

KING COUNTY, WASHINGTON

**SURFACE WATER DESIGN MANUAL**

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**REFERENCE 11-C**

**MEDIA STANDARDS FOR BIORETENTION AND  
OTHER PUBLIC DOMAIN FACILITIES AND BMPS**

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## 1 Introduction

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Historically the Surface Water Design Manual's (SWDM) bioretention design has had a single media mixture at its core, commonly referred to as 60:40 bioretention 'soil' mix; and bioretention has been limited to a non-underdrained infiltrative flow control best management practice (FCBMP). With the introduction of 'high performance bioretention' media, there are now several different bioretention designs; expanding use to include bioretention as a water quality treatment facility, and FCBMPs that may underdrain to phosphorus sensitive waterbodies. The new media do not suffer 60:40's known net discharge of phosphorus, nitrate, and copper. Because of dual function – FCBMP and water quality treatment facility, and varying treatment goals, these designs vary in complexity, with varying number of media layers, each of different composition. These are (noting % values are by volume):

- **'60:40' Bioretention:** For flow control BMP (FCBMP) applications only, and not allowed within ¼ mile of a sensitive lake or any other phosphorus sensitive waterbody unless underlying soil suitability criteria are met.
  - 'Bioretention soil mix' (BSM)
    - 60% sand
    - 40% compost
  - Mulch surface layer
- **'High Performance Bioretention' Designs (HPBD)** for water quality treatment facilities and as an FCBMP option. Depending on use, i.e., *basic*, *enhanced basic*, or *sensitive lake* (phosphorus control) **water quality treatments**, or as an FCBMP, these designs are composed of one to three layers, two of which are media mixes. The **Layer** types are nominally<sup>1</sup>
  - **18 inch Primary Layer.** By volume:
    - 70% sand
    - 20% coconut coir fiber (sometimes referred to commercially as 'coco peat')
    - 10% high carbon wood ash
  - **12 inch Polishing Layer.** By volume:
    - 90 % sand
    - 7.5% activated alumina
    - 2.5% iron aggregate
  - **2 inch Compost Surface Layer**
    - Specification 1 compost in Section 2.1.1 of this Reference.or
  - **3 inch Arborist's wood chip mulch layer**

Besides bioretention, there are other landscape facilities and BMPs that may require or may be optionally amended with compost or mulch. These same media specifications are applicable to those, and are referred to in those facility and BMP designs.

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<sup>1</sup> Detailed specifications with allowed volume variability are given in section 3.2, High Performance Bioretention Designs (HPBD) Assembly

This Reference section is limited to facility and BMP treatment and flow control media, and does not include underdrain aggregate specifications, which are given within those designs in the SWDM.

**Detailed media specifications and reporting requirements are given in following sections.**

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## 2 Media Specifications

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### 2.1 Compost

Compost products shall be the result of the biological degradation and transformation of uncontaminated biological organic materials under controlled conditions designed to promote aerobic decomposition. Compost shall be stable with regard to oxygen consumption, carbon dioxide generation, and seed germination and seedling vigor. Compost shall be mature with regard to its suitability for use in stormwater facilities and BMPs, post-construction soil amendment, general landscaping, or an erosion control BMP as defined below.

Compost shall be tested at a minimum in accordance with the U.S. Composting Council “Testing Methods for the Examination of Compost and Composting” (TMECC), as established in the Composting Council’s “Seal of Testing Assurance” (STA) program. Most Washington compost facilities now use these tests. All tests must be done on compost screened to specification for its intended use. More specific details follow.

There are two fundamental compost specifications.

- **Specification 1 compost** is for bioretention facilities and BMPs, and for water quality treatment facilities other than bioretention that require compost amendment as a specified part of design or involve infiltration; those facilities call out Specification 1 compost.
- **Specification 2 compost** may be used for erosion control, and for stormwater facility adjacent landscaping where compost is not incorporated into the facilities themselves. Where this is allowed is noted in facility design specifications. Specification 1 compost may always be used in lieu of Specification 2; the reverse is not allowed.

#### 2.1.1 Specification 1 Compost

1. Compost must be produced at a facility that is permitted by the jurisdictional health authority. Permitted compost facilities in Washington are included on a list under **Find a compost facility in Washington** posted at <https://ecology.wa.gov/waste-toxics/reducing-recycling-waste/waste-reduction-programs/organic-materials/managing-organics-compost>.
2. Compost must meet the definition of "composted material" in WAC 173-350-100, and must comply with testing parameters and other standards including not exceeding contaminant limits identified in Table 220-B. Testing Parameters, in WAC 173-350-220; and "Physical contaminants" (as defined in WAC 173-350-100) content less than 1% by weight (TMECC 03.08-A) total, not to exceed 0.25 percent film plastic by dry weight.
3. The compost product must originate a minimum of 65 percent by volume from recycled plant waste comprised of “yard debris,” “crop residues,” and “bulking agents” as those terms are defined in WAC 173-350-100. A maximum of 35 percent by volume of “post-consumer food waste” as defined in WAC 173-350-100 may be substituted for recycled

plant waste. Biosolids, manure, and/or bedding straw or wood chips or shavings containing animal excreta are not allowed.

4. Wood waste from chemically treated lumber and manufactured wood products containing adhesives or any other chemical is not allowed; painted and stained wood are not allowed; and only sawdust from virgin lumber allowed. No other toxic or otherwise harmful materials are allowed.
5. For *high-density residential subdivision development, multi-family, commercial, and industrial projects*, and *road projects considered high ADT projects*,<sup>2</sup> the Manufacturer or Vendor shall provide to the end buyer a list of feedstock sources by percentage by volume in the final compost product.
6. Compost shall have a moisture content that has no visible free water or dust produced when handling the material.
7. Compost shall have an organic matter content of 40 percent to 65 percent by dry weight as determined by loss of ignition test method ASTM D 2974, or by U.S. Composting Council TMECC 05.07A "Loss-On-Ignition Organic Matter Method (LOI)".
8. Compost shall have a carbon to nitrogen ratio below 25:1, although the carbon to nitrogen ratio may be as high as 35:1 for plantings composed entirely of plants native to the Puget Sound Lowlands region. The carbon to nitrogen ratio shall be calculated on a dry weight basis using TMECC 5.02A ("Carbon to Nitrogen Ratio"), which uses TMECC 04.01A, "Organic Carbon" divided by the dry weight of "Total N" (TMECC 04.02D).
9. Compost pH shall be between 6.0 and 8.5 when tested in accordance with U.S. Composting Council TMECC 04.11-A, "1:5 Slurry pH"
10. Soluble salt content shall be less than 4.0 dS/m (mmhos/cm) when tested in accordance with U.S. Composting Council TMECC 04.10 "Electrical Conductivity, 1:5 Slurry Method, Mass Basis".
11. Compost maturity indicators from a cucumber bioassay (TMECC 05.05-A "Germination Seedling Emergence and Relative Growth) must be greater than 80% for both emergence and vigor").
12. Stability shall be 7-mg CO<sub>2</sub> – C/g OM/day or below in as determined by U.S. Composting Council TMECC 05.08-B "Carbon Dioxide Evolution Rate", to establish low oxygen use and low CO<sub>2</sub> generation rates.

Compost shall be screened to the Fine Compost size gradation specification in Section 2.1.3 of this Reference.

### **2.1.2 Specification 2 Compost**

1. Specification 2 Compost manufacturing, feedstocks, and testing are all identical to Specification 1 Compost except that:
  - a. A maximum of 35 percent by volume of biosolids or manure may be substituted for recycled plant waste.

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<sup>2</sup> Land uses as described in Bullets 1, 2, and 3, SWDM Section 1.2.8.1, Subsection A "Basic WQ Treatment Areas, Required Treatment Menu".

- b. Compost may be fine or coarse gradation depending on use and need to meet other screened material quality criteria.
- c. Carbon to Nitrogen ratio may be up to 40:1 for coarse compost to be used as a surface mulch (not in a soil mix).

### 2.1.3 Compost Screening Size Gradations: Applies to both Specification 1 and 2 Compost

Where compost gradation is specified, it must meet the following size gradations when tested in accordance with the U.S. Composting Council “Test Methods for the Examination of Compost and Composting” (TMECC) Test Method 02.02-B.

Table 2-1 Fine Compost Gradation <sup>a</sup>		
Sieve Size	Percent Passing	
	Min	Max
1"	100	
5/8"	90	100
1/4"	75	100

Note: Maximum particle length of 4 inches

Table 2-2 Coarse Compost Gradation <sup>b</sup>		
Sieve Size	Percent Passing	
	Min	Max
2"	100	
1"	90	100
3/4"	70	100
1/4"	40	60

Note: Maximum particle length of 6 inches

## 2.2 Mulch

Mulch may only be composed of either chipped or shredded wood as defined in Section 11-C 2.2.1, or compost as defined in Section 11-C 2.2.2. Mulch may not be made of any synthetic materials including but not limited to recycled tire material, virgin rubber material, plastics; and may not be made of any pre- or post-consumer cardboard<sup>c</sup>, or paper<sup>d</sup>.

### 2.2.1 Arborist's Wood Chip Mulch

#### 2.2.1.1 Content

Arborist Wood Chip Mulch shall be wood chips or shreds (approximately ½" for chips to 6" for shreds along the longest dimension) derived from the mechanical chipping or shredding of the above-ground portions of native forestry trees<sup>e</sup> and raw lumbermill tree waste. It may contain only wood, wood fiber, bark (see limitation below), branches, and leaves.

