UNIVERSITY OF Southampton

Clogging of leachate collection systems

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with thanks to Andrew Hudson

Engineering and the Environment

Leachate clogging research

- Work in 90s and 2000s in Germany (Brune), UK (Powrie, Paksy, Nikolova) & America (Koerner)

- Useful review by Levine *et al* (2005) [University of Florida]

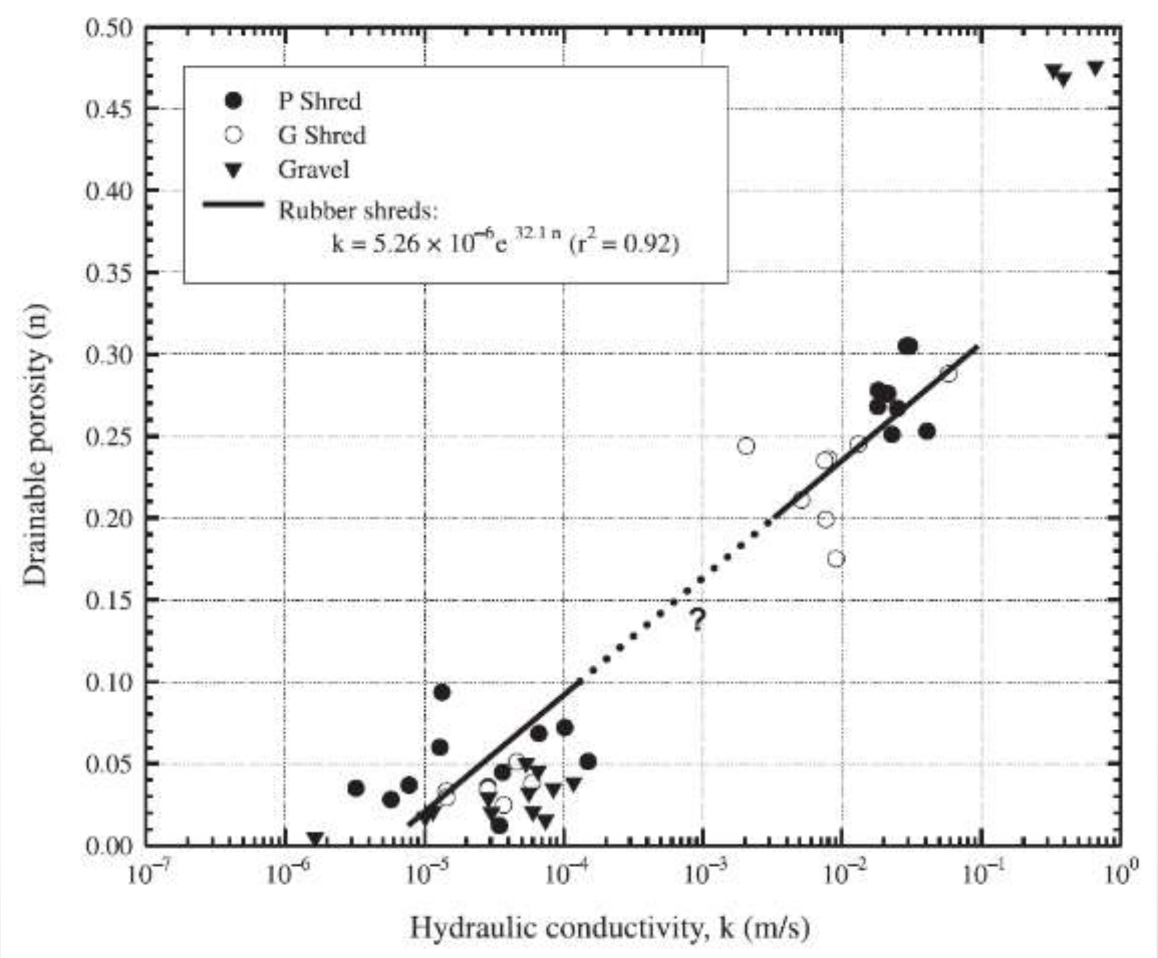
- Main research over 2 decades by Rowe and colleagues (Canada)

Much of Canadian work demonstrated high clogging potential

Engineering and the Environment

From: Fleming, I.R and Rowe, R.K. (2004). Laboratory studies of clogging of landfill leachate collection and drainage systems. *Canadian Geotechnical Journal* 41, 134-153

Clogging occurs in gravel and tyres



- McIsaac, R., and Rowe, R.K. (2005) Change in Leachate Chemistry and Porosity as Leachate Permeates through Tire Shreds and Gravel. Canadian Geotechnical Journal 42(4): 1173-1188

