Effects of scale of kinetic tests on leachate chemistry prediction

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Abstract

Kinetic tests, performed at varying scales under either ambient field or controlled laboratory conditions, form the most commonly used method within the mining industry for predictive assessment of the chemical quality of 'contact water' which may be generated through interaction of runoff or seepage with exposed mine wall rock, waste rock or tailings. At the laboratory scale, such tests are generally performed in accredited installations which deploy industry-standard protocols such as those established by MEND, ASTM and AMIRA. In contrast, field-scale tests are subject to no standardized protocols and tend to be undertaken on a bespoke basis, often dictated by sample material availability, climate and cost.

Given the high reliance placed on kinetic tests for long-term mine water quality prediction, an understanding of the extent to which such tests may be subject to bias through variations of test design or ambient conditions is extremely important. This paper demonstrates the variance observed between tests performed at both laboratory and field scales for a range of mining operations or new development projects across Australia and Latin America. In all cases, the sample materials subject to testing at these contrasting scales were either identical or closely analogous. Differences in water quality evolution trends are regarded as indicative of the effects of test scale, mode of operation and ambient conditions with respect to factors such as sample granulometry, homogeneity and ambient temperature, humidity or redox regime.

Key words: Kinetic testing, ARD, Scaling

Introduction

Accurate prediction of mine water quality prior to the initiation of new mining operations, or forecasting long-term evolution of mine water quality throughout the life of a mine is recognized in the minerals industry as critical for the assessment of project impacts and the pro-active design (and cost-estimation) of mitigation measures, including water treatment. Most commonly, prediction of future acid rock drainage (ARD) and/or metal leaching (ML) risks is undertaken through 'kinetic testing' of samples considered representative of material to be exposed as mine wall rock, or to be stored as waste rock or tailings throughout mine life, with subsequent extrapolation of test results to the mine facility scale, often performed through numerical geochemical modelling.

Kinetic tests are routinely performed at a range of scales and may be conducted under either laboratory or field conditions. All such tests involve the generation of leachate over a sustained period of time (ranging from months to years) through the interaction of infiltrating water with rock or tailings placed in a column or on a test pad. The majority of laboratory scale tests are performed using a relatively small sample mass, ranging from 1 to 10 kg. Most are performed in accredited laboratories in accordance with prescribed protocols established by bodies such as MEND (Canada; MEND 2009), ASTM (USA; ASTM 2013) and AMIRA (Australia; AMIRA International Ltd 2002). Each of these protocols is subject to some degree of idiosyncrasy. As a consequence, variations of weathering reaction rates and attendant solution chemistry may arise in response to differing conditions with respect to factors such as sample granulometry, temperature, solution irrigation rate and moisture content.

Field-scale tests are typically performed at a larger scale than those undertaken in the laboratory, with sample masses commonly ranging from 100 kg to several tons. Test design is generally bespoke and

may involve the construction of large columns, barrels, cribs or leach pads. Irrigation may be undertaken artificially (to provide some level of temporal continuity of leachate production) or subject to natural irrigation by precipitation.

Given the reliance on kinetic tests as an industry-standard tool for the prediction of contact water quality, an understanding of the extent to which the results of such tests may be influenced by scale, design or mode of operation is fundamental for successful data extrapolation and, ultimately, quantitative hazard characterization. This paper provides insight into the nature and magnitude of bias which may be introduced to kinetic tests as a result of variations of scale and design, founded on numerous instances in which tests involving identical or closely analogous sample materials have been executed in parallel. These examples collectively encompass a wide spectrum of geological settings, ore/waste mineralogical compositions and climatic regimes across Latin America and Australia.

Sites and data

Case study settings

A comparative analysis of kinetic test datasets generated from laboratory and field-scale tests of essentially identical sample materials from five locations, as summarized in Table 1, was undertaken to elucidate potential effects of kinetic test design and scale on leachate evolution. The selected sites differ markedly in terms of geological setting, ore/waste mineralogy and climatic regime, thus providing a broad basis for assessment.