#### 2.2.1.2 May not be chipped or shredded from or contain:

- Roots or visible amounts of soil.
- More than 50% bark.



- Fruit trees<sup>f</sup>
- Any ornamentals that may be subject pesticide<sup>3</sup> treatment any time of the year.
- Invasive plants of which any portions are capable of re-sprouting, including but not limited to English Holly<sup>g</sup>, English ivy<sup>h</sup>, horsetail<sup>i</sup>, clematis, knotweed, etc.
- Weeds and weed seeds including but not limited to plants on the King County Noxious Weed list available at: <https://kingcounty.gov/en/legacy/services/environment/animals-and-plants/noxious-weeds.aspx>.
- Construction material including lumber of any kind; and as such may not contain any manufactured material (plastic, concrete, ceramics, metal, paint, stain, pressure treatment, etc.), and may not contain any sharps<sup>4</sup>.

### 2.2.1.3 Gradation

Arborist Wood Chip Mulch, when tested, shall meet the following loose volume gradation:

Table 2-3 Arborist Wood Mulch Gradation <sup>j</sup>	
Sieve Size	Percent Passing
2"	95 – 100
1"	70 – 100
5/8	0 – 50
No. 4	0 – 30

## 2.2.2 Compost Mulch

### 2.2.2.1 Compost Mulch for Bioretention and other Landscape Facilities and BMPs

Compost Mulch for the following facilities and BMPs must meet the **Specification 1** compost requirements of **Section 2.1.1**, except that the **gradation** must be **Coarse Compost** per **Section 2.1.3**.

- Bioretention
- Bioswales
- Vegetated Filter Strips
- Treatment Wetlands
- Infiltration facilities and BMPs other than Bioretention<sup>5</sup>

### 2.2.2.2 Compost Mulch for other facilities and BMPs

Compost Mulch for other facilities and BMPs must meet either Specification 1 or Specification 2 compost of Section 2.1.1 or 2.1.2 respectively, except that the gradation must be Coarse Compost per **Section 2.1.3**.

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<sup>3</sup> E.g., but not limited to insecticide and fungicide.

<sup>4</sup> "Sharps": a contaminant category; means any articles that are able to purposely or accidentally puncture or cut the skin or mucosa; Including, but not limited to, needles, scalpel blades, syringes (with needles); pen needles, lancets; razor blades; tattoo pens and needles, broken and unbroken glassware of any kind, bottles (even intact – may break), window glass, metal shards or fragments, staples, and toothpicks.

<sup>5</sup> e.g., SWDM 5.2.1 flow control infiltration; and while the SWDM does not designate a BMP named Rain Garden, that's analogous to Appendix C Bioretention, and as such has the same media requirements and restrictions.

## 2.3 High Performance Bioretention Designs Media

From the laboratory experiments that were relied upon by WA Ecology to publish its 'high performance bioretention soil mixes' (HPBSM), according to Herrera (2020), "Treatment 4 was the only media blend that met all TAPE<sup>6</sup> objectives for water quality treatment". To be clear, treatment 4 was not a single media blend, or 'mix' – the term Ecology uses; it was two different media-blend treatment layers; a primary layer that achieved basic and enhanced basic (metals) treatments, and a supplementary polishing sub-layer that added phosphorus treatment; the layers were each composed of different media mixes.

### Required Media

Only specifically sourced media that achieved required treatments experimentally qualify for use in KC SWDM High Performance Bioretention water quality treatment facilities and flow control BMPs.

### Alternative Media

Any proposal to use alternative media requires a KC SWDM Adjustment (see Section 1.4). An adjustment will require that any alternative-source media blend proposed for water quality treatment facilities (SWDM Core #8) must undergo the same testing and pass the same treatment efficiency requirements as did the specified media, and must meet content and Synthetic Precipitation Leaching Protocol (SPLP) criteria in following Reference 11-C sections. Testing alternative media sources to meet basic, enhanced basic, and/or phosphorus treatment must follow a sampling and analysis plan or quality assurance project plan (QAPP) equivalent to Herrera (2018)<sup>7</sup>. While there is currently no WA Ecology or King County regulatory requirement for where 6PPD-quinone<sup>8</sup> mitigation is required, should a proponent want to apply that mitigation, or if required by another agency, e.g., USFW<sup>9</sup> or WADFW<sup>10</sup>, then testing alternative media sources to meet 6PPD-quinone mitigation must follow a sampling and analysis plan or QAPP equivalent to King County (2023)<sup>11</sup>.

For use solely in FC BMPs taking runoff solely from NPGIS<sup>12</sup> and/or NPGPS<sup>13</sup>, alternative media blends do not have to undergo pollutant removal testing; but an SWDM Adjustment is still required; and the media must meet characteristics described in the following sections, and the same media content and SPLP testing requirements apply; documentation for all aspects is required.

An Adjustment is not guaranteed just from application; approval depends on media meeting requirements stated above, and documented per Reference 11-C section **5 Reporting**.

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<sup>6</sup> Technology Assessment Protocol – Ecology (Howie 2018a, 2018b). The objectives are: for basic treatment, 80% TSS removal; for enhanced basic treatment, 80% TSS, 30% dissolved copper, and 60% dissolved zinc removal; and for phosphorus (SWDM 'sensitive lake protection'), 50% total phosphorus removal. All percent removal values must meet TAPE-defined statistical confidence levels.

<sup>7</sup> <https://your.kingcounty.gov/dnrp/library/2018/kcr3867/kcr3867.pdf>

<sup>8</sup> <https://pubchem.ncbi.nlm.nih.gov/compound/6PPD-quinone>

<sup>9</sup> US Fish and Wildlife

<sup>10</sup> Washington Department of Fish and Wildlife

<sup>11</sup> <https://your.kingcounty.gov/dnrp/library/2023/kcr3556/kcr3556.pdf>

<sup>12</sup> Non-pollution generating pollution surface(s)

<sup>13</sup> Non-pollution generating pervious surface(s)

## 2.4 High Performance Bioretention Media Component Specifications

### 2.4.1 Coconut Coir

#### 2.4.1.1 Coconut Coir Application

- Coconut coir is a component of the high performance bioretention primary layer, which is also composed of sand and high carbon wood ash.

#### 2.4.1.2 Coir Sourcing

- To date the only primary layer that has been demonstrated meet all treatment goals has used **Botanicare CocoGro coir**<sup>14,k</sup>. As such, this is the only coir qualified for use in KC SWDM bioretention at this time. Any proposal to use alternative media will require a KC SWDM Adjustment (see SWDM Section 1.4). An adjustment will require that any alternative-source media blend proposed for water quality treatment facilities (SWDM Core #8) must undergo the same performance testing and pass the same treatment efficiency requirements as did the specified media. Both WQ treatment and FC BMP media for both the allowed coir and for any adjustment-allowed test coir must meet both content and Synthetic Precipitation Leaching Protocol (SPLP) criteria.

#### 2.4.1.3 Coir Characteristics

- Botanicare CocoGro coir has the following characteristics which are applicable to any proposed alternative coir:
  - Fibers about 1 to 2 inches long and that are loose and easy to separate<sup>l</sup>. Appearance should approximate Figure 1<sup>m</sup>.
  - 'Buffered'<sup>n</sup> with calcium salts, and double-rinsed with fresh water.<sup>15</sup>
  - Aged at the country of origin from 30 to 120 days, outdoors, uncovered, piles managed to a degree to assist and accelerate the removal of the Tannins.
  - Current country of origin specifications: either Sri Lanka or India.



Figure 1. Coconut coir loose fibers<sup>16</sup>

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<sup>14</sup> <https://www.botanicare.com/products/cocogro/>

<sup>15</sup> The double-rinsing requirement is from the Department of Ecology.

<sup>16</sup> Cropped from Wikimedia (2024)

- As noted under heading 2.4.1.2 above, any alternative coir must be performance and quality tested.
  - Any proposed alternative primary layer coir must:
    - In combination with the other primary layer components, meet the relevant TAPE pollutant percent removal specifications.
    - Meet **Table 2-4 Coir Test Specifications**.
    - Be characterized as described under this section's second main bullet (fibers, buffered, etc.), with the exception of named country of origin (may be sourced from other countries).
    - Coir must be certified as not having ever been treated with any kind of pesticide in the growth, manufacturing, transportation, or storage of the product.

#### 2.4.1.4 Coconut Coir Test Specifications

Note regarding synthetic precipitation leaching protocol (SPLP)

If specified SPLP<sup>17</sup> leachate concentration exceeds the Maximum Value, the solid material may be recovered from the test and subject sequential (serial) SPLP up to a maximum of three times<sup>18</sup>. If the Maximum Value is exceeded in the third SPLP, then the material is not qualified to be used in HPBSM.

Table 2-4 Coir Test Specifications			
Parameter	Preparation and Analytical Method	Maximum Value	Testing Responsibility
Physical contaminants <sup>19</sup>	Only limited accidental film plastic debris from packaging is allowed. No other contaminants are allowed.	≤ 0.1 percent by dry weight <sup>o</sup>	Manufacturer
Sharps <sup>20</sup>	Visual observation	0	Manufacturer, vendor, and installer observation <sup>21</sup>

<sup>17</sup> The specified extraction fluid pH is representative of Puget Sound area precipitation pH. Whether runoff is buffered by conveyance material contact in transit to a treatment facility is unknown. To be maximally protective, the method pH is assumed to be representative of facility influent, and is not to be substituted with neutral pH extraction fluid.

