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METAL LEACHING FROM APC RESIDUES SOLIDIFIED USING PORTLAND CEMENT AND GROUND GRANULATED BLAST FURNACE SLAG

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APC Residues

Produced from flue gas cleaning processes at energy from waste plants.

Mixture of alkaline reagents, fly ash and carbon.

Hazardous waste according to the EWC (19 01 07*)

High concentrations of soluble salts (chlorides) and volatile heavy metals such as Zn, Pb and Cd.

Composition will vary depending on the type of plant, composition of waste and the flue gas treatment process.

Metal	Total conc. in APC residues (mg/kg)
Pb	2,800
Zn	7,200
Cd	410
Na	20,000
K	23,000

Current Treatment/Management Options

Current management/treatment options for APC residues include:

- ❑ Solidification/Stabilization
- ❑ Washing to remove salts
- ❑ Thermal treatment (vitrification, melting, sintering)
- ❑ Chemical stabilization (e.g. Ferrox, VKI)
- ❑ Plasma treatment
- ❑ Electrokinetic remediation
- ❑ Storage in deep salt mines

Despite the variety of treatment/management methods for APC residues there is still no consensus on the best technique. Reuse of APC residues has been studied, utilising pre-treatment methods mentioned above before application.

Solidification/Stabilization

Encapsulation of hazardous wastes in a monolithic solid with improved integrity and reduced contaminant leaching.

Containment of the contaminants occurs mainly via:

- ❑ Chemical fixation (Stabilization)
- ❑ Physical containment (Solidification)

Commercially used binders include Portland cement, coal fly ash, ground granulated blast furnace slag (ggbs), silica fume and lime.

Solidification/Stabilisation has been previously recommended for the treatment of APC residues.

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Materials

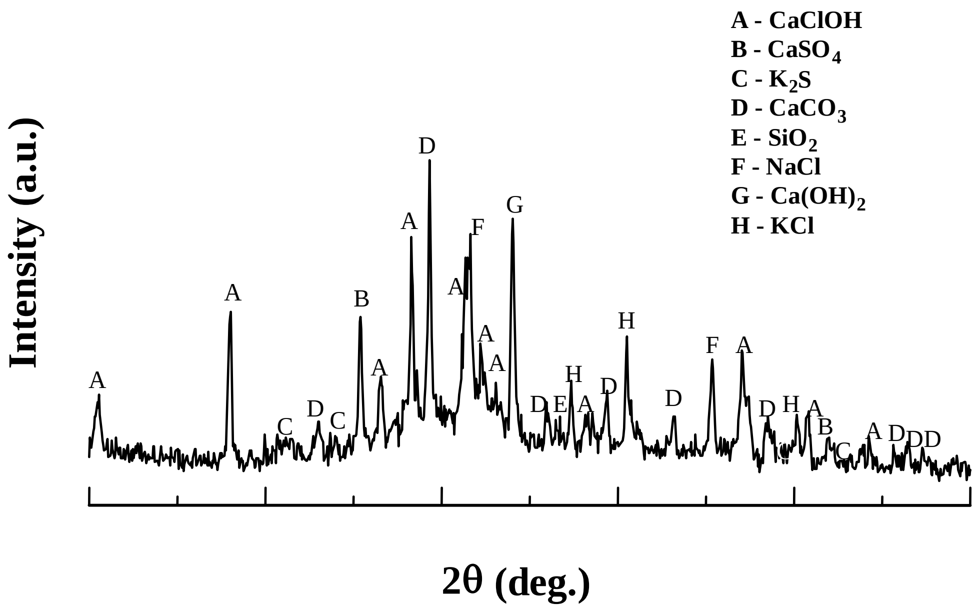
APC residues were obtained from a major energy-from-waste plant in SE England.

Concentrations of **Pb** (300-700 mg/kg) and **Zn** (40-85 mg/kg) leaching from APC residues are greater than the UK Waste Acceptance Criteria.

Free lime (CaO): 15%-20%

Leachable Chloride:

160,000 – 170,000 mg/kg



Materials (continued)

Binders used comprised CEMI and ground granulated blast furnace slag (ggbs).

Binder additions were at 10, 20 and 50% of total dry mass.

Distilled water was used at water-to-solids ratios between 0.35 and 0.80

The free lime in the APC residues was used to activate the ggbs and initiate hydration reactions.

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Testing Parameters

Test	Standard Method
Setting Time	BS EN 196-3:2005
Consistence	BS EN 4551
Unconfined Compressive Strength	BS EN 196-1:2005
Water Content	Drying at 60ºC to constant weight
Bulk Density	Environment Canada Method
Specific Gravity	ASTM D5550-94
Porosity	Environment Canada Method
Acid Neutralization Capacity	Environment Canada ANC Method
Monolithic Leaching Test	NEN 7375:2004

Monolithic Leaching Test (NEN 7375:2004)

Dynamic leaching test based on the bulk diffusion model.

50mm cube specimens (Requirement for smallest dimension > 40mm).

Specimens that had UCS after immersion over 1.0 MPa were tested.

Water immersion for 64 days.

Sampling at 8 different time fractions.

Replenishment of the leachant at each fraction.

Results for chloride have already been reported with all samples failing to meet monolithic WAC for hazardous waste landfill.

