# The impact of water quality on flotation performance

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## Synopsis

**Water represents 80–85% of the volume of mineral pulp processed in flotation circuits. Imperatives for a more detailed focus on circuit water quality and its control have come from increasing requirements to use relatively impure primary water supplies (e.g. high salinity, treated sewage) and high proportions of recycle from tailings dams, thickener overflows, dewatered and filter products. An integrated methodology for examining process water quality and its effect on minerals separation has been developed coupled with minerals surface chemistry across the complete processing circuit. Unrecognised factors, including varying proportions of water streams (daily or hourly), colloidal precipitation, highly variable pH and Eh, reaction and dissolution of minerals, minerals surface layer coatings, residual reagents and their reaction products, and microbiological activity have been studied in eight mineral processing circuits. The methodology combines: solution survey and modelling; microbiological surveys; minerals surface analysis and modelling; and process response. It has been possible to match the predicted (model) pulp chemistry with that measured from surveys of the solution and mineral surfaces. Treatment methods have included: monitored and balanced stream combinations; organic species removal; flocculation and aggregation; induced precipitation; dissolved air flotation; ageing (oxidation, UV exposure); and chemical surface conditioning of minerals. Some specific achievements from the methodology applied in plant and laboratory testing, with examples from case studies, will be described.**

## Introduction

Compared with research and development in the surface chemistry of mineral conditioning, reagent optimization and separation engineering, relatively little R&D has been committed to understanding and controlling water quality in minerals separation processing. Whilst consideration of pulp chemistry has encompassed solution assays and species affecting pH, Eh and some precipitation, a systematic and comprehensive approach to modelling the behaviour of solution species integrated with their effect on mineral surfaces is not normally undertaken. Consequently a 'snapshot' approach to different processing steps has prevailed without full consideration of the solution species in the processing and tailings circuits. Some of the effects of water quality on flotation and other mineral separation response can only be appreciated by a 'whole circuit' approach. This paper sets out to provide justification for the development of this methodology to examine process water quality and treatment integrated with mineral surface chemistry and separation or leaching response across the complete processing and water recycle circuits.

## Imperatives

Some of the imperatives for a more detailed focus on circuit water quality and its control have come from increasing requirements to use relatively impure primary water supplies and high proportions of recycle from tailings dams, thickener overflows, dewatering and filter products. It is well known that there are now mining and minerals processing operations in which zero water release or water release with total dissolved solids (TDS) below 1000 p.p.m. is required by environmental regulation. Primary water supplies from bores containing high levels of salinity including calcium, magnesium and iron salts as potential precipitates are being used in several remote areas. An example of such a saline bore water is given in Table I. Treated sewage effluent water with relatively high levels (>1000 mg/*l*) of total organic carbon (TOC) is being used at some sites for make-up water supply. The return of cyclone underflow from primary grind and regrind operations in several circuits have been shown to introduce high levels of dissolved species from soluble mineral phases (e.g. pyrrhotite, siderite, brucite, and other metal hydroxides, sulphates and carbonates). Examples of the variability of

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pH, Eh, DO and dissolved species in recycle water streams (e.g. thickener overflow, decant (tailings) dam return) contributing to a circuit water are also shown in Table I. TDS and TOC levels may also be raised by reagent addition for pH control (e.g. lime) and recycled organics (e.g. depressants, dispersants, flocculants, collector decomposition products). For instance, TOC levels rise from <50mg/*l* in recycle streams and mill discharge to >200mg/*l* at cyclone overflow, rougher feed, concentrate and tails. At scavenger tails and concentrate thickener overflow, TOC >100mg/*l* is still found. In some cases, scale build-up on equipment due to nucleation and precipitation introduces significant costs in processing.

## Unrecognized or uncontrolled factors

*A combination of water supply streams, as in Figure 1, at different points in the circuit can lead to unrecognized and uncontrolled variation of a large number of important factors in minerals separation processing*. Some of these factors are routinely measured and controlled (e.g. pH, Eh) but many others are established only as addition rates (e.g. reagents).