<sup>18</sup> Allowing 3x sequential (serial) SPLP runs is representative of sequential storm flushing. If Maximum Value is exceeded at the third SPLP, that indicates potential risk of long-term net discharge of the pollutant.

<sup>19</sup> "Contaminant" means any material besides coconut coir.

<sup>20</sup> "Sharps": a specific category of contaminant; means any articles that are able to purposely or accidentally puncture or cut the skin or mucosa; Including, but not limited to, needles, scalpel blades, syringes (with needles); pen needles, lancets; razor blades; tattoo pens and needles, broken and unbroken glassware of any kind, bottles (even intact – may break), window glass, metal shards or fragments, and toothpicks.

<sup>21</sup> When receiving and processing material, if the installer observes any sharps the material may not be used and should be returned to the vendor with cause.

Table 2-4 Coir Test Specifications			
Parameter	Preparation and Analytical Method	Maximum Value	Testing Responsibility
Pathogens <sup>p</sup>	Ether Fecal coliform Most Probable Number (MPN)	< 1,000 MPN per gram of total solids (dry weight) <sup>q</sup>	Manufacturer, vendor, or proponent
	Or Salmonella Most Probable Number (MPN)	< 3 MPN per 4 grams of total solids (dry weight) <sup>r</sup>	
Nitrate+Nitrite <sup>s</sup>	SPLP (EPA Method 1312) <sup>22</sup> and analysis by EPA Method 353.2, rev. 2.0	0.15 mg N /L <sup>t,u</sup>	Proponent
Total Phosphorus	SPLP (EPA Method 1312) <sup>22</sup> and analysis by NEMI <sup>23</sup> Method SM 4500-P E-99	0.10 mg P /L <sup>24,v</sup> 0.50 mg P /L <sup>25,w</sup>	Proponent
Orthophosphate <sup>x</sup>		0.10 mg P /L <sup>24,v</sup> 0.50 mg P /L <sup>25,w</sup>	Proponent
Copper (dissolved)	Synthetic Precipitation Leaching Protocol (EPA Method 1312) <sup>22</sup> and EPA Method 200.8 UCT-KED	3.5 µg/L <sup>y</sup>	Proponent
Arsenic <sup>z</sup> (total)	Synthetic Precipitation Leaching Protocol (EPA Method 1312 – use extraction Fluid #2 per Section 5.4.2) and EPA Method 200.8 UCT-KED.	0.1 µg/L <sup>26,aa</sup>	Proponent
Tannins <sup>bb</sup> , Lignins, and Phenols	TBD <sup>27,cc</sup> For the time being not required for stipulated allowed coir. Permit Adjustment <sup>28</sup> applications to use alternatives will require consultation with and approval by KC WLRD for method and maximum value(s)	? mg/L <sup>29,dd</sup> TBD	Manufacturer, vendor, or proponent
Electrical Conductivity <sup>ee</sup>	Test Methods for the Examination of Compost and Composting (TMECC) Method 04.10-A	1.0 mmhos/cm	Manufacturer or vendor

<sup>22</sup> Use extraction Fluid #2 per Section 5.4.2.

<sup>23</sup> National Environmental Methods Index

<sup>24</sup> For bioretention as a Sensitive Lake Menu water quality treatment facility.

<sup>25</sup> For bioretention in any application – facility or FCBMP – that is not in a sensitive lake basin or discharging within one quarter (¼) mile of s phosphorus sensitive waterbody; regardless of whether by ground or surface discharge.

<sup>26</sup> EPA 200.8 documentation says the selective ion MDL is 0.02 µg/L. Report all of the lab MDL, RL, and all analytical results ≥ MDL.

<sup>27</sup> At time of this HPBSM publication (November, 2024), and for the time being, use of BotaniCare coir will not require testing. The rationale is that establishing a test method is proving challenging, and this specific product has been used in live sensitive organism testing without ill effect. If applying for an Adjustment to use alternative coir, testing will be required; consult with WLRD Stormwater Services staff to establish test method at that time.

<sup>28</sup> Adjustment per SWDM section 1.4

<sup>29</sup> See footnote 27. As with test method uncertainty, acceptable tannin concentration has not yet been established. If applying for an Adjustment to use alternative coir, testing will be required; consult with WLRD Stormwater Services staff regarding acceptable concentration.

Table 2-4 Coir Test Specifications			
Parameter	Preparation and Analytical Method	Maximum Value	Testing Responsibility
All metals are total	Method	Dry weight <sup>ff</sup>	
Arsenic	EPA 6020	0.5 mg/kg	
Cadmium	EPA 6020	0.05 mg/kg	
Chromium	EPA 6010	12 mg/kg	
Cobalt	EPA 6010	2 mg/kg	
Copper	EPA 6010	10.5 mg/kg	
Mercury	EPA 7471	0.01 mg/kg	
Molybdenum	EPA 6010	3.82 mg/kg	
Nickel	EPA 6010	6.1 mg/kg	
Lead	EPA 6020	1.2 mg/kg	
Selenium	EPA 6020	0.6 mg/kg	
Zinc	EPA 6010	26 mg/kg	

## 2.4.2 High Carbon Wood Ash (HCWA)

2.4.2.1 HCWA is a component of the high performance bioretention primary layer, which is also composed of sand and high coconut coir.

### 2.4.2.2 HCWA Sourcing

- To date the only high carbon wood ash (HCWA) product that has been demonstrated to meet all treatment goals is **Biological Carbon HPG (High Performance Grade) Stormwater Char**<sup>30,gg</sup>. As such, this is the only HCWA qualified for use in KC SWDM bioretention at this time. Any proposal to use alternative media will require a KC SWDM Adjustment (see SWDM Section 1.4). An adjustment will require that any alternative-source media blend proposed for water quality treatment facilities (SWDM Core #8) must undergo the same performance testing and pass the same treatment efficiency requirements as did the specified media. Both WQ treatment and FC BMP media for both the allowed HCWA and for any adjustment-allowed test HCWA must meet both content and Synthetic Precipitation Leaching Protocol (SPLP) criteria.

### 2.4.2.3 HCWA Characteristics

- To qualify for consideration for performance-testing alternative HCWA under a Permit Adjustment, the following specifications must be met<sup>hh</sup>: These specifications may be amended pending further information from the supplier of media used in experiments.

<sup>30</sup> Specific product used for experiments was obtained from Walrath Landscape Supply (Tacoma, Gig Harbor). Until such time as performance-qualified HCWA is fully characterized with regard to feedstock, pre-production, production, post-production processes, and finished product characteristics for equivalent alternative sources, only Biological Carbon HPG (High Performance Grade) Stormwater Char qualifies for HPBSM content.



- The HCWA shall be sourced from a producer with at least 5-years of experience producing HCWA for soil amendments and/or water filtration.<sup>ii</sup>
- The HCWA shall be classified as a “Class 1” Biochar following the International Biochar Initiative (IBI) guidelines (IBI 2015).<sup>jj</sup>
- HCWA feedstocks shall be limited to clean cellulosic material from:
  - The woody by-products of pacific northwest forestry operations (including cut residues left after a timber harvest, cut trees that are not marketable as lumber)<sup>kk</sup>, and/or
  - Chipped trees and brush from biomass reduction operations (i.e. commercial tree trimming)<sup>ll</sup>, and/or
  - Chipped agricultural orchard pruning<sup>mm</sup>.
- The biomass feedstocks shall not include any post-consumer or post-industrial sourced woody biomass (e.g., but not limited to construction or demolition waste, wood contaminated with paints, stains, sealers, or preservatives or any other deleterious substances, and shall not include any non-wood materials, e.g., but not limited to metal, plastic, rubber, glass, concrete, or asphalt).
- The biomass feedstocks shall not include any manure, animal bedding, or biosolids.
- The High Carbon Wood Ash (HCWA) shall consist of screened and processed organic and inorganic residue remaining after the thermal processing of biomass in an oxygen-controlled environment. Processing consists of:
- HCWA must meet the following requirements for quality and grading:

### HCWA Test Specifications

Note regarding synthetic precipitation leaching protocol (SPLP)

If specified SPLP<sup>31</sup> leachate concentration exceeds the Maximum Value, the solid material may be recovered from the test and subject to sequential (serial) SPLP up to a maximum of three times<sup>32</sup>. If the Maximum Value is exceeded in the third SPLP, then the material is not qualified to be used in HPBSM.

Table 2-5 High Carbon Wood Ash (HCWA) Test Specifications			
Parameter	Preparation and Analytical Method	Value Max unless stated otherwise	Testing Responsibility
Nitrate+Nitrite	Synthetic Precipitation Leaching Protocol (EPA Method 1312 – use extraction Fluid #2 per Section 5.4.2) and EPA Method 353.2	0.15 mg N /L <sup>tu</sup>	Proponent

<sup>31</sup> The specified extraction fluid pH is representative of Puget Sound area precipitation pH. Whether runoff is buffered by conveyance material contact in transit to a treatment facility is unknown. To be maximally protective, the method pH is assumed to be representative of facility influent, and is not to be substituted with neutral pH extraction fluid.

<sup>32</sup> Allowing 3x sequential (serial) SPLP runs is representative of sequential storm flushing. If Maximum Value is exceeded at the third SPLP, that indicates potential risk of long-term net discharge of the pollutant.

