Conference 2016
Coventry

Centre for Agroecology, Water & Resilience

The retention and *in-situ* treatment of contaminated sediments in laboratory highway filter drain models.

Stephen J. Coupe, Luis A. Sañudo-Fontaneda Anne-Marie M. McLaughlin, Susanne M. Charlesworth and E. Gordon Rowlands

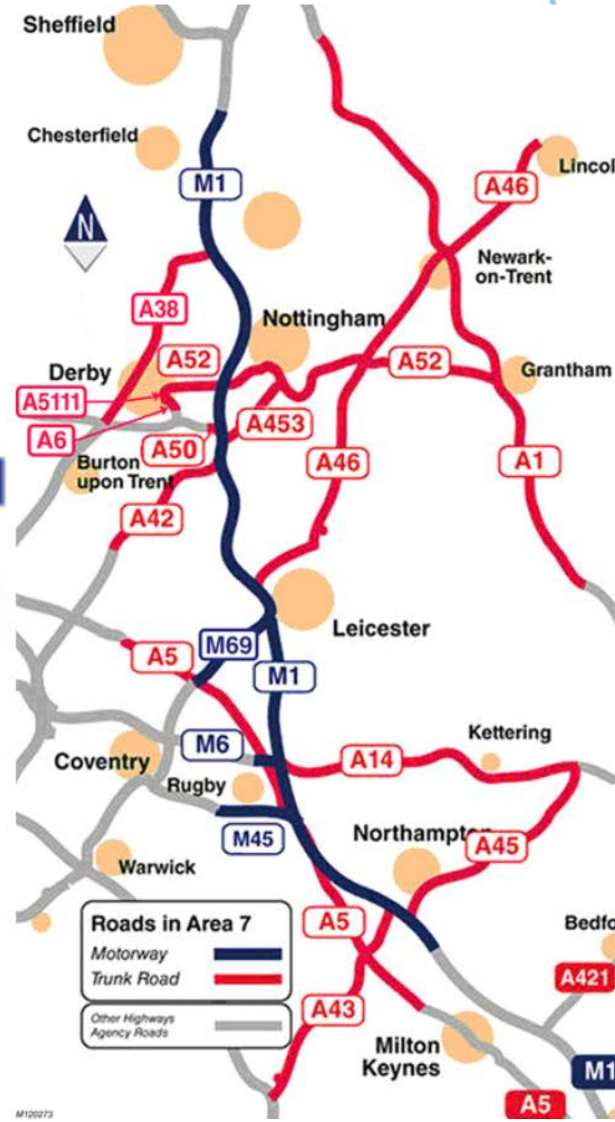
Water Efficiency Conference 7th-9th September 2016

EXCELLENCE WITH IMPACT

Coventry University

UK Road “French Drain”

Road strategic network in England, UK



Source: http://www.constructionenquirer.com/2016/03/21/amey-wins-new-style-423m-highways-england-maintenance-deal/

Road strategic network in England, UK

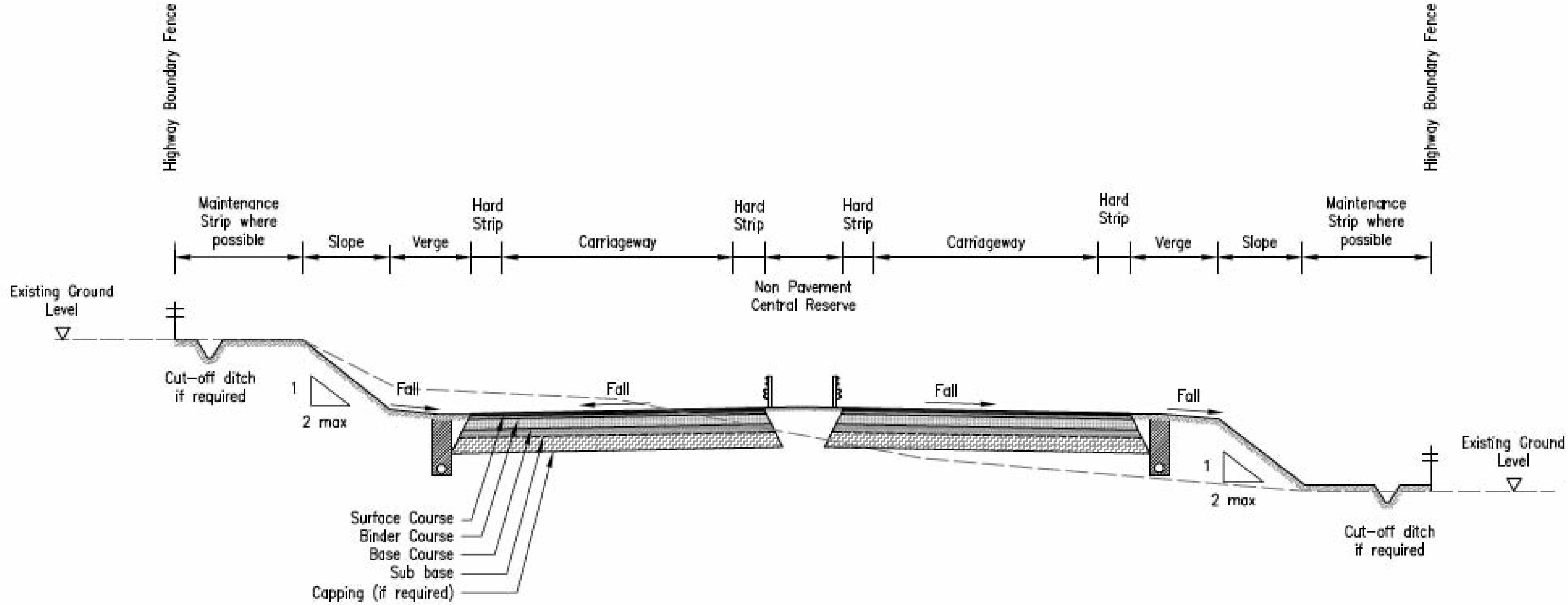
Vehicle traffic in the UK has increased dramatically since the 1950's to more than 300 billion vehicle miles in 2014 (UK Department of Transport, 2015). To cope with this high volume of traffic the UK has a developed road network of nearly 1.8 km road/km^2 land area and a total length of roads of 419,596 km, of which 3,674 km corresponds to motorways and 49,040 km to main or national roads.

The strategic and local road networks are England's most valuable transport infrastructure valued at approximately £344 billion and are made up of roads and other infrastructure such as bridges, embankments and drainage systems (House of Commons 2014). In 2012-2013 public **spending on maintaining England's roads was £4 billion**, divided between the UK Department of Transport, the Highways Agency (**Highways England** since 2015) and Local Authorities. The operation, maintenance and improvement of the strategic road network (motorways and 'A' roads), which represents 2% of the total road network (4,400 miles), is a responsibility of The Department of Transports through the Highways Agency (House of Commons 2014).

