



Centre for Organic
Research & Education

Victorian Bio-Filtration Media Accreditation - Report and Specifications



NOVEMBER 2016

Core Bio-filtration Media Accreditation System

The BIO-filtration Media Accreditation System & Specifications (BIOMASS) process is developed by the not for profit Centre for Organic Research & Education Inc., (CORE) and is designed for all organic and non-organic media systems. The rigorous material accreditation, manufacturing and supply system characteristics of the BIOMASS process can ensure that consistent bio-filtration media performance can be relied upon in any jurisdiction to produce the most appropriate “fit for purpose” media formulation configuration.

What’s the difference between media systems?

The fundamental difference between media systems (e.g. FAWB/ CRCWSC and CORE Organic Media) is the higher organic matter and material nutrient content characteristics of organic media. Practitioner concerns about environmental consequences of the higher organic content (e.g. leaching), the use of recycled materials and the variable nature of media derived from excavated natural soil deposits means that material characterisation, performance analysis and quality control systems must be validated to ensure reliable system performance. The BIOMASS classification system identifies intrinsic material characteristics that enable functional consistency of each individual manufacturer’s media formulations.

CRC for Water Sensitive Cities (CRCWSC) published “Adoption Guidelines for Stormwater Bio filtration Systems, 2015” essential specification’s state that for its systems filtration media formulations that exceed 5% organic matter content and that nitrogen content of media in excess of 1000 mg/k will lead to nutrient leaching.

CORE’s 10 year research program has analysed many different types of organic materials. Studies (e.g. Lucas et al, 2014, McLaughlin, 2008) confirm that there are those organic materials that display unacceptably high leaching characteristics (e.g. labile organic matter). However significant leaching is not characteristic for many other, more stable organic materials. CORE studies have shown that some leachates contain properties that benefit plant establishment and growth.

Research cited in the FAWB specifications (Bratieres et al, Hatt et al.- 2008) that provides the basis for the conclusions on organic matter leaching behaviour is incomplete as the inherent characteristics of the type of organic matter studied is not specifically identified. Therefore there are no descriptors for manufacturers to select or analyse the 5% organic matter fraction required by the CRCWSC/FAWB specifications. This has led to variable performance results being observed in the market. Hence the Stormwater Quality Improvement Device (SQID) sector has expressed the need for performance validation schemes (such as BIOMASS) for natural systems.

Since the publication of the CRCWSC Adoption Guidelines Specification in September 2015, the CRCWSC have publically acknowledged that other filter media systems with higher organic content could perform as well as the CRC/FAWB specification and that organic and nitrogen content do not necessarily lead to leaching.

The CRCWSC acknowledgment is based on conclusive CORE research data demonstrating that high organic (up to 65%) and nitrogen content materials (up to 2500 mg/kg) can be comparable in leaching behaviour and performance to products meeting the FAWB/CRCWSC specification. Organic media accredited and manufactured to the CORE Specifications, using a significant percentage of recycled material and higher organic content, are at least equivalent in performance, quality and price to the FAWB/CRCWSC specification. The evidence also suggests that Organic Media may offer improved capabilities, qualities and value in key performance aspects combined with the additional advantage of closing the loop on recycling.

Victorian Materials and Formulations Accreditation

Studies and analysis in the following report include the accreditation process applied to a range of organic components and reference media formulations for materials available in the Victorian market. Comparisons are also made with a product (M165) supplied to the FAWB/CRCWSC specification. The results show that effective results can be achieved by the FAWB specification in all performance areas. However there can be significant varied performance between different manufacturers thus compromising outcomes. Research has identified that different materials can perform in significantly different ways (Lucas, 2012, 2014, 2016). BIOMASS Accreditation provides science based evidence that the products manufactured are fit for the performance purpose required. It should be noted that the following CORE results identified and compared in this report are based entirely on the chemical reactions in the media. CORE treatment performance results are expected to increase when the effects of plant processes on treatment are added to the results.

The following report provides results from materials that have successfully met the requirements of the industry based BIOMASS process. Several Victorian manufacturers of bio filter materials and formulations have been through the process and accreditation status granted where applicable. Product names have been coded to protect the confidentiality and IP of the individual manufacturers consistent with the requirements of the Australian Research Council Code for the Responsible Conduct of Research.

The BIOMASS process results from over 10 years of independent longitudinal research including studies by University of Newcastle (UoN), University of Technology Sydney, University of NSW and Melbourne University and wide consultation with manufacturers and end users in the public and private sectors. Resultant methods and processes underpin the various CORE Specifications for bio filtration media systems and form part of the system's continuous improvement process. A methodology synopsis is provided as an annexure to this report.

The intention of this report is to publish the results so that the subsequent specifications can be incorporated into sustainable procurement practices and professional training programs and subsequently increase the use of recycled materials in bio filtration/retention systems.

The accreditation process results from testing to the BIOMASS process. Analysis focusses on waters with high and low, conservative and non-conservative pollutant concentrations. While other more specific material tests are conducted during the accreditation process the primary performance factors in this report focus on:

- Pollutant removal efficacy.
- Hydraulic conductivity including PSD analysis.
- Life span prediction.
- Leaching behaviour.
- Surface vegetation integrity.

BIOMASS Process description

An expert inspection of potential organic and non-organic materials is conducted and a *prima face* case established for material suitability. Observably unsuitable materials are rejected at this point. Preference is given to materials of recycled origin.

The material accreditation system commences with baseline laboratory analysis where some materials are eliminated due to ineffective performance attributes or unacceptable characteristics such as high, leachable pollutant loadings. This is identified in elemental and characterisation analyses. Numerous studies have resulted in the development of a classification system that enables homogenisation based on analyses of desired inherent attributes and alignment of relative characteristics.

Effective materials are categorised according to homogenised characteristics before testing begins on the performance efficacy of these in reference formulation media.

Relationships are established between specific characteristics and the resultant performance attributes of each material and reference formulation. This enables subsequent manufacturers' formulations to be tailored for the specific performance requirements of particular systems. The result is a validation system methodology that ensures that the components and formulations used in a filter media design are of dependable quality, known performance within an acceptable range and fit for purpose. Subsequently manufacturing warranties can be offered.