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Total Phosphorus	Synthetic Precipitation Leaching Protocol (EPA Method 1312 – use extraction Fluid #2 per Section 5.4.2) and NEMI Method SM 4500-P E-99	0.10 mg P /L <sup>33</sup> 0.50 mg P /L <sup>34</sup>	Proponent
Orthophosphate <sup>x</sup>		0.10 mg P /L <sup>33</sup> 0.50 mg P /L <sup>34</sup>	Proponent
Copper	Synthetic Precipitation Leaching Protocol (EPA Method 1312 – use extraction Fluid #2 per Section 5.4.2) and EPA Method 200.8 UCT-KED	3.5 µg/L <sup>y</sup>	Proponent
Arsenic <sup>z</sup> (total)	Synthetic Precipitation Leaching Protocol (EPA Method 1312 – use extraction Fluid #2 per Section 5.4.2) and EPA Method 200.8 UCT-KED	0.1 µg/L <sup>35,26</sup>	Proponent
Organic Carbon (C <sub>org</sub> )	Total C and H analysis by dry combustion- elemental analyzer (EPA Method 440.0). Inorganic C analysis by determination of CO <sub>2</sub> - C content with 1N HCl, as outlined in ASTM D4373 Standard Test Method for Rapid Determination of Carbonate Content of Soils. Organic C calculated as Total C – Inorganic C.	60% (Min) <sup>nn</sup>	Manufacturer
H: (C <sub>org</sub> )		0.7 (Max) <sup>nn</sup>	
Volatile Matter	Proximate Analysis (ASTM D1762)	20% <sup>nn</sup>	Manufacturer
Ash		40% <sup>nn</sup>	
Electrical Conductivity	Test Methods for the Examination of Compost and Composting (TMECC) Method 04.10-A	1.0 mmhos/cm <sup>nn</sup>	Proponent
Heavy Metals Same list as given in coir test spec. Table 2-4	EPA 6010, 6020, 7471; depending on analyte	mg/kg for each TBD pending analytical data from media used in experiments	Manufacturer, vendor, or proponent
Cation Exchange Capacity)	USEPA Method 9081 Report only	milliequivalents CEC/100 g dry soil	Manufacturer

## 2.4.3 High Performance Bioretention Designs Aggregates

### 2.4.3.1 HPBSM Primary Layer Sand

- The sand must be natural; manufactured sand is not allowed.
- Volcanic sand is not allowed<sup>oo</sup>.

<sup>33</sup> For bioretention as a Sensitive Lake Menu water quality treatment facility.

<sup>34</sup> For bioretention in any application – facility or FCBMP – that is not in a sensitive lake basin.

<sup>35</sup> EPA 200.8 documentation says the selective ion MDL is 0.02 µg/L. Report all of the lab MDL, RL, and all analytical results ≥ MDL.



- Where underdrained to or infiltrating within ¼ mile of a sphagnum bog wetland, the sand must be silica-based sand rather than an alternative, e.g., aragonite sand.
- Until such time as the experimental sand used to develop the HPBSM has been sufficiently characterized for specifying equivalency, the sand shall be material obtained from ICON Materials Auburn Quarry<sup>36</sup>.
- The sand shall be thoroughly cleaned and free of foreign dirt, clay, silt, asphalt, organic material, and any other foreign matter and all aggregate passing the No. 200 sieve size shall be non-plastic. The filter sand shall meet the following requirements for quality:

Table 2-6 High Performance Bioretention Aggregate Quality Test Specifications			
Parameter	Preparation and Analytical Method	Maximum Value	Testing Responsibility
Nitrate+Nitrite	Synthetic Precipitation Leaching Protocol (EPA Method 1312 – use extraction Fluid #2 per Section 5.4.2) and EPA Method 353.2	0.15 mg N /L <sup>t,u</sup>	Proponent
Total Phosphorus	Synthetic Precipitation Leaching Protocol (EPA Method 1312 – use extraction Fluid #2 per Section 5.4.2) and NEMI Method SM 4500-P E-99	0.10 mg P /L <sup>37,v</sup> 0.50 mg P /L <sup>38</sup>	Proponent
Orthophosphate		0.10 mg P /L <sup>37,v</sup> 0.50 mg P /L <sup>38</sup>	Proponent
Copper (dissolved)	Synthetic Precipitation Leaching Protocol (EPA Method 1312 – use extraction Fluid #2 per Section 5.4.2) and EPA Method 200.8 UCT-KED	3.5 µg/L <sup>v</sup>	Proponent
Arsenic <sup>z</sup>	Synthetic Precipitation Leaching Protocol (EPA Method 1312 – use extraction Fluid #2 per Section 5.4.2) and EPA Method 200.8 UCT-KED	0.1 µg/L <sup>39,26</sup>	Proponent

<sup>36</sup> Listed as 'state sand' Herrera (2020), this and 'volcanic sand' are the only two qualifying types. Because the report's description of volcanic sand leaves open the possibility of some asbestos content (in relation to potential olivine content), until such time as this has been tested for and unless found not to be present, volcanic sand is not allowed (see endnote oo). The alternative sand that met some TAPE criteria was "state sand", found in the report to be from the ICON Auburn Quarry. Until such time as this is characterized with regard to mineral content for equivalent alternative sources, it is to be single-sourced.

<sup>37</sup> For bioretention as a Sensitive Lake Menu water quality treatment facility.

<sup>38</sup> For bioretention in any application – facility or FCBMP – that is not in a sensitive lake basin.

<sup>39</sup> EPA 200.8 documentation says the selective ion MDL is 0.02 µg/L. Report all of the lab MDL, RL, and all analytical results ≥ MDL.

### 2.4.3.2 HPBSD Primary Layer Sand Gradation

The aggregate shall be sand meeting the gradation below and the requirements of Section 9-03.1(2)B (Class 1) of the Washington State Department of Transportation Standard Specifications, and shall have a Coefficient of Uniformity of four (minimum).

<b>Table 2-7 High Performance Bioretention Design Primary Layer Sand Gradation<sup>PP</sup></b>		
Sieve Size	Percent Passing Min.	Percent Passing Max.
3/8 "	99	100
# 4	95	100
# 8	68	86
# 16	47	65
# 30	27	42
# 50	9	20
# 100	0	7
# 200	0	2.5

### 2.4.3.3 HPBSD Polishing Layer Sand Gradation

The aggregate shall be sand meeting the gradation below and the requirements of Section 9-03.1(2)B (Class 1) of the Washington State Department of Transportation Standard Specifications, and shall have a Coefficient of Uniformity of four (minimum).

<b>Table 2-8 High Performance Bioretention Design Polishing Layer Sand Gradation<sup>QQ</sup></b>		
Sieve Size	Percent Passing Min.	Percent Passing Max.
3/8 "	99	100
# 4	95	100
# 8	68	86
# 16	47	65
# 30	27	42
# 50	9	20
# 100	0	7
# 200	0	2.5

## 2.5 Activated Alumina

$\text{Al}_2\text{O}_3 \cdot \text{H}_2\text{O}$  CAS Number 1344-28-1

Activated Alumina shall meet the following requirements for quality and grading:

Table 2-9 Activated Alumina Specifications			
Parameter	Test / Method	Value	Testing Responsibility <sup>40</sup>
$\text{Al}_2\text{O}_3$ Content	n/a	92.7 % (Min)	Manufacturer
Copper <sup>rr</sup> (dissolved)	Synthetic Precipitation Leaching Protocol (EPA Method 1312 – use extraction Fluid #2 per Section 5.4.2) and EPA Method 200.8 UCT-KED	1 µg/L (Max.)	Proponent
$\text{SiO}_2$	n/a	0.02 % (Max)	Manufacturer
$\text{Fe}_2\text{O}_3$	n/a	0.02 % (Max)	Manufacturer
$\text{Na}_2\text{O}$	n/a	0.30 % (Max)	Manufacturer
$\text{H}_2\text{O}$	n/a	7% (balance of content)	Manufacturer
Any other content	n/a	Less than 0.02%	Manufacturer
Bulk density <sup>ss,41</sup>	n/a	760 Kg/m <sup>3</sup> (Min.)	Manufacturer
Surface area <sup>tt,42</sup>	n/a	300 m <sup>2</sup> /g (Min.)	Manufacturer
Grain size	Gradation (ASTM D422)	Taylor 14x28 mesh <sup>uu</sup> 0.6 mm to ? mm <sup>vv</sup>	Manufacturer

<sup>40</sup> Where noted as Manufacturer or Proponent, depends on volume. Though the manufacturer will provide many of the tests indicated in this table, manufacturer tests are only run periodically on the source material not on the exact material supplied for the project. For projects below ### - TBD, manufacturer's tests are acceptable. For projects above ###, the volume of material used requires testing specific to the project.

<sup>41</sup> Subject to change pending findings from vendor/manufacturer of media used in experiments.

<sup>42</sup> Subject to change pending findings from vendor/manufacturer of media used in experiments.