Filter drains

- Highway filter drains (French drains) are stone-filled roadside drainage trenches of approximately 1 metre depth and 1 metre width which run parallel to approximately 7,000 kilometres (4,350 miles) of motorways and main roads in the UK.
- They are the single most important UK highway drainage asset (drainage infrastructure)

Schematic of a standard road cross-section



Drawn by: CG | Checked by: AS | Date: 08/07

A90 Dualling - Balmedie to Tipperty

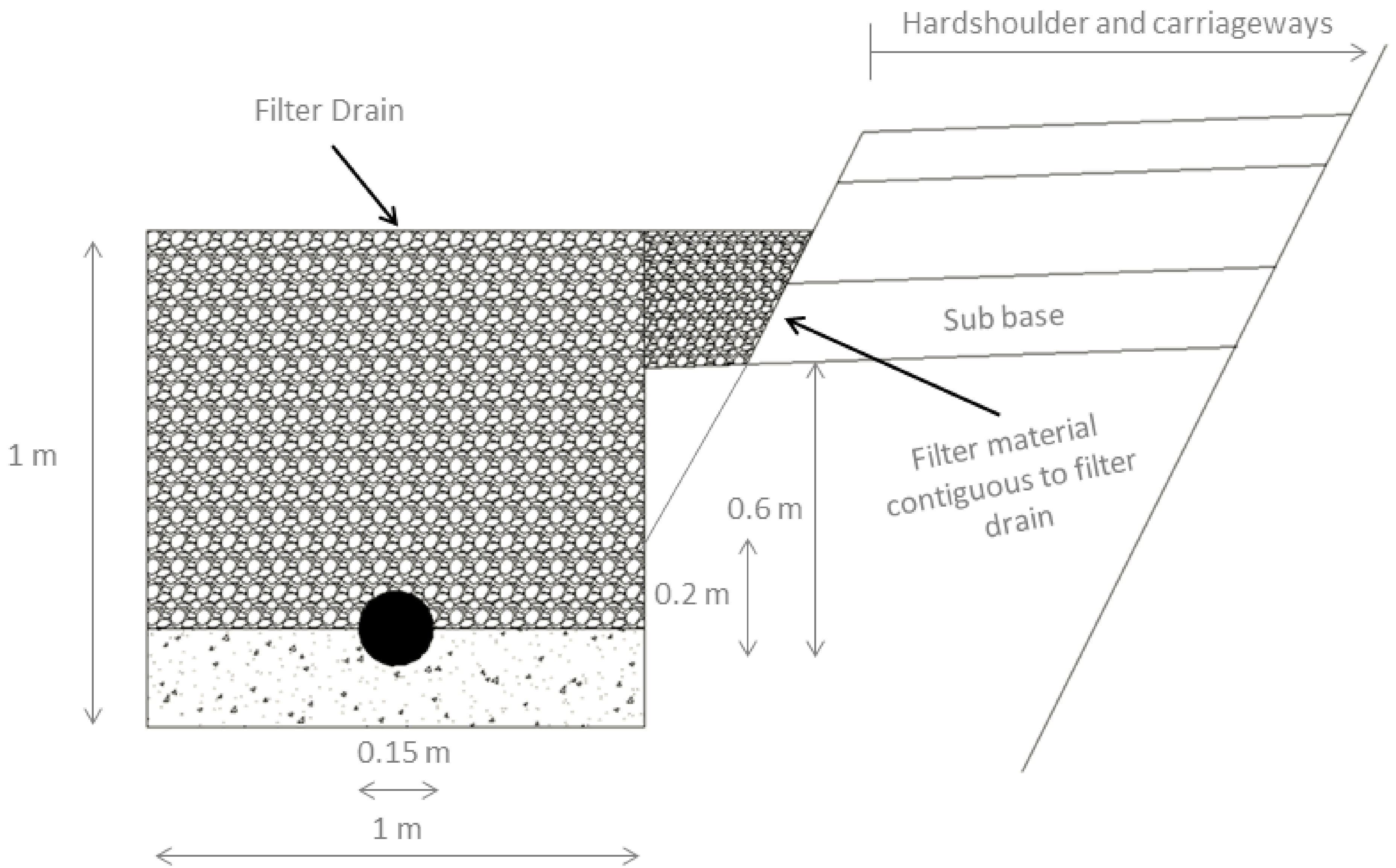
All Purpose Dual Carriageway Typical Cross Section

Figure 3.2

Scale NTS

http://www.transport.gov.scot/report/j8767b-04.htm

Detail of a road "French Drain" in the UK



Filter drains

- **Road user safety** (by removal of water from the carriageway), contributing to roads more resilient to flooding issues.
- **Pavement longevity** (by efficiently eliminating standing water adjacent to the highway sub-base, keeping the water level to a secure distance below the pavement structure and preventing the structure from sudden structural collapse).

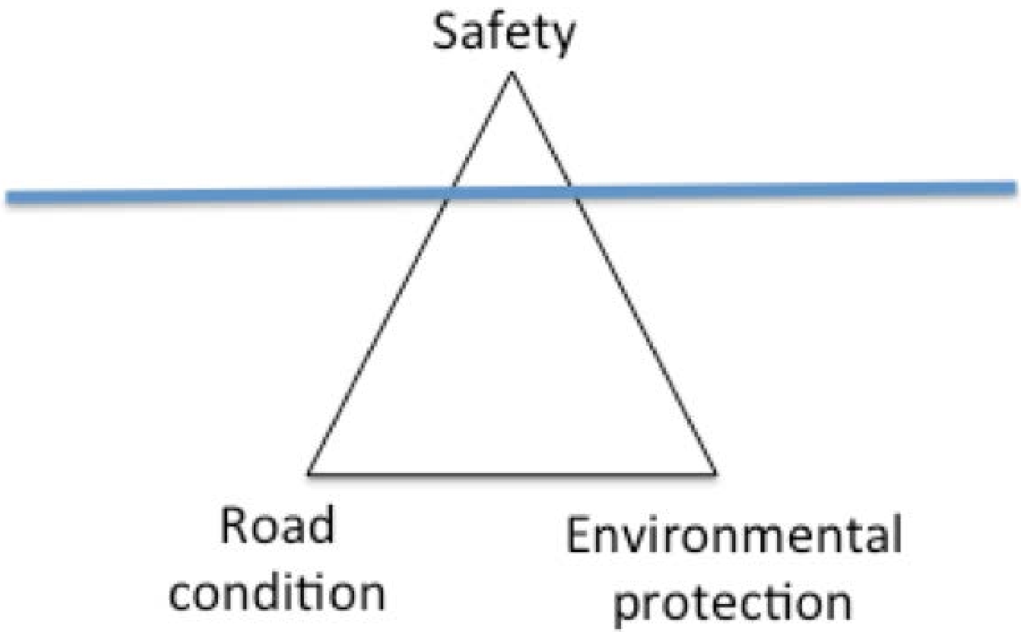
Filter drains and their benefits

Centre for Agroecology, Water & Resilience

Runoff water quality (by the filtering of sediments, hydrocarbons and other road surface contaminants through the 1 metre deep stone filter drain, purifying the water before discharge to the receiving waters downstream through a porous pipe at their base).

The drainage iceberg

Centre for Agroecology, Water & Resilience



The highway drainage iceberg, (concept by E.G. Rowlands).

