonate precipitation during leaching. Other disadvantages are that energy requirements for drying and pre-roasting are high and overall metal recovery is low: 75-80% for Ni and 40-50% for Co [8].

An alternative approach involves direct leaching of untreated limonitic ore with sulfuric acid at high temperatures and pressures under conditions that also result in selective dissolution of nickel and cobalt, while iron is rejected in the solid leach residues [8]. In pressure acid leaching the metal oxides are dissolved to metal sulfates. Silicates dissolve, polymerise and precipitate. The iron precipitates, regenerating acid and aluminium precipitation (as alunites) which can be overlooked, contributes to the net acid consumption. Saprolitic ores are uneconomic to process due to high acid consumption.

The first-generation pressure acid leach was developed and became operational in 1956 at Moa Bay, Cuba, for recovery of Ni from a predominantly limonitic ore. The ore contained low levels of Mg and was suitable to direct sulfuric acid attack. Under the autoclave conditions at 250°C Fe is precipitated thus effecting good Fe removal. Ni and Co recoveries exceeded 90% and the economics are further enhanced by a readily available local source of acid. The disadvantages of the process include the limited application to only limonites with low magnesium (so as to limit acid consumption), high sulfate effluent liquor, and alunite scale problems (layers up to 20 cm thick) in the autoclave requiring lengthy shut-downs for removal [8, 13].

The AMAX process was developed to treat both horizons of a laterite ore-body. Even though laterites are not neatly formed in separately mineable blocks, it is possible to separate them based on their physical characteristics. Low Mg limonites are fine-grained and very friable, whereas high Mg saprolytic ores are coarser and harder. A two-stage leach is used. The limonitic fraction (up to 15% Mg) is leached at 270°C with 40-50 g/l discharge free acid, while the saprolytic fraction acts as the neutralising agent in a second, atmospheric leach stage. The saprolytic ore may need to be pre-reduced, but the lowest energy consumption amongst competitive processes was claimed. Through the use of the higher leach temperature (than Moa Bay-type processes) improved slurry sedimentation and leach kinetics were observed [4]. Ni and Co are recovered by H<sub>2</sub>S precipitation. The AMAX process was developed during several pilot campaigns during the 1970s and 1980s. A disadvantage is that spent liquors are high in magnesium sulfate [36].

When comparing total capital and operating costs between a Caron-type process (reduction roast-ammonia leach) and sulfuric acid pressure leaching, the Co price has a large effect on enhancing the economics. Acid leaching was calculated in 1979 as being more economical than the Caron process [34].

After 40 years of Moa Bay being the only plant producing Ni by pressure leaching [37], in early 1999 the three second-generation acid leach “pioneers” in Western Australia were in the process of ramp-up:

- Cawse [38] had produced its first Ni cathode and Co intermediate product.
- Bulong had produced its first Ni starter sheets, but was yet to produce any saleable Ni cathodes.
- Murrin Murrin (the largest of the three projects) experienced commissioning problems but had produced its first mixed Ni-Co sulfide precipitate [39].

All make use of pressure acid leaching, but the recovery methods for Co and Ni differ. The ore to be treated at these plants contained less Al than the Moa Bay laterite, so less alunite scale was expected, but contained more Mg, so higher acid consumption was expected. For the various ore categories tested at Murrin Murrin, sulfuric acid consumption was around 400 kg/t to yield above 90% recovery for both Ni and Co [40]. Disadvantages of these pressure acid leaching processes included corrosion issues due to high chloride levels in the local groundwater requiring expensive titanium-lined autoclaves; and the high viscosities of the ore slurries. Many commissioning problems were experienced, requiring equipment redesign, and higher-than-anticipated acid consumption and scale problems contributed to slow and difficult ramp up.

CVRD-Inco's Goro process, developed for New Caledonian laterites, uses pressure sulfuric acid leaching at 270°C. Ni and Co are recovered from the weak and impure pregnant leach solution using solvent extraction. The main acid consumers in the leach are Al and Mg. A

one ton per day demonstration plant was built on site in 1999 [5]. The full-scale plant is currently under construction.

An alternative to the low recoveries and high energy cost of the ammoniacal route; the engineering and high-sulfate effluent problems of the Moa Bay plant; and the disappointing Western Australian high pressure acid leaching route, is atmospheric acid leaching. This alternative has received minor attention but some studies have been done on limonitic ores [29, 41, 42, 43].

Several studies have shown [29, 35, 42, 43] that complete extraction of nickel from limonitic ores requires full dissolution of each nickel-bearing goethite grain and that the amount of Ni extracted is directly related to the amount of Fe minerals dissolved. This was confirmed when particle size was reduced and a much greater increase in Ni extraction was seen for limonitic than for saprolytic ores [35]. Thus if a blended feed is to be used, the feed preparation and solid-liquid separation stages must be designed on the basis of the goethite content (the "rate-limiting" mineral). Generally, for economical (90%) Ni extraction in an atmospheric leach, a large excess of acid is required to dissolve the Fe oxides.

One study on Greek limonitic laterites obtained 82% Ni recovery from a 95°C sulfuric acid leach with 350 kg/t acid consumption in a three-stage counter-current setup and 850 kg/t in a single pass leach [41].

Chander [29] studied extractability of Ni from limonitic ore from Sukinda, India, using several inorganic and organic acids. The results showed a correlation between Ni extraction and Fe dissolution for the various solutions tested. Similar results were obtained by Rice and Strong [43]. The study focussed on kinetic considerations.

Das *et al.* [42] used SO<sub>2</sub> as a reductant to enhance leaching of two laterite ores in solutions of H<sub>2</sub>SO<sub>4</sub>, HCl and HClO<sub>4</sub>. The various rates of reductive dissolution of Fe oxides and release of Ni were discussed in conjunction with the Eh/pH of the systems and the complexation of the anion.

### **2.1.2. Laterite processing with hydrochloric acid**

In 1981, the hydrometallurgical treatment of complex ores, especially using chloride-based media, became a strong focus of research activity although pressurised sulfuric acid leaching of nickel laterites appeared promising in terms of minimum use of fossil fuel [44]. Muir [15] extensively reviewed the basic principles of chloride hydrometallurgy. Senanayake and Muir [45] reviewed chloride hydrometallurgy fundamentals and application to metal sulfides.

Only a few commercial plants have been built based on chloride processes, but successful ones include the Falconbridge matte leach (not a laterite process) [46] and all platinum group metal refining.

The advantages of chloride media are that leaching rates are generally rapid, no high-energy pre-treatment is necessary and leaching under atmospheric conditions lessens corrosion; however less selectivity (especially over Fe) is achieved and purification of the leach liquor is more complicated. Although, the recovery of Co from the pregnant leach liquor is easier through chloride-based solvent extraction than in a sulfate medium. The ability to recycle acid is important, but if high Ni and Co recoveries are achieved, increased acid consumption can be justified.

Reasons why chloride hydrometallurgy is not popular are the corrosive nature of the chloride solutions, the volatility of HCl and Cl<sub>2</sub> and the difficulty with recycling reagent. Recovering HCl from solutions of metal chlorides is often not possible. The largest application of HCl regeneration is in the steel picking industry which consists of pyrohydrolysis, pre-concentration and HCl absorption [10]. HCl can be recovered via pyrohydrolysis of FeCl<sub>3</sub> or MgCl<sub>2</sub> to form Fe<sub>2</sub>O<sub>3</sub> or MgO. Pyrohydrolysis is carried out in a spray roaster or fluidised bed at 600-800°C and, in the case of the steel pickle liquors, HCl is produced by the following reaction:



Pyrohydrolysis has often been suggested in chloride Ni laterite processes for HCl recycle [10, 20, 43, 47]. The Jaguar Process [20, 21] incorporated MgCl<sub>2</sub> pyrohydrolysis and the Goro process [5] incorporated NiCl<sub>2</sub> pyrohydrolysis for the production of NiO for sale or neutralisation and HCl for recycle within the solvent extraction circuit.

Ni-bearing lateritic overburden of chrome ore was leached in HCl and H<sub>2</sub>SO<sub>4</sub> by Sukla *et al.* [47]. Leaching in 3 M HCl at 100°C yielded 73% Ni extraction and 87% Fe extraction after four hours. The kinetics of Fe extraction was said to be slower than Ni and after two hours of leaching the Ni was 3% less than the ultimate extraction, while the Fe was 20% less. However, the ultimate Fe leaching data point appears to be an outlier.

The atmospheric leach tests done by Das *et al.* (Section 2.1.1) included HCl as a lixiviant. Over 90% Ni (and similar Fe and Mn) extraction was obtained with HCl strengths of 1.02 M in their HCl-SO<sub>2</sub>-Cu(II) system.

During the early 1970s, Rice and Strong [43] at the University of Leeds published research on HCl leaching of Ni laterites and proposed a flowsheet to treat limonitic laterites. Their process claimed low energy requirement as no pre-roasting or drying was necessary, with purification by solvent extraction. The separation of Mg and Fe from the leach liquor was seen as the key step. Pyrohydrolysis was identified for HCl recycle and MgO and Fe<sub>2</sub>O<sub>3</sub>

products for sale or recycle. Nine different laterites (limonitic and saprolytic) were leached, but no other unit operations were tested. Leach liquor purification was proposed to be through Fe and Co solvent extraction with Ni powder product formation by the Derry Process ( $\text{Ni}(\text{OH})_2$  formation with MgO neutralisation and subsequent  $\text{H}_2$  reduction) [43].

Work at the University of Leeds continued on this HCl route for Ni laterites and Rice published a summary of the project from 1970-1986 [48]. Further work on the leach liquor purification through solvent extraction was done, and in 1997, published by Gibson and Rice [49]. The leaching testwork showed on average over 90% Ni extraction in two hours with 5.5 M HCl at temperatures between 70 and 90°C.

### 2.1.3. The Jaguar Process

A deposit that was to be exploited in Guatemala, Central America, is geologically immature. The effect on the mineralogy is that zones are not fully laterised. Various scouting tests were completed as part of process development. It was found that the high pressure acid leaching route was not suitable due to the higher levels of Mg in the deposit in both the limonitic and saprolytic zones. Atmospheric chloride leaching showed promise and more investigation was done into magnesium chloride brine solution chemistry. The pertinent issue was to attempt to selectively leach Ni and Co, if a hydrometallurgical route was to be followed, which was the case as a smelter was not an option due to environmental and social concerns.

Due to the immature nature of the deposit, more magnetite is present that has not been altered to limonite, and nickel-enriched goethite coats the magnetite grains. It was claimed that Ni can be easily leached from the grains without releasing the Fe and the leach intensity need not be excessive. In almost all other studies (Section 2.1.1), the extraction of lateritic Ni was found to be directly proportional to the dissolution of goethite and magnetite which are independent of the proton activity of the system [29, 35, 42]. Although the HCl route for Ni laterites was not novel, a selective leach on the Jaguar Nickel ore deposit would indeed be unique and advantageous.

The Jaguar Process aimed at controlling impurities (Fe and Mg) through the manipulation of the unique properties of chloride chemistry. HCl/MgCl<sub>2</sub> brines were proposed to treat both the limonitic and saprolytic laterite profiles. In concentrated Cl<sup>-</sup> solutions, base metal species (with the exception of Ni) form stable chloro-complexes, water activity is low and increased concentration of HCl and MgCl<sub>2</sub> enhance the HCl and H<sup>+</sup> activities. This enhanced activity effect is shown in the work of Majima and Awakura [50] and Jansz [17]. Figure 2-1 shows how increasing acid concentration enhances HCl activity and even more so if there are other chlorides present. Included in the introduction, Figure 1-2 focuses on MgCl<sub>2</sub> brines and predicts a strong effect of increasing MgCl<sub>2</sub> concentration on increasing single-ion (H<sup>+</sup>) activity. The effect is however slightly depressed at higher temperatures.

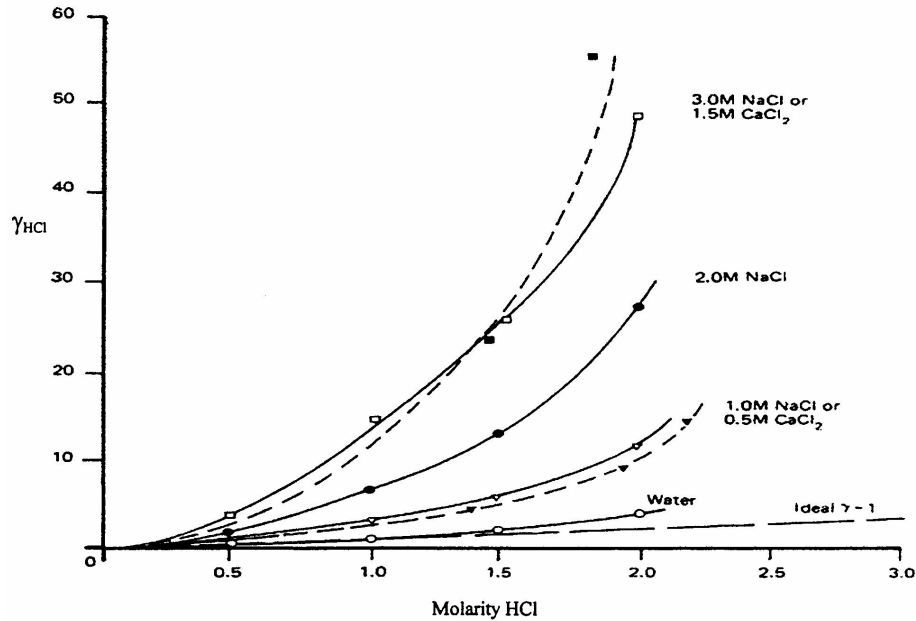


Figure 2-1: Mean activity coefficient of HCl with NaCl or CaCl<sub>2</sub> added (Majima and Awakura [50], Muir [15])

The following properties of MgCl<sub>2</sub> brines were supposedly exploited in the Jaguar Process:

- *High chloride concentration reduces water activity* such that there is effectively no capacity in solution to hold appreciable levels of ferric Fe (which has the lowest pH of hydrolysis). Hydrolysis can occur at a lower apparent pH if the Cl<sup>-</sup> concentration is not too high (which would result in a more stable FeCl<sub>4</sub><sup>-</sup> complex in solution).
- *H<sup>+</sup> activity is enhanced* resulting in lower acid consumption as less HCl would be required to obtain the equivalent “strength” if not used in a high MgCl<sub>2</sub> brine, and less acid neutralisation would be required during downstream Fe removal.
- The combination of *high H<sup>+</sup> activity and low water activity* results in low amounts of free water and as MgCl<sub>2</sub> has a high hydration number (14), Mg leaching would be minimised by this and through the common ion effect.

Preliminary tests on the Jaguar ore showed that 80-93% Ni extraction was possible and that selective leaching occurred. The ratio of Ni to Fe extraction was as high as 40 and the ratio of Ni to Mg extraction was approximately doubled [21].

## 2.2 Solution Thermodynamics: Species Activity

Solutions in hydrometallurgy contain ionic species. Simple solutions containing few, strong electrolytes, as well as very dilute solutions have been comprehensively modelled, but

solutions of higher ionic strength and those containing many electrolytes have not. The charged ionic species interact with coulombic forces and, even at low concentrations, the interactions involve stronger forces at longer ranges than neutral molecules. Metal ions in solution form various hydrolysis products or complex with ligands. It is this speciation which must be established in order to be able to model hydrometallurgical systems at equilibrium.

Balomenos *et al.* [51] outline approaches available to model the chemical equilibrium of electrolyte solutions. Essentially one needs knowledge of each species' Gibbs Free Energy as well as activity coefficients in order to accurately predict departure from ideality. Mean ionic values of electrolyte parameters (activities, concentrations, chemical potential, activity coefficients) must be used, as individual ions cannot be separately considered due to the constraint of electroneutrality in solutions.

The mean activity coefficient is used to obtain the actual species activity,  $a$ , through the equation:

$$a_{\pm} = \gamma_{\pm} m_{\pm} \quad \text{Eq. 2-2}$$

where  $m_{\pm}$  = mean concentration

$\gamma_{\pm}$  = mean activity coefficient (dimensionless)

The ubiquitous measure of hydrogen ion activity is, of course, pH. Equation 2-3 reflects the definition of pH:

$$\text{pH} = -\log(a_{\text{H}^+}) \quad \text{Eq. 2-3}$$

In Equation 2-3, the single-ion activity ( $a_{\text{H}^+}$ ) is used. This means that the only practical way to determine the proton activity is through experiment (such as potentiometric pH or conductivity measurement [52-55]); it cannot be derived directly from true thermodynamic measurements but can be inferred from some extra-thermodynamic assumptions [17].

The most widely used activity coefficient models applicable to describing ionic solutions are outlined below, leading up to the development of the P-H Model. It is not the intention to critically review the development of the thermodynamic assumptions behind these models, but rather to provide an introduction to their applicability. Details of the actual equations and parameters in the models can be found in the references noted. Through Objective 2 of this study, proton activity is investigated and thus an appreciation of how the activity is measured or modelled is important.

### 2.2.1. The meaning and use of pH

There is no precise fundamental definition of pH, but it is essentially "the evaluation of a quasi-thermodynamic constant from a measurement of the electromotive force (emf) of a suitable galvanic cell" [56]. The meaning of experimental pH is largely related to the pH number assigned to the calibration standards used. Although single-ion activity is strongly

linked to chemical thermodynamics, extra-thermodynamic considerations are used to give pH values substance [56].

As described in Equation 2-3, pH is dependent on proton activity and not on concentration, as is often the simplifying assumption. There are a number of effects that have to be taken into account when attempting to use a pH value for interpreting results, including the following:

- The internal buffer of the pH electrode must be constant at all times in order for the Nernst Equation to hold.
- The standard potential must remain unchanged when measuring pH. This will only happen if the solution is dilute and contains simple solutes with acidity close to the calibration standard used [56]. This is mostly not the case in hydrometallurgical solutions and definitely not the case for the solutions in this study. Thus the measured pH cannot be used to approximate hydrogen ion activity.
- The potential difference as a result of a temperature gradient within the measuring and reference electrodes, the Soret effect, is eliminated by calibrating at temperature. The Soret effect is normally small relative to the other diffusion effects, but can be used to separate isotopes by applying a temperature gradient to a multi-component system [57].
- A potential difference arising from the spontaneous tendency for the ions of the concentrated electrolyte to pass into the more dilute solution is established. The differing mobility of the anions and cations leads to the junction potential [58]. The junction potential must be reduced as far as possible so as not to introduce error into a pH reading. The evaluation of the junction potential is discussed below.

Often quoted, Harned, who did much work measuring activities of the electrolytes in aqueous solutions, stated that “we are thus confronted with the interesting perplexity that it is not possible to compute liquid junction potentials without a knowledge of individual ion activities, and it is not possible to determine individual ion activities without an exact knowledge of liquid junction potentials. For the solution of this difficult problem, it is necessary to go outside the domain of exact thermodynamics” [56]. There are methods to estimate the junction potential, but none evaluate the complete junction potential as per its definition. Using the Henderson equation, the junction potentials,  $E_j$ , shown in Table 2-1 were estimated by Bates [56].

Table 2-1 shows that the use of saturated KCl does not eliminate the liquid-junction potential and the magnitudes of the potentials are large for HCl due to the high limiting equivalent conductance of the hydrogen ion compared to other cations (i.e., HCl is a strong acid) and similarly for NaOH [58].

Table 2-1: Liquid-junction potentials at 25°C calculated by Bates [56] using the Henderson equation

Solution	$E_j$ (mV)	
	Saturated KCl bridge	0.1 M KCl bridge
HCl, 0.1 M	4.6	26.9
HCl, 0.01 M	3.0	9.1
NaOH, 0.1 M	-0.4	-19.2

In order to get around these limitations on the use of pH measurements to represent hydrogen ion activity, the P-H Model was developed. Hydration theory and the fitting of data to calibrate the model led to the estimation of single-ion activities, and hence theoretical pH, of HCl-MgCl<sub>2</sub>-H<sub>2</sub>O systems at temperatures up to 100°C. By using HCl solutions and their theoretical pH numbers to calibrate the pH electrode at temperature, the junction potential and other effects were built into the calibration curve.

### 2.2.2. Activity coefficient modelling in aqueous ionic solutions

Long-range electrostatic interactions of ions in solution do not depend on the nature of the ions, but only on their charge. Debye and Hückel [51] derived the theoretical form that ionic activity coefficients should have in dilute solutions by assuming that ions are point charges in a continuous medium of dielectric constant equal to water. The Debye-Hückel relation is applicable to every case of dilute solutions at various temperatures, and in solvents of dielectric constants different to that of water. The long-range interactions are essentially electrostatic attractions of ions of opposite charge, and hence in dilute solutions the activity of an ion is smaller than its concentration. The Debye-Hückel relation is only applicable at concentrations up to 0.1 M.

In more concentrated solutions (> 0.1 M), the activity coefficient may pass through a minimum value and then increase as a result of repulsive forces between ions of like charge. The activity coefficient now depends on both the concentration and the nature of the other ions in solution. The ions no longer behave as point charges and ions of opposite charge associate as ion pairs. In addition, the water molecules which are coordinated to the ion in its primary hydration shell give the ion a larger effective size. When the concentration increases to the point at which essentially all water in solution is bound in primary hydration shells, the activity coefficient can become very large. In an extreme example, for a solution of 20 molal LiBr, the activity coefficient of the salt is 485 [59].

In ionic solutions, the implication of the requirement of overall electrical neutrality is that the concentration of any one ionic species is not independently variable and individual activity coefficients are thus un-measurable. This results in the use of the mean ionic activity coefficient as defined in Equation 2-2. Even though models can theoretically predict both,

only the mean is measurable which can be used to confirm model outputs. The estimation of single-ion activity coefficients is a theoretical exercise [56].

Pitzer established that an effective method for representing the properties of non-ideal gases was to use a series in increasing powers of density or concentrations with the coefficients, called virial coefficients, related to the number of molecules. It was further established through solution theory that a formally similar treatment applies to solutes in a solvent provided the intermolecular potentials are replaced by potentials of mean force in that solvent. For electrolytes, the long-range coulombic forces are not included in this virial series. Pitzer developed his virial coefficient equations (Pitzer Model) using the virial coefficients (for binary, ternary, etc., interactions) to take the short-range inter-particle-potential effects into account, and a Debye-Hückel term in order to describe the long-range electrostatic forces [18].

Meissner approached activity coefficient prediction empirically, although his isotherms are based on an extended Debye-Hückel equation. The Meissner equations involve the use of a single characteristic constant for each cation-anion combination present. This constant is unchanged by the presence of other electrolytes and is readily derived from experimental measurements [19]. It thus presents a simpler (less parameterised) empirical model based on the phenomenological ionic strength dependence of the activity coefficient.

Neither of these models can adequately describe proton (single-ion) activity in high temperature  $\text{H}_2\text{O-HCl-MgCl}_2$  systems. Steyl [22] summarised various researchers' efforts in modelling of chloride systems.

In order to evaluate hydrogen ion activity effects as predicted by Jaguar Nickel, a modified model was required which could predict single-ion activity coefficients. The P-H Model was hence developed and is based on the Pitzer framework, which was seen as being superior in describing thermodynamic properties, especially for mixtures of different electrolytes. Modified parameters were also required for the Hydration Model in order to more accurately estimate  $\text{MgCl}_2$  hydration in strong brines.

As summarised by Steyl [22], Hydration Theory, credited to Stokes and Robinson [60], involves the relation of the mean activity of the salt to the activity of the solvent. With considerable experimental evidence suggesting the anion ( $\text{Cl}^-$ ) is not hydrated, Bates *et al.* [61] extended the theory for the calculation of single un-associated chlorides. In order to account for the change in hydration number with the concentration of the salt, Jansz [17] further extended the theory. Using some assumptions, Jansz related the hydration number to the water activity and in so doing, temperature effects were incorporated via the change in water activity with temperature. Steyl further extended this approach by evaluating the hydration number within a Pitzer framework at various temperatures. An equation fit

formalised the effect of temperature on the hydration number for HCl and MgCl<sub>2</sub>. The mathematical derivation of Jansz was adapted to calculate single-ion activities in mixtures of uni- and bivalent chlorides.

Extrapolation of Steyl's fit of hydration numbers as functions of water activity to unit water activity yields the hydration at infinite dilution. These values compare well with literature values (resulting from different methods) as can be seen in Table 2-2.

Table 2-2: Literature values of hydration numbers at infinite dilution (after Steyl [22])

Hydration Number	HCl	MgCl <sub>2</sub>
Steyl [22]	6.1	10.7
Stokes and Robinson [60]	8.0	13.7
Gluechauf [22]	4.7	6.5
Jansz [17]	6.4	12

Figure 2-2 shows the P-H Model outputs in terms of single-ion activities. As illustrated, there are limited data for strong solutions of HCl and MgCl<sub>2</sub>.

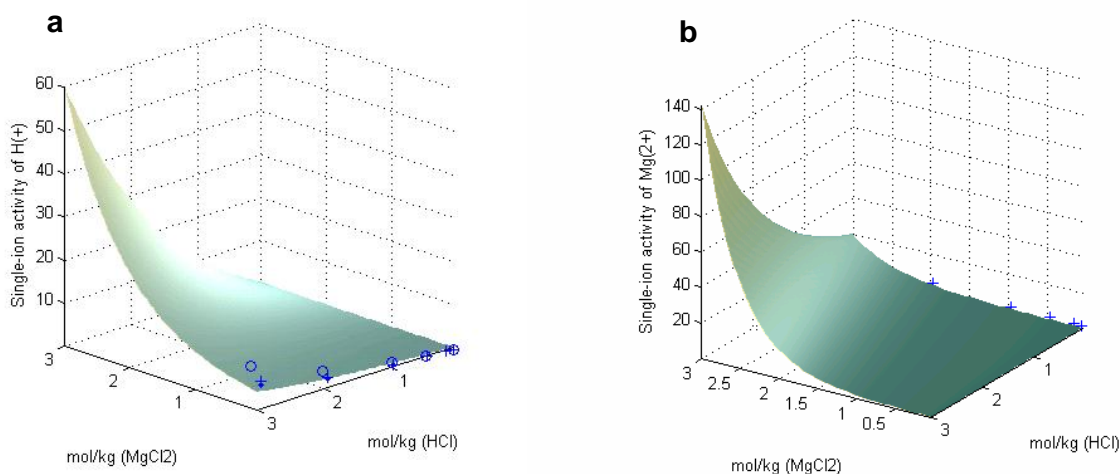


Figure 2-2: Single-ion activities from the P-H Model as a function of HCl and MgCl<sub>2</sub> molalities at 25°C (Steyl [22])

a)	Activity of H <sup>+</sup>
b)	Activity of Mg <sup>2+</sup>
Experimental values from:	Bates <i>et al.</i> (+) [61] Jansz (●) [17] Senanayake and Muir (○) [62]

Another worker in this field, Senanayake, [63] reviewed the theory and practice of measuring proton activity and pH in concentrated chloride solutions with specific reference to oxide leaching. In order to estimate the single ion activity (theoretical pH) a hydration number of 1 or 2 for the chloride ion was assigned and a constant ionic activity for the

hydrated chloride ion proposed. Liquid junction potential corrections were shown to be important. It was concluded that glass electrodes can be used to measure pH in concentrated chloride solutions provided appropriate corrections are made for liquid junction potentials.

A glass electrode calibration using the P-H Model to assign pH to various strength HCl solutions can be used to incorporate liquid junction potential into the pH reading.

Work has also been done Papangelakis and others [52-55] into high temperature modelling of aqueous processes (mostly sulfuric acid pressure leaching of laterites) using a similar approach of accurately describing the solution parameters under process conditions.

### **2.3 Activity and Leaching Behaviour**

Majima and Awakura [50] noted that few studies have applied an activity concept to hydrometallurgical systems. These researchers measured HCl and approximate  $H^+$  and  $Cl^-$  activities at 25°C in order to obtain a better understanding of the hydrometallurgical reactions occurring in concentrated solutions. In order to get around the problem of the unmeasurable junction potential, which is affected by the geometry of the salt bridge between the reference and measuring electrodes, it was estimated using the Henderson equation. It was recommended that further work include the establishment of a method for accurate measurement of ion activities.

Applying the measured activities to the non-oxidative leaching of galena and sphalerite, Majima and Awakura found that leaching rates were better described by proton activity than by using acid concentrations. Similarly for acid dissolution of cupric oxide and auto-oxidation of Fe(II) in hydrochloric acid solutions; the researchers found linear relationships [50].

Chander [29] found that the addition of NaCl and  $CaCl_2$  to  $H_2SO_4$  leaching of limonitic laterite increased the Ni extraction and correspondingly the Fe dissolution. The rate constants for Ni extraction were plotted against acid activity for leaching in sulfuric acid and hydrochloric acid. It is not clear how these single-ion activities were obtained, but the relationships are linear.

## 2.4 Leaching Kinetics

The laterite ores vary widely in composition and the nickel is contained in up to five or more mineral phases. The kinetics of leaching will be dependent on the relative proportion of the various minerals and their reactivities.

In general, the rate of a chemical reaction under conditions of constant volume is defined as:

$$r_A = dC_A / dt \quad \text{Eq 2-4}$$

where  $r_A$  = rate of reaction of component A

$C_A$  = concentration of A

For a simple irreversible reaction, a rate expression can be written as

$$-r_A = k.C_A^a \quad \text{Eq. 2-5}$$

where  $k$  = temperature dependent rate constant

$a$  = reaction order with respect to component A

Through proposal of a reaction scheme to describe the overall reaction, a corresponding rate expression and integrated rate equation can be derived. This can only be done with a thorough understanding of the system and knowledge of rate limiting steps, chemical intermediates and the like. Equally useful are mathematical or empirical models which do not require the exact mechanism to be known, but still can provide insight into factors affecting leaching and be used for scale-up design purposes.

### 2.4.1. Mathematical models

The classic *shrinking core and shrinking particle models* developed in the benchmark book by Levenspiel [65] are the most widely used by hydrometallurgists. Originally, the shrinking core (and particle) models were only discussed in relation to gas-solids systems and a steady state diffusion equation used to determine the concentration profile across the particle [65]. Liddell [66] reviews and summarises some criteria developed by authors on determining the error associated with using shrinking core models for liquid-solid systems. The equations do not accurately account for leaching mechanism or particle shape and yet many excellent fits have been made to leaching data. Shrinking core models are not commonly applicable to leaching of ores with complex mineralogies, such as lattice-type laterites. They are more suited to ores with one or perhaps two mineral phases, and not a matrix of a few phases laterised to varying degrees, with the metal of interest occurring in more than one mineral.

An extension of the shrinking core model, the *crackling core model* proposed by Park and Levenspiel [67], was developed for gas-solid reactions where the reaction gas was assumed to force the particles to develop a system of cracks which then allows easy penetration by the reaction gas. Grains, generally assumed uniform in size, subsequently

react via the shrinking core model. It is suggested that whenever an S-shaped conversion-time curve is observed, this model should be considered. Good fits of iron ore reduction data were obtained.

A model which incorporates the structural properties of solid particles named the *sporulation model* was developed by Adrover *et al.* [68]. It is based on the assumption that during the dissolution of the ore particles, reactive grains are released in the liquid phase.

Other models consider variable activation energy [69, 70], pore size distributions [71] and migrational transport during pore diffusion [72].

Fluid-solid reaction models for porous particles were reviewed by Georgiou and Papangelakis [53] in their search for an appropriate model to describe limonite leaching under pressure with sulfuric acid. The *homogeneous model* considers particles to be an ensemble of small lumps distributed uniformly throughout the solids phase. Leaching is initially chemical reaction controlled until an inert product layer forms. The *uniform pore model* assumes the solid consists of uniform, open and completely wetted cylindrical capillaries and that no diffusional limitations occur. The *random pore model* similarly assumes uniform pores, but with random intersections. The *grain model* visualises solid particles as pellets consisting of individual dense grains compacted together. Each grain reacts as a shrinking core and diffusion through the pores becomes rate limiting.

#### 2.4.2. Empirical analysis

Empirical analysis of kinetic data is often more useful when the leaching mechanism is complicated.

The *integral method* is applicable for kinetic data that may be scattered, but follows a relatively simple mechanism. A simple reaction model must be chosen and integrated. If relevant plots of the data are linear, then the assumed model was correct and kinetic parameters may be obtained from the plot [73].

The *differential method* of fitting leaching data is applicable to systems following a complex mechanism or where integration of the rate expression is difficult, but data should be extensive and precise. The leaching rate can be written in the form of Equation 2-5 and further rearranged into:

$$\log (-r_A) = \log K + a \cdot \log C_A \quad \text{Eq. 2.6}$$

The experimental rate is calculated using the kinetic data. Plotting these against concentrations on a log scale would give intercept equal to  $\log K$  and slope of  $a$ , the reaction order [73].

### 2.4.3. Kinetic studies on laterite leaching

No kinetic studies have been published on atmospheric saprolytic laterite leaching (saprolytic ore normally follows the smelting route). Limonitic leaching kinetics have been reported and some studies are summarised.

Das *et al.* [42] proposed that the leaching of laterite, and chiefly the Fe oxide minerals, takes place through surface dissolution of the Fe oxide particle. Thus they found the shrinking core model (for spherical particles) most appropriate for leaching in acids with an apparent activation energy of 65.5 kJ/mol. Kinetics in three different acids increased in the following order:  $\text{HClO}_4 < \text{H}_2\text{SO}_4 < \text{HCl}$ .

Chander [29] also found that Ni leaching was related to Fe leaching, with kinetics increasing with acids in the following order:  $\text{HClO}_4 < \text{HNO}_3 < \text{H}_2\text{SO}_4 < \text{HCl} < \text{H}_2\text{C}_2\text{O}_4$ .

Senanayake and Das [74] noted that a proper understanding of kinetics and reaction mechanisms is important for development of selective leaching methods. Their study examined the kinetics of limonitic laterites and synthetic iron oxides leaching in  $\text{H}_2\text{SO}_4$  with  $\text{SO}_2$ . At constant  $\text{SO}_2$  concentrations, Fe leaching from the limonitic laterite was approximately first order with respect to  $\text{H}^+$ . Synthetic Fe oxide leaching also followed first-order kinetics and the shrinking particle model. Ni selectivity over Fe was in the range 0.7-0.9 with Ni leaching following a shrinking core model with diffusion through a product layer.

For synthetic Ni oxide, the crystal arrangement was seen to strongly affect the leaching rate which followed chemical reaction control in sulfuric acid and ammoniacal solutions [31]. Leaching of electrolytic Ni in HCl and small amounts of thiourea was also found to be chemical reaction controlled [75].

Georgiou and Papangelakis [53] found that although a shrinking core model fitted their data of pressure sulfuric acid leaching of limonites well, it was not consistent with the physical picture of limonite leaching. They settled on the grain model to describe the leaching with diffusion of  $\text{H}_2\text{SO}_4$  through the limonite pores as the rate limiting step.

## 2.5 Summary

In this study the claimed selectivity of the Jaguar Process is tested on a different laterite ore. Batch leach tests with varying HCl concentrations,  $\text{MgCl}_2$  concentrations, temperature, particle size and solids' concentration are conducted. Glass electrode pH measurements in chloride brines do not represent the hydrogen ion activity mainly due to the liquid junction potential of the electrode system. In order to predict activity, the P-H Model is used.

Leaching kinetics are described empirically, as saprolytic laterite ores would not be expected to leach according to shrinking core, particle or other commonly used leaching models. This is due to the differing reactivities of the mineral phases and variety of minerals hosting Ni.

University of Cape Town

### 3.0 Experimental Equipment and Methods

#### 3.1 Laterite Sample

Sample from Barro Alto, an Anglo American-owned mine in South America, was used after mineralogical investigation deemed the sample to have the simplest mineralogy of available samples. The absolute characteristics of the laterite sample were not of primary concern when selecting the sample as the aim of the testwork was to compare the leaching behaviour when changing solution chemistry, and not changing solid characteristics. However, a sufficient Mg content was required in the sample (such as present in saprolytic laterites) in order to show significant changes in leaching selectivity. In addition, the Jaguar Nickel laterite, being geologically immature with less defined zones, is more saprolytic than limonitic in Mg content and using a similar sample would lead to easier comparisons. Table 3-1 shows the main mineral phases present in the Barro Alto sample and Table 3-2 gives the chemical analysis.

*Table 3-1: Main mineral phases of Barro Alto laterite*

Mineral	Abundance (%)
Serpentine/Altered Serpentine	74
Fe-hydroxides	8.0
Clay (smectitic: Montmorillonite, saponite)	4.1
Talc	3.2
Clinopyroxene/Clinoamphibole	4.5
Cr-spinel	2.4
Quartz	0.7
Chlorite	0.7
Olivine/Orthopyroxene	1.0
Fe-oxide (Hematite/Magnetite)	0.2
Mn-hydroxide	0.4
Other	1.1
Total	100

*Table 3-2: Chemical analysis of Barro Alto laterite*

Element	Al	Ca	Co	Cr	Cu	Fe	Mg	Mn	Ni	Si	Zn
Concentration (wt.%)	1.55	0.44	0.05	0.55	0.05	10.58	15.54	0.19	1.75	18.06	0.05

From Table 3-2 it can be seen that the elements of interest are Al, Fe, Mg, Ni (and Si). The serpentine and altered serpentine phases contain the bulk of the Ni at mean concentrations of 1.65 wt.% Ni [76]. Fe-hydroxide in the form of goethite is the next most abundant phase and contains up to approximately 2.00 wt.% Ni [76]. This profile is typical of a saprolytic laterite in that there is significant Ni enrichment and a higher percentage of serpentines, leading to a higher Mg/Fe ratio than in limonitic laterites.

### 3.2 Feed Solid Sample Preparation

A 5 kg sample of Barro Alto WTO acido laterite, previously milled to 100% passing 1.7 mm was split into two sub-samples, A and B, using a rotary splitter. Sample A was screened at 106  $\mu\text{m}$  and sample B at 38  $\mu\text{m}$ . The -38  $\mu\text{m}$  material was subjected to cloth screening at 10  $\mu\text{m}$  in an ultra-sonic bath to create a +10  $\mu\text{m}$  -38  $\mu\text{m}$  size fraction in order to eliminate fines and produce as narrow a size fraction as possible.

Figure 3-1 shows a Malvern analysis of the final prepared Samples A and B. Sample A (-106  $\mu\text{m}$ ) was used as received. The  $D_{90}$  for each sample is shown as an additional comparison.

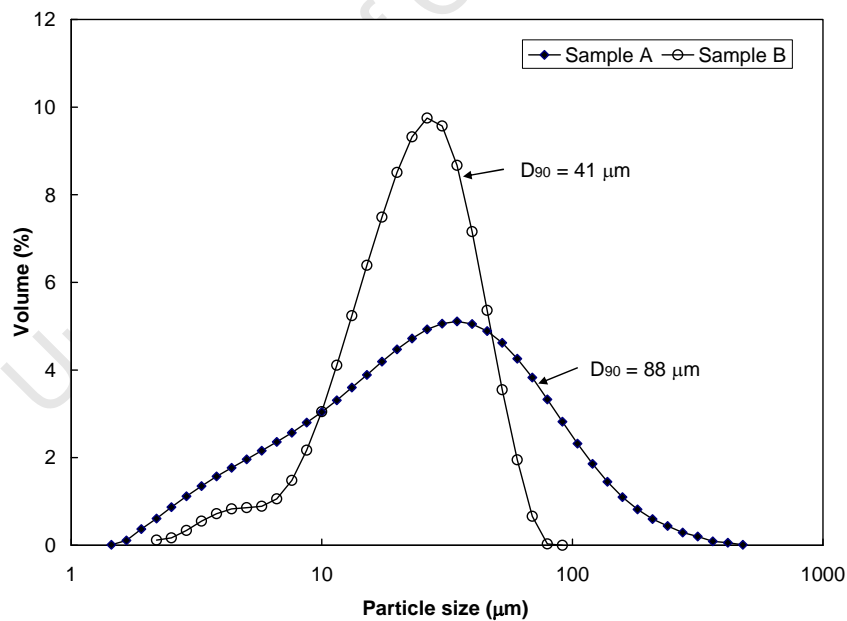


Figure 3-1: Particle size distribution of laterite feed samples

### 3.3 Leaching Experimental Setup

Batch atmospheric leach tests were carried out in a two-litre, jacketed, sealed glass vessel with reflux condenser as shown in Figure 3-2.

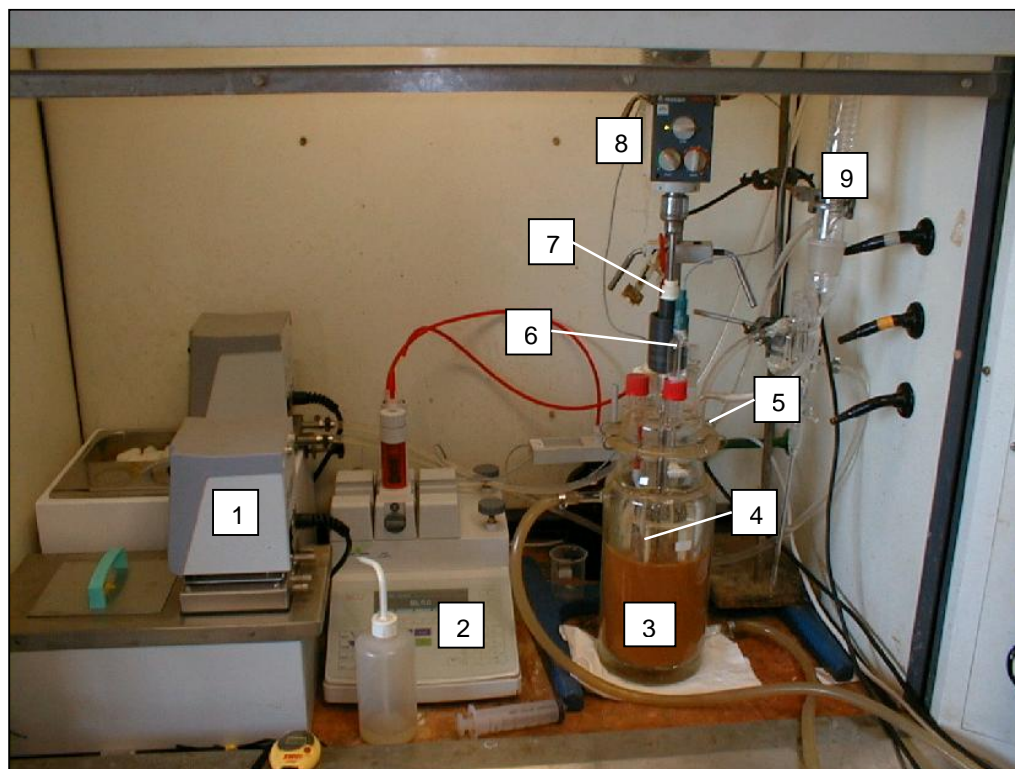


Figure 3-2: Experimental setup for leaching testwork

No.	Description
1	Oil bath (for vessel jacket heating)
2	Auto-titrator
3	Two-litre glass reactor
4	Baffles
5	Lid clamp
6	pH control electrode (linked to auto-titrator)
7	Impeller shaft seal
8	Overhead stirrer
9	Condenser

In order to establish the effect of one process variable at a time, various control methods were put in place. Table 3-3 summarises the methods used to mitigate or eliminate variable influence on the testwork results. The variables tested in this study were: temperature, HCl concentration, MgCl<sub>2</sub> concentration, particle size and solids' concentration.

Table 3-3: Experimental control methods

Variable	Control method
Temperature	Water/oil jacket fed with pump from controlled heated bath
Particle size	Particles screened to a narrow size fraction of +10 -38 $\mu$ m
Solids' composition	Fully blended feed, simplest available mineralogy
Solution composition	Low pulp density of 0.5% solids

The oil or water bath (oil was used for temperatures above 80°C) was set 2°C higher than the desired reaction temperature to counteract heat losses, and was automatically controlled to within 0.5°C. The temperature of the reactor contents was checked manually before each experiment.

A Metrohm Syntrode® combined glass pH electrode was used to measure pH in the reactor during tests. Constant acidity was maintained by using a low solids' concentration.

Six polypropylene baffles 1 cm wide were fixed inside the reactor to aid mixing. A titanium pitched-blade impeller 5 cm in diameter was attached to an overhead stirrer with variable speed settings. All tests were conducted at 800 rpm. The impeller was sealed with a two-piece water-filled polypropylene seal.

The glass reactor lid was fitted to the reactor by a wire clamp fitted over the ground glass lips. Vacuum grease was used to ensure a good seal. The lid had sealable ports on top which were used for the pH probe, kinetic sample removals, reflux condenser connection and impeller.

Kinetic samples were removed from approximately one third of the slurry depth using a 50 ml syringe connected to 2 mm diameter tubing. The slurry was collected in a small beaker, weighed and immediately filtered using a Buchner funnel and Whatman 542 hardened ashless filter paper. Additional solution samples were drawn from Tests 10-19 (see below) using Millipore 0.45  $\mu$ m Millex®-HV filter discs included in the tubing before the syringe to obtain a clear solution sample filtered *in situ*. Filtrates were weighed and, when cooled to 20°C, pH, Eh and density were measured. Solids were washed with pH 2 water using a wash ratio of two and dried in an oven at 60°C.

Room temperature pH measurements were made using a Metrohm Metrosensor 602 combined glass electrode; the Eh was measured using a Hamilton Oxytrode Pt electrode and density was measured using an Anton Paar DMA35N density meter.

### 3.4 Leaching Testwork Methods

Synthetic head solutions were made using demineralised water made on site using a Millipore reverse osmosis unit, 32% AR-grade HCl and AR-grade  $MgCl_2 \cdot 6H_2O$ , both supplied by Associated Chemical Enterprises. Two sample grinds (sample A and Sample B), three solids' concentrations, five leaching durations, three temperatures, three HCl concentrations and two total chloride concentrations (using  $MgCl_2$ ) were tested in various combinations. Table 3-4 summarises the leaching tests performed. Tests named 'XXa-e' represent five separate tests under the same conditions with different durations, the longest duration is shown in the table. A total of 56 separate leach tests were completed.

Table 3-4: Summary of leach testwork performed

Test	Grind $D_{90}$ ( $\mu m$ )	Pulp density (% solids)	Duration (h)	Temperature ( $^{\circ}C$ )	HCl (M)	$MgCl_2$ (M)
01	46.0	2	3	95	0.20	0
02	46.0	2	3	80	0.20	0
03	41.2	5	3	95	0.20	0
04	46.0	2	3	80	0.2	2.0
05	46.0	2	3	80	1	1.6
06	46.0	2	3	80	1.5	1.4
07	46.0	2	3	80	0.2	3.1
08	46.0	2	3	80	1	2.7
09	46.0	2	3	80	1.5	2.5
10a-e	46.0	0.5	2	80	1	0
11a-e	46.0	0.5	2	80	1.5	0
12d-e	46.0	0.5	2	60	0.2	0
13a-e	46.0	0.5	2	80	0.2	0
14a-e	46.0	0.5	2	80	0.2	2.0
15a-e	46.0	0.5	2	80	0.2	2.7
16a-e	46.0	0.5	2	80	1	3.1
17a-e	46.0	0.5	2	60	0.2	0
18a-e	46.0	0.5	2	95	0.2	0
19a-e	106	0.5	2	80	0.2	0

#### 3.4.1. Tests 01-09

Tests 01, 02 and 04-09 were run using a solids' concentration of 2%, and Test 03 was run using 5% solids' concentration. Tests 01 and 03 were run at 95 $^{\circ}C$ . Three acid strengths (0.2, 1.0 and 1.5 M HCl) at two total chloride concentrations (150 and 230 g/l total  $Cl^{-}$ ) were tested. These were chosen from the Jaguar Process conditions tested [21] where optimum selectivity was achieved at 230 g/l total chloride. The  $MgCl_2$  addition was related to the total chloride concentration (either 150 or 230 g/l) and head solutions of specific HCl and  $MgCl_2$

molarity were made up. A mass of this head solution was then used for each test. The pH in the reactor was measured at the kinetic sampling intervals. Test duration was 180 min with kinetic samples (only solutions submitted for analysis) taken at 2, 30, 60 and 120 min.

#### **3.4.2. Tests 10-19**

For these tests, each kinetic point was run as a separate test in order to get solids' assay information. This was a better method (statistically) than taking kinetic samples from one test as any systematic errors were not carried through to each kinetic data point. In addition, a low solids' concentration could be used as only the final residue was analysed, whereas kinetic samples would not yield enough solid mass for analysis. A lower solids' concentration of 0.5% was used to improve on keeping the solution conditions constant. Under these circumstances, solids' assay information was seen as more reliable than solution assays due to the small changes in solution composition. Stock solutions of head liquor were made up as for Tests 01-09. Test durations were 10, 20, 30, 60 and 120 min. After 2 min of leaching and prior to ending a test, solution samples filtered *in situ* were taken in order to determine immediately leachable Ni (after 2 min) and to check if precipitation was occurring during Buchner funnel filtration (end of test). These 2 min samples were also used to confirm repeatability yielding 10 tests effectively repeated five times each.

### **3.5 Mass Balance Calculation Methods**

The overall mass balance and metal balances for 11 elements (Al, Ca, Cl, Co, Cr, Fe, Mg, Mn, Ni, Si and Zn) per test were calculated as the mass ratio of the incoming to the outgoing mass. Incoming mass included the masses of solids, head liquor and wash water. Outgoing masses included kinetic residue and filtrate, final residue and filtrate samples, wash water, cake moisture and evaporation. All masses were weighed except for the cake moisture and evaporation. Cake moisture was calculated as the difference between wet and dry filter cake masses after washing and evaporation was calculated as the total starting mass less kinetic sample slurry mass and final slurry mass.

Extraction of each metal was based on the calculated total mass of solids and calculated total mass of solution at each sample time. The solids' density obtained from kinetic samples was used, with the final slurry mass to calculate a mass of solids at each time interval. The starting solution mass less evaporation at each time interval and kinetic solution removal gave the solution mass at each time, which was related to the volume at room temperature (corresponding to the solution assays) using the densities measured at each sample time interval.

Where solids' analyses were not available (solution kinetic samples) kinetic extraction was calculated using the final solid analysis and the kinetic solution analyses were then used as a ratio to this final extraction. This was seen as more reliable than using the solution assays to calculate the extractions as discussed in Section 4.4.

Acid consumption was calculated using the mass of acid added less the residual acid (measured by titration). Calculated consumption per element assumed the following simplified mineralogy:

- All Ni is present as  $\text{Ni}(\text{OH})_2$ ;
- all Fe as  $\text{FeO}(\text{OH})$ ;
- all Mg as  $\text{Mg}(\text{OH})_2$  and
- all Al as  $\text{Al}_2\text{O}_3$ .

All other elements were assumed not to leach to any appreciable extent (results did confirm this assumption). The stoichiometric amount of HCl required to leach the mass of element leached (based on solids' assays) was calculated. Problems with this method are discussed in Section 4.3.

Leaching selectivity was defined as the ratio of Ni extraction to that of the specified gangue element, that is, % Ni extraction / % Fe extraction and % Ni extraction / % Mg extraction. Only extractions calculated from solids' analyses were used.

### **3.6 Activity Measurement Experimental Setup**

The measurement of proton activity using a split electrode system was conducted using the setup illustrated in Figure 3-3.

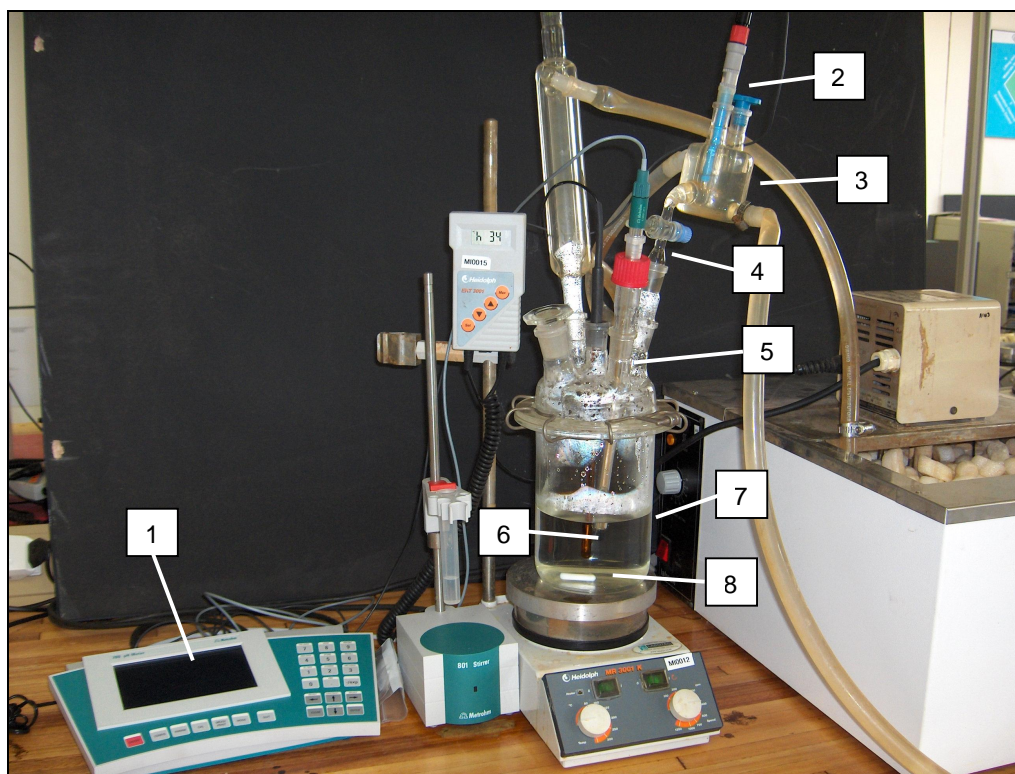


Figure 3-3: Experimental setup to measure theoretical pH

No.	Description
1	pH meter
2	Reference electrode
3	Water jacket
4	3 M KCl bridge/capillary with tap to control flow
5	Measuring electrode
6	Temperature probe linked to controller and hot plate
7	Large volume of measuring solution
8	Magnetic stirrer

A Mettler-Toledo InLab®301 reference electrode filled with 3 M KCl reference electrolyte was used. The reference electrode was kept at a constant temperature of 20°C using a water bath and linked to the measuring electrode via a 3 M KCl bridge. The bridge consisted of a KCl reservoir, into which the reference electrode was placed, descending into a capillary which was placed below the measuring solution surface. A small flowrate of KCl was required to ensure that an electrical link was established with the measuring electrode, a Metrohm Metrosensor® 601 separate pH electrode. The flow of KCl was adjusted by a tap to ensure a constant drip rate. Approximately 5-10 ml of KCl was added to the measuring solution during each determination. For each determination, 500 ml of measuring solution was used. This was done to ensure that the additional Cl<sup>-</sup> from the KCl did not affect the measurement and also to ensure a constant hydrostatic head was exerted on the measuring electrode.

Temperature was controlled to within 1°C of the setpoint by a Heidolph EKT3001 controller linked to a Heidolph MR3001 K hot plate and magnetic stirrer. The temperature probe was situated next to the measuring electrode. A small magnetic stirrer set at low speed was used to aid heat transfer. A Metrohm 780 pH meter was used which could perform nine-point calibrations.

### **3.7 Activity Measurement Method**

#### **3.7.1. Using the P-H Model**

The P-H Model described in Section 2.2.2 was at the time untested. It was desired to compare predicted activities with measured activities using the split electrode system:

- P-H Model predictions of pH in the binary system H<sub>2</sub>O-HCl were used for calibration at temperature in order to incorporate the liquid junction and other potentials into the split electrode calibration.
- P-H Model predictions, at the solution conditions tested, of proton (single-ion) and acid (mean) activities were used.

The P-H Model gave, in theory, the best available estimate of the theoretical hydrogen ion activity (pH) for the chloride system investigated in this study. This was important in order to evaluate whether the proton activity is indeed increased with background chloride salt addition and the cause of selective leaching as claimed by Jaguar Nickel.

#### **3.7.2. Activity measurements**

Hydrogen ion activities calculated using the P-H Model at various HCl concentrations and temperatures were used to calibrate the split electrode system. The calibration data is shown in Figure 3-4, represented by the curves. By using these data to calibrate the electrode, all local effects, such as the liquid junction potential, are incorporated and the best measurement of the theoretical pH is possible.

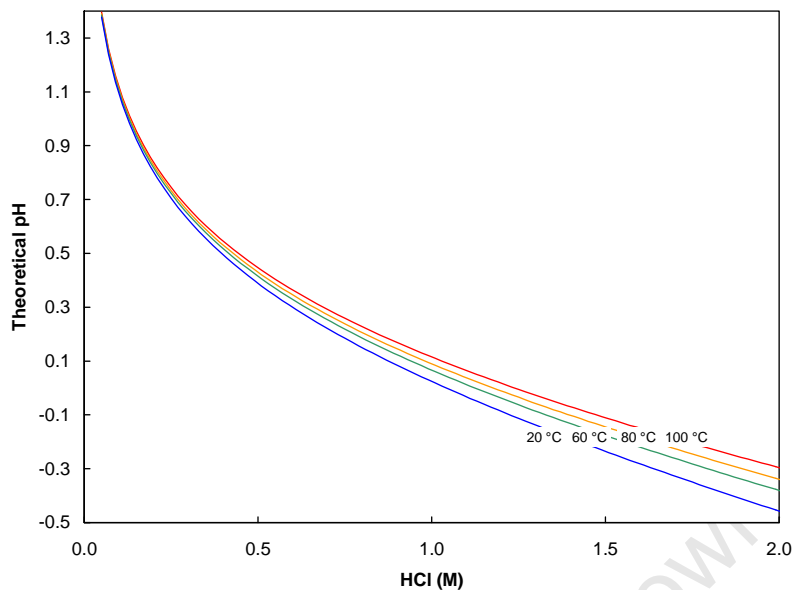


Figure 3-4: Theoretical pH as predicted by the P-H Model as a function of HCl molarity

The split pH electrode system was used to measure hydrogen ion activity. These measurements were made in an attempt to validate the P-H Model. The electrode was calibrated (at temperature) using the P-H Model predictions of pH for various HCl molarities.

To check the temperature compensation of the P-H Model, the pH of the solutions generated by the batch leach tests were measured at 20°C and also at the test temperature.

### 3.7.3. Density measurements

The P-H Model required a description of the relationship between molarity and molality in the ternary system  $\text{H}_2\text{O-HCl-MgCl}_2$ . Thermodynamic models are based on mass calculations (molality) as volume-based (molarity) calculations are temperature dependent. Molality (m) is related to molarity (M) through the following relationship:

$$m = c / (\rho - 0.001 \cdot \Sigma c \cdot M) \quad \text{Eq. 3-1}$$

From Equation 3-1 it can be seen that density ( $\rho$ ) is used to relate the two measures of concentration. No high temperature measurements for the ternary system  $\text{H}_2\text{O-HCl-MgCl}_2$  were found in literature. Thus, density measurements were made in order to correctly relate solution molality and molarity. Synthetic solutions of molar concentrations ranging from 0-2.5 M HCl and 0-2.5 M  $\text{MgCl}_2$  were made up. An oil bath was used to heat solutions to three temperatures: 20, 60 and 95 °C. Accurate volume pycnometers (consisting of 50 ml glass flasks with capillary lids) were used and when solutions were at the target temperatures, the masses were measured. Each pycnometer was calibrated at each

temperature with water to establish the exact volume. All measurements were made in duplicate and masses weighed to three decimal places.

Using each parameter in turn, an equation was fitted to the data which could be used in the P-H Model. This allowed the use of molality in the thermodynamic calculations (necessary to decouple from the effects of temperature and pressure), but provided outputs in molarity (more useful on a practical level).

### **3.8 Mineralogical Analysis**

The following mineralogical investigations were done by the AR Mineralogy Department from which all mineralogical inferences were made (these analyses also formed part of the larger laterite research programme at AR):

- X-ray diffraction analysis was done on the laterite sample to identify mineral phases present.
- Optical and Scanning Electron Microscope (SEM) petrography was performed in order to qualitatively investigate the nature and extent of the lateritic weathering (not discussed in this study).
- Quantitative mineral abundance was determined (see Table 3-1).
- Semi-quantitative Energy Dispersive Spectroscopy (EDS) point mineral analyses were also done to identify the phases that host the Ni and to determine the Ni concentration in each of these Ni-containing phases.

### **3.9 Kinetic Modelling**

As discussed in Section 2.4, there are various methods of kinetic modelling. As the primary aim of this study was to investigate leaching selectivity and activity effects, the bulk of the testwork was not geared towards generating kinetic data. However, Tests 10-19 included variation of parameters such that kinetic modelling could be done.

#### **3.9.1. Choice of method**

Section 4.8.4 includes examples showing the non-applicability of shrinking core/particle models in this case. A fuller investigation would involve integrating over each particle size and mineral type before completely rejecting these models. The differential method of analysis was used which is useful when dealing with complex mechanisms as it involves direct evaluation using the rate expression [73].

### 3.9.2. The differential method

It is proposed that the rate expression is of the following form and the initial rate of Ni extraction given by:

$$-r = K.[H^+]^n.[Cl^-]^m.e^{(-E/RT)} \quad \text{Eq. 3-2}$$

where K = overall rate constant

n,m = respective reaction orders

E = activation energy

R = universal gas constant

Each parameter was evaluated in turn and Ni extraction (not concentration) data were used to ensure constant volume conditions. Assuming all parameters except acid concentration are constant, the rate expression can be re-written in log form incorporating a pseudo rate constant,  $k_1$ :

$$\ln(-r) = \ln(k_1) + n.\ln(H^+) \quad \text{Eq. 3-3}$$

From a straight line fit of  $\ln$  (initial rate) vs.  $\ln$  (acid concentration), the slope, n and intercept  $\ln(k_1)$  were found. Similarly for changing chloride concentration and temperature, m and E were found. For each set of parameters, K was then calculated using Equation 3-2. The model can be tested against data that were not used in the development of the model.

The most widely used method of approximating the temperature-dependence in rate equations uses Arrhenius' Law where the rate constant k is described as:

$$k = Ae^{-E/RT} \quad \text{Eq. 3-4}$$

where A is the frequency factor and E is the activation energy of the reaction. This equation fits most reactions well (especially simple ones) over wide temperature ranges and is regarded as the best approximation of true temperature dependence [65]. If rate measurements are used instead of the true rate constants, the measurements must be made such that the only parameter changing between tests is the temperature [77]. This was attempted in this study and the other parameters affecting rate (particle surface area and solution compositions) were deemed to be reasonably constant as discussed in Section 4.3. Acid concentration did vary by more than 10% in some tests.

The activation energy E gives an indication of the reaction mechanism. Values of 40-80 kJ/mol typically indicate that the reaction rate is controlled by the rate of chemical reaction, while values less than 20 kJ/mol indicate the rate is controlled by mass transfer in the solution phase. Values in the 20-40 kJ/mol range indicate a mixed mechanism [65].

The HCl activity (as predicted by the P-H Model) was then used instead of HCl concentration in order to investigate if the leaching rates were better described by the activity data.

### 3.10 Chemical Analysis

Solution samples were diluted as required and analysed using a Spectro inductively coupled plasma – optical emission spectrometer (ICP-OES). Larger dilution ratios were used for solutions with a high magnesium background (>20 g/l) in order to prevent interferences on the ICP peaks. Dry solid samples were fused, dissolved in acid and analysed against a suitable calibration by ICP-OES. Chloride determinations were done by manual titration and free acid determinations were done by titration with a Mettler-Toledo DL50 auto-titrator using NaOH. All analyses were performed by the AR Analytical Services Department.

### 3.11 Statistical Analysis

All confidence limits were calculated at the 95% level (two-sided  $z = 1.96$ ). To test significance, t-tests were used. A t-test on the significance of the mean difference between pairs of values was used to compare bulk vs. *in situ* filtered sample analyses and acid consumption based on analyses vs. stoichiometry.

## 4.0 Results and Discussion

### 4.1 Results Summary

A summary of the Ni accountabilities and metal extractions achieved for each set of conditions is shown in Table 4-1. Refer to Appendix A for a full summary table, including all parameters, and the test sheets for each test.

Table 4-1: Summary of metal extraction results

Test	Main variable	Ni accountability (%)	Ni ext. (%)	Mg ext. (%)	Fe ext. (%)
01	temperature	95	71	47	33
02	–	97	73	49	31
03	% solids	93	51	33	9
04	MgCl <sub>2</sub>	110	76	43	26
05	HCl, MgCl <sub>2</sub>	96	98	89	92
06	HCl, MgCl <sub>2</sub>	109	98	92	95
07	MgCl <sub>2</sub>	93	77	39	35
08	HCl, MgCl <sub>2</sub>	107	98	88	93
09	HCl, MgCl <sub>2</sub>	90	98	89	93
10e	HCl	102	98	91	89
11e	HCl	122	99	92	92
12e	temperature	94	57	28	25
13e	–	99	92	83	70
14e	HCl, MgCl <sub>2</sub>	96	96	86	85
15e	HCl, MgCl <sub>2</sub>	96	98	88	93
16e	HCl, MgCl <sub>2</sub>	101	97	86	89
17e	temperature	97	51	23	21
18e	temperature	91	79	65	47
19e	grind	113	73	64	32

Ni leaching is achievable under various conditions, with nine test conditions yielding Ni extractions of over 95%. For Tests 10-19, only the ultimate extractions are shown and not those obtained at 10, 20, 30 and 60 min of leaching. See Figure 4-4 for these data. Ni accountability is acceptable with an average of  $96 \pm 3\%$  calculated for the 56 individual tests completed.

## 4.2 Bulk vs. *in situ* Filtered Samples

The aim of the *in situ* filtered sample drawn from the reactor at the end of each test was to obtain a sample at the correct time interval. These samples were only taken for Tests 10-19 after the fast rate of Ni leaching was confirmed. Although filtration of the bulk slurry was performed immediately, there was an amount of time that the leaching could continue. This would lead to slightly inflated leaching results, especially for the shorter tests (10, 20, 30 min) when the Ni leaching rate was high.

Table 4-2 summarises data for Ni and HCl analyses in the bulk and *in situ* samples for Tests 10-19. For example, after 10 min of leaching the bulk analysis was 6.2 g/l more than the *in situ* Ni analysis, with a confidence limit of  $\pm 8.5$  g/l. Comparing the bulk and *in situ* concentrations, the probability that one was statistically larger than the other is reflected in the confidence of the difference or bias; which is the significance of the difference (t-test) between the analyses. Ni analyses after the shorter leaching times of 10 and 20 min resulted in the bulk sample being significantly larger (with 90% and 97% confidence, respectively) than the *in situ* sample analysis. This was due to the fast initial rate of Ni leaching and the extra time taken to process the bulk sample leading to increased leaching, as suspected. The variability of the differences between the two sample analyses is large. The *in situ* results were used where possible.

Table 4-2: Average differences between bulk and *in situ* samples for Ni and HCl analyses

Leaching time (min)	Ni		HCl	
	Average difference (g/l)	Confidence of difference (%)	Average difference (g/l)	Confidence of difference (%)
10	6.2 $\pm$ 8.5	90	0.1 $\pm$ 0.4	< 90
20	10.5 $\pm$ 10.7	97	0.0 $\pm$ 0.2	< 90
30	-2.4 $\pm$ 10.0	< 90	0.3 $\pm$ 0.7	< 90
60	2.5 $\pm$ 13.1	< 90	0.0 $\pm$ 0.4	< 90
120	0.6 $\pm$ 17.7	< 90	-0.4 $\pm$ 1.3	< 90

For HCl analyses, the confidence that the bulk sample was less concentrated than the sample filtered *in situ* was not significant for any length of leaching. In addition the differences are small. Other main metals of interest followed this trend. Bulk HCl analyses were used for acid consumption calculations as these were analysed for all tests.

## 4.3 Acid Consumption

The calculated acid consumption based on the simplified mineralogy, as outlined in Section 3.5, was in most cases an overestimate due to the difficulties with simplifying the mineralogy.

The simplified mineralogy assumes all Ni is present as Ni(OH)<sub>2</sub> whereas in reality, part of the Ni is loosely contained in the lattice and not formally substituted into a mineral phase [76]. Thus the acid breaking down the mineral releases the formally bound Ni as well as the loosely contained Ni, leading to reduced acid consumption per mass of Ni than the calculated amount according to stoichiometry. Figure 4-1 shows the difference between the acid consumption based on analysis and that based on stoichiometry (not including kinetic tests of durations shorter than 2 h). Using stoichiometry, the acid consumption is with >99.5% confidence on average 2.3 ± 1.6 g more than when using acid concentration data.

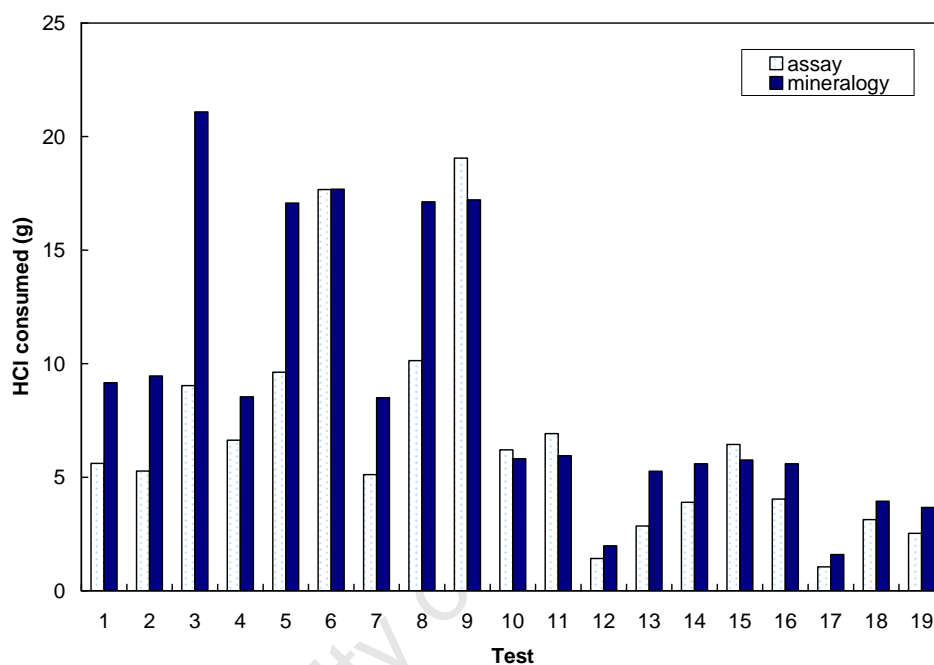


Figure 4-1: Difference between acid consumption based on acid analysis and stoichiometry

Acid consumption was therefore reported as the mass of acid used during the leach test per ton of ore. Consumption per ton of Ni or the relative consumption per main element is not reportable due to the inaccuracies with simplifying the mineralogy. The sum of the calculated acid consumption per mass of Ni, Al, Mg and Fe gave overestimated consumptions. Acid consumptions (kg/t) for each test (not including kinetic tests of durations shorter than 2 h) in order of increasing Ni extraction are shown in Figure 4-2.