The following list indicates some of the factors arising from water quality that can contribute to variability and losses in mineral recovery and selectivity:

- *Varying proportions in combinations of water streams (as in Figure 1) during processing (daily or hourly) or in seasonal water balances, or with changing primary water supplies*. This factor can have major effects on kinetically-controlled changing levels of pH, Eh and colloidal precipitation. Evaporation from tailings dams can markedly alter concentrations of dissolved and colloidal species in water recycle at different times of the year or as a change of supply from different dams or sections of a dam is used. Some examples from site surveys are shown in Table II
- Whilst pH surveys are normally regularly conducted on most plants, *the variability of pH with varying water stream combinations on an hourly basis can be unrecognized in the survey mode*. We have found examples where variations of tailings dam return supplies, different proportions of thickener overflow and filter streams can alter pH across the range from 3–9 in circuit water supplies to different parts of the circuit. This variability needs to be established in surveys across daily operation
- Similarly, *Eh variation resulting from the same changing proportion of water supplies* has been observed across the range -150mV to +350mV. The proportion of grind and regrind cyclone underflow in recycle can also alter Eh through subsequent processing
- Precipitation of colloidal particles as crystallites and gels is determined by the changing concentrations, pH and Eh induced by changing combinations of water supplies, grinding, regrinding, attritioning and reagent additions (Figure 1). *These colloidal species may remain dispersed in solution or attached to mineral particle surfaces as hydrophilic surface layers*. Colloidal material in this category includes iron (III) hydroxide, lead hydroxide, sulphate, carbonate (and combinations), calcium hydroxide and sulphate, magnesium hydroxide and carbonate, aluminium hydroxide, hydrated silica and aluminosilicates all of which have been measured on mineral particle surfaces. In some cases (e.g. calcium sulphate, aluminium hydroxide), relatively uniform gel-like adsorbed surface layers, rather than small crystallites, have been found on sulphide and heavy mineral sands surfaces. In one processing operation, up to 70% of the sulphide mineral surfaces was obscured by deposited calcium sulphate layers. In attritioning operations, resmearing of mineral sands surfaces with iron hydroxides, aluminium hydroxide and silica was measured with extended periods of attritioning
- *Reaction and dissolution during primary grinding and regrind operations produces widely varying concentrations of dissolved species as a function of pH and Eh in the operation*. The downstream consequences of the varying concentrations and speciation, have effects on kinetically-controlled changes in pH, Eh and precipitation which, in turn, require alteration in conditioning strategies and reagent addition rates. Wide variations in dissolution rates from different minerals in feed to the grinding or attritioning mills has been established. Measurement of dissolution in grinding may establish different strategies of stockpiling and blending ore to control these variables
- *Concentrations of reagents and their reaction products in recycle*. These factors are not normally measured in

*Table I*

**Examples of water quality from site surveys**

| | Sample Description | | | |
|---|---|---|---|---|
| | **Bore water** | **Circuit water** | **Thickener O/F** | **Decant pond return** |
| pH | 6.8 | 6.7 | 8.8 | 6.0 |
| Eh mV SHE | 92 | 440 | 338 | 264 |
| TDS mg/l | 180,000 | 9,900 | 11,000 | 11,000 |
| Ni mg/l | 0.15 | 4.15 | n.d. | n.d. |
| Fe mg/l | 0.44 | 6.16 | n.d. | n.d. |
| Na mg/l | 47,300 | 4350 | 4970 | 4540 |
| K mg/l | 280 | 145 | 160 | 150 |
| Ca mg/l | 631 | 120 | 56.4 | 135 |
| Mg mg/l | 6,700 | 1820 | 1480 | 2250 |
| $SO_4^{2-}$ mg/l | 11,600 | 14,418 | 14,114 | 17,076 |
| Silica mg/l | <1 | 10.2 | n.d. | n.d. |
| $Cl^-$ mg/l | 115,000 | 2,087 | 2,340 | 2,213 |
| TOC mg/l | 7 | 15 | 47 | 16 |
| $HCO_3^-$ mg/l | 120 | 176 | 434 | 35 |
| DO mg/l | n.d. | 2.4 | 4.8 | 1.8 |

**n.d. – not determined**

*Table II*

**pH, Eh, D.O. – Plant survey**

| Sampling location | Date | pH | Eh (mV) SHE | D/O (mg/l) |
|---|---|---|---|---|
| Circuit Water- Lab. Site | 10/12/96 | 6.6 | +310 | 0.7 |
| Circuit Water-Lab. Site | 11/12/96 | 6.7 | +305 | 2.4 |
| Thickeners O/F Tank | 11/12/96 | 8.17 | +372 | 4.8 |
| Circuit Water Tank | 11/12/96 | 6.75 | +240 | 2.0 |
| Decant Pond Water | 11/12/96 | 6.05 | +264 | 1.8 |
| Mill Discharge | 11/12/96 | 8.75 | +25 | 0.2 |
| Cyclone O/F | 11/12/96 | 8.50 | +300 | 0.2 |
| Rougher Cell 1 | 11/12/96 | 8.65 | +280 | 0.2 |
| Scav. Bank 1-Head | 11/12/96 | 8.70 | +325 | 1.2 |
| Scav. Bank 1-Tail | 11/12/96 | 8.70 | +335 | 1.8 |
| First Cleaner-Feed | 11/12/96 | 8.33 | +354 | 0.2 |
| First Cleaner-Tail | 11/12/96 | 8.34 | +353 | 4.2 |