What happens when it fails?

http://www.expressandstar.com/news/transport-news/2016/03/28/storm-katie-flooding-closes-m6/

UK Highway Maintenance – Carnell Group Ltd

Courtesy of Carnell Group Ltd, UK. Source: Carnell Group Ltd http://www.carnellgroup.co.uk/Services/Drainage2/index.html

Filter Drain Optimisation

STONEmaster® - Filter Drain Refurbishment
STABLEdrain® - Filter Drain Stabilisation
Ground & Trial Hole Investigations
Flooding Hot Spots
Flow Monitoring
Condition Assessment
Predictive Modelling

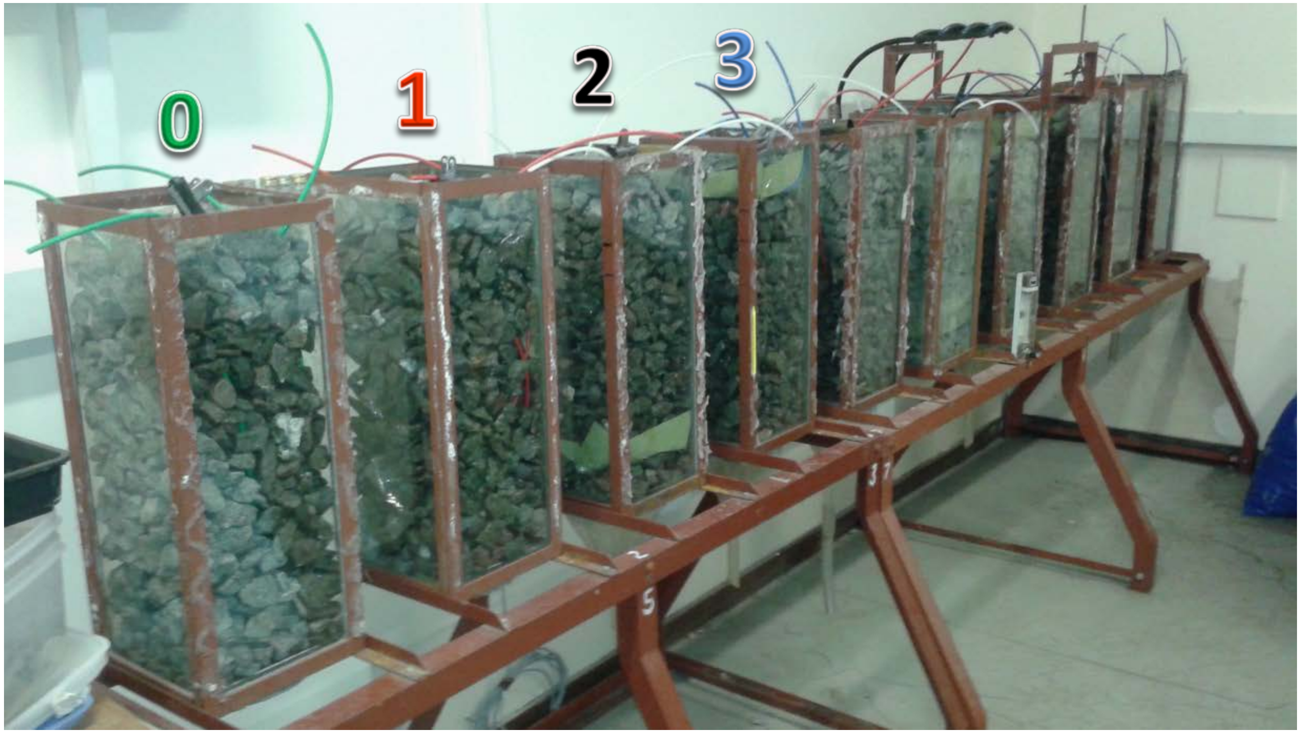
Refurbishment and Repairs

CCTV Surveying
High Pressure Root Cutting
De-Scaling & Encrustation Removal
Trenchless Patch Lining Repairs
Trenchless Structural Relining
Open Cut Repairs & Full Length Renewals
Chamber & Catch Pit Repair & Refurbishment
Drainage Ditch Re-Profiling & Cleaning
Installation of Pollution Control Measures
Site Clearance & Vegetation Control

LABORATORY BASED PROJECTS

Rigs setup

Centre for Agroecology, Water & Resilience



10 rigs

0 No geotextile (1 rig)

---

1 No geotextile (3 rigs)

2 Bottom geotextile (3 rigs)

3 Top geotextile (3 rigs)

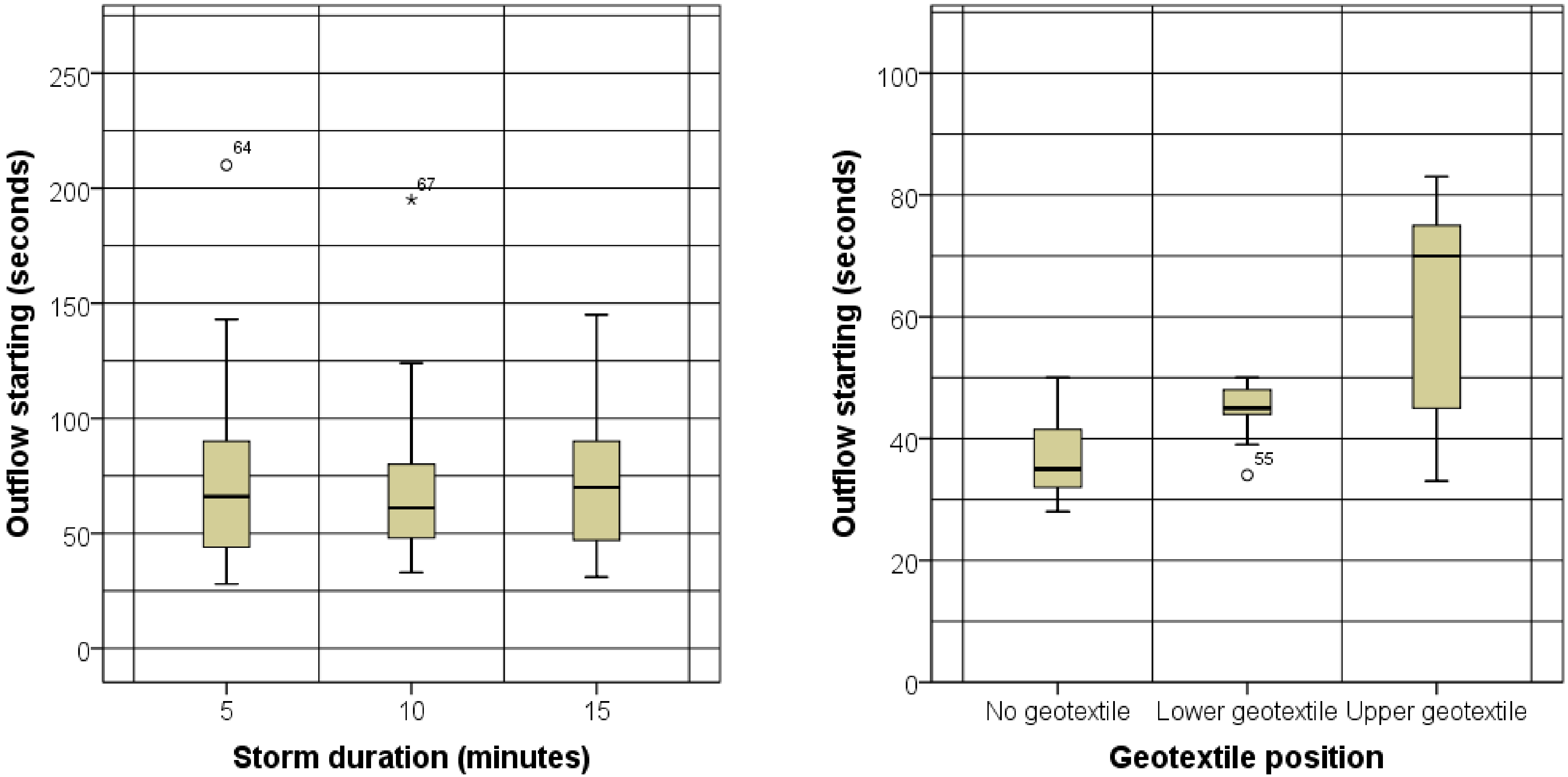
Description of the rigs

- ✓ Volume: 0.029 m^3 (0.21 m x 0.21 m x 0.65 m).
- ✓ Surface: 0.0441 m^2 (0.21 m x 0.21 m).

