End-of-life of a Sustainable Drainage System: Assessment of Potential Risk of Water Pollution through Leaching of Metals

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INTRODUCTION

- ‘End-of-life‘ can be referred to as the expiration of a SuDs device when the pollutants treatment efficiency has started to decline.

- In current context, end-of-life is defined as the phase when the PPS which was previously in service, was dismantled

(SuDs = Sustainable Drainage System; PPS = Pervious Pavement System)

INTRODUCTION

Industry and regulators recommended time frames within which to either replace or reconstruct the PPS

Reference	Recommended replacement/ refurbishment time (years)	Comments
CIRIA 2015	10 – 15	Replacement or reconstruction of part/whole PPS
INTERPAVE 2008; 2006	20	Without maintenance
California Stormwater Quality Association, CASQA 2003	15 – 20	Reconstruction and replacement
Environment Agency 2015	20 – 25	Replacement or reconstruction of part of the whole PPS

INTRODUCTION

Current study set on an 11-yr old pervious pavement installations occupied by one of Coventry University's partners in a Govt-Funded Knowledge Transfer Partnership (KTP)

Location of the Test Site Studied

Background

- Stormwater contains pollutants – heavy metals, hydrocarbons, particulates, microbes and emerging organic pollutants.
- Pollutants trapped in PPS may accumulate over time whilst undergoing biodegradation
- Some previous studies have expressed concerns over the pollutants that accumulate in PPS:
    - Some of the toxins may become hazardous.
    - High accumulation of heavy metals could potentially distort the biological functioning of the PPS system
    - Toxins that are non-degradable could leach out from the device
    - Potential risk of adjoining farmlands , groundwater and surface waters

Background

PPS are SuDs devices designed for stormwater control and treatment at source

Source: Mutual Materials Co. 2016

High infiltration capacity of PPS makes it a product of choice for sustainable development projects.

Source: Majalah 2018

Background

Multi- benefit PPS Applications:

- Ground source heat pump (GSHP) technology for renewable energy
- Rainwater harvesting
- Water recycling
- Mitigation of urban heat island effect

Hanson EcoHouse at BRE, Watford

Sub-base construction with heating/cooling pipes
Hanson EcoHouse 2007

Background

Previous studies showed relatively high removal pollutants efficiencies of PPS:

- 98.7% of total hydrocarbons (Bond 1999),
- 95% of suspended solids (Hogland et al., 1987),
- 93% of lead and 89% of COD (Balades et al., 1992)

- Few studies have evaluated the performance of the PPS system at end-of-life (e.g. hydrological performance - Sañudo-Fontaneda et al. 2018)
- No study till date investigated the potential groundwater and soil pollution by pollutants such as metals

Justification & Aim of Study

Hence, there is the need to determine the sustainability of this SuDS device by evaluating potential for reuse of wastes generated during decommissioning at end-of-life.

Aim of Study

The aim of this study was to evaluate potential risks associated with PPS during decommissioning and beneficial use of waste generated

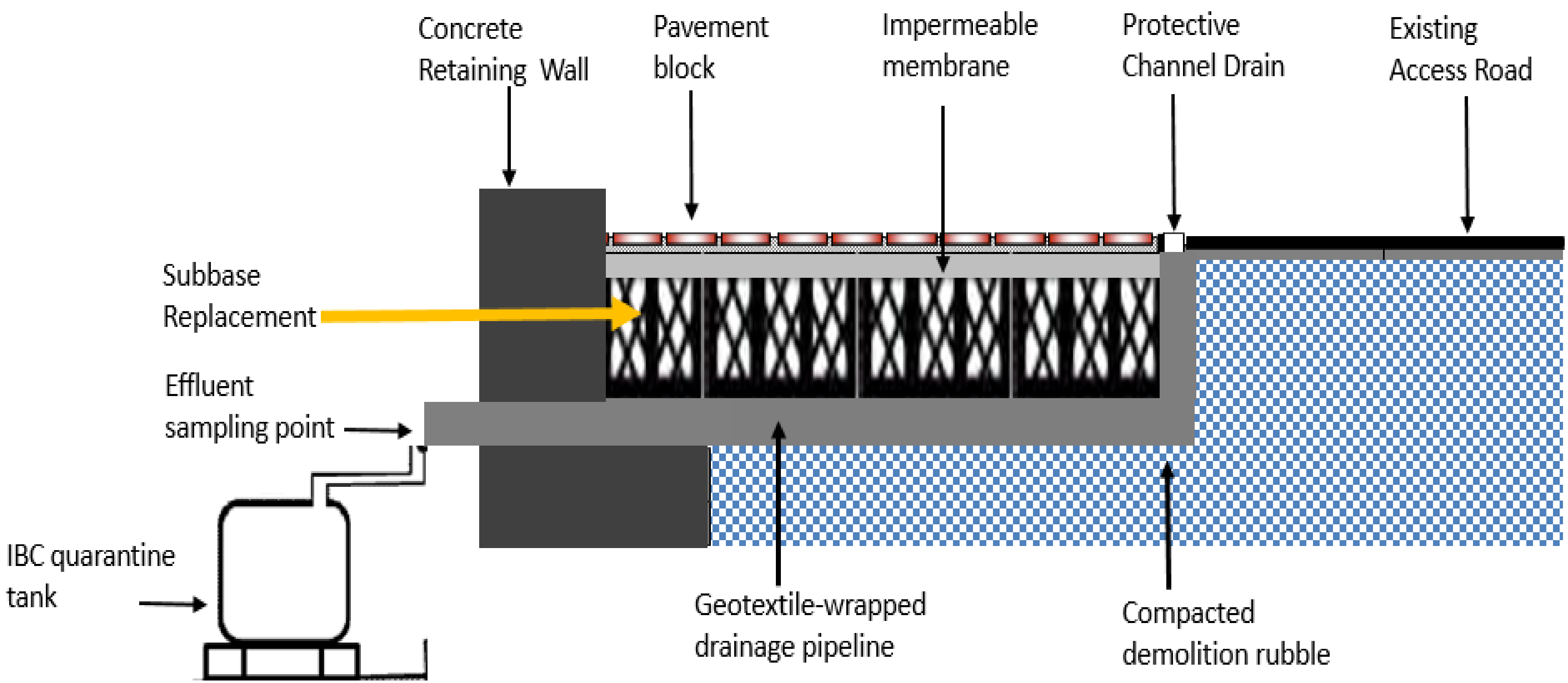
The Occupational Health and Safety aspects of the study have already been accepted for publication in ***Science of the Total Environment (STOTEM)***