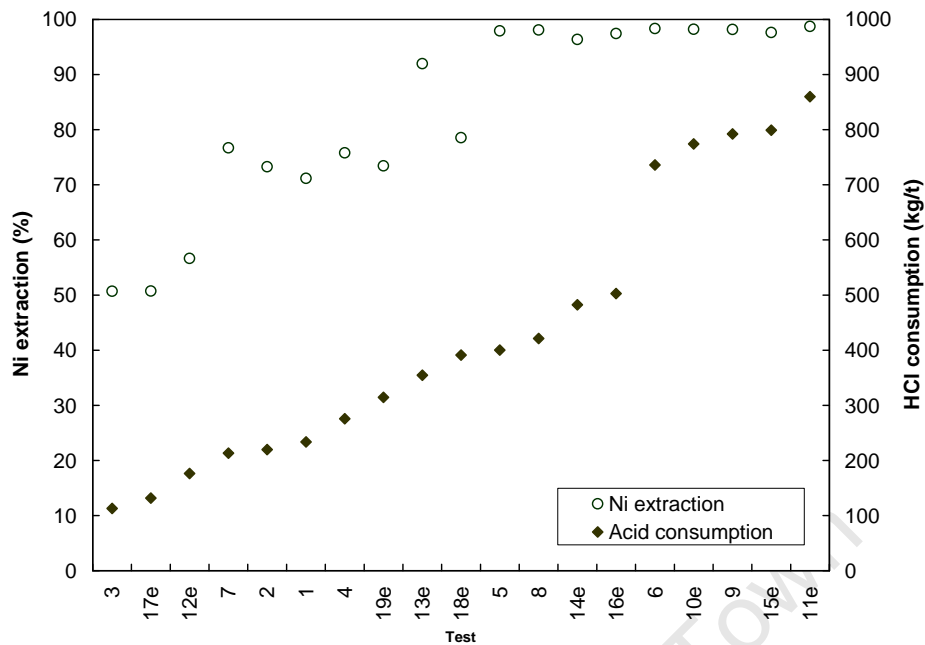


Figure 4-2: Acid consumption per test

Acid consumption varied between 113 and 860 kg/t. For 98% extraction of Ni, acid consumption was a minimum of 400 kg/t using 1 M HCl, 154 g/l  $MgCl_2$  (150 g/l total Cl<sup>-</sup>) at 80°C. Limonitic laterite leaching is normally carried out under pressure and resulting precipitation reactions generate acid leading to much smaller acid consumptions. Jaguar Nickel reported an optimum acid addition of 450 kg/t [78].

It was desired to maintain constant acid concentration during a test. Table 4-3 summarises the actual change in acid concentration during a test. These results indicate why the test method was adapted to a lower % solids' concentration for Tests 10-19 and the marked effect this had on providing a more consistent leaching environment.

Table 4-3: Average change in HCl concentration for two solids' concentrations used

Pulp density (% solids)	Tests	Average change in acid concentration (%)
2	01-09 (not incl. 03)	49 ± 19
0.5	10-19	17 ± 8

#### 4.4 Solution vs. Solid Analyses

Figure 4-3 shows the Ni extraction over time for Tests 01-09, where solution samples were analysed for kinetic data and scaled to match the final solid extraction obtained. Tests 01-03

were baseline tests varying % solids' concentration and temperature, Tests 04-06 had  $MgCl_2$  at a total  $Cl^-$  concentration of 150 g/l and Tests 07-09, 230 g/l. Figure 4-4 shows the Ni extraction over time for Tests 10-19, where each point represents a separate test; a shorter leach time, lower pulp density and only solids' analyses were used. Tests 10, 11 and 13 varied HCl concentration, Tests 12, 17 and 18 varied temperature, Test 19 varied particle size and Tests 14-16 varied  $MgCl_2$  and HCl concentrations.

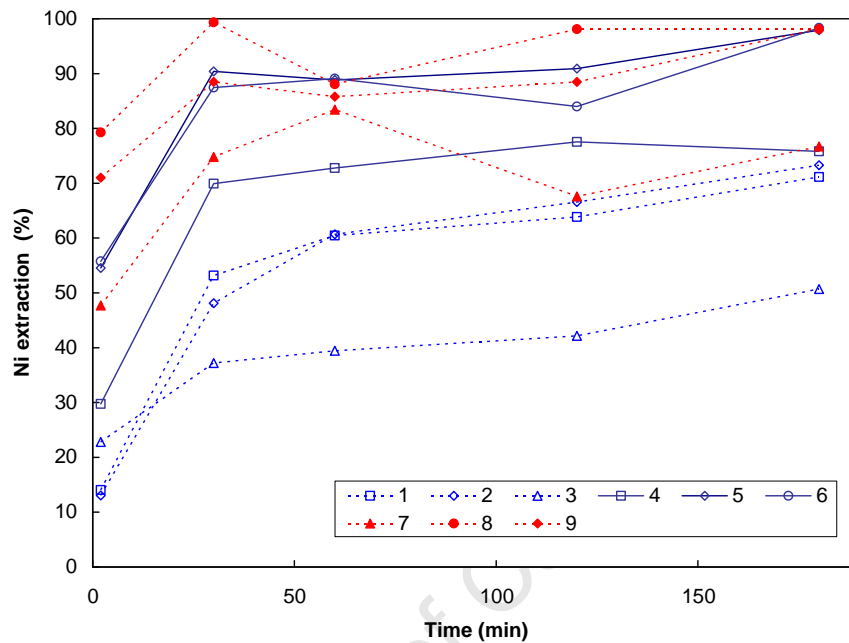


Figure 4-3: Ni extraction for Tests 01-09

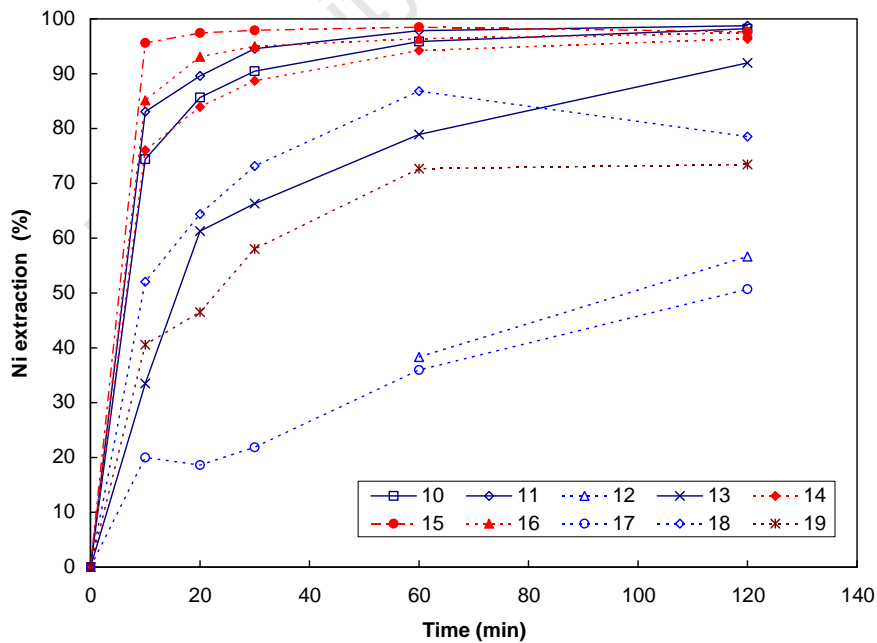


Figure 4-4: Ni extraction for Tests 10-19

Comparing Figures 4-3 and 4-4, it can be seen that the solids' analyses present a more consistent picture. In Figure 4-4, it can be seen that increasing acid strength, total chloride concentration and temperature all increase the leaching rate. Test 15 represents the 'strongest' leaching conditions with 1 M HCl and 230 g/l total chloride, and correspondingly the fastest leaching

For tests where  $MgCl_2$  was added, solution assays cannot be used due to the insignificant changes in Mg concentration during leaching compared to the initial Mg concentration. This is illustrated in Figure 4-5 which shows metal extractions for two of the tests completed where solution samples were analysed at kinetic intervals and both solids and solutions analysed on completion of the tests. The leaching curves are not smooth and Mg extraction is erratic. Other metal extractions shown are Ni, Fe and Al. Final metal extractions after 180 min based on solids' analyses (closed points) do not match final extractions based on solution analyses. In both cases, the Ni extraction based on solids' analyses is higher. This shows that solid-liquid handling after a test was optimal as precipitation or soluble losses did not occur; which would have inflated the Ni analyses, leading to lower extractions calculated using the solids' analyses.

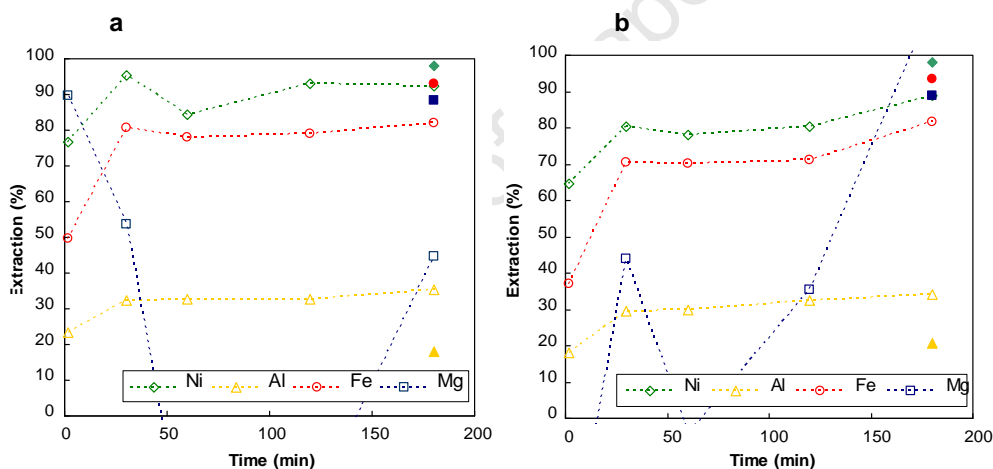


Figure 4-5: Tests 08 (a) and 09 (b) showing solution analyses (open kinetic points) and solid analyses (closed final points)

In Tests 10-19, where each kinetic point was generated from a separate test using solids' analyses, the leaching curves are smoother and Mg extraction can be accurately calculated. Figure 4-6 illustrates this for two conditions tested (10 individual tests). Solids' analyses are thus seen to be more reliable than solution analyses, especially for Mg, for which the extent of leaching cannot be seen through solution analyses under strong brine conditions. All metal extractions presented were therefore calculated using solids' analyses.

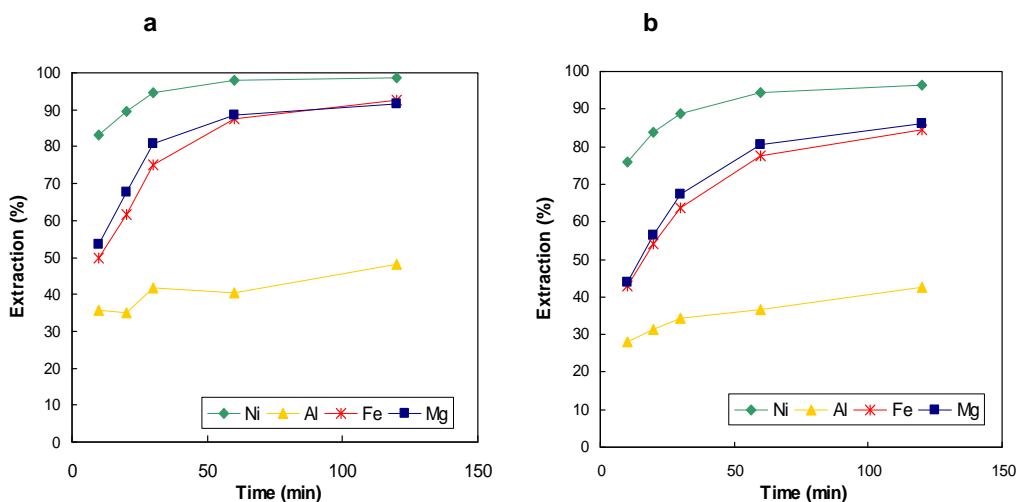


Figure 4-6: Tests 11a-e (a) and 14a-e (b) showing only solid analyses

#### 4.5 Ni Leaching after 2 min

As mentioned in Section 3.4.2, samples were taken after 2 min of leaching from Tests 10-19 in order to determine the immediately leachable Ni in the ore. Due to the fast initial rate of Ni leaching, it was impractical to finish tests at 2 min as slurry handling and filtration time would lead to significant leaching beyond 2 min. Even though it was established that solids' analyses are more accurate, the solution analyses for Ni from samples filtered *in situ* give acceptable indications of leaching extent.

For each set of conditions, five tests of varying ultimate leach time were run in order to generate kinetic information based on solids' analyses. For various reasons, a sample after 2 min of leaching was not always taken, but samples were taken from the following tests:

- Test 10 a, b, d and e
- Test 11 a, c, d and e
- Test 12 d and e
- Test 14 a, b, c, d and e
- Test 15 a, b, c, d and e
- Test 16 a, b, c, d and e

The average data presented in Table 4-4 shows that Ni extraction after 2 min of leaching is high, indicating a high amount of easily leached Ni. The leaching increases with HCl strength and upon addition of  $MgCl_2$  and the table is sorted in order of increasing Ni extraction. In Test 15 where 1 M HCl and 230 g/l total chloride (260 g/l  $MgCl_2$ ) were used to leach the sample, 66.8% of the Ni was extracted after 2 min. This average over the five tests completed at these conditions (Tests 15a-e), has confidence limits of  $\pm 9.1\%$ . The wider confidence limits

compared to Fe, Mg and Al extraction is due to the error associated with sampling after exactly 2 min, where the leaching rate is fast. As discussed below, Mg solution analyses can not be used for calculating Mg extraction.

Table 4-4: Variation in leaching after 2 min, based on average solution assays

Test	Temp. (°C)	Initial HCl (M)	Total Cl <sup>-</sup> (g/l)	Ni ext (ave. %)	HCl ( ave. g/l)	Fe ext (ave. %)	Mg ext (ave. %)	Al ext (ave. %)
12d,e	60	0.2	7	4.0 ± 0.6	7.0 ± 0.2	1.3 ± 0.1	0.4 ± 0.0	2.5 ± 0.0
10a,b,d,e	80	1	35	25.4 ± 6.4	34.4 ± 0.2	10.1 ± 2.4	4.8 ± 1.5	6.5 ± 1.1
11a,c,d,e	80	1.5	53	32.9 ± 5.7	52.3 ± 0.8	13.0 ± 1.8	7.3 ± 1.4	7.9 ± 1.0
14a,b,c,d,e	80	0.2	150	29.7 ± 21.4	6.8 ± 0.1	8.8 ± 2.5	4.8 ± 1.8	9.6 ± 2.0
16a,b,c,d,e	80	0.2	230	54.6 ± 12.2	6.6 ± 0.1	20.5 ± 5.1	83.0 ± 214	13.6 ± 0.6
15a,b,c,d,e	80	1	230	66.8 ± 9.1	34.0 ± 0.3	36.4 ± 3.6	-62.2 ± 206	19.9 ± 1.3

#### 4.6 Error and Repeatability

Some observations can be made from the repeat data presented in Table 4-4 to determine the confidence in reported Ni extractions and the error associated with the test procedure combined with analytical error. Acid concentration analyses varied by less than 1 g/l between repeat tests. Fe and especially Al extraction showed good repeatability. Mg repeatability was good in all but Tests 15 and 16. In these tests the Mg concentration was high due to the addition of MgCl<sub>2</sub> (261 and 299 g/l, respectively) and the small increases from additional Mg leached are not significant, leading to erroneous results. In the other tests where no MgCl<sub>2</sub> was added, Mg extraction was repeatable. Ni extraction showed less favourable repeatability, with Tests 14 and 16 varying by more than 10%.

Using this information, it is concluded that the confidence in reported Ni extraction is in the range 5-10%. This is a conservative conclusion as solution analyses were used.

Two tests run under the same conditions (12 and 17) yielded ultimate Ni extraction based on solids' analyses of 57 and 51%, respectively. These can be regarded as the same, as the variation is within the established 5-10% confidence limit of Ni extraction.

#### 4.7 Objective 1: Leaching Selectivity

Figure 4-7 shows data from all tests performed in this study. The selectivity ratios of Ni extraction over Fe and Mg extractions are plotted against the final Ni extraction achieved. A maximum of 2.6 for Ni/Mg selectivity was calculated and a maximum of 5.8 for Ni/Fe

selectivity. There is a general trend that selectivity over both Fe and Mg decreases under conditions resulting in higher Ni extraction.

The increased selectivity at lower Ni extraction corresponds to weak leaching conditions where acid concentration is low (0.2 M), temperature was low (60°C) or leaching time was short (10 min). Under conditions yielding Ni extraction at acceptable levels (above 90%), no significant selectivity over Mg or Fe was seen (i.e., the selectivity ratio approaches unity).

Shorter residence times could have resulted in mainly the loosely-bound Ni being leached and upon further contact, more of the mineral grain was broken down leading to more Fe and Mg leaching at longer residence times, and hence, less favourable selectivity.

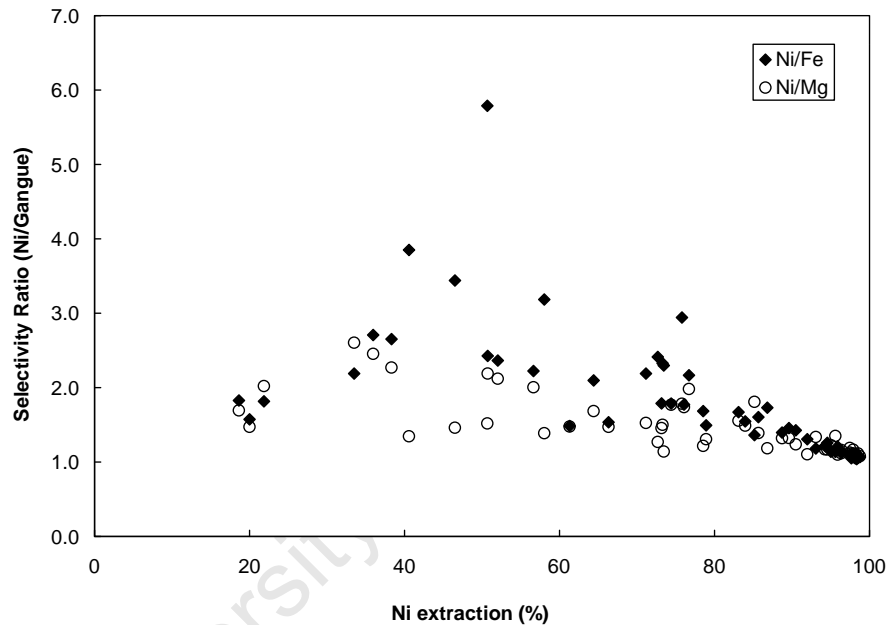


Figure 4-7: Selectivity ratios under various leaching conditions

Figure 4-8 shows the same results as Figure 4-7 with metal extraction (not ratio) results arranged in order of increasing Ni extraction where solids' analyses were used (test durations 10 min and longer). Corresponding to lower Ni extractions is Mg extraction which is higher than Fe extraction. Under conditions leading to Ni extractions from 40 to 92%, Mg extraction is on average  $10 \pm 4\%$  more than Fe extraction (significant with  $> 99\%$  confidence). At higher Ni extractions Fe extraction is marginally larger than Mg extraction by on average  $3 \pm 2\%$  (significant with  $> 98\%$  confidence). This could be due to the serpentine phase being more quickly leached and Ni associated with Mg being leached first followed by breakdown of the Fe-bearing minerals releasing the remainder of the Ni. This supports mineralogical observations discussed in Section 4.8.3.

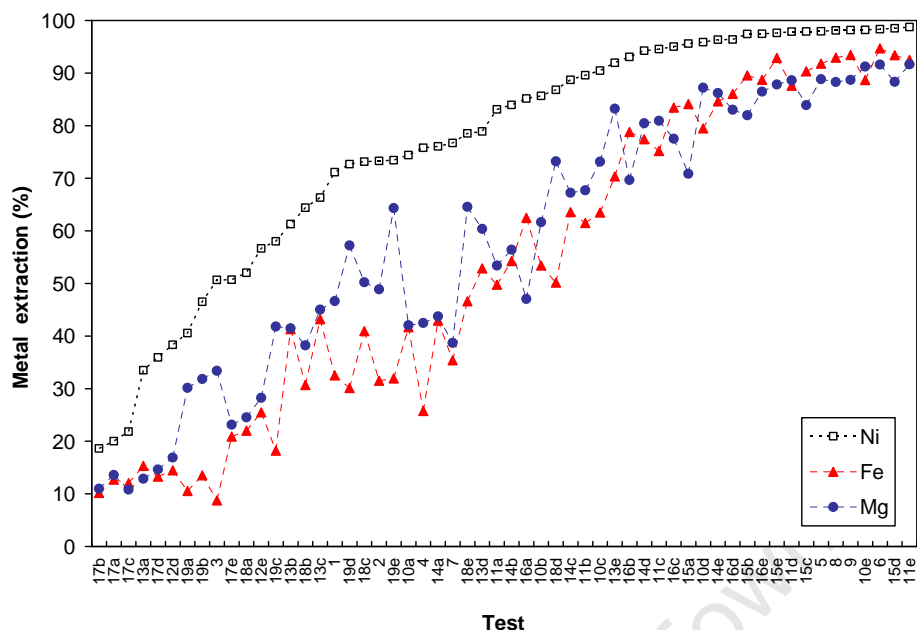


Figure 4-8: Ni, Fe and Mg extraction for all tests

Comparing these data to those reported by Jaguar Nickel for their laterite testwork, some differences are observed. Table 4-5 summarises graphed data presented by Jaguar Nickel [21] which shows that at comparable Ni extractions, selectivity over Fe an order of magnitude higher than in this study was observed. Selectivity over Mg is similar to that observed in the current study. Selectivity decreased with increased Ni extraction, corresponding to stronger leaching conditions, as in the current study. Higher acid strength was required to effect acceptable Ni extraction (over 90%) than in the current study due to the increased limonitic nature of the Jaguar Nickel laterite. Limonitic laterites are more difficult to leach than saprolytic laterites due to the more weathered lattice structure and decreased content of soluble components.

Table 4-5: Jaguar Nickel results – metal extraction as a function of initial acidity at 230 g/l total Cl<sup>-</sup>, 4 h leach time and 100°C [21]

[HCl]	Ni extraction (%)	Fe extraction (%)	Mg extraction (%)	Ni/Fe	Ni/Mg
1	60	2	20	30	3
1.5	70	2	35	35	2
2	82	2	50	41	2
3	90	30	62	3	1
5	95	60	82	2	1

Jaguar Nickel claimed that selectivity over Fe is due to lowered water activity combined with the high solubility of base metal chloride salts. Effectively the brine solution has insufficient

capacity to hold high levels of ferric Fe in solution, since ferric Fe has the lowest pH of hydrolysis of the ions present [21].

It can therefore be concluded that the selectivity effects reported by Jaguar Nickel are specific to the ore studied, rather than generically applicable to saprolytic laterite ores.

#### 4.8 Objective 2: Fundamental Examination

The P-H Model was used to investigate activity effects in the leaching solutions. As described in Section 3.7.3, density measurements were required for use in the activity model. These measurements are presented first, followed by the outcomes of the P-H Model and the validation testwork.

##### 4.8.1. Density measurement

No high temperature measurements for the ternary system H<sub>2</sub>O-HCl-MgCl<sub>2</sub> were found in literature. Thus, density measurements were made in order to correctly relate solution molality and molarity for use in the P-H Model. Figure 4-9 shows the results of the density measurements made in order to obtain an equation to describe the solution density of the ternary system H<sub>2</sub>O-HCl-MgCl<sub>2</sub> up to 2.5 M HCl or MgCl<sub>2</sub>. Literature values [73] were used for water and binary mixtures. Less than 0.5% deviation from literature values for the single-component mixtures was obtained. Refer to Appendix C.

An equation fit was developed using a curve-fitting programme (Table Curve 2D) to fit the experimental data obtained. The density (kg/l) can be predicted using Equation 4-1 with concentrations in molarities and temperature in degrees Celsius:

$$\rho = (a + b(T-20)^{1.5} + c[\text{HCl}] + d[\text{MgCl}_2])^{0.5} \quad \text{Eq. 4-1}$$

where: a = 0.9953

b = -0.0001

c = 0.0341

d = 0.1546

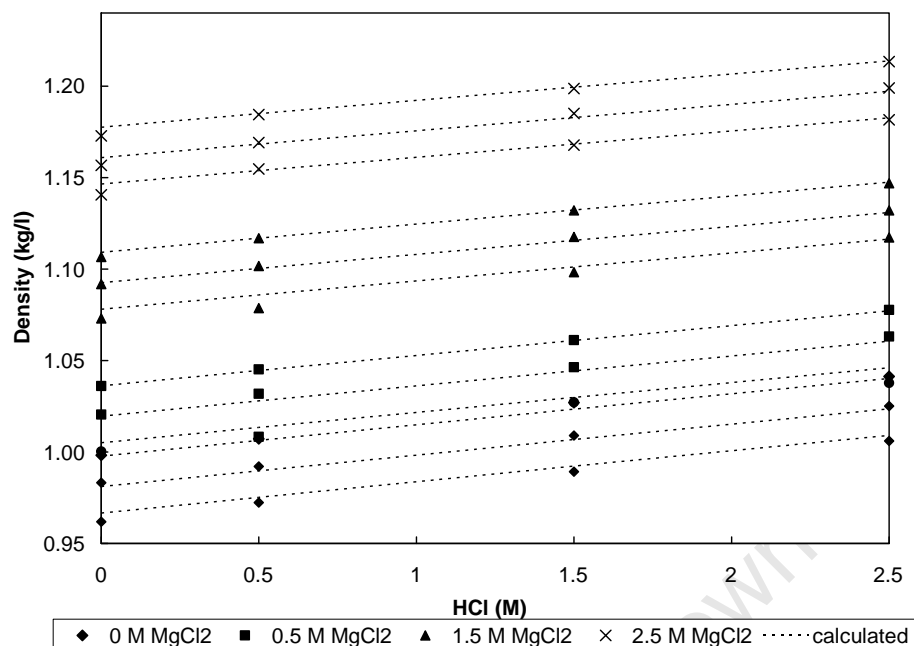


Figure 4-9: Density measurements (points) and fit of Eq. 4-1 (curves)

This density equation was used in the P-H Model as part of the inputs describing the ternary system in order to relate the calculated molalities to practical molarities.

#### 4.8.2. The P-H Model for predicting activity

Refer to Appendix B for all pH data. Four pH readings were measured/generated from different leach test solutions:

- pH was measured at room temperature using a standard combined pH electrode calibrated in the conventional manner with standard buffers.
- The same combined electrode was used, but calibration and sample solutions were heated to the temperature the leach test took place. This indicates the effect of temperature on pH.
- pH was measured at the leach temperature using the split electrode system calibrated, with HCl solutions, using the P-H Model at the leach temperature.
- Theoretical pH was predicted by the P-H Model.

The predicted pH should be the most representative of the true solution pH. If the model was at a sufficient stage of development, then the measured pH ( $\text{pH}^c$ ) should be similar to the predicted pH ( $\text{pH}^d$ ).

Figure 4-10 shows the room temperature pH ( $\text{pH}^a$ ) and that measured at the leach temperature ( $\text{pH}^b$ ). The pH is slightly elevated if measured at the leach temperature.

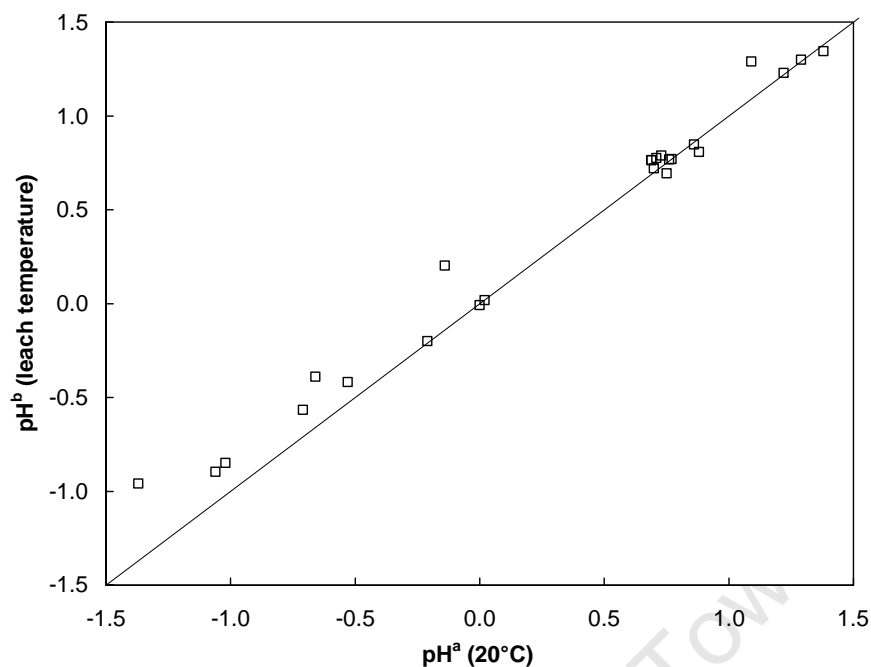


Figure 4-10: Standard pH measurements at different temperatures

*a* – combined electrode, standard buffers, 20°C

*b* – combined electrode, standard buffers, at temperature

Figure 4-11 shows the measured ( $\text{pH}^c$ ) and predicted ( $\text{pH}^d$ ) pH. The points where there is good agreement between measured and predicted pH correspond to solutions which had no  $\text{MgCl}_2$  present. This means the P-H Model predictions for the ternary system need to be refined, but that the binary system is well described. Thus, single-ion activity predictions could not be used with a high level of confidence. Mean HCl activity can be predicted with more confidence as no extra-thermodynamic assumptions are required and these data were used in lieu of single ion data.

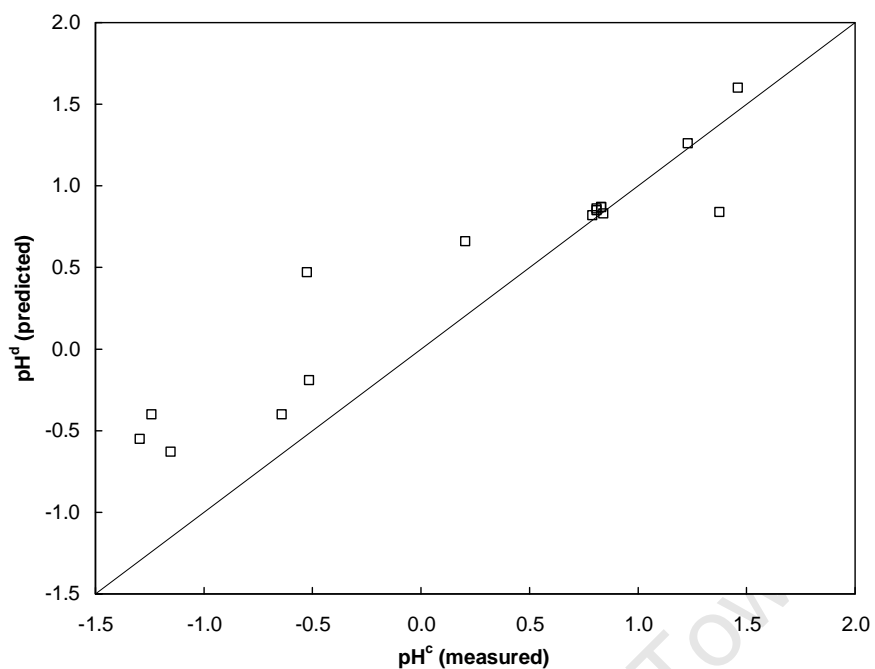


Figure 4-11: Measured and predicted pH using the P-H Model

*c* – split electrode, P-H buffers, at temperature

*d* – P-H Model prediction

Table 4-6 summarises the P-H Model predictions of HCl activity data for conditions used in this study (60, 80 and 95°C) and those used by Jaguar Nickel (100°C). The contribution of the chloride ion to the mean activity is seen as significantly less than that of the proton and the mean HCl activity can therefore be considered indicative of the proton activity.

Table 4-6: HCl activity predicted by the P-H Model

Temperature (°C)	HCl (M)	MgCl <sub>2</sub> (M)	Stoichiometric mean activity coefficient
60	0.20	0	0.74
80	0.20	0	0.73
80	0.20	2.0	3.40
80	0.20	3.1	9.49
80	1.0	0	0.72
80	1.0	1.6	2.81
80	1.0	2.7	7.83
80	1.5	0	0.77
80	1.5	1.4	2.49
80	1.5	2.5	6.94
95	0.2	0	0.71
100	1.0	2.7	5.21
100	1.5	2.5	4.70
100	2.0	2.2	4.24
100	3.0	1.7	3.46
100	5.0	0.7	2.28

Figure 4-12 shows the predictions of mean activity coefficients for HCl by the P-H Model (Table 4-6) graphically. The effect of HCl concentration, MgCl<sub>2</sub> concentration and temperature on HCl activity can be seen. There were five tests where no MgCl<sub>2</sub> was added. These have data labels of "0" and three of the tests at 0.2 M HCl, but different temperatures, fall on the same point. Where no MgCl<sub>2</sub> was added, the acid concentration was slightly less than the acid activity as predicted by the P-H Model and shown in Figure 4-12. Using 0.2 M HCl, the effect of increasing MgCl<sub>2</sub> to 2 and then 3.1 M can be seen on the increasing HCl activity. Effectively, a 'stronger' acid results on addition of 3.1 M MgCl<sub>2</sub> to 0.2 M HCl than by using 1.5 M HCl. The same is seen at higher HCl concentrations. As acid strength is increased, lower concentrations of MgCl<sub>2</sub> are required to effect the same increase in acid activity. Where Jaguar Nickel used the same conditions as used in this study, the P-H predicted acid activities are lower due to the effect of higher temperatures (100°C) used in the Jaguar Process.

All these effects are as predicted by theory, illustrated in Figure 1-2 and Figure 2-1.

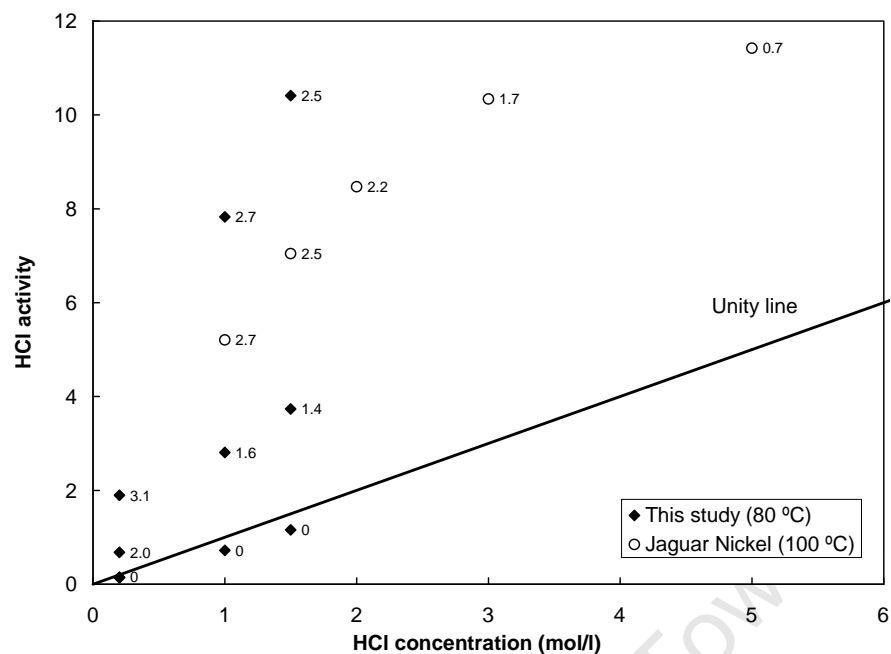


Figure 4-12: Mean HCl activity at various conditions as predicted by the P-H Model (Data labels show MgCl<sub>2</sub> molar concentration)

Figure 4-13 shows selectivity ratio data from this study and those from Jaguar Nickel as a function of the HCl activity. In both cases there appears to be no relationship between increasing HCl activity and selectivity for Ni over either Fe or Mg.

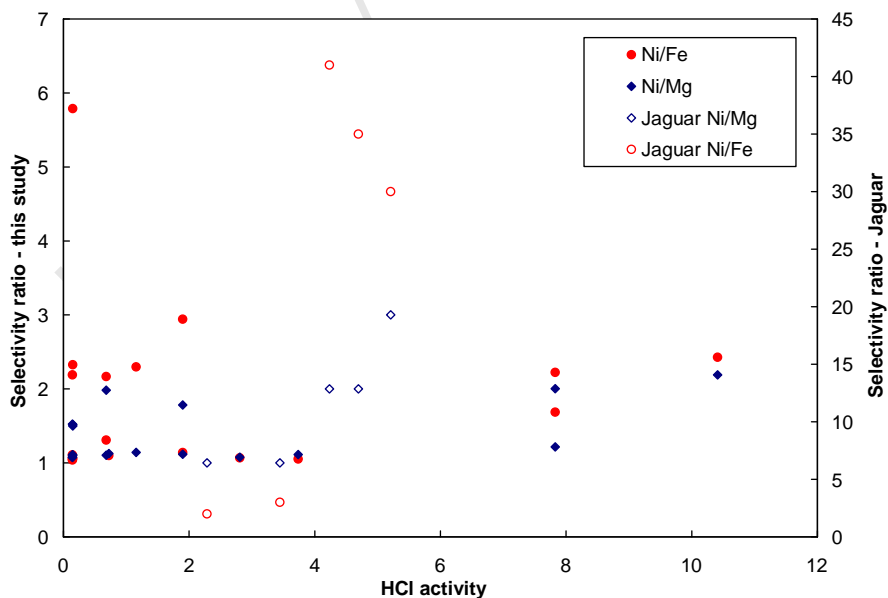


Figure 4-13: Selectivity ratios as a function of HCl activity

### 4.8.3. Mineralogical observations

Appendix D contains the mineralogical analyses. As shown in Table 3-1, the Barro Alto laterite sample used in this study consisted mainly of serpentine/altered serpentine  $[(Mg,Fe)_3Si_2O_5(OH)_4]$  at 74 wt.% and Fe-hydroxides  $[FeO(OH)\pm FeO(OH).xH_2O]$  at 8 wt.%.

The semi-quantitative EDS point mineral analyses identified the mineral phases that host Ni and the mean concentration of the Ni in each of these Ni-containing phases [76].

Table 4-7: Ni distribution in Barro Alto WTO acido laterite

Mineral Phases	Mean Ni Concentration	Ni Distribution
	wt. %	%
Serpentine/altered serpentine	1.65	72.6
Fe-hydroxides	2.00	9.5
Clay	2.25	5.5
Olivine	0.40	0.2
Mn-hydroxide	12.95	3.1
Other	n.a.	9.1
Total		100.0

Table 4-7 shows that most of the nickel is hosted by the serpentine/altered serpentine phase, but the Ni hosted in the Fe-hydroxide phase is present in slightly higher concentrations. The minor Mn-hydroxide phase has significant enrichment of Ni.

The same semi-quantitative EDS point mineral analysis was done on selected leach test residues focusing on the change in the two main mineral phases. Table 4-8 summarises the mean Ni content in the phases after 10 min of leaching. The serpentine/altered serpentine phase was identified as Mg-silicates after leaching. The average head grade of Ni was 1.68%. Due to the lower abundance of Fe-hydroxides, the leaching of this phase led to insignificant remaining points to determine mean Ni accurately and in some cases the phase was completely destroyed.

Table 4-8: Destruction of the main mineral phases during leaching

Test	Mean Ni content in serpentine after 10 min leach	% decrease	Mean Ni content in Fe-hydroxides after 10 min leach	% decrease
10a	0.54	68	1.26	37
11a	0.34	80	0.80	60
14a	0.53	68	–	–
15a	0.32	81	0.66	67
16a	0.18	89	–	–

There are too few data to accurately determine if the serpentine phase is preferentially leached than the Fe-hydroxide phase, but after 10 min of leaching, the serpentine phase appears to be more depleted of Ni than the Fe-hydroxide phase as shown by the % decrease in average Ni content.

Quantitative Electron Microscopy Scan (QEMSCAN) analyses on three kinetic samples from two tests showed the changes in mineral abundance. Interpretation of the data is complicated due to the variety of leach products generated and the variety of laterisation in the head sample. Figure 4-14 shows the serpentine phase being destroyed during leaching, but the Fe-hydroxide phase remaining at constant abundance during the first 30 min of leaching in these two tests. If this phase is being destroyed, other leached material may be appearing as Fe-hydroxides resulting in an apparent constant abundance.

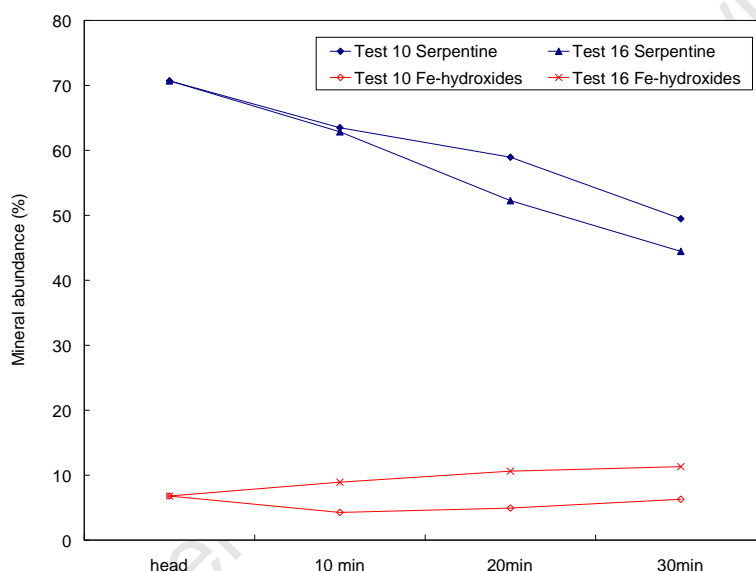


Figure 4-14: Decrease in the main mineral phases during leaching

When investigating sulfuric acid pressure leaching of laterites, Rubisov *et al.* [54] investigated blends of limonitic and saprolytic laterite ores. The saprolytic phase (mainly Mg minerals) dissolved very quickly in sulfuric acid while the limonitic phase (mainly Fe minerals) leached slower. In the kinetic modelling, instantaneous dissolution of the Ni associated with the Mg was assumed, followed by dissolution of Ni associated with the Fe (goethite).

#### 4.8.4. Preliminary kinetic modelling

The data from Tests 10-19 were used for this preliminary kinetic study as these tests were performed under the most controlled conditions using 0.5% solids' concentration and solids' analyses were used for kinetic information. The effect of each parameter was investigated in

turn and a simple empirical model was developed to describe the initial rate (0-20 min) of Ni leaching.

**Effect of acid concentration**

Tests 10, 11 and 13 show the effect of increased acid concentration and the extraction curves are presented in Figure 4-15.

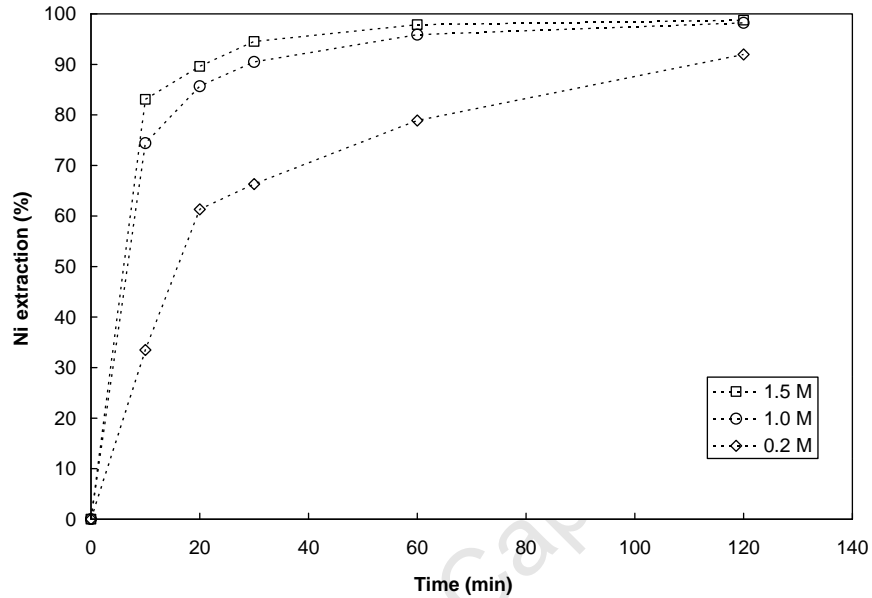


Figure 4-15: Effect of H<sup>+</sup> concentration on Ni extraction

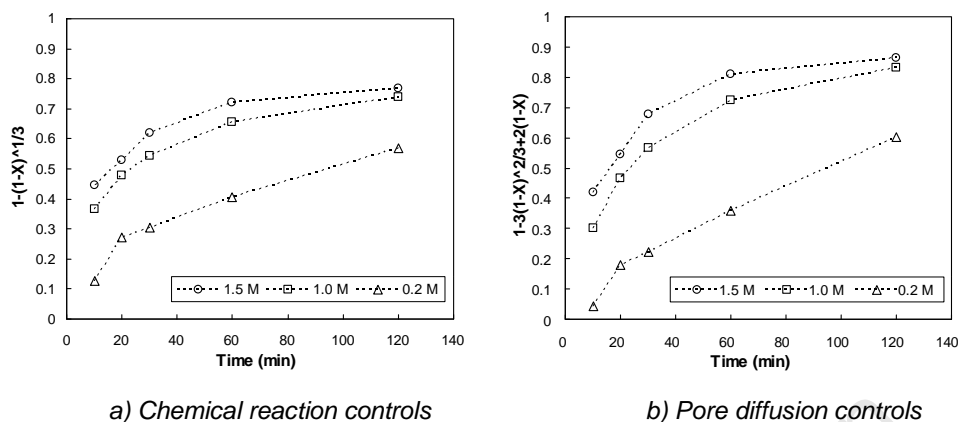
<i>D<sub>90</sub></i>	40
<i>% solids</i>	0.5
<i>Temp.</i>	80°C
<i>[MgCl<sub>2</sub>]</i>	0

Figure 4-16 shows a graphical fit of the shrinking core model for a) reaction controlling (also for shrinking particle) and b) pore diffusion controlling scenarios. These models are not representative of the system and this is expected due to the non-uniformity of both the minerals and the particle sizes. However, some investigators have used shrinking core models to explain laterite leaching data as reviewed in Section 2.4.3. In these cases the ore type was limonitic which is more homogeneous and slower to leach. In this study the initial rate of Ni leaching is fast.

Shrinking core models have been used extensively with much success in leaching systems. However, there is no way to specifically predict the rate-controlling regime of a given system. Pore diffusion and the nature of electrolytes and complex formation are being shown to influence the application of the shrinking core models thus more studies are focussing on the role of these [72].

Although some effort was taken to prepare a sample of as narrow a particle size range as possible, the distribution of particle size was wide (Figure 3-1). Thus the shrinking particle

model, which was developed for particles of a single size (either small or large), can not be applied. Integration over all particle sizes would be necessary, but was beyond the scope of this study.



a) Chemical reaction controls b) Pore diffusion controls  
Figure 4-16: Shrinking core and particle models fitted to data showing effect of HCl concentration

A similar change in slope after 30 min of leaching was seen by Das *et al.* [42] after 2 h of leaching. The higher deviation from shrinking core kinetics was explained as being due to an increasingly significant decrease in excess acid.

In order to model the initial rate (0-20 min) of Ni leaching, the differential approach was used as discussed in Section 2.4.2. Appendix E contains tables of the kinetic calculation data. The initial rate sharply differs from the rate measured from 20 min onwards in all leach tests. This is likely to correspond to the initial leaching of easily-available nickel loosely bound in the lattice and subsequent slower leaching of the other mineral phases. The kinetic parameters were established from a plot of  $\ln [H^+]$  vs.  $\ln$  [initial rate], shown in Figure 4-17.

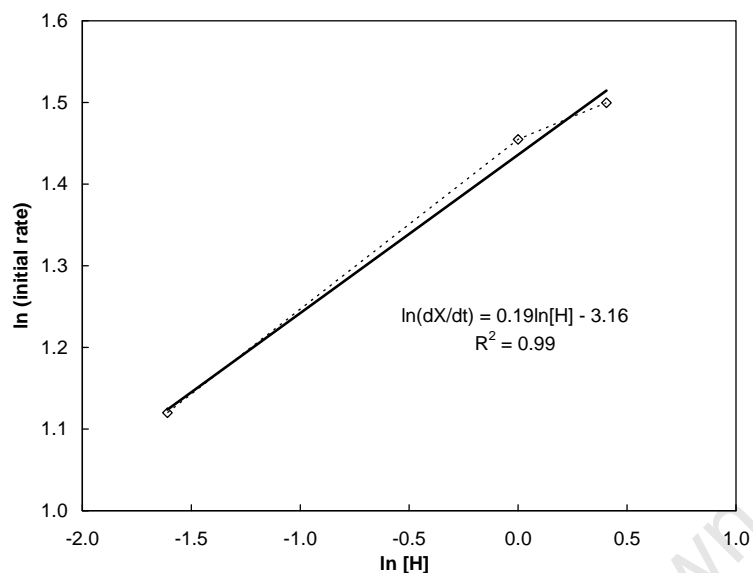


Figure 4-17: Plot to obtain reaction order and pseudo rate constant for effect of  $H^+$  concentration

From Figure 4-17 the pseudo rate constant,  $k' = 0.042 \text{ M}^{-0.19} \cdot \text{min}^{-1}$  and the reaction order with respect to  $H^+$  concentration,  $n = 0.19$ , are deduced.

#### **Effect of total chloride concentration**

The effect of total  $\text{Cl}^-$ , as adjusted with  $\text{MgCl}_2$ , at constant acid concentration, was tested in Tests 13, 14 and 16, and can be seen in Figure 4-18. Increased  $\text{MgCl}_2$  has a similar effect on Ni extraction to increased HCl. This was not observed by Jaguar Nickel where total chloride concentration was seen to have negligible effect on Ni extraction at constant initial acidity.

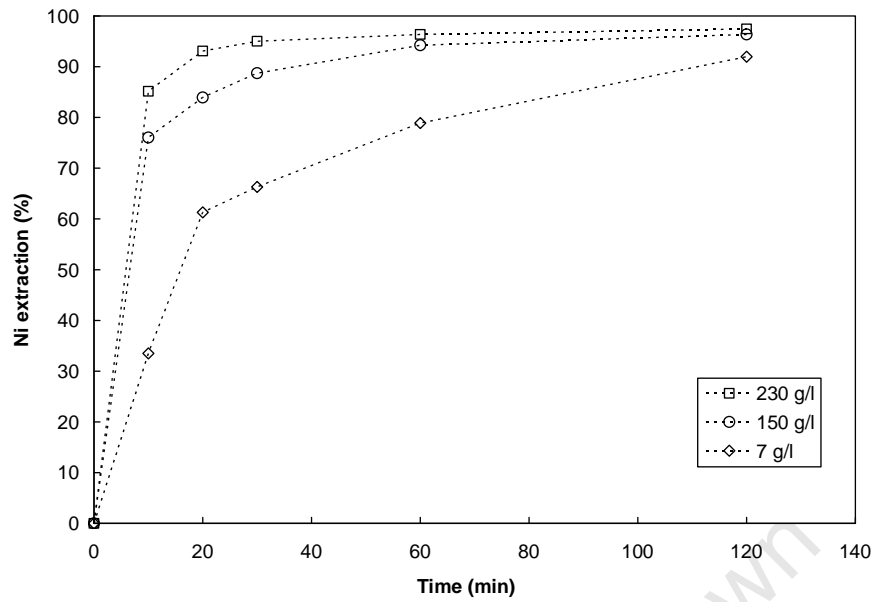


Figure 4-18: Effect of total  $Cl^-$  concentration on Ni extraction

$D_{90}$	40
% solids	0.5
Temp.	80°C
[HCl]	0.2 M

As above, Figure 4-19 was used to obtain the kinetic parameters for the effect of chloride concentration on the initial rate of Ni leaching.

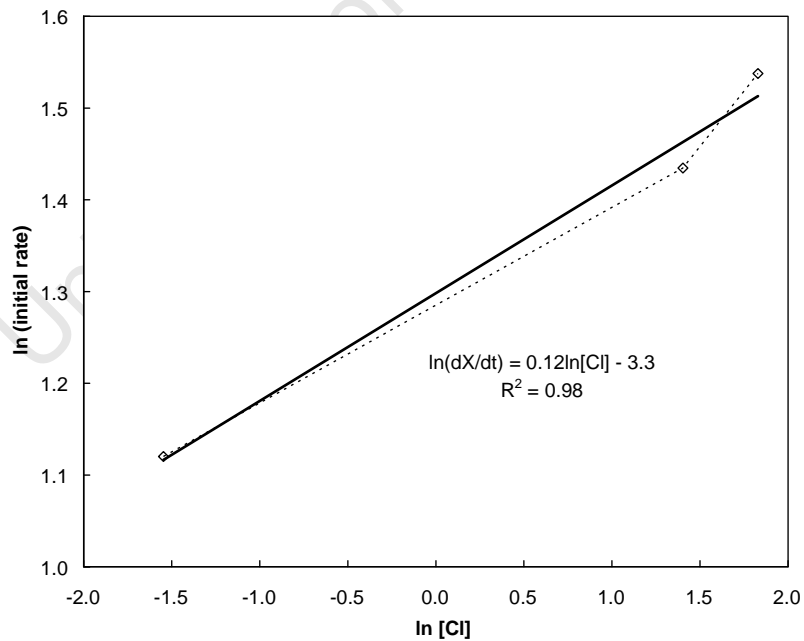


Figure 4-19: Plot to obtain reaction order and pseudo rate constant for effect of  $Cl^-$  concentration

From Figure 4-19, the pseudo rate constant,  $k'' = 0.037 \text{ M}^{-0.12} \cdot \text{min}^{-1}$  and the reaction order with respect to  $\text{Cl}^-$  concentration,  $n = 0.12$ , are deduced.

### Effect of temperature

The effect of temperature can be seen in Figure 4-20. Tests 13, 17 and 18 are represented. The final test 'e' of Test 18, representing 120 min and 95°C, shows an unexpected result of lower Ni extraction (79%) than the equivalent 80°C test (92%). Much lower Ni extraction was observed at 60°C.

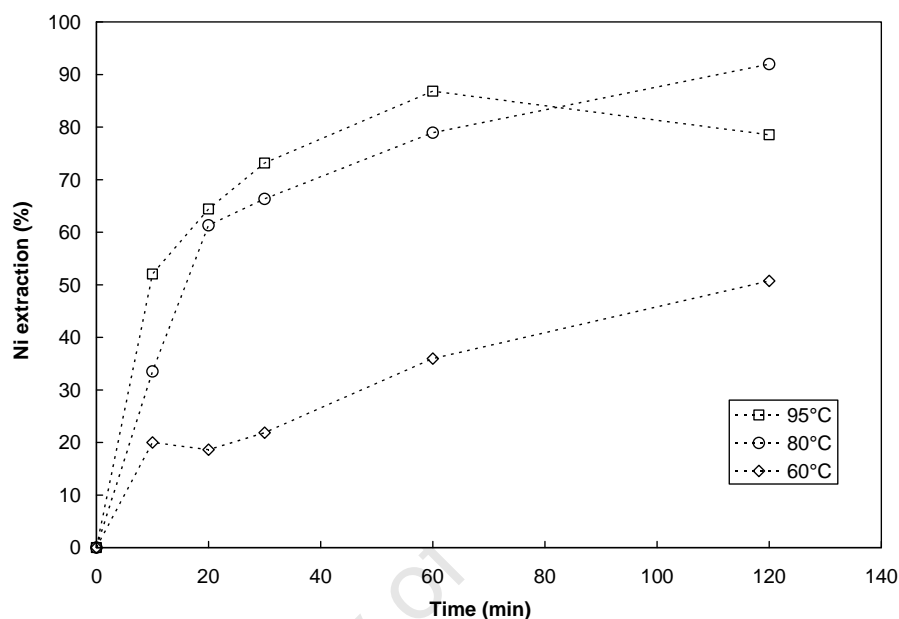


Figure 4-20: Effect of temperature on Ni extraction

$D_{90}$	40
% solids	0.5
$[\text{MgCl}_2]$	0
$[\text{HC}]$	0.2 M

Using Eq. 4.2 in logarithmic form, a plot of  $\ln$  (initial rate) versus  $1/T$  yielded a curve; a straight line drawn through the three points gives a slope equivalent to  $-E/R$  and intercept giving  $A$  as shown in Figure 4-21. The  $R^2$  value of 0.86 falls outside the generally accepted value of 0.9+ used to test kinetic parameters. This might be a result of the errors associated with Ni extraction values as discussed in Section 4.6 or solution composition variation as discussed in Section 4.3. However, with only three points, the non-elementary nature of the leaching reaction and mineralogical effects complicating the interpretation of kinetic data, this lack of fit is expected.

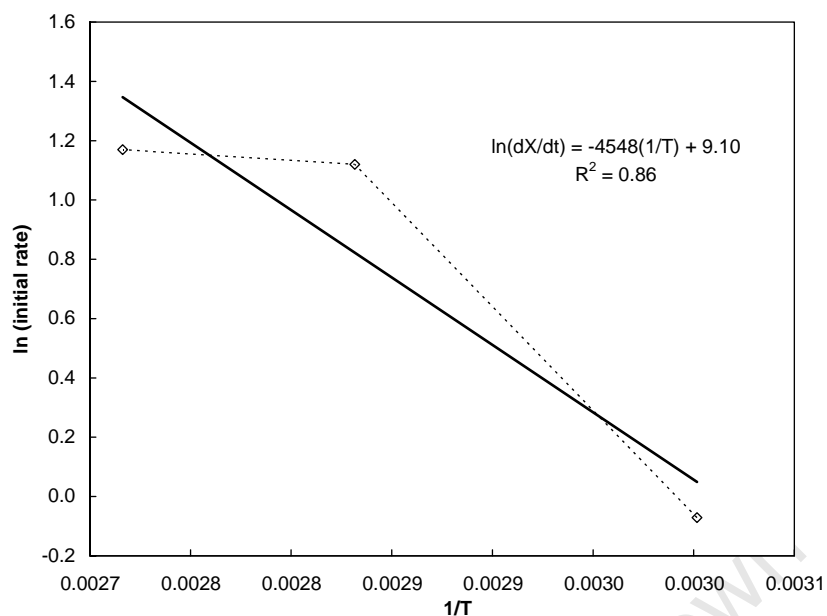


Figure 4-21: Plot to obtain Arrhenius parameters

The value obtained for E of 38 kJ/mol can not be used to indicate possible rate-determining steps given the mineralogical observations that the Ni is contained in more than one mineral phase likely with differing reactivities.

As the temperature increases, reaction mechanisms commonly move from the chemical controlled region into the mixed region and ultimately into an entirely mass transfer controlled region [65]. More data points would indicate if this is the case for this study, however such detail is beyond the scope of this preliminary kinetic study.

#### **Effect of solids' concentration**

Comparing tests where the only variable was the solids' concentration, it can be seen that increasing solids' concentration decreases Ni extraction. The effect was seen at two different temperatures: 95°C (Table 4-9) and 80°C (Table 4-10). This would be due to the consumption of reagent (HCl) and leaching is seen to be suppressed due to the reagent running out. One difference between the tests is the leaching time – this was longer for tests at higher solids' concentrations. This is not seen as a problem as the longer leaching time was insignificant compared to the effect of limited reagent, and still resulted in decreased leaching.

Table 4-9: Effect of solids' concentration of Sample A at 95°C, 0.2 M HCl, 0 M MgCl<sub>2</sub>

Test	18 0.5% solids	1 2% solids	3 5% solids
Ni extraction (%)	79	71	51

Table 4-10: Effect of solids' concentration of Sample A at 80°C, 0.2 M HCl, 0 M MgCl<sub>2</sub>

Test	13	2
	0.5% solids	2% solids
Ni extraction (%)	92	73

This result highlights the importance of conducting experiments under constant solution conditions in order to obtain correct information. Decreased leaching in other systems has before been misinterpreted as caused by particle surface passivation when in fact it is a result of the depletion of the lixiviant.

As mentioned above the Ni extraction after 120 min at 95°C is unexpectedly low and following the trend of the shorter tests conducted at 95°C, should be around 90%, and not 80% (See Figure 4-20). Thus the extraction using 0.5% solids can be regarded as the same, namely 90%, at both temperatures.

#### Effect of particle size

The difference in Ni extraction between using Sample A (Test 19) and Sample B (Test 13) is shown in Figure 4-22. A 19% increase in ultimate Ni extraction is observed at the finer particle size. This indicates that a larger particle surface area increases extraction and the leaching may be affected by mass transport in solution, however there are not enough data to conclusively demonstrate this. The finer grind may have exposed certain mineral species that led to increased Ni leaching.

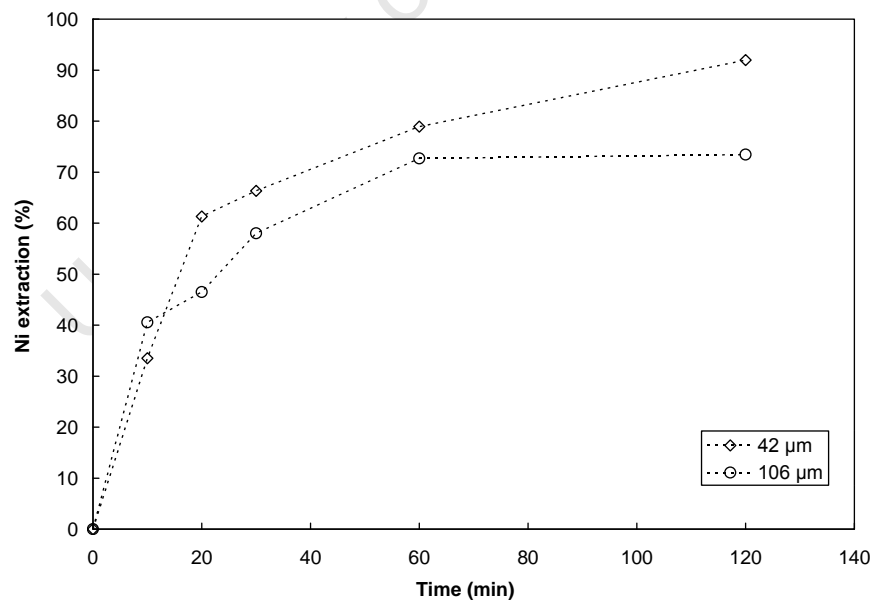


Figure 4-22: Effect of particle size on Ni extraction

% solids	0.5
temp.	80°C
[HCl]	0.2 M
[MgCl <sub>2</sub> ]	0

### Effect of HCl activity

Tests with varying HCl and  $MgCl_2$  concentration (Tests 10, 11, 13-16) were used when investigating the effect of HCl activity. There is an increase in Ni leaching and the rate of Ni leaching with increasing HCl activity as shown in Figure 4-23.

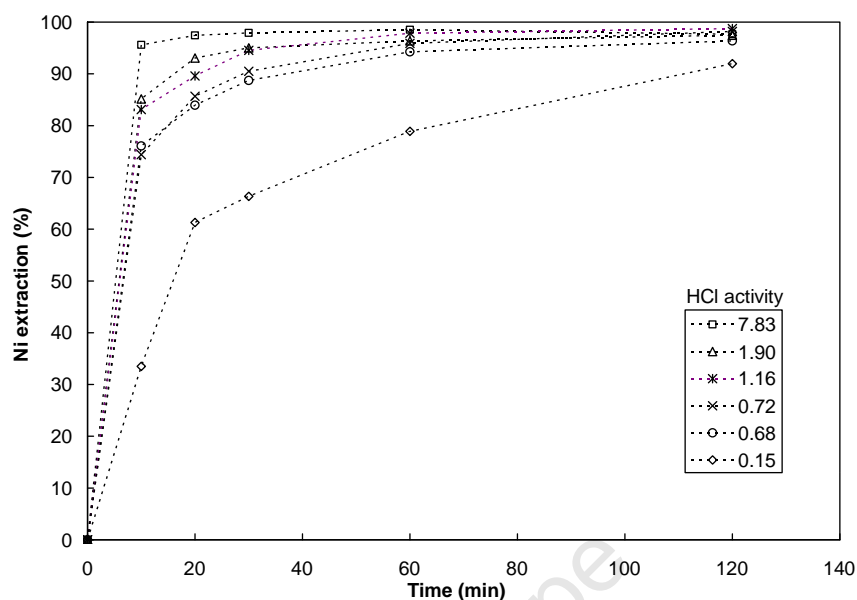


Figure 4-23: Effect of HCl activity on Ni extraction

$D_{90}$	40
% solids	0.5
temp.	80°C

Figure 4-24 does not show a trend. There is a stronger correlation between acid concentration and the initial rate of Ni leaching (Figure 4-17). Even though the manipulation of activity in solution is real (Figure 4-12), it does not appear to directly affect leaching rates. The leaching rate is more strongly dependant on the acid concentration. Concentration data were therefore used in the empirical model development. This is contrary to the conclusions of similar studies by Majima and Awakura [50] in which leaching rates were better described by activity and not concentration data.

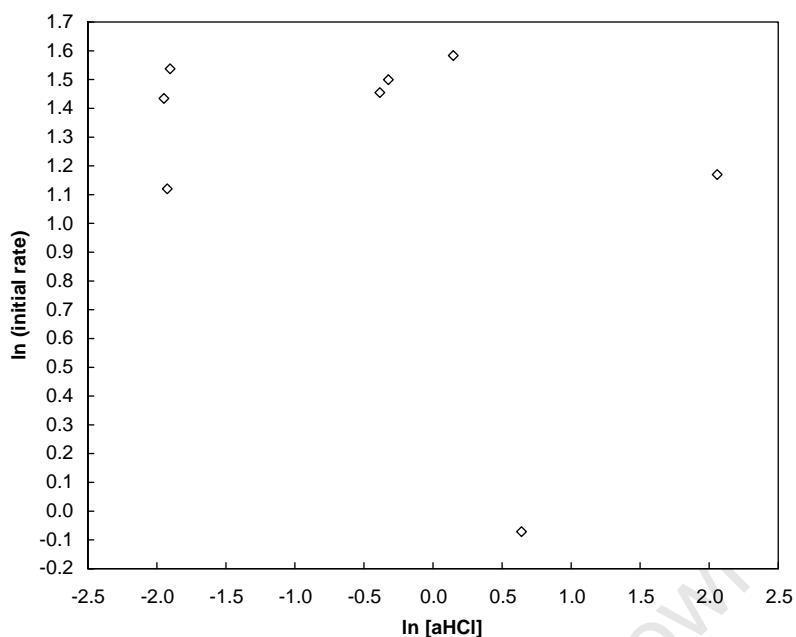


Figure 4-24: Plot to obtain reaction order and pseudo rate constant for effect of HCl activity

#### Empirical rate equation

A preliminary empirical model to describe the initial leaching rate (0-20 min) of Ni in chloride solutions from Barro Alto saprolytic laterite was developed. Substituting conditions from all tests, a rate constant K was calculated, shown in Table 4-11. An optimised K ( $M^{-0.31} \cdot \text{min}^{-1}$ ) was calculated by minimising the sum of squared errors between the calculated and measured initial rates. The initial rate of Ni leaching (% Ni extraction per min) for varying HCl and  $\text{MgCl}_2$  concentrations (M) and temperatures (K) can be described by the following rate expression:

$$d[\text{Ni } \%]/dt_{\text{initial}} = 4.47 \cdot [\text{H}^+]^{0.19} \cdot [\text{Cl}^-]^{0.12} \cdot \exp(-37.8/R.T) \quad \text{Eq. 4-2}$$

Table 4-11: Calculated and measured rate constants

Test	Temperature (°C)	[HCl] (M)	[Cl <sup>-</sup> ] <sub>TOTAL</sub> (g/l)	K ( $M^{-0.31} \cdot \text{min}^{-1}$ )	Calculated initial rate (%/min)	Measured initial rate (%/min)	Relative error (%)
13	80	0.2	7	5.13	2.67	3.07	15.0
17	60	0.2	7	1.57	2.65	0.93	64.8
18	95	0.2	7	5.33	2.70	3.22	19.3
10	80	1	35	4.38	4.37	4.28	-1.9
11	80	1.5	53	4.02	4.97	4.48	-9.9
14	80	0.2	150	5.05	3.71	4.20	13.2
16	80	0.2	230	5.38	3.86	4.65	20.6
	<b>Ave. K:</b>				<b>4.41</b>		
	<b>Optimised K:</b>				<b>4.47</b>		

It is clear that Test 17 (60°C, 0.2 M HCl) is governed by a different mechanism to the other tests as the rate constant of 1.6 is very different from the average of 4.4. Figure 4-20 shows a large difference in Ni leaching at 60°C compared to that at 80 and 95°C.

Considering Test 15, which was not used in the development of the rate expression, the measured initial rate was 4.87%Ni/min. Using Equation 4-2, the calculated initial rate is 5.32%Ni/min (a relative error of 9%) and rate constant  $4.04 \text{ M}^{-0.31} \cdot \text{min}^{-1}$ . This is considered acceptable.

In this study, the calculated initial rate does not necessarily represent an accurate leaching rate as the leaching is very fast with close to 90% Ni conversion achieved within 10 min in some cases.