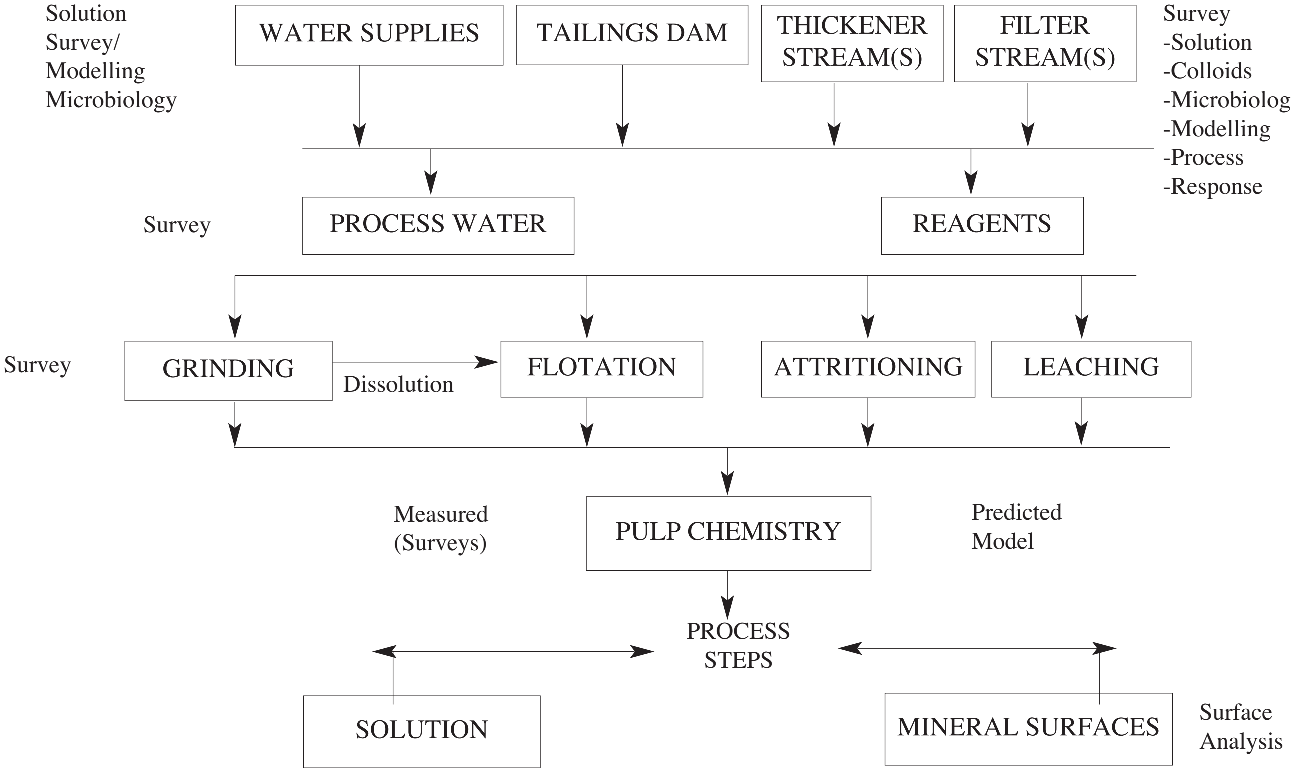

**Figure 1—Methodology**

operation or in circuit surveys. They can have direct consequences for control of recovery and selectivity. Both the origins and destinations of reagents need to be established

