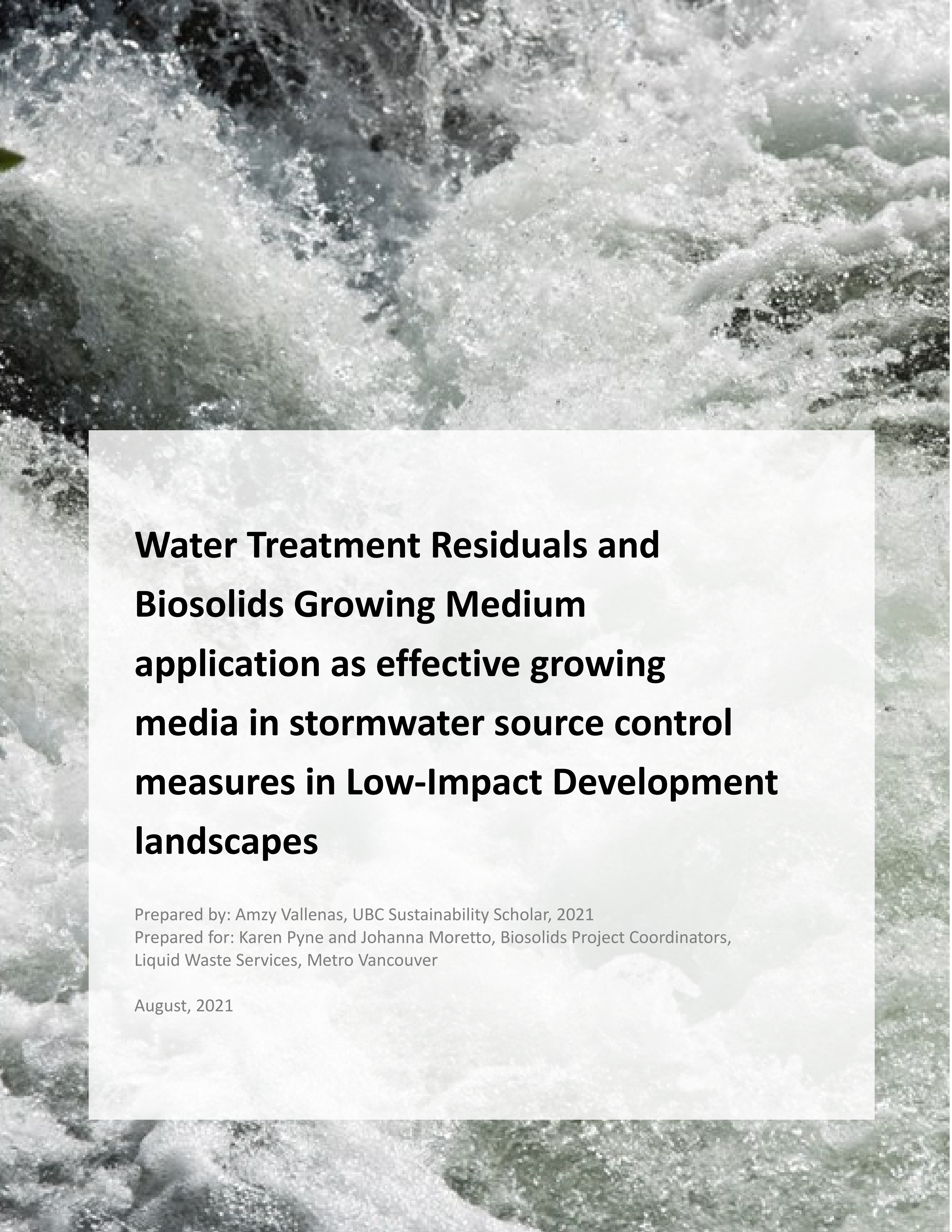

# Water Treatment Residuals and Biosolids Growing Medium application as effective growing media in stormwater source control measures in Low-Impact Development landscapes

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## Disclaimer

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This project was conducted under the mentorship of Metro Vancouver staff. The opinions and recommendations in this report and any errors are those of the author and do not necessarily reflect the views of Metro Vancouver or the University of British Columbia.