Table 1 Summary of test settings and methods

Site	Country	Metallogenic setting	Climate
Boddington	Australia	Archean shear-zone hosted Au	Sub-tropical, temperate
Pascua Lama	Chile / Argentina	High sulphidation epithermal system	Cool, arid
Alumbrera	Argentina	Cu porphyry	Cool, arid
Agua Rica	Argentina	Cu porphyry	Cool, temperate
Gaby	Ecuador	Au porphyry	Tropical, humid

Boddington, Western Australia

Boddington mine is operated by Newmont Boddington Gold (NBG). Gold is exploited from two orebodies, Wandoo North and South, hosted in the Saddleback Greenstone Belt (SGB) of Archean age. Gold mineralization is largely contained within diorite stocks emplaced in a sequence of volcanics ranging in composition from andesite to dacite. Mineralization is typical of Archean shear-zone hosted vein and stockwork systems, with Au occurring in association with minor chalcopyrite, phyrrotite and pyrite. Wandoo North is characterized by relatively intense chlorite/clinozoisite alteration plus minor epidote and trace calcite. Wandoo South is virtually devoid of calcite, with actinolite and albite pervasive.

The environmental geochemistry of Boddington arguably renders kinetic tests of waste rock more susceptible to the influence of subtle variations of test design or operating condition than is the case for other localities listed in Table 1. This reflects the presence of sulphides at trace abundances (70% of run-of-mine waste rock holds total S at <0.2%) in conjunction with effectively zero carbonate neutralization capacity (calcite abundances are routinely <0.01%). This has resulted in poor success throughout historical mine operations in the deployment of ABA and NAG test indices as a basis for differentiating potentially acid forming (PAF) and non-acid forming (NAF) rock in the run-of-mine waste stream. The former approach has been found to be uninformative as net-neutralization potential (NNP) values are virtually always in the range classifiable as 'uncertain' (between -20 and +20 kg/T $CaCO_3$). NAG tests have been found to be of equally limited value as virtually all samples yield pH values of <4.5 (conventionally classifiable as PAF) while NAG acidity values fall below <1 kg/T $CaCO_3$ (conventionally classifiable as NAF or indeterminate).

Column and humidity cell testing performed on Boddington waste rock by numerous consultants over a period spanning more than a decade to 2010 produced results which appeared inconsistent with rock classifications founded on static test indices. Extremely low (<0.2%) S content samples variably

produced leachates ranging in pH between 3.2 and 7.5. Explanation for this highly variable weathering behaviour was first elucidated by Graeme Campbell and Associates Pty Ltd (GCA) through controlled laboratory tests performed using a modified AMIRA format (Campbell et al. 2012). In the trace sulphide, zero carbonate buffering system, maintenance of a near-neutral pH in GCA test columns was shown to be dependent on an aluminosilicate buffering reaction, functional at the inter-granular scale. This buffering mechanism was inferred from the GCA columns to sustain near-neutral pH conditions subject to a proton flux threshold equivalent, in terms of a sulphide oxidation rate, to around 5 mg/kg/day SO_4 yield. At higher rates of sulphide oxidation, the kinetics of alumino-silicate buffering are overwhelmed, resulting in depression of pH.

Pascua Lama, Chile/Argentina

Pascua-Lama lies at an altitude ranging from 4000 to 5300 m a.s.l. in the northern sector of the El Indio Belt, a regional metallogenic province which transgresses the central Chilean and Argentinian Andes. It is potentially a world class Au-Ag-Cu deposit hosted in intrusive, sub-volcanic and volcanic rocks of Late Paleozoic to Late Tertiary age. Hydrothermal activity and mineralization at ca. 8–9 Ma was largely associated with breccia emplacement at the intersections of a series of high angle faults. These are interpreted as the product of explosive phreatomagmatic activity during the waning stages of Miocene volcanism.