- In some cases *combinations of reagents and their reaction products can produce additional precipitation and altered surface layers* (e.g. lime/sulphate; lime/Calgon (phosphate); magnesium carbonate)
- *Reactions in tailings dam storage*. Changes in pH, Eh, dissolved oxygen (DO) and concentrations of dissolved species resulting from oxidative and non-oxidative reactions of minerals can produce similar effects in recycle to those from changes in dissolution rates resulting from grinding and regrinding (above).
- *The actions of dispersants and flocculants added at different points in the circuit can determine water quality and the surface chemistry of the different mineral phases*. Residual levels of dispersants can induce additional precipitation (e.g. hexametaphosphate or Calgon), or competitive adsorption with other reagents (e.g. CMC). Optimized action of flocculants in clarification of recycles from tailings dams, thickeners etc. is often unrecognized and uncontrolled. For instance, control of shear and sedimentation is normally essential for effective flocculation. Cases have been examined in which flocculant is being added at the same point in a tailings dam in which recycle water is drawn off with the consequence that flocculation is ineffective and solids are inadvertently carried back to processing with potential interference
- Microbiological action in circuits and tailings storage is largely unrecognized. *It has now been established that some sulfide flotation circuits operating under conventional processing conditions carry very high levels of microbiological species in both anaerobic and aerobic forms* (Table III). This microbiological activity can induce major changes in pH (from 9.5 to <3), Eh (from +400mV to <-200mV) in relatively short periods of storage (e.g. Table IV). This variable has only recently been isolated in processing circuits as well as tailings dams. *The factors determining its presence (or absence) and the range of its consequences have not yet been established due to a very limited (3 sites) data base*
- Laboratory simulation of circuit performance using aged circuit water has been shown to be ineffective and inaccurate in some cases due to both microbiological action and continuing, kinetically-controlled reactions of dissolved species. In one case, storage of the circuit water for periods as short as a few hours has been sufficient to induce pH and Eh changes invalidating the laboratory results.

## Processing consequences

We will not attempt to list all processing consequences that can result from unrecognized or uncontrolled variation in the factors listed above but the following may result from their actions:

- Loss of recovery due to: surface coatings on value minerals; competitive adsorption of activators and reagents with other species; loss of reagents due to precipitation, overcoating and inadvertent reaction
- Loss of grade due to: non-selective coatings on both value minerals and gangue; ineffective separation of gangue minerals; ineffective activation
- Loss of separation efficiency in subsequent processing after grinding or attritioning, e.g. electrostatic separation, leaching
- Contamination of products
- Hydrophobic coatings of microbiological material on

*Table III*

**Microbiological – Plant survey**

| Sampling Location | Date | Time | pH | Eh (mV) SHE | Dissolved oxygen (mg/l) | Total bacterial counts (cfu/ml) |
|---|---|---|---|---|---|---|
| Circuit Water-Lab. Site | 10/12/96 | 14.45 | 6.60 | +310 | 0.7 | 200,000 |
| Circuit Water-Lab. Site | 11/12/96 | 07.45 | 6.70 | +305 | 2.4 | 3,000,000 |
| Thickeners O/F Tank | 11/12/96 | 17.00 | 8.17 | +372 | 4.8 | 200,000 |
| Circuit Water Tank | 11/12/96 | 17.50 | 6.75 | +240 | 2.0 | 260,000 |
| Rougher-Cell 1-Pulp | 11/12/96 | 15.00 | 8.65 | +280 | 0.2 | 2,000,000 |
| Scav. Bank 4-Tail - Pulp | 11/12/96 | 15.30 | 8.72 | +329 | 2.3 | 1,620,000 |
| Cleaner-Tail-Pulp1 | 1/12/96 | 16.00 | 8.34 | +353 | 4.2 | 7,600,000 |
| Plant Concentrate-Pulp | 11/12/96 | 16.30 | 8.33 | +270 | 0.2 | 1,500,000,000 |

*Table IV*

**Circuit water changes (due to microbiological action): Storage conditions and time (DO mg/l; Eh mV SHE)**

| Days | Aerobic/RT | | | Anaerobic/RT | | | Refrigerated | | | Frozen | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | DO | pH | Eh | DO | pH | Eh | DO | pH | Eh | DO | pH | Eh |
| 0 | 0.2 | 6.6 | 262 | 0.2 | 6.6 | 262 | 0.2 | 6.6 | 262 | 0.2 | 6.6 | 262 |
| 4 | 9.5 | 5.2 | 410 | <0.2 | 6.6 | 110 | 0.7 | 6.0 | 305 | 4.2 | 6.9 | 280 |
| 7 | 10.3 | 4.8 | 480 | <0.2 | 6.5 | 45 | 1.0 | 5.8 | 350 | 4.3 | 6.9 | 290 |
| 15 | 11.2 | 4.4 | 520 | <0.2 | 6.3 | -20 | 1.3 | 5.5 | 370 | 4.2 | 6.9 | 285 |
| 44 | 11.1 | 4.2 | 575 | <0.2 | 6.5 | -15 | 4.5 | 4.7 | 460 | 4.1 | 6.9 | 290 |

non-value minerals causing unwanted flotation

- Dispersants and flocculants affecting processes in ways additional to their intended use.