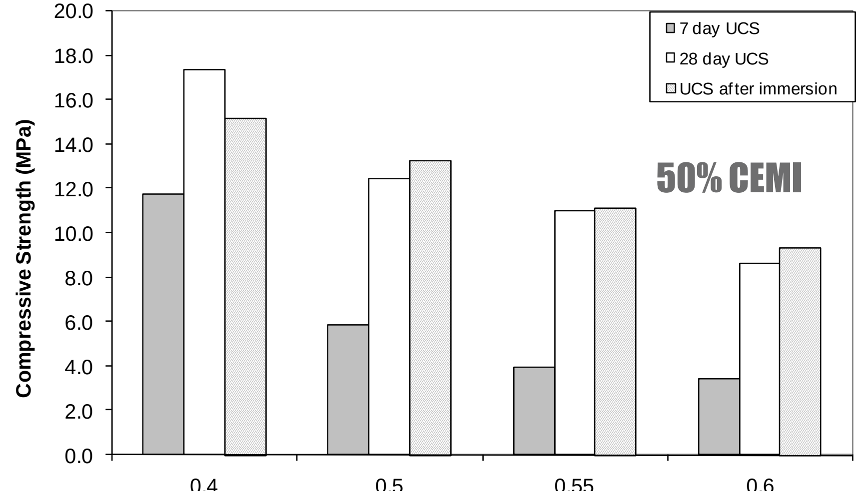
Unconfined Compressive Strength

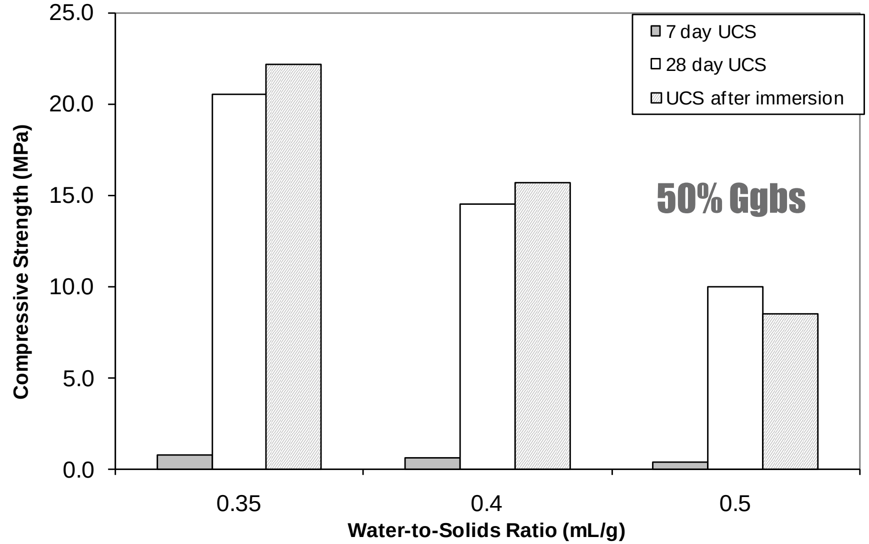
All CEMI mixes achieved UCS > 1 MPa.

Ggbs UCS < 1MPa at 20% and 10% binder additions.

Hydration reactions for ggbs begin after the first week of curing.

UCS was not affected by water immersion for 50 wt% binder addition. It reduced up to 80% for lower CEMI additions.





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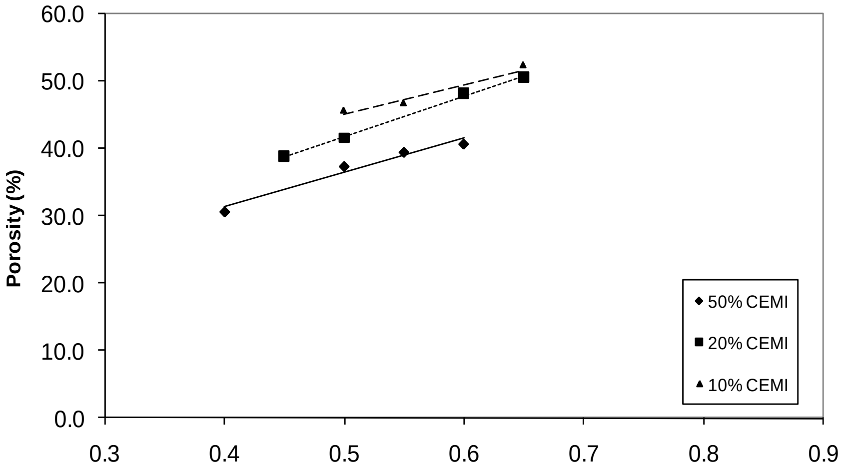
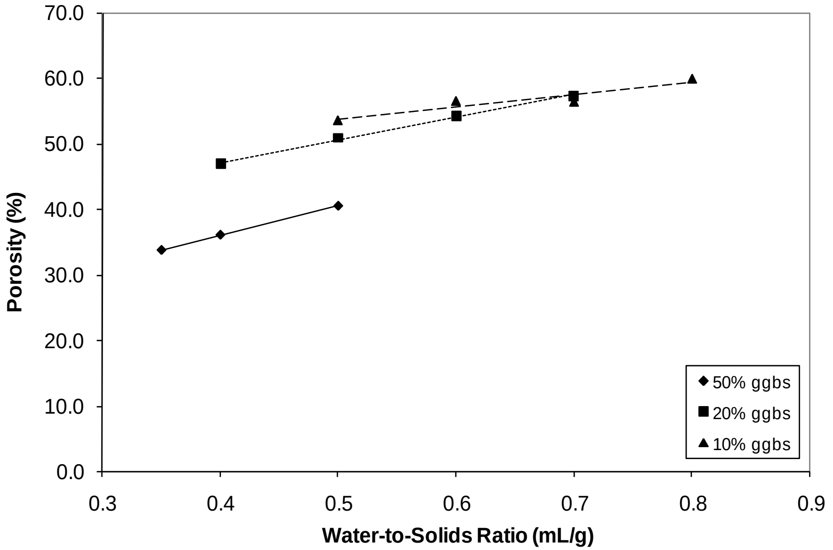
Porosity

Porosity increases linearly with increasing water addition.

Ggbs mixes exhibited greater porosity at low binder additions (10%-20%) compared to CEMI.

Porosity plays an important role controlling permeability, compressive strength and leaching characteristics.