## 2.6 Iron Aggregate

The Iron Aggregate should be ground Iron meeting the following requirements for quality and grading:

Table 2-10 Iron Aggregate Specifications <sup>ww</sup>			
Test / Method	Criterion	Requirement	Testing Responsibility <sup>43</sup>
Synthetic Precipitation Leaching Protocol (EPA Method 1312) and EPA Method 353.2	NO <sub>3</sub> +NO <sub>2</sub> <sup>s</sup>	0.15 mg/L (Max.)	Proponent
Synthetic Precipitation Leaching Protocol (EPA Method 1312) and NEMI Method SM 4500-P E-99	Total Phosphorus	0.15 mg/L (Max.)	Proponent
	Ortho phosphorus	0.15 mg/L (Max.)	Proponent
Synthetic Precipitation Leaching Protocol (EPA Method 1312) and EPA Method 200.8 UCT-KED	Copper	3.5 µg/L <sup>xx</sup>	Proponent
Producer Analysis	Iron Content by weight	80% - 97%	Manufacturer
Gradation (ASTM D422) or Producer Analysis <sup>yy</sup>	#4	100% passing	Manufacturer
	#8	95 -100% passing	Manufacturer
	#16	75-90% passing	Manufacturer
	#30	25-45% passing	Manufacturer
	#50	0-10% passing	Manufacturer
	#100	0-5% passing	Manufacturer
	#200	0-2.5% passing	Manufacturer

<sup>43</sup> Where noted as Manufacturer or Proponent, depends on volume. Though the manufacturer will provide many of the tests indicated in this table, manufacturer tests are only run periodically on the source material not on the exact material supplied for the project. For projects below ### - TBD, manufacturer's tests are acceptable. For projects above ###, the volume of material used requires testing specific to the project.

## **2.6.1 60:40 Bioretention Soil Media (BSM) Aggregate: For Flow Control BMP applications only**

### **2.6.1.1 60:40 BSM Aggregate Material, i.e., Sand**

- The sand must be natural; manufactured sand is not allowed.
- Where underdrained to or infiltrating within ¼ mile of a sphagnum bog wetland, the sand must be silica-based sand rather than an alternative, e.g., aragonite sand.

### **2.6.1.2 60:40 BSM Aggregate Gradation**

The following table provides a gradation guideline for the aggregate component of a 60:40 Bioretention Soil Mix specification in western Washington. This sand gradation is often supplied as a well-graded utility or screened. With compost, this blend provides enough fines for adequate water retention, hydraulic conductivity within recommended range (see below), pollutant removal capability, and plant growth characteristics for meeting design guidelines and objectives.

<b>Table 2-11 60:40 Bioretention Soil Mix Mineral Aggregate Gradation</b>	
<b>Sieve Size</b>	<b>Percent Passing</b>
3/8"	100
#4	95-100
#10	75-90
#40	25-40
#100	4-10
#200	2-4

Where existing soils meet the above aggregate gradation, those soils may be amended rather than importing mineral aggregate.

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## **3 Bioretention Media Assembly**

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**All percent values listed below are by volume**

### **3.1 60:40 Bioretention: For flow control BMP (FCBMP) applications only**

- 60% (+/- 3%) sand meeting specification 11-C 2.6.1.
- 40% (+/- 3%) compost meeting specification Reference 11-C 2.1.1
- Mulch for 60:40 bioretention meeting specification Reference 11-C 2.6

## 3.2 High Performance Bioretention Designs (HPBD) Assembly

'High Performance Bioretention' Designs (HPBD) for water quality treatment facilities and as an FCBMP option. Depending on use, i.e., *basic*, *enhanced basic*, or *sensitive lake* (phosphorus control) **water quality treatments**, or as an FCBMP, these designs are composed of one to three layers, two of which are media mixes. The **Layer** types are:

### 3.2.1 Primary Layer

- 70% (+/- 3%) sand meeting specification Reference 11-C sections **2.4.3.1** and **2.4.3.2**
- 20% (+/- 2%) coconut coir fiber meeting specification Reference 11-C 2.4.1
- 10% (+/- 1%) high carbon wood ash meeting specification Reference 11-C 2.4.2.1 and 0

### 3.2.2 Polishing Layer

- 90 % (+/- 1%) sand meeting specification Reference 11-C sections **2.4.3.1** and **2.4.3.3**.
- 7.5% (+/- 0%) activated alumina meeting specification Reference 11-C **2.5**.
- 2.5% (+/- 0%) iron aggregate meeting specification Reference 11-C **2.6**.

### 3.2.3 2 Inch Compost Layer

Use Reference 11-C 2.1.1 specifications.

### 3.2.4 Mulch

Use 11-C **2.2 specifications**.

## **4 Sampling Frequency**

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### **4.1 Small applications: single family residence flow control BMPs**

#### **4.1.1 For Testing Responsibility - Manufacturer**

##### **4.1.1.1 Bagged / packaged materials**

- Analysis on each bag or package label (copies of all labels), or
- Separate analysis sheet or sheets provide by vendor for each bag or package

##### **4.1.1.2 Bulk**

- Analysis sheet or sheets provided by vendor at a rate of no less than one analysis for each individual truck bed load delivered.

#### **4.1.2 For Testing Responsibility - Proponent**

##### **4.1.2.1 Bagged / packaged materials**

- For a bioretention cell, equal size subsamples to be taken from each bag and mixed thoroughly for a single composite sample for analysis for the cell.

##### **4.1.2.2 Bulk**

- For a bioretention cell, five equal size subsamples to be taken from random representative locations and depths from the bulk delivery and mixed thoroughly for a single composite sample for analysis for the cell.

### **4.2 Large applications: water quality treatment facilities, and high density residential, commercial, and industrial flow control BMPs**

#### **4.2.1 For Testing Responsibility – Manufacturer**

##### **4.2.1.1 Bagged / packaged materials**

- Analysis on each bag or package label (copies of all labels), or
- Separate analysis sheet or sheets provide by vendor for each bag or package

##### **4.2.1.2 Bulk**

- Analysis sheet or sheets provided by vendor at a rate of no less than one analysis for each individual truck bed load delivered.

#### **4.2.2 For Testing Responsibility - Proponent**

##### **4.2.2.1 Bagged / packaged materials**

- For each bioretention cell, equal size subsamples to be taken from one out of every three bags and mixed thoroughly for a single composite sample for analysis per cell.

##### **4.2.2.2 Bulk**

- For each 15 yards or less of material, five equal size subsamples to be taken from random representative locations and depths from the bulk delivery and mixed thoroughly for a single composite sample for analysis for that volume.

## 5 Reporting

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### Qualified Source Material

PDF files are required for submitting all reports except laboratory-provided EDD<sup>44</sup> files which should be in Excel format. Sent to: Department of Natural Resources and Parks Water and Land Resources Division email address:

[WLRD.SWS.SWDM.Data.Submittals@kingcounty.gov](mailto:WLRD.SWS.SWDM.Data.Submittals@kingcounty.gov)

Include the Permit number in the email Subject line for identification. Each subsection that follows lists what is to be reported.

#### Compost

- DLS<sup>45</sup> permit number, volume purchased, purchase date, and date material applied.
- Manufacturer name and compost batch number(s).
- For each batch, laboratory analysis of all parameters in WAC 173-350-220 Table 220-B.

#### Arborist's Wood Mulch

- DLS<sup>45</sup> permit number, volume purchased, purchase date, and date material applied.
- Gradation per ranges in Reference 11-C Table 2-3.

#### All HPBSM Media: sand, coir, high carbon wood ash (HCWA), and iron and activated alumina aggregates

All testing parameter results required in Reference 11-C section **2.4, High Performance Bioretention Media Component Specifications** plus laboratory QA/QC and any laboratory cover letters and/or narratives. Each laboratory report should include all of:

- Laboratory cover letter
- Chain of custody form/report
- Analytical machine printouts
- Analytical results narrative
- QA/QC narrative
- Excel EDD<sup>44</sup> file

#### Alternative HPBSM Media for which an Adjustment for Use is Requested

An alternative HPBSM media request requires performance testing to evaluate whether the proposed mix achieves the required pollutant removal criteria and acceptable hydraulics.

Reports are to be sent in duplicate to:

- Department of Local Services Permitting Division staff in charge of the Permit under which any facility and/or BMP is being installed, and
- Department of Natural Resources and Parks Water and Land Resources Division email address: [WLRD.SWS.SWDM.Data.Submittals@kingcounty.gov](mailto:WLRD.SWS.SWDM.Data.Submittals@kingcounty.gov)

In both cases, Include the Permit number in any communications for identification.

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<sup>44</sup> Electronic Data Deliverable

<sup>45</sup> King County Department of Local Services – Permitting Division



**The following are required:**

- Application for a SWDM Adjustment through King County Department of Local Services
- A quality assurance project plan (QAPP) as described in Reference 11-C section: **2.3**

- **High Performance Bioretention Designs Media.** The QAPP is subject to review and approval by King County WLRD staff. The QAPP must cover:
  - Listing which media are already qualified and which are alternatives.
  - Testing all media for parameters listed above for Qualified source material, plus **for each proposed alternative media:**
    - Manufacturer's name and contact information
    - Vendor's name and contact information
    - Physical and chemical descriptions at least as complete as qualified media characteristics described in individual media sections above; with information garnered from manufacturer and vendor published media specifications, e.g., but not limited to spec. sheets and safety data sheets (SDS); and where necessary characterization by qualified consultants. Specific source citations are required.
- Once the QAPP is approved, testing may commence.
- Testing must be done by a qualified environmental or engineering consulting firm.
- A Technical Information Report must be submitted, reporting on the testing results.

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## 7 Basis and Other Explanatory Notes

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<sup>a</sup> From WSDOT (2025) Section 9-14.5(8) Compost.

<sup>b</sup> From WSDOT (2025) Section 9-14.5(8) Compost.