LABORATORY BASED PROJECTS

Previous rig work – Carnell 1 (Laboratory work) project

- **<u>After the addition of Contaminants</u>**



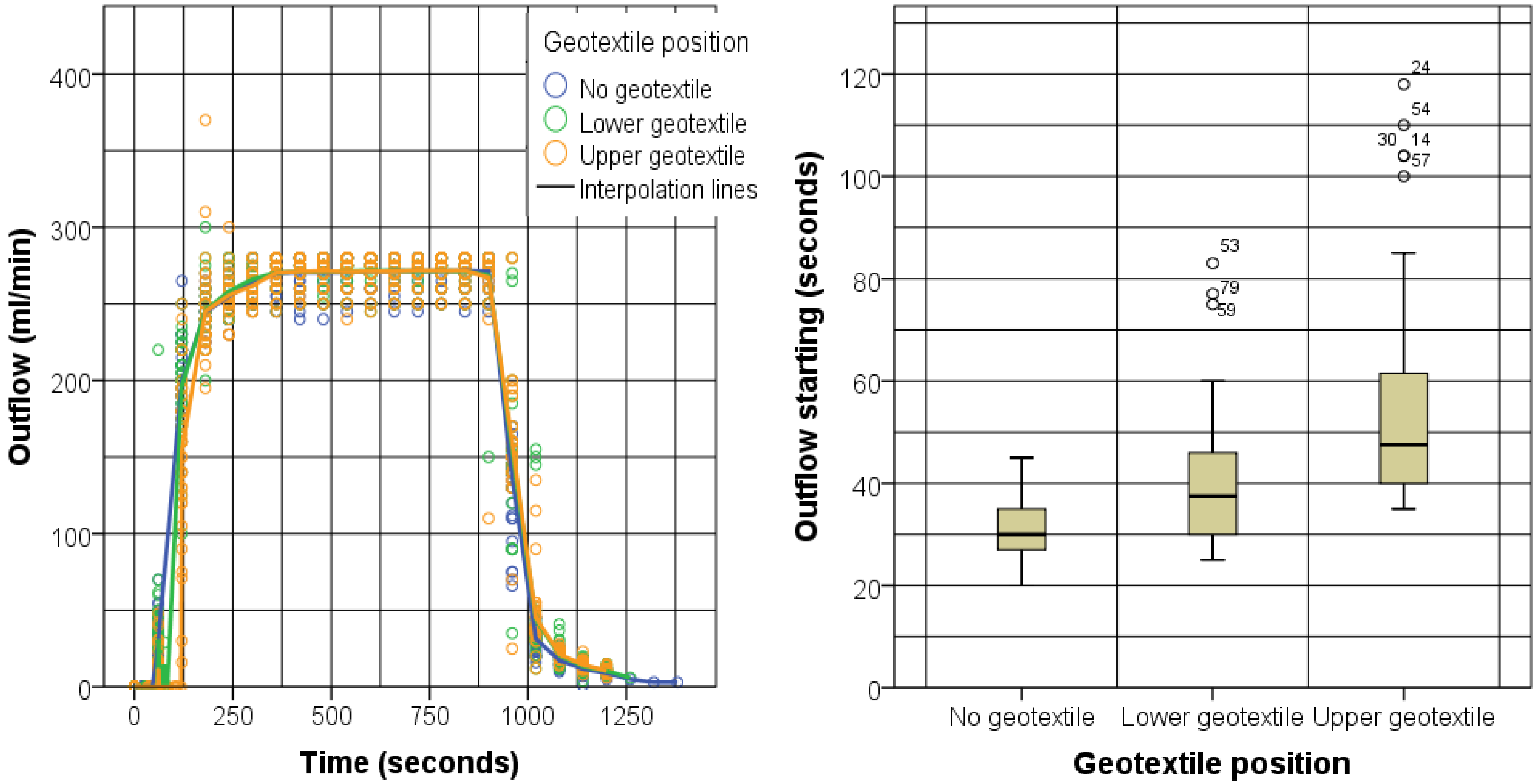
EXCELLENCE WITH IMPACT

Coventry University

LABORATORY BASED PROJECTS

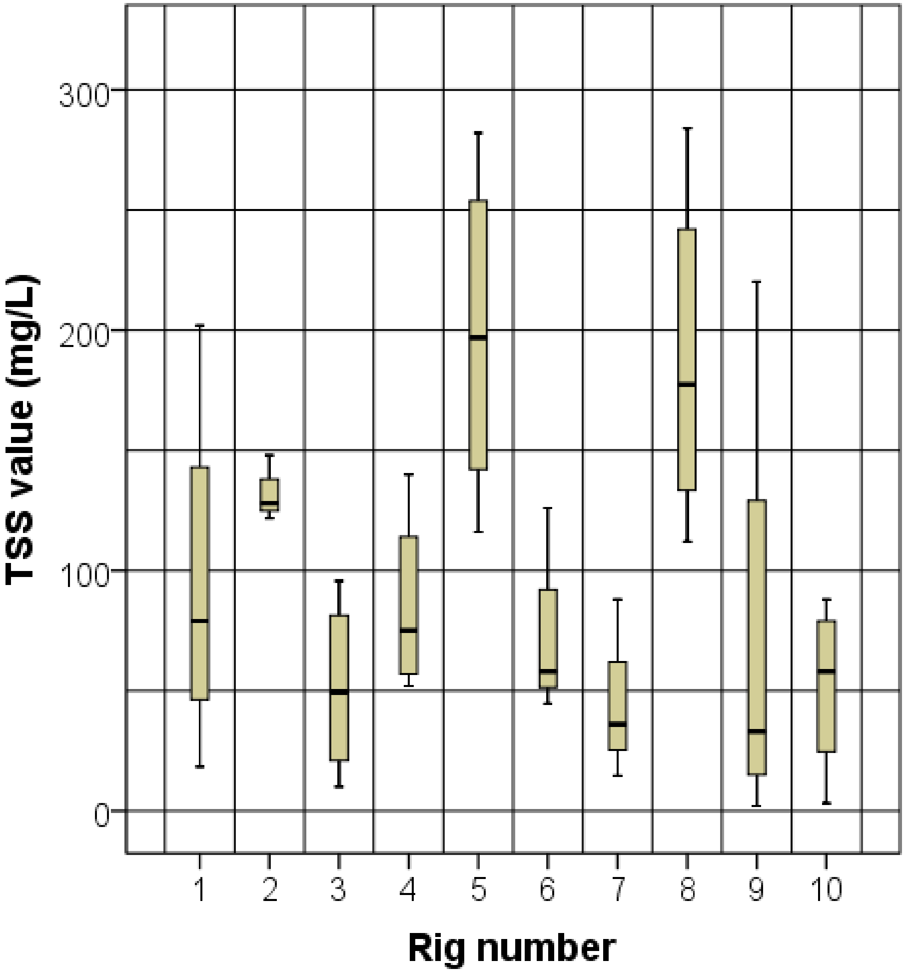
Previous rig work – Carnell 1 (Laboratory work) project