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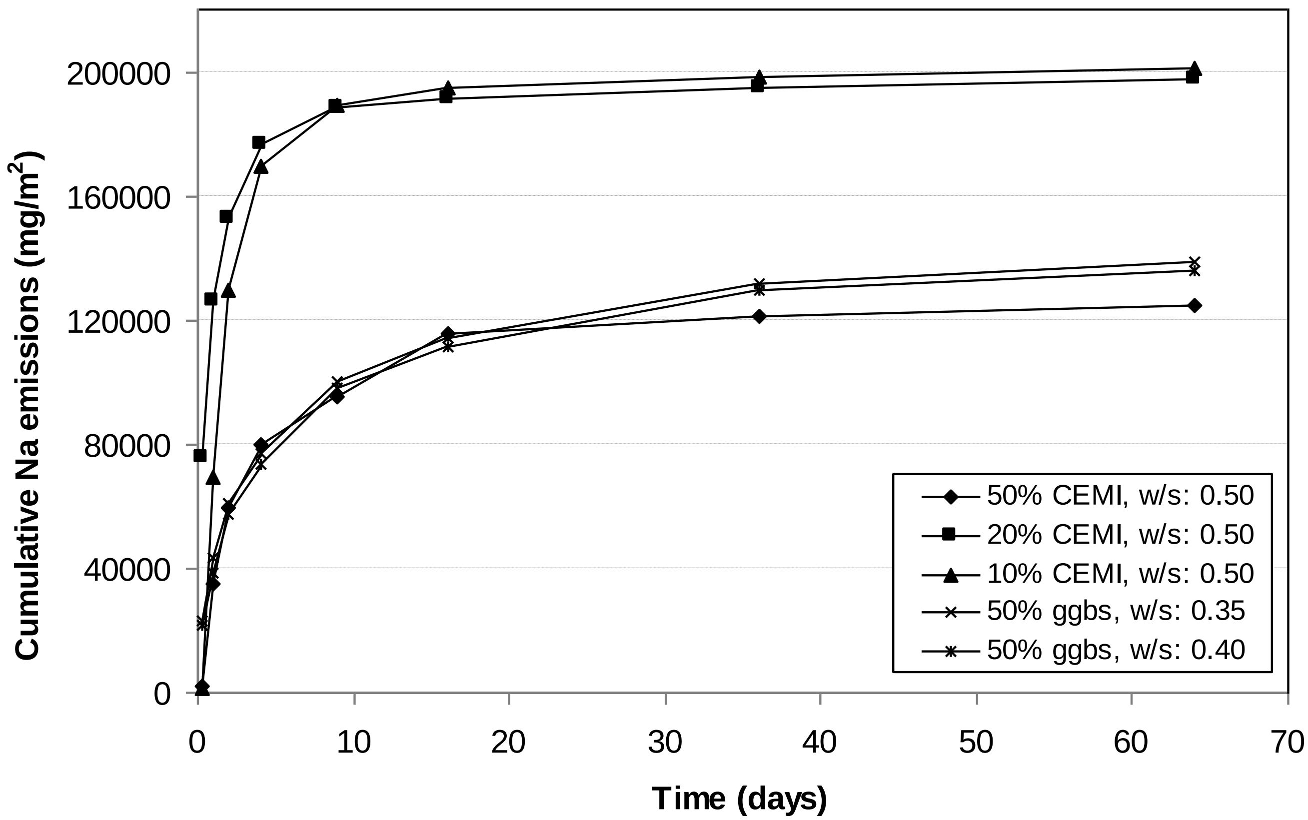
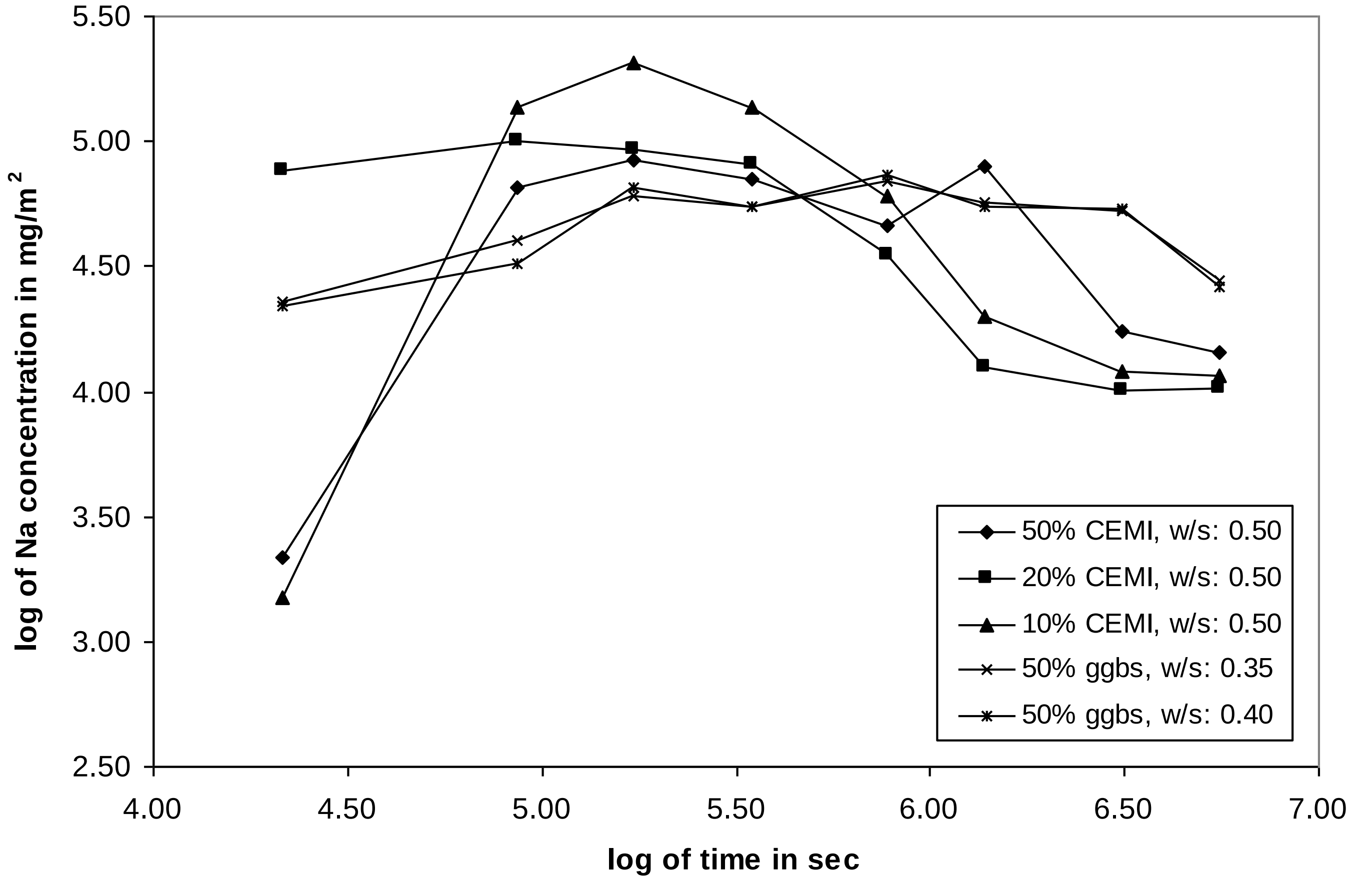
Sodium Leaching



