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Cementitious colloids: integration of laboratory, natural analogue and *in situ* field data

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Abstract

In the case of a cementitious L/ILW or TRU repository, it has been proposed that degradation of the cement may provide a significant source of colloids at both the cement/host rock interface and at the margins of the hyperalkaline plume produced by the leaching of the cementitious pore waters.

In the former case, five laboratory experiments examining colloid production during cement degradation (Pearce, 1991; Wieland, 1997; Gardner et al., 1998; Fujita et al., 2000 and Wieland and Spieler, 2001) and one natural analogue study at Maqarin in Jordan (see Wetton et al., 1998 and Alexander and Smellie, 1998) have been reported. Intercomparison of the data is difficult due to the significantly different methodologies used (see Table 1). Even in the two batch leaching tests, large differences exist. Wieland (1997) shook the samples in synthetic cement pore waters while Gardiner et al. (1998) appear to have employed static leaching in synthetic groundwaters. The method-induced effects are apparent when the colloid populations are compared with the colloid mass concentrations: there are no clear relationships between populations and mass, suggesting significantly different colloid diameters are being measured in each experiment. This is clearly shown in the data of Wieland (1997) where the measured colloid concentration varies over five orders of magnitude, depending on the settling time allowed following shaking of the samples (although the author notes that immediate measurement after end-over-end shaking of the batch cement/water samples used is unrealistic).

With respect to colloids produced at the margins of the hyperalkaline plume, no laboratory experiment has been able to reproduce this region so far. and this margin has, as yet, not been accessed in the Maqarin study Arguably, the most appropriate approach to study such a margin zone would be in a large-scale, *in situ* experiment in an underground rock laboratory.

Clearly, any future work on these cementitious colloid topics would benefit (as shown by the Maqarin/laboratory intercomparison in Alexander and Smellie, 1998) from a common approach which should try to minimise method inherent differences, so producing a more compatible data set for use in performance assessment (PA). In this paper, the existing cementitious colloid data sets are described in detail and a new, integrated approach for future work is defined. In addition, an *in situ* field experiment is proposed which will attempt to examine both the cement/host rock interface and hyperalkaline plume margin colloids simultaneously, so providing an integrated data set for PA studies.

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Table 1 Comparison of existing data on near-field cementitious colloids (after Alexander and Smellie, 1998)

Report	Methodology	Colloid Population (mL^{-1})	Colloid Concentration (mgL^{-1})
Wetton et al., 1998	Collection of groundwater at the cement/host rock interface	$1.15\text{-}4.89\times10^{7}$	0.051-0.190
Pearce, 1991	Incubation cells containing simulated waste, containment and backfill materials in synthetic groundwater	average 5×10^{6}	0.017[a]
Wieland, 1997	Leaching of crushed PZHS[b] monocorn mortar and quartz aggregate with cement pore waters, solid:liquid ratio of 1:10	$0.4\text{-}7.0\times10^{5}$ (total)[c] $1.5\text{-}8.5\times10^{3}$ (undist.)[d] $2\text{-}5\times10^{3}$ (steady)[e]	1-50 0.03-1 0.004-0.021
Wieland and Spieler, 2001	Leaching of crushed mortar in a column with cement pore waters		0.002-0.058
Gardiner et al., 1998	Leaching of crushed cement with groundwaters, solid:liquid ratios of 1:5, 1:10 and 1:50	$3\text{-}9\times10^{6}$ (NRVB)[f] $1\text{-}2\times10^{5}$ (PFA:OPC)[g] $1\text{-}9\times10^{5}$ (BFS:OPC)[h]	As this paper is only an overview of unpublished data, full information is not available to calculate colloid mass

a. No data on colloid diameters available so smallest filter nominal pore size (15nm) used in the calculation. Note, however, that this calculation should be applied only to a size distribution and the error induced by using a single value for the colloid diameter may be up to two orders of magnitude (C.Degueldre, pers. comm. to WRA, 1996).
b. High Sulphate Resistance Portland Cement.
c. Total colloid concentration measured immediately after end-over-end mixing of a batch system. Experimentally defined colloid diameter ≥ 100nm.
d. Colloid concentration measured after leaving batch system undisturbed for 24 hours. Experimentally defined colloid diameters between 100nm and 1000nm
e. Colloid concentration measured after leaving batch system undisturbed for >24 hours. Experimentally defined colloid diameter ≥ 100nm.
f. Nirex Reference Vault Backfill. No data on colloid size distribution.
g. 3:1 mix of Pulverisied Fuel Ash: Ordinary Portland Cement. No data on colloid size distribution.
h. 3:1 mix of Blast Furnace Slag: Ordinary Portland Cement. No data on colloid size distribution.