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*Cover photo provided by Metro Vancouver*

# Contents

## List of Tables



## List of Figures

# Executive Summary

This project examined whether biosolids (dewatered or composted), Drinking Water Treatment Residuals (DWTR), biochar (collectively called residuals) and Biosolids Growing Medium (BGM), can be used as a component in soil growing media to enhance and optimize the performance of Low Impact Development (LID) landscapes locally in a stormwater management context.

Stormwater refers to rainfall or snowmelt that is not absorbed by the ground, but rather flows off impervious surfaces. Stormwater may contain pollutants and may be a concern for aquatic life. Therefore, stormwater needs to be managed through drainage systems that protect natural watersheds.

Low Impact Development (LID) landscapes can achieve stormwater management goals by reducing the impact of rainwater runoff and protecting aquatic ecosystems. Their approach is based on mimicking the natural hydrologic regime offering an on-site solution for stormwater management.

Metro Vancouver provides policy guidance on stormwater source control design to member municipalities in order to achieve stormwater management baseline criteria. The criteria involve improving rainwater runoff quality through the use of best management practices and reducing the amount of rainwater runoff by limiting runoff volume to 40% of the 1 in 2-year storm of 24-hour duration. These goals are achieved by allowing rainwater to drain on permeable surfaces, collecting runoff, limiting impervious surface areas and having a minimum topsoil depth of 450 mm.

LID landscapes can also be designed to provide permeable surfaces for stormwater to soak through using an engineered soil as a filter medium that could contain components such as iron coated sand, activated carbon, biochar, and biosolids to add nutrients and remove specific pollutants. Some common LIDs landscapes in urban areas include absorbent landscapes, infiltration swales, rain gardens, pervious paving, infiltration trenches, tree wells, wetlands, planter boxes, detention ponds, and green roofs.

Landscaping soils used in these LID landscapes, known as bioretention soils, are generally a mixture of organic matter (often as compost), soil, and sand. However, specific ratios vary dramatically from project to project due to lack of scientific evidence of ideal ratios and they are usually assessed on their performance to prevent surface ponding over 48 hours, their capacity to control pollution and support plant growth (Ecological Landscape Alliance, 2021). In LID landscapes, growing medium can act as a filter to remove pollutants from runoff water. However, there are concerns about how applying biosolids to growing media could contribute to the presence of nutrients and pollutants in the runoff water, and the effects of these pollutants in the aquatic environment.

Bioretention soils are often considered to be good pollutant removal filters and research has shown their ability to remove metals and Polycyclic Aromatic Hydrocarbons (PAHs). It has been demonstrated that the addition of biosolids increases the release of nitrogen (N) and phosphorus (P) into the runoff water, potentially causing a risk of eutrophication. Researchers have shown that different compositions of biosolids-containing growing media influence the quality of runoff water. At this time, it is not possible to predict the quality of water based only on the composition of the soil mixture but researchers are developing some predictors for water pollution risks, specifically for nutrients like N and P (Chahal, Shi, & Flury, 2016; Jay, Brown, Kurtz, & Grothkopp, 2017; Jay, Tyler-Plog, Brown, & Grothkopp, 2019). In general, bioretention soils that use biosolids in its composition can be tailored to meet water quality needs and can be modified to limit the release of nutrients (Jay et al., 2019).

In order to use biosolids, BGM and DWTR, these residuals have to comply with the Organic Matter Recycling Regulation (OMRR) and the Code of Practice for Soil Amendments (CoPSA). When the residuals comply with OMRR and CoPSA, they can be further assessed for use in stormwater source control applications. Metro Vancouver's residuals and BGM comply with OMRR and CoPSA, and could potentially be an alternative to improve plant growth, reduce potential for erosion and increase infiltration rates.