## Integrated methodology

The integrated methodological approach developed in the IWRI is summarized in Figure 1.

The methodology combines: solution survey and modelling; microbiological survey; mineral surface analysis and modelling; process response. The scheme for calculation of contribution to solution species, precipitates and mineral surfaces from dissolution of mineral phases, reagents and water samples, is illustrated in Figure 2. In Figure 1, it has been possible to match the predicted (model) pulp chemistry with that measured from surveys of the solution and mineral surfaces.

The solution survey and modelling together with the microbiological survey is conducted, as indicated in Figure 1, on all water supplies and recycle streams. In addition to a full assay for all cationic and anionic species, pH, Eh, DO, TOC and TDS are also measured. Plate counts and effects of microbiological action in aerobic and anaerobic conditions with time of storage are surveyed. Extraction of oxidized colloidal material by complexation with EDTA is compared with solution assay with and without acidification.

The solution is modelled thermodynamically using one of several alternative speciation and precipitation modelling packages, namely: GEOCHEM-PC for redox speciation and prediction of precipitating phases; MINTEQ for effects of solution temperature on speciation and precipitation; or SOLGASWATER for Pourbaix diagrams of pH-Eh speciation control. The results of the modelling predict phases that, subject to kinetic control, are likely to precipitate or are in equilibrium with this solution together with the speciation of the remaining dissolved ions. This prediction allows correlation with the measured colloidal material and species on mineral particle surfaces. Solution modelling has also been used to predict the effects of varied additions of pH modifiers (e.g. soda ash) on speciation, buffering action and the fate of dispersant species (e.g. hexametaphosphate).

Surface analysis of mineral particle surfaces of different phases is conducted by using a combination of XPS and TOF-SIMS with chemical extraction of oxidized species in surface layers using EDTA complexation. Surface/bulk ratios for individual elements and species are determined before and after desliming. The information defines detachable particles (e.g. clays) and precipitates (e.g. magnesium carbonate) as well as adsorbed layers (e.g. copper(I), calcium sulphate).

The methodology has been trialled in two full sulphide flotation plant surveys of solution, colloidal material and mineral surfaces across the primary water supplies, recycle streams, primary grind and rougher flotation process operations. *The survey methodology was successful in determining the proportion of solution and mineral surface species arising from three sources: recycle circuit water streams; dissolution in grinding or attritioning; and reagent addition rates.*

*This methodology can therefore be applied to correlation of the species in solution and on mineral surfaces with separation processes, leaching kinetics or other process response.*

In this way, different process steps in the circuit can be surveyed and matched to process response in order to build up a full circuit model.