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## 5.0 Conclusions and Recommendations

### 5.1 Objective 1: Leaching Selectivity

The leach tests performed using the Jaguar Process conditions showed no appreciable selectivity for nickel leaching over magnesium or iron leaching at economical nickel recoveries. The Jaguar Process selectivity was thus not repeatable on the ore tested. The selectivity seen by Jaguar Nickel may have been a result of the unique mineralogy of the laterite body to be exploited. The Jaguar Nickel ore is geologically immature and Ni may have been contained in minerals which broke down more easily than the main Fe and Mg-bearing minerals.

It is concluded that in order to achieve selective leaching, the laterite mineralogy must be investigated in conjunction with the manipulated solution conditions.

It is possible that the  $\text{MgCl}_2$  background in this study leads to total chloride levels that are high enough to ensure Fe will form  $\text{FeCl}_4^-$ , thus not limiting Fe leaching as suggested by Jaguar Nickel, and that this level of Mg does not saturate the solution enough (and is not enough to result in a common ion effect) to sufficiently decrease the water activity to limit Mg leaching.

Due to the difficulties with solution analyses in the high brine conditions, more repeatability tests are recommended to firmly establish the confidence limits of Ni extraction.

### 5.2 Objective 2: Fundamental Examination

A better understanding of the system was achieved. The solution chemistry effects outlined by Jaguar Nickel are real and confirmed by other investigators. However, the many differences in results from this study and of the Jaguar Nickel study reinforce that laterite leaching is complex and highly dependent on ore mineralogy. Direct comparisons between leaching conditions on different ores is difficult.

#### 5.2.1. Solution thermodynamics

The P-H Model was still in a developmental stage and the activity data used were seen as provisional until model validation had taken place. The single-ion activities could not be used, but mean HCl activity data from the P-H Model were used. The activity data trends were consistent with theory. However, the HCl activity did not appear to affect leaching selectivity or initial leaching rates as strongly as HCl concentration.

The P-H Model has since been developed and validated using vapour pressure as well as pH measurements to regress the mixing parameters of the HCl-MgCl<sub>2</sub>-H<sub>2</sub>O system. Densities in the ternary system are now predicted using OLI Stream Analyser software. It is recommended that further work make use of the improved model.

### 5.2.2. Laterite mineralogy

Mineralogical analyses indicated different leaching rates of the main mineral phases. Ni contained in the serpentine mineral phase appears to leach more quickly than the Ni contained in the Fe-hydroxide mineral phase. This is expected as the serpentine mineral is less weathered than the Fe-hydroxide minerals. In addition, the main serpentine phase is not uniform and consists of serpentine and altered serpentine, which would display differing reactivities. It is important to note that many leach residue products are formed and identified through quantitative mineral abundance investigations; it is difficult to distinguish between original laterised material and newly-destroyed minerals. Mineralogical studies are very useful and key to understanding leaching behaviour.

Mineralogical studies should remain a focus area.

### 5.2.3. Leaching kinetics

Initial leaching rates were very fast and leaching was not well described by shrinking core or particle models. An empirical model was developed. The leaching kinetics appeared to be influenced by temperature (K), HCl (M) and MgCl<sub>2</sub> (M) concentrations in the following manner (Equation 4-2):

$$\text{initial rate (\% Ni extraction/min)} = 4.47(M^{-0.31} \cdot \text{min}^{-1}) \cdot [\text{H}^+]^{0.19} [\text{Cl}^-]^{0.12} \exp(-37.8/RT)$$

There is an indication that, contrary to published work on other oxides, Ni extraction kinetics obtained in this study appear to be dependent on the HCl concentration and not on the HCl activity.

In further work, more tests should be done to establish confidence in the kinetic study. More than three variations of each parameter are necessary. One method should be used for further leach tests for easier interpretation. Tests using 0.5% solids' concentration should be used in order to obtain the most accurate kinetic data.

The nickel leaching rate from the Barro Alto saprolytic-type ore used in this study was fast. It is recommended that a slower-leaching ore be used in further work to better establish factors affecting initial leaching rates. Due to the fast-leaching nature of the ore, the initial rates were essentially the same and the establishment of a kinetic rate expression was difficult. Alternatively, further studies should exclude evaluating the initial rate as its relevance is questionable. An immediately leachable fraction could be established and

subsequent leaching kinetics could be considered. Ideally, isolation of the mineral phases and particles sizes would enable a more meaningful study.

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## **APPENDIX A**

Leach Test Sheets

University of Cape Town

### Leach Test Results Summary

Test	pulp density (% solids)	Duration (hrs)	T (C)	initial HCl (M)	MgCl <sub>2</sub> (M)	total Cl- (g/l)	HCl consumption (kg/t)	Ni accountability (%)	Ni ext (%)	Mg ext (%)	Fe ext (%)	Selectivity ratio (Ni/Mg)	Selectivity ratio (Ni/Fe)
BLT01	2	3	95	0.20	0	7	234	95%	71%	47%	33%	1.53	2.19
BLT02	2	3	80	0.20	0	7	220	97%	73%	49%	31%	1.50	2.33
BLT03	5	3	95	0.20	0	7	113	93%	51%	33%	9%	1.52	5.79
ST04	2	3	80	0.2	2.015	150	275	110%	76%	43%	26%	1.78	2.94
ST05	2	3	80	1	1.615	150	400	96%	98%	89%	92%	1.10	1.07
ST06	2	3	80	1.5	1.365	150	736	109%	98%	92%	95%	1.07	1.04
ST07	2	3	80	0.2	3.144	230	213	93%	77%	39%	35%	1.98	2.17
ST08	2	3	80	1	2.744	230	421	107%	98%	88%	93%	1.11	1.06
ST09	2	3	80	1.5	2.494	230	792	90%	98%	89%	93%	1.11	1.05
BLT10e	0.5	2	80	1	0	35	774	102%	98%	91%	89%	1.08	1.11
BLT11e	0.5	2	80	1.5	0	53	860	122%	99%	92%	92%	1.08	1.07
BLT12e	0.5	2	60	0.2	0	7	176	94%	57%	28%	25%	2.00	2.22
BLT13e	0.5	2	80	0.2	0	7	355	99%	92%	83%	70%	1.10	1.31
ST14e	0.5	2	80	0.2	2.015	150	482	96%	96%	86%	85%	1.12	1.14
ST15e	0.5	2	80	1	2.744	230	799	96%	98%	88%	93%	1.11	1.05
ST16e	0.5	2	80	0.2	3.144	230	503	101%	97%	86%	89%	1.13	1.10
TT17e	0.5	2	60	0.2	0	7	132	97%	51%	23%	21%	2.19	2.43
TT18e	0.5	2	95	0.2	0	7	391	91%	79%	65%	47%	1.22	1.68
PST19e	0.5	2	80	0.2	0	7	314	113%	73%	64%	32%	1.14	2.30

Test name: BLT01  
 Comment: 95°C baseline, 2% solids

Date: 26-Oct-04

	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46 micron
dry ore added:	24	8.5	2.832	2	2.0	T:	95 °C
stock solution added:	1176	1174.5	1.0013	7.29	6.88	duration:	3 hrs
total slurry in:	1200.0			0.20	0.19	agitation rate:	800 rpm
				0	0	impeller:	pitched blade, 5cm φ, T1
				7.00	7.63	vessel:	2litre, baffled, with reflux cor

Sample	time	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
BLT01-0		0		23.1	0.69	1.0013			
BLT01-2		2	20.49	22.2		1.0021	595	794	brown residue
BLT01-30		30	20.01	22.1		1.0046	621	820	light green pls
BLT01-60		60	19.42	22		1.0051	619	818	clear wash
BLT01-120		120	18.77	22.1		1.0055	608	807	
BLT01-180		180	1073.3	22.3	1.38	1.0060	597	796	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	titrant addition cum. ml	calc. evaporation cum. ml
BLT01-2	18.92	18.88		0.25	0.37	23.5	23.5	22.29	0.9982	22.3		0.53
BLT01-30	17.71	17.63		0.62	0.32	38.26	38.3	38.3	0.9986	38.4		8.02
BLT01-60	17.57	17.48		0.71	0.3	19.95	20.0	19.38	0.9989	19.4		16.04
BLT01-120	16.71	16.62		0.27	0.29	22.68	22.7	22.26	0.9990	22.3		32.07
BLT01-180	1018.8	1012.72	34.98	43.15	16.37	253.93	254.4	220.2	0.999	220.4		48.11

ANALYSES

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
BLT01-180	1.69	0.96	0.19	0.05	0.62	8.58	13.7	0.05	0.66	22	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
BLT01-head liquor	2	2	7.63	2	1	2	6.88	2	2	2	2	2
BLT01-2	13	27.6	6.4	2	1	85.8	6.12	113	3.88	49.9	48.6	18.3
BLT01-30	38	28.6	7.34	3.17	3.45	369	3.79	975	21.2	189	197	8.61
BLT01-60	40.5	27.5	12.4	4.06	3.89	396	2.94	1213	25.3	215	239	4.51
BLT01-120	44.5	28.4	8.23	4.91	4.18	430	2.56	1421	31.2	227	269	4.64
BLT01-180	48.8	30.5	7.63	5.03	4.66	464	2.44	1610	34	253	289	4.22
BLT01-comp. wash	3.9	3.46	1.06	2	1	45	0.5	175	3.98	24.6	25	2.04

CALCULATIONS AND MASS BALANCE

H <sup>+</sup>	assay H <sup>+</sup> (free acid) mol/l	measured pH (autotitrator)	H <sup>+</sup> mol/l	initial H <sup>+</sup> mol/l	residual HCl g
BLT01-0	0.10	0.69	0.14	0.189	2.47
BLT01-2	0.08	1.12	0.08		
BLT01-30	0.07	1.26	0.05		
BLT01-60	0.07	1.35	0.04		
BLT01-120	0.01	1.00	1.00		
BLT01-180					
average	0.07	1.15	0.26		64.5

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	
feed solids	24.00	0.37	0.19	0.03	0.01	0.12	2.23	4.51	0.05	0.40	4.50	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si
head liquor	1176.00	1174.47	0.0	0.0	8.961	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	358.32	359.04										
total IN (g)	1558.32		0.37	0.19	8.99	0.014	0.12	2.24	4.51	0.06	0.40	4.50

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	
BLT01-2	0.37	-	-	-	-	-	-	-	-	-	-	
BLT01-30	0.32	-	-	-	-	-	-	-	-	-	-	
BLT01-60	0.30	-	-	-	-	-	-	-	-	-	-	
BLT01-120	0.29	-	-	-	-	-	-	-	-	-	-	
final residue	16.37	0.28	0.16	0.03	0.01	0.10	1.40	2.24	0.01	0.11	3.60	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si
BLT01-2	18.92	18.88	0.000	0.001	0.121	0.000	0.000	0.002	0.002	0.000	0.001	0.001
BLT01-30	17.71	17.63	0.001	0.001	0.129	0.000	0.000	0.007	0.017	0.000	0.003	0.003
BLT01-60	17.57	17.48	0.001	0.000	0.217	0.000	0.000	0.007	0.021	0.000	0.004	0.004
BLT01-120	16.71	16.62	0.001	0.000	0.137	0.000	0.000	0.007	0.024	0.001	0.004	0.004
final filtrate	1018.80	1012.72	0.049	0.031	7.727	0.005	0.005	0.470	1.630	0.034	0.256	0.293
wash water	322.43	322.79	0.001	0.001	0.342	0.001	0.000	0.015	0.056	0.001	0.008	0.008
cake moisture	27.35	27.38	0.000	0.000	0.000	0.000	0.000	0.001	0.005	0.000	0.001	0.001
evaporation	48.01	48.11	-	-	-	-	-	-	-	-	-	-
total OUT (g)	1505.15		0.33	0.19	8.73	0.01	0.11	1.91	4.00	0.05	0.38	3.92
balance (out/in)	97%		89%	100%	97%	99%	91%	86%	89%	82%	95%	87%

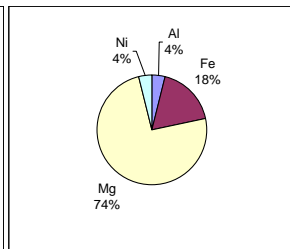
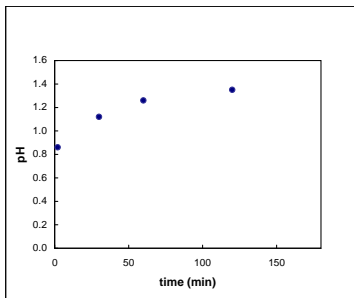
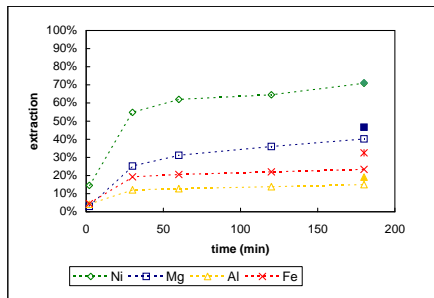
extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT01-2	1173.9	4%	17%	20%	1%	5%	3%	9%	15%	1%	179%
BLT01-30	1166.5	12%	18%	31%	3%	19%	25%	47%	55%	5%	84%
BLT01-60	1158.4	13%	17%	35%	4%	21%	31%	56%	62%	6%	44%
BLT01-120	1142.4	14%	17%	47%	4%	22%	36%	68%	65%	7%	44%
BLT01-180	1126.4	15%	18%	47%	5%	23%	40%	73%	71%	7%	40%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT01-180	17.6	19%	11%	27%	6%	33%	47%	83%	71%	14%	27%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT01-2	1173.9	5%	10%	11%	1%	6%	3%	10%	14%	2%	116%
BLT01-30	1166.5	15%	10%	17%	5%	26%	28%	52%	53%	10%	55%
BLT01-60	1158.4	16%	10%	22%	5%	28%	35%	62%	60%	12%	29%
BLT01-120	1142.4	17%	10%	26%	6%	30%	41%	76%	64%	13%	29%
BLT01-180	1126.4	19%	11%	27%	6%	33%	47%	83%	71%	14%	27%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
BLT01-180	5.61	234					
acid equivalent (g)			0.37	1.62	6.81	0.37	9.16
acid equivalent (%)			4.0	17.7	74.3	4.0	100.0



Test name: BLT02  
 Comment: 80°C baseline, 2% solids

Date: 26-Oct-04

	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46 micron
dry ore added:	23.99	8.5	2.832	2	2.0	T:	80 °C
stock solution added:	1177.3	1175.8	1.0013	7.29	6.88	duration:	3 hrs
total slurry in:	1201.3			0.20	0.19	agitation rate:	800 rpm
				0	0	impeller:	pitched blade, 5cm φ, T1
				7.00	7.63	vessel:	2litre, baffled, with reflux cor

Sample	time	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
BLT02-0	10h15	0		23.1	0.69	1.0013			
BLT02-2		2	20.83	21.8		1.0022	582	781	brown residue
BLT02-30		30	19.63	21.9		1.0034	630	829	light green pls
BLT02-60		60	23.64	22.1		1.0044	627	826	clear wash
BLT02-120		120	24.83	22.4		1.0049	629	828	50min heat-up time
BLT02-180		180	1079.94	24.4	1.22	1.0052	619	818	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	titrant addition cum. ml	calc. evaporation cum. ml
BLT02-2	17.95	17.91		1.72	0.38	48.81	48.9	47.41	0.9984	47.5		0.36
BLT02-30	18.16	18.10		1.73	0.36	24.48	24.5	23.54	0.9987	23.6		5.41
BLT02-60	21.87	21.77		0.61	0.38	21.07	21.1	20.24	0.9988	20.3		10.83
BLT02-120	23.19	23.08		0.62	0.38	20.98	21.0	19.33	0.9987	19.4		21.66
BLT02-180	1025.8	1020.49	38.11	39.62	16.26	254.11	254.6	228.43	0.999	228.7		32.48

ANALYSES

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.6	0.22	1.88	18.8	0.05
BLT02-180	1.75	1.01	0.19	0.05	0.65	8.69	13.1	0.05	0.61	21.9	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
BLT02-head liquor	2	2	7.63	2	1	2	6.88	2	2	2	2	2
BLT02-2	9.49	29.1	7.87	2	1	59.9	6.92	52.2	3.14	46.7	32.5	27.2
BLT02-30	29	28.8	7.58	2	2.6	290	5.37	463	12.2	172	136	41.6
BLT02-60	36.3	27.4	7.3	2.21	3.42	398	3.95	802	20.5	217	190	2.59
BLT02-120	41.1	27.8	7.29	3.14	3.94	455	3.05	1106	28.2	238	238	2.41
BLT02-180	45.1	29.4	7.77	3.73	4.48	490	2.76	1304	32.8	262	263	2.28
BLT02-comp. wash	3.77	3.65	1.1	2	1	50.2	0.5	150	4.14	31.3	25.5	2

CALCULATIONS AND MASS BALANCE

H <sup>+</sup>	assay H <sup>+</sup> (free acid) mol/l	measured pH (autotitrator)	H <sup>+</sup> mol/l	initial H <sup>+</sup> mol/l	residual HCl g
BLT02-0		0.69		0.189	2.82
BLT02-2	0.15	temp set at 95 1.59	0.03		
BLT02-30	0.11	1.86	0.02		
BLT02-60	0.08	2.07	0.01		
BLT02-120	0.08	2.21	0.01		
BLT02-180	0.08	1.00	1.00		
average	0.10	1.88	0.21		

%change in acid conc: 59.9

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	
lead solids	23.99	0.37	0.19	0.03	0.01	0.12	2.23	4.51	0.05	0.40	4.50	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si
head liquor	1177.30	1175.77	0.0	0.0	8.971	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	369.45	370.19	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1570.74</b>		<b>0.37</b>	<b>0.19</b>	<b>9.00</b>	<b>0.014</b>	<b>0.12</b>	<b>2.23</b>	<b>4.51</b>	<b>0.06</b>	<b>0.40</b>	<b>4.50</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	
BLT02-2	0.38	-	-	-	-	-	-	-	-	-	-	
BLT02-30	0.36	-	-	-	-	-	-	-	-	-	-	
BLT02-60	0.38	-	-	-	-	-	-	-	-	-	-	
BLT02-120	0.38	-	-	-	-	-	-	-	-	-	-	
final residue	16.26	0.28	0.16	0.03	0.01	0.11	1.41	2.13	0.01	0.10	3.56	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si
BLT02-2	17.95	17.91	0.000	0.001	0.141	0.000	0.000	0.001	0.001	0.000	0.001	0.001
BLT02-30	18.16	18.10	0.001	0.001	0.137	0.000	0.000	0.005	0.008	0.000	0.003	0.002
BLT02-60	21.87	21.77	0.001	0.001	0.159	0.000	0.000	0.009	0.017	0.000	0.005	0.004
BLT02-120	23.19	23.08	0.001	0.001	0.168	0.000	0.000	0.011	0.026	0.001	0.005	0.005
final filtrate	1025.80	1020.49	0.046	0.030	7.929	0.004	0.005	0.500	1.331	0.033	0.267	0.268
wash water	339.95	339.36	0.001	0.001	0.373	0.001	0.000	0.017	0.051	0.001	0.011	0.009
cake moisture	26.54	26.57	0.000	0.000	0.029	0.000	0.000	0.001	0.004	0.000	0.001	0.001
evaporation	32.42	32.48	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1522.64</b>		<b>0.33</b>	<b>0.20</b>	<b>8.97</b>	<b>0.01</b>	<b>0.11</b>	<b>1.96</b>	<b>3.57</b>	<b>0.04</b>	<b>0.39</b>	<b>3.85</b>

balance (out/in)	97%	91%	103%	100%	90%	94%	88%	79%	81%	97%	86%
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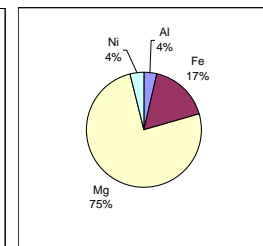
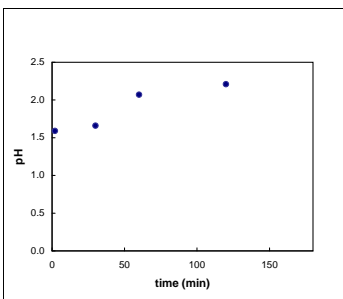
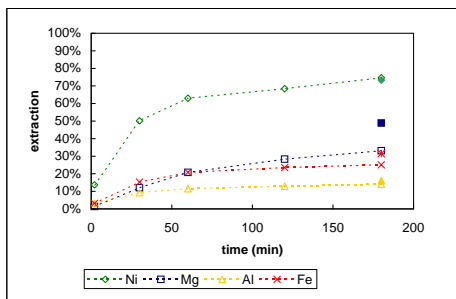
extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT02-2	1176.9	3%	18%	20%	1%	3%	1%	7%	14%	1%	267%
BLT02-30	1171.9	9%	18%	20%	3%	15%	12%	27%	50%	4%	406%
BLT02-60	1166.5	12%	17%	21%	3%	21%	21%	45%	63%	5%	25%
BLT02-120	1155.6	13%	17%	30%	4%	24%	28%	62%	68%	6%	23%
BLT02-180	1144.8	14%	18%	36%	4%	25%	33%	71%	75%	7%	22%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT02-180	17.6	16%	6%	27%	2%	31%	49%	83%	73%	14%	27%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT02-2	1176.9	3%	6%	14%	0%	4%	2%	8%	13%	2%	318%
BLT02-30	1171.9	10%	6%	14%	1%	19%	17%	31%	48%	7%	486%
BLT02-60	1166.5	13%	6%	16%	1%	26%	30%	52%	61%	10%	30%
BLT02-120	1155.6	15%	6%	22%	1%	29%	41%	72%	67%	13%	28%
BLT02-180	1144.8	16%	6%	27%	2%	31%	49%	83%	73%	14%	27%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
BLT02-180	5.27	220					
acid equivalent (g)			0.33	1.60	7.14	0.38	9.46
acid equivalent (%)			3.5	17.0	75.5	4.0	100.0



Test name: BLT03  
 Comment: 95°C baseline, 5% solids

Date: 18-Oct-04

	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective
dry ore added:	80	28.3	2.832	5	4.8
demin water added:	1485.53	1488.5	0.998	7.29	4.87
MgCl <sub>2</sub> ·6H <sub>2</sub> O added:	0	0.0	1.569	0.20	0.21
32% HCl titrant added:	34.78	30.00	1.1593	0	0
total slurry in:	1600.3			7.00	7.54

grind (D90)	41	micron
T:	95	°C
duration:	3	hrs
agitation rate:	800	rpm
impeller:	pitched blade, 5cm $\phi$ , Ti	
vessel:	2litre, baffled, with reflux cor	

Sample	time	minute	slurry removed	sample T	pH	Density @20°C	ORP vs. Ag/AgCl	Eh	Notes
			g	(°C)		(kg/l)	(mV)	(mV)	
BLT03-0		0							
BLT03-2		2	16.41	23.7		1.0028	605	804	
BLT03-30		30	20.75	23.8		1.0040	635	834	
BLT03-60		60	20.41	23.7		1.0043	612	811	
BLT03-120		120	20.28	24		1.0046	592	791	
BLT03-180		180	1486.3	23	1.54	1.0060	604	803	

Sample	filtrate mass	filtrate vol	wet residue mass before wash	wet residue mass after wash	dry residue mass	wash mass in	wash vol in	wash mass out	wash density @20°C	wash vol out	titrant addition	calc. evaporation
	g	ml	g	g	g	g	ml	g	kg/l	ml	cum. ml	cum. ml
BLT03-2	15.17	15.13		0.93	0.67	60.34	60.5	59.01	0.9976	59.2		0.40
BLT03-30	18.72	18.65		1.07	0.86	62.42	62.5	61.23	0.9916	61.7		6.04
BLT03-60	18.79	18.71		1.37	0.94	52.97	53.1	52.34	0.9912	52.8		12.08
BLT03-120	17.35	17.27		1.57	0.86	52.35	52.5	51.76	0.9980	51.9		24.15
BLT03-180	1237.08	1229.70	139.8	144.1	66.61	292.92	293.5	327.54	1.000	327.5		36.23

ANALYSES

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.37	0.58	0.13	0.05	0.49	10.5	19.7	0.22	1.94	18.1	0.05
BLT03-180	1.46	0.61	0.15	0.05	0.49	10.9	15	0.07	1.09	20.2	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
BLT03-2	44.4	47.3	7.54	4.94	3.55	313	4.87	622	24.5	225	136	3.78
BLT03-30	67	50.7	6.34	7.88	5.48	412	2.61	1145	41.1	367	269	5.04
BLT03-60	72.1	50.3	6.73	10.1	5.67	379	2.14	1313	47.6	389	289	5.28
BLT03-120	76.3	50.9	10.4	10.8	5.91	301	1.77	1459	52.2	416	285	5.61
BLT03-180	88.8	55.3	10.7	13.2	6.7	285	1.7	1738	66.7	500	287	6.06
BLT03-comp. wash	20.1	14.4	2.11	3.41	1.57	68.1	0.5	446	18.3	127	69	2

CALCULATIONS AND MASS BALANCE

H <sup>+</sup>	assay H <sup>+</sup> (free acid)	measured pH (autotitrator)	H <sup>+</sup> mol/l	calc. initial H <sup>+</sup> mol/l	residual HCl g
BLT03-0		0.00		0.205	2.09
BLT03-2	0.13	1.10	0.08		
BLT03-30	0.07	1.28	0.05		
BLT03-60	0.06	1.37	0.04		
BLT03-120	0.05	1.45	0.04		
BLT03-180	0.05	1.50	0.03		
average	0.07	1.34	0.05		

%change in acid conc: 65.1

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	
feed solids	80.00	1.10	0.46	0.11	0.04	0.39	8.37	15.79	0.18	1.55	14.45	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si
feed make-up water	1485.53	1488.51	-	-	-	-	-	-	-	-	-	-
wash water	521.00	522.04	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>2086.53</b>		<b>1.10</b>	<b>0.46</b>	<b>0.11</b>	<b>0.04</b>	<b>0.39</b>	<b>8.37</b>	<b>15.79</b>	<b>0.18</b>	<b>1.55</b>	<b>14.45</b>
solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	
BLT03-2	0.67	-	-	-	-	-	-	-	-	-	-	
BLT03-30	0.86	-	-	-	-	-	-	-	-	-	-	
BLT03-60	0.94	-	-	-	-	-	-	-	-	-	-	
BLT03-120	0.86	-	-	-	-	-	-	-	-	-	-	
final residue	66.61	0.97	0.41	0.10	0.03	0.33	7.26	9.99	0.05	0.73	13.46	
solution OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	
BLT03-2	15.17	15.13	0.001	0.001	0.114	0.000	0.005	0.009	0.000	0.003	0.002	
BLT03-30	18.72	18.65	0.001	0.001	0.118	0.000	0.008	0.021	0.001	0.007	0.005	
BLT03-60	18.79	18.71	0.001	0.001	0.126	0.000	0.007	0.025	0.001	0.007	0.005	
BLT03-120	17.35	17.27	0.001	0.001	0.180	0.000	0.005	0.025	0.001	0.007	0.005	
final filtrate	1237.08	1229.70	0.109	0.068	13.158	0.016	0.008	0.350	2.137	0.062	0.615	0.353
wash water	551.98	553.11	0.011	0.008	1.167	0.002	0.001	0.038	0.247	0.010	0.070	0.038
cake moisture	79.10	79.10	0.002	0.001	0.167	0.000	0.005	0.035	0.001	0.010	0.005	
evaporation	36.16	36.23	-	-	-	-	-	-	-	-	-	
<b>total OUT (g)</b>	<b>2044.19</b>		<b>1.10</b>	<b>0.49</b>	<b>15.13</b>	<b>0.05</b>	<b>0.34</b>	<b>7.68</b>	<b>12.49</b>	<b>0.14</b>	<b>1.45</b>	<b>13.87</b>
<b>balance (out/in)</b>	<b>98%</b>		<b>100%</b>	<b>106%</b>	<b>14184%</b>	<b>131%</b>	<b>86%</b>	<b>92%</b>	<b>79%</b>	<b>80%</b>	<b>93%</b>	<b>96%</b>

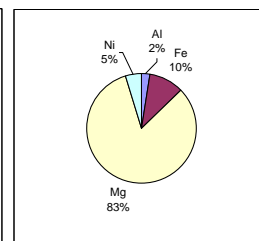
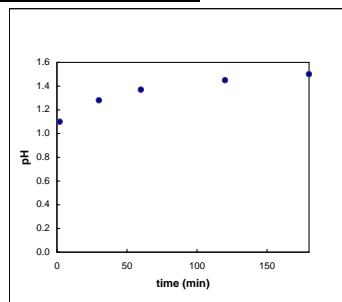
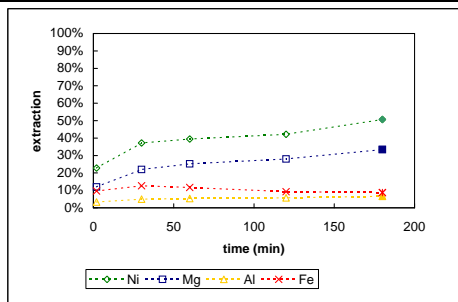
extraction (solution)	calc. total solid volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT03-2	1488.1	6%	16%	18%	1%	6%	6%	20%	22%	1%	14%
BLT03-30	1482.5	9%	16%	29%	2%	7%	11%	34%	35%	3%	19%
BLT03-60	1476.4	10%	16%	37%	2%	7%	12%	39%	37%	3%	19%
BLT03-120	1464.4	10%	16%	40%	2%	5%	14%	43%	39%	3%	21%
BLT03-180	1452.3	12%	17%	48%	2%	5%	16%	54%	47%	3%	22%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT03-180	70.1	7%	7%	12%	12%	9%	33%	73%	51%	2%	12%

extraction (ratio)	calc. total solid volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT03-2	1488.1	3%	6%	5%	6%	10%	12%	27%	23%	1%	8%
BLT03-30	1482.5	5%	7%	7%	10%	13%	22%	45%	37%	2%	10%
BLT03-60	1476.4	5%	7%	9%	10%	12%	25%	52%	39%	2%	11%
BLT03-120	1464.4	6%	7%	10%	10%	9%	28%	57%	42%	2%	11%
BLT03-180	1452.3	7%	7%	12%	12%	9%	33%	73%	51%	2%	12%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
BLT03-180	9.04	113					
acid equivalent (g)			0.50	2.18	17.39	1.02	21.09
acid equivalent (%)			2.4	10.3	82.4	4.8	100.0



Test name: ST04  
 Comment: high pH, low total Cl-

Date: 27-Oct-04

	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46 micron
dry ore added:	24.06	8.5	2.832	2	2.0	T:	80 °C
stock solution added:	1176.7	1025.9	1.147	7.29	6.90	duration:	3 hrs
total slurry in:	1200.8			0.20	0.19	agitation rate:	800 rpm
				192	187	impeller:	pitched blade, 5cmφ, T1
				150	157	vessel:	2litre, baffled, with reflux cor

Sample	time	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
ST04-0	09h20	0		21.5	-0.02	1.147			
ST04-2		2	26.03	21.5	-0.02	1.1406	579	778	55min heat-up time
ST04-30		30	25.11	21.4	0.86	1.1427	590	789	brown residue
ST04-60		60	26.63	21.5	1.17	1.1437	595	794	yellow pls
ST04-120		120	27.03	21.6	1.3	1.1434	593	792	light green wash
ST04-180		180	1094.11	23.3	1.29	1.1499	570	769	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	titrant addition cum. ml	calc. evaporation cum. ml
ST04-2	23.79	20.86		0.92	0.49	20.66	20.7	20.32	1.0130	20.1		0.02
ST04-30	23.3	20.39		0.61	0.39	23.82	23.9	23.79	1.0109	23.5		0.31
ST04-60	24.09	21.06		0.56	0.42	27.93	28.0	27.5	1.0095	27.2		0.62
ST04-120	25.51	22.31		0.37	0.45	21.7	21.7	21.38	1.0109	21.1		1.24
ST04-180	1035.9	900.86	51.21	36.95	18.54	251.69	252.2	248.82	1.023	243.1		1.85

ANALYSES

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
ST04-180	1.61	0.84	0.85	0.05	0.61	8.18	12.8	0.05	0.48	22.3	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
ST04-head liquor	2	2	157	2	1	3.07	6.9	47692	2	3.51	2	20.4
ST04-2	28.2	32.9	143	3.65	2.11	243	5.81	45969	4.42	137	46.4	5.39
ST04-30	59.8	31.6	142	8.37	6.17	760	1.74	46430	29.9	322	114	5.98
ST04-60	59.6	33.2	141	9.35	6.23	764	1.49	46935	35.7	335	109	7.35
ST04-120	56	33	142	10.6	6.33	736	1.36	46395	38.1	357	93.3	5.7
ST04-180	55.8	36.6	148	11.3	7.96	734	0.5	49568	40.8	349	84.7	4.63
ST04-comp. wash	9.68	5.52	23.9	2	2.47	135	0.5	7049	6.55	58.9	13.1	2

CALCULATIONS AND MASS BALANCE

H <sup>+</sup>	assay H <sup>+</sup> (free acid) mol/l	residual HCl g	Δ acid %
ST04-0			92.8
ST04-2	0.05		
ST04-30	0.04		
ST04-60	0.04		
ST04-120	0.01		
ST04-180	0.01	0.45	
average	0.03		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	
feed solids	24.06	0.37	0.19	0.03	0.01	0.12	2.24	4.52	0.05	0.40	4.51	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si
head liquor	1176.70	1025.89	0.0	0.0	161.07	0.0	0.0	0.0	48.9	0.0	0.0	0.0
wash water	345.80	346.49	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1546.56</b>		<b>0.37</b>	<b>0.19</b>	<b>161.10</b>	<b>0.014</b>	<b>0.12</b>	<b>2.24</b>	<b>53.45</b>	<b>0.05</b>	<b>0.41</b>	<b>4.51</b>
solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	
ST04-2	0.49	-	-	-	-	-	-	-	-	-	-	
ST04-30	0.39	-	-	-	-	-	-	-	-	-	-	
ST04-60	0.42	-	-	-	-	-	-	-	-	-	-	
ST04-120	0.45	-	-	-	-	-	-	-	-	-	-	
final residue	18.54	0.30	0.16	0.16	0.01	0.11	1.52	2.37	0.01	0.09	4.13	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si
ST04-2	23.79	20.86	0.001	0.001	2.983	0.000	0.000	0.005	0.959	0.000	0.003	0.001
ST04-30	23.30	20.39	0.001	0.001	2.895	0.000	0.000	0.015	0.947	0.001	0.007	0.002
ST04-60	24.09	21.06	0.001	0.001	2.970	0.000	0.000	0.016	0.989	0.001	0.007	0.002
ST04-120	25.51	22.31	0.001	0.001	3.168	0.000	0.000	0.016	1.035	0.001	0.008	0.002
final filtrate	1035.90	900.86	0.050	0.033	133.327	0.010	0.007	0.661	44.654	0.037	0.314	0.076
wash water	341.81	335.11	0.003	0.002	8.009	0.001	0.001	0.045	2.362	0.002	0.020	0.004
cake moisture	19.12	18.68	0.000	0.000	0.447	0.000	0.000	0.003	0.132	0.000	0.001	0.000
evaporation	1.85	1.85	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1515.66</b>		<b>0.36</b>	<b>0.19</b>	<b>153.96</b>	<b>0.02</b>	<b>0.12</b>	<b>2.28</b>	<b>53.45</b>	<b>0.05</b>	<b>0.45</b>	<b>4.22</b>
<b>balance (out/in)</b>	<b>98%</b>		<b>96%</b>	<b>101%</b>	<b>96%</b>	<b>148%</b>	<b>103%</b>	<b>102%</b>	<b>100%</b>	<b>92%</b>	<b>110%</b>	<b>94%</b>

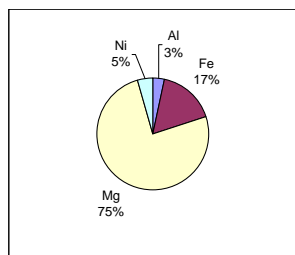
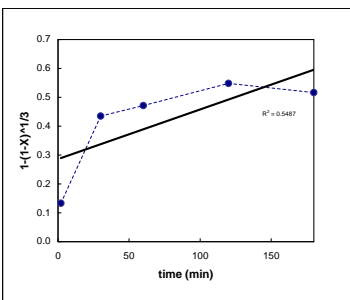
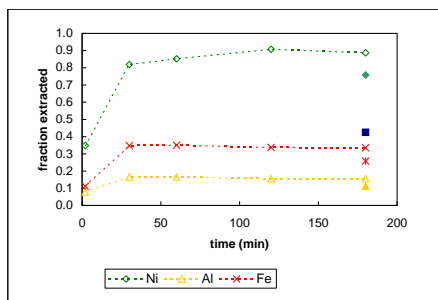
extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST04-2	1025.9	8%	18%	31%	2%	11%	-39%	9%	35%	1%	51%
ST04-30	1025.6	17%	17%	71%	5%	35%	-29%	58%	82%	3%	51%
ST04-60	1025.3	17%	18%	80%	5%	35%	-18%	69%	85%	2%	63%
ST04-120	1024.7	16%	18%	90%	6%	34%	-31%	74%	91%	2%	49%
ST04-180	1024.0	16%	20%	96%	7%	34%	41%	79%	89%	2%	39%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST04-180	20.3	11%	10%	16%	-6%	26%	43%	81%	76%	0%	16%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST04-2	1025.9	6%	9%	5%	-2%	9%	39%	9%	30%	0%	20%
ST04-30	1025.6	12%	9%	12%	-5%	27%	40%	59%	70%	-1%	20%
ST04-60	1025.3	12%	9%	13%	-5%	27%	40%	71%	73%	-1%	25%
ST04-120	1024.7	11%	9%	15%	-5%	26%	40%	75%	78%	0%	19%
ST04-180	1024.0	11%	10%	16%	-6%	26%	43%	81%	76%	0%	16%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
ST04-180	6.63	275					
acid equivalent (g)			0.28	1.41	6.45	0.39	8.54
acid equivalent (%)			3.3	16.6	75.6	4.6	100.0



Test name: ST05  
 Comment: med pH, low total Cl-

Date: 27-Oct-04

	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46 micron	
dry ore added:	24.04	8.5	2.832	2	2.0	T:	80 °C	
stock solution added:	1176.1	1040.3	1.1305	36.46	30.90	duration:	3 hrs	
total slurry in:	1200.14			1.00	0.85	agitation rate:	800 rpm	
				MgCl2 (g/l):	154	145	impeller:	pitched blade, 5cm $\phi$ , Tl
				total Cl- (g/l):	150	149	vessel:	2litre, baffled, with reflux cor

Sample	time	minute	slurry removed	sample T	pH	Density @20°C	ORP vs. Ag/AgCl	Eh	Notes
			g	(°C)		(kg/l)	(mV)	(mV)	
ST05-0	01h20	0		21.1	-0.56	1.1305			
ST05-2		2	26.85	23.6	-0.57	1.1264	554	753	40min heat-up time
ST05-30		30	24.54	23.7	-0.5	1.1321	541	740	greyish white residue
ST05-60		60	27.71	23.9	-0.48	1.1336	538	737	dark yellow pls
ST05-120		120	26.13	22.2	-0.47	1.1329	538	737	light green wash
ST05-180		180	1068.81	22	-0.53	1.1419	520	719	

Sample	filtrate mass	filtrate vol	wet residue mass before wash	wet residue mass after wash	dry residue mass	wash mass in	wash vol in	wash mass out	wash density @20°C	wash vol out	titrant addition	calc. evaporation
	g	ml	g	g	g	g	ml	g	kg/l	ml	cum. ml	cum. ml
ST05-2	25.11	22.29		0.35	0.47	28.01	28.1	27.79	1.0073	27.6		0.29
ST05-30	23	20.32		0.62	0.36	23.11	23.2	22.8	1.0092	22.6		4.36
ST05-60	27.1	23.91		0.61	0.3	21.16	21.2	20.91	1.0111	20.7		8.72
ST05-120	24.66	21.77		0.03	0.3	21.78	21.8	21.62	1.0106	21.4		17.43
ST05-180	1016.6	890.27	43.21	41.47	15.19	255.76	256.3	237.44	1.017	233.6		26.15

ANALYSES

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
ST05-180	1.86	1.2	0.63	0.05	0.77	1.1	3.02	0.05	0.05	31.4	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
ST05-head liquor	2	2.9	148	3.46	1	2.21	30.9	37022	2	3.83	2	5.09
ST05-2	55.1	35.8	146	3.14	5.19	567	31.8	39151	15.7	210	85.8	3.5
ST05-30	94.6	35.4	148	9.29	14.6	1565	25.1	41199	41.7	348	75	3.39
ST05-60	102	36.9	171	8.21	16.1	1657	24.6	41977	43	342	61.4	3.63
ST05-120	107	37.5	142	8.34	16.8	1744	24.1	41406	43.4	350	53.8	3.83
ST05-180	117	41.7	150	9.34	23.6	1935	25.3	44802	47.3	377	50.7	3.21
ST05-comp. wash	13.5	5.12	19.6	2	12.9	285	3.03	5123	6.63	51	6.12	2

CALCULATIONS AND MASS BALANCE

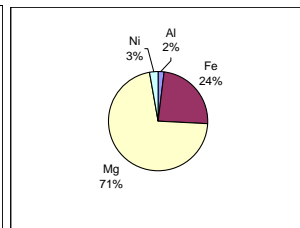
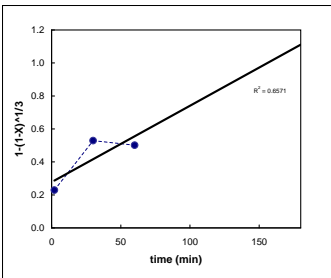
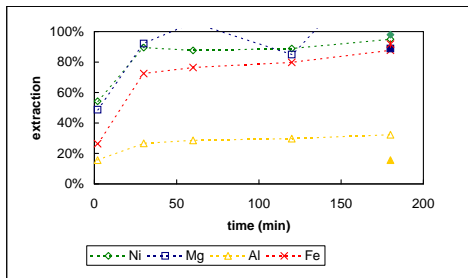
H <sup>+</sup>	assay H+ (free acid)	residual HCl	$\Delta$ acid %	calc. initial H+
ST05-0	mol/l		18.1	0.847
ST05-2	0.69			
ST05-30	0.67			
ST05-60	0.66			
ST05-120	0.69			
ST05-180	0.69	22.52		
average	0.68			

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	
feed solids	24.04	0.37	0.19	0.03	0.01	0.12	2.24	4.52	0.05	0.40	4.51	
solition IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	
head liquor	1176.10	1040.34	0.0	0.0	155.01	0.0	0.0	0.0	38.5	0.0	0.0	
wash water	349.82	350.52	-	-	-	-	-	-	-	-	-	
total IN (g)	1549.96	0.37	0.19	155.04	0.02	0.12	2.24	43.03	0.05	0.41	4.51	
solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	
ST05-2	0.47	-	-	-	-	-	-	-	-	-	-	
ST05-30	0.36	-	-	-	-	-	-	-	-	-	-	
ST05-60	0.30	-	-	-	-	-	-	-	-	-	-	
ST05-120	0.30	-	-	-	-	-	-	-	-	-	-	
final residue	15.19	0.28	0.18	0.10	0.01	0.12	0.17	0.46	0.01	0.01	4.77	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si
ST05-2	25.11	22.29	0.001	0.001	3.255	0.000	0.000	0.013	0.873	0.000	0.005	0.002
ST05-30	23.00	20.32	0.002	0.001	3.007	0.000	0.000	0.032	0.837	0.001	0.007	0.002
ST05-60	27.10	23.91	0.002	0.001	4.088	0.000	0.000	0.040	1.004	0.001	0.008	0.001
ST05-120	24.66	21.77	0.002	0.001	3.091	0.000	0.000	0.038	0.901	0.001	0.008	0.001
filtrate	1016.60	890.27	0.104	0.037	133.541	0.008	0.021	1.723	39.886	0.042	0.336	0.045
wash water	330.56	325.84	0.004	0.002	6.386	0.001	0.004	0.093	1.669	0.002	0.017	0.002
cake moisture	26.46	26.03	0.000	0.000	0.510	0.000	0.000	0.007	0.133	0.000	0.001	0.000
evaporation	26.10	26.15	-	-	-	-	-	-	-	-	-	-
total OUT (g)	1516.21	0.40	0.22	153.97	0.02	0.14	2.11	45.76	0.06	0.39	4.82	
balance (out/in)	98%	108%	116%	99%	110%	122%	94%	106%	100%	96%	107%	

extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST05-2	1040.0	16%	20%	27%	5%	26%	49%	31%	54%	2%	30%
ST05-30	1036.0	27%	19%	80%	13%	72%	92%	82%	90%	2%	29%
ST05-60	1031.6	29%	20%	70%	14%	76%	106%	84%	88%	1%	31%
ST05-120	1022.9	30%	20%	71%	15%	80%	85%	84%	89%	1%	33%
ST05-180	1014.2	32%	22%	79%	21%	88%	153%	91%	95%	1%	27%
extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST05-180	16.7	16%	-5%	31%	-10%	92%	89%	84%	98%	-16%	31%
extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST05-2	1040.0	7%	-5%	10%	-2%	27%	78%	28%	55%	-27%	33%
ST05-30	1036.0	13%	-5%	30%	-6%	74%	82%	74%	90%	-24%	32%
ST05-60	1031.6	14%	-5%	27%	-7%	79%	83%	77%	89%	-20%	35%
ST05-120	1022.9	14%	-5%	27%	-7%	83%	82%	77%	91%	-17%	37%
ST05-180	1014.2	16%	-5%	31%	-10%	92%	89%	84%	98%	-16%	31%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
ST05-180	32.15	1337					
acid equivalent (g)			0.35	4.05	12.18	0.49	17.07
acid equivalent (%)			2.0	23.7	71.4	2.9	100.0



Test name: ST06  
 Comment: low pH, low total Cl-

Date: 28-Oct-04

	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46 micron
dry ore added:	24	8.5	2.832	2	2.0	T:	80 °C
stock solution added:	1175.8	1048.1	1.1218	54.69	51.40	duration:	3 hrs
total slurry in:	1199.8			1.50	1.41	agitation rate:	800 rpm
				MgCl2 (g/l):	130	impeller:	pitched blade, 5cm $\phi$ , Tl
				total Cl- (g/l):	150	vessel:	2litre, baffled, with reflux cor

Sample	time	minute	slurry removed	sample T	pH	Density @20°C	ORP vs. Ag/AgCl	Eh	Notes
			g	(°C)		(kg/l)	(mV)	(mV)	
ST06-0	09h10	0		22.2	-0.74	1.1218			
ST06-2		2	26.81	22.5	-0.68	1.1197	543	742	50min heat-up time
ST06-30		30	30.58	23	-0.65	1.1261	528	727	greyish-white residue
ST06-60		60	26.69	24.2	-0.64	1.1255	527	726	dark orange-yellow pls
ST06-120		120	23.75	22	-0.63	1.1264	524	723	light green wash
ST06-180		180	1068.65	22.2	-0.71	1.1329	496	695	

Sample	filtrate mass	filtrate vol	wet residue mass before wash	wet residue mass after wash	dry residue mass	wash mass in	wash vol in	wash mass out	wash density @20°C	wash vol out	titrant addition	calc. evaporation
	g	ml	g	g	g	g	ml	g	kg/l	ml	cum. ml	cum. ml
ST06-2	25.1	22.42		0.64	0.47	22.95	23.0	22.87	1.0097	22.7		0.26
ST06-30	28.65	25.44		0.69	0.34	29.12	29.2	29.05	1.0079	28.8		3.89
ST06-60	24.87	22.10		0.74	0.33	22.73	22.8	22.79	1.0097	22.6		7.79
ST06-120	22.1	19.62		0.64	0.28	23.06	23.1	22.99	1.0092	22.8		15.58
ST06-180	1020.4	900.70	41.74	36.98	12.08	250.89	251.4	239.51	1.018	235.4		23.37

ANALYSES

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
ST06-180	1.96	1.27	0.45	0.05	0.78	0.89	2.85	0.05	0.05	32.5	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
ST06-head liquor	2.73	4.51	151	2		2	51.4	33968	2	5.63	2	6.27
ST06-2	54.2	32.4	145	4	6.03	717	46.6	33178	16.4	241	74.1	7.77
ST06-30	94.7	33.1	148	9.7	15.5	1770	40.5	35615	40.4	378	53.6	7.95
ST06-60	95.9	34.4	148	8.82	16.8	1852	37.8	35850	40.5	385	44.4	8.26
ST06-120	101	33.6	154	7.63	17.4	1836	40.6	35829	40.9	363	40.7	7.72
ST06-180	105	37.1	153	10.2	30.2	2087	40.2	38069	44.1	425	38.5	7.97
ST06-comp. wash	14.1	5.04	21.7	2	30.7	417	0.5	5022	8.09	70.6	5.66	2

CALCULATIONS AND MASS BALANCE

H <sup>+</sup>	assay H <sup>+</sup> (free acid)	residual HCl	$\Delta$ acid %	calc. initial H <sup>+</sup>
	mol/l	g	%	mol/l
ST06-0			21.8	1.410
ST06-2	1.11			
ST06-30	1.04			
ST06-60	1.11			
ST06-120	1.10			
ST06-180	1.10	36.21		
average	1.09			

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	
feed solids	24.00	0.37	0.19	0.03	0.01	0.12	2.23	4.51	0.05	0.40	4.50	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si
head liquor	1175.80	1048.14	0.0	0.0	158.27	0.0	0.0	0.0	35.2	0.0	0.0	0.0
wash water	348.75	349.45	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1548.55</b>	<b>1047.9</b>	<b>0.37</b>	<b>0.19</b>	<b>158.30</b>	<b>0.01</b>	<b>0.12</b>	<b>2.24</b>	<b>39.70</b>	<b>0.05</b>	<b>0.41</b>	<b>4.50</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	
ST06-2	0.47	-	-	-	-	-	-	-	-	-	-	
ST06-30	0.34	-	-	-	-	-	-	-	-	-	-	
ST06-60	0.33	-	-	-	-	-	-	-	-	-	-	
ST06-120	0.28	-	-	-	-	-	-	-	-	-	-	
final residue	12.08	0.24	0.15	0.05	0.01	0.09	0.11	0.34	0.01	0.01	3.93	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si
ST06-2	25.10	22.42	0.001	0.001	3.250	0.000	0.000	0.016	0.744	0.000	0.005	0.002
ST06-30	28.65	25.44	0.002	0.001	3.765	0.000	0.000	0.045	0.906	0.001	0.010	0.001
ST06-60	24.87	22.10	0.002	0.001	3.270	0.000	0.000	0.041	0.792	0.001	0.009	0.001
ST06-120	22.10	19.62	0.002	0.001	3.021	0.000	0.000	0.036	0.703	0.001	0.007	0.001
final filtrate	1020.40	900.70	0.095	0.033	137.807	0.009	0.027	1.880	34.289	0.040	0.383	0.035
wash water	337.21	332.21	0.005	0.002	7.209	0.001	0.010	0.199	1.668	0.003	0.023	0.002
cake moisture	26.19	25.74	0.000	0.000	0.559	0.000	0.011	0.129	0.000	0.000	0.002	0.000
evaporation	23.32	23.37	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1521.34</b>	<b>1047.9</b>	<b>0.34</b>	<b>0.19</b>	<b>158.94</b>	<b>0.02</b>	<b>0.13</b>	<b>2.27</b>	<b>39.58</b>	<b>0.05</b>	<b>0.44</b>	<b>3.97</b>

balance (out/in)	98%	93%	99%	100%	118%	114%	102%	100%	94%	109%	88%
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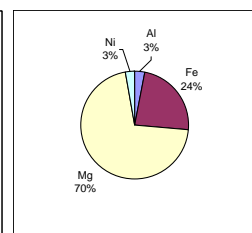
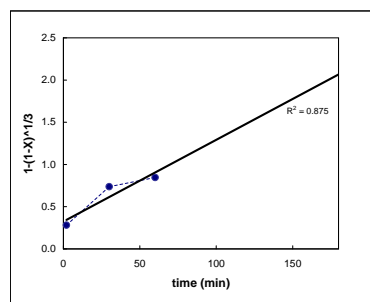
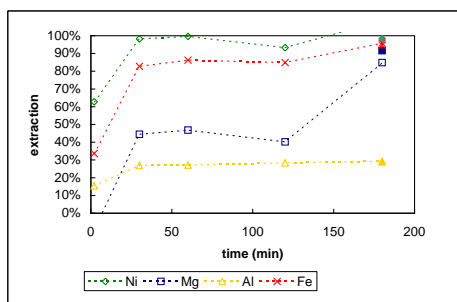
extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST06-2	1047.9	15%	18%	35%	5%	34%	-9%	33%	63%	2%	68%
ST06-30	1044.2	27%	18%	84%	14%	83%	44%	80%	98%	1%	69%
ST06-60	1040.3	27%	19%	76%	15%	86%	47%	80%	100%	1%	72%
ST06-120	1032.6	28%	18%	69%	15%	85%	40%	80%	93%	1%	66%
ST06-180	1024.8	29%	20%	87%	27%	96%	85%	86%	108%	1%	68%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST06-180	13.3	29%	11%	45%	11%	95%	92%	87%	98%	4%	45%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST06-2	1047.9	15%	10%	17%	2%	33%	80%	33%	56%	8%	43%
ST06-30	1044.2	26%	10%	42%	6%	80%	86%	80%	87%	5%	44%
ST06-60	1040.3	27%	10%	39%	6%	84%	86%	80%	89%	5%	46%
ST06-120	1032.6	28%	10%	33%	6%	83%	86%	81%	84%	4%	43%
ST06-180	1024.8	29%	11%	45%	11%	95%	92%	87%	98%	4%	45%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
ST06-180	53.87	2245	0.53	4.16	12.50	0.49	17.69
acid equivalent (g)			3.0	23.5	70.7	2.8	100.0
acid equivalent (%)							



Test name: ST07  
 Comment: high pH, med total Cl-

Date: 29-Oct-04

	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46 micron
dry ore added:	24	8.5	2.832	2	2.0	T:	80 °C
stock solution added:	1176.7	963.6	1.2212	7.29	6.68	duration:	2 hrs
total slurry in:	1200.7			0.20	0.18	agitation rate:	800 rpm
				299	303	impeller:	pitched blade, 5cm $\phi$ , T1
				230	231	vessel:	2litre, baffled, with reflux cor

Sample	time	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
ST07-0	10h00	0		22.9	-0.76	1.2212			
ST07-2		2	31.12	22	-0.61	1.2141	579	778	80min heat-up time
ST07-30		30	30.75	22.1	0.83	1.2205	593	792	brown residue
ST07-60		60	29.62	22.3	1.04	1.2181	602	801	orange pls
ST07-120		120	30.37	22.5	1.07	1.2195	605	804	light green wash
ST07-180		180	1045.82	24.2	1.09	1.2292	558	757	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	titrant addition cum. ml	calc. evaporation cum. ml
ST07-2	28.94	23.84		0.72	0.53	22.3	22.3	22.57	1.0208	22.1		0.37
ST07-30	27.97	22.92		1.11	0.43	24.26	24.3	24.71	1.0212	24.2		5.51
ST07-60	27.14	22.28		0.88	0.46	22.19	22.2	22.64	1.0221	22.2		11.03
ST07-120	28.23	23.15		0.78	0.47	22.98	23.0	23.22	1.0190	22.8		22.06
ST07-180	981.9	798.81	49.44	43.06	19.06	254.05	254.6	249.61	1.035	241.1		33.09

ANALYSES

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
ST07-180	1.72	0.88	0.85	0.05	0.59	6.78	13	0.05	0.44	21.7	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
ST07-head liquor	4.5	5.1	231	2	1	3.71	6.68	77390	2	11.2	2	10.5
ST07-2	41.6	34.8	225	3.15	3.87	433	4.93	76945	7.91	199	43.5	13.1
ST07-30	50.3	35.5	222	6.47	7.89	908	1.76	76130	31.8	312	69.3	14.5
ST07-60	41.1	36.4	220	8.21	7.81	906	1.7	77449	35.7	348	57	14.1
ST07-120	39.7	35.7	220	7.38	7.74	772	1.65	77504	37.8	282	48.2	10.2
ST07-180	42.3	40.2	232	8.3	11.2	829	1.65	80973	41.8	320	41.8	11.3
ST07-comp. wash	14.7	5.94	34.2	2	3.56	149	0.5	11982	6.37	45.8	7.57	2

CALCULATIONS AND MASS BALANCE

H <sup>+</sup>	assay H <sup>+</sup> (free acid) mol/l	residual HCl g	$\Delta$ acid %	calc. initial H <sup>+</sup> mol/l
ST07-0			75.3	0.183
ST07-2	0.05			
ST07-30	0.05			
ST07-60	0.05			
ST07-120	0.05			
ST07-180	0.05	1.32		
average	0.05			

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	
feed solids	24.00	0.37	0.19	0.03	0.01	0.12	2.23	4.51	0.05	0.40	4.50	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si
head liquor	1176.70	963.56	0.0	0.0	222.58	0.0	0.0	0.0	74.6	0.0	0.0	0.0
wash water	345.78	346.47	-	-	-	-	-	-	-	-	-	-
total IN (g)	1546.48		0.37	0.19	222.61	0.01	0.12	2.24	79.08	0.05	0.41	4.50

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si
ST07-2	0.53	-	-	-	-	-	-	-	-	-	-
ST07-30	0.43	-	-	-	-	-	-	-	-	-	-
ST07-60	0.46	-	-	-	-	-	-	-	-	-	-
ST07-120	0.47	-	-	-	-	-	-	-	-	-	-
final residue	19.06	0.33	0.17	0.16	0.01	0.11	1.29	2.48	0.01	0.08	4.14

solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si
ST07-2	28.94	23.84	0.001	0.001	5.363	0.000	0.000	0.010	1.810	0.000	0.005	0.001
ST07-30	27.97	22.92	0.001	0.001	5.088	0.000	0.000	0.021	1.745	0.001	0.007	0.002
ST07-60	27.14	22.28	0.001	0.001	4.902	0.000	0.000	0.020	1.726	0.001	0.008	0.001
ST07-120	28.23	23.15	0.001	0.001	5.093	0.000	0.000	0.018	1.794	0.001	0.007	0.001
final filtrate	981.90	798.81	0.034	0.032	185.324	0.007	0.009	0.662	64.682	0.033	0.256	0.033
wash water	342.75	332.37	0.005	0.002	11.367	0.001	0.001	0.050	3.982	0.002	0.015	0.003
cake moisture	25.60	24.73	0.000	0.000	0.846	0.000	0.000	0.004	0.296	0.000	0.001	0.000
evaporation	33.02	33.09	-	-	-	-	-	-	-	-	-	-
total OUT (g)	1516.50		0.37	0.21	218.14	0.02	0.12	2.08	78.51	0.05	0.38	4.18

balance (out/in)	98%	100%	106%	98%	125%	105%	93%	99%	87%	93%	93%
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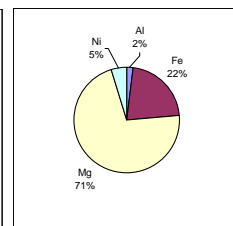
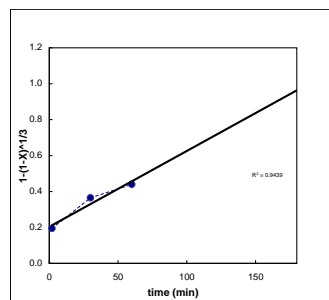
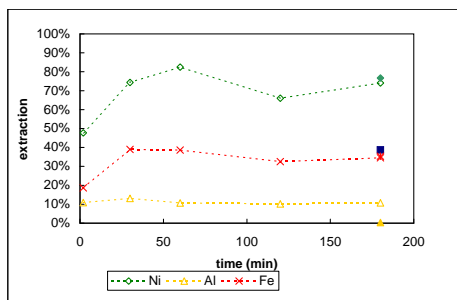
extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST07-2	963.2	11%	18%	25%	3%	19%	-31%	14%	48%	1%	105%
ST07-30	958.0	13%	18%	52%	6%	39%	-36%	58%	74%	1%	116%
ST07-60	952.5	11%	18%	65%	6%	39%	-18%	64%	82%	1%	112%
ST07-120	941.5	10%	18%	58%	6%	33%	-35%	67%	66%	1%	80%
ST07-180	930.5	11%	20%	64%	9%	35%	17%	74%	74%	1%	88%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST07-180	21.3	0%	1%	11%	-8%	35%	39%	80%	77%	-3%	11%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST07-2	963.2	0%	1%	4%	-3%	18%	-16%	15%	48%	-3%	105%
ST07-30	958.0	0%	1%	9%	-6%	39%	-14%	61%	75%	-4%	15%
ST07-60	952.5	0%	1%	11%	-5%	39%	1%	68%	83%	-4%	14%
ST07-120	941.5	0%	1%	10%	-5%	33%	1%	72%	68%	-3%	10%
ST07-180	930.5	0%	1%	11%	-8%	39%	39%	80%	77%	-3%	11%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
ST07-180	6.44	268					
acid equivalent (g)			0.16	1.84	6.10	0.40	8.50
acid equivalent (%)			1.9	21.7	71.8	4.6	100.0



Test name: ST08  
 Comment: med pH, med total Cl-

Date: 1-Nov-04

	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46 micron
dry ore added:	24.06	8.5	2.832	2	2.0	T:	80 °C
stock solution added:	1177.4	976.0	1.2064	36.46	34.63	duration:	2 hrs
total slurry in:	1201.46			1.00	0.95	agitation rate:	800 rpm
				261	264	impeller:	pitched blade, 5cm $\phi$ , T1
				230	229	vessel:	2litre, baffled, with reflux cor

Sample	time	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
ST08-0	09h12	0		22.9	-1.11	1.2064			
ST08-2		2	30.09	20.7	-1.07	1.2114	545	744	52min heat-up time
ST08-30		30	28.8	20.7	-1.05	1.2163	511	710	greyish-white residue
ST08-60		60	27.52	21.2	-0.95	1.2059	515	714	orange pls (darker than ST13)
ST08-120		120	29.11	21	-0.95	1.2093	516	715	light green wash
ST08-180		180	1060.07	22.6	-1.02	1.0334	486	685	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	titrant addition cum. ml	calc. evaporation cum. ml
ST08-2	26.85	22.16		1.5	0.45	27.65	27.7	28.06	1.0174	27.6		0.29
ST08-30	25.5	20.97		1.83	0.3	20.58	20.6	20.83	1.0249	20.3		4.32
ST08-60	25.75	21.35		0.58	0.28	21.91	22.0	22.01	1.0199	21.6		8.64
ST08-120	27.11	22.42		0.64	0.29	20.78	20.8	20.95	1.0216	20.5		17.28
ST08-180	1006.3	973.78	41.66	37.44	13.83	246.22	246.7	232.21	1.219	190.5		25.92

ANALYSES

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
ST08-180	1.97	1.29	0.85	0.05	0.81	1.03	3.45	0.05	0.05	36.4	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
ST08-head liquor	4.22	4.9	2.29	2	2	34.63	67.68	2	10.6	2	10.8	2
ST08-2	87.6	36.5	266	7.75	10.4	1137	29.2	71859	30.1	316	52.7	11.1
ST08-30	123	38.5	231	8.09	17.8	1856	25	70292	45.4	396	28.1	11
ST08-60	124	36.1	219	9.1	17.6	1805	23	66170	43.3	351	22.3	9.7
ST08-120	126	37	215	9.5	18.3	1842	23.1	67410	43.4	391	21	9.57
ST08-180	137	45.7	237	7.33	33.7	1931	24.3	71459	47.7	391	19.4	8.26
ST08-comp. wash	19.6	5.96	34.8	2	47.4	467	3.47	10468	10.1	77.7	3.76	2

CALCULATIONS AND MASS BALANCE

H <sup>+</sup>	assay H <sup>+</sup> (free acid) mol/l	residual HCl g	$\Delta$ acid %	calc. initial H <sup>+</sup> mol/l
ST08-0			29.8	0.950
ST08-2	0.69			
ST08-30	0.63			
ST08-60	0.63			
ST08-120	0.67			
ST08-180	0.67	23.66		
average	0.66			

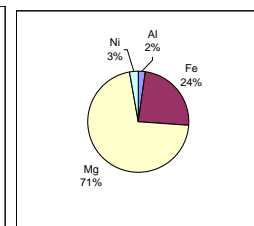
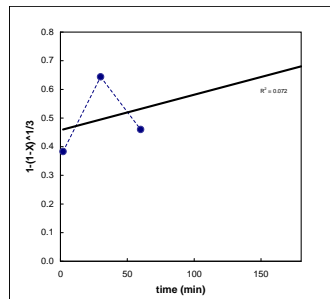
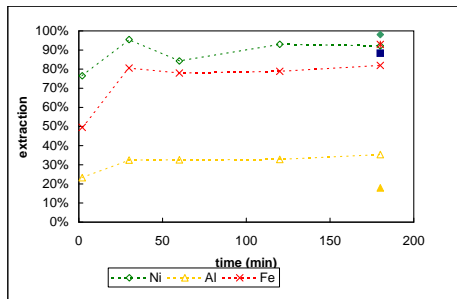
solids IN		total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	
feed solids		24.06	0.37	0.19	0.03	0.01	0.12	2.24	4.52	0.05	0.40	4.51	
solution IN		total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si
head liquor		1177.40	975.96	0.0	0.0	223.50	0.0	0.0	0.0	65.9	0.0	0.0	0.0
wash water		337.14	337.82	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>		<b>1538.60</b>		<b>0.37</b>	<b>0.19</b>	<b>223.53</b>	<b>0.01</b>	<b>0.12</b>	<b>2.24</b>	<b>70.39</b>	<b>0.05</b>	<b>0.41</b>	<b>4.51</b>
solids OUT		total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	
ST08-2		0.45	-	-	-	-	-	-	-	-	-	-	
ST08-30		0.30	-	-	-	-	-	-	-	-	-	-	
ST08-60		0.28	-	-	-	-	-	-	-	-	-	-	
ST08-120		0.29	-	-	-	-	-	-	-	-	-	-	
final residue		13.83	0.27	0.18	0.12	0.01	0.11	0.14	0.48	0.01	0.01	5.03	
solution OUT		total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si
ST08-2		26.85	22.16	0.002	0.001	5.896	0.000	0.000	0.025	1.588	0.001	0.007	0.001
ST08-30		25.50	20.97	0.003	0.001	4.843	0.000	0.000	0.039	1.474	0.001	0.008	0.001
ST08-60		25.75	21.35	0.003	0.001	4.676	0.000	0.000	0.039	1.413	0.001	0.007	0.000
ST08-120		27.11	22.42	0.003	0.001	4.820	0.000	0.000	0.041	1.511	0.001	0.009	0.000
final filtrate		1006.30	973.78	0.133	0.045	230.785	0.007	0.033	1.890	69.585	0.046	0.381	0.019
wash water		324.06	280.53	0.005	0.002	3.762	0.001	0.013	0.131	2.937	0.003	0.022	0.001
cake moisture		26.84	22.02	0.000	0.000	0.766	0.000	0.001	0.010	0.231	0.000	0.002	0.000
evaporation		25.87	25.92	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>		<b>1503.43</b>		<b>0.42</b>	<b>0.23</b>	<b>261.67</b>	<b>0.02</b>	<b>0.16</b>	<b>2.31</b>	<b>79.22</b>	<b>0.06</b>	<b>0.44</b>	<b>5.06</b>
<b>balance (out/in)</b>		<b>98%</b>		<b>113%</b>	<b>117%</b>	<b>117%</b>	<b>110%</b>	<b>136%</b>	<b>103%</b>	<b>113%</b>	<b>109%</b>	<b>107%</b>	<b>112%</b>

extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST08-2	975.7	23%	19%	63%	9%	50%	90%	55%	77%	1%	90%
ST08-30	971.6	32%	20%	65%	15%	81%	54%	83%	95%	1%	89%
ST08-60	967.3	33%	18%	73%	15%	78%	-41%	79%	84%	0%	78%
ST08-120	958.7	33%	19%	76%	15%	79%	-27%	79%	93%	0%	76%
ST08-180	950.0	35%	23%	58%	27%	82%	45%	86%	92%	0%	65%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST08-180	15.3	18%	-4%	36%	-6%	93%	88%	86%	98%	-24%	36%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST08-2	975.7	11%	-3%	38%	-2%	55%	89%	54%	79%	-64%	49%
ST08-30	971.6	16%	-3%	40%	-3%	89%	87%	81%	99%	-34%	48%
ST08-60	967.3	16%	-3%	45%	-3%	87%	82%	78%	88%	-27%	43%
ST08-120	958.7	16%	-3%	47%	-4%	89%	83%	78%	98%	-26%	42%
ST08-180	950.0	18%	-4%	36%	-6%	93%	86%	86%	98%	-24%	36%

based on solids assay		g consumed	kg/t ore	Al	Fe	Mg	Ni	total
acid consumption		33.80	1405					
acid equivalent (g)				0.39	4.11	12.14	0.49	17.13
acid equivalent (%)				2.3	24.0	70.9	2.9	100.0



Test name: ST09  
 Comment: low pH, high total Cl-

Date: 1-Nov-04

	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46 micron
dry ore added:	24.05	8.5	2.832	2	2.0	T:	80 °C
stock solution added:	1177.1	984.9	1.1952	54.69	52.39	duration:	2 hrs
total slurry in:	1201.15			1.50	1.44	agitation rate:	800 rpm
				MgCl <sub>2</sub> (g/l):	237	impeller:	pitched blade, 5cm $\phi$ , T1
				total Cl <sup>-</sup> (g/l):	230	vessel:	2litre, baffled, with reflux cor