Manufacturing to the CORE Specifications can be technically achieved by any filter media manufacturer using their suitable specific (accredited) proprietary ingredients and formulations. CORE Specifications contain the elements that are considered essential for bio filtration manufacturing to the system, however the Specifications do not constitute the entire spectrum of studies examined in the accreditation process. CORE only accredits those materials, formulations and individual manufacturers that have formally completed the entire accreditation process.

Manufacturers' proprietary materials and formulations must fall within specified operational and performance parameters to be awarded accreditation. The following report provides data from materials and formulations that have passed the accreditation process. A databank of over 40 Australian and International materials and formulations has been constructed and is growing.

MATERIAL CHARACTERISTICS

Table 1 identifies examples of characterisation analysis conducted on **component** materials submitted for accreditation. Data sets are shown for: graded sand; categorised carbon materials (RO - CAT 1, 2 & 3); and samples of CRCWSC/FAWB and CORE Specification Reference **Formulations** (RFM1 & RFM2) made from the categorised components. These data are used to identify characteristics required to meet CORE or CRCWSC/FAWB Specifications.

Table 1 identifies CORE Specifications' equivalence with M165 (FAWB/CRCWSC spec) in infiltration rate (K_{sat}). The table also identifies media characteristics that influence treatment and vegetation performance.

Table 1 – Sample material characteristics comparisons

Test Parameter	Method Description	Method Reference	Units	RO-Cat3	RO-Cat2	RO-Cat1	Graded Sand	CRCWSC /FAWB	RFM1	RFM2
pH (1:5 in H ₂ O)	Electrode	R&L 4A2	pH units	7.76	7.87	9.23	7.72	6.8	8.29	7.74
pH (1:5 in CaCl ₂)	Electrode	R&L 4B2	pH units	7.18	7.31	8.15	6.74	6.38	7.45	7.28
Chloride Soluble	Electrode	PMS-05	mg/kg	2810	3030	1585	4.6	212	310	362
Electrical Conductivity	Electrode	R&L 3A1	dS/m	1.93	2.1	1.86	0.02	0.3	0.54	0.36
Total N (LECO)	LECO	R&L 7A5	mg/kg	13350	14590	6870	82.2	235	1624	1745
Extractable Nitrate-N	H ₂ O/UV-Vis	PMS-08	mg/kg	50.7	52.9	2.34	4.4	4.28	10	9.4
Organic Carbon (LECO)	LECO	R&L 6B3	%	32	36.5	5.9	0.11	0.4	3.11	2.01
Total Carbon (LECO)	LECO	R&L 6B2a	%	31.7	36.9	61.1	0.12	0.36	4.88	5.27
Phosphorus Buffer Index	UV-Vis	PMS-12	mg/kg	127	136	460	20.7	43.5	37.5	21.5
Phosphorus (Colwell)	Bicarb/UV-Vis	R&L 9B1	mg/kg	316	322	99.3	7.72	10.9	45.2	38
ECEC	Calculation	PMS-15A1	Cmol/kg	72.7	74.4	26.6	1.32	3.72	14.89	16.2
Ca/Mg Ratio	Calculation	PMS-15A1	Cmol/kg	4.4	4.2	17.8	6.92	3.56	8.18	5.24
K/Mg Ratio	Calculation	PMS-15A1	Cmol/kg	1.97	2.04	6.29	0.30	0.67	4.94	0.87
Air-dried Moisture		UoN	%	27.80	33.29	9	2	8	10	13
Moisture Holding Capacity		UoN	%	66	62	52	19	22	33	33
Bulk density		UoN	kg/m ³	550	550	210	1520	1180	1100	1100
K _{sat}		UoN	mm/hr	720	1400	105	2100	840	840	840



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Analysis includes Effective Cation Exchange Capacity (ECEC) which measures the ability to hold on to contaminants and plant growth factors such as Phosphorous Buffer (Retention) Index and Cation Ratio analysis that support the “integrity of surface vegetation”. ECEC of less than 5 is considered indicative of low soil fertility (Apal, 2014).

CORE Specifications are also available for use in **non-vegetated** applications including trade waste water and secondary treated effluent.

Particle size analysis (e.g. Figure A) is carried out for a number of purposes. With reactive media retention time is a factor in treatment efficiency. The CORE Specification identifies a Hydraulic Conductivity (K_{sat}) of <300mm per hour. This figure is based on research results showing that this provides a retention time conducive to optimum treatment outcomes.

However one of the advantages of media engineering is that media formulations can be configured at various conductivities, either higher or lower than 300 mm per hour. Favourable pollutant removal results are observed for higher K_{sat} . For example some installations are for combined sewer and stormwater systems where quantity management is a factor and higher K_{sat} is required. BIOMASS system testing can identify performance at various rates of conductivity. Conductivity can also affect lifespan (see figure 3 pp8).