<sup>c</sup> The vast majority of web-accessible information on cardboard safety with respect to mulching and composting is anecdotal, i.e., from gardening and composting commercial and forum websites. Most of the sites' content center on recycling packaging, i.e., corrugated cardboard boxes. Some sites opine that corrugated cardboard is OK because the adhesives used in manufacture are starch based. However, those opinions don't factor that the starches may be chemically modified (Pascoli Cereda 2024); whether those modifications render any of the adhesives less biodegradable and/or make them toxic is an open question. Some sites do recognize potential risk from other glues used in forming and sealing boxes, and some acknowledge contamination from plastic tape; we also note risk from stick-on documentation 'windows', and labels and their adhesives. Then there are the issues of coatings, i.e., plastic and wax; and cardboard and/or coatings may in some cases may be treated with pesticide (insecticide or fungicide); and print, which may contain heavy metals and/or toxic organic compounds. last, staples are used to close some packaging, posing sharps hazard. At best, non-corrugated cardboard sheets, e.g., those used to separate layers of goods on warehouse pallets may contain no harmful substances, but mulch made of shreds of that material will fall apart rapidly exposed to the elements; it will in no way emulate the physicochemical characteristics of wood chip mulch; the same can be said of any other cardboard mulch, toxicity questions notwithstanding.

<sup>d</sup> Same arguments against use as presented in endnote c, re: cardboard, with the exception of corrugated material, which is not applicable to paper products.

<sup>e</sup> This falls between Ecology's liberal "Shredded wood mulch is made from shredded tree trimmings, usually from trees cleared on site" and WSDOT's more constrained "Bark or wood chip mulch shall be derived from fir, pine, or hemlock species". Noting that Ecology's 2019 SWMMWW is inconsistent and sometimes refers to wood mulch as shredded as just noted, sometimes, as chipped ("chipped on-site vegetation"), and sometimes both ("Shredded or chipped hardwood or softwood"). Also applying middle ground between - in this case WSDOT's more liberal "Bark or wood chip mulch", ostensibly allowing 100% bark, and Ecology's SWMMWW more constrained, "Mulch shall not be . . . Pure bark (bark is essentially sterile and inhibits plant establishment)". That all said, neither Ecology nor WSDOT provide research citations to support their takes on acceptable woods or percent bark. Literature search and review, and consultation with certified PNW arborists is warranted for future manual updates.

<sup>f</sup> Fruit trees, even those grown organically, are subject to at least dormant oil spray containing "horticultural oil, copper and sulfur" (Pokorny 2023). Non-organic tree culture may be subject to other toxic applications.

<sup>g</sup> No scientific research literature found. From gardening and composting commercial and forum websites, it sounds like – but is not certain – chipped limbs and leaves are unlikely to root and propagate; but it appears certain that berries present may root.

<sup>h</sup> Not itself a tree, but trees may harbor ivy, hence the prohibition included in feedstock restrictions. Oregon State University staff and OSU Extension give conflicting information on fragmented ivy rooting, and it's about composting, but should be equally applicable to mulch. On one web page they say, "is not recommended for all invasive species, since many can re-sprout from even the tiniest fragment. But for ivy, it is probably OK" (OSU Extension 2008 (rev. 2024)). On another web page they say, "Root and stem fragments lying on the soil surface will make new plants" (Samaneck 2023).

<sup>i</sup> Common name: Field horsetail. Taxonomic name: *Equisetum arvense*. Also called scouringrush, mare's tail, and snakegrass. "Although Field Horsetail is a native plant in the Pacific Northwest, it is considered a nuisance weed to gardeners and farmers. It forms dense colonies along irrigation banks, crop fields, and pastures, which can

interfere with crop yield. Field Horsetail reproduces from spores, spreading rhizomes, and tubers. It is toxic to livestock." (Cowlitz County 2023) <https://www.co.cowlitz.wa.us/DocumentCenter/View/146/Field-Horsetail?bidId=>

Common name: Giant horsetail. Taxonomic name *Equisetum telmateia*: "Pacific Northwest Invasive Plant Council does list giant horsetail, *Equisetum telmateia*, as invasive in Oregon. Horsetail is of concern because of its aggressive root system, which consists of rhizomes and tubers, that can spread 2-3 feet wide and 6 feet down into the soil. It also produces spores which are carried in the air. For these reasons, horsetail is one of the most difficult plants to get rid of and should be prevented from becoming established.

Although native, it is native to most of North America and Europe. When found in pastures, it is toxic to livestock and other animals, and when it finds its way to waterways, it can impede waterflow." (OSU Extension 2021).

<sup>j</sup> Percent passing 2 in. and No. 4 confirmed from *WSDOT 2025 Standard Specifications 9-14.5(3) Bark or Wood Chip Mulch* (WSDOT 2025). That spec. lists only those two gradations. 5/8 in. gradation found in "Redmond BSM WSDOT Special Provision (unpublished draft Word file; pers com email from Andy Rheume, City of Redmond; dated 5/29/2014); but other gradations differ from WSDOT's 2025 spec. Further research needed to find where 11-C 5/8 in. gradation came from. In the long run, need to research further for consensus and basis, since there are no research citations for any of the noted specifications.

<sup>k</sup> Hinman (2023)

<sup>l</sup> Hinman (2023)

<sup>m</sup> (Hinman 2023)

<sup>n</sup> Intent is cation exchange, not pH buffering per se; in particular, replacement of sodium ions by calcium. Coconut coir production includes soaking the coconuts in sea water; resulting in raw coir saturation with sodium chloride. The provider of the coir used in experiments indicated the process they use is a calcium replacement of the seawater sodium and potassium. The vendor's product process specifics (calcium salt used, concentration, soak duration, follow-up rinsing, etc.) have not been ascertained at this point in time; a number of coir vendor websites suggest that calcium nitrate use is common. Hinman (2023) suggests that repeated freshwater rinses may achieve the same result; the coir supplier has indicated that as well, even though their process is calcium substitution first, followed by thorough rinsing (thoroughness not defined). The electrical conductivity test in **Table 2-4** is to ensure sufficiently low level of residual salt.

<sup>o</sup> Similar to compost per 173-350-220 WAC. In that case, Table 220-B allows up to dry weight 1% overall and limits 'film plastic' to 0.25%, but footnotes that with a.) a label requirement when film plastic exceeds 0.1%, and that footnote references 173-350-220 (6)(f)(iii)(D)(I), which in turn references labeling requirement (6)(f)(iii)(D)(II); the label to say, "This compost does not meet Department of Ecology standards for film plastic content for unrestricted use. This compost may only be used in locations where a means of removing or containing the film plastic on-site is put in place promptly after use. Acceptable controls include removal from the site, incorporation, planting, covering with soil or another media, or containment in a compost sock or similar device. This product may not be used adjacent to regulated waters of the state (e.g., wetlands, streams, lakes) or in environmentally sensitive areas." Substituting *coir* for *compost* it is clear that media exceeding 0.1% dry wt. film plastic is unsuitable for use as stormwater filter media. 173-350-220 provides no basis for allowing up to 1% contaminants excluding film plastic; we can only guess that the allowance is because of the nature of compost feedstocks, for which there is a large degree of lack of control. Coir on the other hand should be a single-material product with a higher degree of certainty. Hence, the only contaminant allowed for coir is the stated limit of film plastic related to packaging.

<sup>p</sup> Same limit as compost per 173-350-220 WAC.

<sup>q</sup> Same limit as compost per 173-350-220 WAC.

<sup>r</sup> Same limit as compost per 173-350-220 WAC.

<sup>s</sup> Parameter required by WA Ecology's HPBSM Guidance. KC WLRD SWS rationale supplement: Noted by a coir vendor: "To buffer coco coir, you must expose it to higher concentrations of a solution that you want in the



media like calcium nitrate and magnesium nitrate." (Shogun Fertilizers <https://www.shogunfertilisers.com/en/growing-information/blogs/what-is-coco-coir-washing-vs-buffering/>). SPLP is to verify that any potential buffering with calcium nitrate has been followed by rinsing sufficiently to decrease nitrate sufficiently.

<sup>t</sup> For the time being 0.15 mg/L nitrate-nitrite as N appears to be indicative of adequate human health and direct aquatic biota health, but bears a deeper dive into past, ongoing, and future research literature. Reasoning follows:

There are no 173-201A WAC surface water quality criteria for nitrate or nitrite; that is not an assurance of safety – it is simply failure to establish and publish criteria. The 173-200 WAC groundwater quality standard (GWQS) is 10 mg/L nitrate (as N); 173-200 makes a connection between groundwater and drinking water, and refers to the Federal 'Safe Drinking Water Act' (SDWA), from which the maximum contaminant level (MCL) for nitrate is then ostensibly the basis for the 173-200 value. The SDWA is somewhat misleadingly named in that not all of the regulatory maximum contaminant levels (MCLs) are safe; see endnote 26.

Re: surface water quality, there may be nitrogen-limiting TMDLs present or future, and they may set maximum concentrations.

Re: both surface and groundwater and human health with respect to drinking water; whether 10 mg/L as N is a safe drinking water level for infants is debatable. WA DOH (2022) provides no basis for that – one suspects they're just passing on the EPA and 173-200 WAC standard. MDH (2018) does provide a basis claiming 10 mg/L as N is safe, but their claim is based on cited 73-74 year old (at the time of this writing) data encompassing an extremely small sample size relative to the U.S. population, and a single toxicity assessment, i.e., methemoglobinemia in infants. MDH-cited data publications, reported cases dates and sample sizes were Rosenfield and Huston (1950) (n=6: ); and Walton (1951) (n=278, for which MDH (2018) notes, "of which 214 included information about drinking water sources"). Walton (1951) further noted 39 deaths out of the 278 reported cases. US EPA's value of 10 mg/L as N is likewise based on the 1951 data; EWG (1996) offer a critique of using those data as a basis.