Summary of Rowe's research

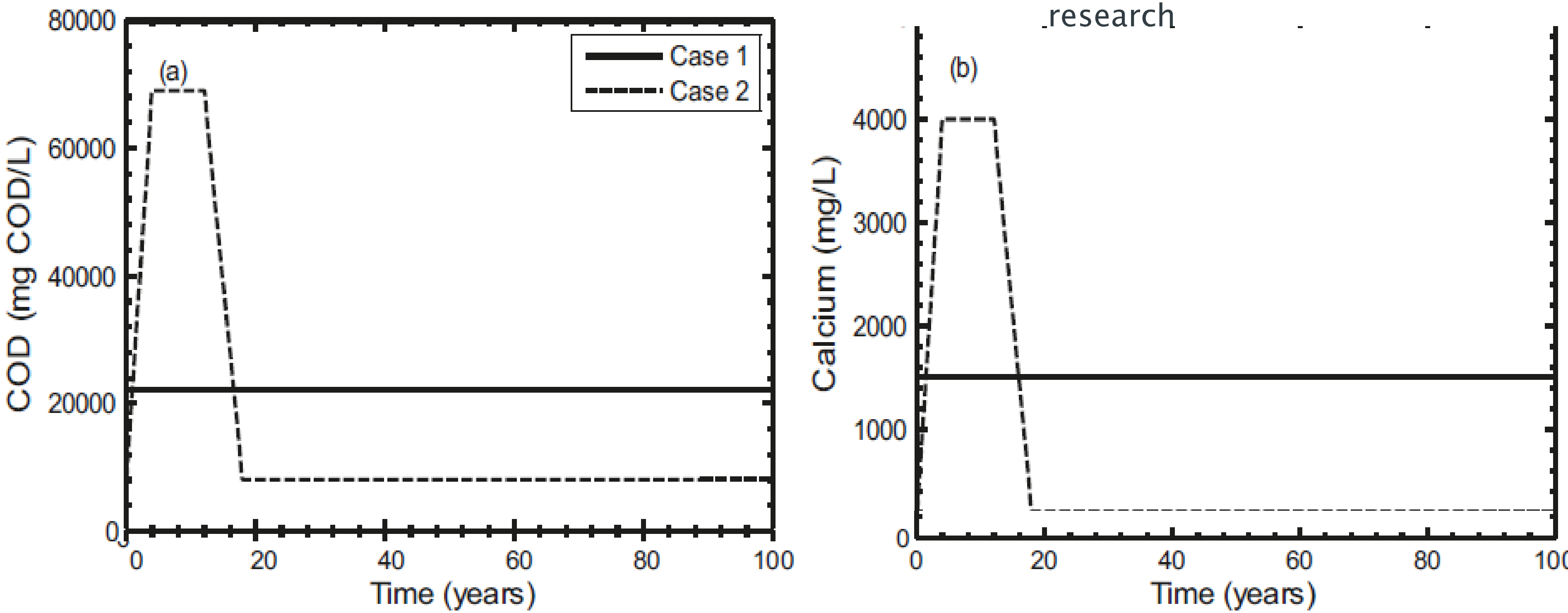
- Large grain size drainage systems better
- Gravel better than tyres - found to have a service life at least three times greater than that of an equivalent thickness of compressed (150 kPa) tire shred
- Clogging mainly from inorganics
- What drains out of a collection system not representative of what goes in – significant *in situ* treatment occurs in drainage layer
- Early articles advocated fully drained collection systems (as clogging greatest in saturated zone).

Canadian research has concentrated on clogging from acidogenic leachates

• **high strength leachate used (COD = 10,000 mg/l)**

methanogenic leachates in UK landfills typically much lower (~1,000 mg/l)

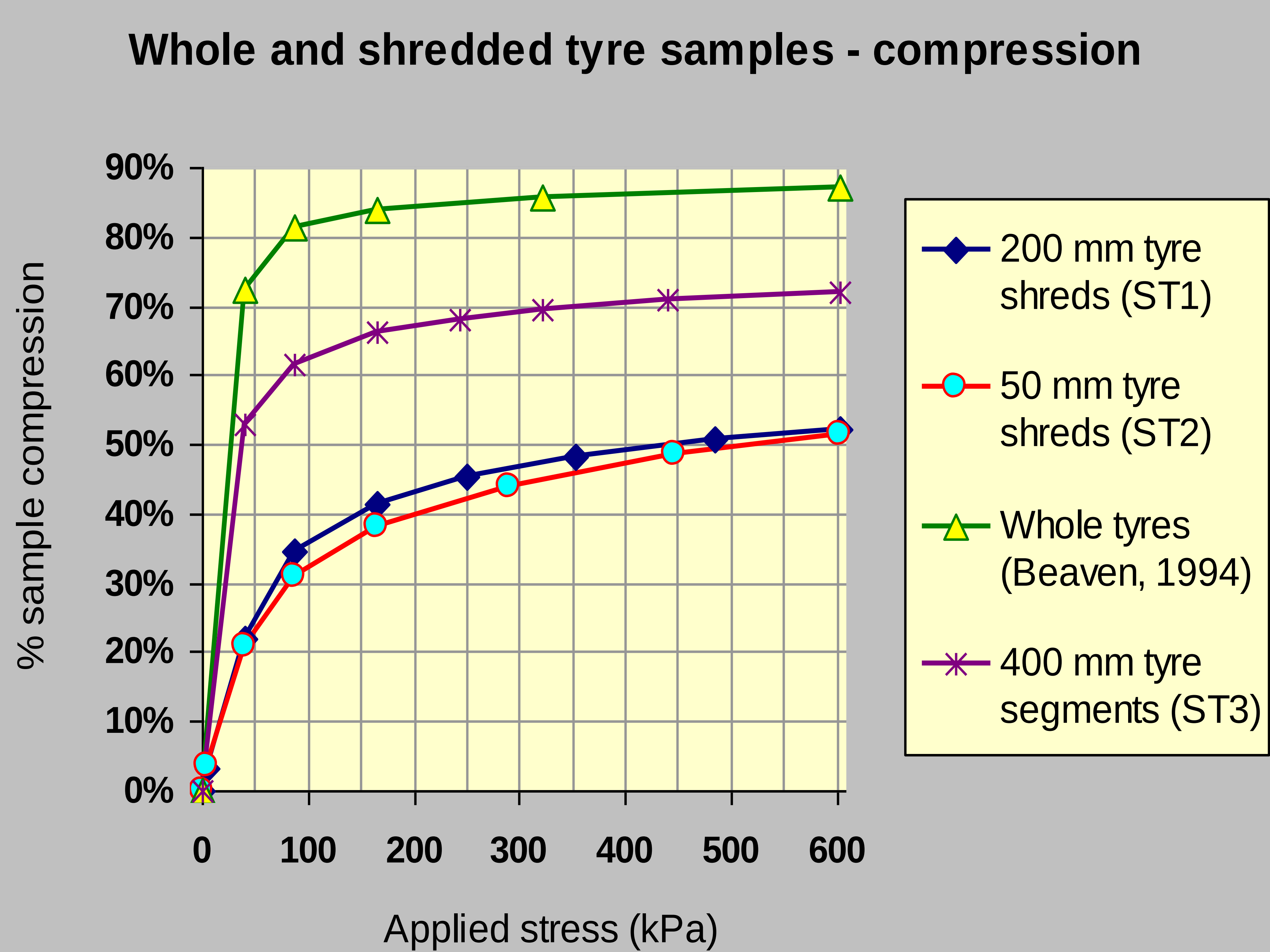
Indication of leachate strength in Canadian research