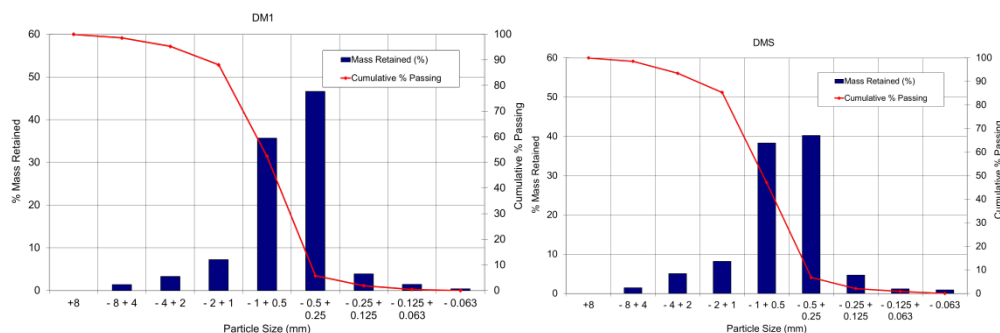


Figure A - Typical PSD's of organic filter media

PERFORMANCE

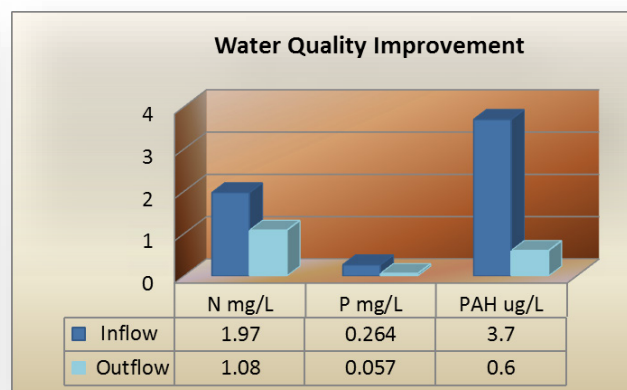
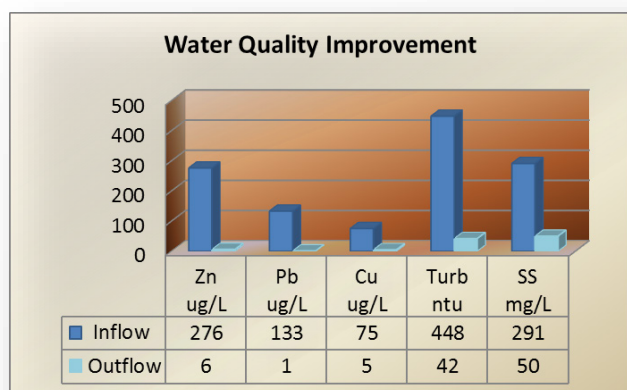
Table 2 identifies results from column leaching experiments showing removal performance for formulations (RFM1&2) exposed to typical stormwater pollutants. The table compares the removal of metals (Cu, Pb, Zn) by the CORE Specifications (RFM1 & 2) and FAWB/CRCWSC Specification. It should be noted that the results are based on reactive (chemical) processes without the influence of plant uptake. Consequently the effect of vegetation would be expected to yield higher removal results. Existing studies are focussed on low organic soils so are not considered reliable indicators of effects from higher organic formulations. Future field studies are being designed to quantify performance effects of improved vegetation integrity on treatment performance.

Table 2 – Sample efficacy testing

Pollutant	Influent (µg/L)	Effluent			% Removal		
	Stormwater	CRC/FAWB	RFM1	RFM2	CRC/FAWB	RFM1	RFM2
Copper	162	4.2	7.2	6.4	97	96	96
Lead	0.4	0.4	< 0.2	< 0.2	0	> 50	> 50
Zinc	138	17	5	4	88	96	97


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Figures 1 & 2 identify results over a range of common pollutants from an independent field study conducted by AWT (now Sydney Water) in early 1999. Note the high concentrations of metals and hydrocarbons which are not covered in many of the Australian treatment requirements or modelling programs.



Figures 1 & 2 – Field results

Performance modelling – TSS & Nutrients

The use of “look-up tables” in the Model for Urban Stormwater Improvement Conceptualisation (MUSIC) for bio-retention nodes is primarily based on the FAWB specification. This has created an algorithmic bias against high nutrient content material irrespective of its actual leaching behaviour. However using actual CORE Specifications performance data from reference formulations (RFM1, RFM2) still produces reasonable treatment results in the model. Nevertheless CORE Specifications performance is expected to be greater than that indicated in the MUSIC model.

The relationship between filter media TN and orthophosphate content and treatment performance may be based on the inconclusive assumption that filter media with organic matter content $\leq 5\%$ leaches excessive nutrients; which this case study and studies by Al-Mashaqbeh, O., et al (2007) have demonstrated not to be the case. The following section elaborates and identifies how the CORE organic media Specifications can be modelled in MUSIC v6 to represent equivalent treatment performance compared to FAWB.

From MUSIC v6:

“The selection of appropriate k and C^ values for modelling the removal of Total Nitrogen cannot easily follow the procedure applied for TSS and TP. The composition of particulate and soluble forms of N in stormwater is highly varied. There is significantly smaller particulate fraction of TN compared with TP, and even that fraction is associated with organic particles which have significantly lower specific gravities than sediment. Calibrated k values for TN in wastewater systems indicate significantly lower values (as much as two orders of magnitude) compared with TP and TSS. The default k and C^* values for TN are thus based on very limited data. There is an expectation that the k values are likely to be an order of magnitude lower than corresponding values for TP, and that the ratios of C^* to inflow Event Mean Concentration (EMC) are likely to be higher for TN than for TP.”*

Therefore, the nature of reference formulations comprising of 50% and 65% “organic matter” with an initial leaching peak that rapidly subsides back to stable levels, means that changes in k and C^* need investigation. Selection of k and C^* were based on Bio retention Systems (Table 5 in MUSIC, “Appendix G: Selecting Appropriate k and C^* Values”). A simple sensitivity analysis was undertaken on three scenarios (changes in k and C^*) and are described in Table 3 below. MUSIC v6 results (% reduction) are presented in Table 4.

Table 3 - Changing k and C^* in MUSIC v6 (sensitivity analysis inputs)

	TSS		TP		TN	
Bio-retention Systems	k	C^*	k	C^*	K	C^*
LOW	4,000	10	3,000	0.08	250	1.1
Default	8,000	20	6,000	0.13	500	1.4
HIGH	15,000	30	12,000	0.18	1,000	1.7



Sensitivity analysis shows that the FAWB Specification product was relatively unchanged with significant changes in k and C^* and is likely a function of the fact that most research and development of the CRC Biofiltration Guidelines (Payne *et al*, 2015) have used sandy loam (FAWB) as their filter media. However, RFM1 and RFM2 (reference formulations) were highly sensitive to changes in k and C^* with respect to TN (difference in treatment performance of 16.9 % and 19 % respectively). Results from this study have demonstrated that RFM1 and RFM2 are comparable filter media to FAWB in terms of pollutant removal and treatment performance yet this performance is not captured in MUSIC v6.