WA DOH (2022) does caution re: miscarriage or birth defects, but only cautions against nitrate consumption above 10 mg/L as N, and provides no basis citations. Ward et al. (2018) point out that "other health effects including cancer and adverse reproductive outcomes were not considered" in establishing the current nitrate drinking water quality standard; followed by, "... nitrate is a precursor in the formation of N-nitroso compounds (NOC); most NOC are carcinogens and teratogens. Thus, exposure to NOC formed after ingestion of nitrate from drinking water and dietary sources may result in cancer, birth defects, or other adverse health effects." They provide a table of cancer studies (January 2004–March 2018). Some of the studies found increased risk of various cancers at < 10 mg/L NO<sub>3</sub> as N as well as at ≥ 10.

<sup>u</sup> Kakavandi et al. (2018) albeit with stated study limitations and caveats, find a specific teratogenic effects, stated as, "Findings from this dose-response meta-analysis indicate that maternal nitrate intake higher than ~3 mg/day is positively associated with NTDs [neural tube defects] risk".

<sup>v</sup> Per Herrera (2020), all results were < 0.09 mg/L. However, there is some uncertainty as to how the contract lab performed the SPLP, including some conjecture that they may have run serial SPLP runs. Reference 11-C allowance for up to 3x SPLP with serial transfer of solids from one to the next allows for that possibility. 0.10 mg/L is the lower end of Ecology's TAPE testing protocol 'typical' stormwater influent treatment range of 0.10 to 0.5 mg/L. Given that the treatment requirement is 50% total P removal, at the high end effluent discharging to a P-sensitive water body is allowed to be as high as 0.25 mg/L. However, inasmuch as we expect treatment itself not to contribute pollutants, 'untreated' lower end of range seems like a reasonable SPLP maximum. Herrera (2020) got a maximum of 0.09 mg/L from SPLP; although there is some uncertainty about how that was carried out, our allowance for sequential SPLP up the 3x should make finding media that meet this value feasible.

<sup>w</sup> 0.5 mg/L is the TAPE influent high end of 'typical' stormwater runoff. Sensitive lakes and phosphorus-sensitive freshwater waterbodies notwithstanding, considering nutrient loading to Puget Sound, treatment media should not discharge more P than typical runoff where treatment is otherwise not required.

<sup>x</sup> Orthophosphate (OP) is a subset of total phosphorus (TP). Seeking both values to inform us with regard to phosphorus loading to freshwater surface waterbodies and to Puget sound. The requirement to measure both might be cut back to requiring one or the other if a statistically robust ratio with low variability is found between the two species over time and with a sufficiently large sample size.

<sup>y</sup> This represents 30% removal from the TAPE influent lower range value of 5 µg/L. Media should not discharge at a concentration that's representative of a land use requiring enhanced basic (metals) treatment.

<sup>z</sup> Both geogenic and plant-based media can contain arsenic; geogenic inherently, and plant-based as a consequence of growth in arsenic-containing soils, (e.g., past use of lead arsenate in WA state apple orchards, soils previously covered by CCA-treated wood decking, adjacent to CCA-treated fence posts and wood fencing, etc.) or industrial contamination (e.g., soils in the Tacoma WA Asarco plume area), and/or irrigation with high-arsenic-bearing groundwater. At least some of the geographical areas documented as having high groundwater arsenic concentrations, e.g., Fendorf et al. (2010), are also coconut coir producing areas; whether that results in translocation of arsenic to coir is an open question. While compost is a limited-depth mulch layer as a component of HPBSM Type 3, that compost-based bioretention can be a net source of arsenic in leachate (Davis and McIntyre 2016; McIntyre et al. 2020; Taylor et al. 2018) is another indicator of need to be mindful that plant material can contain and leach arsenic. Depending on source, bioretention media can leach arsenic for prolonged periods at levels exceeding to greatly exceeding groundwater quality criteria and surface water criteria for human health (consumption). To whatever extent arsenic leachate from compost, coir, or aggregate is arsenate, arsenate chemistry is similar to phosphate. In theory then, the HPBSM polishing layer may sequester whatever leaches as arsenate. This is worth investigating further, as is the question of oxidation state speciation in immediate media leachate, and nature of oxidation state transformation during saturated periods if/when anaerobic; the point being that only arsenate may be sequestered similarly to phosphate. There is also the issue that eventually the polishing layer will become saturated by phosphorus and/or arsenic, and breakthrough will occur.

That arsenic mobilization from native or contaminated soils to groundwater can occur (Fakhreddine et al. 2015; Patterson 2020) is a whole other needed realm of investigation with regard criteria for placing infiltrative bioretention. Prudence dictates at least criteria and assessment of arsenic leachability from media to be used in bioretention, to be sure the installations will not themselves be net sources of arsenic, whether discharging to ground or surface water. Bioretention should explicitly be disallowed in areas where soils are contaminated with arsenic.

<sup>aa</sup> The WAC 173-200 state groundwater quality standards (GWQS) criterion for total arsenic is 0.05 µg/L. The surface water quality standards (SWQS) criteria with Clean Water Act (CWA) applicability for human health are inorganic arsenic 0.018 µg/L for consumption of water and organisms, and 0.14 µg/L for consumption of water only; based on the National Toxics Rule, as documented in EPA memos to Ecology (EPA 2016; US EPA 2019), in the Federal Register (US EPA 2020, 2022), and presently (November, 2024) in WA Ecology's proposed update of WAC 173-201A human health criteria. We are applying 0.10 to bioretention assuming intent is to infiltrate to ground as much as possible, hence to groundwater, although infiltration near or underdrainage to a surface waterbody can result in surface water discharge. and allowing for 2:1 dilution, although this is pure conjecture, and could be greater or less. Whether infiltrative soils provide any sequestration or barrier will vary from one extreme – clay, to the other extreme – gravel outwash, with variable outcomes between those. Surface water affords greater opportunity for flushing and dilution compared to groundwater which flows much more slowly; further, the SWQS is for inorganic arsenic only, not total. While a survey of current literature suggests general agreement that organic arsenic is less toxic than inorganic, opinions vary from little concern to need to take a closer look – especially depending on the organic moiety.

Except for a brief period in the last decade, and up to the time of this publication revision, WAC 173-201A human health criteria for arsenic were set at 10 µg/L; ostensibly from the federal SDWA ('safe' drinking water act) limit of 10 µg/L. The SWDA value however was established politically for what was considered to achievable treatment-wise at affordable cost at the time the value was set; but it is not maximally protective; it does not meet the <1/10<sup>6</sup> cancers per year criterion for most other substances. Also noting that while the SWDA MCL (maximum contaminant level) for arsenic is 10 µg/L, the MCLG (maximum contaminant level goal) is zero – a tacit

acknowledgement that no level is safe. It is an unfortunate consequence of the word Safe in the SWDA title that 10 µg/L is considered by many to be a safe level.

<sup>bb</sup> Information on the coconut coir used in experiments which is to date the basis for these specifications, is garnered from Hinman (2023) and the coir supplier. Conveying information from the source country provider, the coir is described by the U.S. vendor as being composted aerobically from 30 to 90 days to remove tannins, and may be aged for up to 120 days. A follow-up query to the vendor indicated that 'composted aerobically' means 'done out in the open', with piles managed to a degree to assist and accelerate the removal of the tannins, but no indication as to specifics regarding 'managed to a degree', and no indication of temperature management. As such there is no suggestion that the material would meet 173-350-220 WAC composting methodology, hence, questioning use of the term 'composted'; that by itself is not disqualifying, but it obscures exactly what's involved in material processing. Regarding need to mitigate leachable tannins, other than the supplier's indication of that as a concern, Svensson (2014) indicates, "Tannins and lignin . . . are considered a toxic group of compounds". That author mentions leachate phenol toxicity as well. These beg the question, 'toxic to what?' and at what concentrations. Sharma et al. (2021) note that tannins are present in a wide variety of foods, offering these numbers:

*"In India, the daily intake of tannin varies from 1500 – 2500 mg as per the diet analysis whereas in USA, it is 1 g per day (may vary from region to region). Much of the content of tannin in diet is contributed by spices. Daily intake of tannin below the range of 1.5 – 2.5 g is safe for consumption and do not cause any side effects but the consumption beyond this range is responsible for low absorption of iron from diet [citing] (Rao and Prabhavathi 1982)"*

Given no suggestion of associated toxicity at those levels suggests that a drinking water level in the range of ≤ 100 mg/L, even at the maximum poses low risk even at consumption of 10 L/day, with the caveat that that depends on concurrent tannin consumption from food. What about aquatic biota?

Coker (2008a) and (2008b) likewise indicates tannins and phenols as toxic, and are causal BOD agents; and according to Xie et al. (2022), "various types of tannins derived from different plants have different toxicities to fish". Coconut coir is a source of tannins, and tannin is noted as a polyphenolic compound (Sirisangsawang and Phetyim 2023).

Work is needed to establish a most-sensitive aquatic species protective concentration, and how to measure tannin, lignin, and phenol concentrations.

Literature research to date: Re: species sensitivity:

Libralato et al. (2011) report for marine alga *Phaeodactylum tricornutum* (Bohlin); " Lignin and tannin showed an E<sub>C50</sub> of 113.84 (100.90–128.45) mg/L and 26.04 (20.10–33.95) mg/L, respectively. NOEC and LOEC values were together <0.1 mg/L and 0.1 mg/L, in that order. Moreover, it was observed a morphological change of the algae fusiform shape occurring only at tannin concentrations ≥75 mg/L and <185 mg/L."