University of Southampton tyre and aggregate drainage layer research

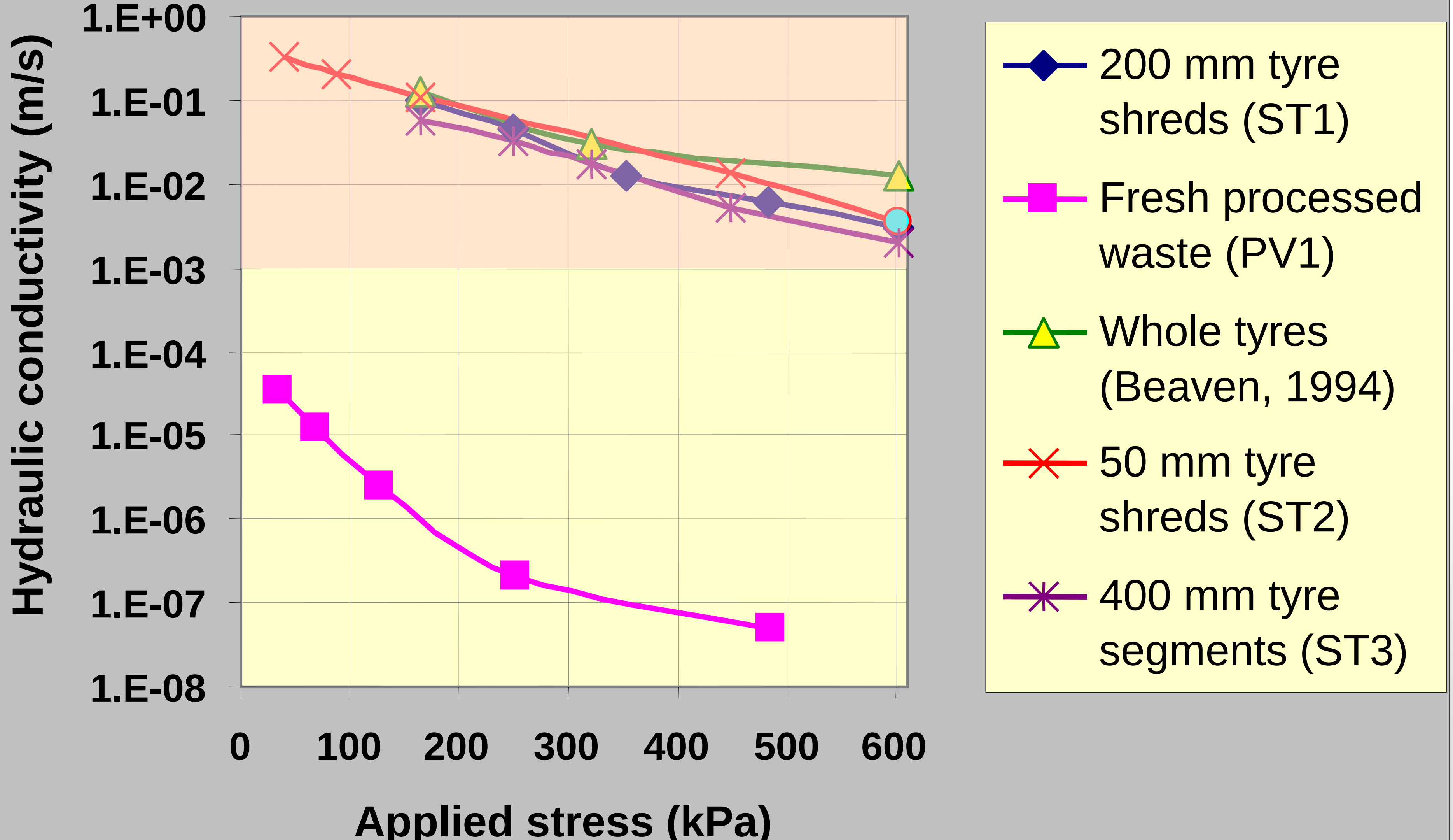
- Aim to investigate clogging potential from methanogenic leachates
  - Originally funded by WRAP
  - Follow up support from EPSRC
- On back of research that look at permeability of whole tyres and tyre shreds at different compressions

University of Southampton waste testing facility at Pitsea landfill site, Essex



Whole and shredded tyre samples - compression
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% sample compression
0
100
200
300
400
500
600
Applied stress (kPa)
200 mm tyre shreds (ST1)
50 mm tyre shreds (ST2)
Whole tyres (Beaven, 1994)
400 mm tyre segments (ST3)

Whole and shredded tyre samples - hydraulic conductivity



will clogging be affected by……

- acetogenic vs methanogenic leachate ?
- saturated or unsaturated conditions ?
- different size shreds (or whole tyres) ?
- stress / compression of the tyre drainage layer ?