- **<u>After the addition of Contaminants</u>**

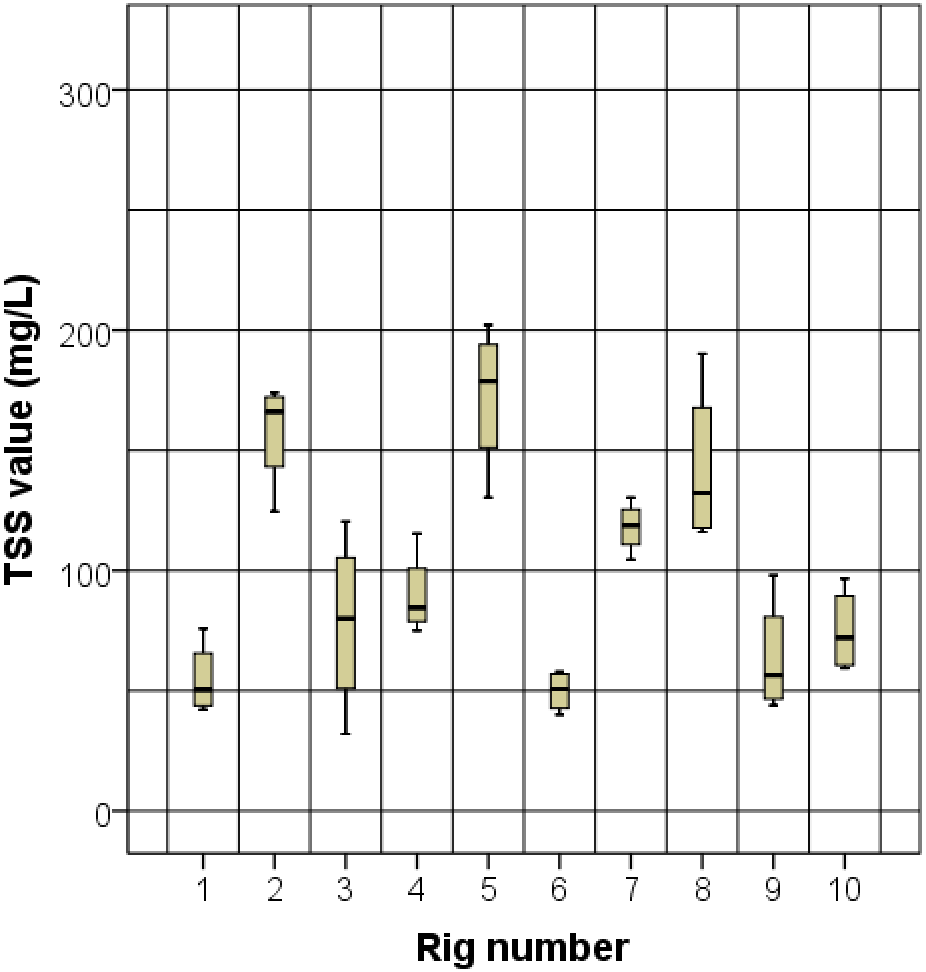


Sediments in effluent

Before sediments



After sediments



Oil and Zinc in effluent

Methodology for Oil extraction

Oil extracted with solvent (S 316) and automated extraction and measurement system.

Results for Oil extraction

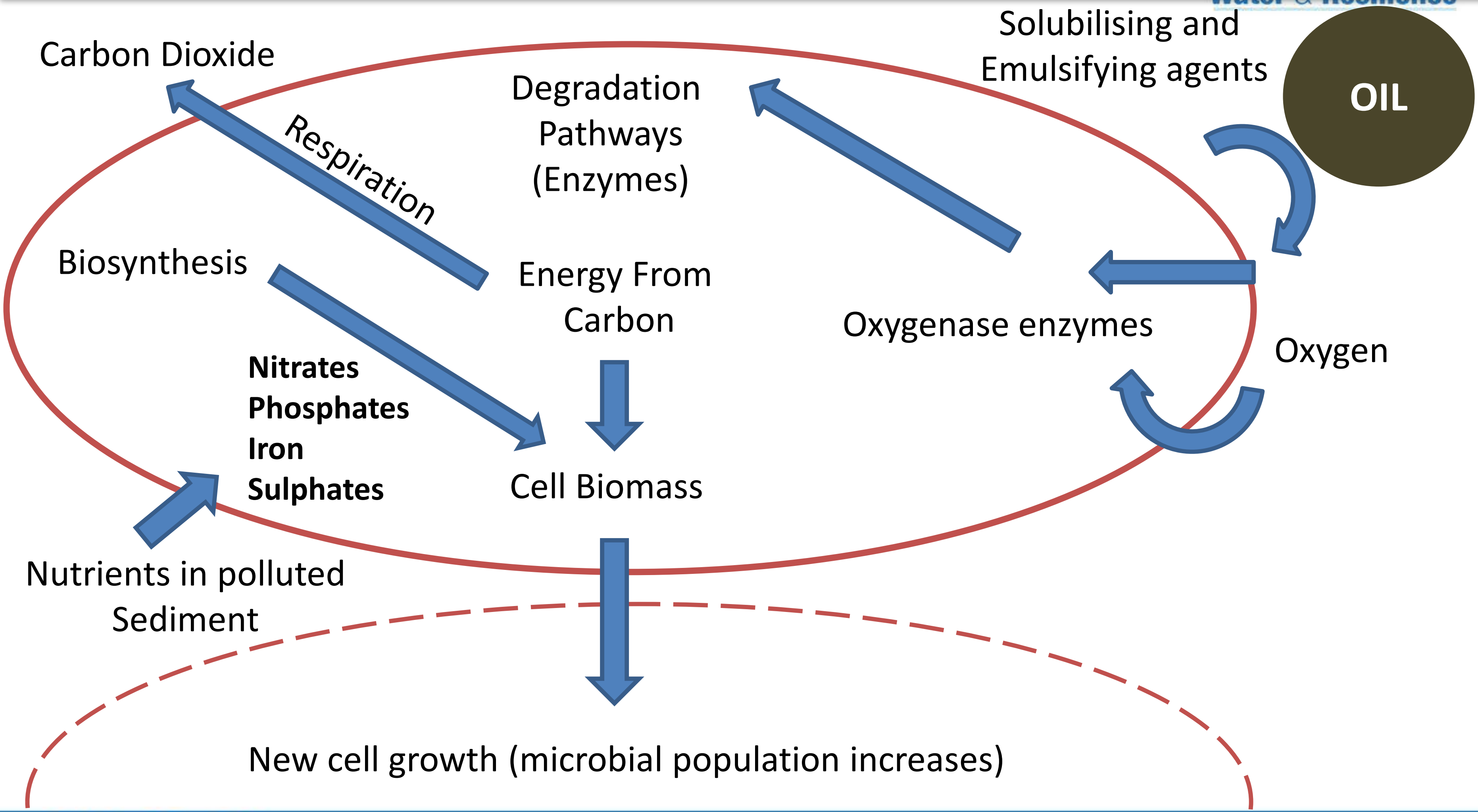
Non geotextile concentration in effluent 0.475 mg/L (n=12).
Bottom geotextile concentration in effluent < 0.100 mg/L (n=12).
Top geotextile concentration effluent < 0.100 mg/L (n=12).
Limit of detection (LOD) 0.100 mg/L.