Sodium Leaching



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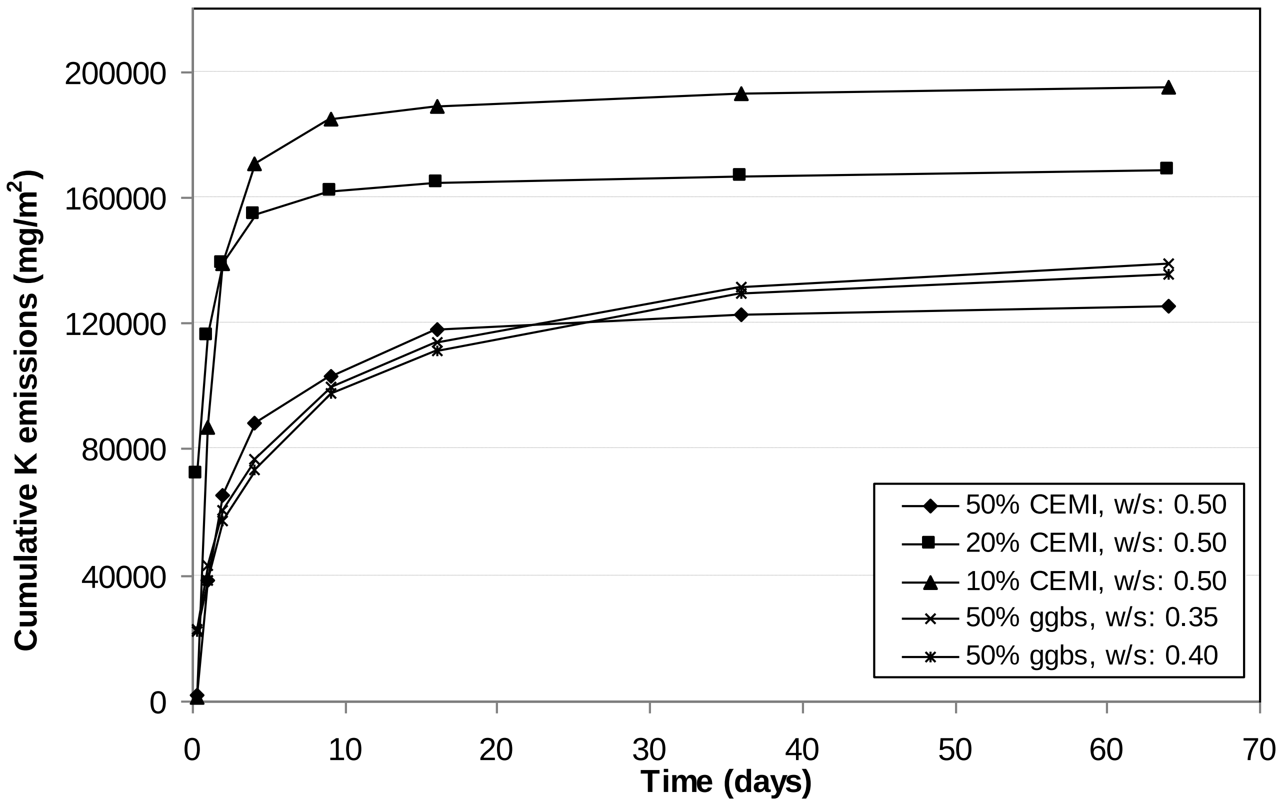
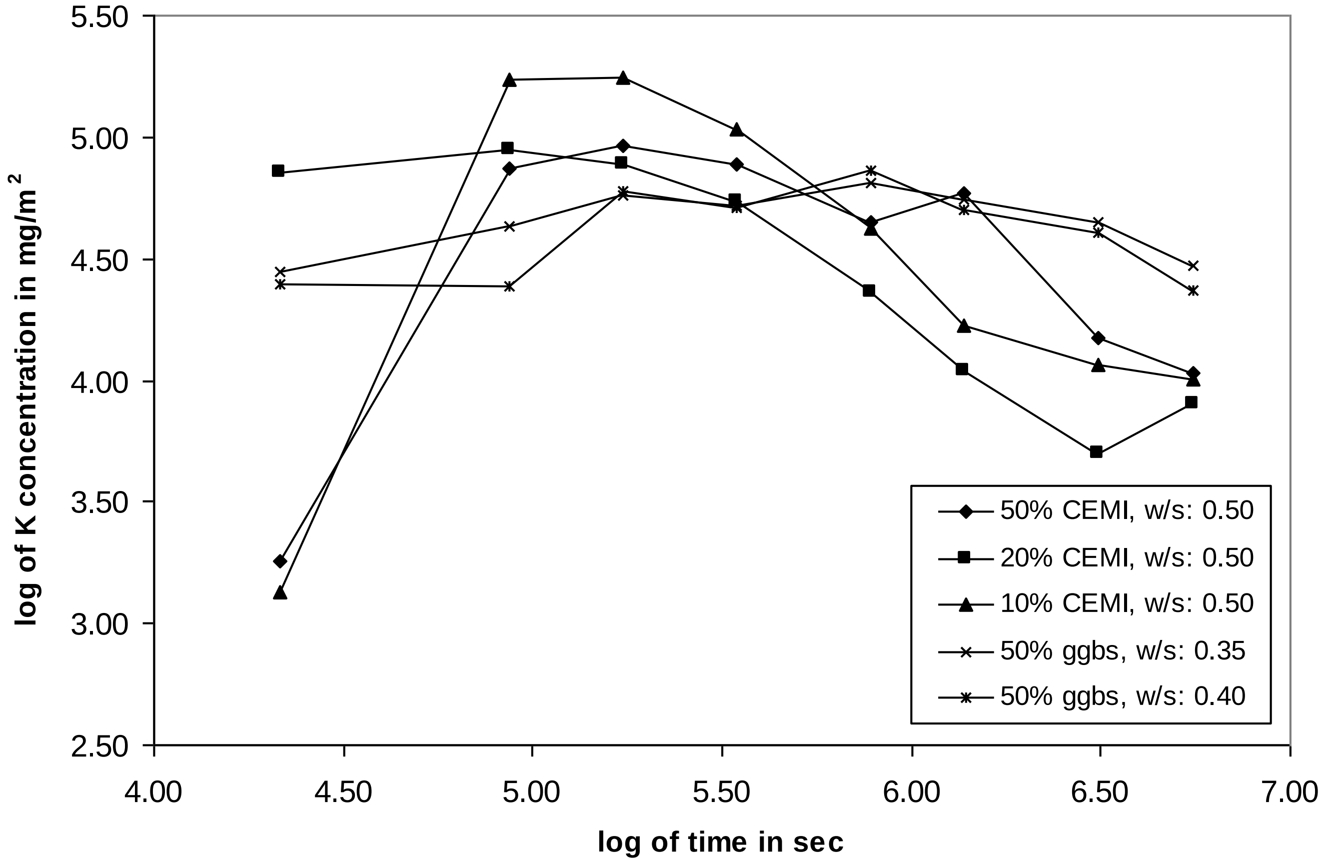
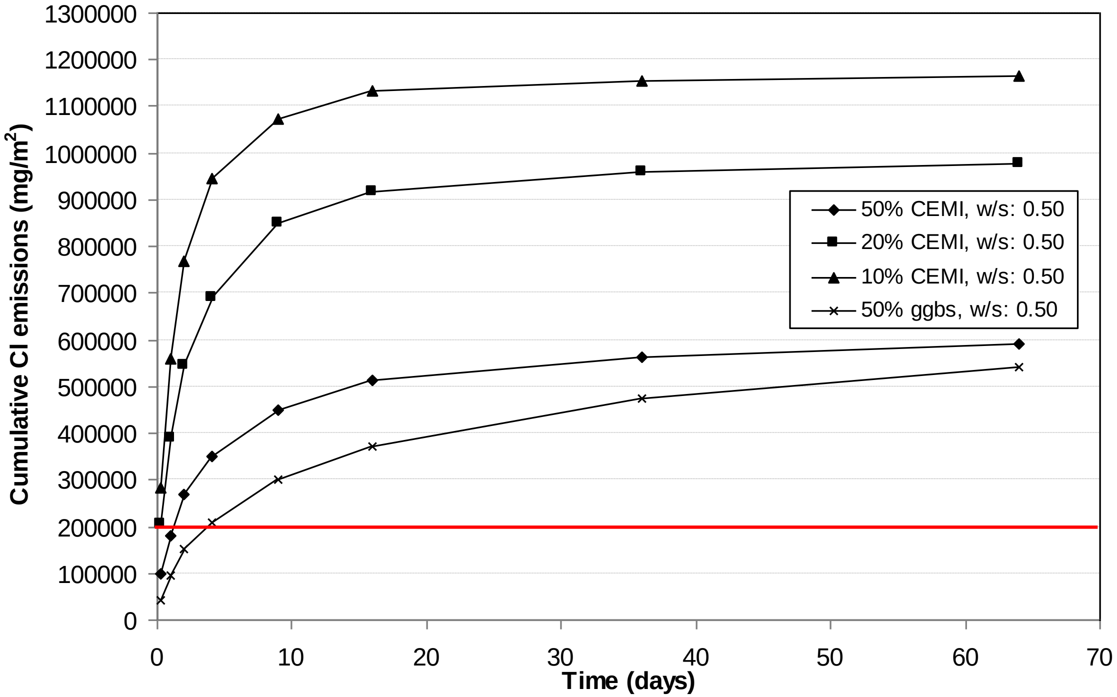
Potassium Leaching



Potassium Leaching



Chloride Leaching



Red line indicates monolithic WAC for hazardous waste landfill (20,000 mg/m^2).