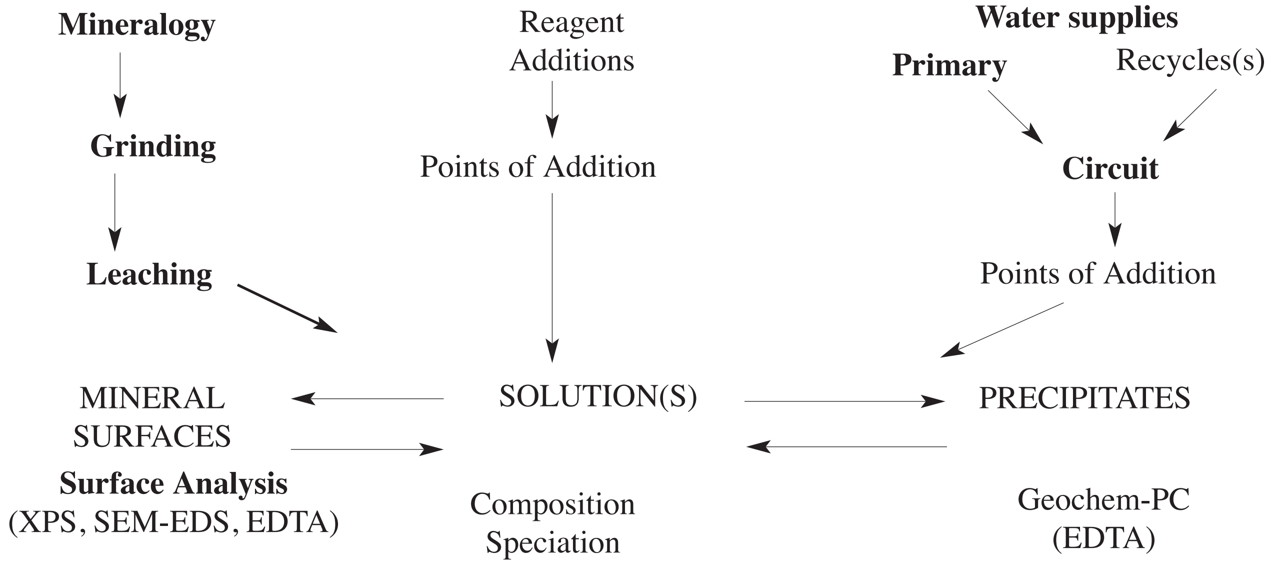

**Figure 2—Schematic contributions to solution, precipitates and mineral surfaces**

The microbiological survey data to date has been used primarily to evaluate additional effects on water quality due to storage and continuing reaction in tailings and recycle streams. This methodology requires further development in order to understand possible effects in circuit during processing. This aim will be assisted by more data at different process steps through the circuit as a function of time, pH, Eh, aeration etc.). It is also clear that more research will need to be conducted on the effects of microbiological action on laboratory testing in order to simulate water quality similar to that in plant operation.

## Treatment methods and achievements

The specific achievements from the methodology applied in plant and laboratory testing have arisen from the information determining the origin of dissolved, precipitated and surface species from water supplies, recycle, ore grinding and reagent additions. The contributions from each source can be quantitatively established. Full plant surveys for dissolved oxygen, pH, Eh, dissolved cationic, anionic and organic species with colloidally precipitated species have shown wide variation through circuits. These variations can occur on an hourly or daily basis and are usually not recognized in current survey practice. The correlation of changes in circuit water quality both within the circuit (e.g. after aeration, reagent additions etc.) and on ageing and laboratory studies due to microbiological action explained above have been established in these surveys. The presence or absence of dissolved oxygen in the circuit, together with determinative changes in pH and Eh, can directly affect flotation recovery and selectivity.

In previous case studies, a variety of methods for control of solution species, precipitates, adsorbed species and surface layers have been trialled including:

- *Reagent replacement.* The substitution of soda ash (sodium carbonate) for lime in the galena flotation section of the Hilton Concentrator at MIM increased the flotation rate due to reduction in the presence of calcium sulphate precipitate at the surface of the sulphide minerals. Before soda ash addition, surface analysis revealed that there was considerably less calcium sulphate on concentrate particles relative to those occurring in the tailings sample suggesting that the flotation process is selective against minerals which have this precipitate layer. After soda ash addition, galena recovery was increased through both the rougher and scavenger banks, e.g. after 30 minutes residence time from 68% to 78%. There was also a significant increase in recovery of sphalerite but much less effect on recovery of pyrite. Solution analyses showed that calcium concentration in solution decreased from $1.5\times10^{-2}$ to $6.7\times10^{-4}$M and magnesium from $4.0\times10^{-3}$ to $7.4\times10^{-4}$M. Surface analysis gave clear evidence for the removal of calcium sulphate from the mineral surfaces without concomitant surface precipitation of calcium carbonate due to dispersion of this precipitate as crystalline precipitates[1]. Successive precipitation/dissolution of calcium and magnesium salts and the pH buffering action produced by incremental additions of sodium carbonate can be directly modelled using the packages described above. Figure 3 illustrates this sequence.
- *Recombination of water streams*. After a full site survey of primary and recycle water streams contributing to circuit process water at one plant, we were able to improve flotation recovery of copper by 4% after recommendations for stabilization of water supply using different combinations of these recycle streams. In particular, one recycle stream arising from mined pit catchment was contributing the majority of species producing precipitated and adsorbed interfering surface layers and this was removed from recycle. At another site, identification of the changing ratio of thickener overflow to tailings dam decant return on an hourly basis was identified producing major changes in pH, Eh and dissolved species in the circuit water returned to the primary grind and makedown for rougher flotation. Stabilization of water supply quality using more consistent combination of streams was recommended together with control of these factors in the circuit water tank.