Materials & Methods

- Research site was an 11-year old parking area built as an experimental test bed.
- Constructed in Bury, Lancashire as a multi-bay block paved system, with each single bay of dimension 2400mm x 4800mm

Materials & Methods

- Schematic cross section of the test bed

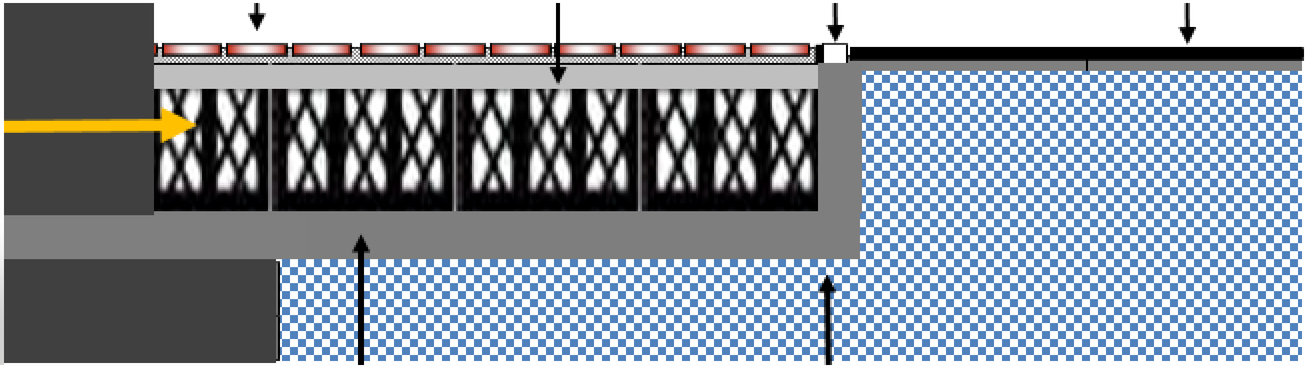


Materials & Methods

- Sampling point showing the 1m^3 IBC storage tank

At end-of-life…

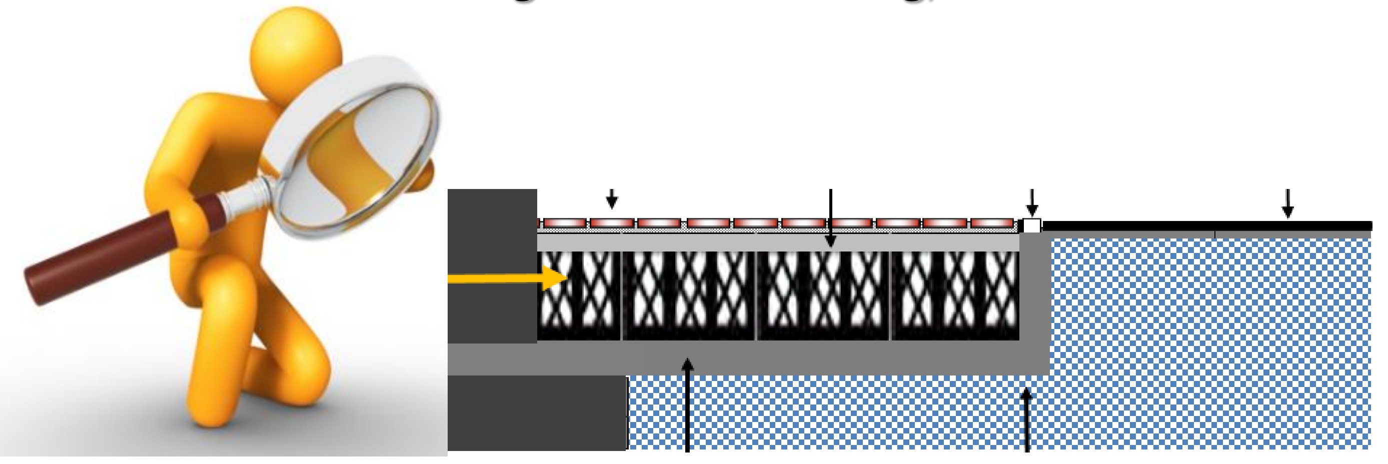
…During decommissioning,



Samples evaluated for potential risks via leaching as well as the sustainability of the materials via end-of-waste (EoW) criteria assessment

At end-of-life…

…During decommissioning,

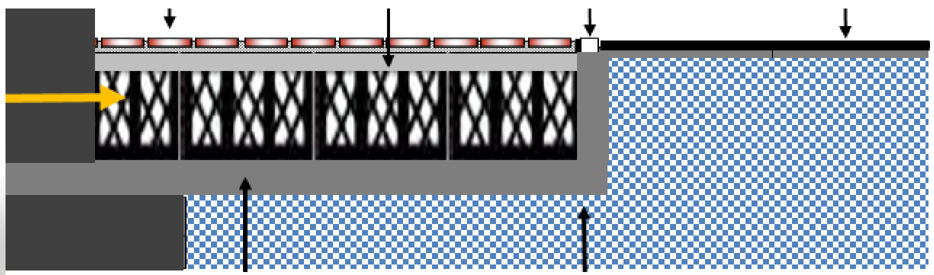


Leachable concentrations of 14 metals in the PPS samples made up of Pavement blocks (P), Aggregates Alone (AA), Aggregates and Dust (AD), Dust alone (D) and Geotextile fibre, were analysed via ICP and compared to appropriate risk-based regulatory threshold limits such as:

- FAO Wastewater quality guidelines for agricultural use
- US EPA Guidelines for Water Reuse: Recommended water quality criteria for irrigation

At end-of-life…