Granular leaching tests showed that granular WAC are also exceeded (> 25,000 mg/kg).

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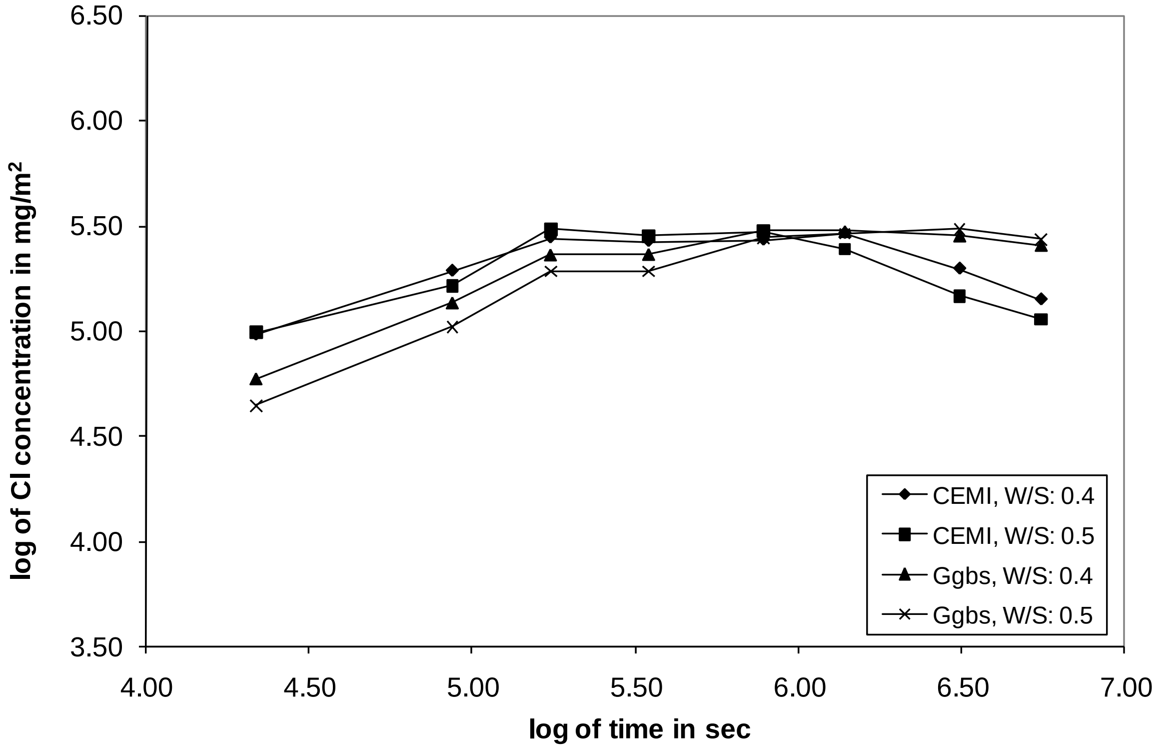
Chloride Leaching