Pascua-Lama is in most respects a classic high-sulfidation epithermal system, characterized by a hypogene suite of sulphides and sulphates. Up to 50% of the sulphide assemblage is composed of pyrite and tetrahedrite-tennantite. The deposit shows evidence of successive phases of alteration, both with and without precious metal deposition. Early advanced argillic alteration was predominantly characterized by quartz-alunite-pyrite. This was followed by brecciation, and subsequently a second stage of advanced argillic alteration characterized by alunite-pyrite-enargite. Much of the zone of advanced argillic alteration is overlain by a silica cap, varying in thickness from 100–300 m.

Pascua Lama is distinguished from most other high sulfidation epithermal systems by an unusually high abundance of hypogene sulphate minerals (coquimbite, volteite, alunite and jarosite), a component of which is of high solubility. This has important implications for the environmental geology of the deposit. Both field and laboratory investigations suggest that contact water evolution is controlled by a complex range of processes involving both sulphide oxidation and sulphate dissolution. While both of these groups of processes constitute proton generating reactions, the dissolution of alunite and attendant precipitation of gibbsite induces buffering at around pH 3.5, subject to suitably constrained rates of proton flux from the oxidation of pyrite or other sulphides. In analogous fashion to the silicate buffering mechanisms described for Boddington (above), the ultimate pH and wider chemical composition of Pascua Lama contact-water may therefore be equally influenced by rates of oxidation as by sulphide abundance or mineralogy.

Alumbrera, Argentina

Alumbrera is a Cu-Au porphyry deposit which has been exploited via a single open pit since the 1990s. Its surface expression was originally that of a large bowl located at around 2600 m a.s.l. The deposit consists of several dacite-porphyry plugs which were intruded at around 8 Ma beneath the Farallon Negro volcano. Syn-intrusive hydrothermal fluid circulation resulted in pervasive alteration and mineralization of the porphyritic plugs and their volcanic host rocks. Subsequent erosion exposed the upper part of the volcano and its underlying porphyry system.

Stocks forming the Alumbrera deposit are compositionally similar, with phenocrysts of plagioclase, hornblende, biotite and quartz in a matrix of fine-grained quartz, K-feldspar, and minor plagioclase, biotite, and magnetite. High Cu-Au grades are associated with the zone of potassic alteration, surrounded by a larger zone of secondary biotite. The biotite zone is surrounded by epidote-chlorite alteration, lacking significant sulfides. Weaker, post-mineralization feldspar destructive alteration occurs both inside and outside this shell. Deposition of Cu-Au occurred within an assemblage comprising bornite-chalcopyrite-magnetite. Later pyrite veins cross-cut the zone of primary mineralization.

In some respects a classically zoned porphyry system, the environmental geochemistry of Alumbrera is distinguished by a high frequency of post-mineralization gypsum veining. This is pervasive throughout

the deposit with the exception of a thin blanket of oxidation and secondary Cu enrichment in which the gypsum veins have been removed. The presence of this source of soluble sulphate is significant to the interpretation of kinetic tests as SO_4 yields appear poorly correlated to rates of sulphide oxidation.

Agua Rica, Argentina

Agua Rica is located in the Province of Catamarca, Argentina. It is a classical porphyry Cu system of late-Tertiary age, with some evidence of epithermal overprinting. The deposit is differentiated from Alumbrera (located only 60 km to the north of Agua Rica) by a significantly more extensive zone of secondary mineralization, dominated by chalcocite and covellite.