This is explained by the fact that the treatment performance data is governed by an extensive “lookup table”, which determines outflow concentrations and/or removal rates for TSS, TP and TN and takes into account all important characteristics of the bio-retention system and its operating conditions. The “lookup tables” are based on extensive research and observations however the FAWB (sandy loam) Specification has been the preferred choice in most of the research over the past 10 years.

Table 4 - Comparison using MUSIC modelling of pollutant treatment

CRC/FAWB	% Reduction			Difference
	LOW	Default	HIGH	
Flow (ML/yr)	5.3	5.3	5.3	0
Total Suspended Solids (kg/yr)	94.5	95.8	96.5	2
Total Phosphorus (kg/yr)	90	90.5	90.6	0.6
Total Nitrogen (kg/yr)	72.3	72.7	73.1	0.8
Gross Pollutants (kg/yr)	100	100	100	0

RFM1	% Reduction			Difference
	LOW	Default	HIGH	
Flow (ML/yr)	5.3	5.3	5.3	0
Total Suspended Solids (kg/yr)	94.6	95.6	95.5	0.9
Total Phosphorus (kg/yr)	83.4	84.1	86	2.6
Total Nitrogen (kg/yr)	52.6	55.5	69.5	16.9
Gross Pollutants (kg/yr)	100	100	100	0

RFM2	% Reduction			Difference
	LOW	Default	HIGH	
Flow (ML/yr)	5.3	5.3	5.3	0
Total Suspended Solids (kg/yr)	94.2	95.3	95.6	1.4
Total Phosphorus (kg/yr)	77.3	77.9	79.7	2.4
Total Nitrogen (kg/yr)	47.6	50.2	66.6	19
Gross Pollutants (kg/yr)	100	100	100	0

The “engineered” filter media RFM1 and RFM2 do not contain significant silt/clay content, as the exchange capacity is provided by the selected organic matter (higher ECEC, refer Table 1). Therefore, future research will look to develop “lookup tables” suited to the use of CORE Specifications materials, such as RFM1 and RFM2, by monitoring flow and water quality (inflow and outflow) of “actual” installations. Furthermore, since RFM1 and RFM2 behave similarly to the FAWB Specification products with respect to nutrient leaching and pollutant removal it makes sense to use similar “inputs” to MUSIC v6 for RFM1 and RFM2, i.e., the same values one would use for FAWB. It is important to repeat that the RFM results are chemistry only and do not include any treatment effects from vegetation which apart from the algorithmic biases in MUSIC would be expected to yield a better treatment result.

Treatment Node:

As a result of the equivalent leaching behaviour with FAWB/ CRCWSC and CORE Specifications the “TN Content of Filter Media” in MUSIC’s Treatment Node “Filter and media properties” variable is to be input at 235 mg/kg.

Performance modelling - Metals

Maintenance is a key factor in any bio-filtration system. Figure 3 is a screen shot of one page from CORE’s computer model (Kalkulus™) specifically developed to calculate metals removal and media life span. UoN studies identify that Metals (conservative pollutants), not nutrients, determine the life span of a media.

Figure 3 – Sample “Kalkulus”™ modelling of conservative pollutant removal and lifespan.

Step	COPPER (Cu)		RFM1	RFM2
1	mg per 150 g	removed by DM	7.49	7.47
2	mg/kg	removed by DM	50	50
3	mg/L/m2	in runoff	0.25	
	Raingarden example			
4	Area (m2)	100		
5	Depth (m)	0.5		
6	Volume (m3)	50		
7	BD (kg/m3)	1,100		
8	Mass (kg)	55,000		

9	Available Cu Store (mg)		2,747,800	2,739,367
Catchment Characteristics				
10	Rainfall (mm/yr)	650		
11	Catchment area (m2)	1,000		
12	Volume of Runoff (L/yr)	650,000		
13	Cu load (mg/yr)	162,500		
14	Life Span (yrs)		16.9	16.9
	Enter data into light blue cells			
		includes "Compaction Factor"		
		(relates to Mass)		
		1500 mm/hr	10.1	10.1
		1100 mm/hr	13.8	13.8
	Test condition	900 mm/hr	16.9	16.9
		850 mm/hr	17.9	17.8
		800 mm/hr	19.0	19.0
		750 mm/hr	20.3	20.2
		450 mm/hr	23.7	23.6
	Test condition	300 mm/hr	25.4	25.3
		100 mm/hr	28.7	28.7



Data from the component and Filter Media formulation testing is used to calculate filter size or alternatively calculate the lifespan where only a certain footprint size can be installed.

You will notice that with the CORE Specifications lifespan can be increased by longer retention time using compaction.

This model is currently under further development as a specification design aid, enabled by funding contributions from the Commonwealth Government.

Performance modelling – Leaching

Figure 4 shows results from UoN leaching studies of components (RO Cat 1, 2 & 3) and reference formulations (FAWB, RFM1 & RFM2). The CORE Specification reference formulations exhibit “acceptably low leaching” of reference formulations (RFM1 & RFM2), equivalent to M165 (FAWB/CRCWSC) and both stabilise relatively quickly.