- ❑ Semi-infinite medium assumption of the diffusion model is violated

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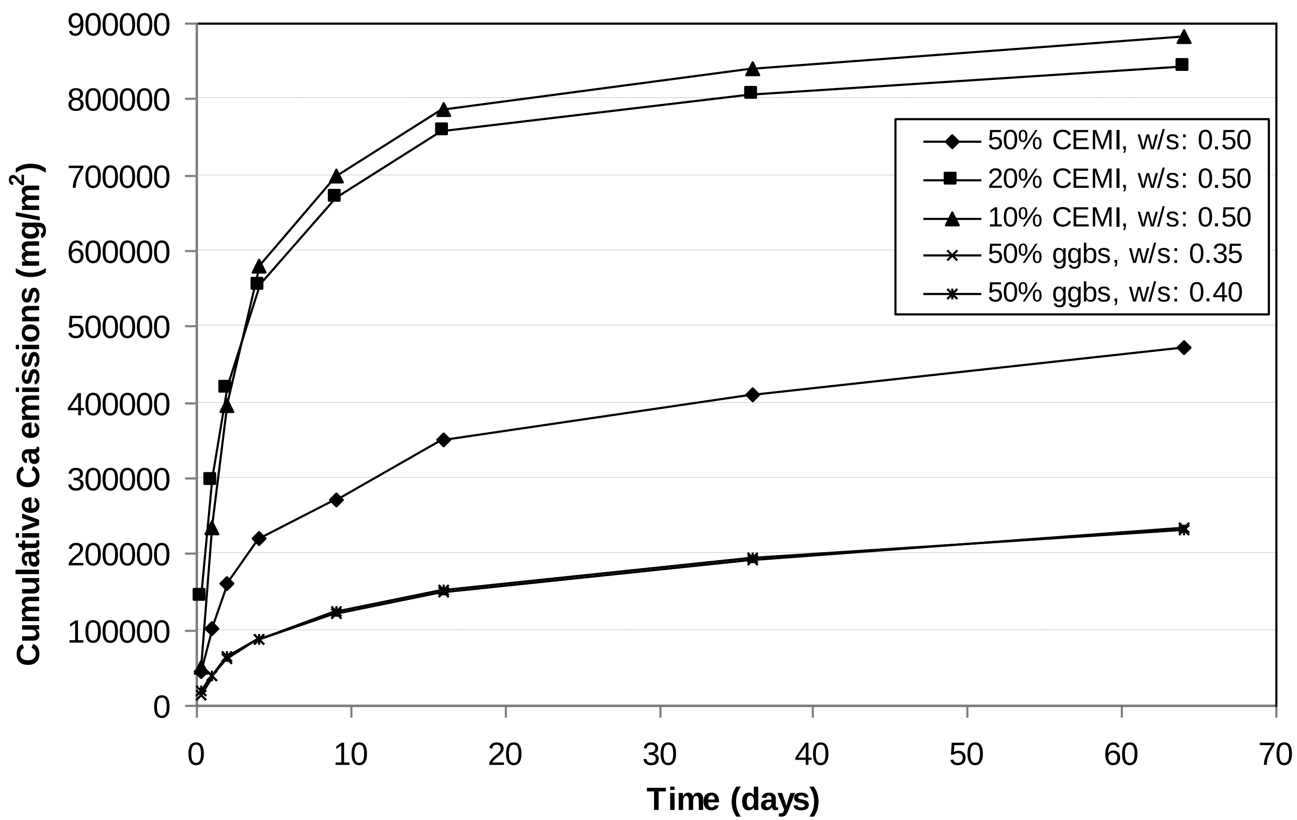
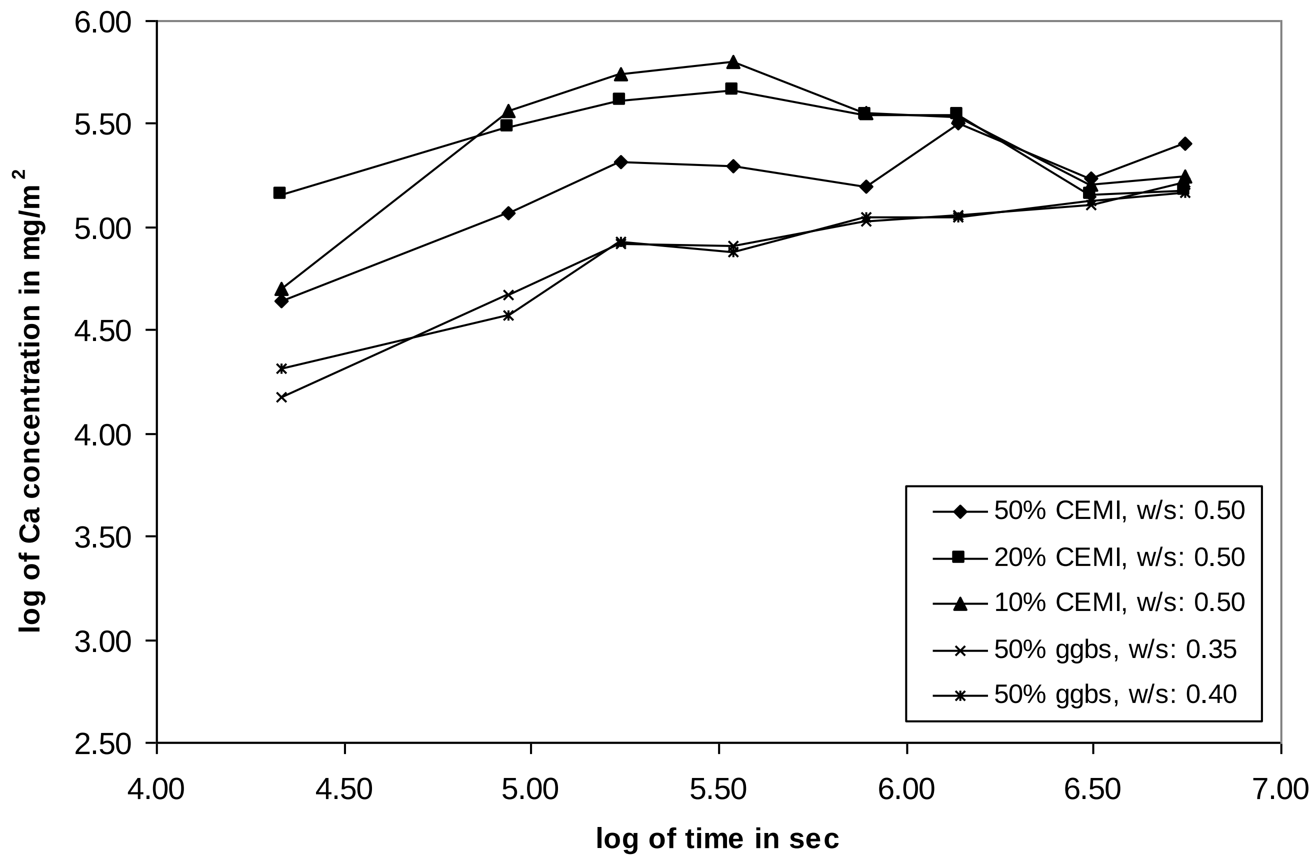
Calcium Leaching



Calcium Leaching



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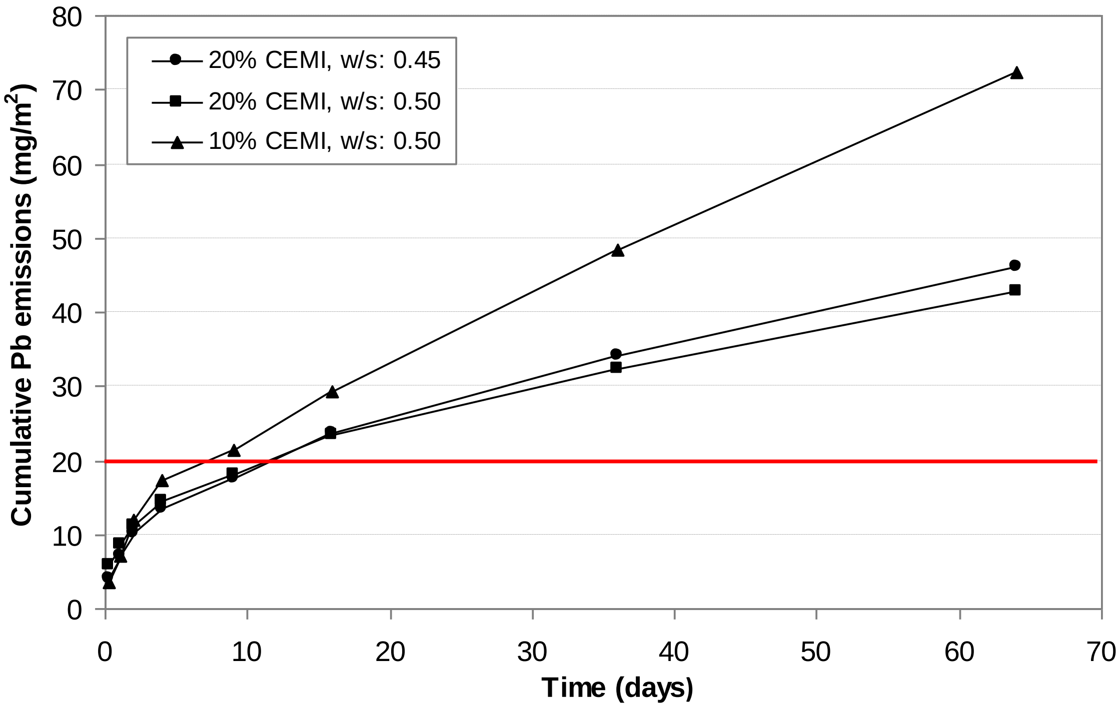
Lead Leaching



Red line indicates monolithic WAC for hazardous waste landfill.

Compliance with granular WAC needs to be evaluated.

Concentrations for 50 %wt CEMI mixes had concentrations below the detection limit at interim test fraction which inhibits analysis according to EA NEN 7375:2004.

Concentrations for 50 %wt ggbs mixes at all test intervals were below the detection limits.