Primary mineralization was developed along the contact between early Paleozoic meta-sediments of the Sierra Anconquija Complex and a series of intrusions dominated by the Capillitas Granite. The intrusive rocks include multiple quartz-feldspar porphyries in association with which several phases of hydrothermal breccia emplacement occurred. The Melcho Intrusive Complex is an early multiphase porphyritic unit which is weakly mineralized and occupies the southern third of the project area. The main mineralized intrusions are centrally located and consist of the Seca and Trampeadero stocks. These are cross-cut by a large breccia pipe. In the northern third of the project area, a weakly mineralized igneous breccia occurs along with a biotite porphyry and a diatreme breccia which appears largely barren. The metasedimentary host rock exhibits mineralized contact zones.

Both the primary and secondary zones of mineralization at Agua Rica are predominantly net-acid forming. In the primary zone, this reflects the presence of assemblages of pyrite, bornite and chalcopyrite (with minor Zn sulphides) at up to 15% abundance. In the secondary blanket, bi-metal sulphides dominate the copper inventory. These are acid generating exclusively on oxidation by ferric Fe.

Gaby, Ecuador

Gaby is a large, low grade Au porphyry system located in the coastal lowland of the Province of Azuay, Ecuador. It occupies a humid tropical setting with annual rainfall ranging from 2000 to 4000 mm. It is, to date, unexploited with the exception of a number of small-scale underground workings which have advanced along the trace of a number of post-pophryry gold-bearing veins (the Tama Vein system).

The Gaby porphyry was emplaced into a sequence of Cretaceous volcanic host rocks during the Late Tertiary period. It comprises a tonalite intrusion, plus a series of breccias. These display pervasive argillic, potassic and propyllitic alteration with the associated development of veins and stockworks of quartz plus chalcopyrite, bornite, pyrite, pyrrhotite and gold. A zone of oxidation extends to depths of up to 50 m at the centre of the deposit. Secondary Au/Cu enrichment is otherwise absent.

The environmental geochemistry of Gaby is uncomplex. With the exception of a relatively small component of the mineralized zone which extends into basaltic host-rocks of the Pallatanga Unit, virtually all potential ore and waste grade material is devoid of carbonate neutralization capacity, with high abundances of pyrite (of the order of 3 to 6%). An extensive static testing program performed in 2005 resulted in the classification of >80% of the rock mass within a feasibility level open pit design developed by former concession holder, International Minerals Corporation, as PAF.

Test data sources

Table 2 provides a summary of the kinetic tests from which leachate data were compiled for use in comparative analysis of the effects of scale on rock weathering behaviour and associated contact water chemistry evolution. For each study location, sub-samples from a single stock of material were typically generated for use in the laboratory and field scale tests. The respective sub-samples were subject to bulk geochemical and/or mineralogical characterization to confirm consistency of composition of the laboratory and field scale test materials. Table 3 provides a summary of the characteristics of each pair of samples.

Table 2 Summary of laboratory and field scale tests of rock materials applied for assessment of scale effects.

Site	Boddington		Pascua Lama		Gaby		Alumbrera		Agua Rica	
	Lab	Field	Lab	Field	Lab	Field	Lab	Field	Lab	Field
Design	AMIRA column	PVC tank	MEND HCT	Field crib	MEND HCT	Field barrel	MEND HCT	Field pad	MEND HCT	Field pad
Sample wt (kg)	1	15000	1	2600 – 3000	1	200	1	500	1	500
Duration (weeks)	128	128	33	12	36	26	40	30	24	162
Irrigation	Weekly irrigation	Natural precipitation	Weekly irrigation	Irrigated based on annual average precipitation	Weekly irrigation	Natural precipitation	Weekly irrigation	Monthly cycle, 2000 litres in 28 days	Weekly irrigation	Natural precipitation
Total sample numbers	10	6	5	5	10	7	7	8	12	5
Comparison samples	C1 C2 C4	B1 B2 B5	HCT1 HCT5	MCRIB1 MCRIB4	HCT2 HCT3	T1 T3	HCT1 HCT5	P5 P8	HCT-11	Pad C

Table 3 Acid base accounting and basic mineralogical characteristics of samples used for assessment of kinetic test scale effects.