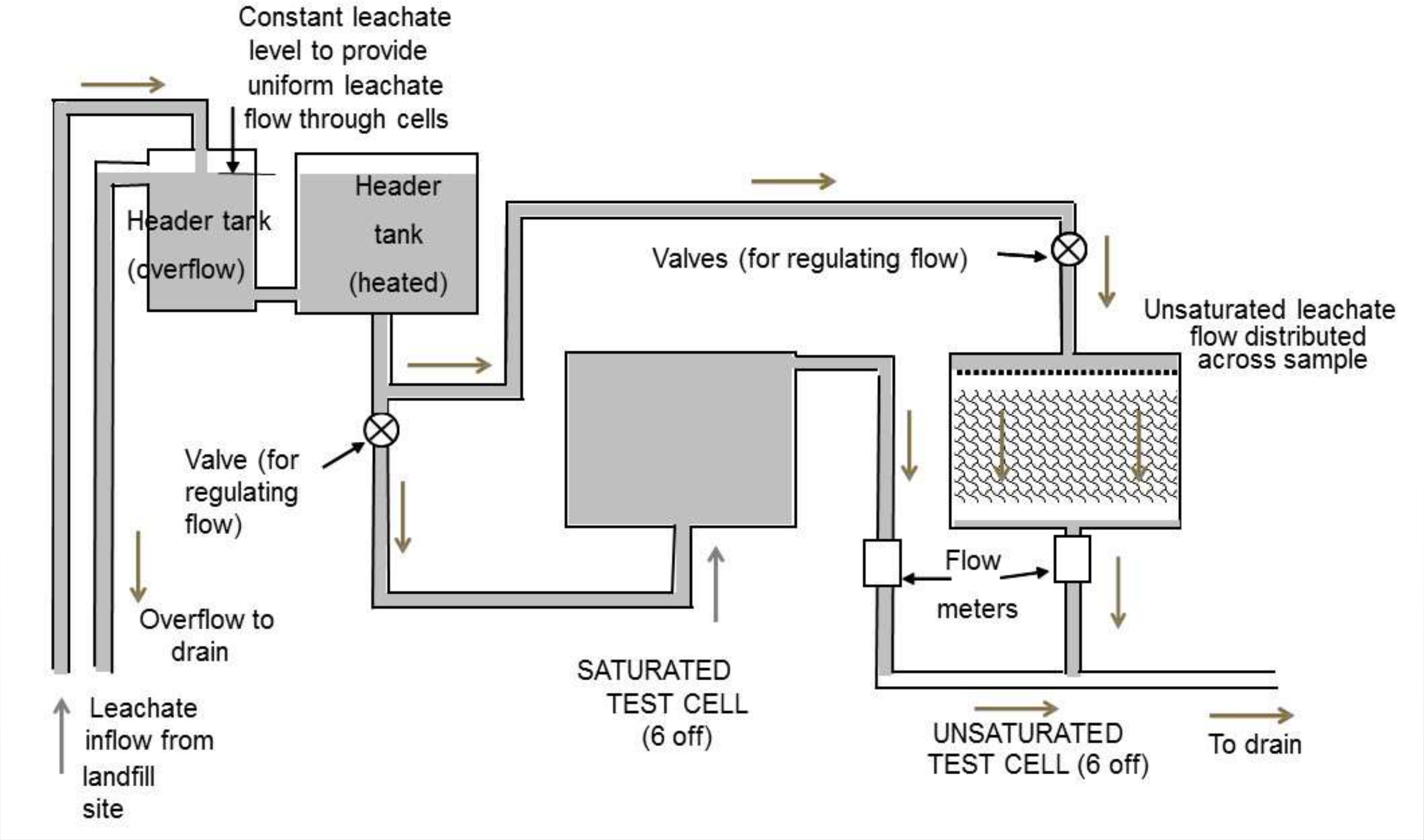
Tyre clogging tests – samples/conditions tested

Tank	Material	Compression	Sat or unsat
1	Gravel	-	Saturated
2	Gravel	-	Unsaturated
3	Tyre bale	-	Saturated
4	Tyre bale	-	Unsaturated
5	50 mm shred	Low	Unsaturated
6	50 mm shred	High	Unsaturated
7	50 mm shred	Low	Saturated
8	50 mm shred	High	Saturated
9	200 mm shred	Low	Unsaturated
10	200 mm shred	High	Unsaturated
11	200 mm shred	Low	Saturated
12	200 mm shred	High	Saturated


520


FIRE EXIT

Leachate drainage layer clogging tests – general arrangement



- Leachate passed through each sample at an accelerated flow rate of 300 litres /m^2/ day (300 mm / day) to represent the passage of leachate anticipated over the operating period of a landfill

= flow rates ranging from 3 l/h for the smallest sample to 20 l/h for the largest samples.

Leachate supply

- Pumped from two sources
  - Direct from leachate well in middle of site

    "strong methanogenic leachate" (TOC~1750mg/l; BOD~500-1000 mg/l; NH_4-N~2000 mg/l; Ca~130 mg/l)
  - Peripheral leachate interceptor trench

    "weak methanogenic leachate" (TOC~275 mg/l; BOD~140 mg/l; NH_4-N~500 mg/l; Ca~150 mg/l

- Insulated and heated feed tank at ~33 to 39 ^{o}C

- Sealed and insulated reactors maintain anaerobic conditions

Monitoring

- Leachate volumes
- Leachate quality in/ out
- Temperature in/out
- Drainable porosity (every few weeks)