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Lead Leaching

50% wt. CEMI	w/s: 0.40		w/s: 0.50		w/s: 0.55		w/s: 0.60	
Days	**mg/L**	**mg/m²**	**mg/L**	**mg/m²**	**mg/L**	**mg/m²**	**mg/L**	**mg/m²**
0.25	<0.01	-	0.04	1.56	0.09	3.42	0.10	3.66
1	0.02	0.62	0.02	0.56	0.02	0.56	0.01	0.40
2	0.02	0.64	< 0.01	-	0.02	0.60	0.01	0.50
4	<0.01	-	0.01	0.44	<0.01	-	<0.01	-
9	<0.01	-	0.01	0.40	0.02	0.60	0.01	0.48
16	0.02	0.60	0.03	1.06	0.04	1.36	0.05	1.74
36	0.03	0.92	0.04	1.46	0.04	1.52	0.05	1.78
64	0.05	1.66	0.08	2.74	0.09	3.20	0.09	3.36

- monWAC for hazardous waste landfill: **20 mg/m²**
- Table does **not** present cumulative leaching with time.
- All 50% ggbs mixes had Pb concentrations lower than the DL (10 ug/L)

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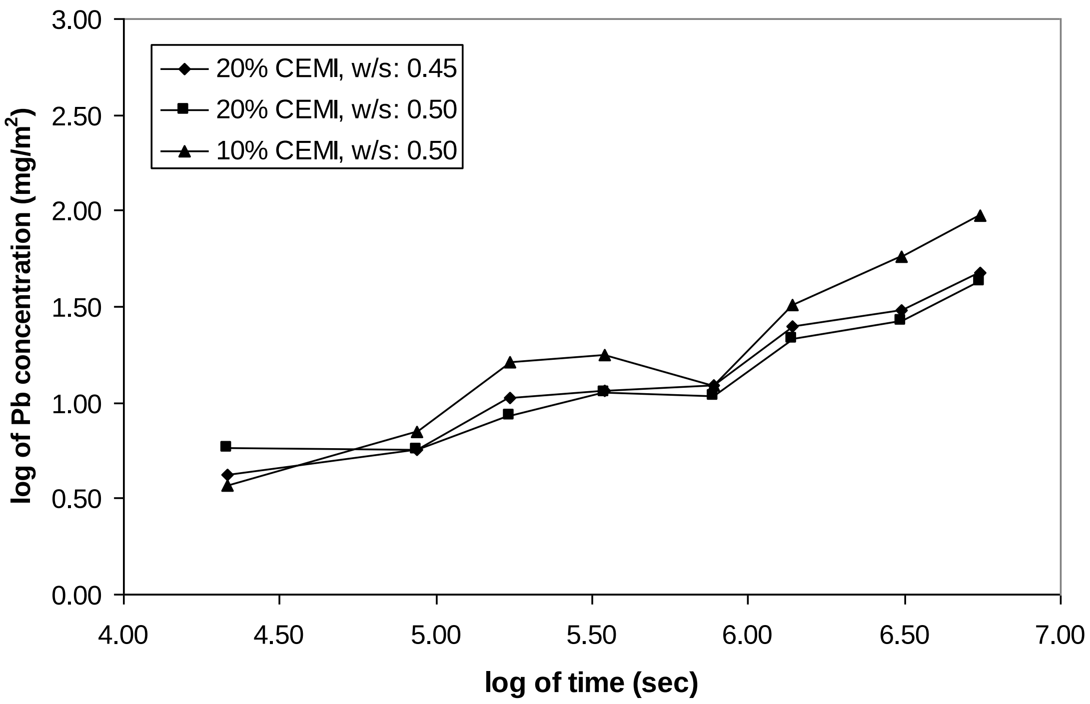
Lead Leaching



Diffusion seems to be the dominant mechanism for the leaching of lead. This is confirmed by the slopes of the cumulative derived leaching curve (0.35 < rc < 0.65)

It is observed that for the 10% CEMI mix leaching was not fully controlled by diffusion.

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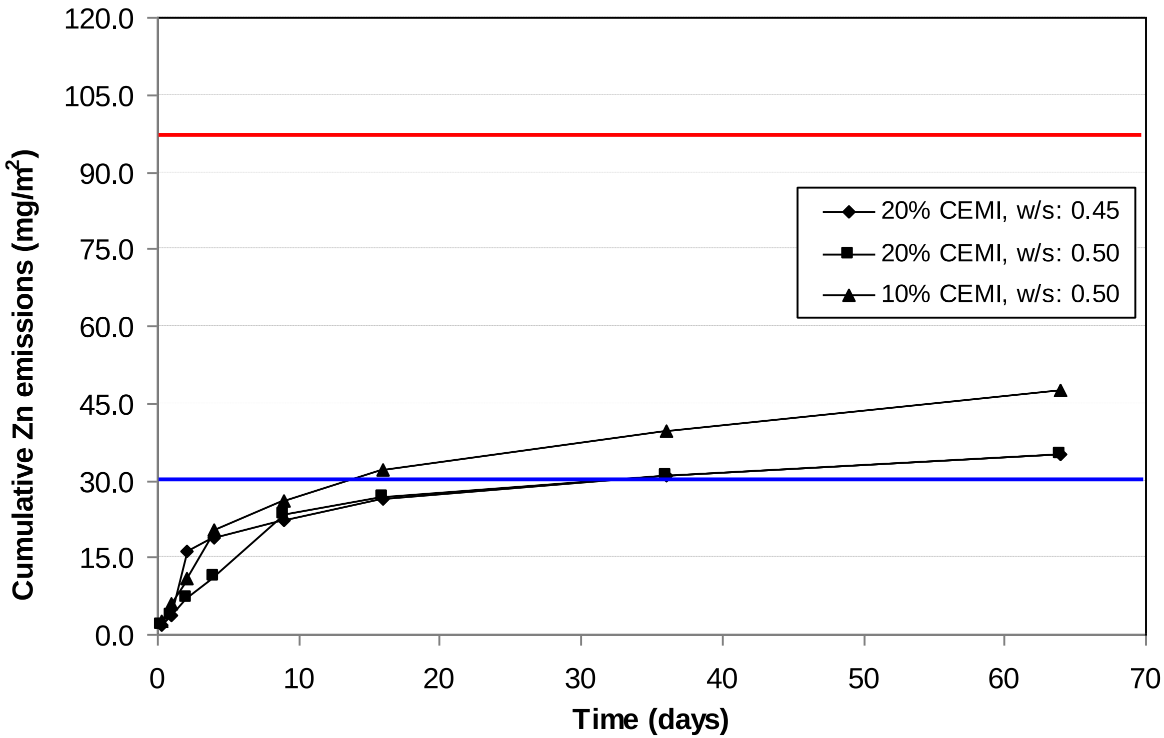
Zinc Leaching