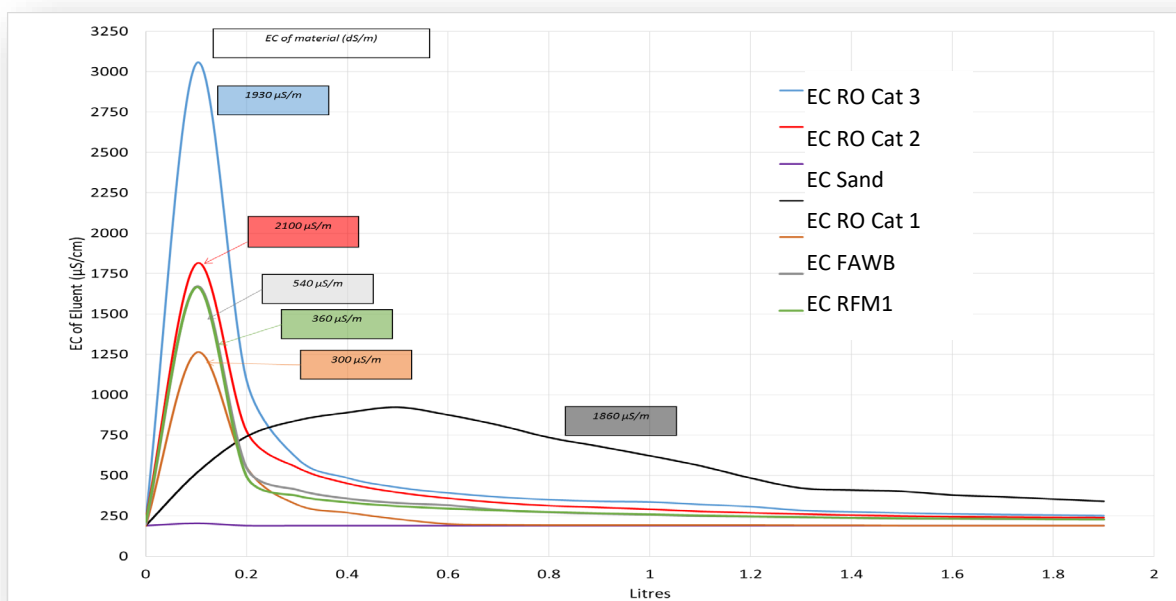


Figure 4 – Sample comparison of leaching behaviour

Tap water eluted through all materials results in leaching of cation/anions (as increasing EC). However all materials, except washed sand and RO Cat 1, produce a relatively high peak before returning near to initial tap water EC (at around 1.4 L). Washed sand did not produce a peak (low ECEC, no cations/anions to be leached). RO Cat 1 displayed a longer wetting time, hence the broadness of the “peak” before trending back to tap water EC values (250 $\mu\text{S}/\text{cm}$).

Due to low wettability properties it takes time for the RO Cat 1 to become fully wetted and start leaching salts, and the leaching curve (Figure 4) exhibits that delay. Due to the relatively low K_{sat} (105 mm/hr, see Table 2), RO Cat 1 did not leach all exchangeable cations/anions over 2 L of tap water application. This material has other valuable properties (refer table1). These factors determine the variable proportions used in media formulations for specific systems.

Washed sand had a low ECEC (1.32 Cmol/kg, refer Table 1) therefore had minimal leaching (see Figure 4). Washed sand had the highest K_{sat} indicating the lowest residence time however potential exchange sites for pollutant removal are very low (low ECEC).

The difference in the EC peak between RO Cat 1 & RO Cat 2) was due to K_{sat} , where the RO Cat 1 had a lower K_{sat} , hence a longer residence time, which resulted in a higher leaching peak (Figure 4). Both RO Cat materials had the highest ECEC (~ 73 Cmol/kg, refer Table 2) indicating their ability to remove pollutants.

FAWB (M165), RFM1 and RFM2 all had similar K_{sat} values (similar residence time in the columns) however RFM1 and RFM2 both have significantly more exchange sites than FAWB for pollutant removal (higher ECEC). The higher leaching peak for RFM1 and RFM2 rapidly subsided and after 2 L of tap water and the EC of the eluted tap water was similar to FAWB at the same stage.

Change in pH is shown in Figure 5. ANZECC (2000) guideline trigger values for aquatic ecosystems (SE Australia) range from 6.5 – 8.5 and all materials achieved this except component material RO Cat 1 (high pH). Results indicate that discharge from these formulations, from a raingarden for example, would be within the desired pH range.

RFM 2 reference formulation has an organic content of 65%. This was used for experimental design purposes and is not expected to be used in field formulations. However it is interesting to note pH and leaching remained within acceptable parameters (ANZECC) even at this high level of organic content.

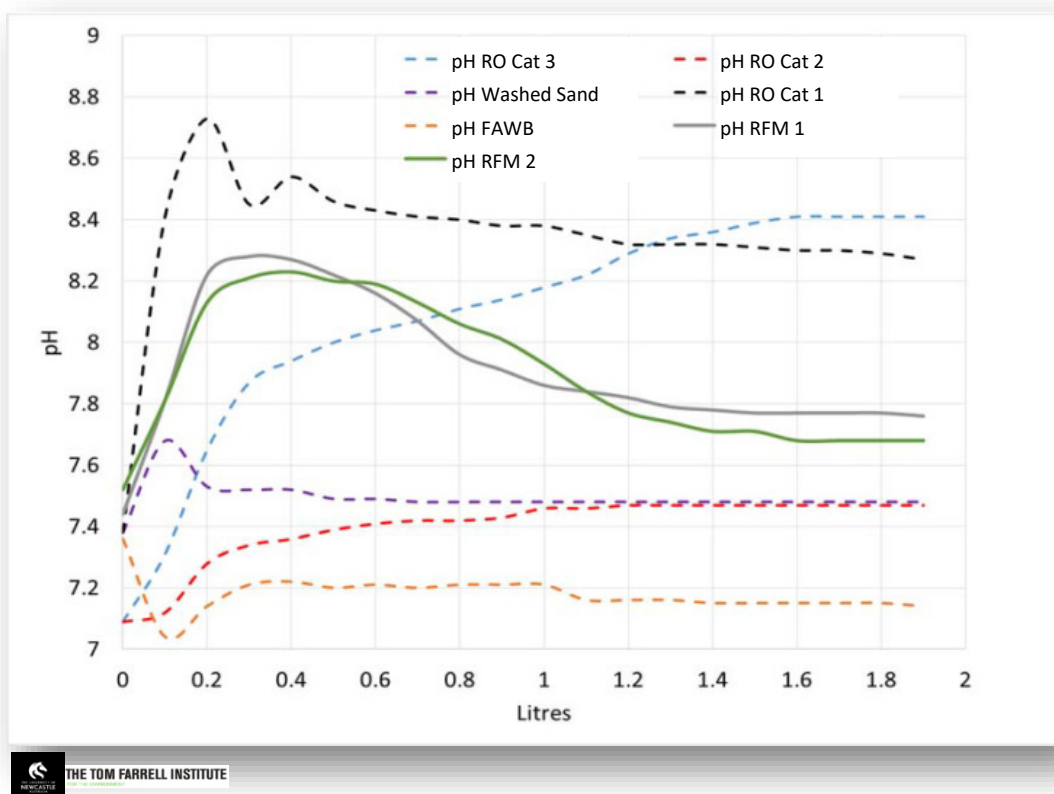


Figure 5 – Sample Change in pH based on applied volume

Research undertaken by McLaughlan (2007) also demonstrated the contaminant leaching of recycled organics and concluded:

1. Long term studies have shown that the level of inorganic nitrogen released from recycled organics amendment is similar or less than soil;
2. Continuous flushing of the recycled organics amendment with water caused leaching of nitrogen, phosphorous and carbon however the rate of leaching declined rapidly to stable values;
3. The amount of nutrients released from stormwater treatment devices using recycled organics amendment is expected to be under the limits required for agricultural application and national water quality guidelines.