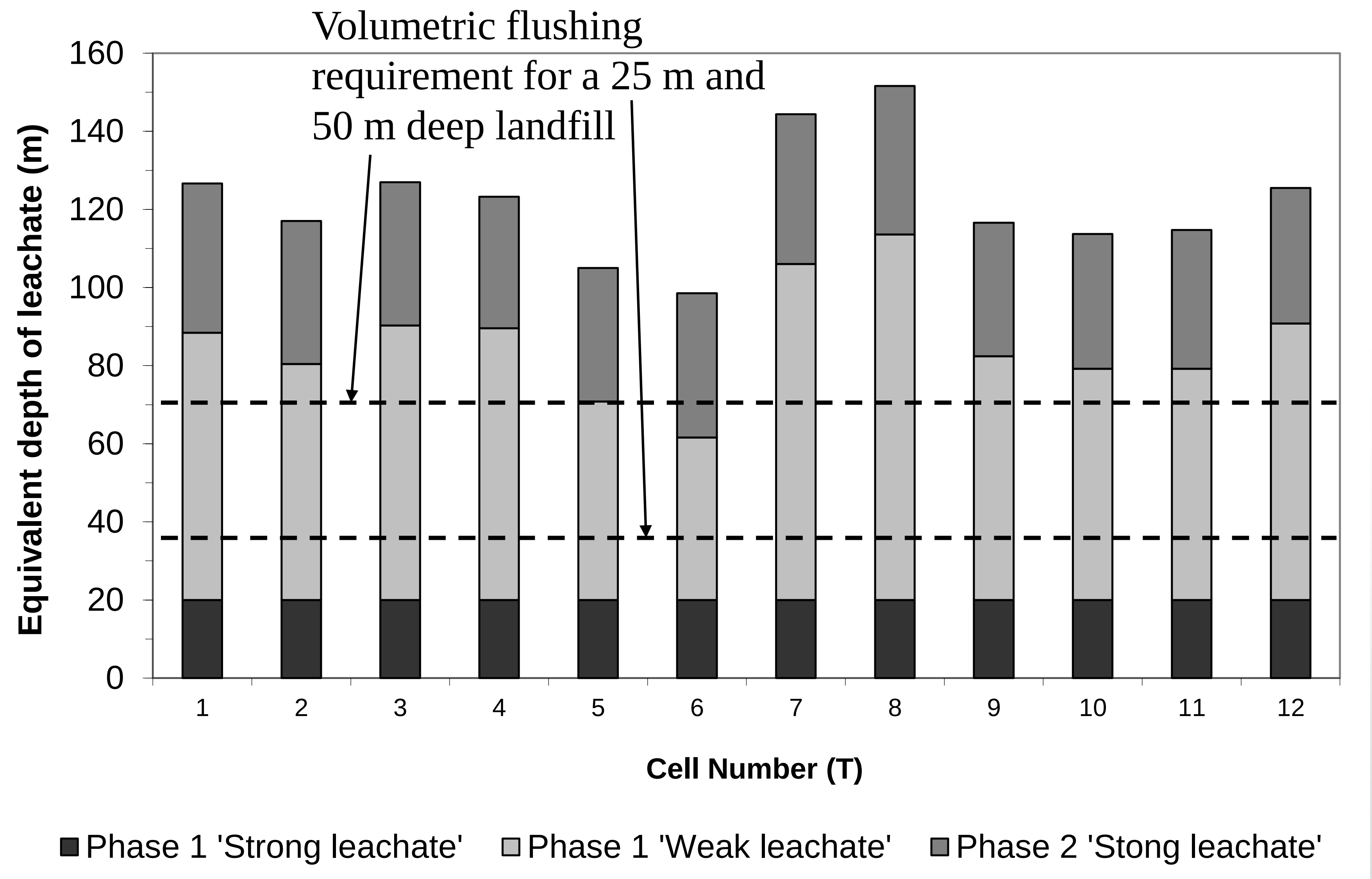
Leachate loading

- Two phases operation
  - Phase 1, 14 months (Sept 06–Nov 07), Strong and weak leachate
  - then a pause of 7 months
  - Phase 2, 4 months (July to Oct 08), Strong leachate

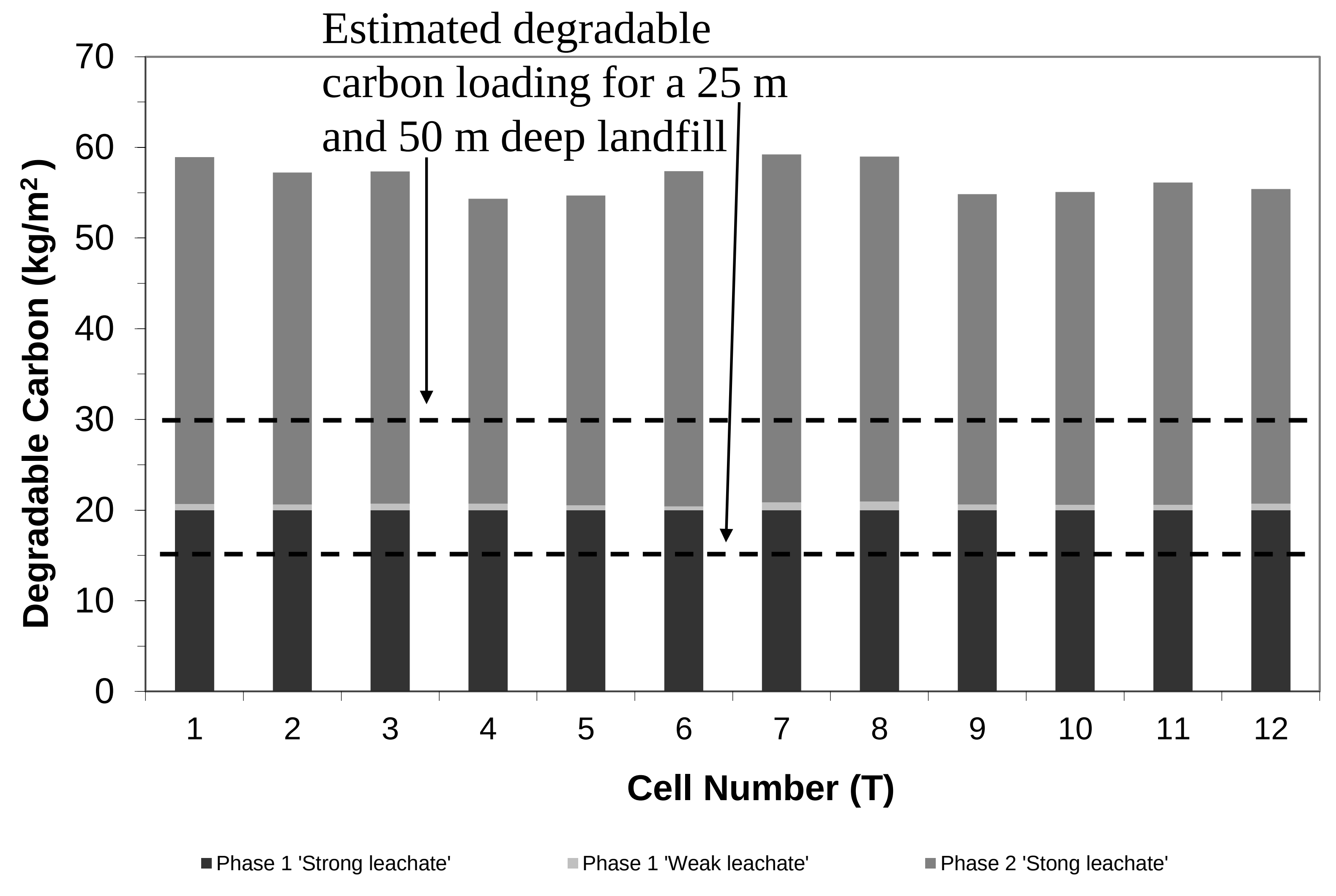
Volumetric and organic design loads

	Units	*Landfill depth of 25 m*	*Landfill depth of 50 m*
volumetric moisture content of waste	%	40	40
Bed Volume (per unit area)	m^3/m^2	10	20
∴ passage of 7 Bed Volumes is equivalent to a leachate depth of:	m^3/m^2	28	56
Equivalent volume of leachate if all at C_0	m^3/m^2	10	20
Additional 50% volume to account for continuing waste degradation	m^3/m^2	5	10
∴ depth of full strength leachate to pass through drainage layer to give equivalent contaminant flux over the period of the experiment	m^3/m^2	15	30
Degradable TOC content of methanogenic leachate	kg/m^3	1	1
Required mass loading of degradable TOC from methanogenic leachate	kg/m^2	15	30