…During decommissioning,



Furthermore, the leached amounts of the 14 metals were determined based on BSEN 12457-3:2000 and then compared with regulatory threshold limits used by some EU Member States (e.g. Austria, Czech Republic and France) for EoW assessment.

Results

Eluate Analysis		Concentration in Eluate	Derived Effluent Standard*	Miscellaneous Irrigation Water Limit		FAO irrigation limits**	US EPA irrigation limits***
Mass of Raw Test Portion (MW) kg		0.179					
Mass of Dried Test Portion (MD) kg		0.175					
Moisture Content Ratio (MC) %		2.83					
Dry Matter Content Ratio (DR) %		97.24					
				Long Term	Short Term		
Metal	**PPS Profile**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
Cadmium as Cd	P	< 0.0001	0.0018	0.01[a]	0.05[a]	0.01	0.01
	AA	< 0.0001					
	AD	< 0.0001					
	D	< 0.0001					
	G	< 0.0001					
Arsenic as As	P	< 0.005	---	0.1	2.0	0.1	0.1
	AA	< 0.005					
	AD	< 0.005					
	D	< 0.005					
	G	< 0.005					
Chromium as Cr	P	0.0058	0.068	0.1[c]	---	0.1	0.1
	AA	< 0.0025					
	AD	< 0.0025					
	D	< 0.0025					
	G	< 0.0025					
Nickel as Ni	P	< 0.02	0.4	0.5[d]	0.05[d]	0.2	0.2
	AA	< 0.02					
	AD	< 0.02					
	D	< 0.02					
	G	< 0.02					