SUMMARY OF MATERIALS ANALYSIS

Table 4 summarises results of organic and non-organic components and media formulations. This section also includes an analysis of comparative results.

Table 4 – Summary of comparative analysis

	CRC Biofiltration Objective	RO-Cat 3	RO-Cat 2	RO-Cat 1	Washed Sand	M165	RFM1	RFM2
Material	Engineered soil/sand	NA	NA	NA	✓	✓	✓	✓
Hydraulic Conductivity	100 - 300 mm/hr	✓	✓	✓	✓	✓	✓	✓
Clay & Silt content	< 3%	✓	✓	✓	✓	✓	✓	✓
Grading of particles	0.05 - 3.4 mm sieve size	NA	NA	NA	✓	✓	✓	✓
Nutrient content	TN < 1000 mg/kg	13350	14590	6870	82	235	1624	1745
	Extractable Nitrate (No limit?)	50.7	52.9	2.34	4.4	4.28	10	9.4
	Available P (Colwell) < 80 mg/kg	316	322	99	8	11	45	38
Organic matter	Minimum content ≤ 5%	100	100	100	0.1	0.4	40	50
Organic carbon	?	32	36.5	5.9	0.11	0.4	3.11	2.01
Total carbon	?	31.7	36.9	61.1	0.12	0.36	4.88	5.27
pH (1:5 in H ₂ O)	5.5 - 7.5	7.76	7.87	9.23	7.72	6.80	8.29	7.74
* Electrical Conductivity	< 1.2 dS/m	1.93	2.1	1.86	0.02	0.3	0.54	0.36
Horticultural suitability	To be assessed by horticulturist	NA	NA	NA	NA	✓	✓	✓
Particle Size Distribution	fine sand (10-30%)	NA	NA	NA	✓	✓	✓	✓
Depth	400 - 600 mm or deeper	NA	NA	NA	✓	✓	✓	✓
Once-off nutrient amelioration	Added to top 100 mm	NA	NA	NA	Yes	Yes	No	No
Submerged Zone	High HC or shallow depth	NA	NA	NA	✓	✓	✓	✓



Material

RO (Cat 1, 2 & 3) are component materials and consequently are not considered as engineered media. Washed sand, M165/FAWB, RFM1 and RFM2 (Reference Formulation Media) can be considered as engineered media and satisfy CRC Guideline requirements.

Hydraulic Conductivity

All materials can be compacted to achieve desired hydraulic conductivity. A formulation based on RFM1 was tested under BS1377 (Part 5) which resulted in a saturated hydraulic conductivity (K_{sat}) of < 300 mm/hr. This is within the CRCWSC Guideline requirements.

Clay and silt content

All materials contained < 3 % clay content and satisfy CRC Guideline requirements.

Grading of particles

RO Cat 1, 2 & 3 (components) have a wider (and higher) range of particle sizes that exceeded CRCWSC Guideline requirements. Greater than 95 % of particle sizes in the washed sand, FAWB, RFM1 and RFM2 (formulations) were within Guidelines (0.05 – 3.4 mm) and are considered satisfactory for use in raingardens.

Nutrient content

RO Cat 1, 2 & 3 (components) contain TN that far exceeds CRC Guideline requirements (> 1000 mg/kg). Washed sand and /FAWB are well below the CRCWSC Guideline requirement and, since this can be too low to sustain plant growth, potassium nitrate and superphosphate are suggested additives to FAWB (at 300g/m³). RFM1 and RFM2 (formulations) exceeded the CRCWSC Guideline requirement however the values modelled in MUSIC v6 in Table 4 demonstrate the suitability of RFM1 and RFM2 as filter media in raingardens. RO Cat 1, 2 & 3) contain orthophosphate (plant-available phosphorous as Colwell P in Table 2) that exceeds CRCWSC Guideline requirements (< 80 mg/kg). Washed sand, FAWB, RO Cat 1 & 2 were all within Guidelines.

Organic matter

RO Cat 1, 2 & 3 (components) are all 100% organic matter and do not satisfy CRCWSC Guideline requirements. RFM1 and RFM2 (formulations) were 50% and 65% organic matter respectively and washed sand and FAWB had minimal organic matter (0.1 % and 0.4 % respectively). This requirement (≤ 5 % organic matter) has been the subject of contention due to claims of excess leaching of nutrients. However it has recently been acknowledged that this is inaccurate:

“There may be soil with higher organic content that the level specified that may not leach nutrients (TN and/or TP). It is also acknowledged that organic matter content does not have a direct link to nutrient leaching.” – CRCWSC, 2015.

pH (1:5 in water)

The pH values in the CRCWSC Guidelines essential specifications prescribe a value of 5.5 to 7.5. The RFM materials ranged from 6.8 (FAWB) to 9.2 (RO Cat 1). It should be noted that pH of components can be buffered by adjusting media formulations accordingly or adding materials with pH buffering characteristics (e.g. calcium) if required. The pH is within ANZECC guidelines for both organic media *reference formulations (RFM1 & 2).

Electrical conductivity (EC, 1:5 in water)

RO Cat 1, 2 & 3 exceeded CRC guideline values (> 1.2 dS/m). Washed sand, FAWB, RFM1 and RFM2 were within CRCWSC Guidelines (< 1.2 dS/m) and are considered satisfactory for use in raingardens.