Volume of leachate through reactors



Degradable carbon load per unit area



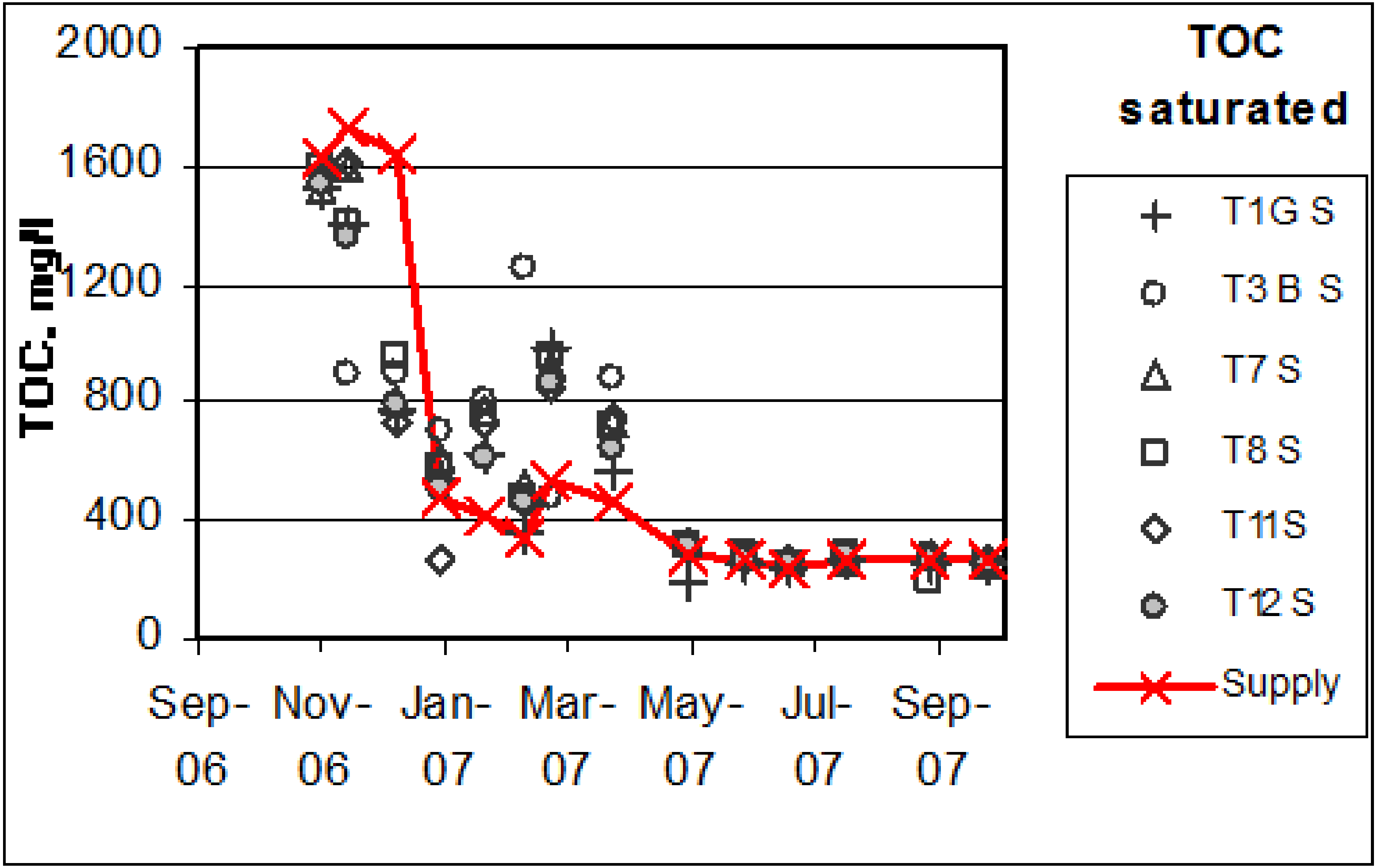
Results

1. Leaachate quality

   – For the conservative indicators chloride and ammonia, there was very close similarity between supply and outlet concentrations in the unsaturated reactors.

   – Significant removal (25 to 150 mg/L) of suspended solids occurred in both unsaturated and saturated reactors.

   – The TOC results show evidence of some removal in the saturated specimens, during the initial stages from the stronger leachate, but not from the weaker leachate. There was little or no evidence of removal of TOC in the unsaturated specimens at any stage.


TOC
saturated
TOC, mg/l
2000
1600
1200
800
400
0
Sep-06
Nov-06
Jan-07
Mar-07
May-07
Jul-07
Sep-07
T1G S
T3 B S
T7 S
T8 S
T11S
T12 S
Supply

Results

2. Drainable porosity

   – No evidence of systematic reduction in drainable porosity over duration of experiment

   – Except for....

Changes in drainable porosity during extended tests

Sample no.	T1 Sat' gravel	T2 Unsat' gravel	T3 Sat' tyre bale	T4 Unsat' tyre bale	T5 Unsat' 50mm LOW	T6 Unsat' 50mm HIGH	T7 Sat' 50mm, LOW	T8 Sat'd 50mm LOW	T9 Unsat 200mm LOW	T10 Unsat 200mm HIGH	T11 Sat' 200mm LOW.	T12 Sat 200mm HIGH
initial drainable porosity	37.2	35.9	50	57	56	58	68	51	56	23	41	28
End drainable porosity	38.3	34.2	53	59	52	50	66	48	55	20	45	27
change in drainable porosity	+1.1	-1.7	+3	+2	-4	**-8**	-2	-3	-1	-3	+4	-1

Dismantling specimen T6 (greatest reduction in drainable porosity): browning is rust

- There were some small (insignificant) accumulations of sludge on some surfaces, and overall the exercise confirmed that there had been little change in drainable porosity and that a free and open pore structure remained.