Site	Samples Lab	Field	LAM description	Total S (%)	Sulphate S (%)	AP (kg $CaCO_3$/t)*	Carbonate NP (kg $CaCO_3$/t)	Principal mineralogical components (from XRD) (%)
Boddington	C1	B1	Diorite - actinolite	0.2	<0.01	6.3	1.8	Biotite (9%), Chlorite (2%), Hornblende (2%)
	C2	B2	Diorite - Clinozoisite	0.2	<0.01	6.3	2.0	Pyrite (0.3%), Chalcopyrite 0.1%), Biotite (18%)
	C4	B5	Diorite - Silica-biotite / actinolite	0.35	<0.01	10.9	1.5	Pyrrhotite (0.3%), Chalcopyrite (0.1%), Sericite (13%)
Pascua Lama	HCT1	MCRIB1	Steam heated granites	0.9	3.6	28.1	0.8	Alunite (4.5%), K-feldspar (3%), Gypsum (0.5%)
	HCT5	MCRIB4	Alunite altered granites	2.1	1.2	65.6	1.2	Alunite (14%), Gypsum (2.2%), Jarosite (1.1%), Pyrite (0.5%)
Gaby	HCT2	T1	Hornblende porphyry	0.9	0.02	27	8	Pyrite (1%), Actinolite (12%)
	HCT3	T3	Avila Breccia	2.2	0.02	69	5.3	Actinolite (47%), Pyrite (2.6%), Pyrrhotite (1.5%), Chalcopyrite (0.4%)
Alumbrera	HCT1	P5	Andesite - K alteration	6	3	94	6	contains Gypsum**
	HCT5	P8	Andesite - epidote chlorite alteration	0.02	<0.01	0.6	97	
Agua Rica	HC11	Pileta C	Trampeadero porphyry	2.0	<0.01	63		Pyrite (2%), Bornite (0.2%), Chalcopyrite (0.2%)

*Calculated from sulphide S

**Indicated by bulk geochemistry and geological description

Results and discussion

Leachate pH and solute concentration trends

Median values of pH, plus the SO_4 and Cu concentrations in leachates from both laboratory and field scale kinetic tests from each selected location are shown in Table 4. The evolution of pH and sulphate concentration in leachates from both types of test are shown in Figure 1. Values of pH in the field tests are routinely lower than in the corresponding laboratory test. Solute concentrations are generally higher.

The nature and magnitude of observed differences in pH evolution in leachates from the laboratory and field scale test pairs (Figure 1) contrasts significantly between sites. In samples characterized by high acid production potentials (with sulphide abundances in excess of 2% or, in the case of one of the two Pascua Lama samples, a significant hypogene sulphate presence), comparably rapid rates of sulphide oxidation are evident in the field tests from their initiation. This results in a more rapid rate of leachate pH depression throughout all phases of the tests. In contrast, two of the Boddington sample pairs (C1-B1, C2-B2) display pH levels which are closely comparable through the first 20 or more weeks of weathering. Thereafter, the field columns are subject to significantly accelerated acidification, with pH values after ca. 140 weeks in the order of 4 compared with laboratory column leachate levels in the pH 5 to 6 range. This differential pH evolution is inferred to arise from the periodic accumulation and subsequent flushing of sulphide oxidation products in the field tests in response to natural (climatic) variations of irrigation regime. These periodic 'pulses' of acidity overwhelm the weak, kinetically-constrained, silicate buffering system characteristic of Boddington rock. This effect does not occur in the laboratory due to the more limited 'storage' of acidity arising from weekly irrigation.

Table 4 Median values of pH, concentrations of sulphate and copper in laboratory and field scale tests of analogous materials.