- *Organic species removal*. In one case study, replacement of a significant percentage of fresh makeup water supplied from township potable water distribution mains (at a cost of $95c/k*l*) with secondary and tertiary treated sewage effluent (supplied free of charge) initially produced processing problems due to a relatively high TOC content of the sewage effluent. A cost-effective, advanced effluent treatment process was developed to remove the organic contaminants in the effluent returning a flotation performance slightly improved on the potable water performance. In a second case study, removal of organic species from recycle water streams by activated carbon produced a statistically significant improvement in nickel grade and recovery using lock-cycle, rougher/cleaner flotation testing. Removal of 63% of TOC was measured together with reduction of more than 90% in total suspended solids. This treatment is apparently also effective for microbiological control with a pH reduction from 6.8 to 6.3 compared with the same sample without activated carbon treatment showing a pH drop from 7.2 to 3.6 in 20 days storage at room temperature
- *pH adjustment*. In some cases, relatively small shifts in pH can dissolve precipitated species interfering with recovery and selectivity. For instance, in one case study, it was established using the integrated methodology that very high surface coverages of sulphide minerals were occurring due to precipitation of zinc hydroxide (with some copper(II) hydroxide) at pH>8. Shifting the pH below 6.5 dissolved these two surface precipitated species giving consistent long-term improvements in separation of sphalerite from galena concentrates and in sphalerite recovery kinetics. In other case studies, it has been established that improved copper activation of sphalerite and pyrite can be achieved by addition at pH<6.5 to give Cu(I) without interference from Cu(II) hydroxide followed by flotation at higher pH. The form of the copper and Cu(I)-collector species can be directly established from surface analysis. Figure 3 also shows that removal of Mg from solution using soda ash is not achieved until the pH is above 8.0, a result in accord with plant trials on soda ash addition rates

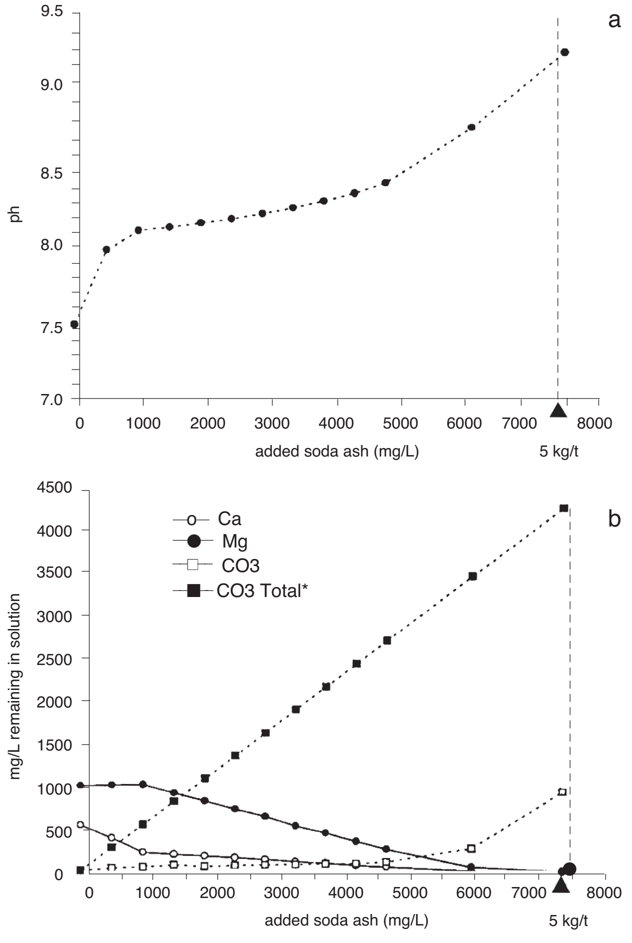

**Figure 3(a)—pH of mill discharge solution versus soda ash addition. (b) concentration of species remaining in solution versus soda ash addition. *denotes precipitates included**

- *Removal of precipitated and colloidal species*. A variety of treatment methods can be used to disperse precipitated colloidal species from mineral particle surfaces. Case studies have been carried out using chemical dispersants (e.g. polyphosphates, sodium carbonate, polymeric dispersants, pH change) and physical dispersion (e.g. high intensity conditioning, hydrocyclone action, ultrasonication, attritioning with quartz)[2]. These methods can be particularly effective for removal of metal (particularly iron) hydroxides and sulphur-oxy species either as adsorbed layers or precipitated colloidal particles. In particular, the shearing action of the hydrocyclone has been shown[3] to be highly effective in removing surface layers thereby exposing more hydrophobic sulphur-rich reaction layers in the sulphide mineral surfaces with measured higher contact angles. In mineral sands operations, improvements in electrostatic separation can be achieved by improved attritioner action with the addition of preconditioning (acid dissolution) and chemical dispersion of material removed during the attritioning. Without the dispersant addition, attritioning tends to re-smear aluminium and iron hydroxides back on to zircon and ilmenite surfaces as shown in surface analysis. Colloidally-dispersed precipitates and particles can be effectively removed by dissolved air flotation (generating micro bubbles) or, in some cases, by hydrocyclone separation. Trials of dissolved air flotation in water treatment have shown removal of more than 90% of suspended solids. In many recycle water streams, this recirculating load of precipitates, particularly calcium sulphate, magnesium carbonate, iron hydroxides, aluminium hydroxides, precipitated silica and clay particles, are the main contributions to mineral surface contamination and can be effectively removed in high-throughput DAF processing
- *Flocculation and aggregation*. In two case studies, a major contribution of gangue minerals to concentrate was shown to arise from oppositely charged surfaces of the sulphide mineral and gangue particles at the pH in the flotation. Hence, aggregation by piggy-backing