Calculation of clog volume

	Value	Units	Source
Total mass loading of degradable TOC, expressed as COD	180	kg/m²	Figure 7 assuming that 1kg TOC ≡ 3 kg COD
Anaerobic growth yield coefficient for biomass from COD	0.04	gVSS/gCOD	Table 10-10, Metcalf and Eddy (2003)
∴ Expected volume of biomass growth	7.2	litre/m²	Assume biofilm density = 1 kg/litre
So, absolute loss of porosity in 0.5m deep layer [7.2litre÷500litre]	1.4	% v/v	

All the drainage media tested were exposed to approximately 60 kg of degradable TOC per m2 (equivalent chemical oxygen demand, COD = 180 kg/m2). If all this TOC was degraded in a 0.5 m drainage layer, then there would be at most a 2% loss in porosity.

Landgraaf test cell: 4400m^3 base area

Sand drainage blanket during exhumation of cell. The cell was filled with ~25000 tonnes of MSW / industrial wastes; was subjected to ~30000 m^3 of leachate recirculation / clean water injection from 2002-2004 and subsequently used in leachate management regime tests including fill and draw

Landgraaf basal drainage sand

- showed no evidence of any cementation
- fine grained black particles washed out of the samples during constant head upflow permeability tests – consistent the findings of Nikolova-Kuscu, Powrie et al. regarding bioclog material in the absence of $CaCO_3$ precipitation.
- The average hydraulic conductivity was measured at 6.23 $\times 10^{-5}$ m/s.
- drainable porosity 32% (by volume)

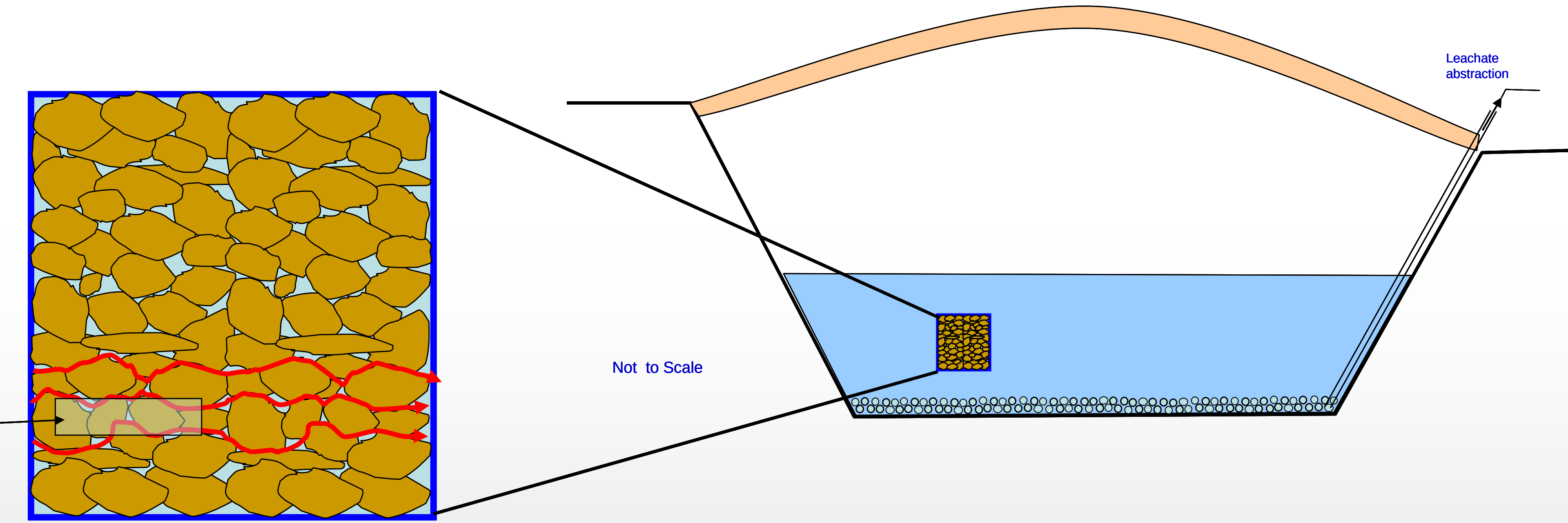
Observations

- Rowe *et al.* show that both aggregate and tyre drainage layers will clog when subjected to strong acetogenic leachates – and shredded tyres are more susceptible to clogging than gravel
- Tests show that passage of methanogenic leachate through drainage layers does not seem to cause clogging
- Field experience in the UK has not shown there to be a general problem with clogging of drainage media

Discussion – Design challenges

- To maintain performance of drainage blanket need to protect it from receiving acidogenic leachates