Site	Laboratory test	Field test	pH (pH units)		SO$_4$ (mg/l)		Cu (mg/l)	
			Laboratory	Field	Laboratory	Field	Laboratory	Field
Boddington	C1	B1	6.1	4.6	29.5	720	0.004	1.266
	C2	B2	5.5	3.7	7.0	745	0.1	31
	C4	B5	5.9	3.1	63.0	3900	0.002	14
Pascua Lama	HCT1	MCRIB1	3.8	3.0	47	2528	0.069	1.5
	HCT5	MCRIB4	3.9	3.0	668	4040	0.230	5.2
Gaby	HCT2	T1	6.2	3.3	26	827	0.119	25.4
	HCT3	T3	5.3	2.6	46	3030	0.175	22.9
Alumbrera	HCT1	P5	6.9	7.2	1037	1463	0.100	0.60
	HCT5	P8	8.6	7.7	0.04	1185	0.020	0.025
Agua Rica	HC11	Pileta C	5.1	2.5	15	ND	5.21	17.20

Role of sulphide oxidation rates

Further elucidation of the causes of differential pH (and solute concentration) evolution in the pairs of field and column tests for which results are presented in Figure 1 is provided from analysis of the estimated sulphide oxidation rates (SOR) characteristic of each test. Table 5 shows the rate of sulphate yield from each test on a mass specific basis, with values shown to represent the average and maximum levels recorded in each case. Sulphate yield may in the majority of the tests be regarded as a reasonable proxy of sulphide oxidation rate. The principal exceptions to this include the HCT1 - P5 sample pair from Alumbrera in which sulphate concentrations in both laboratory and field test leachates are predominantly controlled by gypsum dissolution, and the Pascua Lama sample pairs in which dissolution of alunite, jarosite and other hypogene sulphates is the dominant influence.
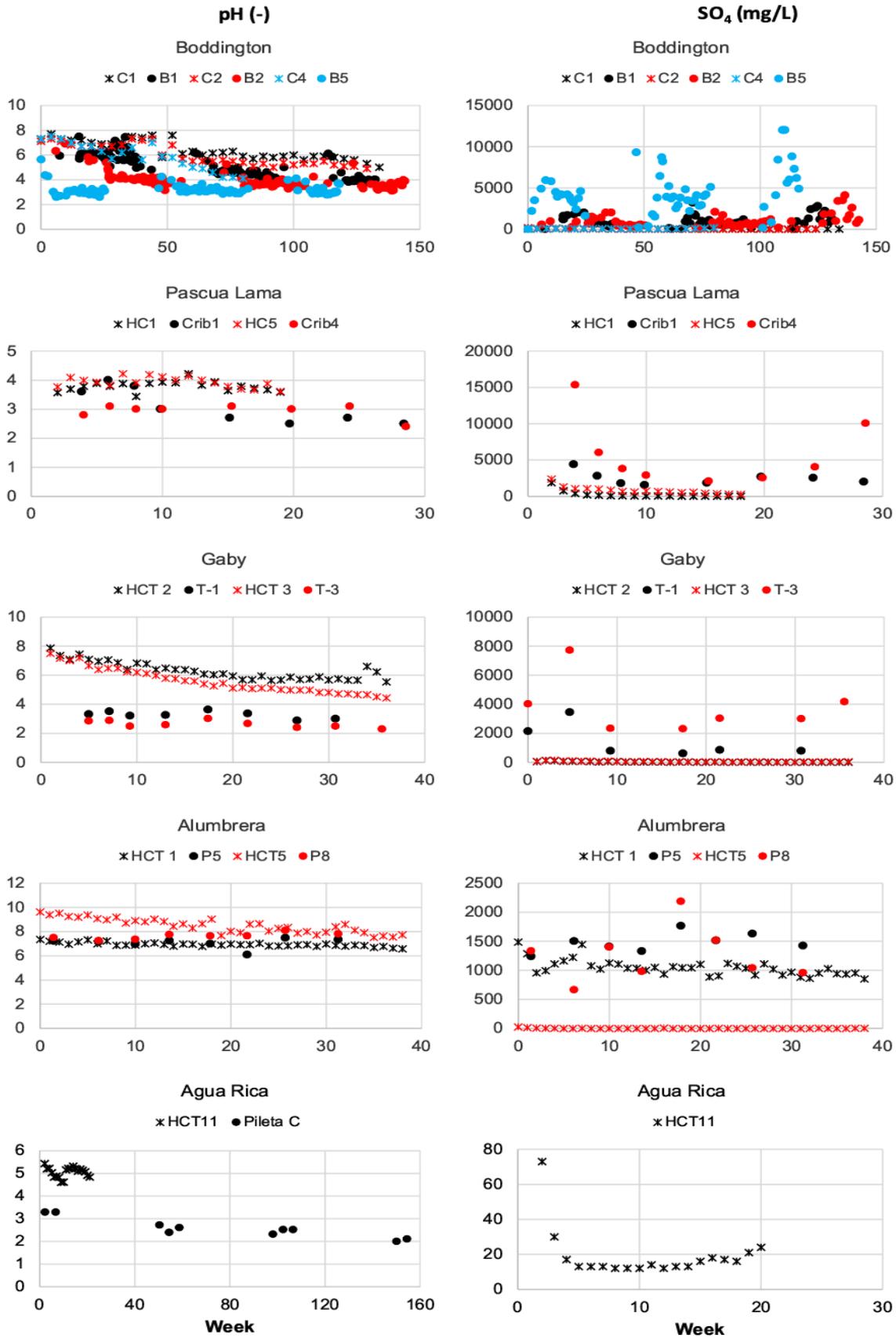
Figure 1 *Evolution of pH and sulphate concentrations in laboratory and field scale tests*