Metals in effluent analysed by Inductively Coupled Plasma (ICP)

Total mass of Zinc per treatment

No geotextile 2.666 g
Bottom geotextile 1.790 g
Top geotextile 2.583 g

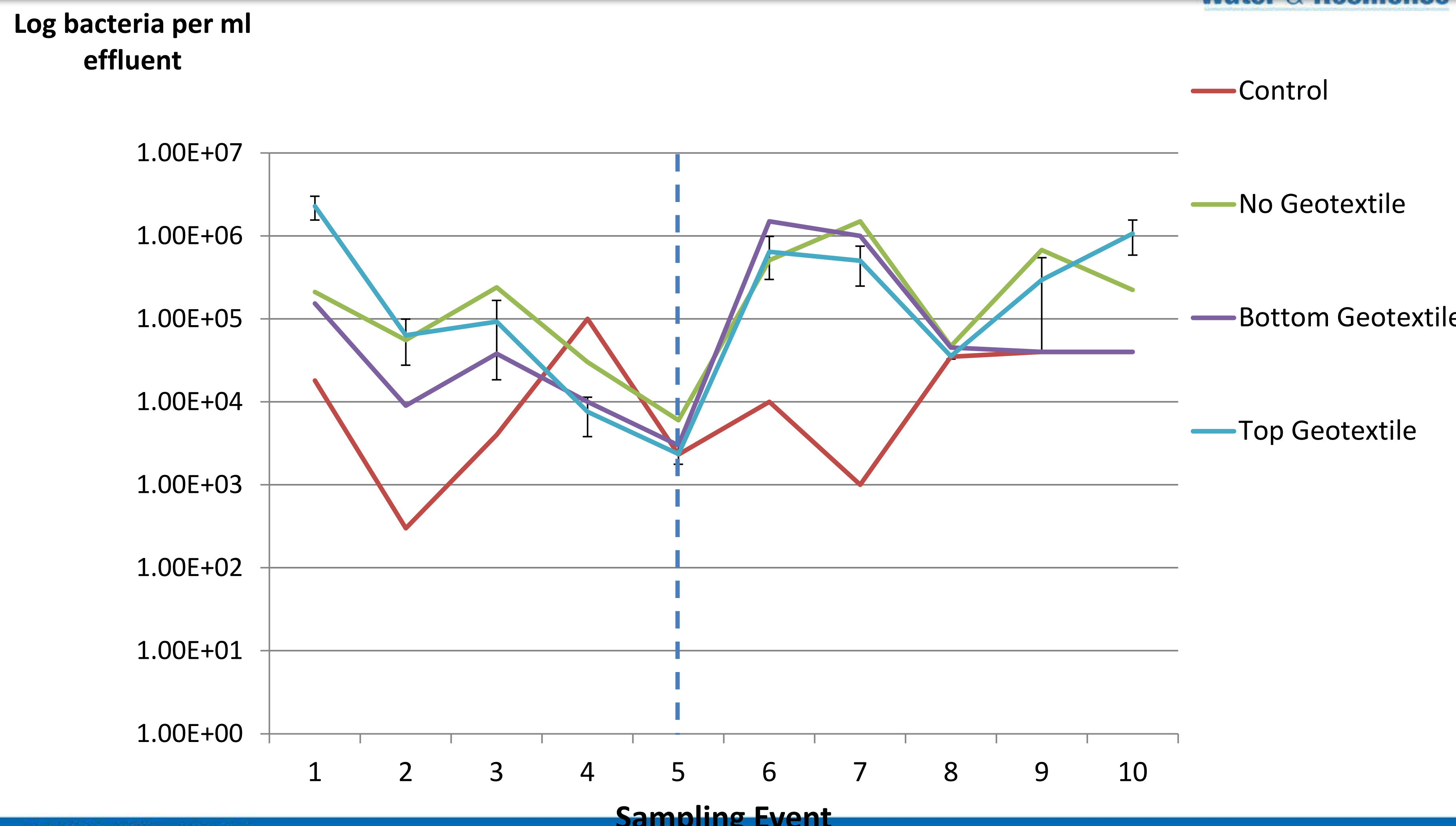
Biodegradation processes



Evolution of CO_2 from biodegradation

Highest evolved CO_2 recorded at the top sampling ports, 5000 ppm in rig atmosphere. This correlates with the accumulation of sediment and oil, showing biodegradation is taking place.
Ambient air CO_2 concentration in the lab is typically 400 ppm.

Bacterial densities



Protist counts

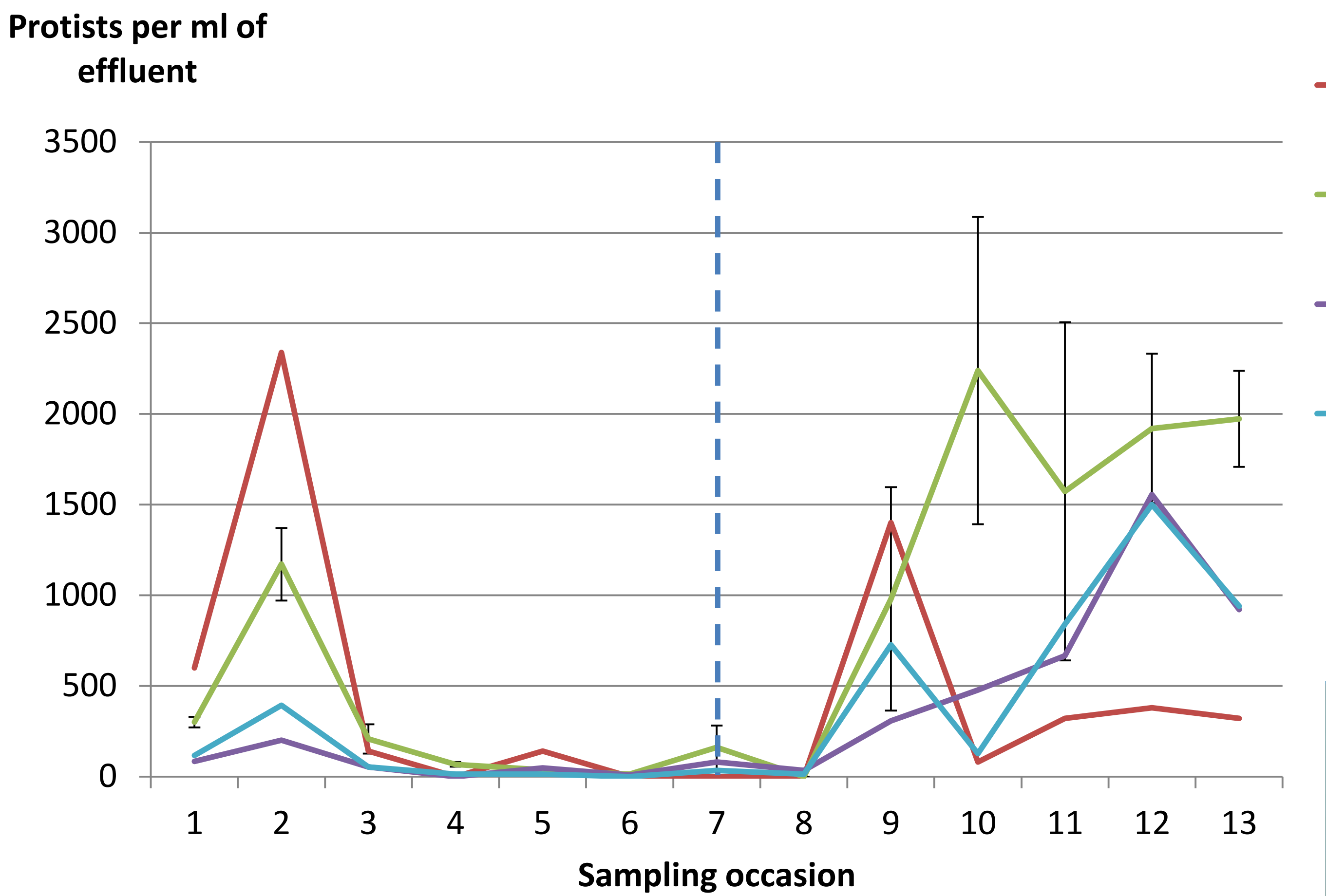
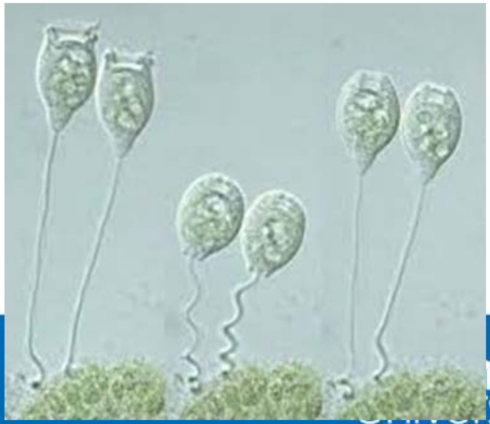