Horticultural suitability

RFM1 and RFM2 (formulations) have been deemed as appropriate for use in raingardens based on the data in Table 1. Note that the FAWB Specification allows for an initial addition of fertilizer at a rate of 300 g/m³ to compensate for the low inherent nutrient levels.

Particle size distribution

The CRCWSC Guideline states that the filter media should be 10–30% fine sand. FAWB, RFM1 and RFM2 ranged between 30 – 35% fine sand and satisfy CRC Guideline requirements. Final mixes for RFM1 and RFM2 have particles over the size range prescribed in the CRC Guidelines. However no negative performance consequences are identified.

Depth

Washed sand, FAWB, RFM1 and RFM2 can be used for the CRC Guideline requirement for depth.

Once-off nutrient amelioration

Not required for RFM1 and RFM2 however FAWB may need amelioration.

Submerged zone

Washed sand, FAWB, RFM1 and RFM2 can be engineered to increase or decrease hydraulic conductivity (depending on compaction) to satisfy the CRC Guideline requirement.

Conclusions

The design mix formulations RFM1 and RFM2 appear to be an acceptable equivalent media to FAWB for use in vegetated devices.

Data presented in this report supports the CRCWSC’s acknowledgment that *“higher organics content than the level specified (in*

the FAWB /CRC guidelines) don't necessarily leach nutrients (TN and or TP). It is also acknowledged that organic matter content does not always have a direct link to nutrient leaching"- Tony Wong CRCWSC.

The nutrient content of the CORE Specifications component materials can eliminate the need for application of fertilisers and/or mulches for plant establishment. The horticultural properties of the CORE Specifications also enable a wider range of plant species to be grown. This includes local species resulting in lower maintenance cost and enhanced plant health and survival.

The media system methods and customisation capabilities of the CORE Specifications enable engineering of component formulations to achieve the performance objectives of the applicable systems. This includes varying hydraulic conductivity to accommodate wide-ranging flow rate variations for high and low flow performance requirements. Previous studies (McLaughlin et al, 2008) show no deterioration in conductivity over a (simulated) 30 year period in organic media.

Quality assurance

QA is considered more than just producing a test certificate showing media compliance with physical properties.

CORE Specifications (attached) are validated consistent with research findings and Australian Standards Guidelines (AS4454, AS 4419). Strict Manufacturing QA guidelines are inspected as part of the accreditation process to ensure consistent performance. Consequently statutory warranties can be provided by manufacturers. Operational Specifications are also developed for usage and installation but are generally consistent with CRC/FAWB guidelines.

Integrity of surface vegetation community

The CRCWSC acknowledgement of the suitability of other media systems states that in addition to hydraulic and leaching behaviour a media system must ensure the "integrity of surface vegetation community". Organic media meeting the CORE Specifications are a new generation of media that achieve best practice pollutant removal and exhibit beneficial plant growth properties.

The CORE Specifications organic media has inherent system properties specifically designed for vegetation health resulting in improved establishment and longevity outcomes while lowering maintenance requirements. The intrinsic horticultural properties also enable a far wider variety of vegetation and plant species to be utilised including plants indigenous to specific geographical jurisdictions. This improves plant viability and lower attrition reduces maintenance costs.

The CORE Specification organic media increases the integrity of plant establishment, growth and phytoremediation through increased root mass development. Figure 6 shows the larger root mass of a plant grown in an organic media compared to the root growth in a nonorganic soil. Larger root mass can facilitate improved pollutant removal and healthier, more resilient vegetation.



Figure 6 - Comparison of root development in organic and non-organic formulations

The following pictures show some examples of surface vegetation plant growth using the CORE Specifications.

Pictures – Examples of vegetation integrity using organic media



Kerbside garden



Median Bio Swale



Bio Retention Basin



Harbour side Car Park

Annexure 1

Synopsis of testing methodologies.

Materials and Methods

The validation report is a culmination of research results from fundamental and original studies over a 10 year period. The production of cogent data has often required the development of new and adapted research methodologies, material characterisation processes and classification systems many of which are covered under international patents. Experimental designs are based on simulating natural soil mechanisms and hydraulic processes to achieve specific performance outcomes. In the interests of sustainable procurement, preference is always given to studies of promising recycled materials.

Special acknowledgment is given to fundamental, independent research studies conducted by UTS, UNSW and Melbourne University (McLaughlan, 2006 - 2008) and original work by University of Newcastle (Lucas, *et al*, 2012-2016). This section is designed as a synopsis of the main methods and types of materials that apply to the data presented in this report, and are used in the ongoing research programs and accreditation processes. Several papers (*op cit*) have been written and published that can provide more detail if of interest.

Materials

CORE Research has already identified and classified a wide range of potential materials that could be used as components in an organic and non-organic bio-filtration filter media formulation. Materials could include organic and mineral materials including zeolite, activated carbon, selective recycled carbon materials, aggregates, clay, perlite, zero valent iron, limestone, pumice, forest residues, sawdust, peat, basalt, sand, recycled glass, titanate, soil & other reactive materials. Each component material accredited by CORE is tested and classified according to its individual characteristics and efficacy in achieving the desired functional requirements when these materials are combined into performance based formulations. An international data bank of materials characteristics is established.

Batch tests

Batch tests are designed and used to identify the efficacy of prospective materials that could potentially be used in bio filter formulations. Batch test are generally conducted at a solid to liquid ration of 1:5. Selected stormwater runoff, industrial waste water and secondary treated effluent (STE) are used as the liquid solutions and are chosen depending on the objective of the experiments. For example STE and industrial waste water better enable removal results to be more clearly identified and measured for higher pollutant concentrations compared to the lower contaminant concentrations in stormwater. Batch tests can be carried out on a number of materials at once and can quickly measure relative efficacy results at a lower cost and contribute to identifying poor performing materials that can be ruled out prior to more extensive testing.