*See Newman et al. (2013) for the method by which these standards were derived
**FAO (1992) Wastewater quality guidelines for agricultural use;
***US EPA (2012) 2012 Guidelines for Water Reuse; Recommended water quality criteria for irrigation; Water Research Centre (2014)
[a] Rowe and AbdelMagid (1995)
[b] National Academy of Sciences -in Harivandi (1982)
[c] Nnadi et al., (2014)
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				Long Term	Short Term		
Metal	**PPS Profile**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
Copper as Cu	P	< 0.01	0.2	0.2[a]	5[a]	0.2	0.2
	AA	< 0.01					
	AD	< 0.01					
	D	< 0.01					
	G	0.017					
Lead as Pb	P	0.013	0.144	5[a]	10[a]	5	5
	AA	< 0.01					
	AD	< 0.01					
	D	0.011					
	G	0.013					
Molybdenum as Mo	P	0.0049	---	0.01	0.05	0.01	0.01
	AA	0.007					
	AD	0.0068					
	D	0.007					
	G	0.0031					
Zinc as Zn	P	< 0.025	1	5[b]	---	2	2
	AA	< 0.025					
	AD	< 0.025					
	D	< 0.025					
	G	< 0.025					
Fluoride as F	P	0.18	---	1.0	15.0	1.0	1.0
	AA	0.073					
	AD	0.083					
	D	0.151					
	G	0.083					
Selenium as Se	P	< 0.01	---	0.02	0.02	0.02	0.02
	AA	< 0.01					
	AD	< 0.01					
	D	< 0.01					
	G	< 0.01					

Results

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Moisture Content Ratio (MC) %		2.83					
Dry Matter Content Ratio (DR) %		97.24					
				Long Term	Short Term		
Metal	**PPS Profile**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**
Barium as Ba	P	0.27	---	---	---	---	2
	AA	< 0.060					
	AD	< 0.060					
	D	< 0.060					
	G	< 0.060					
Mercury as Hg	P	< 0.0005	---	---	---	---	0.002
	AA	< 0.0005					
	AD	< 0.0005					
	D	< 0.0005					
	G	< 0.0005					
Chloride as Cl	P	16.06	---	---	---	---	250
	AA	< 3.7					
	AD	< 3.7					
	D	< 3.7					
	G	< 3.7					
Sulphate as SO4	P	< 4.4	---	---	---	---	250
	AA	23.77					
	AD	21.27					
	D	17.55					
	G	18.6					

*See Newman et al. (2013) for the method by which these standards were derived

**FAO (1992) Wastewater quality guidelines for agricultural use;

***US EPA (2012) 2012 Guidelines for Water Reuse; Recommended water quality criteria for irrigation; Water Research Centre (2014)

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Results

Eluate analysis

Eluate Analysis	Amount leached					EU Landfill Waste Acceptance Criteria BS EN 12457-3 Limit Values (mg/Kg)
Mass of Raw Test Portion (MW) kg	0.179	0.175	0.175	0.175	0.091	
Mass of Dried Test Portion (MD) kg	0.175	0.175	0.175	0.175	0.09	
Moisture Content Ratio (MC) %	2.83	0.2	0.2	0.3	1.32	
Dry Matter Content Ratio (DR) %	97.24	99.8	99.8	99.7	98.7	
	P (mg/Kg)	AA (mg/Kg)	AD (mg/Kg)	D (mg/Kg)	G (mg/Kg)	Inert (mg/Kg)
Arsenic as As	<0.050	<0.050	<0.050	<0.050	<0.050	0.5
Barium as Ba	3.3	<0.60	<0.60	<0.60	<0.60	20
Cadmium as Cd	<0.0010	0.00014	0.00072	0.00061	<0.0010	0.04
Chromium as Cr	0.057	<0.025	<0.025	<0.025	<0.025	0.5
Copper as Cu	<0.10	<0.10	0.045	0.052	0.17	2
Mercury as Hg	0.0034	0.00236	0.0045	<0.0050	0.008	0.01
Molybdenum as Mo	0.051	0.12	0.143	0.085	0.031	0.5
Nickel as Ni	<0.20	<0.20	<0.20	<0.20	<0.20	0.4
Lead as Pb	0.125	0.09	0.073	0.12	0.13	0.5
Selenium as Se	<0.10	<0.10	<0.10	<0.10	<0.10	0.1
Zinc as Zn	0.179	<0.25	<0.25	0.143	<0.25	4
Chloride as Cl	223	9.17	27.9	21.65	<37	800
Fluoride as F	1.6	1.03	1.37	1.5	0.93	10
Sulphate as SO4	50.66	586	893	605	190	1000

Key Findings & Conclusions

- The measured concentrations of all the metals were below the appropriate risk-based regulatory threshold values for irrigation purposes as specified by FAO and USEPA.
  - This suggests that there is no potential pollution of water resources such as groundwater, surface waters, rivers or aquifers.
  - No threats to agricultural farmlands and products.

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Key Findings & Conclusions

- EoW assessment showed that eluate concentrations of the 14 metals were all below EU LFD WAC for inert waste and therefore, may be reused without any environmental concerns.

  - This has potential to increase recycling of aggregates from construction and demolition wastes among EU Member States currently set at 70% by 2020 via WFD

  - Can minimize dependence on virgin aggregates and hence, reduction on exploitation of natural resources and sustainability of the PPS system.

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    - ***Both are gratefully acknowledged.***

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