Image from http://undsci.berkeley.edu/article/0_0_0/endosymbiosis_02

Protist species recorded

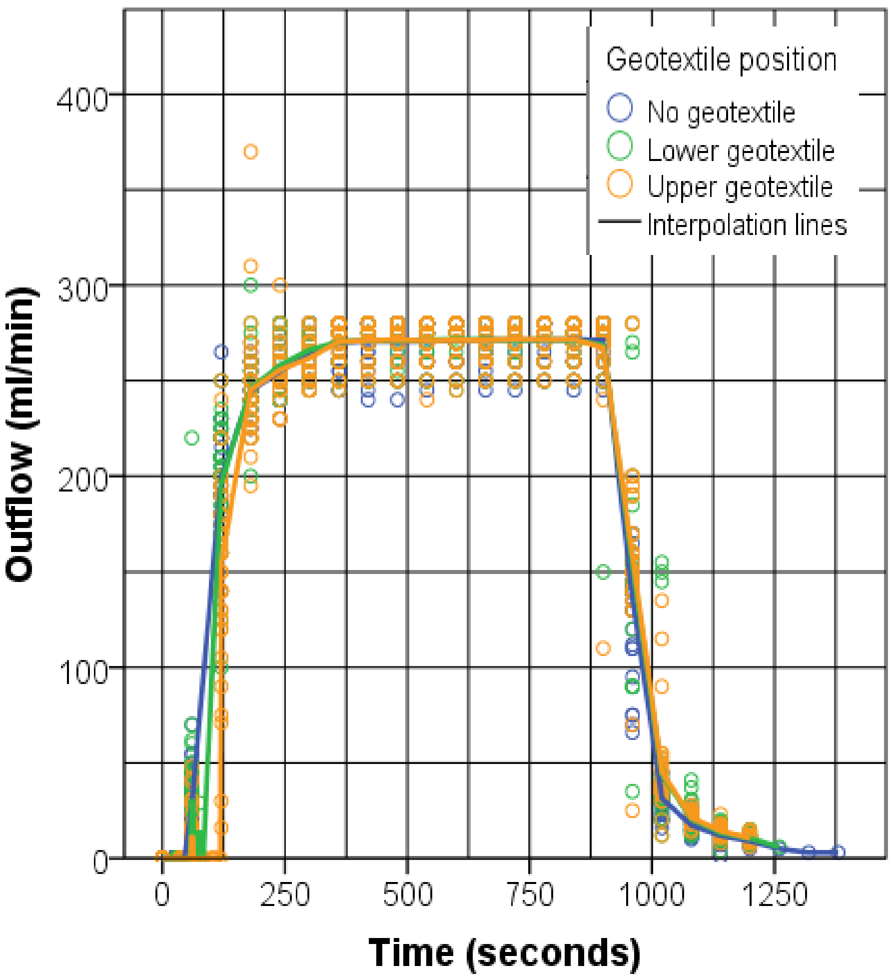
Rig type	Maximum taxa recorded	Maximum protist size (µm)	Key species
Control	1	4	*Bodo saltans*
No geotextile	11	300	*Actinophrys*
Bottom geotextile	11	500	*Caenorhabditis*
Top geotextile	12	250	*Vorticella*

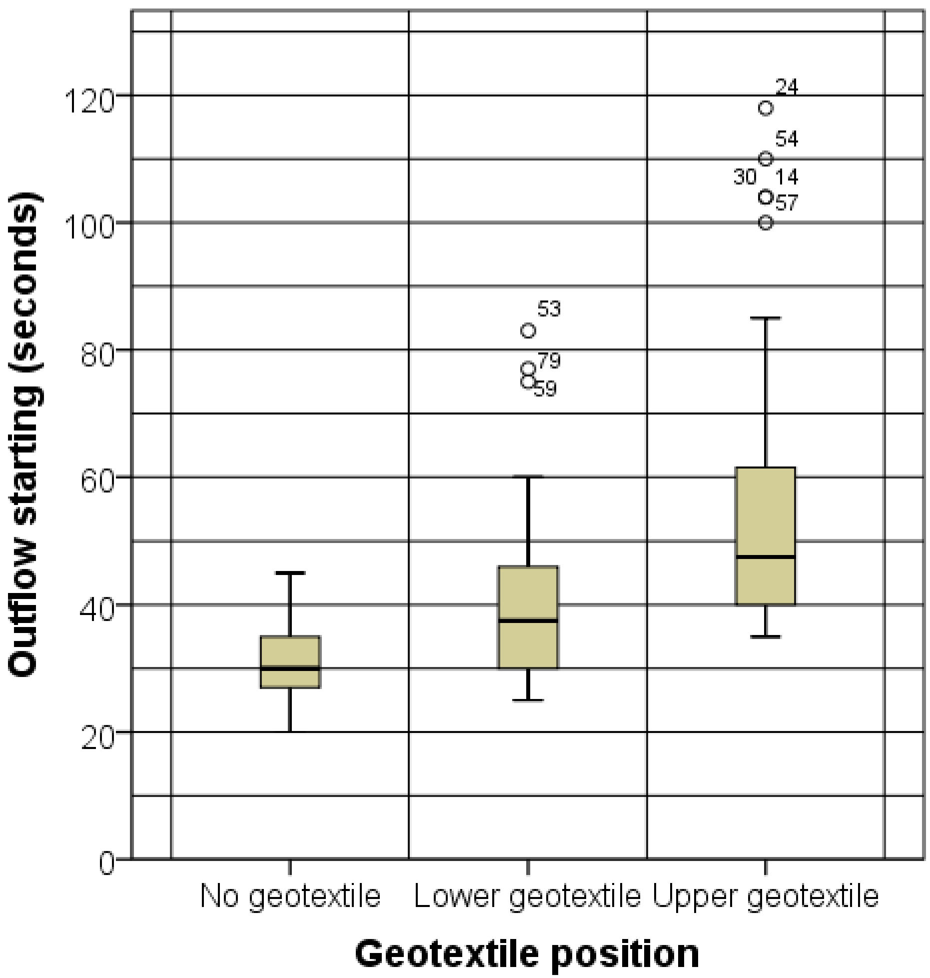


http://protist.i.hosei.ac.jp/pdb/images/Ciliophora/Vorticella/convallaria/convallaria_2.html