caused muscovite in one case and phlogopite in the other case to attach to conditioned value particles. Control of this aggregation mechanism can be achieved through either pH change to the regime in which the particle surfaces are similarly charged (e.g. 8.5 to 7.0) or by addition of specific depressants designed to alter the charge on the gangue mineral surfaces. Aluminium salts and polyphosphates have been used in this category. Floccs and aggregates can also be controlled with high intensity conditioning and high shear action as for removal of precipitated and colloidal species. In this conditioning, the kinetics of flotation after the high energy or high shear process are critical

- *Oxidation or reduction control*. The removal of iron hydroxides in particular can be achieved by reductive chemical conditioning using reagents such as dithionite or hydrazine. For instance, surface analysis combined with solution assay has demonstrated the presence of extremely small hematite and goethite particles (1–3nm) of iron oxide/hydroxide adhering to the surfaces of gibbsite, boehmite and kaolinite in bauxite ultrafines. These particles can be removed by mild reductive leaching using a regenerative dithionite process[4] reducing the total iron oxide content from 5.1wt.% to 1.7wt.% (as lattice-substituted iron). Further discrimination between the clean particles is also possible using chemical dispersion, sedimentation, centrifugation and flocculation techniques. These methods are more costly but can be reduced by regenerative recycling of the reagents in electrochemical treatment. Oxidation control using peroxide and, in some cases, ferric ion, is applied in several case studies where selective oxidation of surfaces (e.g. pyrite, pyrrhotite, arsenopyrite) is required to control rates of dissolution by diffusion-limiting surface layers or to control flotation recovery. Precipitation before removal of colloidal species (e.g. DAF) may also require an oxidative treatment.

## Conclusions

The establishment of the integrated solution/surface/process response methodology applied in both plant and laboratory has enabled a more comprehensive understanding and control of water quality in minerals separation processing. This, with process engineering (including comminution and systems modelling) and pulp chemistry, completes the cycle of control parameters in circuit operation. The insights gained from the full methodology and full circuit surveys have already revealed major considerations in process control—some of which are explored in this paper. In addition to determining the origin of dissolved, precipitated and surface species from different water streams, ore grinding and reagent additions, the recognition of uncontrolled microbiological action has added a new dimension to some circuit operations.

We now have a considerable variety of different treatment options for the problems identified by the methodology. In some cases, a relatively simple fix can be applied through a water management protocol, recognizing the properties of different water streams, to maintain a consistent circuit water quality and eliminate short-term variations. This can allow stabilization of plant operation without the need for new process steps, either chemical or physical. In other cases, removal of interfering species is required using one or more of the treatment methods described above. The choice of method (and cost) can now be informed by previous case studies with each of these treatment methods.

## References

1. GRANO, S.R., WONG, P.L., SKINNER, W.M., JOHNSON, N.W., and RALSTON, J. Detection and control of calcium sulfate precipitation in the Hilton concentrator of Mt. Isa Mines, Ltd., Australia. *Proc. XIX Int. J. Min. Proc. Congress*, 3(29), 1996. pp. 171–179.
2. CLARKE, P., FORNASIERO, D., RALSTON, J., and SMART, R.ST.C. A study of the removal of oxidation products from sulfide mineral surfaces. *Mineral. Eng.* 8, 1995. pp. 1347–1357.
3. PRESTIDGE, C.A. and RALSTON, J. Contact angle studies of galena particles. *J. Colloid Interface Sci.* 172, 1995a. pp. 302–310.
4. KUYS, K., RALSTON, J., SMART, R.ST.C., SOBIERAJ, S., WOOD, R., and TURNER, P.S. Surface characterisation, iron removal and enrichment of bauxite ultrafines. *Min. Eng.*, 3, 1990. pp. 421–435.

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