Alvarez et al. (2016) report "tannins diminish *D[aphnia]. menucoensis*'s survival, locomotion, and the capacity to respond to stimuli". At four tannin concentrations ranging from 0.5 to 7.5 mg/L, designated control, low, medium, and high concentrations, up to 8 days there appear to be no significant organism abundance differences between the tannin levels; at day 16 abundance at 5.0 and 7.5 mg/L is substantially lower than at 0.5 and 2.5 mg/L; at day 16 abundance at 2.5 mg/L is substantially lower than the 0.5 mg/L control, and abundance is yet further substantially lower at 5.0 and 7.5 mg/L. Calculated 48 hour LC50 was 36.4 mg/L, and 100% mortality occurred at 45 mg/L.

Per Amorim et al. (2008), "The tannins are classified, according to their biosynthetic origin, into two groups: the hydrolysable tannins, found in woody and herbaceous dicotyledons, which are characterized by an esterified glycosidic nucleus with gallic acids (gallotannins), and ellagic acids (ellagitannins), formed from the shikimate metabolic route and the condensed tannins or proanthocyanidins, that occur mostly in gymnosperms and angiosperms and are polymers of the flavan-3-ol and/or flavan-3,4-diol, derived from phenylpropanoid metabolism [citing] (Bruneton 1991; Santos and Mello 2004)." Per Mutinda et al. (2024), "Tannins are classified into four types: gallotannins, which contain galloyl units or derivatives bound to various polyol-, catechin-, or triterpenoid units;

ellagitannins, which contain at least two galloyl units C–C coupled to each other but do not contain a glycosidically linked catechin unit; complex tannins, which contain a catechin unit glycosidically bound to either a gallotannin or ellagitannin and condensed tannins, all of which are oligomeric and polymeric proanthocyanidins [citing] (Khanbabaee and Ree 2001)."

Whether these differences in tannin categorization result from 'lumping' vs 'splitting', or the biochemical characterization has improved over time is not being assessed here; the point is that it's clear that there's considerable variability within tannins, hence, it's possible that no single analytical method will be reliable for all plant matter. These factors and concerns bear further looking into, both as to coir constituent content, and whether the 'composting' as described decreases tannins, lignins, and/or phenols to acceptable content and leachate levels. Along the same lines, we will need to revisit test methods and endpoint criteria as more information is generated and maintained.

<sup>cc</sup> Time-limited search unearthed a single test that may be applicable to the matrix, i.e. Hach Method 8193. However, it's limited to a range of 1 to 9 mg/L. Either the Maximum Value criterion is higher than it should be, or a different test needs to be found that is capable of the Max Value.

<sup>dd</sup> Value pending further research. Very little tannin data found in a time-limited search, both with regard to toxicities which are reported in molarity, and limited reporting on molecular wt of tannins, albeit clearly with a substantial range. Nothing specific to coir tannin mol. wt. average or range, and no research done yet on lignins and phenols.

<sup>ee</sup> Verification of low salt content.

<sup>ff</sup> Basis for these concentrations is 95% UCL calculations from laboratory analytical results for three batch samples of Botanicare CocoGro. Lab reports obtained from Lewandowski (2024). For any given analyte, if all three results were non-detects, the limit maximum allowed here is the reporting limit for those analyses. In all detectable cases, the 95% UCL is higher than the maximum value.

<sup>gg</sup> Specific product identified by personal communication with the product manufacturer.

<sup>hh</sup> These specifications are derived from WA Ecology's HPBSM guidance (Howie and Lubliner 2021, 2024), communications with the supplier, and feedstock limitations that are common to green stormwater infrastructure media in order to prevent GSI media from itself being a source of contamination.

<sup>ii</sup> Parameter and value required by WA Ecology's HPBSM Guidance (Howie and Lubliner 2024).

<sup>jj</sup> Parameter and value required by WA Ecology's HPBSM Guidance (Howie and Lubliner 2024).

<sup>kk</sup> Per Howie and Lubliner (2024). However, personal communication with the HCWA producer for the media used in experiments suggests that product may have been produced from specific tree species, as yet unidentified. We do not know if the broad HCWA allowance from Ecology will result in the same performance.

<sup>ll</sup> Per Howie and Lubliner (2024). Same caveats as immediately prior endnote.

<sup>mm</sup> Per Howie and Lubliner (2024) Same caveats as immediately prior endnote – with the addition that we are restricting feedstock to woody material from trees.

<sup>nn</sup> Parameter and value required by WA Ecology's HPBSM Guidance (Howie and Lubliner 2024).

<sup>oo</sup> Herrera (2020) indicates the most successful media blend used volcanic sand, specifically, "All volcanic sand used was a Walrath 4120 product which was dredged from the Toutle and Cowlitz rivers after those channels were filled with sand from the Mt Saint Helens eruption"; report Table A-1, under Material Composition says, "Varies: olivine, pyroxene and magnetite. Usually Fe rich". This information is attributed by footnote to "Sand Atlas. <http://www.sandatlas.org>"; the citation does not represent empirical testing of the specific sand that was used in the experiments; the Atlas descriptors are attributed to "most volcanic sand deposits" globally, so we do not know the actual composition of the volcanic sand used in the experiments, hence the report's description is speculative.

The Atlas description of volcanic sand is generic, indicating potential olivine content, and that in turn leaves open the possibility of some asbestos content. The few web-found descriptors do not include asbestos in the definition of pure olivine; but numerous sources report asbestos in association with olivine deposits, as a consequence of mineral transformation from olivine (Berry et al. 2022; Hendrix et al. 2021; Malpas 1992; Marzini et al. 2024; NC DEQ DWM 2005; Solie and Athey 2015; US EPA 1974; Virta 2002 (?)).

Volcanic ejecta may contain other crystalline media which pose inhalation risk. E.g., Mt St Helens ash contains at least some cristobalite (Buist 1982), which if present in the sand presents silicosis risk and is a carcinogen (NJ Health 2002 (rev 2010)). So if present, that presents at least human health risk from material handling. Until such time as the specific sand has been tested for and found to not contain asbestos or any other hazardous crystalline mineral content, volcanic sand is not allowed.

<sup>pp</sup> Subject to change. This is verbatim from Ecology's guidance, which doesn't specify the exact sand that was used in bioretention experiments that yielded TAPE pollutant removal goals. Herrera noted one type of sand for the polishing layer, with an aggregate gradation that differed from that used in the polishing layer. Hence, separate aggregate sections Reference 11-C for these two – as placeholders, as both mirror the HPBSM single gradation table for the time being.

<sup>qq</sup> Subject to change. This is verbatim from Ecology's guidance, which doesn't specify the exact sand that was used in bioretention experiments that yielded TAPE pollutant removal goals. Herrera noted one type of sand for the polishing layer, with an aggregate gradation that differed from that used in the polishing layer. Hence, separate aggregate sections Reference 11-C for these two – as placeholders, as both mirror the HPBSM single gradation table for the time being.

<sup>rr</sup> Parameter and value required by WA Ecology's HPBSM Guidance (Howie and Lubliner 2024).

<sup>ss</sup> Parameter and value required by WA Ecology's HPBSM Guidance (Howie and Lubliner 2024).

<sup>tt</sup> Parameter and value required by WA Ecology's HPBSM Guidance (Howie and Lubliner 2024).

<sup>uu</sup> Per Herrera (2020)

<sup>vv</sup> Minimum 0.595 (0.6) mm. Maximum somewhere between 1.19 and 1.5 mm. There is some ambiguity regarding Taylor 14x28 mesh screening resultant particle size range. To be clear to start with, 14x28 mesh is inherently a Taylor listing because US Sieve Size does not include 28; Taylor does.

- Two corporate websites lists indicate 14x28 as passing 0.19 mm and not passing 0.0595 mm; i.e., a range of 0.6 to 1.2 mm with rounding
  - <https://www.azom.com/article.aspx?ArticleID=1417>
  - [https://www.agmcontainer.com/wp-content/uploads/2020/06/Mesh\\_Equivalents.pdf](https://www.agmcontainer.com/wp-content/uploads/2020/06/Mesh_Equivalents.pdf).
- Dissimilar to the sites above, [https://www.qclabequipment.com/sieve\\_conversion\\_chart.pdf](https://www.qclabequipment.com/sieve_conversion_chart.pdf) says that 14 Taylor is the same is US Sieve, and gives a value of 1.41 mm as the larger screen size.
- NSF/ANSI/CAN 61. says "0.5-1.5mm (14x28 mesh)"  
<https://info.nsf.org/Certified/PwsComponents/Listings.asp?StandardExt=PMA&MaterialType=>.
- The manufacturer's spec. sheet for the activated alumina used in HPBSM experiments (ActiGuard® F) says 14x28 mesh is "0.6-1.5 mm.

<sup>ww</sup> All required constituents and concentrations per WA Ecology's HPBSM Guidance (Howie and Lubliner 2024), with the exception of the maximum dissolved copper concentration per endnote **xx**.

<sup>xx</sup> This represents 30% removal from the TAPE influent lower range value of 5 µg/L. Media should not discharge at a concentration that's representative of a land use requiring enhanced basic (metals) treatment.

<sup>yy</sup> ECY modification of vendor's specification <https://connellygpm.com/wp-content/uploads/2022/04/Connelly-GPM-ZVI-Specifications.pdf>.