Column tests

Once suitable components are identified, indicative reference formulations media are designed. Column studies are carried out on component materials and reference formulations under constant-head and falling-head conditions to establish performance characteristics. Reference formulations include combinations of organic and mineral materials that are formulated based on batch test results, classification data, judgmental selection and/or snowball design. The reference formulations are designed based on characteristics that would satisfy general requirements such as hydraulic conductivity and pollutant removal performance.

The column studies are generally designed as a single-pass experiment under different hydraulic heads (constant and falling) to investigate the likely *in-situ* performance of the engineered media. For example, column tests are an open system test that indicate how a reference formulations would behave under high flow conditions (saturated, low residence time) and low flow conditions (un-saturated, high residence time).

Packing of the columns is based on volume. For each material or formulation, a column is packed with a known volume of reference formulation and the height in the column is measured. Each column is gently tapped and shaken to promote settling

but no compaction is applied (except during retention studies). Column depth is then measured. The appropriate test solution is then selected for the column tests.

From the unfiltered eluted sample emerging from the column, pH and electrical conductivity (EC, $\mu\text{S}/\text{cm}$) is carried out using a calibrated Horiba pH/EC meter. Nutrient analysis includes Total Kjeldahl Nitrogen (TKN), Total Oxidisable Nitrogen (TON), Total Phosphorous (TP), Total Nitrogen (calculated as TKN + TON). Metals analysis comprised of at least Ca, Na, Mg, K, Cu, Pb, Zn and Cd. Total Suspended Solids (TSS) and Total Petroleum Hydrocarbons (TPH) are also studied.

For constant-head conditions, a measured volumetric flask containing the selected liquid is slowly poured into the top of the column. There is a point where the top of the column contains a “head” and at this time the volumetric flask is quickly inverted and the spout submerged in the liquid above the reference formulations in the column. The volumetric flask is clamped in place and the liquid moves through the column under gravity.

The time taken for the liquid to be eluted through the column reflects the saturated hydraulic conductivity (K_{sat}) of the reference formulation and is determined by calculation (volume/time). The measured volume of liquid is applied under constant-head conditions to measure the equivalent millimetres of a rainfall event. For example, $1\text{L}/\text{m}^2 = 1\text{ mm}$ rainfall depth and since the area of the column and applied liquid volume is known, an equivalent rainfall depth can be calculated. If the area of a column is 0.00238 m^2 ($A = \pi r^2$) then 1L of liquid applied is equivalent to 420 mm of rainfall ($1\text{L} / 0.00238\text{ m}^2$). If 1L takes 1 hour to move through the column, then the K_{sat} would be 420 mm/hr.

After elution, any losses from the liquid are deemed to reflect the inherent moisture retention capacity (MRC) of the reference formulations and is calculated using mass by difference. For example, if 1L of liquid goes into the column and 0.8L is eluted out of the column (when freely drained), then the MRC equals 20 %.

For the falling-head column tests on a reference formulation the liquid is placed in a measured reservoir with a small tap fitted with a slow-release valve that allows the liquid to drip into the column rather than flow freely under constant-head conditions. The reason for the falling-head column test is to better mimic low and/or intermittent rainfall conditions and increase residence time of the liquid in selected reference formulations.

Characterisation method reference

Test Parameter	Method Description	Method Reference
pH (1:5 in H ₂ O)	Electrode	R&L 4A2
pH (1:5 in CaCl ₂)	Electrode	R&L4B2
Chloride Soluble	Electrode	PMS-05
Electrical Conductivity	Electrode	R&L 3A1
Total N (LECO)	LECO	R&L 7A5
Extractable Nitrate-N	H ₂ O/UV-Vis	PMS-08
Organic Carbon (LECO)	LECO	R&L 6B3
Total Carbon (LECO)	LECO	R&L 6B2a
Phosphorus Buffer Index	UV-Vis	PMS-12
Phosphorus (Colwell)	Bicarb/UV-Vis	R&L 9B1
ECEC	Calculation	PMS-15A1
Ca/Mg Ratio	Calculation	PMS-15A1
K/Mg Ratio	Calculation	PMS-15A1
Air-dried Moisture		UoN
Moisture Holding Capacity		UoN
Bulk density		UoN
K _{sat}		UoN

Specification LGE01

Landscape Filter Media

DESCRIPTION:

Purpose designed for specific landscape, detention basin and rain garden applications, Landscape Filter Media allows for the efficient infiltration and treatment of contaminated water run-off from roads, car parks and other impermeable surfaces. The treated water can then be stored and re-used for fit for purpose use such as landscaped areas irrigation. A wide range of plant species and vegetation can be grown in Landscape Filter Media due to the high water retention capacity, organic content and the material nutrient characteristics.

Filter Media is common goods that has been processed and pasteurized. The following specifications are to be used in combination with accredited formulation technology to achieve specific performance requirements. Filter formulations can be purpose designed based on factors such as treatment requirements, hydrology, device, application and plant species used. Product mixtures are to contain CORE accredited components which may include zeolite, recycled carbon materials, perlite, zero valent iron, ash, sawdust, limestone and can also be produced in various grades and mixtures for transition and drainage layers. Compaction, particle size selection and other properties can be engineered to achieve specific hydraulic conductivity, life span and retention time requirements.

Specification for Landscape Filter Media LGE012

Hydraulic Conductivity (K_{sat})	< 300mm/hr (AS1289.6.7.2 - 2001)	Field K_{sat} < 900mm/hr
pH (1:5 in H_2O)	6.5 to 8.0	
Organic Carbon	$\leq 5\%$	
Wettability	< 5mm/m (AS4454)	
Effective Cation Exchange Capacity	> 10 cmol/kg	
Moisture content (air dried)	> 10% < 50%	
Inherent Retention Capacity	> 25%	
Toxicity	> 60mm (AS4454)	
EC	< 1 dS/m (AS4454)	
Dispersion	Emerson Class No 8	
Leaching	EC < 300 $\mu S/cm$ after 350mm rainfall	
Ponding	Stagnant water fully drained from media in 6 hours	
Vegetation integrity	Ca/Mg ratio $\geq 2:1$ K/Mg ratio $\leq 1.5:1$	

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