Sample	time	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
ST09-0	13h12	0		22.8	-1.16	1.1952			
ST09-2		2	25.9	20.9	-1.05	1.1851	552	751	47min heat-up time
ST09-30		30	30.95	22.6	-1.02	1.1921	508	707	greyish white residue
ST09-60		60	22.92	20.8	-0.98	1.1872	505	704	orange pls (darker than ST14)
ST09-120		120	31.9	21.2	-1.02	1.1924	503	702	light green wash
ST09-180		180	1086.36	22.7	-1.06	1.2021	463	662	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	titrant addition cum. ml	calc. evaporation cum. ml
ST09-2	23.91	20.18		0.44	0.33	27.92	28.0	28.12	1.0149	27.7		0.03
ST09-30	29.02	24.34		0.75	0.31	22.5	22.5	22.48	1.0165	22.1		0.52
ST09-60	22.42	18.88		0.44	0.19	23.97	24.0	24.03	1.0176	23.6		1.04
ST09-120	29.79	24.98		0.69	0.3	23.21	23.3	23.48	1.0183	23.1		2.08
ST09-180	1032.1	858.58	41.75	35.91	13.29	241.9	242.4	208.03	1.029	202.1		3.13

ANALYSES

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
ST09-180	1.99	1.33	0.63	0.05	0.83	1	3.48	0.05	0.05	38.3	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
ST09-head liquor	3.81	3.03	2.26	2	1	2	52.39	50466	2	9.48	2	10.3
ST09-2	66.9	30.9	218	3.09	7.83	845	43.3	58422	22.2	264	40.7	6.37
ST09-30	110	34.2	230	7.75	16.2	1603	37.7	62521	41.8	329	26.5	6.44
ST09-60	112	33.7	259	6.05	16.3	1597	35.9	60335	40	319	22.5	6.09
ST09-120	122	34.8	235	7.92	17.1	1623	37	62217	41.7	329	20.6	6.67
ST09-180	128	42.2	262	8.31	38.3	1858	37.9	65896	46.1	365	19.7	6.86
ST09-comp. wash	18.3	5.94	35.3	2	49	434	5.48	8792	9.99	71.4	3.79	2

CALCULATIONS AND MASS BALANCE

H <sup>+</sup>	assay H <sup>+</sup> (free acid) mol/l	residual HCl g	$\Delta$ acid %	calc. initial H <sup>+</sup> mol/l
ST09-0			27.7	1.437
ST09-2	1.03			
ST09-30	0.98			
ST09-60	1.01			
ST09-120	1.04			
ST09-180	1.04	32.54		
average	1.02			

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	
feed solids	24.05	0.37	0.19	0.03	0.01	0.12	2.24	4.52	0.05	0.40	4.51	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si
head liquor	1177.10	984.86	0.0	0.0	222.58	0.0	0.0	0.0	59.6	0.0	0.0	0.0
wash water	339.50	340.18	-	-	-	-	-	-	-	-	-	-
total IN (g)	1540.65		0.37	0.19	222.61	0.01	0.12	2.24	64.07	0.05	0.41	4.51

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	
ST09-2	0.33	-	-	-	-	-	-	-	-	-	-	
ST09-30	0.31	-	-	-	-	-	-	-	-	-	-	
ST09-60	0.19	-	-	-	-	-	-	-	-	-	-	
ST09-120	0.30	-	-	-	-	-	-	-	-	-	-	
final residue	13.29	0.26	0.18	0.08	0.01	0.11	0.13	0.46	0.01	0.01	5.09	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si
ST09-2	23.91	20.18	0.001	0.001	4.398	0.000	0.000	0.017	1.179	0.000	0.005	0.001
ST09-30	29.02	24.34	0.003	0.001	5.599	0.000	0.000	0.039	1.522	0.001	0.008	0.001
ST09-60	22.42	18.88	0.002	0.001	4.891	0.000	0.000	0.030	1.139	0.001	0.006	0.000
ST09-120	29.79	24.98	0.003	0.001	5.871	0.000	0.000	0.041	1.554	0.001	0.008	0.001
final filtrate	1032.10	858.58	0.110	0.036	224.948	0.007	0.033	1.595	56.577	0.040	0.313	0.017
wash water	306.14	298.62	0.005	0.002	10.541	0.001	0.015	0.130	2.625	0.003	0.021	0.001
cake moisture	23.81	23.13	0.000	0.000	0.817	0.000	0.001	0.010	0.203	0.000	0.002	0.000
evaporation	3.12	3.13	-	-	-	-	-	-	-	-	-	-
total OUT (g)	1484.73		0.39	0.22	257.15	0.01	0.16	1.99	65.26	0.05	0.37	5.11

balance (out/in)	96%	105%	113%	118%	107%	138%	89%	102%	96%	90%	113%
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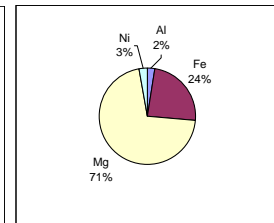
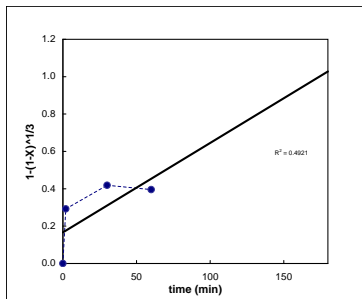
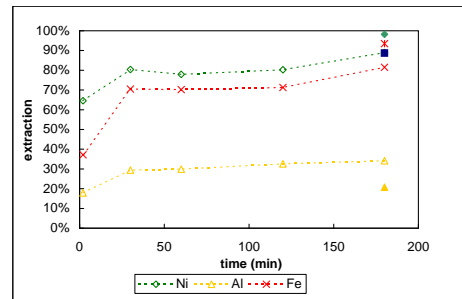
extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST09-2	984.8	18%	16%	25%	7%	37%	-45%	41%	65%	1%	52%
ST09-30	984.3	29%	18%	63%	14%	71%	44%	78%	80%	1%	53%
ST09-60	983.8	30%	17%	49%	14%	70%	-4%	74%	78%	0%	50%
ST09-120	982.8	33%	18%	65%	14%	71%	35%	77%	80%	0%	55%
ST09-180	981.7	34%	22%	68%	32%	82%	114%	86%	89%	0%	56%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST09-180	14.7	21%	-3%	39%	-4%	93%	89%	86%	98%	-24%	39%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST09-2	984.8	11%	-2%	15%	-1%	43%	79%	41%	71%	-51%	36%
ST09-30	984.3	18%	-2%	36%	-2%	81%	84%	78%	88%	-33%	37%
ST09-60	983.8	18%	-2%	28%	-2%	80%	81%	75%	86%	-28%	35%
ST09-120	982.8	20%	-2%	37%	-2%	82%	84%	78%	88%	-26%	38%
ST09-180	981.7	21%	-3%	39%	-4%	93%	89%	86%	98%	-24%	39%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
ST09-180	51.60	2145	0.42	4.12	12.18	0.49	17.21
acid equivalent (g)			2.4	24.0	70.8	2.9	100.0
acid equivalent (%)							



Test name: **BLT10a**  
 Comment: 80°C baseline, med pH

Date: **2-Dec-04**

	mass (g)	volume (ml)	density @20°C (kg/l)		nominal	assay	grind (D90)	46	micron
dry ore added:	8.06	2.8	2.832	initial pulp % solids:	0.5	0.5	T:	80	°C
stock solution added:	1592.1	1567.5	1.0157	initial HCl (g/l):	36.5	35.9	duration:	10	min
total slurry in:	1600.16			initial HCl (M):	1.00	0.98	agitation rate:	800	rpm
				MgCl2 (g/l):	0	0	impeller:	pitched blade, 5cm $\phi$ , Ti	
				total Cl- (g/l):	35	38.6	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
BLT10a-0	0		24.5	0.00	1.0157	519	718	60min heat-up time, yellow-green PLS, clear green wash, light brown solids
BLT10a-2	2	21.9			1.016		-	
BLT10a-10	10	19.92					-	
BLT10a-10bulk	10bulk	1537.17	24.9	0.00	1.0166	549	748	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
BLT10a-2	21.9	21.56					0.0			-	4.24	-
BLT10a-10	19.92	19.59					0.0			-	21.21	-
BLT10a-10bulk	1502.07	1477.54	19.3	16.0	5.7	99.56	99.8	94.5	1.002	94.3	21.21	0.37

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
BLT10a-10bulk	1.52	0.88	0.26	0.05	0.57	7.47	15	0.16	0.59	22	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
BLT10a-head liquor	2	2	38.6	2	1	2	35.9	2	2	2	2	2
BLT10a-2	4.15	6.49	35.9	2	1	44.6	34.5	33.5	2	20.7	17.5	2
BLT10a-10	9.64	6.48	36.7	2	1.21	137	34.2	217	2.66	53.5	56.3	2
BLT10a-10bulk	10.6	6.45	37.1	2	1.49	186	34.5	292	3.54	61.8	69.3	2
BLT10a-comp. wash	3.62	2		2	1	69.8	7.27	188	4.05	22.5	22.3	2

37.08

**CALCULATIONS AND MASS BALANCE**

H <sup>+</sup>	assay H+ mol/l	residual HCl g	$\Delta$ acid %
BLT10a-0	0.98		3.9
BLT10a-2	0.95		
BLT10a-10	0.94	50.53	
BLT10a-10bulk	0.95	50.98	
average	0.95		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.06	0.12	0.06	0.01	0.00	0.04	0.75	1.52	0.02	0.14	1.51	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
head liquor	1592.10	1567.49	0.0	0.0	60.51	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	99.56	99.76	-	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1699.72</b>		<b>0.13</b>	<b>0.07</b>	<b>60.52</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.52</b>	<b>0.02</b>	<b>0.14</b>	<b>1.51</b>	<b>0.01</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
BLT10a-2	0.00	-	-	-	-	-	-	-	-	-	-	-	
BLT10a-10	0.00	-	-	-	-	-	-	-	-	-	-	-	
BLT10a-10bulk	5.70	0.09	0.05	0.01	0.00	0.03	0.43	0.86	0.01	0.03	1.25	0.00	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT10a-2	21.90	21.56	0.000	0.000	0.774	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000
BLT10a-10	19.92	19.59	0.000	0.000	0.719	0.000	0.000	0.003	0.004	0.000	0.001	0.001	0.000
BLT10a-10bulk	1502.07	1477.54	0.016	0.010	54.817	0.003	0.002	0.275	0.431	0.005	0.091	0.102	0.003
wash water	94.50	94.31	0.000	0.000	0.763	0.000	0.000	0.007	0.018	0.000	0.002	0.002	0.000
cake moisture	10.30	10.28	0.000	0.000	0.083	0.000	0.000	0.001	0.002	0.000	0.000	0.000	0.000
evaporation	21.17	-	-	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1675.56</b>		<b>0.10</b>	<b>0.06</b>	<b>57.17</b>	<b>0.01</b>	<b>0.03</b>	<b>0.71</b>	<b>1.31</b>	<b>0.01</b>	<b>0.13</b>	<b>1.36</b>	<b>0.01</b>

<b>balance (out/in)</b>	99%	81%	90%	94%	85%	86%	94%	86%	71%	93%	90%	85%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT10a-2	1541.7	5%	16%	77%	4%	9%	3%	17%	24%	2%	77%
BLT10a-10	1505.1	12%	15%	75%	5%	27%	21%	23%	60%	6%	75%
BLT10a-10bulk	1505.1	13%	15%	75%	6%	37%	29%	30%	69%	7%	75%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT10a-10bulk	5.9	28%	19%	27%	15%	42%	42%	47%	74%	15%	27%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT10a-2	1541.7	11%	19%	27%	10%	10%	5%	27%	25%	4%	27%
BLT10a-10	1505.1	25%	19%	27%	12%	31%	31%	35%	64%	12%	27%
BLT10a-10bulk	1505.1	28%	19%	27%	15%	42%	42%	47%	74%	15%	27%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
BLT10a-10	5.74	712					
BLT10a-10bulk	5.30	657					
acid equivalent (g)			0.15	0.63	1.98	0.13	2.89
acid equivalent (%)			5.1	22.0	68.5	4.4	100.0

Test name: **BLT10b**  
 Comment: 80°C baseline, med pH

Date: **3-Dec-04**

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46	micron
stock solution added:	8.04	2.8	2.832	0.5	0.5	T:	80	°C
total slurry in:	1592.2	1567.6	1.0157	initial pulp % solids:	36.5	34.9	duration:	10
	1600.24			initial HCl (g/l):	1.00	0.96	agitation rate:	800
				MgCl2 (g/l):	0	0	impeller:	pitched blade, 5cm <sup>2</sup> , Ti
				total Cl- (g/l):	35	37.2	vessel:	2litre, baffled, with reflux condenser

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
BLT10b-0	0		24.5	0.00	1.0157	519	718	65min heat-up time, yellow-green PLS, clear green wash, light brown solids
BLT10b-2	2	17.43	24.4		1.0156			
BLT10b-20	20	26.75						
BLT10b-20bulk	20bulk	1538.91	24.9	0.00	1.0170	547	746	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
BLT10b-2	17.43	17.16					0.0			-	1.72	-
BLT10b-20	26.75	26.30					0.0			-	17.18	-
BLT10b-20bulk	1501.48	1476.38	18.4	13.0	4.94	99.63	99.8	96.99	1.0018	96.8	17.18	0.32

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
BLT10b-20bulk	1.86	1.1	0.33	0.05	0.72	6.86	11.4	0.11	0.38	24.6	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
BLT10b-head liquor	2	2	37.2	2	1	34.9	2	2	2	2	2	2
BLT10b-2	4.78	6.53	35.7	2	1	38.8	34.3	39.9	2	16.5	19.3	2
BLT10b-20	14.6	6.59	36.9	2	1.96	189	33.6	435	5.67	54.8	96.9	2
BLT10b-20bulk	13.9	7.07	37.1	2	2.17	201	33.7	487	6.36	56.2	107	2
BLT10b-comp. wash	3.31	2	7.53	2	1	53.3	6.88	165	3.2	12.2	25.5	2

**CALCULATIONS AND MASS BALANCE**

H <sup>+</sup>	assay H <sup>+</sup> mol/l	residual HCl g	Δ acid %
BLT10b-0	0.96		3.4
BLT10b-2	0.94		
BLT10b-20	0.92	49.61	
BLT10b-20bulk	0.92	49.75	
average	0.94		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.04	0.12	0.06	0.01	0.00	0.04	0.75	1.51	0.02	0.13	1.51	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
head liquor	1592.20	1567.59	0.0	0.0	58.31	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	99.63	99.83	-	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1699.87</b>		<b>0.13</b>	<b>0.07</b>	<b>58.33</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.51</b>	<b>0.02</b>	<b>0.14</b>	<b>1.51</b>	<b>0.01</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
BLT10b-2	0.00	-	-	-	-	-	-	-	-	-	-	-	
BLT10b-20	0.00	-	-	-	-	-	-	-	-	-	-	-	
BLT10b-20bulk	4.94	0.09	0.05	0.02	0.00	0.04	0.34	0.56	0.01	0.02	1.22	0.00	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT10b-2	17.43	17.16	0.000	0.000	0.613	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000
BLT10b-20	26.75	26.30	0.000	0.000	0.971	0.000	0.000	0.005	0.011	0.000	0.001	0.003	0.000
BLT10b-20bulk	1501.48	1476.38	0.021	0.010	54.774	0.003	0.003	0.297	0.719	0.009	0.063	0.158	0.003
wash water	96.99	96.82	0.000	0.000	0.729	0.000	0.000	0.005	0.016	0.000	0.001	0.002	0.000
cake moisture	8.06	8.05	0.000	0.000	0.061	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
evaporation	17.15	17.18	-	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1672.80</b>		<b>0.11</b>	<b>0.07</b>	<b>57.16</b>	<b>0.01</b>	<b>0.04</b>	<b>0.65</b>	<b>1.31</b>	<b>0.02</b>	<b>0.10</b>	<b>1.38</b>	<b>0.01</b>

<b>balance (out/in)</b>	98%	90%	98%	98%	80%	96%	86%	87%	74%	76%	91%	80%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT10b-2	1548.71	6%	16%	77%	4%	8%	4%	18%	19%	2%	77%
BLT10b-20	1506.94	18%	16%	75%	8%	38%	43%	48%	61%	10%	75%
BLT10b-20bulk	1506.94	17%	17%	75%	8%	40%	48%	54%	63%	11%	75%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT10b-20bulk	5.1	23%	12%	37%	6%	53%	62%	68%	86%	17%	37%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT10b-2	1548.7	8%	11%	37%	3%	10%	5%	22%	25%	3%	37%
BLT10b-20	1506.9	24%	11%	37%	6%	50%	55%	61%	84%	15%	37%
BLT10b-20bulk	1506.9	23%	12%	37%	6%	53%	62%	68%	86%	17%	37%

based on solids assay

acid consumption	q consumed	kg/t ore	Al	Fe	Mg	Ni	total
BLT10b-20	5.10	635					
BLT10b-20bulk	4.95	616					
acid equivalent (g)			0.13	0.80	2.85	0.14	3.92
acid equivalent (%)			3.2	20.5	72.6	3.7	100.0

Test name: **BLT10c**  
 Comment: 80°C baseline, med pH

Date: **2-Dec-04**

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46	micron
stock solution added:	8.08	2.9	2.832	0.5	0.5	T:	80	°C
total slurry in:	1592.6	1568.0	1.0157	initial pulp % solids:	36.5	34.9	duration:	10
				initial HCl (g/l):	1.00	0.96	agitation rate:	800
				MgCl2 (g/l):	0	0	impeller:	pitched blade, 5cm $\phi$ , Ti
				total Cl- (g/l):	35	37.2	vessel:	2litre, baffled, with reflux condenser

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
BLT10c-0	0		24.5	0.00	1.0157	519	718	50min heat-up time, yellow-green PLS, clear green wash, light brown solids
BLT10c-2	2							
BLT10c-30	30	19.05						
BLT10c-30bulk	30bulk	1561.7	24.9	0.01	1.0173	545	744	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
BLT10c-2	0						0.0			-	1.33	-
BLT10c-30	19.05	18.73					0.0			-	19.97	-
BLT10c-30bulk	1529.85	1503.83	11.6	14.5	4.39	99.56	99.8	88.26	1.0011	88.2	19.97	0.28

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
BLT10c-30bulk	1.99	1.2	0.18	0.05	0.76	6.18	9.18	0.07	0.29	25.5	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
BLT10c-head liquor	2	2	37.2	2	1	2	34.9	2	2	2	2	2
BLT10c-2												
BLT10c-30	11.7	6.92	35.8	2	2.41	247	33.2	523	6.91	76.7	115	2
BLT10c-30bulk	11.6	6.83	36.9	2	2.6	232	34	575	7.63	56.4	125	2
BLT10c-comp. wash	2.74	2	5.67	2	1	47.7	5.85	146	2.67	11.7	19.7	2

**CALCULATIONS AND MASS BALANCE**

H <sup>+</sup>	assay H <sup>+</sup> mol/l	residual HCl g	$\Delta$ acid %
BLT10c-0	0.96		2.6
BLT10c-2			
BLT10c-30	0.91	49.93	
BLT10c-30bulk	0.93	51.13	
average	0.93		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.08	0.12	0.06	0.01	0.00	0.04	0.75	1.52	0.02	0.14	1.52	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
head liquor	1592.60	1567.98	0.0	0.0	58.33	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	99.56	99.76	-	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1700.24</b>		<b>0.13</b>	<b>0.07</b>	<b>58.34</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.52</b>	<b>0.02</b>	<b>0.14</b>	<b>1.52</b>	<b>0.01</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
BLT10c-2	0.00	-	-	-	-	-	-	-	-	-	-	-	
BLT10c-30	0.00	-	-	-	-	-	-	-	-	-	-	-	
BLT10c-30bulk	4.39	0.09	0.05	0.01	0.00	0.03	0.27	0.40	0.00	0.01	1.12	0.00	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT10c-2	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BLT10c-30	19.05	18.73	0.000	0.000	0.670	0.000	0.000	0.005	0.010	0.000	0.001	0.002	0.000
BLT10c-30bulk	1529.85	1503.83	0.017	0.010	55.491	0.003	0.004	0.349	0.865	0.011	0.085	0.188	0.003
wash water	88.26	88.16	0.000	0.000	0.500	0.000	0.000	0.004	0.013	0.000	0.001	0.002	0.000
cake moisture	10.11	10.10	0.000	0.000	0.057	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
evaporation	19.93	19.97	-	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1671.59</b>		<b>0.11</b>	<b>0.06</b>	<b>56.73</b>	<b>0.01</b>	<b>0.04</b>	<b>0.63</b>	<b>1.29</b>	<b>0.01</b>	<b>0.10</b>	<b>1.31</b>	<b>0.01</b>

<b>balance (out/in)</b>	98%	83%	94%	97%	76%	92%	83%	85%	71%	72%	86%	76%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT10c-2	1566.65	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
BLT10c-30	1529.29	14%	17%	76%	9%	50%	52%	59%	87%	12%	76%
BLT10c-30bulk	1529.29	14%	16%	76%	10%	47%	58%	66%	64%	13%	76%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT10c-30bulk	4.4	28%	16%	45%	14%	63%	73%	83%	90%	25%	45%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT10c-2	1566.7	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
BLT10c-30	1529.3	29%	17%	45%	13%	68%	67%	75%	123%	23%	45%
BLT10c-30bulk	1529.3	28%	16%	45%	14%	63%	73%	83%	90%	25%	45%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
BLT10c-30	4.80	593					
BLT10c-30bulk	3.59	445					
acid equivalent (g)			0.15	0.94	3.35	0.15	4.59
acid equivalent (%)			3.2	20.5	73.0	3.3	100.0

Test name: **BLT10d**  
 Comment: 80°C baseline, med pH

Date: **2-Dec-04**

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46	micron
stock solution added:	8	2.8	2.832	0.5	0.5	T:	80	°C
total slurry in:	1592	1567.7	1.0155	initial pulp % solids:	36.5	34.9	duration:	10
	1600			initial HCl (g/l):	1.00	0.96	agitation rate:	800
				MgCl2 (g/l):	0	0	impeller:	pitched blade, 5cm $\phi$ , Ti
				total Cl- (g/l):	35	37.2	vessel:	2litre, baffled, with reflux condenser

Sample	minute	slurry removed (g)	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
BLT10d-0	0		24.7	0.00	1.0155	497	696	60min heat-up time, yellow-green PLS, clear green wash, light brown solids
BLT10d-2	2	25.56	24.1		1.0159			
BLT10d-60	60	19.29						
BLT10d-60bulk	60bulk	1534.91	24.9	0.02	1.0177	543	742	

Sample	filtrate mass (g)	filtrate vol (ml)	wet residue mass before wash (g)	wet residue mass after wash (g)	dry residue mass (g)	wash mass in (g)	wash vol in (ml)	wash mass out (g)	wash density @20°C (kg/l)	wash vol out (ml)	calc. evaporation cum. ml	calc. sample pulp density % solids
BLT10d-2	25.56	25.16					0.0			-	0.68	-
BLT10d-60	19.29	18.95					0.0			-	20.28	-
BLT10d-60bulk	1507.49	1481.27	9.8	13.1	3.57	98.47	98.7	87.31	1.0005	87.3	20.28	0.23

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
BLT10d-60bulk	2.07	1.31	0.18	0.05	0.79	4.16	5.23	0.05	0.15	28.7	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
BLT10d-head liquor	2	2	37.2	2	1	2	34.9	2	2	2	2	2
BLT10d-2	5.28	6.19	36.5	2	1	46	34.5	53.7	2	21.2	21.5	2
BLT10d-60	18.5	7.57	36.3	2	3.48	300	33.1	769	9.88	68.3	171	2
BLT10d-60bulk	20.3	7.55	36.7	2	3.66	330	33.3	769	9.9	65.4	171	2
BLT10d-comp. wash	2.6	2	5.41	2	1	50.6	5.02	124	2	10.4	17.7	2

**CALCULATIONS AND MASS BALANCE**

H <sup>+</sup>	assay H+ (mol/l)	residual HCl (g)	$\Delta$ acid %
BLT10d-0	0.96		4.6
BLT10d-2	0.95		
BLT10d-60	0.91	49.03	
BLT10d-60bulk	0.91	49.33	
average	0.93		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.00	0.12	0.06	0.01	0.00	0.04	0.74	1.50	0.02	0.13	1.50	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
head liquor	1592.00	1567.70	0.0	0.0	58.32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	98.47	98.67	-	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1698.47</b>		<b>0.13</b>	<b>0.07</b>	<b>58.33</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.51</b>	<b>0.02</b>	<b>0.14</b>	<b>1.50</b>	<b>0.01</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
BLT10d-2	0.00	-	-	-	-	-	-	-	-	-	-	-	
BLT10d-60	0.00	-	-	-	-	-	-	-	-	-	-	-	
BLT10d-60bulk	3.57	0.07	0.05	0.01	0.00	0.03	0.15	0.19	0.00	0.01	1.02	0.00	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT10d-2	25.56	25.16	0.000	0.000	0.918	0.000	0.000	0.001	0.001	0.000	0.001	0.001	0.000
BLT10d-60	19.29	18.95	0.000	0.000	0.688	0.000	0.006	0.015	0.000	0.000	0.001	0.003	0.000
BLT10d-60bulk	1507.49	1481.27	0.030	0.011	54.363	0.003	0.005	0.489	1.139	0.015	0.097	0.253	0.003
wash water	87.31	87.27	0.000	0.000	0.472	0.000	0.000	0.004	0.011	0.000	0.001	0.002	0.000
cake moisture	9.53	9.53	0.000	0.000	0.052	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
evaporation	20.24	20.28	-	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1672.99</b>		<b>0.10</b>	<b>0.06</b>	<b>56.50</b>	<b>0.01</b>	<b>0.03</b>	<b>0.65</b>	<b>1.35</b>	<b>0.02</b>	<b>0.11</b>	<b>1.28</b>	<b>0.01</b>

<b>balance (out/in)</b>	98%	83%	88%	97%	70%	84%	87%	90%	81%	77%	85%	70%
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extraction (solution)	calc. total soln volume (ml)	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT10d-2	1541.86	7%	15%	77%	4%	10%	5%	18%	24%	2%	77%
BLT10d-60	1503.31	23%	18%	75%	13%	61%	77%	84%	77%	17%	75%
BLT10d-60bulk	1503.31	25%	18%	75%	14%	67%	77%	85%	73%	17%	75%

extraction (solids)	calc. total solid mass (g)	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT10d-60bulk	3.7	38%	24%	54%	25%	79%	87%	90%	96%	30%	54%

extraction (ratio)	calc. total soln volume (ml)	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT10d-2	1541.9	10%	20%	54%	7%	11%	6%	18%	31%	4%	54%
BLT10d-60	1503.3	35%	24%	54%	24%	72%	87%	89%	100%	30%	54%
BLT10d-60bulk	1503.3	38%	24%	54%	25%	79%	87%	90%	96%	30%	54%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
BLT10d-60	5.68	710					
BLT10d-60bulk	5.39	673					
acid equivalent (g)			0.20	1.17	3.95	0.16	5.48
acid equivalent (%)			3.6	21.3	72.2	2.9	100.0

Test name: **BLT10e**  
 Comment: 80°C baseline, med pH

Date: **2-Dec-04**

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46	micron
stock solution added:	8.02	2.8	2.832	0.5	0.5	T:	80	°C
total slurry in:	1592	1567.9	1.0154	initial pulp % solids:	36.5	35.3	duration:	10
	1600.02			initial HCl (M):	1.00	0.97	agitation rate:	800
				MgCl2 (g/l):	0	0	impeller:	pitched blade, 5cm <sup>2</sup> , Ti
				total Cl- (g/l):	35	36.3	vessel:	2litre, baffled, with reflux condenser

Sample	minute	slurry removed (g)	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
BLT10e-0	0	36.3	24.5	0.00	1.0154	480	679	70min heat-up time, yellow-green PLS, clear green wash, grey-brown solids
BLT10e-2	2	13.84			1.0164			
BLT10e-120	120	16.38						
BLT10e-120bulk	120bulk	1546.52	24.9	0.02	1.0181	542	741	

Sample	filtrate mass (g)	filtrate vol (ml)	wet residue mass before wash (g)	wet residue mass after wash (g)	dry residue mass (g)	wash mass in (g)	wash vol in (ml)	wash mass out (g)	wash density @20°C (kg/l)	wash vol out (ml)	calc. evaporation cum. ml	calc. sample pulp density % solids
BLT10e-2	13.84	13.62					0.0				0.39	-
BLT10e-120	16.38	16.09					0.0				23.33	-
BLT10e-120bulk	1506.79	1480.00	8.0	11.3	3.37	106.19	106.4	94.66	1.0004	94.6	23.33	0.22

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
BLT10e-120bulk	2.07	1.33	0.07	0.05	0.81	2.46	3.85	0.05	0.07	36.5	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
BLT10e-head liquor	2	2	36.3	2	1	65.9	34.1	66.3	2	29.8	24.3	2
BLT10e-2	6.29	6.78	36.4	2	1	371	32.5	753	9.47	91.1	164	2
BLT10e-120	20.3	6.89	36.1	2	4.2	417	33.2	771	9.69	90.7	168	2
BLT10e-120bulk	19.4	6.93	36.9	2	1	54	4.74	118	2	13.5	18	2
BLT10e-comp. wash	2.78	2	5.04	2								

**CALCULATIONS AND MASS BALANCE**

H <sup>+</sup>	assay H+ mol/l	residual HCl g	Δ acid %
BLT10e-0	0.97		5.9
BLT10e-2	0.94		
BLT10e-120	0.89	48.10	
BLT10e-120bulk	0.91	49.14	
average	0.93		

solids IN feed solids	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT10e-2	0.00	-	-	-	-	-	-	-	-	-	-	-
BLT10e-120	0.00	-	-	-	-	-	-	-	-	-	-	-
BLT10e-120bulk	3.37	0.07	0.04	0.00	0.00	0.03	0.08	0.13	0.00	0.00	1.23	0.00

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT10e-2	13.84	0.000	0.000	0.496	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000
BLT10e-120	16.38	0.000	0.000	0.581	0.000	0.000	0.006	0.012	0.000	0.001	0.003	0.000
BLT10e-120bulk	1506.79	1480.00	0.029	54.612	0.003	0.006	0.617	1.141	0.014	0.134	0.249	0.003
wash water	94.66	94.62	0.000	0.477	0.000	0.000	0.005	0.011	0.000	0.001	0.002	0.000
cake moisture	7.93	0.000	0.000	0.040	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
evaporation	23.28	23.33	-	-	-	-	-	-	-	-	-	-
total OUT (g)	1666.25	0.10	0.06	56.21	0.000	0.03	0.71	1.30	0.02	0.14	1.48	0.00

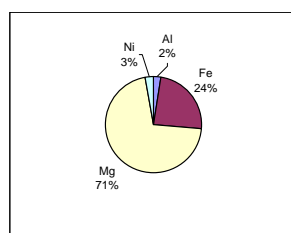
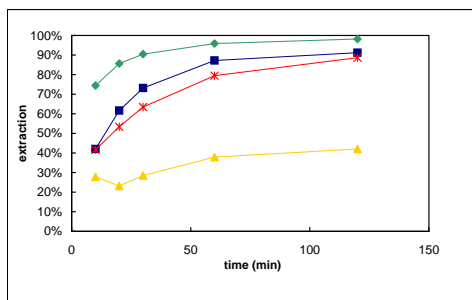
balance (out/in)	98%	79%	83%	99%	69%	83%	95%	86%	79%	102%	98%	69%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT10a-2	1553.85	5%	16%	77%	4%	9%	3%	17%	24%	2%	77%
BLT10b-2		6%	16%	77%	4%	8%	4%	18%	19%	2%	77%
BLT10c-2		7%	15%	77%	4%	10%	5%	18%	24%	2%	77%
BLT10d-2		8%	17%	77%	4%	14%	7%	18%	34%	3%	77%
BLT10e-2		8%	17%	77%	4%	14%	7%	18%	34%	3%	77%
BLT10e-2 ave.		6%	16%	77%	4%	10%	5%	18%	25%	2%	77%
std deviation		1%	1%	0%	0%	2%	2%	0%	7%	0%	0%
confidence limits		1.1%	0.6%	0.4%	0.0%	2.4%	1.5%	0.1%	6.4%	0.3%	0.4%
BLT10a-10		12%	15%	75%	5%	27%	21%	23%	60%	6%	75%
BLT10b-20		18%	16%	75%	8%	38%	43%	48%	61%	10%	75%
BLT10c-30		14%	17%	76%	9%	50%	52%	59%	87%	12%	76%
BLT10d-60		23%	18%	75%	13%	61%	77%	84%	77%	17%	75%
BLT10e-120	1514.82	25%	16%	76%	15%	75%	75%	81%	103%	17%	76%
BLT10e-120bulk	1514.82	24%	17%	76%	16%	85%	77%	83%	102%	17%	76%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT10a-10bulk	3.4	28%	19%	27%	15%	42%	42%	47%	74.41%	15%	27%
BLT10b-20bulk		23%	12%	37%	6%	53%	62%	68%	85.66%	17%	37%
BLT10c-30bulk		28%	16%	45%	14%	63%	73%	83%	90.48%	25%	45%
BLT10d-60bulk		38%	24%	54%	25%	79%	87%	90%	95.89%	30%	54%
BLT10e-120bulk		42%	28%	57%	28%	89%	91%	90%	98.21%	17%	57%

**based on solids assay**

acid consumption	g consumed	kg/ore	Al	Fe	Mg	Ni	total
BLT10e-120	7.25	903					
BLT10e-120bulk	6.21	774					
acid equivalent (g)			0.21	1.30	4.13	0.16	5.81
acid equivalent (%)			3.7	22.4	71.1	2.8	100.0



Test name: **BLT11a**  
 Comment: 80°C baseline, low pH

Date: **7-Dec-04**

	mass (g)	volume (ml)	density @20°C (kg/l)		nominal	effective	grind (D90)	46	micron
dry ore added:	8.04	2.8	2.832	initial pulp % solids:	0.5	0.5	T:	80	°C
stock solution added:	1770.5	1728.2	1.0245	initial HCl (g/l):	54.7	54.0	duration:	10	min
total slurry in:	1778.54			initial HCl (M):	1.50	1.48	agitation rate:	800	rpm
				MgCl2 (g/l):	0	0	impeller:	pitched blade, 5cm $\phi$ , Ti	
				total Cl- (g/l):	53	56.5	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
BLT11a-0	0		23.6	-0.22	1.0245	490	689	65min heat-up time, yellow PLS, clear green wash, light brown solids
BLT11a-2	2	21.21	24.3		1.0249		-	
BLT11a-10	10	18.28					-	
BLT11a-10bulk	10bulk	1721.09	25.4	-0.22	1.0254	539	738	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
BLT11a-2	21.21	20.69					0.0			-	3.60	-
BLT11a-10	18.28	17.83					0.0			-	18.00	-
BLT11a-10bulk	1691.69	1649.79	11.7	15.3	5.06	100.56	100.8	88.02	1.0024	87.8	18.00	0.29

#### ANALYSES

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
BLT11a-10bulk	1.53	0.9	0.15	0.05	0.58	7.26	13.6	0.16	0.44	31.6	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
BLT11a-head liquor	2	2	56.5	2	1	2	54	2	2	2	2	2
BLT11a-2	5.78	5.99	57	2	1	59.6	52.1	60.2	2	29.1	22.8	2
BLT11a-10	11.6	6.15	54.5	2	1.59	150	51.6	292	3.43	58.1	66.9	2
BLT11a-10bulk	12.9	5.99	55.4	2	1.88	197	51.8	362	4.35	74.2	80.2	2
BLT11a-comp. wash	3.77	2	9.08	2	1	79	8.17	194	4.63	21.6	13.3	2

#### CALCULATIONS AND MASS BALANCE

H <sup>+</sup>	assay H+ mol/l	residual HCl g	$\Delta$ acid %
BLT11a-0	1.48		4.1
BLT11a-2	1.43		
BLT11a-10	1.42	85.13	
BLT11a-10bulk	1.42	85.46	
average	1.44		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
feed solids	8.04	0.12	0.06	0.01	0.00	0.04	0.75	1.51	0.02	0.13	1.51	0.00
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
head liquor	1770.50	1728.16	0.0	0.0	97.64	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	-	100.56	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1879.10</b>		<b>0.13</b>	<b>0.07</b>	<b>97.65</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.51</b>	<b>0.02</b>	<b>0.14</b>	<b>1.51</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
BLT11a-2	0.00	-	-	-	-	-	-	-	-	-	-	-	
BLT11a-10	0.00	-	-	-	-	-	-	-	-	-	-	-	
BLT11a-10bulk	5.06	0.08	0.05	0.01	0.00	0.03	0.37	0.69	0.01	0.02	1.60	0.00	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT11a-2	21.21	20.69	0.000	0.000	1.180	0.000	0.000	0.001	0.001	0.000	0.001	0.000	0.000
BLT11a-10	18.28	17.83	0.000	0.000	0.972	0.000	0.000	0.003	0.005	0.000	0.001	0.001	0.000
BLT11a-10bulk	1691.69	1649.79	0.021	0.010	91.398	0.003	0.003	0.325	0.597	0.007	0.122	0.132	0.003
wash water	88.02	87.81	0.000	0.000	0.797	0.000	0.007	0.017	0.000	0.000	0.002	0.001	0.000
cake moisture	10.24	10.22	0.000	0.000	0.093	0.000	0.000	0.001	0.002	0.000	0.000	0.000	0.000
evaporation	17.96	18.00	-	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1852.46</b>		<b>0.10</b>	<b>0.06</b>	<b>94.45</b>	<b>0.01</b>	<b>0.03</b>	<b>0.70</b>	<b>1.31</b>	<b>0.02</b>	<b>0.15</b>	<b>1.73</b>	

balance (out/in)	99%	79%	83%	97%	82%	80%	94%	87%	75%	107%	115%	82%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT11a-2	1703.9	8%	16%	85%	4%	14%	7%	19%	37%	3%	85%
BLT11a-10	1671.6	16%	16%	83%	7%	34%	32%	32%	72%	7%	83%
BLT11a-10bulk	1671.6	18%	16%	83%	8%	44%	40%	41%	92%	9%	83%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT11a-10bulk	5.2	36%	27%	36%	23%	50%	53%	53%	83%	-8%	36%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT11a-2	1703.9	16%	27%	36%	12%	15%	9%	24%	33%	-2%	36%
BLT11a-10	1671.6	32%	27%	36%	19%	38%	43%	42%	65%	-7%	36%
BLT11a-10bulk	1671.6	36%	27%	36%	23%	50%	53%	53%	83%	-8%	36%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
BLT11a-10	8.19	1019					
BLT11a-10bulk	7.86	978					
acid equivalent (g)			0.18	0.75	2.47	0.14	3.54
acid equivalent (%)			5.2	21.1	69.8	3.9	100.0

Test name: **BLT11b**  
 Comment: 80°C baseline, low pH

Date: **7-Dec-04**

	mass (g)	volume (ml)	density @20°C (kg/l)		nominal	effective		grind (D90)	46	micron
dry ore added:	8.05	2.8	2.832	initial pulp % solids:	0.5	0.5	T:	80	°C	
stock solution added:	1592.4	1554.3	1.0245	initial HCl (g/l):	54.7	54.0	duration:	20	min	
total slurry in:	1600.45			initial HCl (M):	1.50	1.48	agitation rate:	800	rpm	
				MgCl2 (g/l):	0	0	impeller:	pitched blade, 5cmφ, T1		
				total Cl- (g/l):	53	56.5	vessel:	2litre, baffled, with reflux condenser		

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
BLT11b-0	0		23.6	-0.22	1.0245	490	689	55min heat-up time, yellow PLS, clear green wash, light brown solids
BLT11b-2	2							
BLT11b-20	20	28.67						
BLT11b-20bulk	20bulk	1548.5	24.6	-0.22	1.0263	538	737	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
BLT11b-2	0						0.0				2.33	-
BLT11b-20	28.67	27.94					0.0				23.33	-
BLT11b-20bulk	1522.18	1483.17	11.5	10.5	4.44	102.55	102.8	92.68	1.0028	92.4	23.33	0.29

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
BLT11b-20bulk	1.77	1.04	0.4	0.05	0.69	6.38	10.8	0.1	0.31	34.9	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
BLT11b-head liquor	2	2	56.5	2	1	2	54	2	2	2	2	2
BLT11b-2												
BLT11b-20	16.2	6.79	55.7	2	2.64	265	51.5	497	6.34	80.2	108	2
BLT11b-20bulk	18.3	6.82	56.4	2	2.66	297	51.3	536	6.96	91.5	114	2
BLT11b-comp. wash	3.09	2	9.62	2	1	62.1	9.06	154	2.84	14.9	18.2	2

**CALCULATIONS AND MASS BALANCE**

H*	assay H+ mol/l	residual HCl g	Δ acid %
BLT11b-0	1.48		5.0
BLT11b-2			
BLT11b-20	1.41	76.38	
BLT11b-20bulk	1.41	76.09	
average	1.43		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.05	0.12	0.06	0.01	0.00	0.04	0.75	1.51	0.02	0.13	1.51	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
head liquor	1592.40	1554.32	0.0	0.0	87.82	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	102.55	102.76	-	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1703.00</b>		<b>0.13</b>	<b>0.07</b>	<b>87.83</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.52</b>	<b>0.02</b>	<b>0.14</b>	<b>1.51</b>	<b>0.01</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
BLT11b-2	0.00	-	-	-	-	-	-	-	-	-	-	-	
BLT11b-20	0.00	-	-	-	-	-	-	-	-	-	-	-	
BLT11b-20bulk	4.44	0.08	0.05	0.02	0.00	0.03	0.28	0.48	0.00	0.01	1.55	0.00	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT11b-2	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BLT11b-20	28.67	27.94	0.000	0.000	1.556	0.000	0.000	0.007	0.014	0.000	0.002	0.003	0.000
BLT11b-20bulk	1522.18	1483.17	0.027	0.010	83.651	0.003	0.004	0.441	0.795	0.010	0.136	0.169	0.003
wash water	92.68	92.42	0.000	0.000	0.889	0.000	0.000	0.006	0.014	0.000	0.001	0.002	0.000
cake moisture	6.06	6.04	0.000	0.000	0.058	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
evaporation	23.28	23.33	-	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1677.31</b>		<b>0.11</b>	<b>0.06</b>	<b>86.17</b>	<b>0.01</b>	<b>0.03</b>	<b>0.74</b>	<b>1.30</b>	<b>0.02</b>	<b>0.15</b>	<b>1.72</b>	<b>0.01</b>

balance (out/in)	98%	84%	85%	98%	76%	86%	98%	86%	73%	111%	114%	76%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT11b-2	1551.99	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
BLT11b-20	1503.06	20%	16%	75%	10%	53%	49%	54%	89%	11%	75%
BLT11b-20bulk	1503.06	22%	16%	75%	10%	60%	53%	59%	102%	11%	75%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT11b-20bulk	4.5	35%	26%	44%	20%	61%	68%	74%	90%	-5%	44%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT11b-2	1552.0	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
BLT11b-20	1503.1	31%	26%	44%	20%	55%	63%	68%	79%	-4%	44%
BLT11b-20bulk	1503.1	35%	26%	44%	20%	61%	68%	74%	90%	-5%	44%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
BLT11b-20	7.55	938					
BLT11b-20bulk	7.85	975					
acid equivalent (g)			0.18	0.91	3.10	0.15	4.35
acid equivalent (%)			4.2	21.0	71.4	3.5	100.0

Test name: **BLT11c**  
 Comment: 80°C baseline, low pH

Date: **6-Dec-04**

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46	micron
stock solution added:	8.08	2.9	2.832	0.5	0.5	T:	80	°C
total slurry in:	1592.2	1555.2	1.0238	54.7	51.6	duration:	30	min
	1600.28			1.50	1.42	agitation rate:	800	rpm
				MgCl2 (g/l):	0	0	impeller:	pitched blade, 5cmφ, T1
				total Cl- (g/l):	53	54.6	vessel:	2litre, baffled, with reflux condenser

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
BLT11c-0	0		24.7	-0.22	1.0238	470	689	55min heat-up time, yellow PLS, clear green wash, light brown solids
BLT11c-2	2	25.03	23.8		1.0245			
BLT11c-30	30	21.73						
BLT11c-30bulk	30bulk	1538.25	23.6	-0.22	1.0269	536	735	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
BLT11c-2	25.03	24.43					0.0			-	1.02	-
BLT11c-30	21.73	21.16					0.0			-	15.30	-
BLT11c-30bulk	1475.1	1436.46	11.7	21.0	3.77	113.59	113.8	99.35	1.0042	98.9	15.30	0.25

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
BLT11c-30bulk	1.85	1.18	0.26	0.05	0.73	4.8	7.46	0.05	0.19	38.6	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
BLT11c-head liquor	2	2	54.6	2	1	2	51.6	2	2	2	2	2
BLT11c-2	5.3	6.66	54.4	2	1	51.9	51.5	59.9	2	21.8	23.5	2
BLT11c-30	16.2	7.31	53.5	2	3.15	276	49.3	623	8.08	67.5	130	2
BLT11c-30bulk	16.3	7.16	66.7	2	5.35	307	51.8	665	8.82	64.5	135	2
BLT11c-comp. wash	4.81	2	11.4	2	1.35	116	9.86	293	7.33	17.2	9.78	2

**CALCULATIONS AND MASS BALANCE**

H*	assay H+ mol/l	residual HCl g	Δ acid %
BLT11c-0	1.42		-0.4
BLT11c-2	1.41		
BLT11c-30	1.35	70.82	
BLT11c-30bulk	1.42	74.41	
average	1.40		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.08	0.12	0.06	0.01	0.00	0.04	0.75	1.52	0.02	0.14	1.52	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
head liquor	1592.20	1555.19	0.0	0.0	84.91	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
wash water	113.59	113.82	-	-	-	-	-	-	-	-	-	-	
<b>total IN (g)</b>	<b>1713.87</b>		<b>0.13</b>	<b>0.07</b>	<b>84.92</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.52</b>	<b>0.02</b>	<b>0.14</b>	<b>1.52</b>	

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
BLT11c-2	0.00	-	-	-	-	-	-	-	-	-	-	-	
BLT11c-30	0.00	-	-	-	-	-	-	-	-	-	-	-	
BLT11c-30bulk	3.77	0.07	0.04	0.01	0.00	0.03	0.18	0.28	0.00	0.01	1.46	0.00	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT11c-2	25.03	24.43	0.000	0.000	1.329	0.000	0.001	0.001	0.000	0.001	0.001	0.001	
BLT11c-30	21.73	21.16	0.000	0.000	1.132	0.000	0.006	0.013	0.000	0.001	0.003	0.000	
BLT11c-30bulk	1475.10	1436.46	0.023	0.010	95.812	0.003	0.008	0.441	0.955	0.013	0.093	0.194	
wash water	99.35	98.93	0.000	0.000	1.128	0.000	0.000	0.011	0.029	0.001	0.002	0.001	
cake moisture	17.23	17.16	0.000	0.000	0.196	0.000	0.000	0.002	0.005	0.000	0.000	0.000	
evaporation	15.27	15.30	-	-	-	-	-	-	-	-	-	-	
<b>total OUT (g)</b>	<b>1657.48</b>		<b>0.09</b>	<b>0.06</b>	<b>99.61</b>	<b>0.01</b>	<b>0.04</b>	<b>0.64</b>	<b>1.29</b>	<b>0.02</b>	<b>0.10</b>	<b>1.65</b>	

<b>balance (out/in)</b>	97%	74%	83%	117%	71%	87%	85%	84%	75%	75%	109%	71%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT11c-2	1529.74	7%	16%	76%	4%	11%	6%	17%	25%	2%	76%
BLT11c-30	1494.29	20%	17%	74%	12%	55%	61%	68%	75%	13%	74%
BLT11c-30bulk	1494.29	20%	17%	74%	20%	61%	65%	74%	71%	13%	74%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT11c-30bulk	3.9	42%	28%	52%	28%	75%	81%	89%	95%	1%	52%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT11c-2	1529.7	14%	26%	52%	5%	13%	7%	20%	32%	0%	52%
BLT11c-30	1494.3	42%	29%	52%	16%	68%	76%	82%	99%	1%	52%
BLT11c-30bulk	1494.3	42%	28%	52%	28%	75%	81%	89%	95%	1%	52%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
BLT11c-30	9.43	1167					
BLT11c-30bulk	5.84	723					
acid equivalent (g)			0.22	1.12	3.71	0.16	5.21
acid equivalent (%)			4.2	21.5	71.3	3.1	100.0

Test name: **BLT11d**  
 Comment: 80°C baseline, low pH

Date: **6-Dec-04**

	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46 micron	
dry ore added:	8.07	2.9	2.832	0.5	0.5	T:	80 °C	
stock solution added:	1592.7	1554.6	1.0245	54.7	54.0	duration:	60 min	
total slurry in:	1600.77			1.50	1.48	agitation rate:	800 rpm	
				MgCl2 (g/l):	0	0	impeller:	pitched blade, 5cmφ, T1
				total Cl- (g/l):	53	56.5	vessel:	2litre, baffled, with reflux condenser

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
BLT11d-0	0		23.6	-0.22	1.0245	490	689	135min heat-up time, yellow PLS, clear green wash, grey-brown solids
BLT11d-2	2	24.54	23.8		1.0254			
BLT11d-60	60	25.23						
BLT11d-60bulk	60bulk	1510.95	23.2	-0.22	1.0275	534	733	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
BLT11d-2	24.54	23.93					0.0				1.34	-
BLT11d-60	25.23	24.55					0.0				40.13	-
BLT11d-60bulk	1486.64	1446.85	9.5	10.9	3.5	103.27	103.5	93.34	1.0027	93.1	40.13	0.23

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
BLT11d-60bulk	2.03	1.28	0.18	0.05	0.81	2.58	4.77	0.05	0.08	39.3	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
BLT11d-head liquor	2	2	56.5	2	1	2	54	2	2	2	2	2
BLT11d-2	6.31	6.69	58.6	2	1	62.5	53.4	76.3	2	29.3	26.9	2
BLT11d-60	18	7.07	57.3	2	4.03	354	52.5	752	9.58	70	142	2
BLT11d-60bulk	19	7.04	57.4	2	4.13	370	53	754	9.67	64.4	144	2
BLT11d-comp. wash	3.23	2	8.75	2	1	62	7.94	136	2	12.7	16.5	2

**CALCULATIONS AND MASS BALANCE**

H*	assay H+ mol/l	residual HCl g	Δ acid %
BLT11d-0	1.48		1.9
BLT11d-2	1.46		
BLT11d-60	1.44	75.96	
BLT11d-60bulk	1.45	76.68	
average	1.46		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.07	0.12	0.06	0.01	0.00	0.04	0.75	1.52	0.02	0.14	1.51	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
head liquor	1592.70	1554.61	0.0	0.0	87.84	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	103.27	103.48	-	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1704.04</b>		<b>0.13</b>	<b>0.07</b>	<b>87.85</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.52</b>	<b>0.02</b>	<b>0.14</b>	<b>1.52</b>	<b>0.01</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
BLT11d-2	0.00	-	-	-	-	-	-	-	-	-	-	-	
BLT11d-60	0.00	-	-	-	-	-	-	-	-	-	-	-	
BLT11d-60bulk	3.50	0.07	0.04	0.01	0.00	0.03	0.09	0.17	0.00	0.00	1.38	0.00	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT11d-2	24.54	23.93	0.000	0.000	1.402	0.000	0.000	0.001	0.002	0.000	0.001	0.001	0.000
BLT11d-60	25.23	24.55	0.000	0.000	1.407	0.000	0.000	0.009	0.018	0.000	0.002	0.003	0.000
BLT11d-60bulk	1486.64	1446.85	0.027	0.010	83.049	0.003	0.006	0.535	1.091	0.014	0.093	0.208	0.003
wash water	93.34	93.09	0.000	0.000	0.815	0.000	0.000	0.006	0.013	0.000	0.001	0.002	0.000
cake moisture	7.40	7.38	0.000	0.000	0.065	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
evaporation	40.05	40.13	-	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1680.70</b>		<b>0.10</b>	<b>0.06</b>	<b>86.74</b>	<b>0.00</b>	<b>0.03</b>	<b>0.64</b>	<b>1.29</b>	<b>0.02</b>	<b>0.10</b>	<b>1.59</b>	<b>0.00</b>

balance (out/in)	99%	79%	83%	99%	69%	85%	85%	85%	78%	72%	105%	69%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT11d-2	1529.34	8%	16%	76%	4%	13%	7%	17%	33%	3%	76%
BLT11d-60	1465.99	21%	16%	73%	15%	69%	72%	79%	76%	14%	73%
BLT11d-60bulk	1465.99	23%	16%	73%	15%	72%	73%	80%	70%	14%	73%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT11d-60bulk	3.6	41%	27%	55%	25%	88%	89%	90%	98%	6%	55%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT11d-2	1529.3	13%	26%	55%	6%	15%	9%	19%	45%	1%	55%
BLT11d-60	1466.0	38%	28%	55%	25%	84%	88%	89%	106%	6%	55%
BLT11d-60bulk	1466.0	41%	27%	55%	25%	88%	89%	90%	98%	6%	55%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
BLT11d-60	7.99	990					
BLT11d-60bulk	7.27	900					
acid equivalent (g)			0.21	1.29	4.05	0.16	5.72
acid equivalent (%)			3.7	22.6	70.8	2.9	100.0

Test name: **BLT11e**  
 Comment: 80°C baseline, low pH

Date: **6-Dec-04**

	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46	micron
dry ore added:	8.05	2.8	2.832	initial pulp % solids:	0.5	T:	80	°C
stock solution added:	1592.2	1555.2	1.0238	initial HCl (g/l):	54.7	duration:	120	min
total slurry in:	1600.25			initial HCl (M):	1.50	agitation rate:	800	rpm
				MgCl2 (g/l):	0	impeller:	pitched blade, 5cm φ, T1	
				total Cl- (g/l):	53	vesse:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
BLT11e-0	0		24.7	-0.22	1.0238	470	689	60min heat-up time, yellow PLS, clear green wash, grey solids
BLT11e-2	2	24.4	23.6		1.0248			
BLT11e-120	120	24.21						
BLT11e-120bulk	120bulk	1510.57	23.3	-0.21	1.0273	533	732	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
BLT11e-2	24.4	23.81					0.0				0.69	-
BLT11e-120	24.21	23.57					0.0				41.15	-
BLT11e-120bulk	1479.89	1440.56	12.7	14.2	3.26	99.88	100.1	89.36	1.0029	89.1	41.15	0.22

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
BLT11e-120bulk	1.9	1.28	0.07	0.05	0.78	1.67	3.76	0.05	0.05	41.2	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
BLT11e-head liquor	2	2	54.6	2	1	2	51.6	2	2	2	2	2
BLT11e-2	7.33	6.72	56.3	2	1	73.4	52.3	92.6	2	32.6	29.5	2
BLT11e-120	20.4	7.33	56	2	4.31	392	50.3	753	9.49	112	141	2
BLT11e-120bulk	19.8	7.52	56.9	2	4.35	399	50.9	771	9.95	113	143	2
BLT11e-comp. wash	3.17	2	8.59	2	1	65.5	7.96	134	2	10.4	15.6	2

**CALCULATIONS AND MASS BALANCE**

H*	assay H+ mol/l	residual HCl g	Δ acid %
BLT11e-0	1.42		1.4
BLT11e-2	1.43		
BLT11e-120	1.38	72.46	
BLT11e-120bulk	1.40	73.32	
average	1.41		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
feed solids	8.05	0.12	0.06	0.01	0.00	0.04	0.75	1.51	0.02	0.13	1.51	0.00
<b>solution IN</b>	<b>total g</b>	<b>total ml</b>	<b>Al</b>	<b>Ca</b>	<b>Cl</b>	<b>Co</b>	<b>Cr</b>	<b>Fe</b>	<b>Mg</b>	<b>Mn</b>	<b>Ni</b>	<b>Zn</b>
head liquor	1592.20	1555.19	0.0	0.0	84.91	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	99.88	100.08	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1700.13</b>	<b>0.13</b>	<b>0.07</b>	<b>0.07</b>	<b>84.92</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.52</b>	<b>0.02</b>	<b>0.14</b>	<b>1.51</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT11e-2	0.00	-	-	-	-	-	-	-	-	-	-	-
BLT11e-120	0.00	-	-	-	-	-	-	-	-	-	-	-
BLT11e-120bulk	3.26	0.06	0.04	0.00	0.00	0.03	0.05	0.12	0.00	0.00	1.34	0.00
<b>solution OUT</b>	<b>total g</b>	<b>total ml</b>	<b>Al</b>	<b>Ca</b>	<b>Cl</b>	<b>Co</b>	<b>Cr</b>	<b>Fe</b>	<b>Mg</b>	<b>Mn</b>	<b>Ni</b>	<b>Zn</b>
BLT11e-2	24.40	23.81	0.000	0.000	1.340	0.000	0.000	0.002	0.002	0.000	0.001	0.001
BLT11e-120	24.21	23.57	0.000	0.000	1.320	0.000	0.000	0.009	0.018	0.000	0.003	0.003
BLT11e-120bulk	1479.89	1440.56	0.029	0.011	81.968	0.003	0.006	0.575	1.111	0.014	0.163	0.206
wash water	89.36	89.10	0.000	0.000	0.765	0.000	0.000	0.006	0.012	0.000	0.001	0.001
cake moisture	10.94	10.91	0.000	0.000	0.094	0.000	0.000	0.001	0.001	0.000	0.000	0.000
evaporation	41.07	41.15	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1673.13</b>	<b>0.09</b>	<b>0.05</b>	<b>0.05</b>	<b>85.49</b>	<b>0.00</b>	<b>0.03</b>	<b>0.65</b>	<b>1.27</b>	<b>0.02</b>	<b>0.17</b>	<b>1.55</b>

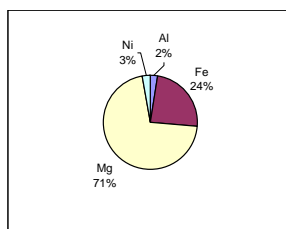
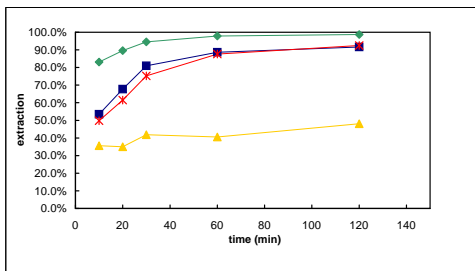
balance (out/in)	98%	72%	80%	101%	67%	79%	86%	84%	79%	122%	103%	67%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT11a-2		8%	16%	85%	4%	14%	7%	19%	37%	3%	85%
BLT11b-2											
BLT11c-2		7%	16%	76%	4%	11%	6%	17%	25%	2%	76%
BLT11d-2		8%	16%	76%	4%	13%	7%	17%	33%	3%	76%
BLT11e-2	1530.69	9%	16%	76%	4%	15%	9%	17%	37%	3%	76%
BLT11e-2 ave.		8%	16%	78%	4%	13%	7%	18%	33%	3%	78%
std deviation		1%	0%	4%	0%	2%	1%	1%	6%	0%	4%
confidence limits		1.0%	0.1%	4.4%	0.2%	1.8%	1.4%	1.0%	5.7%	0.3%	4.4%
BLT11a-10		16%	16%	83%	7%	34%	32%	32%	72%	7%	83%
BLT11b-20		20%	16%	75%	10%	53%	49%	54%	89%	11%	75%
BLT11c-30		20%	17%	74%	12%	55%	61%	68%	75%	13%	74%
BLT11d-60		21%	16%	73%	15%	69%	72%	79%	76%	14%	73%
BLT11e-120	1466.66	24%	17%	73%	16%	77%	73%	79%	122%	14%	73%
BLT11e-120bulk	1466.66	24%	17%	73%	16%	78%	75%	82%	123%	14%	73%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT11a-10bulk		36%	27%	36%	23%	50%	53%	53%	83.1%	-8%	36%
BLT11b-20bulk		35%	26%	44%	20%	61%	68%	74%	89.6%	-5%	44%
BLT11c-30bulk		42%	28%	52%	28%	75%	81%	89%	94.5%	1%	52%
BLT11d-60bulk		41%	27%	55%	25%	88%	89%	90%	97.9%	6%	55%
BLT11e-120bulk	3.4	48%	32%	58%	33%	92%	92%	91%	98.8%	8%	58%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
BLT11e-120	7.79	967					
BLT11e-120bulk	6.92	860					
acid equivalent (g)			0.25	1.36	4.17	0.17	5.95
acid equivalent (%)			4.2	22.9	70.2	2.8	100.0



Test name: **BLT12d**  
 Comment: 60°C baseline, high pH

Date: **8-Dec-04**

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46	micron
stock solution added:	8.07	2.9	2.832	initial pulp % solids:	0.5	T:	60	°C
total slurry in:	1592.5	1590.4	1.0013	initial HCl (g/l):	7.3	duration:	60	min
				initial HCl (M):	0.20	agitation rate:	800	rpm
				MgCl2 (g/l):	0	impeller:	pitched blade, 5cmφ, T1	
				total Cl- (g/l):	7	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
BLT12d-0	0		23.9	0.72	1.0013	524	723	
BLT12d-2	2	22.42	24		1.0013			
BLT12d-10	10	23.75	24.1	0.73	1.0013	578	777	
BLT12d-20	20	24.19	24.1	0.72	1.0014	592	791	
BLT12d-30	30	23.71	24.1	0.73	1.0015	606	805	
BLT12d-60	60	27.02						
BLT12d-60bulk	60bulk	1463.13	23.9	0.73	1.0016	621	820	60min heat-up time, light green PLS, clear wash, brown solids

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
BLT12d-2	22.42	22.39					0.0				0.55	-
BLT12d-10	23.75	23.72									2.73	-
BLT12d-20	24.19	24.16									5.46	-
BLT12d-30	23.71	23.67									8.19	-
BLT12d-60	27.02	26.98					0.0				16.38	-
BLT12d-60bulk	1437.3	1435.00	13.3	16.0	6.47	100.88	101.1	91.74	0.9987	91.9	16.38	0.44

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
BLT12d-60bulk	1.43	0.71	0.15	0.05	0.5	9.17	18	0.19	1.19	24.6	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
BLT12d-head liquor	2	2	6.98	2	1	2	7.06	2	2	2.61	2	2
BLT12d-2	2	6.11	7	2	1	6.21	7.09	6.17	2	3.69	3.33	2
BLT12d-10	2.03	6.09	8.24	2	1	12.2	7.07	9.6	2	7.42	7.02	2
BLT12d-20	2.7	6.01	6.93	2	1	19.7	7.07	16.3	2	12	11.3	2
BLT12d-30	3.37	6.1	7.98	2	1	26.9	7	24.2	2	16.5	15.2	2
BLT12d-60	4.9	6.09	7.67	2	1	51.4	6.87	64.8	2	30.8	27.9	2
BLT12d-60bulk	5.19	6.19	7.49	2	1	54.1	6.87	71.1	2	28.9	29.8	2
BLT12d-comp. wash	2	2	0.5	2	1	14.3	1.54	33.1	2	8.13	11.3	2

**CALCULATIONS AND MASS BALANCE**

H <sup>+</sup>	assay H+ mol/l	residual HCl g	Δ acid %
BLT12d-0	0.19		2.7
BLT12d-2	0.19		
BLT12d-10	0.19		
BLT12d-20	0.19		
BLT12d-30	0.19		
BLT12d-60	0.19	9.86	
BLT12d-60bulk	0.19	9.86	
average	0.19		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
feed solids	8.07	0.12	0.06	0.01	0.00	0.04	0.75	1.52	0.02	0.14	1.51	0.00
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
head liquor	1592.50	1590.43	0.0	0.0	11.10	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	100.88	101.08	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1701.45</b>	<b>0.13</b>	<b>0.07</b>	<b>11.11</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.52</b>	<b>0.02</b>	<b>0.14</b>	<b>1.52</b>	<b>0.01</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT12d-2	0.00	-	-	-	-	-	-	-	-	-	-	-
BLT12d-10	0.00	-	-	-	-	-	-	-	-	-	-	-
BLT12d-20	0.00	-	-	-	-	-	-	-	-	-	-	-
BLT12d-30	6.47	0.09	0.05	0.01	0.00	0.03	0.59	1.16	0.01	0.08	1.59	0.00
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
BLT12d-2	22.42	22.39	0.000	0.000	0.157	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BLT12d-10	23.75	23.72	0.000	0.000	0.195	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BLT12d-20	24.19	24.16	0.000	0.000	0.167	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BLT12d-30	23.71	23.67	0.000	0.000	0.189	0.000	0.000	0.001	0.001	0.000	0.000	0.000
BLT12d-60	27.02	26.98	0.000	0.000	0.207	0.000	0.000	0.001	0.002	0.000	0.001	0.001
BLT12d-60bulk	1437.30	1435.00	0.007	0.009	10.748	0.003	0.001	0.078	0.102	0.003	0.041	0.043
wash water	91.74	91.86	0.000	0.000	0.046	0.000	0.000	0.001	0.003	0.000	0.001	0.001
cake moisture	9.53	9.54	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000
evaporation	16.35	16.38	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1682.48</b>	<b>0.10</b>	<b>0.06</b>	<b>11.72</b>	<b>0.01</b>	<b>0.03</b>	<b>0.68</b>	<b>1.27</b>	<b>0.02</b>	<b>0.12</b>	<b>1.64</b>	<b>0.01</b>

balance (out/in)	99%	79%	83%	106%	91%	83%	90%	84%	75%	87%	108%	91%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT12d-2	1567.50	3%	15%	78%	4%	1%	18%	4%	0%	78%	
BLT12d-10	1541.59	3%	15%	76%	4%	3%	1%	17%	8%	1%	76%
BLT12d-20	1514.71	3%	14%	75%	4%	4%	2%	17%	13%	1%	75%
BLT12d-30	1488.30	4%	14%	74%	4%	5%	2%	17%	18%	1%	74%
BLT12d-60	1453.13	6%	14%	72%	4%	10%	6%	16%	33%	3%	72%
BLT12d-60bulk	1453.13	6%	14%	72%	4%	10%	7%	16%	31%	3%	72%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT12d-60bulk	7.0	19%	22%	13%	11%	14%	17%	25%	38%	-14%	13%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT12d-2	1567.5	7%	22%	13%	11%	2%	1%	25%	5%	-2%	13%
BLT12d-60	1453.1	18%	22%	13%	11%	14%	15%	25%	41%	-13%	13%
BLT12d-60bulk	1453.1	19%	22%	13%	11%	14%	17%	25%	38%	-14%	13%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
BLT12d-60	1.37	170					
BLT12d-60bulk	1.37	170					
acid equivalent (g)			0.13	0.31	1.06	0.07	1.56
acid equivalent (%)			8.0	19.7	67.6	4.6	100.0

Test name: **BLT12e**  
 Comment: 60°C baseline, high pH

Date: **7-Dec-04**

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46	micron
stock solution added:	8.07	2.9	2.832	initial pulp % solids:	0.5	T:	60	°C
total slurry in:	1592.3	1590.1	1.0014	initial HCl (g/l):	7.3	duration:	120	min
	1600.37			initial HCl (M):	0.20	agitation rate:	800	rpm
				MgCl2 (g/l):	0	impeller:	pitched blade, 5cm $\phi$ , T1	
				total Cl <sup>-</sup> (g/l):	7	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
BLT12e-0	0		23.9	0.72	1.0014	531	730	60min heat-up time, light green PLS, clear wash, brown solids
BLT12e-2	2	22.96	23.9		1.0013			
BLT12e-120	120	21.37						
BLT12e-120bulk	120bulk	1542.75	23.8	0.76	1.0019	616	815	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
BLT12e-2	22.96	22.93					0.0				0.22	-
BLT12e-120	21.37	21.33					0.0				13.32	-
BLT12e-120bulk	1507.38	1504.52	21.5	21.6	6.26	100.19	100.4	92.89	0.9989	93.0	13.32	0.41

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
BLT12e-120bulk	1.58	0.83	0.18	0.05	0.54	8.69	16.9	0.17	0.91	26.1	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
BLT12e-head liquor	2	2	6.85	2	1	2	6.97	2	2	2.61	2	2
BLT12e-2	2	6.4	6.85	2	1	5.9	6.93	6.23	2	3.2	3.22	2
BLT12e-120	7.77	6.53	6.74	2	1	89.8	6.49	156	3.03	47.2	49.4	2
BLT12e-120bulk	8.07	6.4	6.94	2	1	93.3	6.42	168	3.13	47.5	52.7	2
BLT12e-comp. wash	2	2	0.5	2	1	22.1	1.77	53.8	2	12.3	16.5	2

**CALCULATIONS AND MASS BALANCE**

H <sup>+</sup>	assay H <sup>+</sup> mol/l	residual HCl g	$\Delta$ acid %
BLT12e-0	0.19		7.9
BLT12e-2	0.19		
BLT12e-120	0.18	9.76	
BLT12e-120bulk	0.18	9.66	
average	0.18		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
feed solids	8.07	0.12	0.06	0.01	0.00	0.04	0.75	1.52	0.02	0.14	1.51	0.00
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
head liquor	1592.30	1590.07	0.0	0.0	10.89	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	100.19	100.39	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1700.56</b>	<b>0.13</b>	<b>0.07</b>	<b>10.90</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.52</b>	<b>0.02</b>	<b>0.14</b>	<b>1.52</b>	<b>0.01</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT12e-2	0.00	-	-	-	-	-	-	-	-	-	-	-
BLT12e-120	0.00	-	-	-	-	-	-	-	-	-	-	-
BLT12e-120bulk	6.26	0.10	0.05	0.01	0.00	0.03	0.54	1.06	0.01	0.06	1.63	0.00
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
BLT12e-2	22.96	22.93	0.000	0.000	0.157	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BLT12e-120	21.37	21.33	0.000	0.000	0.144	0.000	0.002	0.003	0.003	0.000	0.001	0.001
BLT12e-120bulk	1507.38	1504.52	0.012	0.010	10.441	0.003	0.002	0.140	0.253	0.005	0.071	0.079
wash water	92.89	92.99	0.000	0.000	0.046	0.000	0.000	0.002	0.005	0.000	0.001	0.002
cake moisture	15.34	15.36	0.000	0.000	0.008	0.000	0.000	0.000	0.001	0.000	0.000	0.000
evaporation	13.29	13.32	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1679.49</b>	<b>13.32</b>	<b>0.11</b>	<b>0.06</b>	<b>10.81</b>	<b>0.01</b>	<b>0.04</b>	<b>0.69</b>	<b>1.32</b>	<b>0.02</b>	<b>0.13</b>	<b>1.72</b>