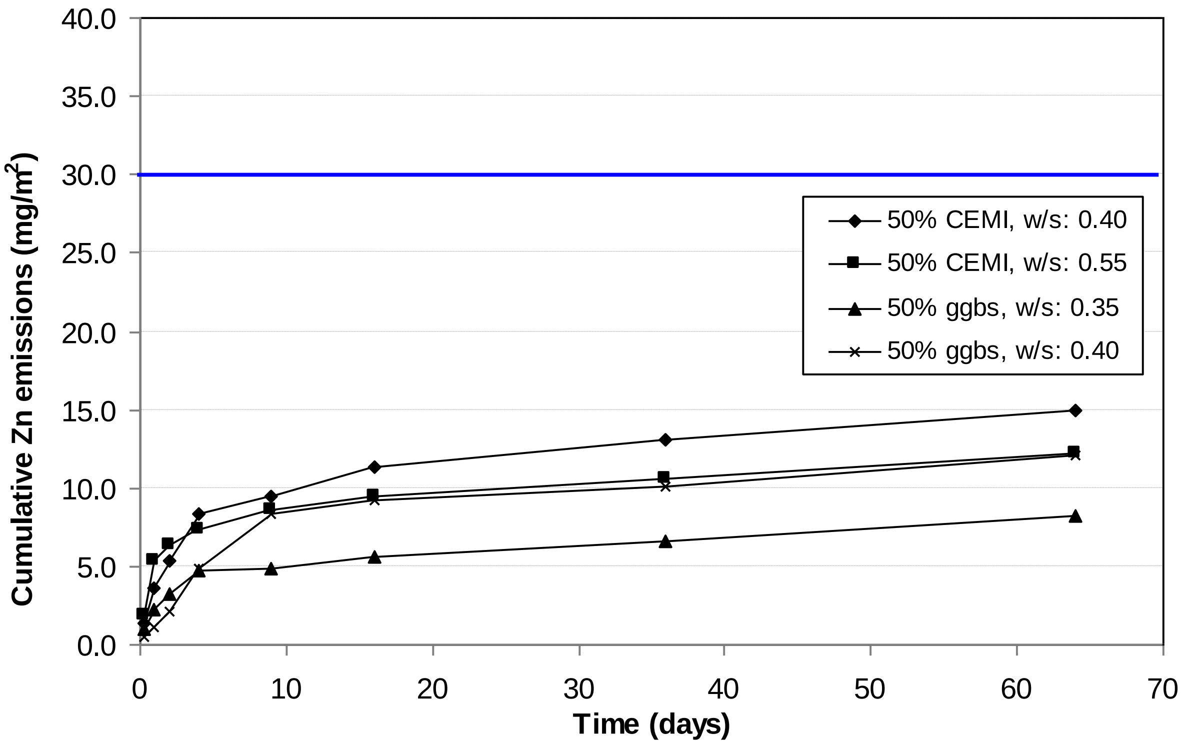


Red line indicates monolithic WAC for hazardous waste landfill.

Blue line indicates monolithic WAC for stable non-reactive waste in non-hazardous waste landfill.

Results comply with monolithic WAC for hazardous waste landfill.

Zinc Leaching



Blue line indicates monolithic WAC for stable non-reactive waste in non-hazardous waste landfill.

50% binder additions result in products compliant with monolithic WAC for stable non-reactive waste in non-hazardous waste landfill.

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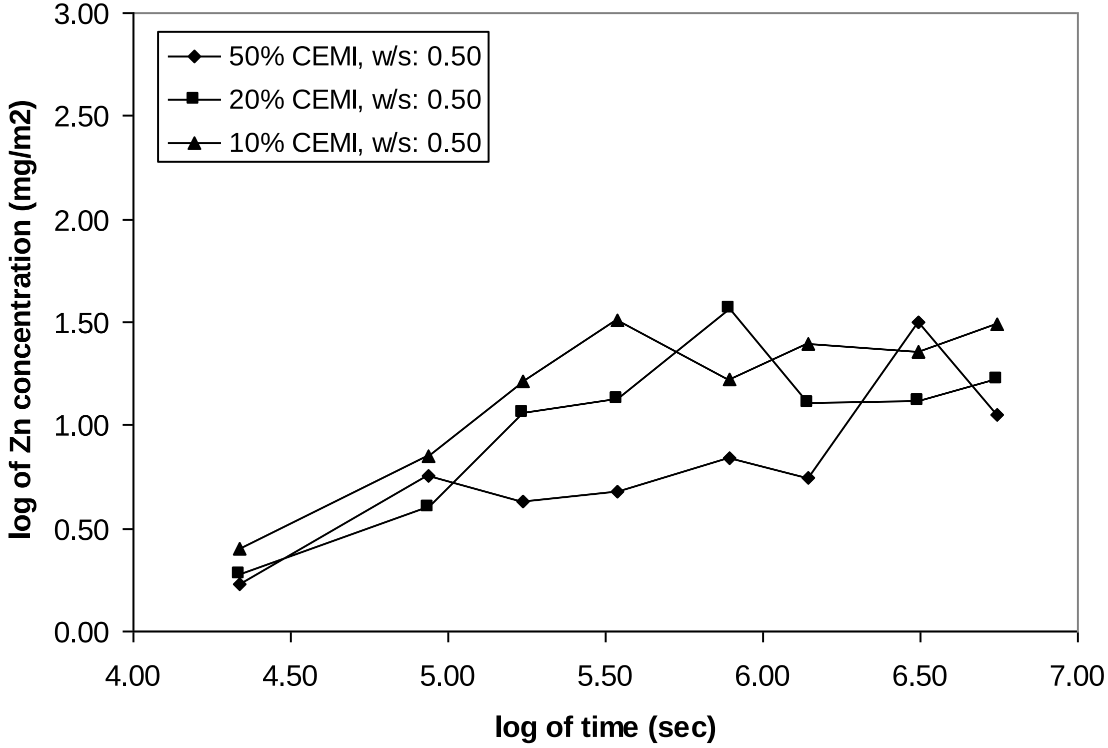
Zinc Leaching



Leaching of zinc did not seem to be fully diffusion controlled as it is observed by the plot patterns and slopes. Surface wash-off and dissolution may have occurred during the test. (rc < 0.35, rc> 0.65)

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Conclusions

- 50% binder additions meet the monolithic WAC for zinc for stable non-reactive waste in non-hazardous waste landfill
- 50% ggbs additions showed concentrations of lead lower than the detection limit throughout the test fractions.
- 20 and 10% CEMI additions meet the monolithic WAC for zinc for hazardous waste landfill but fail to meet monolithic WAC for lead.
- High amounts of sodium, potassium and calcium are being released which may affect the physical properties of the s/s matrix in the long-term.
- Chloride is highly mobile and is of greatest significance for the s/s process. Pretreatment is required.

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ProCeSS Project

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Academia: *University College London, Imperial College London, University of Surrey, University of Cambridge, Birkbeck University of London*.

Industry: *British Cement Association, The Concrete Centre, UK Quality Ash Association, Cementitious Slag Makers Association, British Lime Association, Elkem Materials, Surface Engineering Association, SELCHP, Corus, Veolia Environmental Services, Grundon Waste Management, Sita UK, Scott Wilson, May Gurney Ltd, White Young Green Environmental, CIRIA and WRc*.

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Questions and Answers

Thank you for your attention!

Merci pour votre attention!

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