Hydraulics after addition of sediments

Hydrographs and attenuation levels





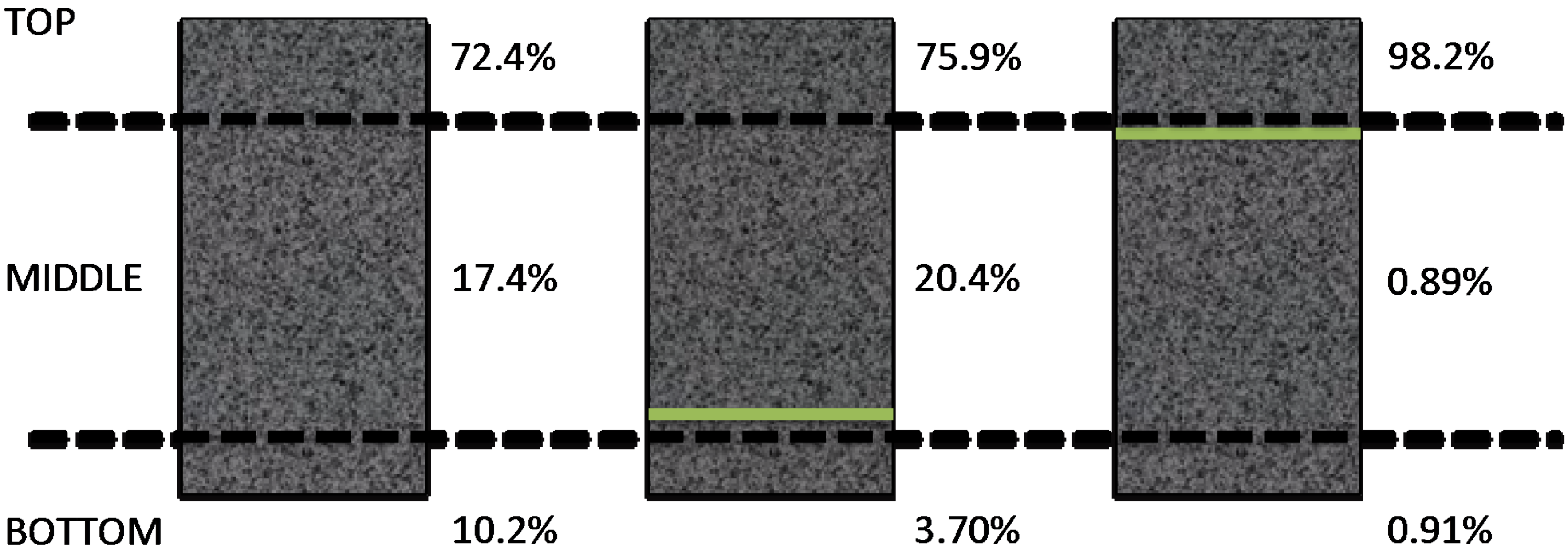
Mass of recovered sediment

Centre for Agroecology, Water & Resilience

NO GEOTEXTILE
431g recovered

LOWER GEOTEXTILE
427g recovered

UPPER GEOTEXTILE
448g recovered



Metals in remaining sediment

NCA Reference			16-20686	16-20687	16-20688
Client Sample Reference			Rigs 2, 5 & 8	Rigs 3, 6 & 9	Rigs 4, 7, 10
Client Sample Location			Combined	Combined	Combined
Depth (m)			Not provided	Not provided	Not provided
Date of Sampling			Not provided	Not provided	Not provided
Time of Sampling			Not provided	Not provided	Not provided
Sample Matrix			Sand	Sand	Sand
Determinant	**Units**	**Accreditation**	**Deviant**	**Deviant**	**Deviant**
Antimony	(mg/kg)	u	7.8	8.7	8.0
Arsenic	(mg/kg)	MCERTS	< 10	< 10	< 10
Barium	(mg/kg)	u	123	156	137
Cadmium	(mg/kg)	MCERTS	1.2	1.4	1.1
Chromium (Total)	(mg/kg)	UKAS	99.0	137	89.4
Copper	(mg/kg)	MCERTS	118	313	140
Lead	(mg/kg)	MCERTS	42.6	50.7	47.4
Mercury	(mg/kg)	UKAS	< 2.5	< 2.5	< 2.5
Molybdenum	(mg/kg)	u	5.5	8.7	6.8
Nickel	(mg/kg)	MCERTS	26.6	49.2	31.3
Selenium	(mg/kg)	u	< 8	< 8	< 8
Zinc	(mg/kg)	MCERTS	374	430	353

PAH in remaining sediment

Centre for Agroecology,

Acenaphthene	(mg/kg)	MCERTS	<0.2	1.52	<0.2
Acenaphthylene	(mg/kg)	UKAS	<0.2	0.26	<0.2
Anthracene	(mg/kg)	UKAS	0.26	0.58	0.51
Benzo (a) anthracene	(mg/kg)	MCERTS	0.92	2.32	2.65
Benzo (a) pyrene	(mg/kg)	MCERTS	1.07	2.86	3.10
Benzo (b) fluoranthene	(mg/kg)	MCERTS	2.52	5.69	6.07
Benzo (g, h, i) perylene	(mg/kg)	MCERTS	1.07	2.34	2.51
Benzo (k) fluoranthene	(mg/kg)	MCERTS	0.94	2.34	2.38
Chrysene	(mg/kg)	MCERTS	1.62	3.59	3.91
Dibenzo (a,h) anthracene	(mg/kg)	MCERTS	<0.2	0.44	0.48
Fluoranthene	(mg/kg)	MCERTS	1.24	4.70	3.25
Fluorene	(mg/kg)	MCERTS	<0.2	1.79	0.35
Indeno (1, 2, 3,-cd) pyrene	(mg/kg)	MCERTS	0.96	2.53	2.57
Naphthalene	(mg/kg)	MCERTS	<0.2	0.66	<0.2
Phenanthrene	(mg/kg)	MCERTS	0.69	4.19	2.30
Pyrene	(mg/kg)	MCERTS	1.25	4.14	3.57
Coronene	(mg/kg)	u	0.27	0.36	0.39
PAH Content (PAH17)	(mg/kg)	UKAS	13.8	40.3	34.6

Oil fractions in remaining sediment

Centre for Agroecology, Water & Resilience

GRO (> C_8 to C_{10})	(mg/kg)	UKAS	<500	<500	<500
DRO (> C_{10} to C_{21})	(mg/kg)	MCERTS	1700	2400	2800
MRO (> C_{21} to C_{40})	(mg/kg)	MCERTS	25000	45000	57000
Total TPH (> C_8 to C_{40})	(mg/kg)	MCERTS	27000	48000	60000
Benzene	(mg/kg)	MCERTS	<0.04	<0.04	<0.04
Toluene	(mg/kg)	MCERTS	<0.04	<0.04	<0.04
Ethyl Benzene	(mg/kg)	MCERTS	<0.04	<0.04	<0.04
Xylene (meta / para)	(mg/kg)	MCERTS	<0.04	<0.04	<0.04
Xylene (ortho)	(mg/kg)	MCERTS	<0.04	<0.04	<0.04

KNPS in remaining sediment

Centre for Agroecology, Water & Resilience

Nitrogen	(mg/kg)	u	2200	2300	1900
Phosphorus	(mg/kg)	u	636	620	623
Potassium	(mg/kg)	u	999	1059	1048
TOC	(%)	MCERTS	11.9	7.3	9.0
Sulphide	(mg/kg)	u	28	25	23

Conclusions

- A geotextile placed at the base of the rig produces the best effluent quality in simulated filter drains
- A geotextile placed at the top of the rig best restricts the downward movement of the sediment
- For metals, PAH, residual oils/TPH and KN the rigs without geotextile had the lowest remaining concentrations.
- Lower no geotextile rig sediment concentrations could indicate the export of pollutants in discharge rather than treatment efficiency
- The dispersal of oil and sediment in NG rigs could have increased the processing rate of organics by biological action.

WatEF Conference 2016 Coventry

Centre for Agroecology, Water & Resilience

The retention and *in-situ* treatment of contaminated sediments in laboratory highway filter drain models.

Stephen J. Coupe, Luis A. Sañudo-Fontaneda Anne-Marie M. McLaughlin, Susanne M. Charlesworth and E. Gordon Rowlands

Water Efficiency Conference 7th-9th September 2016

EXCELLENCE WITH IMPACT

Coventry University