In several test pairs the more rapid depression of leachate pH level over time, with associated increase of solute load, can be equated to a systematically higher level of sulphide oxidation from an early stage in the test period. Typically this is seen in samples where significant net acid production potential is indicated by ABA analyses, with AP >20 kg/T $CaCO_3$ equivalent, with low, but some carbonate buffering capacity present (Table 3). The Gaby pair HCT3 - T3 reflects this condition. In the laboratory test, an average SOR of around 9 mg/kg/wk appears initially to be countered by carbonate dissolution in the early stages of the test, and to some extent throughout. In contrast a much higher rate (in excess of 70 mg/kg/wk) in the field test consumes carbonate rapidly and permits an acute depression of pH.

In certain tests, the relationship between SOR and pH evolution in the paired laboratory and field tests is more complex. This is demonstrated by the Boddington sample pairs C1 – B1 and C2 – B2, characterized by trace sulphides (0.2%) in a matrix virtually devoid of carbonate. In these test pairs, the average SOR is actually greater in the laboratory environment than in the field test. However, the range of SORs recorded over time, and in particular the maxima recorded during the test period are greater in the field tests. In the laboratory tests, buffering by non-carbonate mechanisms appears adequate to counter the proton yields associated with a relatively constant SOR of around 5 mg/kg/wk with excursions of up to no more than around 14 mg/kg/wk. The buffering system is not able to react effectively to sporadic maxima of up to 20 mg/kg/wk or greater as observed in seasonal 'first-flush' events in the field setting.

Table 5 Average and maximum mass-normalised sulphide oxidation rates (SOR) in laboratory and field scale tests of analogous materials.