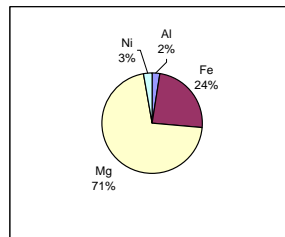
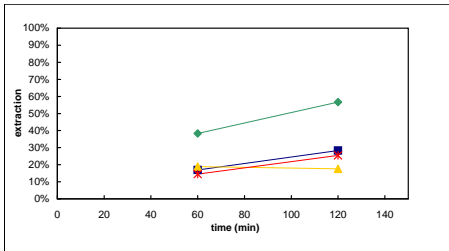
balance (out/in)	99%	88%	93%	99%	89%	87%	91%	87%	75%	94%	113%	89%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT12d-2	1566.92	3%	15%	78%	4%	1%	0%	18%	4%	0%	78%
BLT12e-2		3%	16%	78%	4%	1%	0%	18%	4%	0%	78%
BLT12e-2 ave.		3%	15%	78%	4%	1%	0%	18%	4%	0%	78%
std deviation		0%	1%	0%	0%	0%	0%	0%	0%	0%	0%
confidence limits		0.0%	0.7%	0.0%	0.1%	0.0%	0.0%	0.0%	0.6%	0.0%	0.0%
BLT12d-60	1532.50	6%	14%	72%	4%	10%	6%	16%	33%	3%	72%
BLT12e-120		10%	16%	76%	4%	18%	16%	26%	54%	5%	76%
BLT12e-120bulk		10%	15%	76%	4%	19%	17%	27%	54%	5%	76%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT12d-60bulk	6.4	19%	22%	13%	11%	14%	17%	25%	38%	-14%	13%
BLT12e-120bulk		18%	16%	20%	11%	25%	28%	38%	57%	-11%	20%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
BLT12e-120	1.32	163					
BLT12e-120bulk	1.42	176					
acid equivalent (g)			0.10	0.41	1.38	0.10	1.98
acid equivalent (%)			5.0	20.5	69.6	4.9	100.0



Test name: BLT13a  
 Comment: 80°C baseline, 0.5% solids

Date: 1-Apr-05

	mass (g)	volume (ml)	density @20°C (kg/l)		nominal	effective	grind (D90)	46	micron
dry ore added:	8	2.8	2.832	initial pulp % solids:	0.5	0.5	T:	80	°C
stock solution added:	1592.4	1589.9	1.0016	initial HCl (g/l):	7.3	7.1	duration:	10	min
total slurry in:	1600.4			initial HCl (M):	0.20	0.19	agitation rate:	800	rpm
				MgCl2 (g/l):	0	0	impeller:	pitched blade, 5cmφ, Ti	
				total Cl- (g/l):	7	8.13	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
BLT13a-0	0				1.0016		-	
BLT13a-2	2						-	
BLT13a-10	10	20.81					-	
BLT13a-10bulk	10bulk	1561.6		0.75	1.0018	588	787	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
BLT13a-2							0.0			-	3.61	-
BLT13a-10	20.4	20.36					0.0			-	18.03	-
BLT13a-10bulk	1537.8	1535.04	7.7	8.7	7.39	223.57	224.0	215.23	0.9985	215.6	18.03	0.47

#### ANALYSES

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
BLT13a-10bulk	1.34	0.73	0.18	0.05	0.49	8.42	17.5	0.2	1.19	17.6	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
BLT13a-head liquor	2	2	8.13	2	1	2	7.08	2	2	2	2	2
BLT13a-2												
BLT13a-10	4.31	3.5	7.24	2	1	32.4	7.07	38.9	2	18.9	15.1	2
BLT13a-10bulk	5.62	3.56	7.57	2	1	44.9	6.9	64.9	2	29	20.6	2
BLT13a-comp. wash	2	2	0.5	2	1	2.67	0.5	11.7	2	2	3.15	2

#### CALCULATIONS AND MASS BALANCE

H <sup>+</sup>	assay H+ mol/l	residual HCl g	Δ acid %
BLT13a-0	0.19		2.5
BLT13a-2			
BLT13a-10	0.19	10.85	
BLT13a-10bulk	0.19	10.59	
average	0.19		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.00	0.12	0.06	0.01	0.00	0.04	0.74	1.50	0.02	0.13	1.50	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
head liquor	1592.40	1589.86	0.0	0.0	12.93	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	223.57	224.02	-	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1823.97</b>		<b>0.13</b>	<b>0.07</b>	<b>12.94</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.51</b>	<b>0.02</b>	<b>0.14</b>	<b>1.50</b>	<b>0.01</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
BLT13a-2	0.00	-	-	-	-	-	-	-	-	-	-	-	
BLT13a-10	0.00	-	-	-	-	-	-	-	-	-	-	-	
BLT13a-10bulk	7.39	0.10	0.05	0.01	0.00	0.04	0.62	1.29	0.01	0.09	1.30	0.00	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT13a-2	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BLT13a-10	20.40	20.36	0.000	0.000	0.147	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000
BLT13a-10bulk	1537.80	1535.04	0.009	0.008	11.620	0.003	0.002	0.069	0.100	0.003	0.045	0.032	0.003
wash water	215.23	215.55	0.000	0.000	0.108	0.000	0.000	0.001	0.003	0.000	0.000	0.001	0.000
cake moisture	1.31	1.31	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
evaporation	17.99	18.03	-	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1800.12</b>		<b>0.11</b>	<b>0.06</b>	<b>11.89</b>	<b>0.01</b>	<b>0.04</b>	<b>0.69</b>	<b>1.40</b>	<b>0.02</b>	<b>0.13</b>	<b>1.33</b>	<b>0.01</b>

balance (out/in)	99%	86%	90%	92%	101%	94%	93%	93%	88%	97%	89%	101%

extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT13a-2	1586.3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
BLT13a-10	1551.5	5%	9%	78%	4%	7%	4%	18%	22%	2%	78%
BLT13a-10bulk	1551.5	7%	9%	78%	4%	9%	6%	18%	34%	2%	78%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT13a-10bulk	7.5	18%	14%	6%	5%	15%	13%	15%	34%	12%	6%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT13a-2	1586.3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
BLT13a-10	1551.5	14%	13%	6%	5%	11%	8%	15%	22%	9%	6%
BLT13a-10bulk	1551.5	18%	14%	6%	5%	15%	13%	15%	34%	12%	6%

#### based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
BLT13a-10	0.40	50					
BLT13a-10bulk	0.66	83					
acid equivalent (g)			0.09	0.24	0.63	0.06	1.02
acid equivalent (%)			9.3	23.4	61.8	5.6	100.0

Test name: **BLT13b**  
 Comment: 80°C baseline, 0.5% solids

Date: **31-Mar-05**

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46	micron
stock solution added:	8.03	2.8	2.832	0.5	0.5	T:	80	°C
total slurry in:	1592	1589.5	1.0016	initial pulp % solids:		duration:	20	min
	1600.03			initial HCl (g/l):	7.3	7.1	800	rpm
				MgCl2 (g/l):	0	0	impeller:	pitched blade, 5cmφ, Ti
				total Cl- (g/l):	7	8.13	vessel:	2litre, baffled, with reflux condenser

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
BLT13b-0	0				1.0016		-	
BLT13b-2	2						-	
BLT13b-20	20	23.35					-	
BLT13b-20bulk	20bulk	1556.3		0.76	1.0020	599	798	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
BLT13b-2	0						0.0				2.04	-
BLT13b-20	22.45	22.41					0.0				20.42	-
BLT13b-20bulk	1521.8	1518.76	8.3	8.5	5.18	192.83	193.2	184.18	0.9986	184.4	20.42	0.33

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
BLT13b-20bulk	1.41	0.8	0.22	0.05	0.53	8.34	16.8	0.18	0.99	18.9	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
BLT13b-head liquor	2	2	8.13	2	1	2	7.08	2	2	2	2	2
BLT13b-2												
BLT13b-20	6.33	3.61	8.04	2	1	58.9	6.74	93	2	33	26	2
BLT13b-20bulk	8.17	3.74	7.46	2	1	79.1	6.77	148	2.6	43.2	35	2
BLT13b-comp. wash	2	2	0.5	2	1	4.97	2.22	18.4	2	2.21	3.91	2

**CALCULATIONS AND MASS BALANCE**

H <sup>+</sup>	assay H+ mol/l	residual HCl g	Δ acid %
BLT13b-0	0.19		4.4
BLT13b-2			
BLT13b-20	0.18	10.24	
BLT13b-20bulk	0.19	10.28	
average	0.19		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
feed solids	8.03	0.12	0.06	0.01	0.00	0.04	0.75	1.51	0.02	0.13	1.51	0.00
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
head liquor	1592.00	1589.46	0.0	0.0	12.92	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	192.83	193.22	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1792.86</b>	<b>0.13</b>	<b>0.07</b>	<b>12.93</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.51</b>	<b>0.02</b>	<b>0.14</b>	<b>1.51</b>	<b>0.01</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT13b-2	0.00	-	-	-	-	-	-	-	-	-	-	-
BLT13b-20	0.00	-	-	-	-	-	-	-	-	-	-	-
BLT13b-20bulk	5.18	0.07	0.04	0.01	0.00	0.03	0.43	0.87	0.01	0.05	0.98	0.00
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
BLT13b-2	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BLT13b-20	22.45	22.41	0.000	0.000	0.180	0.000	0.001	0.002	0.000	0.001	0.001	0.000
BLT13b-20bulk	1521.80	1518.76	0.012	0.006	11.330	0.003	0.002	0.120	0.225	0.004	0.066	0.053
wash water	184.18	184.44	0.000	0.000	0.092	0.000	0.001	0.003	0.000	0.000	0.001	0.000
cake moisture	3.32	3.32	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
evaporation	20.38	20.42	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1757.31</b>	<b>0.09</b>	<b>0.05</b>	<b>11.62</b>	<b>0.01</b>	<b>0.03</b>	<b>0.55</b>	<b>1.10</b>	<b>0.01</b>	<b>0.12</b>	<b>1.03</b>	<b>0.01</b>

<b>balance (out/in)</b>	<b>98%</b>	<b>68%</b>	<b>71%</b>	<b>90%</b>	<b>84%</b>	<b>72%</b>	<b>74%</b>	<b>73%</b>	<b>66%</b>	<b>86%</b>	<b>68%</b>	<b>84%</b>
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT13b-2	1587.41	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
BLT13b-20	1546.63	8%	9%	77%	4%	12%	9%	18%	38%	3%	77%
BLT13b-20bulk	1546.63	10%	9%	77%	4%	16%	15%	23%	50%	4%	77%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT13b-20bulk	5.3	40%	34%	35%	28%	41%	41%	46%	61%	34%	35%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT13b-2	1587.4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
BLT13b-20	1546.6	31%	33%	35%	28%	31%	26%	36%	47%	25%	35%
BLT13b-20bulk	1546.6	40%	34%	35%	28%	41%	41%	46%	61%	34%	35%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
BLT13b-20	1.02	127					
BLT13b-20bulk	0.97	121					
acid equivalent (g)			0.20	0.62	1.92	0.10	2.84
acid equivalent (%)			7.1	21.7	67.5	3.6	100.0

Test name: **BLT13c**  
 Comment: 80°C baseline, 0.5% solids

Date: **31-Mar-05**

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	initial pulp % solids:	nominal	effective	grind (D90)	46	micron
stock solution added:	8.06	2.8	2.832	initial HCl (g/l):	0.5	0.5	T:	80	°C
total slurry in:	1592.6	1590.1	1.0016	initial HCl (M):	7.3	7.1	duration:	30	min
	1600.66			MgCl2 (g/l):	0.20	0.19	agitation rate:	800	rpm
				total Cl- (g/l):	0	0	impeller:	pitched blade, 5cmφ, Ti	
					7	8.13	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
BLT13c-0	0				1.0016		-	
BLT13c-2	2						-	
BLT13c-30	30	24.4					-	
BLT13c-30bulk	30bulk	1556.04		0.79	1.0024	601	800	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
BLT13c-2	0						0.0				1.35	-
BLT13c-30	23.37	23.31					0.0				20.26	-
BLT13c-30bulk	1525.3	1521.65	9.1	10.6	5.03	197.66	198.1	194.81	0.9984	195.1	20.26	0.32

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
BLT13c-30bulk	1.49	0.85	0.33	0.05	0.57	8.34	16.3	0.17	0.89	19.8	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
BLT13c-head liquor	2	2	8.13	2	1	2	7.08	2	2	2	2	2
BLT13c-2												
BLT13c-30	8.17	3.8	7.33	2	1	88.3	6.34	170	2.68	47.1	37.7	2
BLT13c-30bulk	9.46	3.59	7.54	2	1	101	6.41	222	3.44	52.1	45.3	2.89
BLT13c-comp. wash	2	2	0.5	2	1	6.29	8.57	23.7	2	2	4.19	2

**CALCULATIONS AND MASS BALANCE**

H <sup>+</sup>	assay H+ mol/l	residual HCl g	Δ acid %
BLT13c-0	0.19		9.5
BLT13c-2	0.00		
BLT13c-30	0.17	9.65	
BLT13c-30bulk	0.18	9.75	
average	0.14		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
feed solids	8.06	0.12	0.06	0.01	0.00	0.04	0.75	1.52	0.02	0.14	1.51	0.00
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
head liquor	1592.60	1590.06	0.0	0.0	12.93	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	197.66	198.06	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1798.32</b>	<b>0.13</b>	<b>0.07</b>	<b>12.94</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.52</b>	<b>0.02</b>	<b>0.14</b>	<b>1.51</b>	<b>0.01</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT13c-2	0.00	-	-	-	-	-	-	-	-	-	-	-
BLT13c-30	0.00	-	-	-	-	-	-	-	-	-	-	-
BLT13c-30bulk	5.03	0.07	0.04	0.02	0.00	0.03	0.42	0.82	0.01	0.04	1.00	0.00
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
BLT13c-2	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BLT13c-30	23.37	23.31	0.000	0.000	0.171	0.000	0.002	0.004	0.000	0.001	0.001	0.000
BLT13c-30bulk	1525.30	1521.65	0.014	0.005	11.473	0.003	0.002	0.154	0.338	0.005	0.079	0.069
wash water	194.81	195.12	0.000	0.000	0.098	0.000	0.001	0.005	0.000	0.000	0.001	0.000
cake moisture	5.57	5.58	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
evaporation	20.22	20.26	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1774.30</b>	<b>0.09</b>	<b>0.05</b>	<b>11.76</b>	<b>0.01</b>	<b>0.03</b>	<b>0.58</b>	<b>1.17</b>	<b>0.01</b>	<b>0.13</b>	<b>1.07</b>	<b>0.01</b>

balance (out/in)	99%	71%	73%	91%	83%	75%	77%	77%	68%	91%	70%	102%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT13c-2	1588.71	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
BLT13c-30	1546.48	10%	9%	77%	4%	18%	17%	23%	54%	4%	77%
BLT13c-30bulk	1546.48	12%	9%	77%	4%	21%	22%	30%	60%	5%	111%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT13c-30bulk	5.1	38%	32%	37%	26%	43%	45%	51%	66%	33%	37%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT13c-2	1588.7	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
BLT13c-30	1546.5	33%	34%	37%	26%	38%	34%	40%	60%	28%	25%
BLT13c-30bulk	1546.5	38%	32%	37%	26%	43%	45%	51%	66%	33%	37%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
BLT13c-30	1.61	200					
BLT13c-30bulk	1.50	187					
acid equivalent (g)			0.20	0.65	2.09	0.11	3.04
acid equivalent (%)			6.4	21.3	68.6	3.7	100.0

Test name: **BLT13d**  
 Comment: 80°C baseline, 0.5% solids

Date: **30-Mar-05**

	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46 micron
dry ore added:	8.02	2.8	2.832	0.5	0.5	T: 80	°C
stock solution added:	1592.6	1590.1	1.0016	7.3	7.1	duration: 60	min
total slurry in:	1600.62			0.20	0.19	agitation rate: 800	rpm
				0	0	impeller: pitched blade, 5cmφ, Ti	
				7	8.13	vessel: 2litre, baffled, with reflux condenser	

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
BLT13d-0	0				1.0016		-	
BLT13d-2	2						-	
BLT13d-60	60	21.53					-	
BLT13d-60bulk	60bulk	1558.6		0.81	1.0027	600	799	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
BLT13d-2	0						0.0			-	0.68	-
BLT13d-60	20.91	20.85					0.0			-	20.53	-
BLT13d-60bulk	1533.4	1529.27	9.8	10.9	4.3	195.39	195.8	180.86	0.9985	181.1	-	0.28

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
BLT13d-60bulk	1.54	0.92	0.29	0.05	0.61	8.07	13.7	0.12	0.65	20.6	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
BLT13d-head liquor	2	2	8.13	2	1	2	7.08	2	2	2	2	2
BLT13d-2												
BLT13d-60	11.5	3.59	7.55	2	1.16	147	6.04	361	5.22	64	67.4	2
BLT13d-60bulk	12.2	3.68	8.35	2	1.22	142	5.77	402	5.74	64.1	73.8	4
BLT13d-comp. wash	2	2	0.5	2	1	8.91	1.29	40.5	2	3.93	5.4	2

**CALCULATIONS AND MASS BALANCE**

H <sup>+</sup>	assay H+ mol/l	residual HCl g	Δ acid %
BLT13d-0	0.19		18.5
BLT13d-2	0.00		
BLT13d-60	0.17	9.24	
BLT13d-60bulk	0.16	8.82	
average	0.13		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
feed solids	8.02	0.12	0.06	0.01	0.00	0.04	0.75	1.51	0.02	0.13	1.60	0.00
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
head liquor	1592.60	1590.06	0.0	0.0	12.93	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	195.39	195.78	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1798.01</b>	<b>0.13</b>	<b>0.07</b>	<b>12.94</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.51</b>	<b>0.02</b>	<b>0.14</b>	<b>1.51</b>	<b>0.01</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT13d-2	0.00	-	-	-	-	-	-	-	-	-	-	-
BLT13d-60	0.00	-	-	-	-	-	-	-	-	-	-	-
BLT13d-60bulk	4.30	0.07	0.04	0.01	0.00	0.03	0.35	0.59	0.01	0.03	0.89	0.00
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
BLT13d-2	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BLT13d-60	20.91	20.85	0.000	0.000	0.157	0.000	0.003	0.008	0.000	0.001	0.001	0.000
BLT13d-60bulk	1533.40	1529.27	0.019	0.006	12.769	0.003	0.002	0.217	0.615	0.009	0.098	0.113
wash water	180.86	181.13	0.000	0.000	0.091	0.000	0.002	0.007	0.000	0.001	0.001	0.000
cake moisture	6.60	6.61	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
evaporation	20.49	20.53	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1766.56</b>	<b>0.09</b>	<b>0.05</b>	<b>13.03</b>	<b>0.01</b>	<b>0.03</b>	<b>0.57</b>	<b>1.22</b>	<b>0.01</b>	<b>0.13</b>	<b>1.00</b>	<b>0.01</b>

balance (out/in)	98%	68%	69%	101%	78%	70%	76%	81%	69%	93%	66%	121%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT13d-2	1589.37	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
BLT13d-60	1548.67	15%	9%	77%	5%	31%	37%	46%	74%	7%	77%
BLT13d-60bulk	1548.67	15%	9%	77%	5%	29%	41%	50%	74%	8%	154%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT13d-60bulk	4.4	45%	37%	46%	32%	53%	60%	70%	79%	40%	46%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT13d-2	1589.4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
BLT13d-60	1548.7	43%	36%	46%	30%	55%	54%	64%	79%	37%	23%
BLT13d-60bulk	1548.7	45%	37%	46%	32%	53%	60%	70%	79%	40%	46%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
BLT13d-60	2.02	252					
BLT13d-60bulk	2.43	303					
acid equivalent (g)			0.23	0.78	2.76	0.13	3.90
acid equivalent (%)			5.9	20.1	70.7	3.4	100.0

Test name: **BLT13e**  
 Comment: 80°C baseline, 0.5% solids

Date: **30-Mar-05**

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	initial pulp % solids:	nominal	effective	grind (D90)	46	micron
stock solution added:	8.04	2.8	2.832	initial HCl (g/l):	0.5	0.5	T:	80	°C
total slurry in:	1592.3	1589.8	1.0016	initial HCl (M):	7.3	7.1	duration:	120	min
	1600.34			MgCl2 (g/l):	0.20	0.19	agitation rate:	800	rpm
				total Cl- (g/l):	0	0	impeller:	pitched blade, 5cmφ, Ti	
					7	8.13	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
BLT13e-0	0				1.0016			
BLT13e-2	2							
BLT13e-120	120	21.14						
BLT13e-120bulk	120bulk	1580.2		0.88	1.0032	586	785	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
BLT13e-2	0										-0.02	-
BLT13e-120	20.6	20.53									-1.00	-
BLT13e-120bulk	1552.7	1547.75	10.9	13.7	3.14	191.35	191.7	179.8	0.9987	180.0	-1.00	0.20

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
BLT13e-120bulk	1.63	0.99	0.26	0.05	0.7	6.97	7.96	0.05	0.34	20.5	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
BLT13e-head liquor	2	2	8.13	2	1	2	7.08	2	2	2	2	2
BLT13e-2												
BLT13e-120	15	3.66	7.29	2	1.76	217	5.09	652	8.28	81.6	120	2
BLT13e-120bulk	15.5	3.64	7.46	2	1.83	211	5.43	673	8.51	79.6	124	2
BLT13e-comp. wash	2	2	0.5	2	1	14.8	0.5	57.7	2	5.12	7.63	2

**CALCULATIONS AND MASS BALANCE**

H <sup>+</sup>	assay H+ mol/l	residual HCl g	Δ acid %
BLT13e-0	0.19		23.3
BLT13e-2			
BLT13e-120	0.14	7.88	
BLT13e-120bulk	0.15	8.40	
average	0.16		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.04	0.12	0.06	0.01	0.00	0.04	0.75	1.51	0.02	0.13	1.51	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
head liquor	1592.30	1589.76	0.0	0.0	12.92	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	191.35	191.73	-	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1791.69</b>	<b>0.13</b>	<b>0.07</b>	<b>12.94</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.51</b>	<b>0.02</b>	<b>0.14</b>	<b>1.51</b>	<b>0.01</b>	

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
BLT13e-2	0.00	-	-	-	-	-	-	-	-	-	-	-	
BLT13e-120	0.00	-	-	-	-	-	-	-	-	-	-	-	
BLT13e-120bulk	3.14	0.05	0.03	0.01	0.00	0.02	0.22	0.25	0.00	0.01	0.64	0.00	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT13e-2	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
BLT13e-120	20.60	20.53	0.000	0.000	0.150	0.000	0.004	0.013	0.000	0.002	0.002	0.000	0.000
BLT13e-120bulk	1552.70	1547.75	0.024	0.006	11.546	0.003	0.327	1.042	0.013	0.123	0.192	0.003	0.000
wash water	179.80	180.03	0.000	0.000	0.090	0.000	0.003	0.010	0.000	0.001	0.001	0.000	0.000
cake moisture	10.56	10.57	0.000	0.000	0.005	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
evaporation	-1.00	-1.00	-	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1765.80</b>	<b>0.08</b>	<b>0.04</b>	<b>11.80</b>	<b>0.01</b>	<b>0.03</b>	<b>0.55</b>	<b>1.32</b>	<b>0.02</b>	<b>0.14</b>	<b>0.84</b>	<b>0.01</b>	

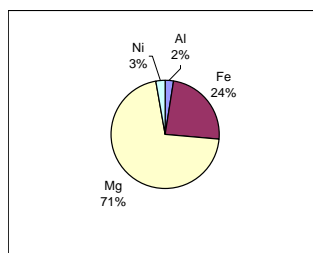
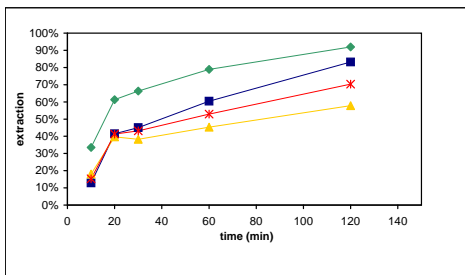
<b>balance (out/in)</b>	99%	60%	56%	91%	71%	62%	74%	87%	73%	99%	56%	71%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT13a-10		5%	9%	78%	4%	7%	4%	18%	22%	2%	78%
BLT13b-20		8%	9%	77%	4%	12%	9%	18%	38%	3%	77%
BLT13c-30		10%	9%	77%	4%	18%	17%	23%	54%	4%	77%
BLT13d-60		15%	9%	77%	5%	31%	37%	46%	74%	7%	77%
BLT13e-120	1570.22	19%	9%	78%	7%	46%	68%	74%	95%	12%	78%
BLT13e-120bulk	1570.22	20%	9%	78%	7%	44%	70%	76%	93%	13%	78%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
BLT13a-10bulk		18%	14%	6%	5%	15%	13%	15%	34%	12%	6%
BLT13b-20bulk		40%	34%	35%	28%	41%	41%	46%	61%	34%	35%
BLT13c-30bulk		38%	32%	37%	26%	43%	45%	51%	66%	33%	37%
BLT13d-60bulk		45%	37%	46%	32%	53%	70%	79%	79%	40%	46%
BLT13e-120bulk	3.2	58%	50%	60%	43%	70%	83%	91%	92%	57%	60%

**based on solids assay**

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
BLT13e-120	3.38	420					
BLT13e-120bulk	2.85	355					
acid equivalent (g)			0.29	1.04	3.79	0.15	5.27
acid equivalent (%)			5.5	19.7	71.9	2.9	100.0



Test name: **ST14a**  
 Comment: high pH, low total Cl-

Date: **10-Dec-04**

	mass (g)	volume (ml)	density @20°C (kg/l)		nominal	effective	grind (D90)	46	micron
dry ore added:	8.05	2.8	2.832	initial pulp % solids:	0.5	0.5	T:	80	°C
stock solution added:	1592.5	1389.4	1.1462	initial HCl (g/l):	7.3	7.6	duration:	10	min
total slurry in:	1600.55			initial HCl (M):	0.20	0.21	agitation rate:	800	rpm
				MgCl2 (g/l):	191.63	190	impeller:	pitched blade, 5cm $\phi$ , Ti	
				total Cl- (g/l):	150	147	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
ST14a-0	0		25	-0.47	1.1462	496	695	90min heat-up time, yellow PLS, clear green wash, light brown solids
ST14a-2	2	25.85	25.6		1.1471	566	765	
ST14a-10	10	14.53					-	
ST14a-10bulk	10bulk	1529.76	26.1	-0.19	1.1495	560	759	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
ST14a-2	25.85	22.54					0.0			-	6.09	-
ST14a-10	14.53	12.64					0.0			-	30.47	-
ST14a-10bulk	1507.14	1311.13	7.3	7.6	5.72	102.74	102.9	94.76	1.0229	92.6	30.47	0.37

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
ST14a-10bulk	1.51	0.83	0.58	0.05	0.58	7.28	14.5	0.17	0.55	22.2	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
ST14a-head liquor	2	2	147	2	1	4.73	7.56	48426	2	8.06	2	2
ST14a-2	9.32	6.33	149	2.59	1.28	50	6.96	46246	2	28.9	10.7	2
ST14a-10	16.9	6.5	148	2.06	1.36	196	6.19	47579	2.37	57.3	29.4	2
ST14a-10bulk	19.2	6.31	150	2.06	1.88	232	5.84	48202	3.67	77.3	35	2
ST14a-comp. wash	3.67	2	23.6	2	1	47.8	0.92	6798	2	18.2	5.67	2

**CALCULATIONS AND MASS BALANCE**

H <sup>+</sup>	assay H <sup>+</sup> mol/l	residual HCl g	$\Delta$ acid %
ST14a-0	0.21		22.8
ST14a-2	0.19		
ST14a-10	0.17	8.12	
ST14a-10bulk	0.16	7.66	
average	0.18		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.05	0.12	0.06	0.01	0.00	0.04	0.75	1.51	0.02	0.13	1.51	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
head liquor	1592.50	1389.37	0.0	0.0	204.24	0.0	0.0	0.0	67.3	0.0	0.0	0.0	0.0
wash water	102.74	102.95	-	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1703.29</b>		<b>0.13</b>	<b>0.07</b>	<b>204.25</b>	<b>0.01</b>	<b>0.04</b>	<b>0.76</b>	<b>68.80</b>	<b>0.02</b>	<b>0.15</b>	<b>1.51</b>	<b>0.01</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
ST14a-2	0.00	-	-	-	-	-	-	-	-	-	-	-	
ST14a-10	0.00	-	-	-	-	-	-	-	-	-	-	-	
ST14a-10bulk	5.72	0.09	0.05	0.03	0.00	0.03	0.42	0.83	0.01	0.03	1.27	0.00	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST14a-2	25.85	22.54	0.000	0.000	3.358	0.000	0.000	0.001	1.042	0.000	0.001	0.000	0.000
ST14a-10	14.53	12.64	0.000	0.000	1.871	0.000	0.002	0.601	0.000	0.001	0.001	0.000	0.000
ST14a-10bulk	1507.14	1311.13	0.025	0.008	196.669	0.003	0.002	0.304	63.199	0.005	0.101	0.046	0.003
wash water	94.76	92.64	0.000	0.000	2.186	0.000	0.000	0.004	0.630	0.000	0.002	0.001	0.000
cake moisture	1.88	1.84	0.000	0.000	0.043	0.000	0.000	0.000	0.012	0.000	0.000	0.000	0.000
evaporation	30.41	30.47	-	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1680.29</b>		<b>0.11</b>	<b>0.06</b>	<b>204.16</b>	<b>0.01</b>	<b>0.04</b>	<b>0.73</b>	<b>66.31</b>	<b>0.01</b>	<b>0.14</b>	<b>1.32</b>	<b>0.01</b>

<b>balance (out/in)</b>	99%	89%	85%	100%	86%	88%	96%	96%	72%	93%	87%	84%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST14a-2	1360.7	10%	14%	88%	4%	9%	-288%	15%	29%	1%	68%
ST14a-10	1323.7	18%	14%	68%	5%	35%	-284%	18%	56%	3%	66%
ST14a-10bulk	1323.7	21%	13%	68%	6%	41%	-230%	27%	76%	3%	66%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST14a-10bulk	5.9	28%	23%	27%	13%	43%	44%	44%	76%	14%	27%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST14a-2	1360.7	14%	23%	34%	9%	9%	42%	24%	28%	4%	27%
ST14a-10	1323.7	25%	24%	27%	9%	36%	43%	28%	56%	11%	27%
ST14a-10bulk	1323.7	28%	23%	27%	13%	43%	44%	44%	76%	14%	27%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
ST14a-10	2.39	297					
ST14a-10bulk	2.85	354					
acid equivalent (g)			0.15	0.65	2.05	0.13	2.98
acid equivalent (%)			5.0	21.9	68.8	4.3	100.0

Test name: **ST14b**  
 Comment: high pH, low total Cl-

Date: **10-Dec-04**

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46	micron
stock solution added:	8.05	2.8	2.832	initial pulp % solids:	0.5	T:	80	°C
total slurry in:	1592.5	1389.4	1.1462	initial HCl (g/l):	7.3	duration:	20	min
	1600.55			initial HCl (M):	0.20	agitation rate:	800	rpm
				MgCl2 (g/l):	192	impeller:	pitched blade, 5cm, Ti	
				total Cl- (g/l):	150	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed	sample T	pH	Density @20°C	ORP vs. Ag/AgCl	Eh	Notes
		g	(°C)		(kg/l)	(mV)	(mV)	
ST14b-0	0		25	-0.42	1.1462	515	714	70min heat-up time, yellow PLS, light green wash, light brown solids
ST14b-2	2	25.76	25.7		1.1468	565	764	
ST14b-20	20	18.37						
ST14b-20bulk	20bulk	1529.68	26	-0.17	1.1495	561	760	

Sample	filtrate mass	filtrate vol	wet residue mass before wash	wet residue mass after wash	dry residue mass	wash mass in	wash vol in	wash mass out	wash density @20°C	wash vol out	calc. evaporation cum. ml	calc. sample pulp density % solids
	g	ml	g	g	g	g	ml	g	kg/l	ml		
ST14b-2	25.76	22.46					0.0				2.68	-
ST14b-20	18.37	15.98					0.0				26.79	-
ST14b-20bulk	1511.3	1314.75	6.2	12.8	5.13	103	103.2	96.37	1.0206	94.4	26.79	0.34

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
ST14b-20bulk	1.6	0.92	0.58	0.05	0.62	6.49	12.5	0.14	0.41	24.2	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
ST14b-head liquor	2	2.05	148	2	1	5.38	6.96	47731	2	7.58	2	2
ST14b-2	8.23	6.34	147	2.06	1	58.8	6.79	47063	2	69	9.39	2
ST14b-20	21.6	6.13	148	3.4	1.81	306	5.46	47236	5.08	77.2	43.1	2
ST14b-20bulk	19.6	6.24	149	2.61	2.11	348	5.31	47765	5.69	123	45.6	2
ST14b-comp. wash	3.77	2	21.5	2	1	58.6	0.7	6225	2	19.1	6.04	2

**CALCULATIONS AND MASS BALANCE**

H <sup>+</sup>	assay H <sup>+</sup> mol/l	residual HCl g	Δ acid %
ST14b-0	0.19		23.7
ST14b-2	0.19		
ST14b-20	0.15	7.18	
ST14b-20bulk	0.15	6.98	
average	0.17		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.05	0.12	0.06	0.01	0.00	0.04	0.75	1.51	0.02	0.13	1.51	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
head liquor	1592.50	1389.37	0.0	0.0	205.63	0.0	0.0	0.0	66.3	0.0	0.0	0.0	0.0
wash water	103.00	103.21	-	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1703.55</b>		<b>0.13</b>	<b>0.07</b>	<b>205.64</b>	<b>0.01</b>	<b>0.04</b>	<b>0.76</b>	<b>67.83</b>	<b>0.02</b>	<b>0.15</b>	<b>1.51</b>	<b>0.01</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST14b-2	0.00	-	-	-	-	-	-	-	-	-	-	-
ST14b-20	0.00	-	-	-	-	-	-	-	-	-	-	-
ST14b-20bulk	5.13	0.08	0.05	0.03	0.00	0.03	0.33	0.64	0.01	0.02	1.24	0.00

solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST14b-2	25.76	22.46	0.000	0.000	3.302	0.000	0.000	0.001	1.057	0.000	0.002	0.000	0.000
ST14b-20	18.37	15.98	0.000	0.000	2.365	0.000	0.000	0.005	0.755	0.000	0.001	0.001	0.000
ST14b-20bulk	1511.30	1314.75	0.026	0.008	195.897	0.003	0.003	0.458	62.799	0.007	0.162	0.060	0.003
wash water	96.37	94.42	0.000	0.000	2.030	0.000	0.000	0.006	0.588	0.000	0.002	0.001	0.000
cake moisture	7.70	7.54	0.000	0.000	0.162	0.000	0.000	0.000	0.047	0.000	0.000	0.000	0.000
evaporation	26.74	26.79	-	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1691.37</b>		<b>0.11</b>	<b>0.06</b>	<b>203.79</b>	<b>0.01</b>	<b>0.03</b>	<b>0.80</b>	<b>65.89</b>	<b>0.01</b>	<b>0.19</b>	<b>1.30</b>	<b>0.01</b>

balance (out/in)	99%	86%	84%	99%	93%	86%	106%	97%	73%	129%	86%	80%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST14b-2	1364.23	9%	14%	70%	3%	11%	-140%	15%	70%	1%	68%
ST14b-20	1324.14	23%	13%	112%	6%	54%	-249%	38%	76%	4%	66%
ST14b-20bulk	1324.14	21%	13%	86%	7%	62%	-203%	43%	121%	4%	66%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST14b-20bulk	5.3	31%	24%	34%	16%	54%	56%	58%	84%	15%	34%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST14b-2	1364.2	13%	24%	27%	8%	9%	56%	20%	47%	3%	34%
ST14b-20	1324.1	35%	23%	45%	14%	48%	56%	52%	53%	15%	34%
ST14b-20bulk	1324.1	31%	24%	34%	16%	54%	56%	58%	84%	15%	34%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
ST14b-20	2.49	310					
ST14b-20bulk	2.69	334					
acid equivalent (g)			0.17	0.82	2.62	0.14	3.74
acid equivalent (%)			4.5	21.8	70.0	3.8	100.0

Test name: **ST14c**  
 Comment: high pH, low total Cl-

Date: **10-Dec-04**

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46	micron
stock solution added:	8.03	2.8	2.832	0.5	0.5	T:	80	°C
total slurry in:	1591.9	1388.7	1.1463	7.3	6.9	duration:	30	min
	1599.93			0.20	0.19	agitation rate:	800	rpm
				MgCl2 (g/l):	192	impeller:	pitched blade, 5cm, Ti	
				total Cl- (g/l):	150	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed	sample T	pH	Density @20°C	ORP vs. Ag/AgCl	Eh	Notes
		g	(°C)		(kg/l)	(mV)	(mV)	
ST14c-0	0		25	-0.46	1.1463	517	716	60min heat-up time, yellow PLS, light green wash, light brown solids
ST14c-2	2	27.43	25.2		1.1465			
ST14c-30	30	27.01						
ST14c-30bulk	30bulk	1526.19	29	0.33	1.1480	561	760	

Sample	filtrate mass	filtrate vol	wet residue mass before wash	wet residue mass after wash	dry residue mass	wash mass in	wash vol in	wash mass out	wash density @20°C	wash vol out	calc. evaporation cum. ml	calc. sample pulp density % solids
	g	ml	g	g	g	g	ml	g	kg/l	ml		
ST14c-2	27.43	23.92						0.0			1.29	-
ST14c-30	27.01	23.53						0.0			19.34	-
ST14c-30bulk	1504.2	1310.28	6.1	6.3	4.73	101.83	102.0	87.44	1.0238	85.4	19.34	0.31

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
ST14c-30bulk	1.65	0.97	0.62	0.05	0.64	5.56	10.1	0.09	0.31	27.1	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
ST14c-head liquor	2	2	149	2	1	4.89	6.94	48515	2	7.68	2	2
ST14c-2	7.15	7.65	154	2	1.46	27.3	6.65	49150	2	14.1	11.2	2
ST14c-30	48.1	17.1	148	3.06	5.93	544	5.11	50168	15.1	123	136	2
ST14c-30bulk	25.9	8.11	149	2	3.42	274	4.97	50464	7.43	95.4	69.5	2
ST14c-comp. wash	2	2	25.2	2	1	39.6	0.93	7921	2	9.63	10.5	2

**CALCULATIONS AND MASS BALANCE**

H <sup>+</sup>	assay H+	residual HCl	Δ acid %
	mol/l	g	%
ST14c-0	0.19		28.4
ST14c-2	0.18		
ST14c-30	0.14	6.70	
ST14c-30bulk	0.14	6.51	
average	0.16		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.03	0.12	0.06	0.01	0.00	0.04	0.75	1.51	0.02	0.13	1.51	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
head liquor	1591.90	1388.73	0.0	0.0	206.92	0.0	0.0	0.0	67.4	0.0	0.0	0.0	0.0
wash water	101.83	102.03	-	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1701.76</b>	<b>0.13</b>	<b>0.07</b>	<b>206.93</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>68.88</b>	<b>0.02</b>	<b>0.15</b>	<b>1.51</b>	<b>0.01</b>	

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
ST14c-2	0.00	-	-	-	-	-	-	-	-	-	-	-	
ST14c-30	0.00	-	-	-	-	-	-	-	-	-	-	-	
ST14c-30bulk	4.73	0.08	0.05	0.03	0.00	0.03	0.26	0.48	0.00	0.01	1.28	0.00	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST14c-2	27.43	23.92	0.000	0.000	3.684	0.000	0.000	0.001	1.176	0.000	0.000	0.000	0.000
ST14c-30	27.01	23.53	0.001	0.000	3.482	0.000	0.000	0.013	1.180	0.000	0.003	0.003	0.000
ST14c-30bulk	1504.20	1310.28	0.034	0.011	195.232	0.003	0.004	0.359	66.122	0.010	0.125	0.091	0.003
wash water	87.44	85.41	0.000	0.000	2.152	0.000	0.000	0.003	0.677	0.000	0.001	0.001	0.000
cake moisture	1.57	1.53	0.000	0.000	0.039	0.000	0.000	0.000	0.012	0.000	0.000	0.000	0.000
evaporation	19.30	19.34	-	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1671.68</b>	<b>0.11</b>	<b>0.06</b>	<b>204.62</b>	<b>0.01</b>	<b>0.04</b>	<b>0.64</b>	<b>69.64</b>	<b>0.01</b>	<b>0.14</b>	<b>1.38</b>	<b>0.01</b>	

<b>balance (out/in)</b>	98%	90%	86%	99%	78%	87%	85%	101%	71%	99%	91%	77%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST14c-2	1363.51	8%	16%	68%	5%	5%	-24%	15%	14%	1%	68%
ST14c-30	1321.94	52%	36%	101%	20%	96%	-70%	113%	121%	12%	66%
ST14c-30bulk	1321.94	28%	17%	66%	12%	48%	-44%	56%	94%	6%	66%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST14c-30bulk	4.9	34%	25%	39%	20%	64%	67%	75%	89%	12%	39%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST14c-2	1363.5	9%	24%	39%	8%	6%	65%	20%	13%	2%	39%
ST14c-30	1321.9	64%	53%	60%	34%	126%	67%	153%	114%	23%	39%
ST14c-30bulk	1321.9	34%	25%	39%	20%	64%	67%	75%	89%	12%	39%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
ST14c-30	2.94	366					
ST14c-30bulk	3.13	389					
acid equivalent (g)			0.18	0.95	3.10	0.15	4.37
acid equivalent (%)			4.2	21.7	70.8	3.4	100.0

Test name: **ST14d**  
 Comment: high pH, low total Cl-

Date: **9-Dec-04**

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46	micron
stock solution added:	8.03	2.8	2.832	0.5	0.5	T:	80	°C
total slurry in:	1592	1404.0	1.1339	7.3	7.0	duration:	60	min
	1600.03			0.20	0.19	agitation rate:	800	rpm
				MgCl2 (g/l):	171	impeller:	pitched blade, 5cm, Ti	
				total Cl- (g/l):	150	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed	sample T	pH	Density @20°C	ORP vs. Ag/AgCl	Eh	Notes
		g	(°C)		(kg/l)	(mV)	(mV)	
ST14d-0	0		24.3	-0.17	1.1339	500	699	60min heat-up time, orange-yellow PLS, clear green wash, light brown solids
ST14d-2	2	23.95	25.2		1.1436			
ST14d-60	60	24.5						
ST14d-60bulk	60bulk	1520.02	25.7	-0.24	1.1463	562	761	

Sample	filtrate mass	filtrate vol	wet residue mass before wash	wet residue mass after wash	dry residue mass	wash mass in	wash vol in	wash mass out	wash density @20°C	wash vol out	calc. evaporation	calc. sample pulp density
	g	ml	g	g	g	g	ml	g	kg/l	ml	cum. ml	% solids
ST14d-2	23.95	20.94						0.0			1.05	-
ST14d-60	24.5	21.37						0.0			31.62	-
ST14d-60bulk	1496.01	1305.08	7.2	7.6	4.17	106.59	106.8	99.93	1.0208	97.9	31.62	0.27

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
ST14d-60bulk	1.81	1.14	0.62	0.05	0.72	3.92	6.86	0.05	0.18	30.1	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
ST14d-head liquor	2	2	135	2	1	4.18	6.98	43691	2	6.16	2	2
ST14d-2	11.6	8.68	141	2	6.06	65.8	6.75	47749	2	27.9	14.7	2
ST14d-60	27.9	8.5	145	2	4.15	313	4.72	49286	9.21	47.2	82.2	2
ST14d-60bulk	28.3	8.03	146	3.44	4.16	322	4.56	49638	9.39	96.4	84.7	2
ST14d-comp. wash	3.96	2	21.6	2	1	44.8	0.5	6804	2	8.74	9.23	2

**CALCULATIONS AND MASS BALANCE**

H <sup>+</sup>	assay H <sup>+</sup>	residual HCl	Δ acid %
	mol/l	g	%
ST14d-0	0.19		34.7
ST14d-2	0.19		
ST14d-60	0.13	6.16	
ST14d-60bulk	0.13	5.95	
average	0.16		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.03	0.12	0.06	0.01	0.00	0.04	0.75	1.51	0.02	0.13	1.51	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
head liquor	1592.00	1404.00	0.0	0.0	189.54	0.0	0.0	0.0	61.3	0.0	0.0	0.0	0.0
wash water	106.59	106.80	-	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1706.62</b>	<b>0.13</b>	<b>0.07</b>	<b>189.55</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>62.85</b>	<b>0.02</b>	<b>0.14</b>	<b>1.51</b>	<b>0.01</b>	

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
ST14d-2	0.00	-	-	-	-	-	-	-	-	-	-	-	
ST14d-60	0.00	-	-	-	-	-	-	-	-	-	-	-	
ST14d-60bulk	4.17	0.08	0.05	0.03	0.00	0.03	0.16	0.29	0.00	0.01	1.26	0.00	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST14d-2	23.95	20.94	0.000	0.000	2.953	0.000	0.000	0.001	1.000	0.000	0.001	0.000	0.000
ST14d-60	24.50	21.37	0.001	0.000	3.099	0.000	0.000	0.007	1.053	0.000	0.001	0.002	0.000
ST14d-60bulk	1496.01	1305.08	0.037	0.010	190.541	0.004	0.005	0.420	64.781	0.012	0.126	0.111	0.003
wash water	99.93	97.89	0.000	0.000	2.115	0.000	0.000	0.004	0.666	0.000	0.001	0.001	0.000
cake moisture	3.43	3.36	0.000	0.000	0.073	0.000	0.000	0.000	0.023	0.000	0.000	0.000	0.000
evaporation	31.56	31.62	-	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1683.55</b>	<b>0.11</b>	<b>0.06</b>	<b>198.81</b>	<b>0.01</b>	<b>0.04</b>	<b>0.60</b>	<b>67.81</b>	<b>0.01</b>	<b>0.14</b>	<b>1.37</b>	<b>0.00</b>	

<b>balance (out/in)</b>	99%	90%	88%	105%	101%	89%	79%	108%	72%	95%	91%	73%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST14d-2	1382.01	13%	19%	69%	22%	12%	308%	16%	29%	1%	69%
ST14d-60	1330.06	30%	18%	66%	14%	56%	279%	69%	47%	7%	66%
ST14d-60bulk	1330.06	31%	17%	114%	14%	57%	310%	71%	95%	7%	66%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST14d-60bulk	4.3	37%	23%	46%	20%	77%	80%	88%	94%	14%	46%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST14d-2	1382.0	15%	25%	27%	30%	16%	77%	19%	27%	2%	46%
ST14d-60	1330.1	36%	24%	27%	20%	75%	80%	86%	46%	14%	46%
ST14d-60bulk	1330.1	37%	23%	46%	20%	77%	80%	88%	94%	14%	46%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
ST14d-60	3.64	453					
ST14d-60bulk	3.85	479					
acid equivalent (g)			0.19	1.14	3.67	0.16	5.16
acid equivalent (%)			3.7	22.1	71.1	3.1	100.0

Test name: ST14e  
Comment: high pH, low total Cl-

Date: 9-Dec-04

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46	micron
stock solution added:	8.08	2.9	2.832	0.5	0.5	T:	80	°C
total slurry in:	1592.2	1404.2	1.1339	initial pulp % solids:	7.3	duration:	120	min
	1600.28			initial HCl (g/l):	0.20	agitation rate:	800	rpm
				MgCl2 (g/l):	192	impeller:	pitched blade, 5cm, Ti	
				total Cl- (g/l):	150	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
ST14e-0	0		24.3	-0.17	1.1339	500	699	65min heat-up time, orange-yellow PLS, clear green wash, grey-brown solids
ST14e-2	2	28.32	25.1		1.135			
ST14e-120	120	29.68						
ST14e-120bulk	120bulk	1521.57	25.3	-0.14	1.1372	563	762	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
ST14e-2	28.32	24.95					0.0				0.35	-
ST14e-120	29.68	26.10					0.0				20.75	-
ST14e-120bulk	1501.71	1320.53	6.1	7.0	3.65	103.86	104.1	97.05	1.02	95.1	20.75	0.24

ANALYSES

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
ST14e-120bulk	1.87	1.18	0.55	0.05	0.8	3.05	5.53	0.05	0.13	32.3	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
ST14e-head liquor	2	2	135	2	1	4.18	6.98	43691	2	6.16	2	2
ST14e-2	6.66	7.58	136	2	1.57	37.2	6.86	43720	2	6.3	12.7	2
ST14e-120	29.5	7.55	136	2	4.47	380	4.52	44959	9.99	65.1	90.7	2
ST14e-120bulk	30.8	7.66	138	2	4.43	392	4.47	46093	10	98.6	89.9	2
ST14e-comp. wash	4.01	2	20.7	2	1	50.5	0.7	6540	2	12.7	11	2

CALCULATIONS AND MASS BALANCE

H+	assay H+	residual HCl	Δ acid
	mol/l	g	%
ST14e-0	0.19		36.0
ST14e-2	0.19		
ST14e-120	0.12	5.97	
ST14e-120bulk	0.12	5.90	
average	0.16		

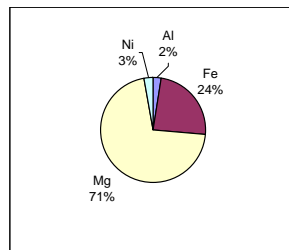
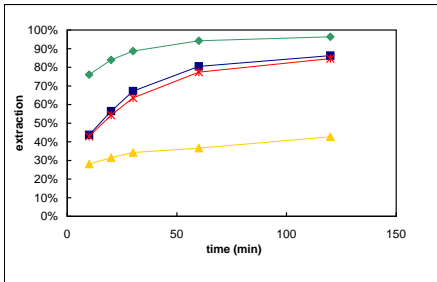
solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.08	0.12	0.06	0.01	0.00	0.04	0.75	1.52	0.02	0.14	1.52	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
head liquor	1592.20	1404.18	0.0	0.0	189.56	0.0	0.0	61.4	0.0	0.0	0.0	0.0	0.0
wash water	103.86	104.07	-	-	-	-	-	-	-	-	-	-	-
total IN (g)	1704.14	0.13	0.07	0.01	189.58	0.01	0.04	0.76	62.87	0.02	0.14	1.52	0.01
solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
ST14e-2	0.00	-	-	-	-	-	-	-	-	-	-	-	
ST14e-120	0.00	-	-	-	-	-	-	-	-	-	-	-	
ST14e-120bulk	3.65	0.07	0.04	0.02	0.00	0.03	0.11	0.20	0.00	0.00	1.18	0.00	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST14e-2	28.32	24.95	0.000	0.000	3.393	0.000	0.000	0.001	1.091	0.000	0.000	0.000	0.000
ST14e-120	29.68	26.10	0.001	0.000	3.549	0.000	0.000	0.010	1.173	0.000	0.002	0.002	0.000
ST14e-120bulk	1501.71	1320.53	0.041	0.010	182.234	0.003	0.006	0.518	60.867	0.013	0.130	0.119	0.003
wash water	97.05	95.15	0.000	0.000	1.970	0.000	0.000	0.005	0.622	0.000	0.001	0.001	0.000
cake moisture	3.35	3.28	0.000	0.000	0.068	0.000	0.000	0.000	0.021	0.000	0.000	0.000	0.000
evaporation	20.71	20.75	-	-	-	-	-	-	-	-	-	-	-
total OUT (g)	1684.47	0.11	0.05	0.01	191.23	0.00	0.04	0.64	63.98	0.02	0.14	1.30	0.00
balance (out/in)	99%	87%	81%	101%	70%	87%	85%	102%	75%	96%	86%	70%	

extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST14a-2		10%	14%	88%	4%	9%	-288%	15%	29%	1%	68%
ST14b-2		9%	14%	70%	3%	11%	-140%	15%	70%	1%	68%
ST14c-2		8%	16%	68%	5%	5%	-24%	15%	14%	1%	68%
ST14d-2		13%	19%	69%	22%	12%	308%	16%	29%	1%	69%
ST14e-2	1378.88	7%	16%	68%	6%	7%	-70%	16%	6%	1%	68%
ST14e-2 ave.		10%	16%	72%	8%	9%	-43%	15%	30%	1%	68%
std deviation		2%	2%	7%	8%	3%	220%	0%	24%	0%	0%
confidence limits		2.0%	2.0%	7.4%	6.5%	2.5%	192.7%	0.1%	21.4%	0.2%	0.4%
ST14a-10		18%	14%	68%	5%	35%	-284%	18%	56%	3%	66%
ST14b-20		23%	13%	112%	6%	54%	-249%	38%	76%	4%	66%
ST14c-30		52%	36%	101%	20%	96%	-70%	113%	121%	12%	66%
ST14d-60		30%	18%	66%	14%	56%	279%	69%	47%	7%	66%
ST14e-120	1332.38	32%	16%	66%	15%	67%	-95%	75%	64%	8%	66%
ST14e-120bulk	1332.38	33%	16%	66%	15%	69%	4%	75%	97%	8%	66%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST14a-10bulk		28%	23%	27%	13%	43%	44%	44%	76%	14%	27%
ST14b-20bulk		31%	24%	34%	16%	54%	56%	58%	84%	15%	34%
ST14c-30bulk		34%	25%	39%	20%	64%	67%	75%	89%	12%	39%
ST14d-60bulk		37%	23%	46%	20%	77%	80%	88%	94%	14%	46%
ST14e-120bulk	3.8	43%	30%	53%	23%	85%	86%	89%	96%	19%	53%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
ST14e-120	3.83	474					
ST14e-120bulk	3.90	482					
acid equivalent (g)			0.22	1.25	3.95	0.16	5.59
acid equivalent (%)			4.0	22.4	70.7	2.9	100.0



Test name: **ST15a**  
 Comment: med pH, med total Cl-

Date: **20-Dec-04**

	mass (g)	volume (ml)	density @20°C (kg/l)		nominal	effective	grind (D90)	46 micron
dry ore added:	8.31	2.9	2.832	initial pulp % solids:	0.5	0.5	T:	80 °C
stock solution added:	1594	1320.7	1.2069	initial HCl (g/l):	36.5		duration:	10 min
total slurry in:	1602.31			initial HCl (M):	1.00	0.00	agitation rate:	800 rpm
				MgCl2 (g/l):	260	243	impeller:	pitched blade, 5cm $\phi$ , Ti
				total Cl- (g/l):	230	230	vessel:	2litre, baffled, with reflux condenser

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
ST15a-0	0		24.2	-1.12	1.2069	476	675	60min heat-up time, orange PLS, light green wash, grey solids
ST15a-2	2	26.6	24.4		1.2081	554	753	
ST15a-10	10	26.62					-	
ST15a-10bulk	10bulk	1531.14	24.2	-1.13	1.2125	519	718	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
ST15a-2	26.6	22.02					0.0			-	3.60	-
ST15a-10	26.62	21.95					0.0			-	17.99	-
ST15a-10bulk	1508.2	1243.88	9	12.1	4.55	101.22	101.4	98.12	1.0358	94.7	17.99	0.30

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
ST15a-10bulk	1.59	0.96	1.02	0.05	0.63	2.61	9.67	0.05	0.13	27.6	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
ST15a-head liquor	2	2.27	230	2	1	3.94		62066	2	9.61	2	2
ST15a-2	18.8	8.65	229	2	2.19	240	33.9	60225	5.62	79.9	23.4	2.52
ST15a-10	26.6	9.08	234	2.2	4.72	421	34.2	59514	11.2	102	33.8	2.7
ST15a-10bulk	27.8	9.89	237	2.16	4.08	431	33	61205	11.3	99.3	31	2.3
ST15a-comp. wash	5.26	2	36.9	2	1	78.4	3.81	9233	2.27	16.6	4.68	2

**CALCULATIONS AND MASS BALANCE**

H <sup>+</sup>	assay H+ mol/l	residual HCl g	$\Delta$ acid %
ST15a-0	0.00		
ST15a-2	0.93		
ST15a-10	0.94	42.54	
ST15a-10bulk	0.91	41.05	
average	0.69		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.31	0.13	0.07	0.01	0.00	0.04	0.77	1.56	0.02	0.14	1.56	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
head liquor	1594.00	1320.74	0.0	0.0	303.77	0.0	0.0	0.0	82.0	0.0	0.0	0.0	0.0
wash water	101.22	101.42											
<b>total IN (g)</b>	<b>1703.53</b>		<b>0.13</b>	<b>0.07</b>	<b>303.78</b>	<b>0.01</b>	<b>0.04</b>	<b>0.78</b>	<b>83.54</b>	<b>0.02</b>	<b>0.15</b>	<b>1.56</b>	<b>0.01</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
ST15a-2	0.00	-	-	-	-	-	-	-	-	-	-	-	
ST15a-10	0.00	-	-	-	-	-	-	-	-	-	-	-	
ST15a-10bulk	4.55	0.07	0.04	0.05	0.00	0.03	0.12	0.44	0.00	0.01	1.26	0.00	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST15a-2	26.60	22.02	0.000	0.000	5.042	0.000	0.000	0.005	1.326	0.000	0.002	0.001	0.000
ST15a-10	26.62	21.95	0.001	0.000	5.137	0.000	0.000	0.009	1.307	0.000	0.002	0.001	0.000
ST15a-10bulk	1508.20	1243.88	0.035	0.012	294.799	0.003	0.005	0.536	76.131	0.014	0.124	0.039	0.003
wash water	98.12	94.73	0.000	0.000	3.495	0.000	0.000	0.007	0.875	0.000	0.002	0.000	0.000
cake moisture	7.55	7.29	0.000	0.000	0.269	0.000	0.000	0.001	0.067	0.000	0.000	0.000	0.000
evaporation	17.95	17.99	-	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1689.59</b>		<b>0.11</b>	<b>0.06</b>	<b>308.79</b>	<b>0.01</b>	<b>0.03</b>	<b>0.68</b>	<b>80.15</b>	<b>0.02</b>	<b>0.14</b>	<b>1.30</b>	<b>0.01</b>

balance (out/in)	99%	84%	82%	102%	77%	82%	87%	96%	81%	89%	83%	80%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST15a-2	1295.1	19%	17%	62%	7%	40%	-254%	40%	74%	2%	79%
ST15a-10	1258.8	26%	17%	67%	15%	69%	-452%	77%	92%	3%	82%
ST15a-10bulk	1258.8	28%	19%	65%	13%	70%	-316%	78%	90%	3%	70%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST15a-10bulk	4.7	41%	31%	43%	26%	84%	71%	87%	96%	17%	43%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST15a-2	1295.1	28%	27%	40%	14%	47%	70%	43%	77%	13%	47%
ST15a-10	1258.8	39%	29%	44%	31%	82%	69%	86%	98%	18%	51%
ST15a-10bulk	1258.8	41%	31%	43%	26%	84%	71%	87%	96%	17%	43%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
ST15a-10	-42.54	-5119					
ST15a-10bulk	-41.05	-4940					
acid equivalent (g)			0.22	1.28	3.37	0.17	5.04
acid equivalent (%)			4.4	25.5	66.9	3.3	100.0

Test name: **ST15b**  
 Comment: med pH, med total Cl-

Date: **20-Dec-04**

	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46 micron
dry ore added:	8.05	2.8	2.832	0.5	0.5	T:	80 °C
stock solution added:	1592.6	1319.6	1.2069	36.5		duration:	20 min
total slurry in:	1600.65			1.00	0.00	agitation rate:	800 rpm
				259.88	243	impeller:	pitched blade, 5cmφ, T1
				230	230	vessel:	2litre, baffled, with reflux condenser

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
ST15b-0	0	24.2	24.2	-1.12	1.2069	476	675	170min heat-up time, orange PLS, light green wash, grey solids
ST15b-2	2	29.95	24.4		1.2088	556	755	
ST15b-20	20	26.92						
ST15b-20bulk	20bulk	1517.72	24.2	-1.13	1.2122	510	709	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
ST15b-2	29.95	24.78					0.0			-	2.61	-
ST15b-20	26.92	22.21					0.0			-	26.11	-
ST15b-20bulk	1493.87	1232.36	9	7.7	4.15	99.47	99.7	96.76	1.0384	93.2	26.11	0.27

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
ST15b-20bulk	1.56	1.01	1.02	0.05	0.64	1.82	6.34	0.05	0.08	29.3	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
ST15b-head liquor	2	2.27	230	2	1	3.94		62066	2	9.61	2	2
ST15b-2	17.6	8.07	230	2	2.28	210	34.3	62608	5.15	73.9	22.1	2
ST15b-20	29	8.3	232	3.02	4.05	423	32.2	62494	11	93	24.8	2
ST15b-20bulk	30.6	8.51	234	2.74	4.45	435	32.8	61977	11.3	95.8	27.4	2
ST15b-comp. wash	5.81	2	39.6	2	1	85.8	4.18	10060	2.19	19.5	4.04	2

**CALCULATIONS AND MASS BALANCE**

H*	assay H+ mol/l	residual HCl g	Δ acid %
ST15b-0	0.00		
ST15b-2	0.94		
ST15b-20	0.88	39.68	
ST15b-20bulk	0.90	40.42	
average	0.68		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
feed solids	8.05	0.12	0.06	0.01	0.00	0.04	0.75	1.51	0.02	0.13	1.51	0.00
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
head liquor	1592.60	1319.58	0.0	0.0	303.50	0.0	0.0	0.0	81.9	0.0	0.0	0.0
wash water	99.47	99.67	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1700.12</b>		<b>0.13</b>	<b>0.07</b>	<b>303.51</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>83.41</b>	<b>0.02</b>	<b>0.15</b>	<b>1.51</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST15b-2	0.00	-	-	-	-	-	-	-	-	-	-	-
ST15b-20	0.00	-	-	-	-	-	-	-	-	-	-	-
ST15b-20bulk	4.15	0.06	0.04	0.04	0.00	0.03	0.08	0.26	0.00	0.00	1.22	0.00
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
ST15b-2	29.95	24.78	0.000	0.000	5.899	0.000	0.005	1.551	0.000	0.002	0.001	0.000
ST15b-20	26.92	22.21	0.001	0.000	5.152	0.000	0.009	1.388	0.000	0.002	0.001	0.000
ST15b-20bulk	1493.87	1232.36	0.038	0.010	288.373	0.003	0.005	0.536	76.378	0.014	0.118	0.034
wash water	96.76	93.18	0.001	0.000	3.690	0.000	0.000	0.937	0.000	0.002	0.000	0.000
cake moisture	3.55	3.42	0.000	0.000	0.135	0.000	0.000	0.034	0.000	0.000	0.000	0.000
evaporation	26.06	26.11	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1681.26</b>		<b>0.10</b>	<b>0.05</b>	<b>303.09</b>	<b>0.01</b>	<b>0.03</b>	<b>0.63</b>	<b>80.55</b>	<b>0.02</b>	<b>0.13</b>	<b>1.25</b>

balance (out/in)	99%	83%	80%	100%	86%	80%	84%	97%	81%	86%	83%	72%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST15b-2	1292.19	18%	16%	64%	8%	36%	-66%	38%	71%	2%	64%
ST15b-20	1246.48	29%	16%	94%	13%	70%	-265%	77%	86%	2%	62%
ST15b-20bulk	1246.48	31%	17%	85%	14%	72%	-307%	80%	89%	2%	62%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST15b-20bulk	4.3	45%	32%	47%	29%	90%	82%	88%	97%	16%	47%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST15b-2	1292.2	26%	30%	34%	15%	43%	83%	40%	75%	13%	47%
ST15b-20	1246.5	43%	31%	51%	27%	87%	83%	86%	95%	15%	47%
ST15b-20bulk	1246.5	45%	32%	47%	29%	90%	82%	88%	97%	16%	47%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
ST15b-20	-39.68	-4929					
ST15b-20bulk	-40.42	-5021					
acid equivalent (g)			0.24	1.32	3.75	0.16	5.47
acid equivalent (%)			4.3	24.1	68.6	3.0	100.0

Test name: ST15c  
 Comment: med pH, med total Cl-

Date: 20-Dec-04

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46 micron
stock solution added:	8.05	2.8	2.832	0.5	0.5	T:	80 °C
total slurry in:	1593	1319.9	1.2069	initial pulp % solids:		duration:	30 min
	1601.05			initial HCl (g/l):	36.5	agitation rate:	800 rpm
				MgCl2 (g/l):	260	impeller:	pitched blade, 5cmφ, T1
				total Cl- (g/l):	230	vessel:	2litre, baffled, with reflux condenser

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
ST15c-0	0		24.2	-1.12	1.2069	476	675	60min heat-up time, orange PLS, light green wash, grey solids
ST15c-2	2	26.6	24.4		1.2081	554	753	
ST15c-30	30	26.62						
ST15c-30bulk	30bulk	1531.14	24.2	-1.13	1.2125	519	718	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
ST15c-2	26.6	22.02					0.0				1.11	-
ST15c-30	26.62	21.95					0.0				16.72	-
ST15c-30bulk	1508.2	1243.88	9.0	12.1	4.55	101.22	101.4	98.12	1.0358	94.7	16.72	0.30

ANALYSES

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
ST15c-30bulk	1.64	1.07	1.02	0.05	0.68	1.54	5.17	0.05	0.06	30.7	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
ST15c-head liquor	2	2.27	230	2	1	3.94		62066	2	9.61	2	2
ST15c-2	18.8	8.48	230	2.04	1.83	201	34.3	59295	4.68	70.2	22.5	2
ST15c-30	32.5	8.49	232	2.7	5.2	475	32.6	61674	12	102	26.6	2
ST15c-30bulk	27.4	8.13	231	2.73	4.56	453	32.2	62132	11.8	107	25.5	2
ST15c-comp. wash	6.1	2	39.5	2	1	77.9	4.28	10158	2.09	18.8	3.82	2

CALCULATIONS AND MASS BALANCE

H*	assay H+ mol/l	residual HCl g	Δ acid %
ST15c-0	0.00		
ST15c-2	0.94		
ST15c-30	0.89	40.55	
ST15c-30bulk	0.88	40.05	
average	0.68		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
feed solids	8.05	0.12	0.06	0.01	0.00	0.04	0.75	1.51	0.02	0.13	1.51	0.00
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
head liquor	1593.00	1319.91	0.0	0.0	303.58	0.0	0.0	0.0	81.9	0.0	0.0	0.0
wash water	101.22	101.42	-	-	-	-	-	-	-	-	-	-
total IN (g)	1702.27		0.13	0.07	303.59	0.01	0.04	0.75	83.43	0.02	0.15	1.51

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST15c-2	0.00	-	-	-	-	-	-	-	-	-	-	-
ST15c-30	0.00	-	-	-	-	-	-	-	-	-	-	-
ST15c-30bulk	4.55	0.07	0.05	0.05	0.00	0.03	0.07	0.24	0.00	0.00	1.40	0.00
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
ST15c-2	26.60	22.02	0.000	0.000	5.064	0.000	0.004	1.306	0.000	0.002	0.000	0.000
ST15c-30	26.62	21.95	0.001	0.000	5.093	0.000	0.010	1.354	0.000	0.002	0.001	0.000
ST15c-30bulk	1508.20	1243.88	0.034	0.010	287.335	0.003	0.006	0.563	77.285	0.015	0.133	0.032
wash water	98.12	94.73	0.001	0.000	3.742	0.000	0.000	0.962	0.000	0.002	0.000	0.000
cake moisture	7.55	7.29	0.000	0.000	0.288	0.000	0.000	0.074	0.000	0.000	0.000	0.000
evaporation	16.69	16.72	-	-	-	-	-	-	-	-	-	-
total OUT (g)	1688.33		0.11	0.06	301.57	0.01	0.04	0.66	81.22	0.02	0.14	1.43

balance (out/in)	99%	88%	89%	99%	90%	91%	87%	97%	86%	96%	95%	76%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST15c-2	1296.78	20%	17%	66%	6%	35%	-332%	34%	68%	2%	64%
ST15c-30	1259.21	33%	17%	84%	17%	80%	-282%	85%	95%	2%	63%
ST15c-30bulk	1259.21	28%	16%	85%	15%	76%	-243%	84%	100%	2%	63%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST15c-30bulk	4.7	37%	21%	42%	18%	90%	84%	87%	4%	42%	

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST15c-2	1296.8	26%	22%	31%	7%	40%	80%	34%	64%	4%	42%
ST15c-30	1259.2	44%	22%	41%	21%	95%	83%	88%	93%	4%	42%
ST15c-30bulk	1259.2	37%	21%	42%	18%	90%	84%	87%	98%	4%	42%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
ST15c-30	-40.55	-5037					
ST15c-30bulk	-40.05	-4976					
acid equivalent (g)			0.20	1.33	3.83	0.16	5.53
acid equivalent (%)			3.6	24.1	69.4	3.0	100.0

Test name: **ST15d**  
 Comment: med pH, med total Cl-

Date: **9-Dec-04**

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	initial pulp % solids:	nominal	effective	grind (D90)	46	micron
stock solution added:	8.05	2.8	2.832	initial HCl (g/l):	0.5	0.5	T:	80	°C
total slurry in:	1592.7	1320.6	1.206	initial HCl (M):	36.5	34.1	duration:	60	min
	1600.75			MgCl2 (g/l):	1.00	0.94	agitation rate:	800	rpm
				total Cl- (g/l):	260	269	impeller:	pitched blade, 5cmφ, T1	
					230	226	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
ST15d-0	0		25.3	-1.4	1.206	490	689	60min heat-up time, orange PLS, light green wash, grey solids
ST15d-2	2	15.23	25.2		1.2054			
ST15d-60	60	32.09						
ST15d-60bulk	60bulk	1528.9	25.2	-1.37	1.2110	502	701	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
ST15d-2	15.23	12.63					0.0			-	0.82	-
ST15d-60	32.09	26.50					0.0			-	24.58	-
ST15d-60bulk	1509.52	1246.51	6.8	6.4	3.9	101.74	101.9	95.36	1.0344	92.2	24.58	0.26

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
ST15d-60bulk	1.79	1.14	0.73	0.05	0.76	1.23	4.39	0.05	0.05	33.5	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
ST15d-head liquor	2	2.46	226	2	1	6.57	34.1	68689	2	11	2	2
ST15d-2	18.5	10	228	2	3.09	174	33.5	70946	4.22	75	20.6	2
ST15d-60	31.9	10.2	235	3.31	6.31	563	32.4	72054	10.9	128	18.2	2
ST15d-60bulk	36.8	9.36	231	2.69	6.3	545	31.3	72924	10.9	114	17.2	2
ST15d-comp. wash	5.52	3.56	35	2	1.37	81.9	3.48	10197	2	20.1	2.37	2