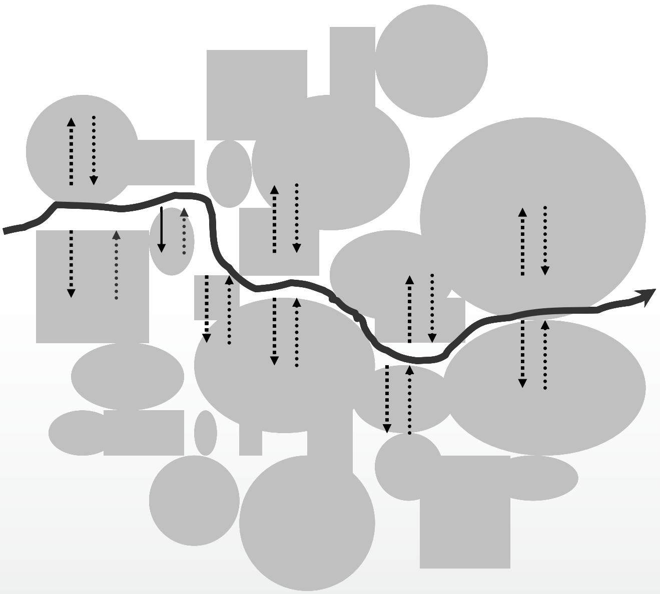
Flow paths in waste

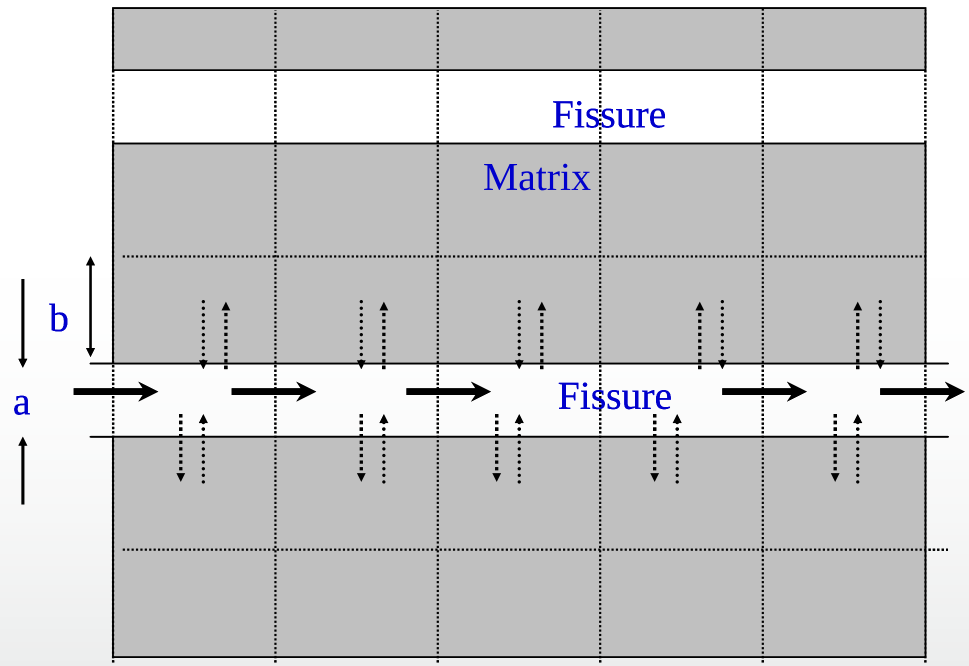


Saturated Flushing (Dual Porosity Models)

(a) conceptual model

(b) a representation in DP-Pulse: Slab Geometry





Diffusion between fissure and matrix

Advective flow from cell to cell in fissure

Potential short-circuiting of flow mean that there may be rapid flow paths, especially though unsaturated zone. This may provide a route for new water entering site to pick up newly solubilised organics and transport it to basal layer even if majority of site is methanogenic

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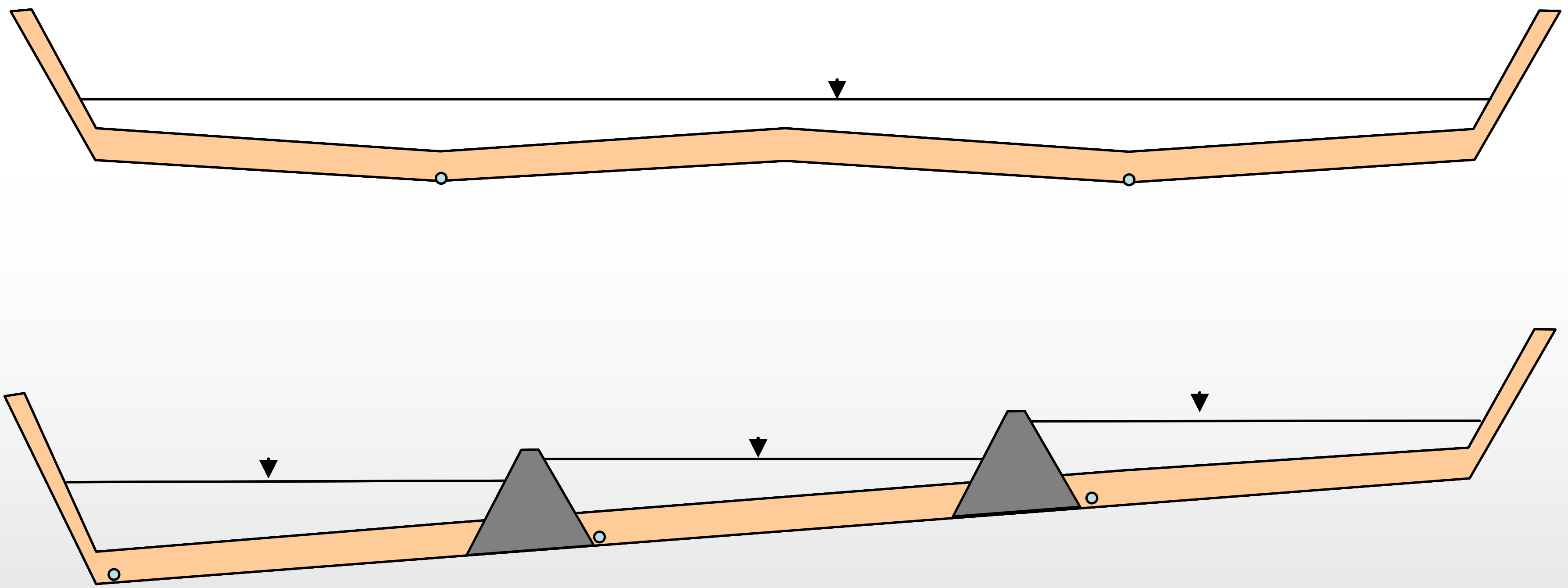
Discussion – Design challenges

- To maintain performance of drainage blanket need to protect it from receiving acidogenic leachates
- maintain a methanogenic buffer zone in both the drainage layer and the bottom layer of waste
- Acidogenic leachate would then be treated within the waste layer rather than in the drainage blanket
- To achieve this, drainage blankets should be operated fully saturated
- May need to build landfills either with flat bases or corrugated basal profiles, to limit the increase in leachate head associated with a sloped base

Conceptual leachate basal drain designs to maintain an overlying buffering layer of methanogenic waste



Conclusions

- Work of Rowe and others indicate significant clogging potential of acidogenic leachates to drainage layers of all descriptions
- Methanogenic leachates do not cause clogging of leachate drainage layers
- Design challenge is therefore how to prevent acidogenic leachates reaching the drainage layer
- Creating a buffer zone of saturated methanogenic wastes may be a better environmental option

Acknowledgements

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Clogging of landfill tyre and aggregate drainage layers by methanogenic leachate and implications for practice

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