Site	Laboratory test	Field test	Average laboratory SOR (mg/kg/week)	Maximum laboratory SOR (mg/kg/week)	Average field SOR (mg/kg/week)	Maximum field SOR (mg/kg/week)
Boddington	C1	B1	5	14	3	19
	C2	B2	5	14	3	22
	C4	B5	10	25	13	72
Pascua Lama	HCT1	MCRIB1	10	46	97	231
	HCT5	MCRIB4	60	106	199	721
Gaby	HCT2	T1	17	66	19	148
	HCT3	T3	9	85	76	153
Alumbrera*	HCT1	P5	515	744	46	54
	HCT5	P8	1	12	226	265
Agua Rica	HC11	Pileta C	9	31	No SO$_4$ data	

*Assumes a volume of 500 ml discharging from the HCT

Causes of differential sulphide oxidation rate

Investigations performed for paired laboratory and field tests involving either (a) empirical correlation of variations of SOR with environmental factors such as temperature and precipitation or (b) experimental variation of specific factors such as temperature and moisture cycles in laboratory columns has provided strong evidence to explain the generally more aggressive oxidation regime created in field scale versus laboratory tests. The specific factors considered of importance in this context include the following:

1) Sample homogeneity. In virtually all laboratory scale tests, the preparation of samples involved crushing to a uniform sub-2 mm or finer grain size. This has the fundamental effect of creating a relatively homogeneous medium in terms of mineralogy. Under such conditions, sulphide oxidation throughout the test sample is likely to be uniformly equilibrated with buffering reactions, including carbonate dissolution. This stops the generation of localized zones within the sample matrix where disproportionately high abundances of sulphides may acutely depress the pH of interstitial water within the pore space, the related stabilization of ferric Fe and the resultant propagation of an enhanced sulphide oxidation rate through the sample matrix. In field

tests, the inherently greater degree of sample heterogeneity with respect to both mineralogy and hydraulic properties favours the induction of localized centres for acute ARD propagation.

2) Granulometry. A further consequence of the fine-grained nature of laboratory test samples is that sulphides, plus those phases which are instrumental in acid consumption are intimately mixed in a manner which facilitates reactions to occur at the granular scale in a manner which optimizes their respective kinetics. This contrasts significantly from conditions inferred to exist in several of the field tests for which data are presented.

3) Moisture content. Field columns or cribs show evidence that oxidation rates may rise to exceed buffering capacity sooner when permitted to dry to, or near, residual moisture. This is particularly evident in the Boddington field cribs. In Pascua Lama Crib 1, a sharp reduction in pH is also observed in conjunction with the first flushing event (snowmelt) following a prolonged period of zero water infiltration. Such conditions are specifically averted in laboratory humidity cells run in accordance with any of the MEND, AMIRA or ASTM protocols. For the Boddington laboratory columns, the significance of variation of the moisture content regime was assessed through advertent drying of the columns for several weeks with effect from week 109 (see Figure 1). After re-wetting, the pH decreased by 1.5 to 2.5 pH units and remained at these comparatively low levels until test completion.

4) Temperature. A further factor which has been confirmed experimentally to influence SOR rates within both field and laboratory test environments is temperature. In the field setting, this is inevitably a direct function of climate. For substantial periods the Pascua Lama crib tests were operated at close to 0 ℃, with oxidation kinetics inherently constrained. A more striking bias in the leachate chemistries from paired laboratory and field tests has been confirmed to occur in the case of the Boddington samples, where laboratory columns were operated at 20°C while field tests were subject to summer ambient temperatures of 30ºC. Following the induced elevation of temperature to around 30°C in a series of test columns performed on Boddington rock demonstrated significant increases of SOR to levels broadly comparable to those documented in Table 5 for the field crib tests (Campbell et al. 2012).

Conclusions

The results and interpretation presented in this paper of comparative leachate chemistry evolution trends in 'paired' kinetic tests performed at laboratory and field scales prompts the central conclusion that more 'conservative' test results are routinely derived from large scale tests performed under ambient field conditions. A critical implication of this is that the chemistry of kinetic test leachates is not exclusively a function of mineralogical properties of the sample medium. In making inter-site comparisons of kinetic test data, due regard must therefore be afforded to the specifics of test design and operation. Without the necessary understanding of the context or environmental conditions under which leachate data are generated, their value for extrapolation to 'real world' field conditions may be critically undermined.

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