**CALCULATIONS AND MASS BALANCE**

H*	assay H+ mol/l	residual HCl g	Δ acid %
ST15d-0	0.94		8.2
ST15d-2	0.92		
ST15d-60	0.89	40.39	
ST15d-60bulk	0.86	39.02	
average	0.90		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
feed solids	8.05	0.12	0.06	0.01	0.00	0.04	0.75	1.51	0.02	0.13	1.51	0.00
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
head liquor	1592.70	1320.65	0.0	0.0	298.47	0.0	0.0	0.0	90.7	0.0	0.0	0.0
wash water	101.74	101.94	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1702.49</b>		<b>0.13</b>	<b>0.07</b>	<b>298.48</b>	<b>0.01</b>	<b>0.04</b>	<b>0.76</b>	<b>92.23</b>	<b>0.02</b>	<b>0.15</b>	<b>1.51</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
ST15d-2	0.00	-	-	-	-	-	-	-	-	-	-	-	
ST15d-60	0.00	-	-	-	-	-	-	-	-	-	-	-	
ST15d-60bulk	3.90	0.07	0.04	0.03	0.00	0.03	0.05	0.17	0.00	0.00	1.31	0.00	
<b>solution OUT</b>	<b>total g</b>	<b>total ml</b>	<b>Al</b>	<b>Ca</b>	<b>Cl</b>	<b>Co</b>	<b>Cr</b>	<b>Fe</b>	<b>Mg</b>	<b>Mn</b>	<b>Ni</b>	<b>Si</b>	<b>Zn</b>
ST15d-2	15.23	12.63	0.000	0.000	2.881	0.000	0.002	0.896	0.000	0.001	0.000	0.000	
ST15d-60	32.09	26.50	0.001	0.000	6.227	0.000	0.015	1.909	0.000	0.003	0.000	0.000	
ST15d-60bulk	1509.52	1246.51	0.046	0.012	287.943	0.003	0.008	6.679	90.900	0.014	0.142	0.021	
wash water	95.36	92.19	0.001	0.000	3.227	0.000	0.000	0.008	0.940	0.000	0.002	0.000	
cake moisture	2.50	2.42	0.000	0.000	0.085	0.000	0.000	0.000	0.025	0.000	0.000	0.000	
evaporation	24.53	24.58	-	-	-	-	-	-	-	-	-	-	
<b>total OUT (g)</b>	<b>1683.13</b>		<b>0.12</b>	<b>0.06</b>	<b>300.39</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>94.84</b>	<b>0.02</b>	<b>0.15</b>	<b>1.33</b>	

balance (out/in)	99%	93%	85%	101%	84%	94%	99%	103%	79%	101%	88%	71%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST15d-2	1307.19	20%	21%	65%	10%	30%	134%	31%	73%	2%	65%
ST15d-60	1256.93	33%	20%	103%	20%	94%	-10%	77%	119%	2%	62%
ST15d-60bulk	1256.93	38%	18%	84%	20%	91%	63%	77%	106%	1%	62%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST15d-60bulk	4.0	42%	28%	50%	22%	93%	88%	89%	99%	11%	50%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST15d-2	1307.2	21%	30%	37%	11%	30%	86%	34%	65%	13%	50%
ST15d-60	1256.9	36%	30%	62%	22%	96%	87%	89%	111%	11%	50%
ST15d-60bulk	1256.9	42%	28%	50%	22%	93%	88%	89%	99%	11%	50%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
ST15d-60	4.65	577					
ST15d-60bulk	6.02	748					
acid equivalent (g)			0.22	1.37	4.03	0.17	5.78
acid equivalent (%)			3.7	23.8	69.7	2.9	100.0

**Test name:** ST15e  
**Comment:** med pH, med total Cl-

**Date:** 10-Dec-04

	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46	micron
dry ore added:	8.06	2.8	2.832	initial pulp % solids:	0.5	T:	80	°C
stock solution added:	1592.6	1320.2	1.2063	initial HCl (g/l):	36.5	duration:	120	min
total slurry in:	1600.66			initial HCl (M):	1.00	agitation rate:	800	rpm
				MgCl2 (g/l):	260	impeller:	pitched blade, 5cmφ, T1	
				total Cl- (g/l):	230	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
ST15e-0	0		25.2	-1.41	1.2063	482	681	50min heat-up time, orange PLS, light green wash, grey solids
ST15e-2	2	21.18	25.1					
ST15e-120	120	9.8						
ST15e-120bulk	120bulk	1540.42	25.5	-1.37	1.2114	475	674	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
ST15e-2	21.18	17.55					0.0				0.49	-
ST15e-120	9.8	8.09					0.0				29.32	-
ST15e-120bulk	1518.91	1253.85	7.3	6.1	3.89	103.49	103.7	99.17	1.0322	96.1	29.32	0.25

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
ST15e-120bulk	1.72	1.15	0.77	0.05	0.72	1.35	4.65	0.05	0.08	33.6	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
ST15e-head liquor	2	2.45	227	2	3.27	6.79	34.7	66941	2	11.1	2	2
ST15e-2	21.3	9.67	228	2	2	232	34.1	70284	3.92	50.5	22.5	2
ST15e-120	34.4	9.04	229	2	5.15	417	31.3	70260	10.4	79.8	19.4	2
ST15e-120bulk	36.1	9.48	232	2	5.33	497	31.4	71372	10.7	108.7	18.9	2
ST15e-comp. wash	7.01	4.01	36	2	1.13	82.6	3.03	11049	2.9	22.3	3.02	2

**CALCULATIONS AND MASS BALANCE**

H*	assay H+ mol/l	residual HCl g	Δ acid %
ST15e-0	0.95		9.5
ST15e-2	0.94		
ST15e-120	0.86	39.25	
ST15e-120bulk	0.86	39.37	
average	0.90		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
feed solids	8.06	0.12	0.06	0.01	0.00	0.04	0.75	1.52	0.02	0.14	1.51	0.00
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
head liquor	1592.60	1320.24	0.0	0.0	299.69	0.0	0.0	0.0	88.4	0.0	0.0	0.0
wash water	103.49	103.70	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1704.15</b>		<b>0.13</b>	<b>0.07</b>	<b>299.70</b>	<b>0.01</b>	<b>0.04</b>	<b>0.76</b>	<b>89.89</b>	<b>0.02</b>	<b>0.15</b>	<b>1.51</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST15e-2	0.00	-	-	-	-	-	-	-	-	-	-	-
ST15e-120	0.00	-	-	-	-	-	-	-	-	-	-	-
ST15e-120bulk	3.89	0.07	0.04	0.03	0.00	0.03	0.05	0.18	0.00	0.00	1.31	0.00
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
ST15e-2	21.18	17.55	0.000	0.000	4.001	0.000	0.004	1.233	0.000	0.001	0.000	0.000
ST15e-120	9.80	8.09	0.000	0.000	1.853	0.000	0.003	0.568	0.000	0.001	0.000	0.000
ST15e-120bulk	1518.91	1253.85	0.045	0.012	290.892	0.018	0.007	6.623	89.490	0.013	0.136	0.024
wash water	99.17	96.08	0.001	0.000	3.459	0.000	0.008	1.062	0.000	0.002	0.000	0.000
cake moisture	2.21	2.14	0.000	0.000	0.077	0.000	0.000	0.024	0.000	0.000	0.000	0.000
evaporation	29.26	29.32	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1684.42</b>		<b>0.11</b>	<b>0.06</b>	<b>300.31</b>	<b>0.00</b>	<b>0.03</b>	<b>0.69</b>	<b>92.56</b>	<b>0.02</b>	<b>0.14</b>	<b>1.33</b>

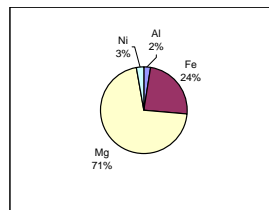
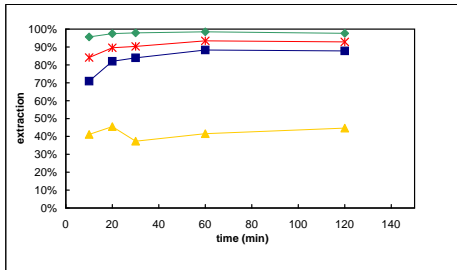
<b>balance (out/in)</b>	99%	90%	86%	100%	70%	86%	91%	103%	78%	96%	88%	70%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST15a-2		19%	17%	62%	7%	40%	-254%	40%	74%	2%	79%
ST15b-2		18%	16%	64%	8%	38%	-66%	39%	71%	2%	64%
ST15c-2		20%	17%	68%	6%	35%	-332%	34%	68%	2%	64%
ST15d-2		20%	21%	65%	10%	30%	134%	31%	73%	2%	65%
ST15e-2	1302.20	22%	20%	65%	11%	40%	208%	29%	49%	2%	65%
ST15e-2 ave.		20%	18%	64%	8%	36%	-62%	34%	67%	2%	67%
std deviation		2%	2%	1%	2%	4%	235%	5%	10%	0%	6%
confidence limits		1.3%	1.6%	1.1%	1.9%	3.6%	206.1%	4.0%	9.1%	0.1%	5.5%
ST15a-10		26%	17%	67%	15%	69%	-452%	77%	92%	3%	82%
ST15b-20		29%	16%	94%	13%	70%	-265%	77%	86%	2%	62%
ST15c-30		33%	17%	84%	17%	80%	-282%	85%	95%	2%	63%
ST15d-60		33%	20%	103%	20%	94%	-10%	77%	119%	2%	62%
ST15e-120	1265.28	35%	18%	63%	17%	70%	34%	74%	75%	2%	63%
ST15e-120bulk	1265.28	37%	19%	63%	17%	84%	127%	76%	102%	2%	63%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST15a-10bulk		41%	31%	43%	26%	84%	71%	87%	96%	17%	43%
ST15b-20bulk		45%	32%	47%	29%	90%	82%	88%	97%	16%	47%
ST15c-30bulk		37%	21%	42%	18%	90%	84%	87%	98%	4%	42%
ST15d-60bulk		42%	28%	50%	22%	93%	88%	89%	99%	11%	50%
ST15e-120bulk	4.0	45%	28%	51%	27%	93%	88%	89%	98%	12%	51%

**based on solids assay**

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
ST15e-120	6.57	815					
ST15e-120bulk	6.44	799					
acid equivalent (g)			0.23	1.37	4.00	0.16	5.76
acid equivalent (%)			4.0	23.7	69.5	2.8	100.0



Test name: **ST16a**  
 Comment: high pH, med total Cl-

Date: **15-Dec-04**

	mass (g)	volume (ml)	density @20°C (kg/l)		nominal	effective	grind (D90)	46	micron
dry ore added:	8.03	2.8	2.832	initial pulp % solids:	0.5	0.5	T:	80	°C
stock solution added:	1593.3	1306.1	1.2199	initial HCl (g/l):	7.3	7.1	duration:	10	min
total slurry in:	1601.33			initial HCl (M):	0.20	0.20	agitation rate:	800	rpm
				MgCl2 (g/l):	299	275	impeller:	pitched blade, 5cm $\phi$ , Ti	
				total Cl- (g/l):	230	226	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
ST16a-0	0		26.1	-0.85	1.2199	537	736	65min heat-up time, orange PLS, light green wash, light brown solids
ST16a-2	2	29.02	26.1		1.2206	570	769	
ST16a-10	10	27.01					-	
ST16a-10bulk	10bulk	1526.78	26.2	-0.77	1.2233	561	760	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
ST16a-2	29.02	23.78					0.0			-	3.71	-
ST16a-10	27.01	22.08					0.0			-	18.56	-
ST16a-10bulk	1502.72	1228.41	9.6	8.9	5.84	105.27	105.5	103.32	1.0362	99.7	18.56	0.38

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
ST16a-10bulk	1.48	0.86	0.8	0.05	0.57	4.63	13.2	0.13	0.33	23.9	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
ST16a-head liquor	2	2.79	226	2	1	7.82	7.13	70314	2	18	2	2
ST16a-2	12.3	7.8	224	2.06	1.53	131	6.65	73831	2	52.4	11.9	2
ST16a-10	25.5	9.12	226	2.37	2.38	438	5.47	75499	5.2	116	29.8	2
ST16a-10bulk	26.1	7.94	229	2.73	3.16	504	5.57	77610	6.33	99	32.9	2
ST16a-comp. wash	4.8	2	35.8	2	1	87.2	0.92	10741	2.06	26	5.45	2

**CALCULATIONS AND MASS BALANCE**

H <sup>+</sup>	assay H+ mol/l	residual HCl g	$\Delta$ acid %
ST16a-0	0.20		21.9
ST16a-2	0.18		
ST16a-10	0.15	6.72	
ST16a-10bulk	0.15	6.84	
average	0.17		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.03	0.12	0.06	0.01	0.00	0.04	0.75	1.51	0.02	0.13	1.51	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
head liquor	1593.30	1306.09	0.0	0.0	295.18	0.0	0.0	0.0	91.8	0.0	0.0	0.0	0.0
wash water	105.27	105.48	-	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1706.60</b>		<b>0.13</b>	<b>0.07</b>	<b>295.19</b>	<b>0.01</b>	<b>0.04</b>	<b>0.76</b>	<b>93.35</b>	<b>0.02</b>	<b>0.16</b>	<b>1.51</b>	<b>0.01</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
ST16a-2	0.00	-	-	-	-	-	-	-	-	-	-	-	
ST16a-10	0.00	-	-	-	-	-	-	-	-	-	-	-	
ST16a-10bulk	5.84	0.09	0.05	0.05	0.00	0.03	0.27	0.77	0.01	0.02	1.40	0.00	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST16a-2	29.02	23.78	0.000	0.000	5.326	0.000	0.000	0.003	1.755	0.000	0.001	0.000	0.000
ST16a-10	27.01	22.08	0.001	0.000	4.990	0.000	0.000	0.010	1.667	0.000	0.003	0.001	0.000
ST16a-10bulk	1502.72	1228.41	0.032	0.010	281.307	0.003	0.004	0.619	95.337	0.008	0.122	0.040	0.002
wash water	103.32	99.71	0.000	0.000	3.570	0.000	0.000	0.009	1.071	0.000	0.003	0.001	0.000
cake moisture	3.06	2.95	0.000	0.000	0.106	0.000	0.000	0.000	0.032	0.000	0.000	0.000	0.000
evaporation	18.52	18.56	-	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1689.49</b>		<b>0.12</b>	<b>0.06</b>	<b>295.34</b>	<b>0.01</b>	<b>0.04</b>	<b>0.91</b>	<b>100.63</b>	<b>0.02</b>	<b>0.15</b>	<b>1.44</b>	<b>0.01</b>

<b>balance (out/in)</b>	99%	96%	90%	100%	99%	93%	120%	108%	78%	93%	95%	86%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST16a-2	1278.6	13%	16%	66%	5%	22%	170%	14%	50%	1%	64%
ST16a-10	1241.7	26%	18%	73%	8%	73%	126%	37%	107%	2%	62%
ST16a-10bulk	1241.7	26%	16%	84%	10%	84%	300%	44%	91%	3%	62%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST16a-10bulk	6.1	27%	18%	25%	11%	62%	47%	55%	85%	4%	25%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST16a-2	1278.6	13%	18%	19%	6%	16%	45%	18%	45%	1%	25%
ST16a-10	1241.7	26%	21%	21%	9%	54%	46%	46%	100%	4%	25%
ST16a-10bulk	1241.7	27%	18%	25%	11%	62%	47%	55%	85%	4%	25%

*based on solids assay*

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
ST16a-10	2.59	323					
ST16a-10bulk	2.47	308					
acid equivalent (g)			0.15	0.93	2.22	0.14	3.44
acid equivalent (%)			4.3	27.1	64.4	4.2	100.0

Test name: **ST16b**  
 Comment: high pH, med total Cl-

Date: **20-Dec-04**

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46	micron
stock solution added:	8.05	2.8	2.832	0.5	0.5	T:	80	°C
total slurry in:	1592.4	1305.4	1.2199	7.3	7.1	duration:	20	min
	1600.45			0.20	0.20	agitation rate:	800	rpm
				MgCl2 (g/l):	299.05	275	impeller:	pitched blade, 5cm, Ti
				total Cl- (g/l):	230	226	vessel:	2litre, baffled, with reflux condenser

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
ST16b-0	0		26.1	-0.85	1.2199	537	736	55min heat-up time, orange PLS, light green wash, light brown solids
ST16b-2	2	31.13	24.5		1.2214	556	755	
ST16b-20	20	25.67						
ST16b-20bulk	20bulk	1523.99	24.2	-0.68	1.2246	543	742	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
ST16b-2	31.13	25.49						0.0			1.97	-
ST16b-20	25.67	20.96						0.0			19.70	-
ST16b-20bulk	1500.42	1225.23	9.3	7.4	4.5	100.76	101.0	97.64	1.04	93.9	19.70	0.30

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
ST16b-20bulk	1.57	0.94	1.06	0.05	0.61	3.4	9.83	0.07	0.2	26.2	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
ST16b-head liquor	2	2.79	226	2	1	7.82	7.13	70314	2	18	2	2
ST16b-2	12.8	9.36	227	2	1.79	88.2	6.72	71426	2	56.4	13.2	2
ST16b-20	28.1	9.04	228	2	3.24	334	4.96	72297	9.08	94.8	39.9	2
ST16b-20bulk	28.3	9.32	230	2.75	3.44	357	4.87	71476	9.7	103	41.1	2
ST16b-comp. wash	5.05	2	39.3	2	1	59.3	0.7	11097	2.26	16.5	6.11	2

**CALCULATIONS AND MASS BALANCE**

H <sup>+</sup>	assay H <sup>+</sup> mol/l	residual HCl g	Δ acid %
ST16b-0	0.20		31.7
ST16b-2	0.18		
ST16b-20	0.14	6.08	
ST16b-20bulk	0.13	5.97	
average	0.16		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
feed solids	8.05	0.12	0.06	0.01	0.00	0.04	0.75	1.51	0.02	0.13	1.51	0.00
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
head liquor	1592.40	1305.35	0.0	0.0	295.01	0.0	0.0	0.0	91.8	0.0	0.0	0.0
wash water	100.76	100.96	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1701.21</b>	<b>0.13</b>	<b>0.07</b>	<b>0.07</b>	<b>295.02</b>	<b>0.01</b>	<b>0.04</b>	<b>0.76</b>	<b>93.30</b>	<b>0.02</b>	<b>0.16</b>	<b>1.51</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST16b-2	0.00	-	-	-	-	-	-	-	-	-	-	-
ST16b-20	0.00	-	-	-	-	-	-	-	-	-	-	-
ST16b-20bulk	4.50	0.07	0.04	0.05	0.00	0.03	0.15	0.44	0.00	0.01	1.18	0.00
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
ST16b-2	31.13	25.49	0.000	0.000	5.786	0.000	0.000	0.002	1.820	0.000	0.001	0.000
ST16b-20	25.67	20.96	0.001	0.000	4.779	0.000	0.000	0.007	1.515	0.000	0.002	0.001
ST16b-20bulk	1500.42	1225.23	0.035	0.011	281.804	0.003	0.004	0.437	87.575	0.012	0.126	0.050
wash water	97.64	93.88	0.000	0.000	3.690	0.000	0.000	0.006	1.042	0.000	0.002	0.001
cake moisture	2.90	2.79	0.000	0.000	0.110	0.000	0.000	0.000	0.031	0.000	0.000	0.000
evaporation	19.66	19.70	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1681.92</b>	<b>0.11</b>	<b>0.05</b>	<b>296.22</b>	<b>0.01</b>	<b>0.03</b>	<b>0.61</b>	<b>92.43</b>	<b>0.02</b>	<b>0.14</b>	<b>1.23</b>	<b>0.00</b>
<b>balance (out/in)</b>	<b>99%</b>	<b>85%</b>	<b>81%</b>	<b>100%</b>	<b>89%</b>	<b>79%</b>	<b>80%</b>	<b>99%</b>	<b>76%</b>	<b>89%</b>	<b>81%</b>	<b>75%</b>

extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST16b-2	1277.90	13%	19%	63%	6%	15%	-34%	14%	53%	1%	63%
ST16b-20	1239.20	28%	18%	62%	10%	55%	-145%	64%	87%	3%	62%
ST16b-20bulk	1239.20	28%	18%	85%	11%	59%	-212%	68%	95%	3%	62%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST16b-20bulk	4.7	41%	31%	42%	27%	79%	70%	82%	93%	19%	42%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST16b-2	1277.9	18%	31%	31%	14%	19%	70%	17%	51%	6%	42%
ST16b-20	1239.2	40%	30%	31%	26%	74%	70%	76%	86%	18%	42%
ST16b-20bulk	1239.2	41%	31%	42%	27%	79%	70%	82%	93%	19%	42%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
ST16b-20	3.23	401					
ST16b-20bulk	3.34	415					
acid equivalent (g)			0.21	1.17	3.21	0.16	4.75
acid equivalent (%)			4.5	24.6	67.6	3.3	100.0

Test name: **ST16c**  
 Comment: high pH, med total Cl-

Date: **20-Dec-04**

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46	micron	
stock solution added:	8.04	2.8	2.832	0.5	0.5	T:	80	°C	
total slurry in:	1593.2	1306.0	1.2199	initial pulp % solids:	7.3	7.1	duration:	30	min
	1601.24			initial HCl (g/l):	0.20	0.20	agitation rate:	800	rpm
				MgCl2 (g/l):	299	275	impeller:	pitched blade, 5cm, Ti	
				total Cl- (g/l):	230	226	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
ST16c-0	0		26.1	-0.85	1.2199	537	736	65min heat-up time, orange PLS, light green wash, grey solids
ST16c-2	2	29.35	24.5		1.2215	550	749	
ST16c-30	30	22.56						
ST16c-30bulk	30bulk	1529.81	24.3	-0.68	1.2255	535	734	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
ST16c-2	29.35	24.03						0.0			1.30	-
ST16c-30	22.56	18.41						0.0			19.56	-
ST16c-30bulk	1501.09	1224.88	11.8	10.9	4.33	106.82	107.0	104.88	1.0388	101.0	19.56	0.28

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
ST16c-30bulk	1.6	0.99	1.13	0.05	0.63	2.77	7.59	0.05	0.15	27.1	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
ST16c-head liquor	2	2.79	226	2	1	7.82	7.13	70314	2	18	2	2
ST16c-2	12.9	9.02	234	2	1.11	81.3	6.62	71875	2	48.9	12.3	2
ST16c-30	29.8	9.49	233	2.52	5.57	378	4.68	69300	10.5	100	41.3	2
ST16c-30bulk	31.7	9.45	236	3.13	3.86	374	4.65	71667	10.9	110.1	40.3	2
ST16c-comp. wash	5.15	2	39.5	2	1	63.6	0.7	10596	2.11	17.3	5.74	2

**CALCULATIONS AND MASS BALANCE**

H <sup>+</sup>	assay H <sup>+</sup> mol/l	residual HCl g	Δ acid %
ST16c-0	0.20		34.8
ST16c-2	0.18		
ST16c-30	0.13	5.73	
ST16c-30bulk	0.13	5.70	
average	0.16		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.04	0.12	0.06	0.01	0.00	0.04	0.75	1.51	0.02	0.13	1.51	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn	
head liquor	1593.20	1306.01	0.0	0.0	295.16	0.0	0.0	0.0	91.8	0.0	0.0	0.0	
wash water	106.82	107.03	-	-	-	-	-	-	-	-	-	-	
<b>total IN (g)</b>	<b>1708.06</b>	<b>0.13</b>	<b>0.07</b>	<b>0.07</b>	<b>295.17</b>	<b>0.01</b>	<b>0.04</b>	<b>0.76</b>	<b>93.34</b>	<b>0.02</b>	<b>0.16</b>	<b>1.51</b>	<b>0.01</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST16c-2	0.00	-	-	-	-	-	-	-	-	-	-	-
ST16c-30	0.00	-	-	-	-	-	-	-	-	-	-	-
ST16c-30bulk	4.33	0.07	0.04	0.05	0.00	0.03	0.12	0.33	0.00	0.01	1.17	0.00
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
ST16c-2	29.35	24.03	0.000	0.000	5.623	0.000	0.000	0.002	1.727	0.000	0.001	0.000
ST16c-30	22.56	18.41	0.001	0.000	4.289	0.000	0.000	0.007	1.276	0.000	0.002	0.001
ST16c-30bulk	1501.09	1224.88	0.039	0.012	289.072	0.004	0.005	0.458	87.783	0.013	0.135	0.049
wash water	104.88	100.96	0.001	0.000	3.988	0.000	0.000	0.006	1.070	0.000	0.002	0.001
cake moisture	6.57	6.32	0.000	0.000	0.250	0.000	0.000	0.067	0.000	0.000	0.000	0.000
evaporation	19.52	19.56	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1688.30</b>	<b>0.11</b>	<b>0.06</b>	<b>303.27</b>	<b>0.01</b>	<b>0.03</b>	<b>0.59</b>	<b>92.25</b>	<b>0.02</b>	<b>0.15</b>	<b>1.22</b>	<b>0.00</b>

<b>balance (out/in)</b>	99%	87%	82%	103%	95%	80%	78%	99%	79%	92%	81%	74%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST16c-2	1280.68	13%	18%	64%	4%	14%	14%	14%	47%	1%	64%
ST16c-30	1244.01	30%	19%	78%	18%	63%	-372%	74%	92%	3%	62%
ST16c-30bulk	1244.01	32%	19%	97%	12%	62%	-177%	77%	102%	3%	62%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST16c-30bulk	4.5	42%	30%	44%	28%	83%	78%	87%	95%	20%	44%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST16c-2	1280.7	17%	29%	28%	8%	18%	78%	16%	42%	6%	44%
ST16c-30	1244.0	39%	30%	36%	40%	84%	75%	84%	86%	20%	44%
ST16c-30bulk	1244.0	42%	30%	44%	28%	83%	78%	87%	95%	20%	44%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
ST16c-30	3.58	445					
ST16c-30bulk	3.62	450					
acid equivalent (g)			0.22	1.23	3.55	0.16	5.16
acid equivalent (%)			4.2	23.9	68.8	3.1	100.0

Test name: **ST16d**  
 Comment: high pH, med total Cl-

Date: 15-Dec-04

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46	micron
stock solution added:	8	2.8	2.832	initial pulp % solids:	0.5	T:	80	°C
total slurry in:	1592.1	1304.0	1.2209	initial HCl (g/l):	7.3	duration:	60	min
	1600.1			initial HCl (M):	0.20	agitation rate:	800	rpm
				MgCl2 (g/l):	299	impeller:	pitched blade, 5cm, Ti	
				total Cl- (g/l):	230	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
ST16d-0	0		26	-0.85	1.2209	525	724	140min heat-up time, orange PLS, light green wash, grey solids
ST16d-2	2	29.86	26.2		1.2212	567	766	
ST16d-60	60	5.85						
ST16d-60bulk	60bulk	1542.24	26.2	-0.65	1.2258	553	752	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
ST16d-2	29.86	24.45					0.0			-	0.74	-
ST16d-60	5.85	4.77					0.0			-	22.19	-
ST16d-60bulk	1518.24	1238.57	7.3	10.1	4.75	99.36	99.6	96.58	1.0414	92.7	22.19	0.31

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
ST16d-60bulk	1.65	1.03	1.02	0.05	0.66	2.14	5.25	0.05	0.1	28	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
ST16d-head liquor	2	2.84	224	2	1	8.11	6.99	68879	2	17.6	2	2
ST16d-2	14.1	8.04	224	2.3	1	138	6.6	68000	2	46.5	10.9	2
ST16d-60	30.8	9.35	216	4.96	5.14	619	4.1	71980	10.2	143	33.2	2
ST16d-60bulk	32.2	8.73	228	4.49	4.09	658	4.18	77480	10.7	126	33.7	2
ST16d-comp. wash	6.02	2.45	41.4	2	1	109	0.5	12189	2.16	25.9	6.2	2

**CALCULATIONS AND MASS BALANCE**

H <sup>+</sup>	assay H <sup>+</sup> mol/l	residual HCl g	Δ acid %
ST16d-0	0.19		40.2
ST16d-2	0.18		
ST16d-60	0.11	5.08	
ST16d-60bulk	0.11	5.18	
average	0.15		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
feed solids	8.00	0.12	0.06	0.01	0.00	0.04	0.74	1.50	0.02	0.13	1.50	0.00
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
head liquor	1592.10	1304.04	0.0	0.0	292.10	0.0	0.0	0.0	89.8	0.0	0.0	0.0
wash water	99.36	99.56	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1699.46</b>		<b>0.13</b>	<b>0.07</b>	<b>292.12</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>91.32</b>	<b>0.02</b>	<b>0.16</b>	<b>1.50</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST16d-2	0.00	-	-	-	-	-	-	-	-	-	-	-
ST16d-60	0.00	-	-	-	-	-	-	-	-	-	-	-
ST16d-60bulk	4.75	0.08	0.05	0.05	0.00	0.03	0.10	0.25	0.00	0.00	1.33	0.00
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
ST16d-2	29.86	24.45	0.000	0.000	5.477	0.000	0.000	0.003	1.663	0.000	0.001	0.000
ST16d-60	5.85	4.77	0.000	0.000	1.031	0.000	0.000	0.003	0.344	0.000	0.001	0.000
ST16d-60bulk	1518.24	1238.57	0.040	0.011	282.394	0.006	0.005	0.815	95.964	0.013	0.156	0.042
wash water	96.58	92.74	0.001	0.000	3.839	0.000	0.000	0.010	1.130	0.000	0.002	0.001
cake moisture	5.33	5.12	0.000	0.000	0.212	0.000	0.000	0.001	0.062	0.000	0.000	0.000
evaporation	22.15	22.19	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1682.76</b>		<b>0.12</b>	<b>0.06</b>	<b>293.00</b>	<b>0.01</b>	<b>0.04</b>	<b>0.93</b>	<b>99.41</b>	<b>0.02</b>	<b>0.17</b>	<b>1.37</b>
<b>balance (out/in)</b>	<b>99%</b>		<b>95%</b>	<b>90%</b>	<b>100%</b>	<b>124%</b>	<b>91%</b>	<b>124%</b>	<b>109%</b>	<b>79%</b>	<b>105%</b>	<b>91%</b>

extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST16d-2	1278.85	15%	16%	74%	3%	24%	-190%	15%	44%	1%	64%
ST16d-60	1252.62	32%	19%	155%	17%	104%	23%	73%	134%	3%	63%
ST16d-60bulk	1252.62	33%	17%	141%	13%	111%	481%	76%	118%	3%	63%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST16d-60bulk	4.9	34%	21%	39%	17%	86%	83%	86%	96%	9%	39%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST16d-2	1278.8	15%	19%	20%	4%	18%	73%	16%	36%	3%	39%
ST16d-60	1252.6	33%	22%	43%	22%	81%	77%	82%	109%	9%	39%
ST16d-60bulk	1252.6	34%	21%	39%	17%	86%	83%	86%	96%	9%	39%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
ST16d-60	4.04	505					
ST16d-60bulk	3.94	492					
acid equivalent (g)			0.18	1.26	3.76	0.16	5.36
acid equivalent (%)			3.3	23.5	70.2	3.0	100.0

**Test name:** ST16e  
**Comment:** high pH, med total Cl-

**Date:** 15-Dec-04

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46	micron
stock solution added:	8.03	2.8	2.832	initial pulp % solids:	0.5	T:	80	°C
total slurry in:	1592.2	1303.9	1.2211	initial HCl (g/l):	7.3	duration:	120	min
	1600.23			initial HCl (M):	0.20	agitation rate:	800	rpm
				MgCl <sub>2</sub> (g/l):	299	impeller:	pitched blade, 5cm, Ti	
				total Cl <sup>-</sup> (g/l):	230	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed (g)	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
ST16e-0	0		26.1	-0.83	1.2211	525	724	75min heat-up time, orange PLS, light green wash, grey solids
ST16e-2	2	25.76	26.1		1.2223	567	766	
ST16e-120	120	29.86						
ST16e-120bulk	120bulk	1513.04	26.2	-0.66	1.2272	553	752	

Sample	filtrate mass (g)	filtrate vol (ml)	wet residue mass before wash (g)	wet residue mass after wash (g)	dry residue mass (g)	wash mass in (g)	wash vol in (ml)	wash mass out (g)	wash density @20°C (kg/l)	wash vol out (ml)	calc. evaporation cum. ml	calc. sample pulp density % solids
ST16e-2	25.76	21.08						0.0			0.53	-
ST16e-120	29.86	24.33						0.0			31.63	-
ST16e-120bulk	1493	1216.59	6.1	4.4	4.71	103.3	103.5	100.44	1.0346	97.1	31.63	0.31

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
ST16e-120bulk	1.63	1.03	0.88	0.05	0.68	1.73	4.18	0.05	0.07	28.6	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
ST16e-head liquor	2	2.81	226	2	1.08	7.79	6.81	68831	2	15.4	2	2
ST16e-2	13.1	8.48	227	2.24	1.97	159	6.48	75340	2	82.5	12.8	2
ST16e-120	35.3	9.73	230	4.96	4.65	747	4.05	77520	11.1	178	27.3	2
ST16e-120bulk	32.8	8.22	230	4.2	4.87	752	3.98	75320	11.1	118.7	26.5	2
ST16e-comp. wash	5.05	2	34.4	2	1	101	0.5	10180	2	25.8	4.18	2

**CALCULATIONS AND MASS BALANCE**

H <sup>+</sup>	assay H <sup>+</sup> mol/l	residual HCl g	Δ acid %
ST16e-0	0.19		41.6
ST16e-2	0.18		
ST16e-120	0.11	4.93	
ST16e-120bulk	0.11	4.84	
average	0.15		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.03	0.12	0.06	0.01	0.00	0.04	0.75	1.51	0.02	0.13	1.51	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
head liquor	1592.20	1303.91	0.0	0.0	294.68	0.0	0.0	0.0	89.7	0.0	0.0	0.0	0.0
wash water	103.30	103.51	-	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1703.53</b>	<b>0.13</b>	<b>0.07</b>	<b>0.01</b>	<b>294.69</b>	<b>0.01</b>	<b>0.04</b>	<b>0.76</b>	<b>91.26</b>	<b>0.02</b>	<b>0.15</b>	<b>1.51</b>	<b>0.01</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
ST16e-2	0.00	-	-	-	-	-	-	-	-	-	-	-	
ST16e-120	0.00	-	-	-	-	-	-	-	-	-	-	-	
ST16e-120bulk	4.71	0.08	0.05	0.04	0.00	0.03	0.08	0.20	0.00	0.00	1.35	0.00	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST16e-2	25.76	21.08	0.000	0.000	4.784	0.000	0.000	0.003	1.588	0.000	0.002	0.000	0.000
ST16e-120	29.86	24.33	0.001	0.000	5.596	0.000	0.000	0.018	1.886	0.000	0.004	0.001	0.000
ST16e-120bulk	1493.00	1216.59	0.040	0.010	275.816	0.005	0.006	0.915	91.634	0.014	0.144	0.032	0.002
wash water	100.44	97.08	0.000	0.000	3.340	0.000	0.000	0.010	0.988	0.000	0.003	0.000	0.000
cake moisture	-0.31	-0.30	0.000	0.000	-0.010	0.000	0.000	0.000	-0.003	0.000	0.000	0.000	0.000
evaporation	31.57	31.63	-	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1685.03</b>	<b>0.12</b>	<b>0.06</b>	<b>0.06</b>	<b>293.57</b>	<b>0.01</b>	<b>0.04</b>	<b>1.03</b>	<b>96.29</b>	<b>0.02</b>	<b>0.16</b>	<b>1.38</b>	<b>0.01</b>

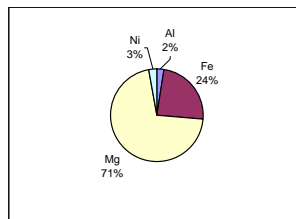
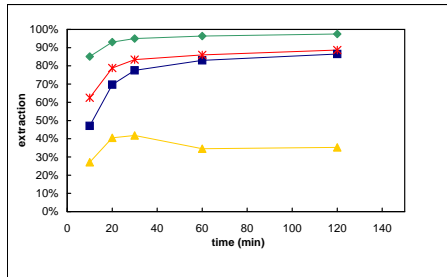
balance (out/in)	99%	94%	88%	100%	118%	95%	136%	106%	81%	101%	92%	77%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST16a-2	1282.30	13%	16%	66%	5%	22%	170%	14%	50%	1%	64%
ST16b-2		13%	19%	63%	6%	15%	-34%	14%	53%	1%	63%
ST16c-2		13%	18%	64%	4%	14%	14%	14%	47%	1%	64%
ST16d-2		15%	16%	74%	3%	24%	-190%	15%	44%	1%	64%
ST16e-2		14%	17%	72%	6%	27%	454%	15%	79%	1%	64%
ST16e-2 ave.			14%	17%	68%	5%	20%	83%	14%	55%	1%
std deviation		1%	1%	5%	1%	6%	244%	0%	14%	0%	0%
confidence limits		0.6%	1.1%	4.1%	1.2%	5.1%	214.0%	0.7%	12.2%	0.1%	0.2%
ST16a-10		26%	18%	73%	8%	73%	126%	37%	107%	2%	62%
ST16b-20		28%	18%	62%	10%	55%	-145%	64%	87%	3%	62%
ST16c-30		30%	19%	78%	18%	63%	-372%	74%	92%	3%	62%
ST16d-60		32%	19%	155%	17%	104%	23%	73%	134%	3%	63%
ST16e-120	1226.87	35%	19%	152%	15%	123%	355%	77%	162%	2%	61%
ST16e-120bulk	1226.87	33%	16%	128%	15%	123%	176%	77%	108%	2%	61%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
ST16a-10bulk		27%	18%	25%	11%	62%	47%	55%	85%	4%	25%
ST16b-20bulk		41%	31%	42%	27%	79%	70%	82%	93%	19%	42%
ST16c-30bulk		42%	30%	44%	28%	83%	78%	87%	95%	20%	44%
ST16d-60bulk		34%	21%	39%	17%	86%	83%	86%	96%	9%	39%
ST16e-120bulk	4.9	35%	21%	39%	15%	89%	86%	86%	97%	7%	39%

**based on solids assay**

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
ST16e-120	3.95	492					
ST16e-120bulk	4.04	503					
acid equivalent (g)			0.19	1.30	3.94	0.16	5.59
acid equivalent (%)			3.3	23.3	70.4	2.9	100.0



Test name: TT17a  
 Comment: 60°C baseline, 0.5% solids

Date: 5-Apr-05

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	initial pulp % solids:	nominal	effective	grind (D90)	46	micron
stock solution added:	8.02	2.8	2.832	initial HCl (g/l):	0.5	0.5	T:	60	°C
total slurry in:	1592.5	1590.1	1.0015	initial HCl (M):	7.3	6.9	duration:	10	min
	1600.52			MgCl2 (g/l):	0.20	0.19	agitation rate:	800	rpm
				total Cl- (g/l):	0	0	impeller:	pitched blade, 5cmφ, Ti	
					7	7.18	vesse:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. (mV)	Eh (mV)	Notes
TT17a-0	0				1.0015		-	
TT17a-2	2						-	
TT17a-10	10	21.71					-	
TT17a-10bulk	10bulk	1566.6		0.69	1.0016	557	756	

Sample	filtrate mass g	filtrate vol ml	wet residue g	wet residue g	dry residue g	wash mass in g	wash vol in ml	wash mass g	wash density kg/l	wash vol out ml	calc. cum. ml	calc. sample % solids
TT17a-2							0.0			-	2.45	-
TT17a-10	21.15	21.12					0.0			-	12.23	-
TT17a-10bulk	1542.6	1540.14	16.3	18.1	7.26	206.77	207.2	195.94	0.9983	196.3	12.23	0.46

ANALYSES

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
TT17a-10bulk	1.39	0.66	0.33	0.05	0.49	8.85	17.7	0.21	1.46	17.2	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
TT17a-head liquor	2	2	7.18	2	1	2	6.86	2	2	2.93	2	2
TT17a-2												
TT17a-10	2.62	3.96	7.34	2	1	11.7	6.84	9.63	2	6.62	6.75	2
TT17a-10bulk	2.81	3.88	7.5	2	1	16.6	7.17	17.5	2	7.94	8.62	2
TT17a-comp. wash	2	2	0.5	2	1	2	0.91	3.64	2	2.93	3.79	2

CALCULATIONS AND MASS BALANCE

H <sup>+</sup>	assay H+ mol/l	residual HCl g	Δ acid %
TT17a-0	0.19		-4.5
TT17a-2	0.00		
TT17a-10	0.19	10.53	
TT17a-10bulk	0.20	11.04	
average	0.14		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.02	0.12	0.06	0.01	0.00	0.04	0.75	1.51	0.02	0.13	1.50	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
head liquor	1592.50	1590.11	0.0	0.0	11.42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	206.77	207.18	-	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1807.29</b>	<b>0.13</b>	<b>0.07</b>	<b>11.43</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.51</b>	<b>0.02</b>	<b>0.14</b>	<b>1.51</b>	<b>0.01</b>	

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
TT17a-2	0.00	-	-	-	-	-	-	-	-	-	-	-	
TT17a-10	0.00	-	-	-	-	-	-	-	-	-	-	-	
TT17a-10bulk	7.26	0.10	0.05	0.02	0.00	0.04	0.64	1.29	0.02	0.11	1.25	0.00	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT17a-2	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TT17a-10	21.15	21.12	0.000	0.000	0.155	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TT17a-10bulk	1542.60	1540.14	0.004	0.006	11.551	0.003	0.002	0.026	0.027	0.003	0.012	0.013	0.003
wash water	195.94	196.27	0.000	0.000	0.098	0.000	0.000	0.000	0.001	0.000	0.001	0.001	0.000
cake moisture	10.84	10.86	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
evaporation	12.21	12.23	-	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1790.00</b>	<b>0.11</b>	<b>0.05</b>	<b>11.83</b>	<b>0.01</b>	<b>0.04</b>	<b>0.67</b>	<b>1.31</b>	<b>0.02</b>	<b>0.12</b>	<b>1.26</b>	<b>0.01</b>	

balance (out/in)	99%	84%	82%	104%	100%	92%	89%	87%	90%	86%	84%	100%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT17a-2	1587.7	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
TT17a-10	1556.8	3%	10%	78%	4%	2%	1%	18%	8%	1%	78%
TT17a-10bulk	1556.8	4%	10%	78%	4%	3%	2%	18%	9%	1%	78%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT17a-10bulk	7.4	17%	23%	8%	7%	13%	14%	12%	20%	16%	8%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT17a-2	1587.7	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
TT17a-10	1556.8	15%	24%	8%	7%	9%	7%	12%	17%	12%	8%
TT17a-10bulk	1556.8	17%	23%	8%	7%	13%	14%	12%	20%	16%	8%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
TT17a-10	0.37	47					
TT17a-10bulk	-0.13	-17					
acid equivalent (g)			0.09	0.20	0.67	0.04	1.00
acid equivalent (%)			8.9	20.4	67.2	3.5	100.0

Test name: TT17b  
 Comment: 60°C baseline, 0.5% solids

Date: 5-Apr-05

dry ore added:	8.06	2.8	2.832	initial pulp % solids:	0.5	0.5	grind (D90)	46	micron
stock solution added:	1592	1589.6	1.0015	initial HCl (g/l):	7.3	6.9	T:	60	°C
total slurry in:	1600.06			initial HCl (M):	0.20	0.19	duration:	20	min
				MgCl2 (g/l):	0	0	agitation rate:	800	rpm
				total Cl- (g/l):	7	7.18	impeller:	pitched blade, 5cmφ, Ti	
							vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
TT17b-0	0				1.0015		-	
TT17b-2	2						-	
TT17b-20	20	22.38					-	
TT17b-20bulk	20bulk	1560.06		0.69	1.0016	575	774	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
TT17b-2	0						0.0			-	1.77	-
TT17b-20	22.1	22.06					0.0			-	17.66	-
TT17b-20bulk	1542	1539.54	10.1	11.1	7.47	195.04	195.4	189.52	0.9982	189.9	17.66	0.48

ANALYSES

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
TT17b-20bulk	1.35	0.69	0.22	0.05	0.5	8.89	17.8	0.21	1.45	17.4	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
TT17b-head liquor	2	2	7.18	2	1	2	6.86	2	2	2.93	2	2
TT17b-2												
TT17b-20	3.07	3.73	7.51	2	1	16.3	6.8	13.9	2	9.67	9.22	2
TT17b-20bulk	3.06	3.84	7.48	2	1	19	7.09	18.3	2	11	11.3	2
TT17b-comp. wash	2	2	0.5	2	1	5.14	0.71	17.2	2	2.93	4.42	2

CALCULATIONS AND MASS BALANCE

H <sup>+</sup>	assay H+ mol/l	residual HCl g	Δ acid %
TT17b-0	0.19		-3.4
TT17b-2	0.00		
TT17b-20	0.19	10.47	
TT17b-20bulk	0.19	10.92	
average	0.14		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
feed solids	8.06	0.12	0.06	0.01	0.00	0.04	0.75	1.52	0.02	0.14	1.51	0.00
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
head liquor	1592.00	1589.62	0.0	0.0	11.41	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	195.04	195.43	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1795.10</b>	<b>0.13</b>	<b>0.07</b>	<b>11.42</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.52</b>	<b>0.02</b>	<b>0.14</b>	<b>1.51</b>	<b>0.01</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT17b-2	0.00	-	-	-	-	-	-	-	-	-	-	-
TT17b-20	0.00	-	-	-	-	-	-	-	-	-	-	-
TT17b-20bulk	7.47	0.10	0.05	0.02	0.00	0.04	0.66	1.33	0.02	0.11	1.30	0.00
<b>solution OUT</b>	<b>total g</b>	<b>total ml</b>	<b>Al</b>	<b>Ca</b>	<b>Cl</b>	<b>Co</b>	<b>Cr</b>	<b>Fe</b>	<b>Mg</b>	<b>Mn</b>	<b>Ni</b>	<b>Zn</b>
TT17b-2	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TT17b-20	22.10	22.06	0.000	0.000	0.166	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TT17b-20bulk	1542.00	1539.54	0.005	0.006	11.516	0.003	0.002	0.029	0.028	0.003	0.017	0.017
wash water	189.52	189.86	0.000	0.000	0.095	0.000	0.001	0.003	0.003	0.001	0.001	0.000
cake moisture	3.63	3.64	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
evaporation	17.62	17.66	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1782.34</b>	<b>0.11</b>	<b>0.06</b>	<b>11.79</b>	<b>0.01</b>	<b>0.04</b>	<b>0.69</b>	<b>1.36</b>	<b>0.02</b>	<b>0.13</b>	<b>1.32</b>	<b>0.01</b>

balance (out/in)	99%	84%	87%	103%	100%	96%	92%	90%	92%	90%	87%	100%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT17b-2	1587.85	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
TT17b-20	1549.90	4%	9%	77%	4%	3%	1%	17%	11%	1%	77%
TT17b-20bulk	1549.90	4%	9%	77%	4%	4%	2%	17%	13%	1%	77%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT17b-20bulk	7.6	17%	18%	6%	3%	10%	11%	10%	19%	13%	6%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT17b-2	1587.9	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
TT17b-20	1549.9	17%	17%	6%	3%	9%	8%	10%	16%	10%	6%
TT17b-20bulk	1549.9	17%	18%	6%	3%	10%	11%	10%	19%	13%	6%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
TT17b-20	0.44	54					
TT17b-20bulk	-0.01	-1					
acid equivalent (g)			0.09	0.17	0.56	0.03	0.85
acid equivalent (%)			10.7	19.8	65.6	3.9	100.0

Test name: TT17c  
 Comment: 60°C baseline, 0.5% solids

Date: 5-Apr-05

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	initial pulp % solids:	nominal	effective	grind (D90)	46	micron
stock solution added:	8.02	2.8	2.832	initial HCl (g/l):	0.5	0.5	T:	60	°C
total slurry in:	1592	1589.6	1.0015	initial HCl (M):	7.3	6.9	duration:	30	min
	1600.02			MgCl2 (g/l):	0.20	0.19	agitation rate:	800	rpm
				total Cl- (g/l):	0	0	impeller:	pitched blade, 5cmφ, Ti	
					7	7.18	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
TT17c-0	0				1.0015		-	
TT17c-2	2						-	
TT17c-30	30	20.03					-	
TT17c-30bulk	30bulk	1565		0.70	1.0018	583	782	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
TT17c-2	0						0.0				15.02	-
TT17c-30	19.28	19.25					0.0				15.02	-
TT17c-30bulk	1548	1545.22	8.7	9.9	7.1	201.65	202.1	196.02	0.9982	196.4	15.02	0.45

ANALYSES

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
TT17c-30bulk	1.42	0.7	0.37	0.05	0.53	9.13	18.7	0.22	1.46	17.9	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
TT17c-head liquor	2	2	7.18	2	1	2	6.86	2	2	2.93	2	2
TT17c-2												
TT17c-30	3.31	3.84	7.52	2	1	20.5	6.77	19.4	2	12.2	11.6	2
TT17c-30bulk	3.68	3.85	8.66	2	1	22.8	6.69	24.5	2	12.4	13.4	2
TT17c-comp. wash	2	2	0.5	2	1	2	0.73	2.52	2	2.93	2.6	2

CALCULATIONS AND MASS BALANCE

H <sup>+</sup>	assay H+ mol/l	residual HCl g	Δ acid %
TT17c-0	0.19		2.5
TT17c-2	0.00		
TT17c-30	0.19	10.46	
TT17c-30bulk	0.18	10.34	
average	0.14		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
feed solids	8.02	0.12	0.06	0.01	0.00	0.04	0.75	1.51	0.02	0.13	1.50	0.00
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
head liquor	1592.00	1589.62	0.0	0.0	11.41	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	201.65	202.05	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1801.67</b>		<b>0.13</b>	<b>0.07</b>	<b>11.42</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.51</b>	<b>0.02</b>	<b>0.14</b>	<b>1.51</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT17c-2	0.00	-	-	-	-	-	-	-	-	-	-	-
TT17c-30	0.00	-	-	-	-	-	-	-	-	-	-	-
TT17c-30bulk	7.10	0.10	0.05	0.03	0.00	0.04	0.65	1.33	0.02	0.10	1.27	0.00
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
TT17c-2	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TT17c-30	19.28	19.25	0.000	0.000	0.145	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TT17c-30bulk	1548.00	1545.22	0.006	0.006	13.382	0.003	0.002	0.035	0.038	0.003	0.019	0.021
wash water	196.02	196.37	0.000	0.000	0.098	0.000	0.000	0.000	0.000	0.000	0.001	0.001
cake moisture	2.80	2.81	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
evaporation	14.99	15.02	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1788.19</b>		<b>0.11</b>	<b>0.06</b>	<b>13.65</b>	<b>0.01</b>	<b>0.04</b>	<b>0.68</b>	<b>1.37</b>	<b>0.02</b>	<b>0.12</b>	<b>1.29</b>

balance (out/in)	99%	85%	84%	120%	98%	97%	91%	90%	92%	89%	86%	98%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT17c-2	1588.61	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
TT17c-30	1555.35	4%	9%	78%	4%	4%	2%	18%	14%	1%	78%
TT17c-30bulk	1555.35	5%	9%	78%	4%	5%	2%	18%	14%	1%	78%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT17c-30bulk	7.2	17%	21%	10%	2%	12%	11%	10%	22%	14%	10%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT17c-2	1588.6	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
TT17c-30	1555.4	15%	21%	10%	2%	11%	9%	10%	21%	12%	10%
TT17c-30bulk	1555.4	17%	21%	10%	2%	12%	11%	10%	22%	14%	10%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
TT17c-30	0.44	55					
TT17c-30bulk	0.57	71					
acid equivalent (g)			0.09	0.19	0.54	0.04	0.86
acid equivalent (%)			10.3	22.4	62.9	4.4	100.0

Test name: TT17d  
 Comment: 60°C baseline, 0.5% solids

Date: 4-Apr-05

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	initial pulp % solids:	nominal	effective	grind (D90)	46	micron
stock solution added:	8.03	2.8	2.832	initial HCl (g/l):	0.5	0.5	T:	60	°C
total slurry in:	1592.4	1590.0	1.0015	initial HCl (M):	7.3	6.9	duration:	60	min
	1600.43			MgCl2 (g/l):	0.20	0.19	agitation rate:	800	rpm
				total Cl- (g/l):	0	0	impeller:	pitched blade, 5cmφ, Ti	
					7	7.18	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
TT17d-0	0				1.0016		-	
TT17d-2	2						-	
TT17d-60	60	22.19					-	
TT17d-60bulk	60bulk	1554.2		0.71	1.0020	606	805	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
TT17d-2	0						0.0				0.80	-
TT17d-60	21.88	21.84					0.0				24.09	-
TT17d-60bulk	1534.7	1531.64	10	12.7	7.26	208.16	208.6	198.14	0.9986	198.4	24.09	0.47

ANALYSES

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
TT17d-60bulk	1.38	0.72	0.26	0.05	0.51	8.8	17.5	0.2	1.17	18.5	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
TT17d-head liquor	2	2	7.18	2	1	2	6.86	2	2	2.93	2	2
TT17d-2												
TT17d-60	4.76	3.96	7.48	2	1	39	6.72	50.9	2	21.4	21	2
TT17d-60bulk	5.78	4.05	7.36	2	1	54.3	6.51	79.6	2.2	30.7	26.7	2
TT17d-comp. wash	2	2	0.5	2	1	3.76	0.88	11.4	2	2.93	4.59	2

CALCULATIONS AND MASS BALANCE

H <sup>+</sup>	assay H+ mol/l	residual HCl g	Δ acid %
TT17d-0	0.19		5.1
TT17d-2	0.00		
TT17d-60	0.18	10.29	
TT17d-60bulk	0.18	9.97	
average	0.14		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
feed solids	8.03	0.12	0.06	0.01	0.00	0.04	0.75	1.51	0.02	0.13	1.51	0.00
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
head liquor	1592.40	1590.01	0.0	0.0	11.42	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	208.16	208.58	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1808.59</b>		<b>0.13</b>	<b>0.07</b>	<b>11.43</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.51</b>	<b>0.02</b>	<b>0.14</b>	<b>1.51</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT17d-2	0.00	-	-	-	-	-	-	-	-	-	-	-
TT17d-60	0.00	-	-	-	-	-	-	-	-	-	-	-
TT17d-60bulk	7.26	0.10	0.05	0.02	0.00	0.04	0.64	1.27	0.01	0.08	1.34	0.00
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Zn
TT17d-2	0.00	0.00	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TT17d-60	21.88	21.84	0.000	0.000	0.163	0.000	0.001	0.001	0.000	0.000	0.000	0.000
TT17d-60bulk	1534.70	1531.64	0.009	0.006	11.273	0.003	0.002	0.083	0.122	0.003	0.047	0.041
wash water	198.14	198.42	0.000	0.000	0.099	0.000	0.001	0.002	0.000	0.001	0.001	0.001
cake moisture	5.44	5.45	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000
evaporation	24.04	24.09	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1791.46</b>		<b>0.11</b>	<b>0.06</b>	<b>11.56</b>	<b>0.01</b>	<b>0.04</b>	<b>0.72</b>	<b>1.40</b>	<b>0.02</b>	<b>0.13</b>	<b>1.39</b>

balance (out/in)	99%	87%	89%	101%	99%	96%	96%	92%	88%	96%	92%	99%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT17d-2	1589.21	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
TT17d-60	1544.09	6%	10%	77%	4%	8%	5%	17%	25%	2%	77%
TT17d-60bulk	1544.09	7%	10%	77%	4%	11%	8%	19%	35%	3%	77%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT17d-60bulk	7.4	17%	16%	8%	4%	13%	15%	17%	36%	10%	8%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT17d-2	1589.2	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
TT17d-60	1544.1	14%	16%	8%	4%	10%	9%	15%	25%	7%	8%
TT17d-60bulk	1544.1	17%	16%	8%	4%	13%	15%	17%	36%	10%	8%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
TT17d-60	0.61	77					
TT17d-60bulk	0.94	117					
acid equivalent (g)			0.09	0.21	0.72	0.06	1.08
acid equivalent (%)			8.5	19.6	66.2	5.7	100.0

Test name: TT17e  
 Comment: 60°C baseline, 0.5% solids

Date: 4-Apr-05

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46	micron
stock solution added:	8	2.8	2.832	0.5	0.5	T:	60	°C
total slurry in:	1592.8	1590.4	1.0015	initial pulp % solids:	7.3	6.9	duration:	120
				initial HCl (g/l):	0.20	0.19	agitation rate:	800
				MgCl2 (g/l):	0	0	impeller:	pitched blade, 5cmφ, T1
				total Cl- (g/l):	7	7.18	vessel:	2litre, baffled, with reflux condenser

Sample	minute	slurry removed (g)	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
TT17e-0	0				1.0016		-	
TT17e-2	2						-	
TT17e-120	120	22.8					-	
TT17e-120bulk	120bulk	1561.5		0.73	1.0024	599	798	

Sample	filtrate mass (g)	filtrate vol (ml)	wet residue mass before wash (g)	wet residue mass after wash (g)	dry residue mass (g)	wash mass in (g)	wash vol in (ml)	wash mass out (g)	wash density @20°C (kg/l)	wash vol out (ml)	calc. evaporation (cum. ml)	calc. sample pulp density (% solids)
TT17e-2	0										0.28	-
TT17e-120	22.33	22.28									16.53	-
TT17e-120bulk	1543.7	1540.00	10.2	11.2	6.78	196.23	196.6	189.22	0.9984	189.5	16.53	0.43

ANALYSES

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
TT17e-120bulk	1.47	0.77	0.22	0.05	0.58	8.56	16.8	0.18	0.96	19	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
TT17e-head liquor	2	2	7.18	2	1	2	6.86	2	2	2.93	2	2
TT17e-120	8.02	3.89	7.62	2	1	90.5	6.39	159	3.29	42.6	43.2	2
TT17e-120bulk	8.58	4.02	7.38	2	1	91.9	6.4	163	3.41	44.1	44.6	2
TT17e-comp. wash	2	2	0.5	2	1	2	0.74	2	2	2.93	2.53	2

CALCULATIONS AND MASS BALANCE

H+	assay H+ mol/l	residual HCl g	Δ acid %
TT17e-0	0.19		6.7
TT17e-120	0.18	9.84	
TT17e-120bulk	0.18	9.86	
average	0.18		

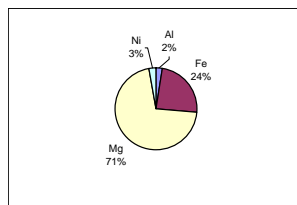
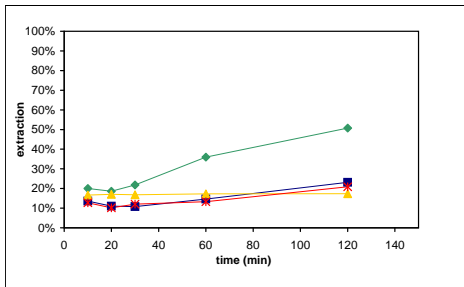
solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.00	0.12	0.06	0.01	0.00	0.04	0.74	1.50	0.02	0.13	1.50	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
head liquor	1592.80	1590.41	0.0	0.0	11.42	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	196.23	196.62											
<b>total IN (g)</b>	<b>1797.03</b>	<b>1797.03</b>	<b>0.13</b>	<b>0.07</b>	<b>11.43</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.51</b>	<b>0.02</b>	<b>0.14</b>	<b>1.50</b>	<b>0.01</b>
<b>solids OUT</b>	<b>total g</b>	<b>Al</b>	<b>Ca</b>	<b>Cl</b>	<b>Co</b>	<b>Cr</b>	<b>Fe</b>	<b>Mg</b>	<b>Mn</b>	<b>Ni</b>	<b>Si</b>	<b>Zn</b>	
TT17e-120	0.00	-	-	-	-	-	-	-	-	-	-	-	
TT17e-120bulk	6.78	0.10	0.05	0.01	0.00	0.04	0.58	1.14	0.01	0.07	1.29	0.00	
<b>solution OUT</b>	<b>total g</b>	<b>total ml</b>	<b>Al</b>	<b>Ca</b>	<b>Cl</b>	<b>Co</b>	<b>Cr</b>	<b>Fe</b>	<b>Mg</b>	<b>Mn</b>	<b>Ni</b>	<b>Si</b>	<b>Zn</b>
TT17e-120	22.33	22.28	0.000	0.000	0.170	0.000	0.000	0.002	0.004	0.000	0.001	0.001	0.000
TT17e-120bulk	1543.70	1540.00	0.013	0.006	11.365	0.003	0.002	0.142	0.251	0.005	0.068	0.069	0.003
wash water	189.22	189.52	0.000	0.000	0.095	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000
cake moisture	4.42	4.43	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
evaporation	16.50	16.53	-	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1782.95</b>	<b>1782.95</b>	<b>0.11</b>	<b>0.06</b>	<b>11.65</b>	<b>0.01</b>	<b>0.04</b>	<b>0.72</b>	<b>1.39</b>	<b>0.02</b>	<b>0.13</b>	<b>1.36</b>	<b>0.01</b>
<b>balance (out/in)</b>	<b>99%</b>	<b>99%</b>	<b>90%</b>	<b>89%</b>	<b>102%</b>	<b>96%</b>	<b>102%</b>	<b>97%</b>	<b>92%</b>	<b>86%</b>	<b>97%</b>	<b>90%</b>	<b>96%</b>

extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT17a-10		3%	10%	78%	4%	2%	1%	18%	8%	1%	78%
TT17b-20		4%	9%	77%	4%	3%	1%	17%	11%	1%	77%
TT17c-30		4%	9%	78%	4%	4%	2%	18%	14%	1%	78%
TT17d-60		6%	10%	77%	4%	8%	5%	17%	25%	2%	77%
TT17e-120	1551.60	10%	10%	78%	4%	19%	16%	29%	49%	4%	78%
TT17e-120bulk	1551.60	11%	10%	78%	4%	19%	17%	30%	51%	5%	78%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT17a-10bulk		17%	23%	8%	7%	13%	14%	12%	20%	16%	8%
TT17b-20bulk		17%	18%	6%	3%	10%	11%	10%	19%	13%	6%
TT17c-30bulk		17%	21%	10%	2%	12%	11%	10%	22%	14%	10%
TT17d-60bulk		17%	16%	8%	4%	13%	15%	17%	36%	10%	8%
TT17e-120bulk	6.9	17%	16%	14%	-3%	21%	23%	30%	51%	13%	14%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
TT17e-120	1.07	134					
TT17e-120bulk	1.05	132					
acid equivalent (g)			0.09	0.32	1.09	0.09	1.59
acid equivalent (%)			5.8	20.2	68.7	5.4	100.0



Test name: TT18a  
 Comment: 60°C baseline, 0.5% solids

Date: 5-Apr-05

	mass (g)	volume (ml)	density @20°C (kg/l)		nominal	effective	grind (D90)	46	micron
dry ore added:	8	2.8	2.832	initial pulp % solids:	0.5	0.5	T:	95	°C
stock solution added:	1592.6	1590.2	1.0015	initial HCl (g/l):	7.3	7.7	duration:	10	min
total slurry in:	1600.6			initial HCl (M):	0.20	0.21	agitation rate:	800	rpm
				MgCl <sub>2</sub> (g/l):	0	0	impeller:	pitched blade, 5cmφ, Ti	
				total Cl <sup>-</sup> (g/l):	7	8.17	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
TT18a-0	0				1.0015		-	
TT18a-10	10	22.51					-	
TT18a-10bulk	10bulk	1552.7		0.77	1.0026	595	794	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
TT18a-10	22.1	22.04					0.0			-	25.44	-
TT18a-10bulk	1525	1521.05	7.1	9.8	6.74	217.48	217.9	205.36	0.9985	205.7	25.44	0.43

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
TT18a-10bulk	1.46	0.82	0.34	0.05	0.56	8.49	16.6	0.18	0.94	17.7	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
TT18a-head liquor	2	2	8.17	2	1	2	7.69	2	2	2	2	2
TT18a-10	6.41	3.52	8.3	2	1	62.3	7.44	97.8	2	34.3	27.1	2
TT18a-10bulk	8.08	5.25	7.55	2	1	87.3	7.39	154	2.82	42.3	36.9	2
TT18a-comp. wash	2	2	0.5	2	1	6.92	1.32	21.8	2	3.56	3.89	2

**CALCULATIONS AND MASS BALANCE**

H <sup>+</sup>	assay H+ mol/l	residual HCl g	Δ acid %
TT18a-0	0.21		3.9
TT18a-10	0.20	11.32	
TT18a-10bulk	0.20	11.24	
average	0.21		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
feed solids	8.00	0.12	0.06	0.01	0.00	0.04	0.74	1.50	0.02	0.13	1.50	0.00
<b>solution IN</b>	<b>total g</b>	<b>total ml</b>	<b>Al</b>	<b>Ca</b>	<b>Cl</b>	<b>Co</b>	<b>Cr</b>	<b>Fe</b>	<b>Mg</b>	<b>Mn</b>	<b>Ni</b>	<b>Zn</b>
head liquor	1592.60	1590.21	0.0	0.0	12.99	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	217.48	217.92	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1818.08</b>	<b>0.13</b>	<b>0.07</b>	<b>13.00</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.51</b>	<b>0.02</b>	<b>0.14</b>	<b>1.50</b>	<b>0.01</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT18a-10	0.00	-	-	-	-	-	-	-	-	-	-	-
TT18a-10bulk	6.74	0.10	0.06	0.02	0.00	0.04	0.57	1.12	0.01	0.06	1.19	0.00
<b>solution OUT</b>	<b>total g</b>	<b>total ml</b>	<b>Al</b>	<b>Ca</b>	<b>Cl</b>	<b>Co</b>	<b>Cr</b>	<b>Fe</b>	<b>Mg</b>	<b>Mn</b>	<b>Ni</b>	<b>Zn</b>
TT18a-10	22.10	22.04	0.000	0.000	0.183	0.000	0.000	0.001	0.002	0.000	0.001	0.001
TT18a-10bulk	1525.00	1521.05	0.012	0.008	11.484	0.003	0.002	0.133	0.234	0.004	0.064	0.056
wash water	205.36	205.67	0.000	0.000	0.103	0.000	0.000	0.001	0.004	0.000	0.001	0.001
cake moisture	3.06	3.06	0.000	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000
evaporation	25.39	25.44	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1787.65</b>	<b>0.11</b>	<b>0.06</b>	<b>11.79</b>	<b>0.01</b>	<b>0.04</b>	<b>0.71</b>	<b>1.36</b>	<b>0.02</b>	<b>0.13</b>	<b>1.25</b>	<b>0.01</b>

balance (out/in)	98%	89%	96%	91%	96%	98%	95%	90%	81%	94%	83%	96%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT18a-10	1542.7	8%	9%	77%	4%	13%	10%	18%	39%	3%	77%
TT18a-10bulk	1542.7	10%	13%	77%	4%	18%	16%	25%	49%	4%	77%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT18a-10bulk	6.8	18%	11%	15%	1%	22%	25%	30%	52%	19%	15%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT18a-10	1542.7	15%	8%	15%	1%	16%	16%	21%	42%	14%	15%
TT18a-10bulk	1542.7	18%	11%	15%	1%	22%	25%	30%	52%	19%	15%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
TT18a-10	0.91	114					
TT18a-10bulk	0.99	124					
acid equivalent (g)			0.10	0.34	1.16	0.09	1.68
acid equivalent (%)			5.8	20.1	68.9	5.2	100.0

Test name: TT18b  
 Comment: 60°C baseline, 0.5% solids

Date: 5-Apr-05

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	46	micron
stock solution added:	8.04	2.8	2.832	0.5	0.5	T:	95	°C
total slurry in:	1592	1589.6	1.0015	7.3	7.7	duration:	20	min
	1600.04			0.20	0.21	agitation rate:	800	rpm
				MgCl2 (g/l):	0	impeller:	pitched blade, 5cmφ, Ti	
				total Cl- (g/l):	7	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed (g)	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
TT18b-0	0				1.0015		-	
TT18b-20	20	24.22					-	
TT18b-20bulk	20bulk	1550.7		0.80	1.0027	591	790	

Sample	filtrate mass (g)	filtrate vol (ml)	wet residue mass before wash (g)	wet residue mass after wash (g)	dry residue mass (g)	wash mass in (g)	wash vol in (ml)	wash mass out (g)	wash density @20°C (kg/l)	wash vol out (ml)	calc. evaporation (cum. ml)	calc. sample pulp density (% solids)
TT18b-20	23.65	23.59					0.0				25.17	-
TT18b-20bulk	1519.4	1515.31	7.2	8.9	6.21	222.23	222.7	213.6	0.9984	213.9	25.17	0.40

ANALYSES

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
TT18b-20bulk	1.46	0.87	0.41	0.05	0.58	8.22	14.8	0.15	0.76	19.8	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
TT18b-head liquor	2	2	8.17	2	1	2	7.69	2	2	2	2	2
TT18b-20	9.62	3.71	7.89	2	1	104	6.99	215	3.47	49.8	49.3	2
TT18b-20bulk	10	5.23	7.57	2	1.09	120	6.43	248	4.29	52.5	54.9	2
TT18b-comp. wash	2	2	0.5	2	1	7.19	1.31	27.6	2	3.91	4.81	2

CALCULATIONS AND MASS BALANCE

H+	assay H+	residual HCl	Δ acid %
TT18b-0	0.21		16.4
TT18b-20	0.19	10.59	
TT18b-20bulk	0.18	9.74	
average	0.19		

Solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.04	0.12	0.06	0.01	0.00	0.04	0.75	1.51	0.02	0.13	1.51	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
head liquor	1592.00	1589.62	0.0	0.0	12.99	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	222.23	222.68											
<b>total IN (g)</b>	<b>1822.27</b>	<b>0.13</b>	<b>0.07</b>	<b>13.00</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.51</b>	<b>0.02</b>	<b>0.14</b>	<b>1.51</b>	<b>0.01</b>	

Solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
TT18b-20	0.00	-	-	-	-	-	-	-	-	-	-	-	
TT18b-20bulk	6.21	0.09	0.05	0.03	0.00	0.04	0.51	0.92	0.01	0.05	1.23	0.00	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT18b-20	23.65	23.59	0.000	0.000	0.186	0.000	0.000	0.002	0.005	0.000	0.001	0.001	0.000
TT18b-20bulk	1519.40	1515.31	0.015	0.008	11.471	0.003	0.002	0.182	0.376	0.007	0.080	0.083	0.003
wash water	213.60	213.94	0.000	0.000	0.107	0.000	0.000	0.002	0.006	0.000	0.001	0.001	0.000
cake moisture	2.69	2.69	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
evaporation	25.12	25.17	-	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1790.67</b>	<b>0.11</b>	<b>0.06</b>	<b>11.79</b>	<b>0.01</b>	<b>0.04</b>	<b>0.70</b>	<b>1.31</b>	<b>0.02</b>	<b>0.13</b>	<b>1.31</b>	<b>0.01</b>	
<b>balance (out/in)</b>	<b>98%</b>	<b>84%</b>	<b>94%</b>	<b>91%</b>	<b>92%</b>	<b>93%</b>	<b>93%</b>	<b>86%</b>	<b>78%</b>	<b>93%</b>	<b>87%</b>	<b>92%</b>	

extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT18b-20	1540.86	12%	9%	77%	4%	21%	22%	30%	57%	5%	77%
TT18b-20bulk	1540.86	13%	13%	77%	4%	25%	25%	37%	60%	6%	77%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT18b-20bulk	6.3	25%	14%	22%	6%	31%	38%	47%	64%	17%	22%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT18b-20	1540.9	24%	10%	22%	6%	27%	33%	38%	61%	15%	22%
TT18b-20bulk	1540.9	25%	14%	22%	6%	31%	38%	47%	64%	17%	22%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
TT18b-20	1.63	203					
TT18b-20bulk	2.48	309					
acid equivalent (g)			0.13	0.47	1.78	0.11	2.48
acid equivalent (%)			5.3	18.7	71.6	4.4	100.0

Test name: TT18c  
 Comment: 60°C baseline, 0.5% solids

Date: 5-Apr-05

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	initial pulp % solids:	nominal	effective	grind (D90)	46	micron
stock solution added:	8.02	2.8	2.832	initial HCl (g/l):	0.5	0.5	T:	95	°C
total slurry in:	1592.5	1590.1	1.0015	initial HCl (M):	7.3	7.7	duration:	30	min
	1600.52			MgCl2 (g/l):	0.20	0.21	agitation rate:	800	rpm
				total Cl- (g/l):	0	0	impeller:	pitched blade, 5cmφ, Ti	
					7	8.17	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed (g)	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
TT18c-0	0				1.0015		-	
TT18c-30	30	23.05					-	
TT18c-30bulk	30bulk	1536.9		0.81	1.0030	586	785	

Sample	filtrate mass (g)	filtrate vol (ml)	wet residue mass before wash (g)	wet residue mass after wash (g)	dry residue mass (g)	wash mass in (g)	wash vol in (ml)	wash mass out (g)	wash density @20°C (kg/l)	wash vol out (ml)	calc. evaporation (cum. ml)	calc. sample pulp density (% solids)
TT18c-30	22.31	22.24					0.0				40.65	-
TT18c-30bulk	1501.8	1497.31	12.9	4.8	5.73	214.71	215.1	200.86	0.9986	201.1	40.65	0.37

ANALYSES

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
TT18c-30bulk	1.35	0.79	0.34	0.05	0.55	7.58	12.9	0.11	0.62	18.7	0.06

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
TT18c-head liquor	2	2	8.17	2	1	2	7.69	2	2	2	2	2
TT18c-30	11	3.9	7.37	2	1.06	129	6.51	266	4.53	57.4	59.8	2
TT18c-30bulk	11.3	5.6	7.74	2	1.15	140	6.78	309	5.45	57.9	67.7	2
TT18c-comp. wash	2	2	0.5	2	1	12.1	1.93	37.1	2	5.02	7.54	2

CALCULATIONS AND MASS BALANCE

H+	assay H+	residual HCl	Δ acid %
TT18c-0	0.21		11.8
TT18c-30	0.18	9.75	
TT18c-30bulk	0.19	10.15	
average	0.19		

Solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.02	0.12	0.06	0.01	0.00	0.04	0.75	1.51	0.02	0.13	1.50	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
head liquor	1592.50	1590.11	0.0	0.0	12.99	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	214.71	215.14	-	-	-	-	-	-	-	-	-	-	-
total IN (g)	1815.23	0.13	0.07	13.00	0.01	0.04	0.75	1.51	0.02	0.14	1.51	0.01	

Solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
TT18c-30	0.00	-	-	-	-	-	-	-	-	-	-	-	
TT18c-30bulk	5.73	0.08	0.05	0.02	0.00	0.03	0.43	0.74	0.01	0.04	1.07	0.00	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT18c-30	22.31	22.24	0.000	0.000	0.164	0.000	0.000	0.003	0.006	0.000	0.001	0.001	0.000
TT18c-30bulk	1501.80	1497.31	0.017	0.008	11.589	0.003	0.002	0.210	0.463	0.008	0.087	0.101	0.003
wash water	200.86	201.14	0.000	0.000	0.101	0.000	0.000	0.002	0.007	0.000	0.001	0.002	0.000
cake moisture	-0.93	-0.93	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
evaporation	40.57	40.65	-	-	-	-	-	-	-	-	-	-	-
total OUT (g)	1770.34	0.09	0.05	11.87	0.01	0.03	0.65	1.22	0.01	0.12	1.18	0.01	
balance (out/in)	98%	75%	81%	91%	88%	83%	87%	80%	72%	91%	78%	96%	

extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT18c-30	1527.22	14%	9%	76%	4%	26%	27%	39%	65%	6%	76%
TT18c-30bulk	1527.22	14%	13%	76%	5%	29%	31%	47%	66%	7%	76%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT18c-30bulk	5.8	36%	27%	27%	18%	41%	50%	64%	73%	28%	13%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT18c-30	1527.2	35%	19%	27%	16%	37%	43%	53%	73%	24%	13%
TT18c-30bulk	1527.2	36%	27%	27%	18%	41%	50%	64%	73%	28%	13%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
TT18c-30	2.48	309					
TT18c-30bulk	2.08	259					
acid equivalent (g)			0.18	0.61	2.31	0.12	3.22
acid equivalent (%)			5.7	19.0	71.5	3.8	100.0

Test name: TT18d  
 Comment: 60°C baseline, 0.5% solids

Date: 4-Apr-05

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	initial pulp % solids:	nominal	effective	grind (D90)	46	micron
stock solution added:	8.08	2.9	2.832	initial HCl (g/l):	0.5	0.5	T:	95	°C
total slurry in:	1592.3	1589.9	1.0015	initial HCl (M):	7.3	7.7	duration:	60	min
	1600.38			MgCl2 (g/l):	0.20	0.21	agitation rate:	800	rpm
				MgCl2 (M):	0	0	impeller:	pitched blade, 5cmφ, Ti	
				total Cl- (g/l):	7	8.17	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed (g)	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
TT18d-0	0				1.0016		-	
TT18d-60	60	23.77					-	
TT18d-60bulk	60bulk	1548.3		0.88	1.0035	582	781	

Sample	filtrate mass (g)	filtrate vol (ml)	wet residue mass before wash (g)	wet residue mass after wash (g)	dry residue mass (g)	wash mass in (g)	wash vol in (ml)	wash mass out (g)	wash density @20°C (kg/l)	wash vol out (ml)	calc. evaporation (cum. ml)	calc. sample pulp density (% solids)
TT18d-60	23.26	23.18					0.0				28.37	-
TT18d-60bulk	1516.2	1510.91	10.1	11.2	4.51	227.85	228.3	219.61	0.9985	219.9	28.37	0.29

ANALYSES

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
TT18d-60bulk	1.72	1.09	0.34	0.05	0.74	8.18	8.88	0.05	0.39	23.9	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
TT18d-head liquor	2	2	8.17	2	1	2	7.69	2	2	2	2	2
TT18d-60	14.1	5.11	7.53	2	1.62	199	6.19	500	7.68	70.3	110	2
TT18d-60bulk	14.9	5.18	7.56	2	1.7	203	6.04	530	8.2	70.5	119	2
TT18d-comp. wash	2	2	0.5	2	1	12.5	0.5	43.2	2	4.54	7.66	2

CALCULATIONS AND MASS BALANCE

H+	assay H+	residual HCl	Δ acid %
TT18d-0	0.21		21.5
TT18d-60	0.17	9.35	
TT18d-60bulk	0.17	9.13	
average	0.18		

Solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.08	0.12	0.06	0.01	0.00	0.04	0.75	1.52	0.02	0.14	1.52	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
head liquor	1592.30	1589.92	0.0	0.0	12.99	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	227.85	228.31											
<b>total IN (g)</b>	<b>1828.23</b>	<b>0.13</b>	<b>0.07</b>	<b>13.00</b>	<b>0.01</b>	<b>0.04</b>	<b>0.76</b>	<b>1.52</b>	<b>0.02</b>	<b>0.14</b>	<b>1.52</b>	<b>0.01</b>	

Solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
TT18d-60	0.00	-	-	-	-	-	-	-	-	-	-	-	
TT18d-60bulk	4.51	0.08	0.05	0.02	0.00	0.03	0.37	0.40	0.00	0.02	1.08	0.00	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT18d-60	23.26	23.18	0.000	0.000	0.175	0.000	0.000	0.005	0.012	0.000	0.002	0.003	0.000
TT18d-60bulk	1516.20	1510.91	0.023	0.008	11.422	0.003	0.003	0.307	0.801	0.012	0.107	0.180	0.003
wash water	219.61	219.94	0.000	0.000	0.110	0.000	0.000	0.003	0.010	0.000	0.001	0.002	0.000
cake moisture	6.69	6.70	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
evaporation	28.31	28.37	-	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1798.58</b>	<b>0.10</b>	<b>0.06</b>	<b>11.73</b>	<b>0.01</b>	<b>0.04</b>	<b>0.68</b>	<b>1.22</b>	<b>0.02</b>	<b>0.13</b>	<b>1.26</b>	<b>0.01</b>	
<b>balance (out/in)</b>	<b>98%</b>	<b>80%</b>	<b>86%</b>	<b>90%</b>	<b>80%</b>	<b>89%</b>	<b>90%</b>	<b>80%</b>	<b>73%</b>	<b>92%</b>	<b>83%</b>	<b>80%</b>	

extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT18d-60	1538.37	18%	12%	76%	6%	41%	50%	66%	80%	11%	76%
TT18d-60bulk	1538.37	19%	12%	76%	7%	42%	53%	71%	80%	12%	76%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT18d-60bulk	4.6	36%	22%	43%	14%	50%	73%	87%	87%	28%	43%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT18d-60	1538.4	34%	22%	43%	13%	49%	69%	82%	87%	26%	43%
TT18d-60bulk	1538.4	36%	22%	43%	14%	50%	73%	87%	87%	28%	43%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
TT18d-60	2.87	356					
TT18d-60bulk	3.10	384					
acid equivalent (g)			0.19	0.75	3.36	0.15	4.44
acid equivalent (%)			4.2	16.9	75.6	3.3	100.0

Test name: TT18e  
 Comment: 60°C baseline, 0.5% solids

Date: 6-Apr-05

	mass (g)	volume (ml)	density @20°C (kg/l)		nominal	effective	grind (D90)	46	micron
dry ore added:	8.02	2.8	2.832	initial pulp % solids:	0.5	0.5	T:	95	°C
stock solution added:	1592.3	1589.9	1.0015	initial HCl (g/l):	7.3	7.7	duration:	120	min
total slurry in:	1600.32			initial HCl (M):	0.20	0.21	agitation rate:	800	rpm
				MgCl2 (g/l):	0	0	impeller:	pitched blade, 5cmφ, T1	
				total Cl- (g/l):	7	8.17	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed (g)	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
TT18e-0	0				1.0016		-	
TT18e-120	120	21.77					-	
TT18e-120bulk	120bulk	1524.3		0.86	1.0034	580	779	

Sample	filtrate mass (g)	filtrate vol (ml)	wet residue mass before wash (g)	wet residue mass after wash (g)	dry residue mass (g)	wash mass in (g)	wash vol in (ml)	wash mass out (g)	wash density @20°C (kg/l)	wash vol out (ml)	calc. evaporation (cum. ml)	calc. sample pulp density (% solids)
TT18e-120	21.34	21.27					0.0				54.36	-
TT18e-120bulk	1490.1	1485.05	7.2	7.6	4.66	206.19	206.6	196.95	0.9984	197.3	54.36	0.31

ANALYSES

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
TT18e-120bulk	1.68	1.06	0.3	0.05	0.72	8.43	11.3	0.07	0.61	23.1	0.06

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
TT18e-head liquor	2	2	8.17	2	1	2	7.69	2	2	2	2	2
TT18e-120	13.7	5.27	7.52	2	1.67	187	6.06	464	7.44	67	119	2
TT18e-120bulk	13.2	5.16	8.1	2	1.66	184	6.12	464	7.53	63.3	118	2
TT18e-comp. wash	2	2	0.5	2	1	10.7	3.43	37	2	4.49	7.03	2

CALCULATIONS AND MASS BALANCE

H+	assay H+ (mol/l)	residual HCl (g)	Δ acid %
TT18e-0	0.21		20.4
TT18e-120	0.17	9.00	
TT18e-120bulk	0.17	9.09	
average	0.18		

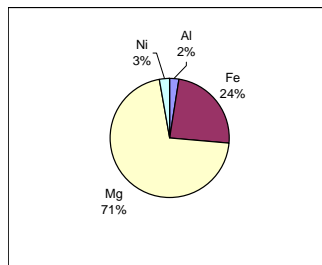
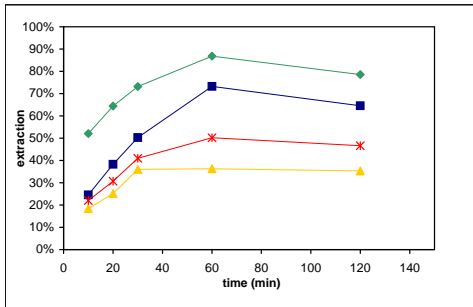
solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.02	0.12	0.06	0.01	0.00	0.04	0.75	1.51	0.02	0.13	1.50	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
head liquor	1592.30	1589.92	0.0	0.0	12.99	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	206.19	206.60											
<b>total IN (g)</b>	<b>1806.51</b>	<b>0.13</b>	<b>0.07</b>	<b>0.07</b>	<b>13.00</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.51</b>	<b>0.02</b>	<b>0.14</b>	<b>1.51</b>	<b>0.01</b>
solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
TT18e-120	0.00	-	-	-	-	-	-	-	-	-	-	-	
TT18e-120bulk	4.66	0.08	0.05	0.01	0.00	0.03	0.39	0.53	0.00	0.03	1.08	0.00	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT18e-120	21.34	21.27	0.000	0.000	0.160	0.000	0.000	0.004	0.010	0.000	0.001	0.003	0.000
TT18e-120bulk	1490.10	1485.05	0.020	0.008	12.029	0.003	0.002	0.273	0.689	0.011	0.094	0.175	0.003
wash water	196.95	197.27	0.000	0.000	0.099	0.000	0.000	0.002	0.007	0.000	0.001	0.001	0.000
cake moisture	2.94	2.94	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
evaporation	54.25	54.36	-	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1770.24</b>	<b>0.10</b>	<b>0.06</b>	<b>12.30</b>	<b>0.01</b>	<b>0.04</b>	<b>0.67</b>	<b>1.23</b>	<b>0.02</b>	<b>0.12</b>	<b>1.26</b>	<b>0.01</b>	
<b>balance (out/in)</b>	<b>98%</b>	<b>78%</b>	<b>87%</b>	<b>95%</b>	<b>80%</b>	<b>90%</b>	<b>90%</b>	<b>82%</b>	<b>72%</b>	<b>91%</b>	<b>83%</b>	<b>86%</b>	

extraction (solution)	calc. total soln volume (ml)	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT18a-10		8%	9%	77%	4%	13%	10%	18%	39%	3%	77%
TT18b-20		12%	9%	77%	4%	21%	22%	30%	57%	5%	77%
TT18c-30		14%	9%	76%	4%	26%	27%	39%	65%	6%	76%
TT18d-60		18%	12%	76%	6%	41%	50%	66%	80%	11%	76%
TT18e-120	1514.29	17%	13%	76%	7%	38%	46%	64%	76%	12%	76%
TT18e-120bulk	1514.29	16%	12%	76%	6%	37%	46%	65%	71%	12%	76%

extraction (solids)	calc. total solid mass (g)	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
TT18a-10bulk		18%	11%	15%	1%	22%	25%	30%	52%	19%	15%
TT18b-20bulk		25%	14%	22%	6%	31%	38%	47%	64%	17%	22%
TT18c-30bulk		36%	27%	27%	18%	41%	50%	64%	73%	28%	13%
TT18d-60bulk		36%	22%	43%	14%	50%	73%	87%	87%	28%	43%
TT18e-120bulk	4.7	35%	21%	41%	13%	47%	65%	81%	79%	27%	29%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
TT18e-120	3.23	402					
TT18e-120bulk	3.14	391					
acid equivalent (g)			0.18	0.69	2.94	0.13	3.95
acid equivalent (%)			4.6	17.5	74.6	3.3	100.0



Test name: PST19a  
 Comment: 106µm, 0.5% solids

Date: 14-Apr-05

	mass (g)	volume (ml)	density @20°C (kg/l)		nominal	effective	grind (D90)	106	micron
dry ore added:	8.03	2.8	2.832	initial pulp % solids:	0.5	0.5	T:	80	°C
stock solution added:	1592.1	1588.9	1.002	initial HCl (g/l):	7.3	6.7	duration:	10	min
total slurry in:	1600.13			initial HCl (M):	0.20	0.18	agitation rate:	800	rpm
				MgCl2 (g/l):	0	0	impeller:	pitched blade, 5cmφ, Ti	
				total Cl- (g/l):	7	7.4	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed g	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
PST19a-0	0				1.002		-	
PST19a-10	10	21.06					-	
PST19a-10bulk	10bulk	1561.3		0.77	1.0018	616	815	

Sample	filtrate mass g	filtrate vol ml	wet residue mass before wash g	wet residue mass after wash g	dry residue mass g	wash mass in g	wash vol in ml	wash mass out g	wash density @20°C kg/l	wash vol out ml	calc. evaporation cum. ml	calc. sample pulp density % solids
PST19a-10	19.96	19.92					0.0			-	17.81	-
PST19a-10bulk	1521.4	1518.67	17.23	17.8	6.8	202.55	203.0	196.77	0.9983	197.1	17.81	0.44

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
PST19a-10bulk	1.69	0.59	0.11	0.05	0.66	9.7	15.3	0.15	1.16	19.3	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
PST19a-head liquor	2	2.59	7.4	2	1	2	6.73	2	2	2	2	2
PST19a-10	6.22	2	7.44	2	1	50.1	6.32	73.4	2	28.9	26.8	2
PST19a-10bulk	8.14	2	7.56	2	1	76.7	6.43	124	2	40.5	40.2	2
PST19a-comp. wash	2	2	0.5	2	1	9.39	0.5	22.4	2	3.27	8.83	2

**CALCULATIONS AND MASS BALANCE**

H <sup>+</sup>	assay H+ mol/l	residual HCl g	Δ acid %
PST19a-0	0.18		4.5
PST19a-10	0.17	9.60	
PST19a-10bulk	0.18	9.77	
average	0.18		

solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
feed solids	8.03	0.12	0.06	0.01	0.00	0.04	0.75	1.51	0.02	0.13	1.51	0.00
<b>solution IN</b>	<b>total g</b>	<b>total ml</b>	<b>Al</b>	<b>Ca</b>	<b>Cl</b>	<b>Co</b>	<b>Cr</b>	<b>Fe</b>	<b>Mg</b>	<b>Mn</b>	<b>Ni</b>	<b>Zn</b>
head liquor	1592.10	1588.92	0.0	0.0	11.76	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	202.55	202.96	-	-	-	-	-	-	-	-	-	-
<b>total IN (g)</b>	<b>1802.68</b>	<b>0.13</b>	<b>0.07</b>	<b>11.77</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.51</b>	<b>0.02</b>	<b>0.14</b>	<b>1.51</b>	<b>0.01</b>

solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
PST19a-10	0.00	-	-	-	-	-	-	-	-	-	-	-
PST19a-10bulk	6.80	0.11	0.04	0.01	0.00	0.04	0.66	1.04	0.01	0.08	1.31	0.00
<b>solution OUT</b>	<b>total g</b>	<b>total ml</b>	<b>Al</b>	<b>Ca</b>	<b>Cl</b>	<b>Co</b>	<b>Cr</b>	<b>Fe</b>	<b>Mg</b>	<b>Mn</b>	<b>Ni</b>	<b>Zn</b>
PST19a-10	19.96	19.92	0.000	0.000	0.148	0.000	0.000	0.001	0.001	0.000	0.001	0.000
PST19a-10bulk	1521.40	1518.67	0.012	0.004	11.481	0.003	0.002	0.116	0.188	0.003	0.062	0.061
wash water	196.77	197.11	0.000	0.000	0.099	0.000	0.000	0.002	0.004	0.000	0.001	0.002
cake moisture	11.00	11.02	0.000	0.000	0.006	0.000	0.000	0.000	0.000	0.000	0.000	0.000
evaporation	17.77	17.81	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1773.70</b>	<b>0.13</b>	<b>0.04</b>	<b>11.74</b>	<b>0.01</b>	<b>0.05</b>	<b>0.78</b>	<b>1.23</b>	<b>0.01</b>	<b>0.14</b>	<b>1.38</b>	<b>0.01</b>

balance (out/in)	98%	101%	66%	100%	96%	115%	104%	82%	66%	103%	91%	96%
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extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
PST19a-10	1551.2	8%	5%	77%	4%	10%	7%	18%	33%	3%	77%
PST19a-10bulk	1551.2	10%	6%	77%	4%	16%	13%	18%	47%	4%	77%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
PST19a-10bulk	6.9	5%	36%	14%	-17%	11%	30%	41%	41%	12%	14%

extraction (ratio)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
PST19a-10	1551.2	4%	28%	14%	-17%	7%	18%	41%	29%	8%	14%
PST19a-10bulk	1551.2	5%	36%	14%	-17%	11%	30%	41%	41%	12%	14%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
PST19a-10	1.10	136					
PST19a-10bulk	0.93	116					
acid equivalent (g)			0.03	0.17	1.41	0.07	1.68
acid equivalent (%)			1.9	10.2	83.8	4.1	100.0

Test name: **PST19b**  
 Comment: 106mm, 0.5% solids

Date: **14-Apr-05**

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	initial pulp % solids:	nominal	effective	grind (D90)	106	micron
stock solution added:	8	2.8	2.832	initial HCl (g/l):	0.5	0.5	T:	80	°C
total slurry in:	1592	1588.8	1.002	initial HCl (M):	7.3	6.7	duration:	20	min
	1600			MgCl2 (g/l):	0.20	0.18	agitation rate:	800	rpm
				total Cl <sup>-</sup> (g/l):	0	0	impeller:	pitched blade, 5cmφ, Ti	
					7	7.4	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed (g)	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
PST19b-0	0				1.002		-	
PST19b-20	20	23.48					-	
PST19b-20bulk	20bulk	1559.1		0.77	1.0021	593	792	

Sample	filtrate mass (g)	filtrate vol (ml)	wet residue mass before wash (g)	wet residue mass after wash (g)	dry residue mass (g)	wash mass in (g)	wash vol in (ml)	wash mass out (g)	wash density @20°C (kg/l)	wash vol out (ml)	calc. evaporation (cum. ml)	calc. sample pulp density (% solids)
PST19b-20	22.7	22.65					0.0				17.45	-
PST19b-20bulk	1522.5	1519.31	16.7	16.8	6.6	211.06	211.5	207.37	0.9984	207.7	17.45	0.42

**ANALYSES**

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
PST19b-20bulk	1.74	0.61	0.11	0.05	0.69	9.61	15.3	0.14	1.07	19.9	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
PST19b-head liquor	2	2.59	7.4	2	1	2	6.73	2	2	2	2	2
PST19b-20	7.68	2	8.07	2	1	69.1	6.39	113	2	37.6	37.1	2
PST19b-20bulk	9.46	2	7.47	2	1	94	6.42	162	2.44	48.5	48.9	2
PST19b-comp. wash	2	2	0.5	2	1	10.4	0.5	28.3	2	3.82	8.33	2

**CALCULATIONS AND MASS BALANCE**

H <sup>+</sup>	assay H+ (mol/l)	residual HCl (g)	Δ acid (%)
PST19b-0	0.18		4.6
PST19b-20	0.18	9.71	
PST19b-20bulk	0.18	9.75	
average	0.18		

Solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.00	0.12	0.06	0.01	0.00	0.04	0.74	1.50	0.02	0.13	1.50	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
head liquor	1592.00	1588.82	0.0	0.0	11.76	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	211.06	211.48											
<b>total IN (g)</b>	<b>1811.06</b>	<b>0.13</b>	<b>0.07</b>	<b>0.01</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.51</b>	<b>0.02</b>	<b>0.14</b>	<b>1.50</b>	<b>0.01</b>	

Solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
PST19b-20	0.00	-	-	-	-	-	-	-	-	-	-	-	
PST19b-20bulk	6.60	0.11	0.04	0.01	0.00	0.05	0.63	1.01	0.01	0.07	1.31	0.00	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
PST19b-20	22.70	22.65	0.000	0.000	0.183	0.000	0.000	0.002	0.003	0.000	0.001	0.001	0.000
PST19b-20bulk	1522.50	1519.31	0.014	0.003	11.349	0.003	0.002	0.143	0.246	0.004	0.074	0.074	0.003
wash water	207.37	207.70	0.000	0.000	0.104	0.000	0.000	0.002	0.006	0.000	0.001	0.002	0.000
cake moisture	10.20	10.22	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
evaporation	17.42	17.45	-	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1786.79</b>	<b>0.13</b>	<b>0.04</b>	<b>11.65</b>	<b>0.01</b>	<b>0.05</b>	<b>0.78</b>	<b>1.26</b>	<b>0.01</b>	<b>0.15</b>	<b>1.39</b>	<b>0.01</b>	

<b>balance (out/in)</b>	99%	103%	65%	99%	95%	117%	104%	84%	65%	106%	92%	95%
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extraction (solution)	calc. total soln volume (ml)	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
PST19b-20	1548.72	10%	5%	77%	4%	14%	11%	18%	43%	4%	77%
PST19b-20bulk	1548.72	12%	5%	77%	4%	20%	16%	21%	56%	5%	77%

extraction (solids)	calc. total solid mass (g)	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
PST19b-20bulk	6.7	5%	35%	16%	-19%	14%	32%	47%	47%	11%	16%

extraction (ratio)	calc. total soln volume (ml)	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
PST19b-20	1548.7	4%	35%	16%	-19%	10%	22%	38%	36%	8%	16%
PST19b-20bulk	1548.7	5%	35%	16%	-19%	14%	32%	47%	47%	11%	16%

**based on solids assay**

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
PST19b-20	0.98	123					
PST19b-20bulk	0.94	117					
acid equivalent (g)			0.03	0.22	1.48	0.08	1.81
acid equivalent (%)			1.7	11.9	82.0	4.4	100.0

Test name: PST19c  
 Comment: 106mm, 0.5% solids

Date: 14-Apr-05

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	nominal	effective	grind (D90)	106	micron
stock solution added:	8.03	2.8	2.832	0.5	0.5	T:	80	°C
total slurry in:	1592.3	1589.1	1.002	initial pulp % solids:	7.3	duration:	30	min
	1600.33			initial HCl (g/l):	0.20	agitation rate:	800	rpm
				MgCl2 (g/l):	0	impeller:	pitched blade, 5cmφ, Ti	
				total Cl- (g/l):	7	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed (g)	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
PST19c-0	0				1.002			
PST19c-30	30	23.53						
PST19c-30bulk	30bulk	1558.1		0.80	1.0021	611	810	

Sample	filtrate mass (g)	filtrate vol (ml)	wet residue mass before wash (g)	wet residue mass after wash (g)	dry residue mass (g)	wash mass in (g)	wash vol in (ml)	wash mass out (g)	wash density @20°C (kg/l)	wash vol out (ml)	calc. evaporation (cum. ml)	calc. sample pulp density (% solids)
PST19c-30	22.8	22.75					0.0				18.74	-
PST19c-30bulk	1518.9	1515.72	17.53	16.3	6.18	202.15	202.6	195.96	0.9982	196.3	18.74	0.40

ANALYSES

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
PST19c-30bulk	1.68	0.63	0.11	0.05	0.67	9.74	14	0.13	0.9	20.8	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
PST19c-head liquor	2	2.59	7.4	2	1	2	6.73	2	2	2	2	2
PST19c-30	9.99	2	7.29	2	1	104	6.11	194	2.66	51.4	56.9	2
PST19c-30bulk	11.7	2	7.48	2	1	129	6.11	248	3.3	60.3	68.3	2
PST19c-comp. wash	2	2	0.5	2	1	14.1	0.5	38.6	2	4.57	10.7	2

CALCULATIONS AND MASS BALANCE

H+	assay H+ (mol/l)	residual HCl (g)	Δ acid (%)
PST19c-0	0.18		9.2
PST19c-30	0.17	9.26	
PST19c-30bulk	0.17	9.26	
average	0.17		

Solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.03	0.12	0.06	0.01	0.00	0.04	0.75	1.51	0.02	0.13	1.51	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
head liquor	1592.30	1589.12	0.0	0.0	11.76	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	202.15	202.56											
<b>total IN (g)</b>	<b>1802.48</b>	<b>0.13</b>	<b>0.07</b>	<b>0.01</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.51</b>	<b>0.02</b>	<b>0.14</b>	<b>1.51</b>	<b>0.01</b>	

Solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
PST19c-30	0.00	-	-	-	-	-	-	-	-	-	-	-	
PST19c-30bulk	6.18	0.10	0.04	0.01	0.00	0.04	0.60	0.87	0.01	0.06	1.29	0.00	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
PST19c-30	22.80	22.75	0.000	0.000	0.166	0.000	0.000	0.002	0.004	0.000	0.001	0.001	0.000
PST19c-30bulk	1518.90	1515.72	0.018	0.003	11.338	0.003	0.002	0.196	0.376	0.005	0.091	0.104	0.003
wash water	195.96	196.31	0.000	0.000	0.098	0.000	0.000	0.003	0.008	0.000	0.001	0.002	0.000
cake moisture	10.12	10.14	0.000	0.000	0.005	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
evaporation	18.70	18.74	-	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1772.66</b>	<b>0.12</b>	<b>0.04</b>	<b>11.61</b>	<b>0.01</b>	<b>0.04</b>	<b>0.80</b>	<b>1.25</b>	<b>0.01</b>	<b>0.15</b>	<b>1.39</b>	<b>0.01</b>	

<b>balance (out/in)</b>	98%	97%	63%	99%	91%	106%	107%	83%	65%	108%	92%	91%
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extraction (solution)	calc. total soln volume (ml)	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
PST19c-30	1547.63	13%	5%	77%	4%	22%	20%	23%	59%	6%	77%
PST19c-30bulk	1547.63	15%	5%	77%	4%	27%	25%	29%	69%	7%	77%

extraction (solids)	calc. total solid mass (g)	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
PST19c-30bulk	6.3	14%	38%	22%	-8%	18%	42%	54%	58%	13%	22%

extraction (ratio)	calc. total soln volume (ml)	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
PST19c-30	1547.6	12%	38%	22%	-8%	15%	33%	43%	49%	11%	22%
PST19c-30bulk	1547.6	14%	38%	22%	-8%	18%	42%	54%	58%	13%	22%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
PST19c-30	1.43	179					
PST19c-30bulk	1.43	179					
acid equivalent (g)			0.08	0.28	1.93	0.10	2.39
acid equivalent (%)			3.2	11.9	80.8	4.1	100.0

Test name: PST19d  
 Comment: 106mm, 0.5% solids

Date: 13-Apr-05

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	initial pulp % solids:	nominal	effective	grind (D90)	106	micron
stock solution added:	8.05	2.8	2.832	initial HCl (g/l):	0.5	0.5	T:	80	°C
total slurry in:	1592.8	1589.6	1.002	initial HCl (M):	7.3	6.7	duration:	60	min
	1600.85			MgCl2 (g/l):	0.20	0.18	agitation rate:	800	rpm
				total Cl- (g/l):	0	0	impeller:	pitched blade, 5cmφ, Ti	
					7	7.4	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed (g)	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
PST19d-0	0				1.0016		-	
PST19d-60	60	22.71					-	
PST19d-60bulk	60bulk	1545.3		0.83	1.0026	588	787	

Sample	filtrate mass (g)	filtrate vol (ml)	wet residue mass before wash (g)	wet residue mass after wash (g)	dry residue mass (g)	wash mass in (g)	wash vol in (ml)	wash mass out (g)	wash density @20°C (kg/l)	wash vol out (ml)	calc. evaporation (cum. ml)	calc. sample pulp density (% solids)
PST19d-60	22.17	22.11					0.0				32.91	-
PST19d-60bulk	1510.5	1506.58	16.6	15.3	5.5	203.77	204.2	191.73	0.9985	192.0	32.91	0.36

ANALYSES

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
PST19d-60bulk	1.85	0.75	0.15	0.05	0.77	9.38	11.6	0.1	0.66	22.5	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
PST19d-head liquor	2	2.59	7.4	2	1	2	6.73	2	2	2	2	2
PST19d-60	13.7	2	7.24	2	1.27	164	5.7	370	4.47	69.4	96.4	2
PST19d-60bulk	14.6	2	7.35	2	1.38	182	6.79	414	4.87	77.4	106	2
PST19d-comp. wash	2	2	0.5	2	1	16.6	0.5	53.1	2	5.65	11.5	2

CALCULATIONS AND MASS BALANCE

H+	assay H+ (mol/l)	residual HCl (g)	Δ acid (%)
PST19d-0	0.18		15.3
PST19d-60	0.16	8.59	
PST19d-60bulk	0.19	10.23	
average	0.18		

Solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.05	0.12	0.06	0.01	0.00	0.04	0.75	1.51	0.02	0.13	1.51	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
head liquor	1592.80	1589.62	0.0	0.0	11.76	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
wash water	203.77	204.18											
<b>total IN (g)</b>	<b>1804.62</b>	<b>0.13</b>	<b>0.07</b>	<b>0.01</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.52</b>	<b>0.02</b>	<b>0.14</b>	<b>1.51</b>	<b>0.01</b>	

Solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
PST19d-60	0.00	-	-	-	-	-	-	-	-	-	-	-	
PST19d-60bulk	5.50	0.10	0.04	0.01	0.00	0.04	0.52	0.64	0.01	0.04	1.24	0.00	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
PST19d-60	22.17	22.11	0.000	0.000	0.160	0.000	0.000	0.004	0.008	0.000	0.002	0.002	0.000
PST19d-60bulk	1510.50	1506.58	0.022	0.003	11.073	0.003	0.002	0.274	0.624	0.007	0.117	0.160	0.003
wash water	191.73	192.02	0.000	0.000	0.096	0.000	0.000	0.003	0.010	0.000	0.001	0.002	0.000
cake moisture	9.78	9.79	0.000	0.000	0.005	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
evaporation	32.84	32.91	-	-	-	-	-	-	-	-	-	-	-
<b>total OUT (g)</b>	<b>1772.52</b>	<b>0.12</b>	<b>0.04</b>	<b>11.34</b>	<b>0.01</b>	<b>0.04</b>	<b>0.80</b>	<b>1.28</b>	<b>0.01</b>	<b>0.16</b>	<b>1.40</b>	<b>0.01</b>	

balance (out/in)	98%	99%	66%	96%	86%	110%	106%	84%	64%	113%	93%	86%
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extraction (solution)	calc. total soln volume (ml)	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
PST19d-60	1534.60	17%	5%	76%	5%	34%	37%	39%	79%	10%	76%
PST19d-60bulk	1534.60	18%	5%	76%	5%	37%	42%	42%	88%	11%	76%

extraction (solids)	calc. total solid mass (g)	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
PST19d-60bulk	5.6	16%	34%	31%	-10%	30%	57%	68%	73%	17%	31%

extraction (ratio)	calc. total soln volume (ml)	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
PST19d-60	1534.6	15%	34%	31%	-9%	27%	51%	63%	65%	15%	31%
PST19d-60bulk	1534.6	16%	34%	31%	-10%	30%	57%	68%	73%	17%	31%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
PST19d-60	2.11	262					
PST19d-60bulk	0.47	58					
acid equivalent (g)			0.09	0.46	2.63	0.12	3.29
acid equivalent (%)			2.6	13.9	79.8	3.7	100.0

Test name: PST19e  
 Comment: 106mm, 0.5% solids

Date: 13-Apr-05

dry ore added:	mass (g)	volume (ml)	density @20°C (kg/l)	initial pulp % solids:	nominal	effective	grind (D90)	106	micron
stock solution added:	8.06	2.8	2.832	initial HCl (g/l):	0.5	0.5	T:	80	°C
total slurry in:	1592.7	1589.5	1.002	initial Cl <sub>2</sub> (M):	7.3	6.7	duration:	120	min
	1600.76			MgCl <sub>2</sub> (g/l):	0.20	0.18	agitation rate:	800	rpm
				total Cl <sub>2</sub> (g/l):	0	0	impeller:	pitched blade, 5cmφ, T1	
					7	7.4	vessel:	2litre, baffled, with reflux condenser	

Sample	minute	slurry removed (g)	sample T (°C)	pH	Density @20°C (kg/l)	ORP vs. Ag/AgCl (mV)	Eh (mV)	Notes
PST19e-0	0				1.0016		-	
PST19e-120	120	23.13						
PST19e-120bulk	120bulk	1547.4		0.85	1.0028	582	781	

Sample	filtrate mass (g)	filtrate vol (ml)	wet residue mass before wash (g)	wet residue mass after wash (g)	dry residue mass (g)	wash mass in (g)	wash vol in (ml)	wash mass out (g)	wash density @20°C (kg/l)	wash vol out (ml)	calc. evaporation cum. ml	calc. sample pulp density % solids
PST19e-120	22.64	22.58					0.0				30.29	-
PST19e-120bulk	1516.1	1511.87	18.6	17.2	5.12	208.62	209.0	192.06	0.9983	192.4	30.29	0.33

ANALYSES

Residue (%)	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
Head	1.53	0.79	0.13	0.05	0.49	9.3	18.8	0.22	1.68	18.8	0.05
PST19e-120bulk	1.88	0.74	0.15	0.05	0.77	9.82	10.4	0.08	0.69	23.3	0.05

Solution (mg/l)	Al	Ca	Cl (g/l)	Co	Cr	Fe	HCl (g/l)	Mg	Mn	Ni	Si	Zn
PST19e-head liquor	2	2.59	7.4	2	1	2	6.73	2	2	2	2	2
PST19e-120	14.6	2	7.26	2	1.46	183	5.43	450	5.19	72.2	122	2
PST19e-120bulk	15.9	2	7.55	2	1.6	203	5.4	494	5.68	78.2	132	2
PST19e-comp. wash	2	2	0.5	2	1	14.4	0.5	49.6	2	5.36	11.7	2

CALCULATIONS AND MASS BALANCE

H <sup>+</sup>	assay H+ mol/l	residual HCl g	Δ acid %
PST19e-0	0.18		19.8
PST19e-120	0.15	8.21	
PST19e-120bulk	0.15	8.16	
average	0.16		

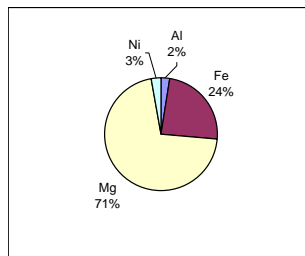
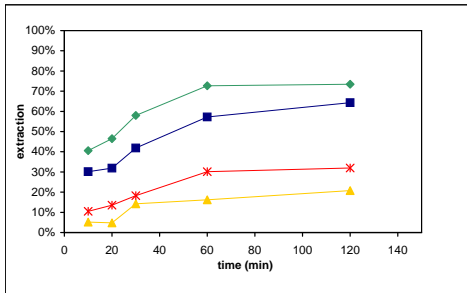
solids IN	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
feed solids	8.06	0.12	0.06	0.01	0.00	0.04	0.75	1.52	0.02	0.14	1.51	0.00	
solution IN	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
head liquor	1592.70	1589.52	0.0	0.0	11.76	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
wash water	208.62	209.04											
<b>total IN (g)</b>	<b>1809.38</b>	<b>0.13</b>	<b>0.07</b>	<b>0.01</b>	<b>0.01</b>	<b>0.04</b>	<b>0.75</b>	<b>1.52</b>	<b>0.02</b>	<b>0.14</b>	<b>1.51</b>	<b>0.01</b>	
solids OUT	total g	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn	
PST19e-120	0.00	-	-	-	-	-	-	-	-	-	-	-	
PST19e-120bulk	5.12	0.10	0.04	0.01	0.00	0.04	0.50	0.53	0.00	0.04	1.19	0.00	
solution OUT	total g	total ml	Al	Ca	Cl	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
PST19e-120	22.64	22.58	0.000	0.000	0.164	0.000	0.000	0.004	0.010	0.000	0.002	0.003	
PST19e-120bulk	1516.10	1511.87	0.024	0.003	11.415	0.003	0.002	0.307	0.747	0.009	0.118	0.200	
wash water	192.06	192.39	0.000	0.000	0.096	0.000	0.000	0.003	0.010	0.000	0.001	0.002	
cake moisture	12.10	12.12	0.000	0.000	0.006	0.000	0.000	0.000	0.001	0.000	0.000	0.000	
evaporation	30.23	30.29	-	-	-	-	-	-	-	-	-	-	
<b>total OUT (g)</b>	<b>1778.25</b>	<b>0.12</b>	<b>0.04</b>	<b>0.01</b>	<b>11.69</b>	<b>0.01</b>	<b>0.04</b>	<b>0.82</b>	<b>1.30</b>	<b>0.01</b>	<b>0.16</b>	<b>1.40</b>	
<b>balance (out/in)</b>	<b>98%</b>	<b>96%</b>	<b>61%</b>	<b>99%</b>	<b>84%</b>	<b>103%</b>	<b>108%</b>	<b>86%</b>	<b>63%</b>	<b>113%</b>	<b>92%</b>	<b>84%</b>	

extraction (solution)	calc. total soln volume ml	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
PST19a-10		8%	5%	77%	4%	10%	7%	18%	33%	3%	77%
PST19b-20		10%	5%	77%	4%	14%	11%	18%	43%	4%	77%
PST19c-30		13%	5%	77%	4%	22%	23%	23%	59%	6%	77%
PST19d-60		17%	5%	76%	5%	34%	37%	39%	79%	10%	76%
PST19e-120	1536.65	18%	5%	76%	6%	37%	45%	45%	82%	12%	76%
PST19e-120bulk	1536.65	20%	5%	76%	6%	42%	50%	49%	89%	13%	76%

extraction (solids)	calc. total solid mass g	Al	Ca	Co	Cr	Fe	Mg	Mn	Ni	Si	Zn
PST19a-10bulk		5%	36%	14%	-17%	11%	30%	41%	41%	12%	14%
PST19b-20bulk		5%	35%	16%	-19%	14%	32%	47%	47%	11%	16%
PST19c-30bulk		14%	38%	22%	-8%	18%	42%	54%	58%	13%	22%
PST19d-60bulk		16%	34%	31%	-10%	30%	57%	68%	73%	17%	31%
PST19e-120bulk	5.2	21%	40%	36%	-2%	32%	64%	77%	73%	20%	36%

based on solids assay

acid consumption	g consumed	kg/t ore	Al	Fe	Mg	Ni	total
PST19e-120	2.49	309					
PST19e-120bulk	2.53	314					
acid equivalent (g)			0.11	0.48	2.95	0.12	3.67
acid equivalent (%)			3.0	13.2	80.4	3.4	100.0



## **APPENDIX B**

pH Calibration and Pitzer-Hydration Model Outputs

University of Cape Town

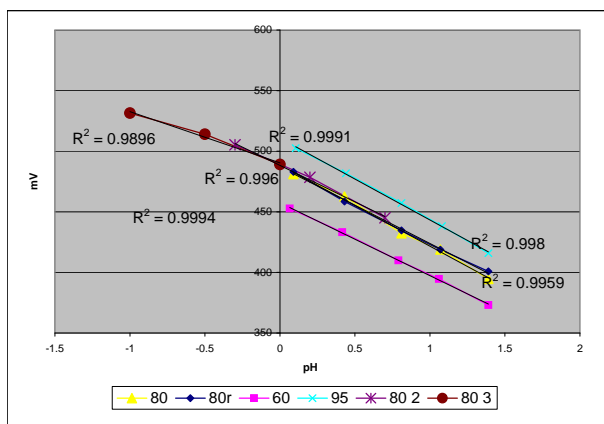
		Calculated pH according to the combined Pitzer-Hydration theory (Steyl 2004)										
M_HCl <sub>120C</sub>	m_HCl	20 C	25 C	40 C	50 C	60 C	65 C	70C	80 C	90 C	95 C	100 C
0.05	0.05	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.39
0.07	0.07	1.24	1.24	1.24	1.24	1.24	1.24	1.24	1.25	1.25	1.25	1.25
0.09	0.09	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.15	1.15
0.11	0.11	1.05	1.05	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
0.13	0.13	0.98	0.98	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	1.00
0.15	0.15	0.92	0.92	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.94	0.94
0.17	0.17	0.87	0.87	0.87	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
0.19	0.19	0.82	0.82	0.83	0.83	0.83	0.83	0.83	0.83	0.84	0.84	0.84
0.21	0.21	0.78	0.78	0.78	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.80
0.23	0.23	0.74	0.74	0.75	0.75	0.75	0.75	0.75	0.75	0.76	0.76	0.76
0.25	0.25	0.70	0.71	0.71	0.71	0.71	0.71	0.72	0.72	0.72	0.72	0.72
0.27	0.27	0.67	0.67	0.68	0.68	0.68	0.68	0.68	0.68	0.69	0.69	0.69
0.29	0.29	0.64	0.64	0.64	0.65	0.65	0.65	0.65	0.65	0.66	0.66	0.66
0.31	0.31	0.61	0.61	0.61	0.62	0.62	0.62	0.62	0.62	0.63	0.63	0.63
0.33	0.33	0.58	0.58	0.59	0.59	0.59	0.59	0.59	0.60	0.60	0.60	0.60
0.35	0.35	0.56	0.56	0.56	0.56	0.57	0.57	0.57	0.57	0.57	0.58	0.58
0.37	0.37	0.53	0.53	0.54	0.54	0.54	0.54	0.54	0.55	0.55	0.55	0.55
0.39	0.39	0.51	0.51	0.51	0.51	0.52	0.52	0.52	0.52	0.53	0.53	0.53
0.41	0.41	0.48	0.48	0.49	0.49	0.49	0.50	0.50	0.50	0.50	0.50	0.51
0.43	0.43	0.46	0.46	0.47	0.47	0.47	0.47	0.47	0.48	0.48	0.48	0.48
0.45	0.46	0.44	0.44	0.44	0.45	0.45	0.45	0.45	0.46	0.46	0.46	0.46
0.47	0.48	0.42	0.42	0.42	0.43	0.43	0.43	0.43	0.44	0.44	0.44	0.44
0.49	0.50	0.40	0.40	0.40	0.41	0.41	0.41	0.41	0.42	0.42	0.42	0.42
0.51	0.52	0.38	0.38	0.39	0.39	0.39	0.39	0.40	0.40	0.40	0.40	0.41
0.53	0.54	0.36	0.36	0.37	0.37	0.37	0.38	0.38	0.38	0.38	0.39	0.39
0.55	0.56	0.34	0.34	0.35	0.35	0.36	0.36	0.36	0.36	0.37	0.37	0.37
0.57	0.58	0.32	0.33	0.33	0.34	0.34	0.34	0.34	0.35	0.35	0.35	0.35
0.59	0.60	0.31	0.31	0.32	0.32	0.32	0.32	0.33	0.33	0.33	0.33	0.34
0.61	0.62	0.29	0.29	0.30	0.30	0.31	0.31	0.31	0.31	0.32	0.32	0.32
0.63	0.64	0.27	0.28	0.28	0.29	0.29	0.29	0.29	0.30	0.30	0.30	0.31
0.65	0.66	0.26	0.26	0.27	0.27	0.27	0.28	0.28	0.28	0.29	0.29	0.29
0.67	0.68	0.24	0.25	0.25	0.25	0.26	0.26	0.26	0.27	0.27	0.27	0.28
0.69	0.70	0.23	0.23	0.24	0.24	0.24	0.25	0.25	0.25	0.26	0.26	0.26
0.71	0.72	0.21	0.22	0.22	0.23	0.23	0.23	0.23	0.24	0.24	0.24	0.25
0.73	0.74	0.20	0.20	0.21	0.21	0.21	0.22	0.22	0.22	0.23	0.23	0.23
0.75	0.76	0.18	0.19	0.19	0.20	0.20	0.20	0.21	0.21	0.21	0.22	0.22
0.77	0.78	0.17	0.18	0.18	0.18	0.19	0.19	0.19	0.20	0.20	0.20	0.21
0.79	0.80	0.16	0.16	0.17	0.17	0.17	0.18	0.18	0.18	0.19	0.19	0.19
0.81	0.83	0.14	0.15	0.15	0.16	0.16	0.16	0.16	0.17	0.17	0.18	0.18
0.83	0.85	0.13	0.13	0.14	0.14	0.15	0.15	0.15	0.16	0.16	0.16	0.17
0.85	0.87	0.12	0.12	0.13	0.13	0.13	0.14	0.14	0.14	0.15	0.15	0.15
0.87	0.89	0.10	0.11	0.11	0.12	0.12	0.12	0.13	0.13	0.14	0.14	0.14
0.89	0.91	0.09	0.09	0.10	0.11	0.11	0.11	0.11	0.12	0.12	0.13	0.13
0.91	0.93	0.08	0.08	0.09	0.09	0.10	0.10	0.10	0.11	0.11	0.11	0.12
0.93	0.95	0.07	0.07	0.08	0.08	0.09	0.09	0.09	0.10	0.10	0.10	0.11
0.95	0.97	0.05	0.06	0.06	0.07	0.07	0.08	0.08	0.08	0.09	0.09	0.09
0.97	0.99	0.04	0.04	0.05	0.06	0.06	0.06	0.07	0.07	0.08	0.08	0.08
0.99	1.01	0.03	0.03	0.04	0.05	0.05	0.05	0.06	0.06	0.07	0.07	0.07
1.01	1.03	0.02	0.02	0.03	0.03	0.04	0.04	0.04	0.05	0.06	0.06	0.06
1.03	1.05	0.01	0.01	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.05	0.05
1.05	1.08	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.04	0.04
1.07	1.10	-0.02	-0.01	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.03	0.03
1.09	1.12	-0.03	-0.02	-0.02	-0.01	-0.01	0.00	0.00	0.01	0.01	0.01	0.02
1.11	1.14	-0.04	-0.04	-0.03	-0.02	-0.02	-0.01	-0.01	0.00	0.00	0.00	0.01
1.13	1.16	-0.05	-0.05	-0.04	-0.03	-0.03	-0.02	-0.02	-0.01	-0.01	-0.01	0.00
1.15	1.18	-0.06	-0.06	-0.05	-0.04	-0.04	-0.03	-0.03	-0.03	-0.02	-0.02	-0.01
1.17	1.20	-0.07	-0.07	-0.06	-0.05	-0.05	-0.04	-0.04	-0.04	-0.03	-0.03	-0.02
1.19	1.22	-0.08	-0.08	-0.07	-0.06	-0.06	-0.05	-0.05	-0.05	-0.04	-0.04	-0.03
1.21	1.24	-0.09	-0.09	-0.08	-0.07	-0.07	-0.07	-0.06	-0.06	-0.05	-0.05	-0.04
1.23	1.26	-0.10	-0.10	-0.09	-0.08	-0.08	-0.08	-0.07	-0.07	-0.06	-0.06	-0.05
1.25	1.28	-0.11	-0.11	-0.10	-0.09	-0.09	-0.09	-0.08	-0.08	-0.07	-0.07	-0.06
1.27	1.31	-0.12	-0.12	-0.11	-0.10	-0.10	-0.10	-0.09	-0.09	-0.08	-0.08	-0.07
1.29	1.33	-0.13	-0.13	-0.12	-0.11	-0.11	-0.11	-0.10	-0.10	-0.09	-0.09	-0.08
1.31	1.35	-0.14	-0.14	-0.13	-0.12	-0.12	-0.11	-0.11	-0.10	-0.10	-0.09	-0.09
1.33	1.37	-0.15	-0.15	-0.14	-0.13	-0.13	-0.12	-0.12	-0.11	-0.11	-0.10	-0.10
1.35	1.39	-0.16	-0.16	-0.15	-0.14	-0.14	-0.13	-0.13	-0.12	-0.12	-0.11	-0.11
1.37	1.41	-0.17	-0.17	-0.16	-0.15	-0.15	-0.14	-0.14	-0.13	-0.13	-0.12	-0.12
1.39	1.43	-0.18	-0.18	-0.17	-0.16	-0.16	-0.15	-0.15	-0.14	-0.13	-0.13	-0.13
1.41	1.45	-0.19	-0.19	-0.18	-0.17	-0.17	-0.16	-0.16	-0.15	-0.14	-0.14	-0.14
1.43	1.47	-0.20	-0.20	-0.19	-0.18	-0.18	-0.17	-0.17	-0.16	-0.15	-0.15	-0.15
1.45	1.50	-0.21	-0.21	-0.20	-0.19	-0.18	-0.18	-0.18	-0.17	-0.16	-0.16	-0.16
1.47	1.52	-0.22	-0.22	-0.21	-0.20	-0.19	-0.19	-0.19	-0.18	-0.17	-0.17	-0.16
1.49	1.54	-0.23	-0.23	-0.22	-0.21	-0.20	-0.20	-0.20	-0.19	-0.18	-0.18	-0.17
1.51	1.56	-0.24	-0.24	-0.23	-0.22	-0.22	-0.21	-0.21	-0.20	-0.19	-0.19	-0.18
1.53	1.58	-0.25	-0.25	-0.23	-0.23	-0.22	-0.22	-0.22	-0.21	-0.20	-0.19	-0.19
1.55	1.60	-0.26	-0.25	-0.24	-0.24	-0.23	-0.23	-0.22	-0.21	-0.21	-0.20	-0.20
1.57	1.62	-0.27	-0.26	-0.25	-0.25	-0.24	-0.23	-0.23	-0.22	-0.21	-0.21	-0.21

M_HCl <sub>20C</sub>	m_HCl	Calculated pH according to the combined Pitzer-Hydration theory (Steyl 2004)										
		20 C	25 C	40 C	50 C	60 C	65 C	70C	80 C	90 C	95 C	100 C
1.59	1.64	-0.28	-0.27	-0.26	-0.25	-0.25	-0.24	-0.24	-0.23	-0.22	-0.22	-0.22
1.61	1.67	-0.29	-0.28	-0.27	-0.26	-0.26	-0.25	-0.25	-0.24	-0.23	-0.23	-0.22
1.63	1.69	-0.30	-0.29	-0.28	-0.27	-0.27	-0.26	-0.26	-0.25	-0.24	-0.24	-0.23
1.65	1.71	-0.30	-0.30	-0.29	-0.28	-0.27	-0.27	-0.27	-0.26	-0.25	-0.24	-0.24
1.67	1.73	-0.31	-0.31	-0.30	-0.29	-0.28	-0.28	-0.28	-0.27	-0.26	-0.25	-0.25
1.69	1.75	-0.32	-0.32	-0.31	-0.30	-0.29	-0.29	-0.28	-0.27	-0.27	-0.26	-0.26
1.71	1.77	-0.33	-0.33	-0.32	-0.31	-0.30	-0.30	-0.29	-0.28	-0.27	-0.27	-0.27
1.73	1.79	-0.34	-0.34	-0.32	-0.32	-0.31	-0.30	-0.30	-0.29	-0.28	-0.28	-0.27
1.75	1.82	-0.35	-0.35	-0.33	-0.32	-0.32	-0.31	-0.31	-0.30	-0.29	-0.29	-0.28
1.77	1.84	-0.36	-0.35	-0.34	-0.33	-0.33	-0.32	-0.32	-0.31	-0.30	-0.30	-0.29
1.79	1.86	-0.37	-0.36	-0.35	-0.34	-0.33	-0.33	-0.32	-0.32	-0.31	-0.30	-0.30
1.81	1.88	-0.38	-0.37	-0.36	-0.35	-0.34	-0.34	-0.33	-0.32	-0.32	-0.31	-0.31
1.83	1.90	-0.39	-0.38	-0.37	-0.36	-0.35	-0.35	-0.34	-0.33	-0.32	-0.32	-0.31
1.85	1.92	-0.39	-0.39	-0.38	-0.37	-0.36	-0.35	-0.35	-0.34	-0.33	-0.33	-0.32
1.87	1.95	-0.40	-0.40	-0.38	-0.38	-0.37	-0.36	-0.36	-0.35	-0.34	-0.33	-0.33
1.89	1.97	-0.41	-0.41	-0.39	-0.38	-0.38	-0.37	-0.37	-0.36	-0.35	-0.34	-0.34
1.91	1.99	-0.42	-0.41	-0.40	-0.39	-0.38	-0.38	-0.37	-0.36	-0.35	-0.35	-0.35
1.93	2.01	-0.43	-0.42	-0.41	-0.40	-0.39	-0.39	-0.38	-0.37	-0.36	-0.36	-0.35
1.95	2.03	-0.44	-0.43	-0.42	-0.41	-0.40	-0.40	-0.39	-0.38	-0.37	-0.37	-0.36
1.97	2.05	-0.44	-0.44	-0.43	-0.42	-0.41	-0.40	-0.40	-0.39	-0.38	-0.37	-0.37
1.99	2.08	-0.45	-0.45	-0.43	-0.43	-0.42	-0.41	-0.41	-0.40	-0.39	-0.38	-0.38
2.01	2.10	-0.46	-0.46	-0.44	-0.43	-0.42	-0.42	-0.41	-0.40	-0.39	-0.39	-0.38
2.03	2.12	-0.47	-0.46	-0.45	-0.44	-0.43	-0.43	-0.42	-0.41	-0.40	-0.40	-0.39
2.05	2.14	-0.48	-0.47	-0.46	-0.45	-0.44	-0.44	-0.43	-0.42	-0.41	-0.41	-0.40
2.07	2.16	-0.49	-0.48	-0.47	-0.46	-0.45	-0.44	-0.44	-0.43	-0.42	-0.41	-0.41
2.09	2.18	-0.50	-0.49	-0.48	-0.47	-0.46	-0.45	-0.45	-0.44	-0.42	-0.42	-0.41
2.11	2.21	-0.50	-0.50	-0.48	-0.47	-0.46	-0.46	-0.45	-0.44	-0.43	-0.43	-0.42
2.13	2.23	-0.51	-0.51	-0.49	-0.48	-0.47	-0.47	-0.46	-0.45	-0.44	-0.44	-0.43
2.15	2.25	-0.52	-0.51	-0.50	-0.49	-0.48	-0.47	-0.47	-0.46	-0.45	-0.44	-0.44
2.17	2.27	-0.53	-0.52	-0.51	-0.50	-0.49	-0.48	-0.48	-0.47	-0.46	-0.45	-0.44
2.19	2.30	-0.54	-0.53	-0.52	-0.51	-0.50	-0.49	-0.49	-0.47	-0.46	-0.46	-0.45
2.21	2.32	-0.54	-0.54	-0.52	-0.51	-0.50	-0.50	-0.49	-0.48	-0.47	-0.47	-0.46
2.23	2.34	-0.55	-0.55	-0.53	-0.52	-0.51	-0.51	-0.50	-0.49	-0.48	-0.47	-0.47
2.25	2.36	-0.56	-0.56	-0.54	-0.53	-0.52	-0.51	-0.51	-0.50	-0.49	-0.48	-0.47
2.27	2.38	-0.57	-0.56	-0.55	-0.54	-0.53	-0.52	-0.52	-0.50	-0.49	-0.49	-0.48
2.29	2.40	-0.58	-0.57	-0.56	-0.55	-0.53	-0.53	-0.52	-0.51	-0.50	-0.50	-0.49
2.31	2.43	-0.59	-0.58	-0.56	-0.55	-0.54	-0.54	-0.53	-0.52	-0.51	-0.50	-0.50
2.33	2.45	-0.59	-0.59	-0.57	-0.56	-0.55	-0.54	-0.54	-0.53	-0.51	-0.51	-0.50
2.35	2.47	-0.60	-0.60	-0.58	-0.57	-0.56	-0.55	-0.55	-0.53	-0.52	-0.52	-0.51
2.37	2.49	-0.61	-0.60	-0.59	-0.58	-0.57	-0.56	-0.55	-0.54	-0.53	-0.52	-0.52
2.39	2.51	-0.62	-0.61	-0.59	-0.58	-0.57	-0.56	-0.55	-0.54	-0.53	-0.53	-0.53
2.41	2.54	-0.63	-0.62	-0.60	-0.59	-0.58	-0.57	-0.57	-0.56	-0.54	-0.54	-0.53
2.43	2.56	-0.63	-0.63	-0.61	-0.60	-0.59	-0.58	-0.58	-0.56	-0.55	-0.55	-0.54
2.45	2.58	-0.64	-0.64	-0.62	-0.61	-0.60	-0.59	-0.58	-0.57	-0.56	-0.55	-0.55
2.47	2.60	-0.65	-0.64	-0.63	-0.61	-0.60	-0.60	-0.59	-0.58	-0.57	-0.56	-0.55
2.49	2.63	-0.66	-0.65	-0.63	-0.62	-0.61	-0.60	-0.60	-0.59	-0.57	-0.57	-0.56
2.51	2.65	-0.67	-0.66	-0.64	-0.63	-0.62	-0.61	-0.61	-0.59	-0.58	-0.57	-0.57
2.53	2.67	-0.67	-0.67	-0.65	-0.64	-0.63	-0.62	-0.61	-0.60	-0.59	-0.58	-0.58
2.55	2.69	-0.68	-0.68	-0.66	-0.65	-0.63	-0.63	-0.62	-0.61	-0.60	-0.59	-0.58
2.57	2.71	-0.69	-0.68	-0.66	-0.65	-0.64	-0.63	-0.63	-0.62	-0.60	-0.60	-0.59
2.59	2.74	-0.70	-0.69	-0.67	-0.66	-0.65	-0.64	-0.64	-0.62	-0.61	-0.60	-0.60
2.61	2.76	-0.71	-0.70	-0.68	-0.67	-0.66	-0.65	-0.64	-0.63	-0.62	-0.61	-0.60
2.63	2.78	-0.71	-0.71	-0.69	-0.68	-0.66	-0.66	-0.65	-0.64	-0.62	-0.62	-0.61
2.65	2.80	-0.72	-0.72	-0.70	-0.68	-0.67	-0.66	-0.66	-0.64	-0.63	-0.62	-0.62
2.67	2.83	-0.73	-0.72	-0.70	-0.69	-0.68	-0.67	-0.67	-0.65	-0.64	-0.63	-0.63
2.69	2.85	-0.74	-0.73	-0.71	-0.70	-0.69	-0.68	-0.67	-0.66	-0.64	-0.64	-0.63
2.71	2.87	-0.75	-0.74	-0.72	-0.71	-0.69	-0.69	-0.68	-0.67	-0.65	-0.65	-0.64
2.73	2.89	-0.75	-0.75	-0.73	-0.71	-0.70	-0.69	-0.69	-0.67	-0.66	-0.65	-0.65
2.75	2.91	-0.76	-0.75	-0.73	-0.72	-0.71	-0.70	-0.69	-0.68	-0.67	-0.66	-0.65
2.77	2.94	-0.77	-0.76	-0.74	-0.73	-0.72	-0.71	-0.70	-0.69	-0.67	-0.67	-0.66
2.79	2.96	-0.78	-0.77	-0.75	-0.74	-0.72	-0.72	-0.71	-0.70	-0.68	-0.67	-0.67
2.81	2.98	-0.78	-0.78	-0.76	-0.74	-0.73	-0.72	-0.72	-0.70	-0.69	-0.68	-0.67
2.83	3.00	-0.79	-0.79	-0.76	-0.75	-0.74	-0.73	-0.72	-0.71	-0.69	-0.69	-0.68
2.85	3.03	-0.80	-0.79	-0.77	-0.76	-0.75	-0.74	-0.73	-0.72	-0.70	-0.70	-0.69
2.87	3.05	-0.81	-0.80	-0.78	-0.77	-0.75	-0.74	-0.74	-0.72	-0.71	-0.70	-0.69
2.89	3.07	-0.82	-0.81	-0.79	-0.77	-0.76	-0.75	-0.75	-0.73	-0.72	-0.71	-0.70
2.91	3.10	-0.82	-0.82	-0.80	-0.78	-0.77	-0.76	-0.75	-0.74	-0.72	-0.72	-0.71
2.93	3.12	-0.83	-0.82	-0.80	-0.79	-0.77	-0.77	-0.76	-0.74	-0.73	-0.72	-0.71
2.95	3.14	-0.84	-0.83	-0.81	-0.80	-0.78	-0.77	-0.77	-0.75	-0.74	-0.73	-0.72
2.97	3.16	-0.85	-0.84	-0.82	-0.80	-0.79	-0.78	-0.77	-0.76	-0.74	-0.74	-0.73
2.99	3.18	-0.85	-0.85	-0.83	-0.81	-0.80	-0.79	-0.78	-0.77	-0.75	-0.74	-0.74
3.01	3.21	-0.86	-0.86	-0.83	-0.82	-0.80	-0.80	-0.79	-0.77	-0.76	-0.75	-0.74
3.03	3.23	-0.87	-0.86	-0.84	-0.83	-0.81	-0.80	-0.80	-0.78	-0.76	-0.76	-0.75
3.05	3.25	-0.88	-0.87	-0.85	-0.83	-0.82	-0.81	-0.80	-0.79	-0.77	-0.76	-0.76
3.07	3.28	-0.89	-0.88	-0.86	-0.84	-0.83	-0.82	-0.81	-0.79	-0.78	-0.77	-0.76
3.09	3.30	-0.89	-0.89	-0.86	-0.85	-0.83	-0.83	-0.82	-0.80	-0.79	-0.78	-0.77
3.11	3.32	-0.90	-0.89	-0.87	-0.85	-0.84	-0.83	-0.82	-0.81	-0.79	-0.78	-0.78
3.13	3.34	-0.91	-0.90	-0.88	-0.86	-0.85	-0.84	-0.83	-0.82	-0.80	-0.79	-0.78

M_HCl <sub>20C</sub>	m_HCl	Calculated pH according to the combined Pitzer-Hydration theory (Steyl 2004)										
		20 C	25 C	40 C	50 C	60 C	65 C	70C	80 C	90 C	95 C	100 C
3.15	3.37	-0.92	-0.91	-0.89	-0.87	-0.85	-0.85	-0.84	-0.82	-0.81	-0.80	-0.79
3.17	3.39	-0.93	-0.92	-0.89	-0.88	-0.86	-0.85	-0.85	-0.83	-0.81	-0.81	-0.80
3.19	3.41	-0.93	-0.92	-0.90	-0.88	-0.87	-0.86	-0.85	-0.84	-0.82	-0.81	-0.80
3.21	3.44	-0.94	-0.93	-0.91	-0.89	-0.88	-0.87	-0.86	-0.84	-0.83	-0.82	-0.81
3.23	3.46	-0.95	-0.94	-0.92	-0.90	-0.88	-0.88	-0.87	-0.85	-0.83	-0.83	-0.82
3.25	3.48	-0.96	-0.95	-0.92	-0.91	-0.89	-0.88	-0.87	-0.86	-0.84	-0.83	-0.82
3.27	3.51	-0.96	-0.96	-0.93	-0.91	-0.90	-0.89	-0.88	-0.86	-0.85	-0.84	-0.83
3.29	3.53	-0.97	-0.96	-0.94	-0.92	-0.91	-0.90	-0.89	-0.87	-0.85	-0.85	-0.84
3.31	3.55	-0.98	-0.97	-0.95	-0.93	-0.91	-0.90	-0.90	-0.88	-0.86	-0.85	-0.84
3.33	3.57	-0.99	-0.98	-0.95	-0.94	-0.92	-0.91	-0.90	-0.89	-0.87	-0.86	-0.85
3.35	3.60	-1.00	-0.99	-0.96	-0.94	-0.93	-0.92	-0.91	-0.89	-0.88	-0.87	-0.86
3.37	3.62	-1.00	-0.99	-0.97	-0.95	-0.93	-0.93	-0.92	-0.90	-0.88	-0.87	-0.86
3.39	3.64	-1.01	-1.00	-0.98	-0.96	-0.94	-0.93	-0.92	-0.91	-0.89	-0.88	-0.87
3.41	3.67	-1.02	-1.01	-0.98	-0.97	-0.95	-0.94	-0.93	-0.91	-0.90	-0.89	-0.88
3.43	3.69	-1.03	-1.02	-0.99	-0.97	-0.96	-0.95	-0.94	-0.92	-0.90	-0.89	-0.88
3.45	3.71	-1.03	-1.02	-1.00	-0.98	-0.96	-0.95	-0.95	-0.93	-0.91	-0.90	-0.89
3.47	3.74	-1.04	-1.03	-1.01	-0.99	-0.97	-0.96	-0.95	-0.93	-0.92	-0.91	-0.90
3.49	3.76	-1.05	-1.04	-1.01	-1.00	-0.98	-0.97	-0.96	-0.94	-0.92	-0.91	-0.90
3.51	3.78	-1.06	-1.05	-1.02	-1.00	-0.98	-0.98	-0.97	-0.95	-0.93	-0.92	-0.91
3.53	3.81	-1.07	-1.06	-1.03	-1.01	-0.99	-0.98	-0.97	-0.96	-0.94	-0.93	-0.92
3.55	3.83	-1.07	-1.06	-1.03	-1.02	-1.00	-0.99	-0.98	-0.96	-0.94	-0.93	-0.92
3.57	3.85	-1.08	-1.07	-1.04	-1.02	-1.01	-1.00	-0.99	-0.97	-0.95	-0.94	-0.93
3.59	3.88	-1.09	-1.08	-1.05	-1.03	-1.01	-1.00	-1.00	-0.98	-0.96	-0.95	-0.94
3.61	3.90	-1.10	-1.09	-1.06	-1.04	-1.02	-1.01	-1.00	-0.98	-0.96	-0.95	-0.94
3.63	3.92	-1.10	-1.09	-1.07	-1.05	-1.03	-1.02	-1.01	-0.99	-0.97	-0.96	-0.95
3.65	3.95	-1.11	-1.10	-1.07	-1.05	-1.04	-1.03	-1.02	-1.00	-0.98	-0.97	-0.96
3.67	3.97	-1.12	-1.11	-1.08	-1.06	-1.04	-1.03	-1.02	-1.00	-0.98	-0.97	-0.96
3.69	3.99	-1.13	-1.12	-1.09	-1.07	-1.05	-1.04	-1.03	-1.01	-0.99	-0.98	-0.97
3.71	4.02	-1.13	-1.12	-1.10	-1.08	-1.06	-1.05	-1.04	-1.02	-1.00	-0.99	-0.98
3.73	4.04	-1.14	-1.13	-1.10	-1.08	-1.06	-1.05	-1.04	-1.02	-1.00	-0.99	-0.98
3.75	4.06	-1.15	-1.14	-1.11	-1.09	-1.07	-1.06	-1.05	-1.03	-1.01	-1.00	-0.99
3.77	4.09	-1.16	-1.15	-1.12	-1.10	-1.08	-1.07	-1.06	-1.04	-1.02	-1.01	-1.00
3.79	4.11	-1.16	-1.15	-1.12	-1.10	-1.08	-1.07	-1.06	-1.04	-1.02	-1.01	-1.00
3.81	4.13	-1.17	-1.16	-1.13	-1.11	-1.09	-1.08	-1.07	-1.05	-1.03	-1.02	-1.01
3.83	4.16	-1.18	-1.17	-1.14	-1.12	-1.10	-1.09	-1.08	-1.06	-1.04	-1.03	-1.02
3.85	4.18	-1.19	-1.18	-1.15	-1.13	-1.11	-1.10	-1.09	-1.07	-1.05	-1.04	-1.02
3.87	4.20	-1.20	-1.19	-1.15	-1.13	-1.11	-1.10	-1.09	-1.07	-1.05	-1.04	-1.03
3.89	4.23	-1.20	-1.19	-1.16	-1.14	-1.12	-1.11	-1.10	-1.08	-1.06	-1.05	-1.04
3.91	4.25	-1.21	-1.20	-1.17	-1.15	-1.13	-1.12	-1.11	-1.09	-1.07	-1.06	-1.04
3.93	4.27	-1.22	-1.21	-1.18	-1.16	-1.14	-1.12	-1.11	-1.09	-1.07	-1.06	-1.05
3.95	4.30	-1.23	-1.22	-1.18	-1.16	-1.14	-1.13	-1.12	-1.10	-1.08	-1.07	-1.06
3.97	4.32	-1.24	-1.22	-1.19	-1.17	-1.15	-1.14	-1.13	-1.11	-1.09	-1.08	-1.06
3.99	4.34	-1.24	-1.23	-1.20	-1.18	-1.16	-1.15	-1.14	-1.11	-1.09	-1.08	-1.07
4.01	4.37	-1.25	-1.24	-1.21	-1.19	-1.16	-1.15	-1.14	-1.12	-1.10	-1.09	-1.08
4.03	4.39	-1.26	-1.25	-1.22	-1.19	-1.17	-1.16	-1.15	-1.13	-1.11	-1.10	-1.08

**pH Calibrations**

buffer type:		metrohm																			
		hamilton																			
		steyl:	0.05M HCl	0.11M HCl	0.21M HCl	0.50M HCl	1.00M HCl														
		#26	0.26M	0.77M	1.75M																
calibration probe	temp (°C)	buffer 1 pH	mV	buffer 2 pH	mV	buffer 3 pH	mV	buffer 4 pH	mV	buffer 5 pH	mV	slope (%)	pH(0)	[mV] σ <sup>2</sup>	[mV] σ	R <sup>2</sup>	linear fit	notes			
1	21.8	7.02	-3.4	3.99	191.9							99.27	6.954								
2	21.8	7.02	-3.4	3.99	172.4	1.09	342.7					99.57	6.956								
3	22.5	2.00	292.1	1.68	308.9	1.09	344.1					98	9.069								
5	22.8	7.02	-3.4	3.99	172.5	2.00	292.5	1.68	309.6	1.09	343.9	100	6.954								
6	23.3	1.05	346.8	0.39	381.2	0.025	403.3					93.2	7.365								
7	22	7.02	7.5	3.99	184.9							100.37	7.139								
8	22	7.02	7.8	3.99	184.4	1.09	351.8					99.05	7.160								
9	22	2.00	302.6	1.68	319.4	1.09	352.9					94.78	7.444								
10	22	7.02	7.1	3.99	184.3	2.00	302.4	1.68	319.7	1.09	353.9	100.02	7.142	0.625	0.791					slow downward drift with time when reading pH. manual temperature set as no PT1000 (left at 20deg for all futher calibrations) readings slow to stabilise (1-3 minutes)	
11	22	1.05	356	0.39	391.9	0.025	410.2					90.64	7.761	0.771	0.878						
12	22	2.00	302.9	1.68	319.6	1.09	353.3					94.86	7.445	0.648	0.805						
13	20	7.02	14.4	3.99	184.7	2.00	302.7	1.68	320.8	1.09	353.3	98.01	7.254	3.418	1.849						
14	20	1.05	355.9	0.39	390.6	0.025	408.5					87.8	7.976	0.407	0.638						
15	23	1.05	347.4	0.39	382.3	0.025	398.1					85.04	8.011	3.166	1.779						
16	22	1.05	347.3	0.39	381.9	0.025	397.4					84.3	8.095	3.611	1.900						
17	22	1.38	329.8	1.05	347.3	0.78	361.3	0.39	381	0.025	397.1	85.27	8.000	1.154	1.074						
18	60	1.39	373.1	1.06	394.6	0.79	410	0.415	433.2	0.065	452.8	103.33	7.611	0.81	0.900	0.9994				metrohm measuring electrode used from here onwards. Check: "0.78 pH" measured 0.741 and "1.38 pH" measured 1.403 check: "0.78 pH" measured 0.778 and "1.38 pH" measured 1.421	
19	80	1.39	394.6	1.07	419	0.81	432.3	0.43	462.6	0.09	481.1	115.55	7.273	6.619	2.573	0.9959					
20	80	1.39	400.8	1.07	418.8	0.81	434.7	0.43	458.6	0.09	483	108.76	7.700	2.798	1.673	0.998					
21	95	1.39	415.9	1.08	438.2	0.81	457.3	0.44	481.8	0.105	502.6	116.14	7.562	1.516	1.231	0.9991					
KN:																					
22	60	6.97	6.4	4.068	194.6							98.37	7.069								
23	60	6.97	4.8	4.068	194.6							99.21	7.044								
24	80	7	7.4	4.15	201.5							97.22	7.108								
25	95	7.018	8.2	4.223	206.2							97.34	7.133								
26	80	0.7	445.1	0.2	478.5	-0.3	505.3					103.92	8.079	7.349	2.711	0.996					
27	80	0	489.1	-0.5	514	-1	531.4					73.48	11.467	9.4	3.066	0.9896					

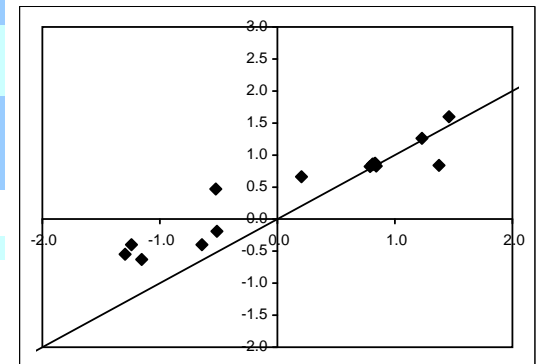


## Activity Measurement

- Measurements made in 1 litre glass vessel using 500ml of solution
- Hot plate linked to temperature probe and controller used to control temperature
- Magnetic stirrer used at low speed
- 5-point calibrations done at each temperature
- reference kept at 20°C and linked through 3 M KCl bridge
- Metrohm measuring electrode used
- Calibration #18: 60°C, Calibration #20: 80°C, Calibration #21: 95°C (see "Calibrations" sheet)

Test soln no.	Leach T [°C]	HCl [g/l]	[M]	Mg [mg/l]	[M]	Cl- [g/l]	Ni [mg/l]	Fe [mg/l]	Ni acc [%]	pH (20°C)	pH (T)	pH (T, steyl)	Calculated pH (Steyl)	Calc. - Measured
ST09-180	80	37.9	1.04	65896	2.71	262	365	1858	90	-1.06	-0.90	-1.15	-0.63	0.5
ST15e-120	80	31.4	0.86	71372	2.94	232	108.7	497	96	-1.37	-0.96	-1.30	-0.55	0.7
ST06-180	80	40.2	1.10	38069	1.57	153	425	2087	109	-0.71	-0.57	-0.64	-0.40	0.2
ST08-180	80	24.3	0.67	71459	2.94	237	391	1931	107	-1.02	-0.85	-1.24	-0.40	0.8
ST05-180	80	25.3	0.69	44802	1.84	150	377	1935	96	-0.53	-0.42	-0.52	-0.19	0.3
ST16e-120	80	3.98	0.11	75320	3.10	230	118.7	752	101	-0.66	-0.39	-0.53	0.47	1.0
ST14e-120	80	4.47	0.12	46093	1.90	138	98.6	392	96	-0.14	0.20	0.21	0.66	0.5
TT17a-10	60	7.17	0.20	17.5	0.00	7.5	7.94	16.6	86	0.69	0.76	0.79	0.82	0.0
TT17b-20	60	7.09	0.19	18.3	0.00	7.48	11	19	90	0.69	0.76	0.84	0.83	0.0
ST07-180	80	1.65	0.05	80973	3.33	232	320	829	93	1.09	1.29	1.38	0.84	0.5
TT17c-30	60	6.69	0.18	24.5	0.00	8.66	12.4	22.8	89	0.70	0.72	0.81	0.85	0.0
TT17d-60	60	6.51	0.18	79.6	0.00	7.36	30.7	54.3	96	0.71	0.78	0.81	0.86	0.0
BLT12e-120	60	6.42	0.18	168	0.01	6.94	47.5	93.3	94	0.76	0.77	0.83	0.87	0.0
TT17e-120	60	6.39	0.18	3.41	0.00	7.38	44.1	91.9	97	0.73	0.79	0.83	0.87	0.0
BLT02-180	80	2.76	0.08	1304	0.05	7.77	262	490	97	1.22	1.23	1.23	1.26	0.0
ST04-180	80	<0.5	0.01	49568	2.04	148	349	734	110	1.29	1.30	1.46	1.60	0.1
BLT01-180	95	2.44	0.07	1610	0.07	7.63	253	464	95	1.38	1.35	1.45		
BLT10a-10	80	34.5	0.95	292	0.01	37.1	61.8	186	93	0.00	-0.01	0.08		
BLT10e-120	80	33.2	0.91	771	0.03	36.9	90.7	417	102	0.02	0.02	0.06		
BLT11e-120	80	50.9	1.40	771	0.03	56.9	113	399	122	-0.21	-0.20	-0.07		
BLT13a-10	80	6.9	0.19	64.9	0.00	7.57	29	44.9	97	0.75	0.69	0.79		
BLT13e-120	80	5.43	0.15	673	0.03	7.46	79.6	211	99	0.88	0.81	0.90		
TT18a-10	95	7.39	0.20	154	0.01	7.55	42.3	87.3	94	0.77	0.77	0.86		
TT18e-120	95	6.12	0.17	464	0.02	8.1	63.3	184	91	0.86	0.85	0.94		

outside calibration range



**Steyl/Pitzer Model Output**

T (°C)	HCl (mol/kg)	MgCl <sub>2</sub> (mol/kg)	H <sup>+</sup> (mol/kg)	Mg <sup>2+</sup> (mol/kg)	Cl <sup>-</sup> (mol/kg)	Stoichiometric mean activity coefficient		Stoichiometric mean osmotic coefficient of Solution
						HCl	MgCl <sub>2</sub>	
60	0.2	0	0.200	0.000	0.200	0.7444	-	0.9366
80	0.2	0	0.200	0.000	0.200	0.7295	-	0.9304
80	0.2	2.015	0.200	2.015	4.230	3.4022	0.8002	1.4592
80	0.2	3.144	0.200	3.144	6.488	9.4881	1.6195	1.8974
80	1	0	1.000	0.000	1.000	0.7233	-	0.9994
80	1	1.615	1.000	1.615	4.230	2.8071	1.0733	1.6093
80	1	2.744	1.000	2.744	6.488	7.8272	2.0956	2.0211
80	1.5	0	1.500	0.000	1.500	0.7720	-	1.0546
80	1.5	1.365	1.500	1.365	4.230	2.4902	1.2893	1.6532
80	1.5	2.494	1.500	2.494	6.488	6.9412	2.4613	2.0697
95	0.2	0	0.200	0.000	0.200	0.7124	-	0.9254
100	1	2.744	1.000	2.744	6.488	5.2074	1.5572	1.8541
100	1.5	2.494	1.500	2.494	6.488	4.6958	1.7760	1.8806
100	2	2.244	2.000	2.244	6.488	4.2350	2.0251	1.8935
100	3	1.744	3.000	1.744	6.488	3.4459	2.6315	1.8825
100	5	0.744	5.000	0.744	6.488	2.2843	4.4280	1.7356

Comments

**HCl**

%Ion-specific binary (beta0, beta2) interaction parameters (kg/mol) and ternary (Cphi) interaction parameter (kg/mol)<sup>2</sup>  
%Holmes et al (1987), Temperature range: 0 - 250C, Molality range: 0 - 7 mol/kg.

**MgCl2**

%Ion-specific binary (beta0, beta2) interaction parameters (kg/mol) and ternary (Cphi) interaction parameter (kg/mol)<sup>2</sup>  
%Pabalan and Pitzer (1987), Temperature range: 25 - 200C, Molality range: 0 - 14 mol/kg

%PITZER MIXING TERMS

**%H(+) Mg(2+)**

Optimised by J Steyl From vapour pressure measurement - need to refit when latest vapour pressure data is available

**%H(+) Mg(2+) Cl(-)**

Optimised by J Steyl From vapour pressure measurement - need to refit when latest vapour pressure data is available

*The osmotic coefficient is directly related to the water activity (see Pitzer or other solution thermo handbook)*  
 $osmc = -m_{water}/\sum(mi)*\ln(a_{water})$

## **APPENDIX C**

Density Measurement

University of Cape Town

Density Worksheet

temperature °C	stock soln No.	A					B					Average kg/l	Std. dev
		pycnometer No.	volume ml	mass pycnometer g	mass with solution g	Solution Density kg/l	pycnometer No.	volume ml	mass pycnometer g	mass with solution g	Solution Density kg/l		
20	10	25	49.89	38.216	88.216	1.002	24	50.04	38.575	88.813	1.004	1.003	0.129%
20	11	27	50.15	37.007	88.391	1.025	7	49.98	41.182	92.554	1.028	1.026	0.227%
20	12	11	49.72	43.210	94.998	1.042	17	50.00	37.006	88.897	1.038	1.040	0.270%
20	13	21	50.02	40.400	92.260	1.037	25	49.89	38.216	89.981	1.038	1.037	0.058%
20	14	15	49.97	41.508	96.968	1.110	20	49.87	40.677	95.991	1.109	1.110	0.043%
20	15	29	49.85	41.528	100.175	1.177	14	49.84	40.094	98.809	1.178	1.177	0.110%
20	1	13	49.93	40.887	93.068	1.045	10	49.90	37.858	90.013	1.045	1.045	0.005%
20	2	12	49.90	37.628	93.359	1.117	23	50.10	38.241	94.206	1.117	1.117	0.010%
20	3	19	50.16	36.049	95.468	1.185	17	50.00	37.006	96.228	1.184	1.184	0.008%
20	4	17	50.00	37.006	90.063	1.061	15	49.97	41.508	94.543	1.061	1.061	0.012%
20	5	23	50.10	38.241	94.951	1.132	25	49.89	38.216	94.713	1.132	1.132	0.039%
20	6	29	49.85	41.528	101.275	1.199	7	49.98	41.182	101.106	1.199	1.199	0.024%
20	7	13	49.93	40.887	94.699	1.078	20	49.87	40.677	94.412	1.078	1.078	0.020%
20	8	14	49.84	40.094	97.267	1.147	27	50.15	37.007	94.519	1.147	1.147	0.023%
20	9	19	50.16	36.049	96.920	1.213	12	49.90	37.628	98.178	1.213	1.213	0.002%
60	1	27	50.15	37.007	88.661	1.030	15	49.82	41.508	92.998	1.034	1.032	0.251%
60	2	25	49.89	38.216	93.197	1.102	23	50.15	38.241	93.471	1.101	1.102	0.053%
60	3	24	50.04	38.575	97.085	1.169	21	50.05	40.400	98.903	1.169	1.169	0.026%
60	4	13	49.93	40.887	93.112	1.046	10	49.87	37.858	90.055	1.047	1.046	0.037%
60	5	11	49.72	43.210	98.760	1.117	12	49.85	37.628	93.351	1.118	1.118	0.044%
60	6	7	49.98	41.182	100.442	1.186	27	50.16	37.007	96.424	1.185	1.185	0.079%
60	7	29	49.85	41.528	94.530	1.063	17	50.01	37.006	90.165	1.063	1.063	0.016%
60	8	14	49.84	40.094	96.588	1.133	20	49.90	40.677	97.098	1.131	1.132	0.196%
60	9	19	50.16	36.049	96.164	1.198	25	49.87	38.216	98.037	1.200	1.199	0.080%
95	1	17	50.00	37.006	87.016	1.000	7	49.14	41.182	91.128	1.016	1.008	1.150%
95	2	11	49.72	43.210	96.703	1.076	10	49.57	37.858	91.453	1.081	1.079	0.382%
95	3	21	50.02	40.400	97.923	1.150	15	49.53	41.508	99.126	1.163	1.157	0.948%
95	4	20	49.87	40.677	91.272	1.015	19	49.36	36.049	87.369	1.040	1.027	1.782%
95	5	13	49.93	40.887	95.440	1.093	14	49.44	40.094	94.674	1.104	1.098	0.793%
95	6	24	50.04	38.575	96.904	1.166	27	49.28	37.007	95.500	1.187	1.176	1.495%
95	7	25	49.89	38.216	89.668	1.031	12	49.24	37.628	89.049	1.044	1.038	0.913%
95	8	15	49.97	41.508	97.139	1.113	23	49.73	38.241	94.005	1.121	1.117	0.569%
95	9	29	49.85	41.528	100.439	1.182	11	49.25	43.210	101.891	1.192	1.187	0.694%
90	1 repeat	23	50.14	38.24	96.1014	1.154	11	49.73	43.21	100.6718	1.155	1.155	0.088%
90	2 repeat	20	49.89	40.68	98.911	1.167	25	49.94	38.21	96.5538	1.168	1.168	0.061%
90	3 repeat	29	49.89	41.53	100.4858	1.182	11	49.73	43.21	101.9732	1.182	1.182	0.017%
20	1 repeat	11	49.73	43.21	102.1128	1.184	23	50.14	38.24	97.6458	1.185	1.185	0.042%

t-test: 0.0029  
99.7072 % probability of no difference between replicates A and B

1.782% max  
0.002% min

### Pycnometer Calibration

pycnometer No.	dry mass	pycnometer + water @20°C	Calculated volume	pycnometer + water @60°C	Calculated volume	pycnometer + water @95°C	Calculated volume
	g	g	ml	g	ml	g	ml
7	41.182	91.074	49.98	90.334	49.99	88.449	49.14
10	37.858	87.667	49.90	86.895	49.87	85.535	49.57
11	43.210	92.840	49.72	92.101	49.73	90.579	49.25
12	37.628	87.438	49.90	86.637	49.85	84.996	49.24
13	40.887	90.724	49.93	89.941	49.89	88.649	49.65
14	40.094	89.845	49.84	89.073	49.82	87.654	49.44
15	41.508	91.391	49.97	90.490	49.82	89.148	49.53
16	38.526	88.69	50.25	87.84	50.16	86.423	49.79
17	37.006	86.918	50.00	86.173	50.01	84.696	49.58
19	36.049	86.122	50.16	85.393	50.19	83.526	49.36
20	40.677	90.456	49.87	89.737	49.90	88.170	49.37
21	40.400	90.332	50.02	89.606	50.05	88.030	49.52
23	38.241	88.254	50.10	87.549	50.15	86.079	49.73
24	38.575	88.522	50.04	87.752	50.02	86.300	49.62
25	38.216	88.017	49.89	87.249	49.87	85.807	49.48
27	37.007	87.067	50.15	86.326	50.16	84.413	49.28
29	41.528	91.287	49.85	90.535	49.84	89.031	49.38

### Pycnometer Calibration - Repeats

pycnometer No.	dry mass	pycnometer + water @20°C	Calculated volume	pycnometer + water @90°C	Calculated volume
	g	g	ml	g	ml
11	43.2105	92.8558	49.73	91.033	49.54
20	40.6763	90.4738	49.89	88.752	49.80
23	38.2398	88.285	50.14	86.696	50.20
25	38.2148	88.0648	49.94	86.480	50.00
29	41.5290	91.3284	49.89	89.701	49.90

Density @20°C \* 998.204 kg/m<sup>3</sup>

Density @60°C \* 983.200 kg/m<sup>3</sup>

Density @90°C \* 965.321 kg/m<sup>3</sup>

Density @95°C \* 961.902 kg/m<sup>3</sup>

\* Perry's p. 3-76

Literature and Interpolated Data

HCl

Weast	wt %	M	density, 20°C
0	0	0	0.9982
0.5	0.137	1.0007	1.0007
1	0.275	1.0031	1.0031
1.5	0.414	1.0056	1.0056
2	0.553	1.0081	1.0081
2.5	0.693	1.0105	1.0105
3	0.833	1.013	1.013
3.5	0.975	1.0154	1.0154
4	1.116	1.0179	1.0179
4.5	1.259	1.0204	1.0204
5	1.402	1.0228	1.0228
5.5	1.546	1.0253	1.0253
6	1.691	1.0278	1.0278
6.5	1.836	1.0302	1.0302
7	1.982	1.0327	1.0327
7.5	2.129	1.0352	1.0352
8	2.276	1.0377	1.0377
8.5	2.424	1.0401	1.0401
9	2.573	1.0426	1.0426
9.5	2.722	1.0451	1.0451
10	2.872	1.0476	1.0476

Density @20° 998.204 kg/m3  
 Density @60° 983.200 kg/m3  
 Density @95° 961.902 kg/m3

MgCl2

Weast	wt %	M	density, 20°C
0	0	0	0.9982
0.5	0.053	1.0022	1.0022
1	0.106	1.0062	1.0062
2	0.213	1.0144	1.0144
3	0.322	1.0226	1.0226
4	0.433	1.0309	1.0309
5	0.546	1.0394	1.0394
6	0.66	1.0479	1.0479
7	0.777	1.0564	1.0564
8	0.895	1.0651	1.0651
9	1.015	1.0738	1.0738
10	1.137	1.0826	1.0826
12	1.387	1.1005	1.1005
14	1.645	1.1189	1.1189
16	1.911	1.1372	1.1372
18	2.184	1.1553	1.1553
20	2.466	1.1742	1.1742
22	2.758	1.1938	1.1938
24	3.06	1.214	1.214

Perry	wt %	density, kg/l				curve fit
		20°C	60°C	80°C	100°C	
1	1.0032	0.9881	0.9768	0.9636	0.9673	
2	1.0082	0.9930	0.9819	0.9688	0.9724	
4	1.0181	1.0026	0.9919	0.9791	0.9826	
6	1.0279	1.0121	1.0016	0.9892	0.9925	
8	1.0376	1.0215	1.0111	0.9992	1.0023	
10	1.0474	1.0310	1.0206	1.0090	1.0119	

Perry	wt %	density, kg/l				curve fit
		20°C	60°C	80°C	100°C	
2	1.0146	0.9995	0.9883	0.9753	0.978907	
4	1.0311	1.0159	1.005	0.9923	0.995765	
8	1.0646	1.0493	1.0388	1.026	1.02948	
12	1.0989	1.0836	1.0735	1.0622	1.065123	
16	1.1342	1.1188	1.1092	1.0984	1.101112	
20	1.1706	1.1552	1.146	1.1359	1.138632	

wt%	M	dens	Weast
1.809	0.5	1.0071	
5.340	1.5	1.0245	
8.755	2.5	1.0414	

wt%	M	dens	Weast
4.593	0.5	1.0359	
12.876	1.5	1.1086	
20.233	2.5	1.1765	

wt%	M	dens 20	Perry	curve fit	
				dens 60	dens 95
1.809	0.5	1.0072		0.992077	0.97236233
5.340	1.5	1.0270		1.008961	0.9892136
8.755	2.5	1.0413		1.025111	1.00598141

wt%	M	dens 20	Perry	curve fit	
				dens 60	dens 95
4.593	0.5	1.0361		1.020421	1.000329
12.876	1.5	1.1066		1.091748	1.072989
20.233	2.5	1.1728		1.156752	1.140583

Temp, °C	HCl, M			
	0	0.5	1.5	2.5
20		1.007	1.027	1.041
		1.007	1.025	1.041
% diff		-0.005	-0.120	0.005

Perry p. 3-80  
Weast p. D-240

Temp, °C	MgCl <sub>2</sub> , M			
	0	0.5	1.5	2.5
20		1.036	1.107	1.173
		1.036	1.109	1.176
% diff		-0.006	0.087	0.156

Perry p. 3-80  
Weast p. D-244

## Development of Equation Fit to Describe Density of H<sub>2</sub>O-HCl-MgCl<sub>2</sub> system

Software used: TableCurve 2D v2.02, MS Excel

### 1. Density as a function of MgCl<sub>2</sub> molarity

For each molar concentration of HCl and each temperature measured, the data was plotted and fitted such that a common equation form described the density for all data sets.

Equation:  $y^2 = a + bx$

where:  $y =$  solution density (kg/l)

$x =$  MgCl<sub>2</sub> molarity (mol/l)

T (°C) 20				
HCl (M)	0	0.5	1.5	2.5
r <sup>2</sup>	1.000	1.000	1.000	1.000
a	0.99714	1.00932	1.05077	1.08269
b	0.15570	0.15784	0.15429	0.15554

T (°C) 95				
HCl (M)	0	0.5	1.5	2.5
r <sup>2</sup>	1.000	0.999	0.998	0.999
a	0.92502	0.94205	0.97801	1.00872
b	0.15075	0.16185	0.16397	0.16497

T (°C) 60				
HCl (M)	0	0.5	1.5	2.5
r <sup>2</sup>	1.000	1.000	1.000	1.000
a	0.96730	0.98603	1.01848	1.05131
b	0.14863	0.15243	0.15434	0.15431

### 2. Density as a function of HCl molarity

For each temperature, the constant a above was plotted and fitted against HCl molarity. Constant b was averaged as no fit existed.

Equation:  $a = a' + b'x$

where:  $x =$  HCl molarity (mol/l)

T (°C)	20	60	95
r <sup>2</sup>	0.995	0.999	0.999
a'	0.99528	0.96826	0.92551
b'	0.03529	0.03335	0.03374

T (°C)	20	60	95
std. dev	0.0015	0.0027	0.0066
<b>b</b>	0.15584	0.15243	0.16039

### 3. Density as a function of temperature

Finally, a was plotted and fitted against temperature. Constant b was averaged.

Equation: $a' = a'' + b''x^{1.5}$
where: $x =$ (T-20) (°C)
$r^2 =$ 1.0000
$a'' =$ 0.99534
$b'' =$ -0.000107

Equation: $b =$ constant
where: $b =$ 0.15622
std. dev = 0.003993

Equation: $b' =$ constant
where: $b =$ 0.03413
std. dev = 0.001025

The sum of all errors was then minimised by modifying the constant b. All deviations occur at high temperature and MgCl<sub>2</sub> concentration.

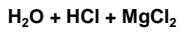
### 4. Final Equation Fit

$$\rho = (a'' + b''[T-20]^{1.5} + b'[HCl] + b[MgCl_2])^{0.5}$$

Where:  $a'' =$  0.99534  
 $b'' =$  -0.00011  
 $b' =$  0.03413  
 $b =$  0.15464

T = °C  
MgCl<sub>2</sub> = mol/l  
HCl = mol/l  
 $\rho =$  kg/l

**Solution Densities (kg/l)**



**MEASURED (Literature for water and binary mixtures)**

**20 °C**

MgCl <sub>2</sub> , M	HCl, M			
	0	0.5	1.5	2.5
0	0.9982	1.007	1.027	1.041
0.5	1.036	1.045	1.061	1.078
1.5	1.107	1.117	1.132	1.147
2.5	1.173	1.184	1.199	1.213

**60 °C**

MgCl <sub>2</sub> , M	HCl, M			
	0	0.5	1.5	2.5
0	0.9832	0.992	1.009	1.025
0.5	1.020	1.032	1.046	1.063
1.5	1.092	1.102	1.118	1.132
2.5	1.157	1.169	1.185	1.199

**95 °C**

MgCl <sub>2</sub> , M	HCl, M			
	0	0.5	1.5	2.5
0	0.9619	0.972	0.989	1.006
0.5	1.000	1.008	1.027	1.038
1.5	1.073	1.079	1.098	1.117
2.5	1.141	1.155	1.168	1.182

**CALCULATED**

**20 °C**

MgCl <sub>2</sub> , M	HCl, M			
	0	0.5	1.5	2.5
0	0.998	1.006	1.023	1.040
0.5	1.036	1.044	1.060	1.076
1.5	1.108	1.116	1.131	1.146
2.5	1.176	1.183	1.197	1.211

**60 °C**

MgCl <sub>2</sub> , M	HCl, M			
	0	0.495	1.5	2.5
0	0.984	0.992	1.010	1.026
0.5	1.022	1.031	1.047	1.063
1.5	1.096	1.103	1.119	1.134
2.5	1.164	1.171	1.186	1.200

**95 °C**

MgCl <sub>2</sub> , M	HCl, M			
	0	0.5	1.5	2.5
0	0.962	0.971	0.988	1.005
0.5	1.001	1.010	1.027	1.043
1.5	1.076	1.084	1.099	1.115
2.5	1.145	1.153	1.168	1.182

**DIFFERENCE**

T	MgCl <sub>2</sub> (M)	HCl (M)			
		0	0.5	1.5	2.5
20	0	0.00	0.00	0.00	0.00
20	0.5	0.00	0.00	0.00	0.00
20	1.5	0.00	0.00	0.00	0.00
20	2.5	0.00	0.00	0.00	0.00
60	0	0.00	0.00	0.00	0.00
60	0.5	0.00	0.00	0.00	0.00
60	1.5	0.00	0.00	0.00	0.00
60	2.5	0.01	0.00	0.00	0.00
95	0	0.00	0.00	0.00	0.00
95	0.5	0.00	0.00	0.00	0.01
95	1.5	0.00	0.01	0.00	0.00
95	2.5	0.00	0.00	0.00	0.00
<b>sum of errors =</b>		0.08			

**t-test on differences:**

ave. difference	0.002
sqrt n	6.93
stdev of difference	0.0015
t	8.009
Probability of difference	0.000 %
t for 95% conf. limits	4.303
confidence limits	0.0009

## **APPENDIX D**

Mineralogical Analyses

University of Cape Town

AS040065 Brief Note No.1 Solly Theron

**Table 1 Mineral Abundance Analysis of Barro Alto WTO Acido ore, size fraction +10µm to -38µm (Karen MacKellar).**

Mineral	WTO Acido +10/-38µm
Serpentine - Altered Serpentine :	73.92
Fe-hydroxides :	7.96
Clay (Smectitic) :	4.07
Talc :	3.15
Clinopyroxene/Clinoamphibole :	4.45
Cr-spinel :	2.41
Quartz :	0.65
Chlorite :	0.67
Olivine/Orthopyroxene :	1.03
Fe-oxide (Hematite/Magnetite) :	0.18
Mn-hydroxide :	0.41
Others :	1.10
<b>Total:</b>	<b>100.00</b>

The group "others" include analyses that could not be positively identified, dolomite, and Al-hydroxides.

**Table 2 Comparison between the mineralogy of Karen MacKellar's Barro Alto WTO Acido +10/-38µm sample and the bulk WTO Acido I ore.**

Mineral	WTO Acido (+10/-38µm)	WTO Acido I* (Bulk)
Serpentine - Altered Serpentine :	73.92	63.02
Fe-hydroxides :	7.96	18.14
Clay (Smectitic)	4.07	4.98
Talc :	3.15	3.37
Clinopyroxene/Clinoamphibole :	4.45	2.98
Cr-spinel :	2.41	2.41
Quartz :	0.65	1.05
Chlorite :	0.67	0.99
Olivine/Orthopyroxene :	1.03	0.43
Fe-oxide (Hematite/Magnetite)	0.18	0.41
Mn-hydroxide :	0.41	0.27
Others :	1.10	1.96
<b>Total:</b>	<b>100.00</b>	<b>100.00</b>

The group "others" include analyses that could not be positively identified, dolomite, and Al-hydroxides.

\*There are minor differences between this mineral abundance analyses and that reported in AARL Process Mineralogy Technical Note No.2 dated 22 December 2004. This is due to a refinement of the ASCAN mineral processing software.

**Table 3** Calculated nickel distribution in the Barro Alto WTO Acido +10/-38 $\mu$ m sample. (Assayed Nickel Head Grade = 1.68wt.%)

Mineral Phases:	Mean Ni (wt.%) Content:	Percentage Contained Nickel:
Serpentine - Altered Serpentine :	1.65*	72.6
Fe-hydroxides :	2.00*	9.5
Clay :	2.25*	5.5
Olivine :	0.40*	0.2
Mn-hydroxide :	12.95*	3.1
Others :	n.a.	9.1
<b>Total:</b>		<b>100.00</b>

\* As reported in AARL Process Mineralogy Technical Note No.2, dated 22 December 2004. Others = Talc and Chlorite, as well as unaccounted Ni due to analytical error.

**Table 4** Calculated nickel distribution in the Barro Alto WTO Acido +10/-38 $\mu$ m sample (Assayed Nickel Head Grade = 1.68 wt.%) vs. that of Barro Alto WTO Acido I (Bulk) (Assayed Nickel Head Grade = 1.76 wt.%)

Mineral Phases:	Mean Ni (wt.%) Content:	Percentage Contained Nickel:	
		(+10/-38 $\mu$ m)	(Bulk)
Serpentine - Altered Serpentine :	1.65*	72.6	59.1
Fe-hydroxides :	2.00*	9.5	20.6
Clay :	2.25*	5.5	6.4
Olivine :	0.40*	0.2	0.1
Mn-hydroxide :	12.95*	3.1	2.0
Others :	n.a.	9.1	11.9
<b>Total:</b>		<b>100.0</b>	<b>100.0</b>

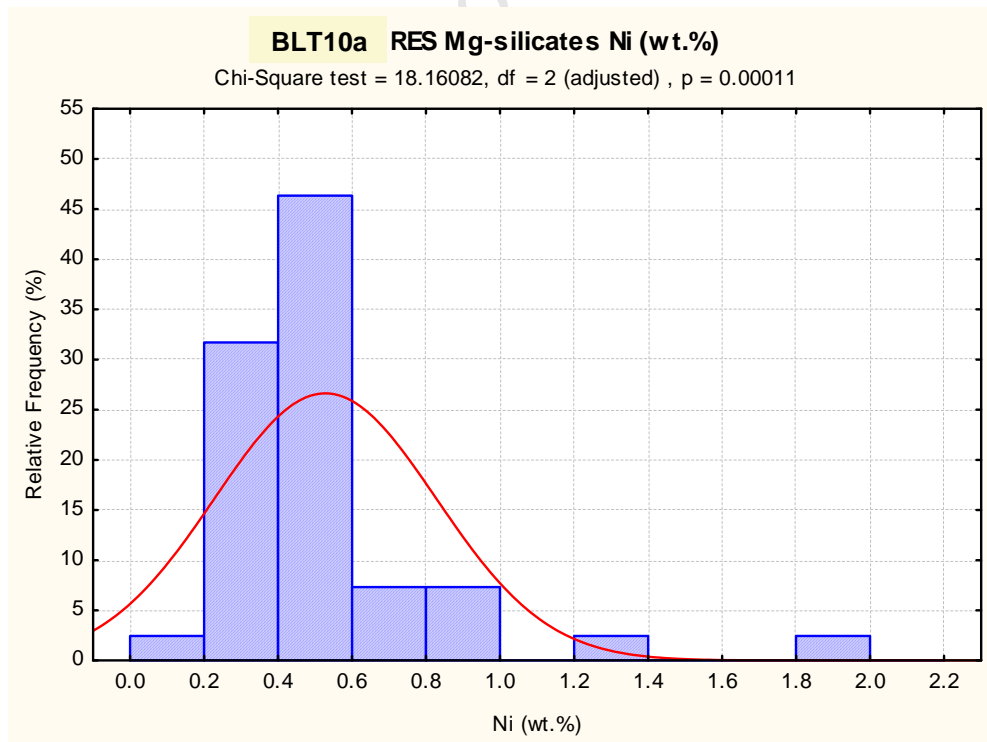
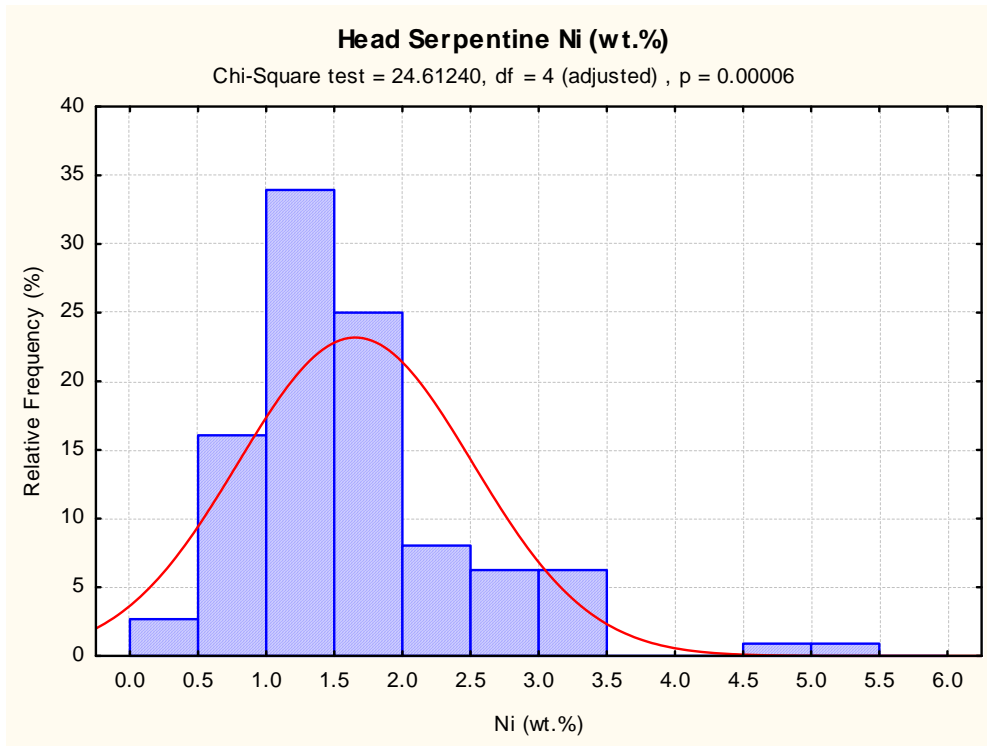
\* As reported in AARL Process Mineralogy Technical Note No.2, dated 22 December 2004. Others = Talc and Chlorite, as well as unaccounted Ni due to analytical error.

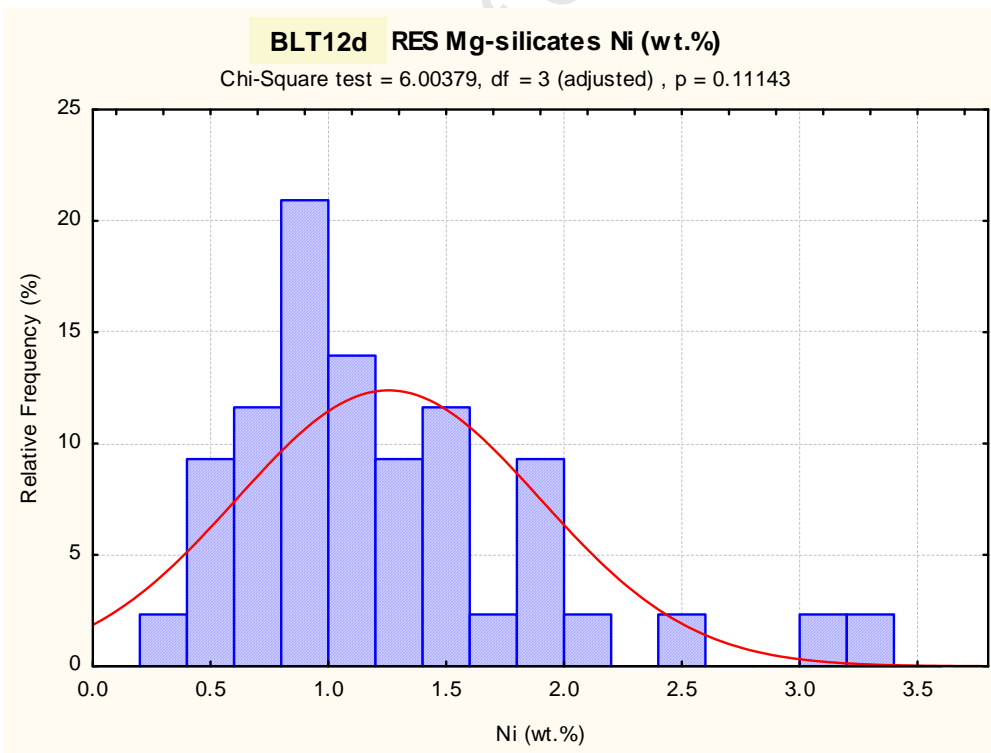
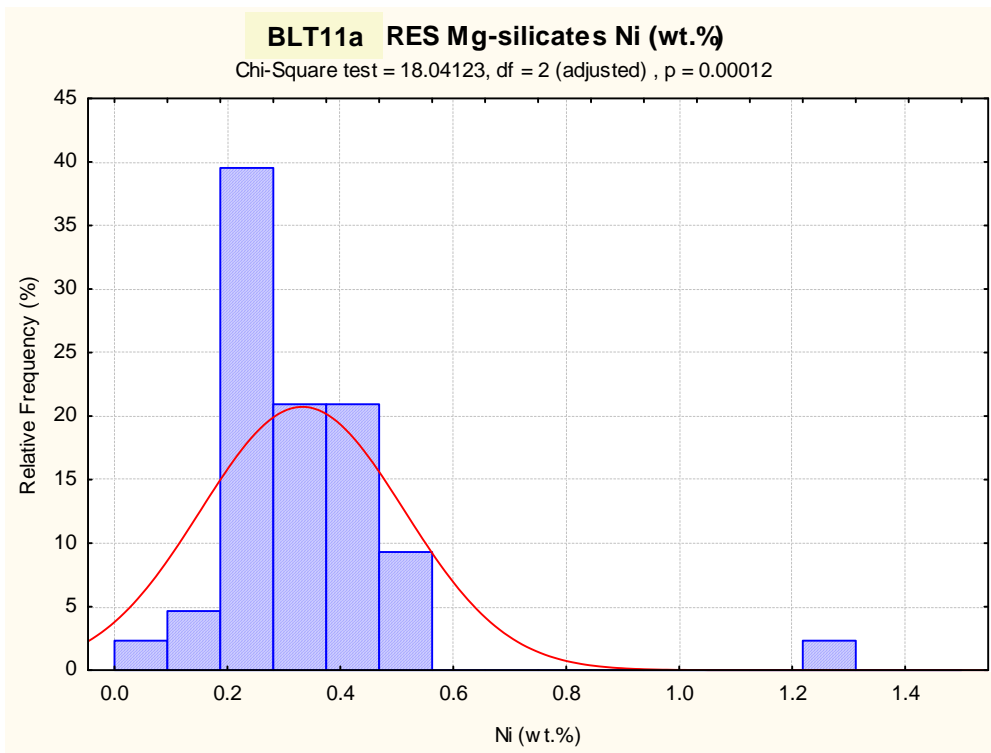
#### Summary Notes:

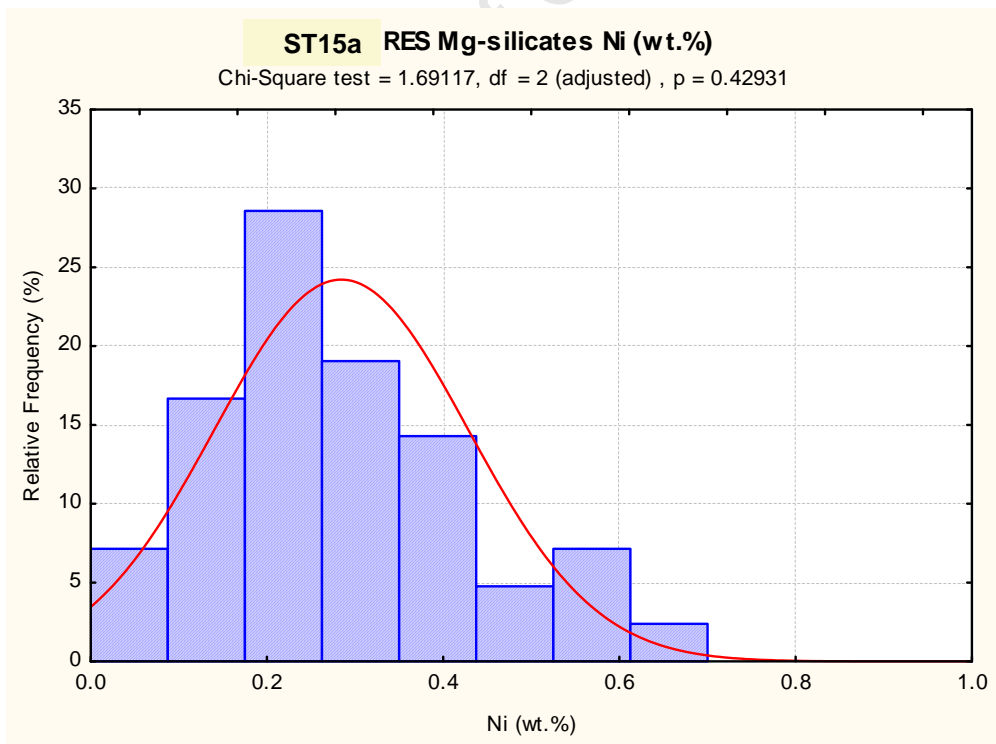
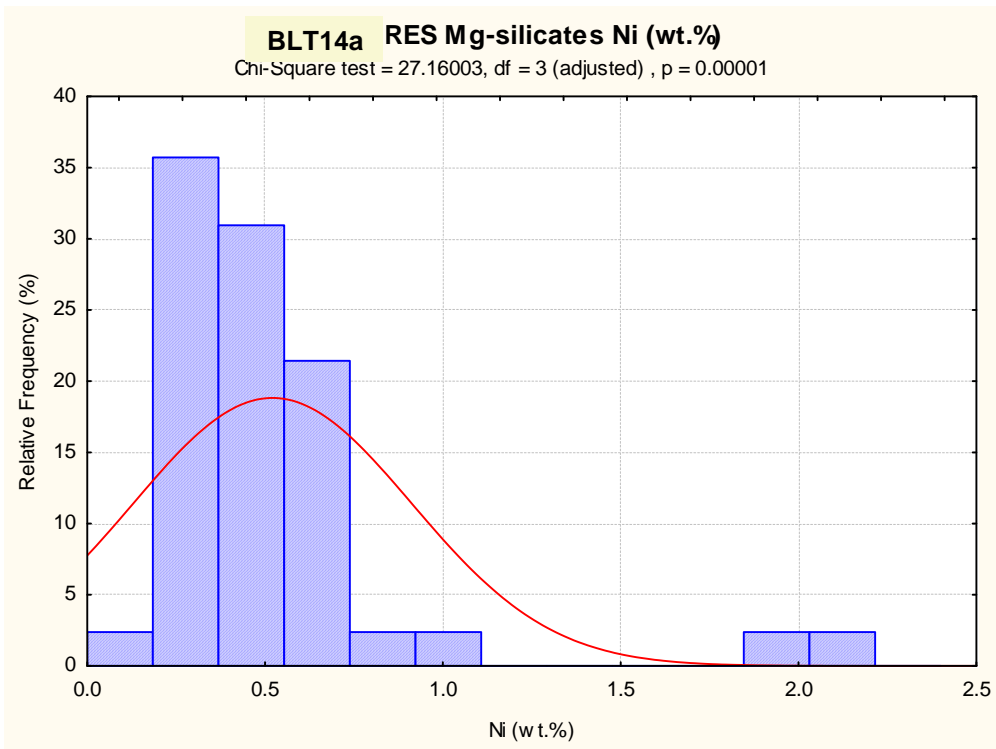
- Karen MacKellar's +10/-38 $\mu$ m fraction is more serpentine - altered serpentine rich ( $\pm 73$  mass %) than the bulk Barro Alto WTO Acido ore ( $\pm 63$  mass %).
- The +10/-38 $\mu$ m fraction contains less Fe-hydroxides ( $\pm 8.0$  mass %) compared to the bulk ore ( $\pm 18$  mass %).
- The nickel grade of the +10/-38 $\mu$ m fraction is thus slightly lower (1.68 wt.%) if compared to the bulk sample (1.76 wt.%) as the Fe-hydroxides are more enriched in Ni (average Ni-content 2.0 wt.%) than the serpentine - altered serpentine (average Ni-content 1.65 wt.%).
- Most of the nickel in the +10/-38 $\mu$ m fraction and bulk sample,  $\pm 73$  % and  $\pm 59$  % respectively, is contained by serpentine - altered serpentine. The serpentine - altered serpentine in the bulk sample hosts slightly less of the nickel as it is present in lower proportions.
- On the other hand, more of the nickel ( $\pm 21$  %) in the bulk sample is hosted by Fe-hydroxides as it is present in higher proportions. While in the +10/-38 $\mu$ m fraction the Fe-hydroxides only host  $\pm 10$  % of the nickel.

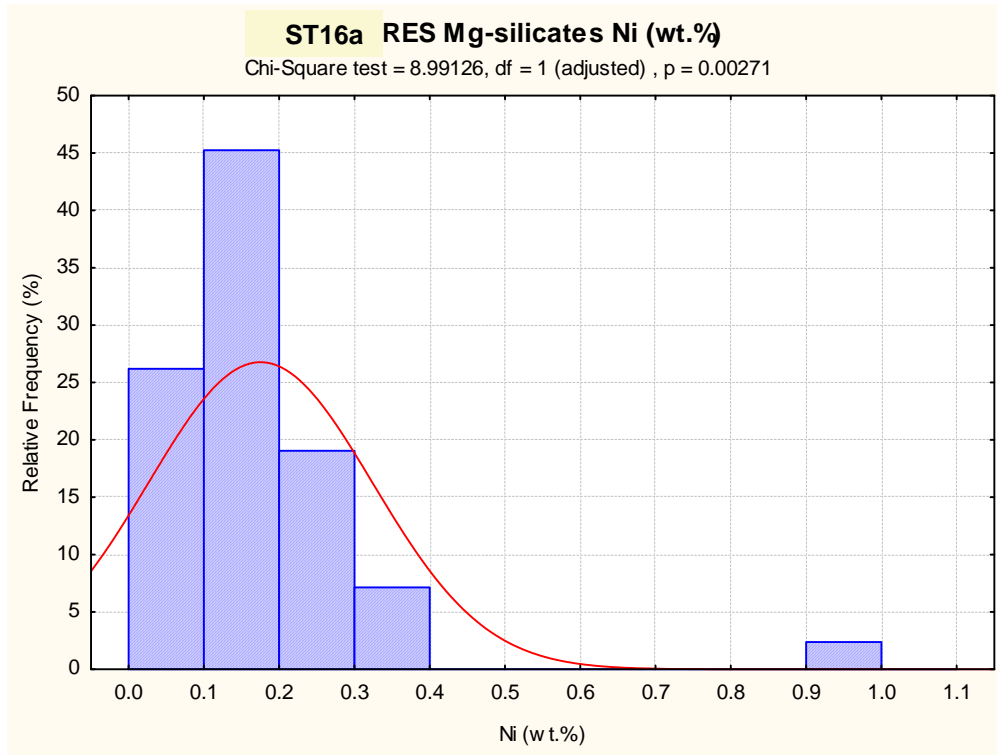
## Semi-Quantitative EDS Point Mineral Analyses

Barro Alto WTO Acido head and residues









University of C

**Project no.:** A49076 - AS04\_0065  
**Project:** Barro Alto Ni-laterite - leach testwork  
**Client:** Karen MacKellar  
**Samples:** Leach products  
**Date:** 6-Jul-05  
**Database:** Ni-Laterite\_3

**TABLE 1: Mineral Abundance Analyses of Head and BLT10 residue samples and comparison of ASCAN AND QEMSCAN results on HEAD**

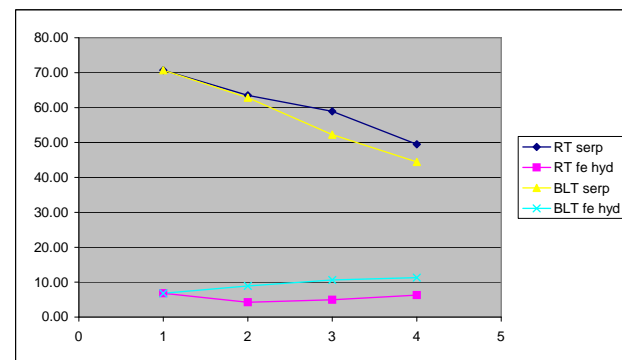
ASCAN	head	Mineral	head	BLT10			comments
				10 min	20min	30min	
				mass-%			
Fe-hydroxide/Jasper	7.96	Fe-hydroxide	6.80	8.91	10.62	11.31	Fe-hydroxide; contains Si, Al
		Jasper	3.06	3.69	7.24	8.44	Jasper could be a leach residue of serpentine with high Si, low Mg, medium Fe
Fe-oxide	0.18	Magnetite(Cr)	0.06	0.19	0.09	0.53	(Fe,Cr)3O4 - magnetite contains ~10% Cr
Cr-spinel	2.41	Cr-spinel	1.33	2.14	2.30	2.05	two types of Cr-spinel occur (i) Al-rich-Cr-Fe-Mg-spinel, (ii) Cr-rich-Fe-Al-Mg-spinel
Mn-hydroxide	0.41	Mn-hydroxide	0.60	0.48	0.03	0.01	
Clinopyroxene/Clinocamphibole	4.45	Ca-pyroxene/amph	3.50	5.54	7.83	11.27	XRD indicates the presence of tremolite (Ca,Na,Fe,Mg-silicate)
Talc	3.15	Talc	0.03	1.47	3.51	2.53	increase in talc concentration in the leach residues is most probably due to the fact that talc and leached serpentine might have similar X-ray spectral characteristics
Serpentine	73.92	Serpentine	70.69	62.85	52.27	44.45	Mg-silicate (contains Fe)
		Serp epoxy interphase	4.56	1.70	1.50	1.20	mixed analysis of serpentine and mounting material
		Serp Fe-hydr interphase	0.40	0.22	0.07	0.05	mixed analysis of serpentine and Fe-hydroxide
Clay	4.07	Serpentine_2 (high Fe)/clay	7.44	2.56	2.16	1.10	possibly a saponitic/nontronitic clay
		Leached serpen	0.17	4.86	4.43	2.81	leached serpentine where Mg is removed and Si and Fe are relatively enriched
Chlorite	0.67	Chlorite	0.46	0.61	0.56	0.68	
Quartz	0.65	Quartz/Si-oxide (leac product)	0.15	1.44	2.89	6.92	the head contains some quartz; it is believed that the final leach product of serpentine is similar in X-ray characteristics to SiO2 and can therefore not be distinguished
		Al Silicate	0.13	0.71	1.51	2.43	analyses that are grouped by QEMSCAN into Al-silicate (possibly needs further refinement)
Others/Olivine	2.13	Other	0.62	2.64	2.97	4.22	analyses that are grouped by QEMSCAN into "Other"
	100.00		100.00	100.00	100.00	100.00	

**TABLE 2: Assays calculated from QEMSCAN results for BLT10 leach residues**

	head	BLT10		
		10 min	20min	30min
Mg	15.5	13.5	12.2	10.9
Al	0.4	0.7	0.9	1.1
Si	16.9	17.8	18.8	19.9
Ca	0.4	0.9	0.9	1.3
Cr	0.5	0.8	0.8	0.7
Mn	0.3	0.2	0.0	0.0
Fe	6.8	8.3	9.4	10.0
Ni	1.6	1.4	1.2	1.1

**TABLE 3: chemical assays**

	head	BLT10		
		10 min	20min	30min
Mg	18.8	15.0	11.4	9.2
Al	1.5	1.5	1.9	2.0
Si	18.8	22.0	24.6	25.5
Ca	0.8	0.9	1.1	1.2
Cr	0.5	0.6	0.7	0.8
Mn	0.2	0.2	0.1	0.1
Fe	9.3	7.5	6.9	6.2
Ni	1.7	0.6	0.4	0.3



**TABLE 4:** Mineral Abundance Analyses of Head and ST16 residue samples

Mineral	head	ST16		
		10 min	20min	30min
Fe-hydroxide	6.80	4.26	4.94	6.29
Jasper	3.06	0.81	3.34	3.39
Magnetite(Cr)	0.06	0.14	0.15	0.00
Cr_spinel	1.33	3.28	3.13	6.02
Mn-hydroxide	0.60	0.04	0.47	0.01
Ca-pyroxene/amph	3.50	10.17	9.46	12.70
Talc	0.03	3.64	4.05	0.00
Serpentine	70.69	63.48	58.95	49.47
Serp epoxy interphase	4.56	0.31	0.69	0.00
Serp_Fe-hydr_interphase	0.40	0.00	0.00	0.00
Serpentine_2 (high Fe)/clay	7.44	0.04	0.33	0.00
Leached serpen	0.17	1.79	2.36	0.00
Chlorite	0.46	0.35	0.73	0.24
Quartz/Si-oxide (leac product)	0.15	7.74	6.60	17.09
Al Silicate	0.13	1.41	1.58	2.79
Other	0.62	2.54	3.21	2.01
	100.00	100.00	100.00	100.00

**TABLE 5:** Assays calculated from QEMSCAN results for ST16 leach residues

	head	ST16		
		10 min	20min	30min
Mg	15.5	14.08	13.40	11.31
Al	0.4	0.86	0.91	1.37
Si	16.9	20.47	20.16	22.32
Ca	0.4	1.07	1.13	1.29
Cr	0.5	1.16	1.10	2.11
Mn	0.3	0.02	0.23	0.00
Fe	6.8	5.23	6.19	6.12
Ni	1.6	1.16	1.13	0.96

**TABLE 6:** chemical assays

	head	ST16		
		10 min	20min	30min
Mg	18.8	13.2	9.8	7.6
Al	1.5	1.5	1.6	1.6
Si	18.8	23.9	26.2	27.1
Ca	0.8	0.9	0.9	1.0
Cr	0.5	0.6	0.6	0.6
Mn	0.2	0.1	0.1	< 0.05
Fe	9.3	4.6	3.4	2.8
Ni	1.7	0.3	0.2	0.2

## **APPENDIX E**

Kinetic Calculations

University of Cape Town

### Batch Leaching of Barro Alto WTO acido (Saprolitic Laterite)

solid analyses used to calculate extraction, each point represents a separate test  
 It is proposed:  $\text{rate of extraction} = K.[H^+]^n.[Cl^-]^m \exp(-E/RT)$

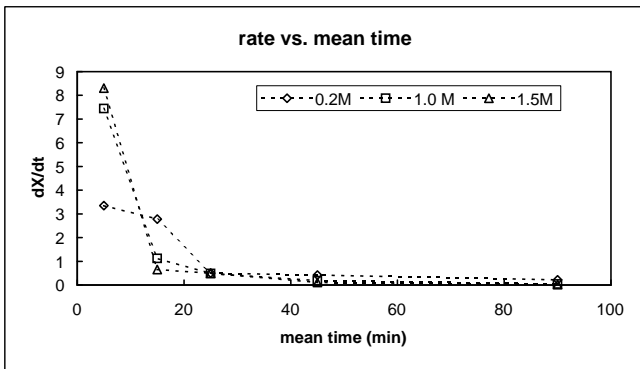
#### 1. Effect of Acid Concentration

grind 46  
 temp 80  
 % solids 0.5  
 $[MgCl_2]$  0

test	13	10	11
Time min	Ni conv. 0.2M	Ni conv. 1.0M	Ni conv. 1.5M
0	0	0	0
10	34	74	83
20	61	86	90
30	66	90	95
60	79	96	98
120	92	98	99
ave. initial [H]	0.20	1.00	1.50
ln [H]	-1.61	0.00	0.41

Test	13	10	11
Nominal [H]	0.2 M	1.0 M	1.5 M
Mean time (min)	dX/dt	dX/dt	dX/dt
5	3.3501	7.4413	8.3089
15	2.7802	1.1248	0.6515
25	0.5019	0.4818	0.4943
45	0.4195	0.1803	0.1105
90	0.2176	0.0387	0.0149
ave. initial rate	3.065	4.283	4.480
ln(rate)	1.12	1.45	1.50
ave. initial [H]	0.200	1.000	1.500
ln [H]	-1.66	-0.06	0.36

From plot of  $\ln(\text{initial rate})$  vs.  $\ln[H]$ , order (slope) = 0.19  
 ln rate constant (intercept) = -3.1596  
 Thus,  $k_1 = 0.042$



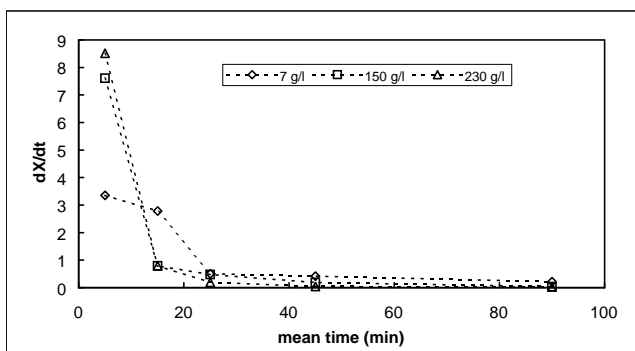
#### 2. Effect of Total Chloride Concentration

grind 46  
 temp 80  
 % solids 0.5  
 [HCl] 0.2

test	13	14	16
Time min	Ni conv. 7 g/l	Ni conv. 150 g/l	Ni conv. 230 g/l
0	0	0	0
10	33.5	76.1	85.1
20	61.3	84.0	93.1
30	66.3	88.7	95.0
60	78.9	94.2	96.4
120	92.0	96.4	97.5
ave. initial [Cl]	0.21	4.07	6.23
ln [Cl]	-1.55	1.40	1.83

Test	13	14	16
Nominal $[Cl]^{-0}$	0.2 M	4.2 M	6.5 M
Mean time (min)	dX/dt	dX/dt	dX/dt
5	3.3501	7.6054	8.5147
15	2.7802	0.7898	0.7930
25	0.5019	0.4758	0.1937
45	0.4195	0.1844	0.0453
90	0.2176	0.0353	0.0181
Ave. initial rate	3.065	4.198	4.654
ln(rate)	1.12	1.43	1.54
Ave. initial [Cl]	0.213	4.066	6.226
ln [Cl]	-1.55	1.40	1.83

From plot of  $\ln(\text{initial rate})$  vs.  $\ln[Cl]$ , order (slope) = 0.12  
 ln rate constant (intercept) = -3.307  
 Thus,  $k_2 = 0.037$



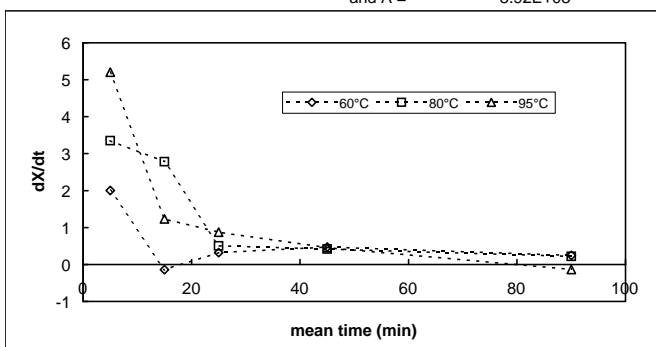
### 3. Effect of Temperature

grind 46  
 % solids 0.5  
 [MgCl<sub>2</sub>] 0  
 [HCl] 0.2

test	17	13	18	12
Time min	Ni conv. 60°C	Ni conv. 80°C	Ni conv. 95°C	Ni conv. 60°C
0	0	0	0	
10	20.00	33.50	52.04	
20	18.62	61.30	64.41	
30	21.85	66.32	73.16	
60	35.95	78.91	86.81	0.38
120	50.72	91.97	78.54	0.57
ave. temp (K)	333	353	368	
1/T	0.00300	0.00283	0.00272	

test	17	13	18
mean min	dX/dt 60°C	dX/dt 80°C	dX/dt 95°C
5	2.0005	3.3501	5.2037
15	-0.1382	2.7802	1.2372
25	0.3228	0.5019	0.8751
45	0.4700	0.4195	0.4548
90	0.2462	0.2176	-0.1377
ave. initial rate	0.931	3.065	3.220
ln(rate)	-0.07	1.12	1.17

From plot of ln(initial rate) vs. 1/T, -E/R (slope) = -4548.20  
 ln A (intercept) = 9.096  
 Thus, Ea = 37.814 kJ/K.mol  
 and A = 8.92E+03



#### Calculation of rate constants

Ea	n	m	Kone	Ktwo
37.814	0.19	0.12	0.042	0.037
3781.37348				

test	K (/min)	calc. initial rate	measured initial rate	[H] mol/l	[C] mol/l	T K	squared error	% relative error
13	5.134	2.666	3.065	0.19	0.21	353	0.16	13.0
10	4.380	4.366	4.283	0.94	1.01	353	0.01	1.9
11	4.024	4.972	4.480	1.43	1.54	353	0.24	11.0
14	5.054	3.708	4.198	0.18	4.07	353	0.24	11.7
16	5.384	3.860	4.654	0.17	6.23	353	0.63	17.1
17	1.571	2.647	0.931	0.19	0.20	333	2.94	184.3
18	5.329	2.699	3.220	0.20	0.22	368	0.27	16.2
ave. K:	4.411						SSE:	4.50
optimised K:	4.465							

15	4.040	5.320	4.872	0.92	6.36	353	2.00E-01	9.2
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### 4. Effect of Particle Size

temp 80  
 % solids 0.5  
 [MgCl<sub>2</sub>] 0  
 [HCl] 0.2

test	13	19
Time min	Ni conv. 42um	Ni conv. 106um
0	0	0
10	33.50	40.57
20	61.30	46.51
30	66.32	58.03
60	78.91	72.69
120	91.97	73.44

### 5. Effect of Pulp Density

temp 95  
grind 46  
[MgCl<sub>2</sub>] 0  
[HCl] 0.2

test	18	1	3
Time min	Ni conv. 0.5 %solids	Ni conv. 2 %solids	Ni conv. 5 %solids
120	0.79		
180		0.71	0.51

temp 80  
grind 46  
[MgCl<sub>2</sub>] 0  
[HCl] 0.2

test	13	2
Time min	Ni conv. 0.5 %solids	Ni conv. 2 %solids
120	0.92	
180		0.73

### 6. Effect of hydrogen ion activity

grind 46  
% solids 0.5

test	13	14	16	10	11	15	17	18
Time min	Ni conv.			Ni conv.		Ni conv.		
0	0	0	0	0	0	0	0	0
10	34	76	85	74	83	96	20	52
20	61	84	93	86	90	97	19	64
30	66	89	95	90	95	98	22	73
60	79	94	96	96	98	99	36	87
120	92	96	97	98	99	98	51	79
ave. initial [H]	0.19	0.18	0.17	0.94	1.43	0.92	0.19	0.20
ave. initial [MgCl <sub>2</sub> ]	0.00	1.96	3.00	0	0.00	2.53	0.00	0
temperature	80	80	80	80	80	80	60	95
H+ activity	0.1493	0.3884	0.6223	0.7633	1.33	4	0.1526	0.1467

from JS model

nominal [H]	0.2	0.2	0.2	1	1.50	1	0.2	0.2
nominal [MgCl <sub>2</sub> ]	0	2.01	3.14	0	0.00	2.73	0	0
HCl activity	0.15	0.68	1.90	0.72	1.16	7.83	0.15	0.14
H+ activity	0.1493	0.3884	0.6551	0.8126	1.40	4.072	0.1526	0.1467
ln activity	-1.901797574	-0.945719543	-0.422967383	-0.2075163	0.333252774	1.404134279	-1.87993516	-1.91936559
ln HCl activity	-1.924833823	-0.385015631	0.640600469	-0.3239312	0.146694379	2.057604847	-1.904614667	-1.94855364

test	13	14	16	10	11	15	17	18
mean min	dX/dt	dX/dt	dX/dt	dX/dt	dX/dt	dX/dt	dX/dt	dX/dt
5	3.3501	7.6054	8.5147	7.4413	8.3089	9.5603	2.0005	5.2037
15	2.7802	0.7898	0.7930	1.1248	0.6515	0.1843	-0.1382	1.2372
25	0.5019	0.4758	0.1937	0.4818	0.4943	0.0459	0.3228	0.8751
45	0.4195	0.1844	0.0453	0.1803	0.1105	0.0201	0.4700	0.4548
90	0.2176	0.0353	0.0181	0.0387	0.0149	-0.0143	0.2462	-0.1377
ave. initial rate	3.065	4.198	4.654	4.283	4.480	4.872	0.931	3.220
ln(rate)	1.12	1.43	1.54	1.45	1.50	1.58	-0.07	1.17