There is a need for further investigation on the use of Metro Vancouver's residuals and BGM as soil retention media in order to assess the possibility of using these materials in stormwater management and to address concerns about the resulting stormwater quality. There is no reason to believe that using Metro Vancouver's residuals or BGM in stormwater source control systems could cause an increased risk over the use of other composted materials and it could potentially be an acceptable alternative for stormwater management systems.

# Background

Metro Vancouver's five wastewater treatment plants generate residuals including biosolids, grit, bar screenings, scum and sludge screenings, and the Seymour Capilano Filtration Plant generates Drinking Water Treatment Residuals (DWTR). A portion of these residuals (Class A biosolids) are used in the fabrication of a Biosolids Growing Medium (BGM), a topsoil containing biosolids, sand and a carbon source (either sawdust or aged bark).

This project examined whether biosolids (dewatered or composted), DWTR, biochar (collectively called residuals) and BGM, can be used as components in a soil growing medium to enhance and optimize the performance of Low Impact Development (LID) landscapes within the Metro Vancouver region. This project reviewed existing regulations, current practices, and scientific literature on the subject and identified opportunities for the use of residuals and BGM to address stormwater challenges in the region.

Objectives for the project were to:

- Identify the current regulations and bylaws on LID landscapes within Metro Vancouver.
- Identify main challenges and opportunities for using residuals and BGM in stormwater source control systems in Metro Vancouver.
- Identify current practices in LID landscapes being used in the region, or in places with similar climate to Metro Vancouver's.
- Conduct a literature review to identify LID landscapes that use residuals or BGM to address stormwater quality and quantity challenges.

# Definitions

### Biosolids

Biosolids are stabilized municipal solids from wastewater treatment plants that has been sufficiently treated to reduce pathogen densities and vector attraction to allow the solids to be beneficially recycled in accordance with the requirements of the Organic Matter Recycling Regulation (OMRR) (Queen's Printer, n.d.-a). Nutrifor™ is the trademark name for biosolids produced by Metro Vancouver.

## Biosolids Growing Medium (BGM)

Biosolids Growing Medium (BGM) is a fabricated soil containing biosolids and feedstocks like wood fibre and sand that meet the requirements for biosolids growing medium under the Organic Matter Recycling Regulation (OMRR) (Queen's Printer, n.d.-a). Metro Vancouver markets its BGM product to municipalities as Nutrifor Landscaping Soil.

## Drinking Water Treatment Residuals (DWTR)

Drinking Water Treatment Residuals (DWTR) are the residues from the treatment of water for domestic use or industrial use. This material complies with the definition and quality criteria established in the Code of Practice for Soil Amendments (CoPSA) (Queen's Printer, n.d.-b).

## Integrated Stormwater Management Plans (ISMPs)

Integrated Stormwater Management Plans (ISMPs) are comprehensive studies about drainage services, land use and environmental protection in a specific area. ISMPs are a planning tool that support the growth of a community while protecting watersheds. Under Metro Vancouver's Integrated Liquid Waste and Management Plan (ILWRMP), municipalities are encouraged to develop ISMPs to protect watersheds and plan urban development in their territories (Metro Vancouver, 2012a).

## Low Impact Developments (LID)

Low impact developments (LIDs) have been significantly successful in reducing impacts and protecting aquatic ecosystems with added benefits of cost effectiveness. LIDs help maintain pre-development hydrological regimes and protect ecological integrity within a watershed. LIDs can achieve stormwater's protection goals through the creation of a hydrologically functional landscape that mimics the natural hydrologic regime (Hinman, 2005). LIDs have been identified as sustainable stormwater management solutions for use in the Pacific Northwest region due to their service of better on-site runoff and pollutant reduction (Department of Environmental Resources, 1999).

## Stormwater

The term "urban stormwater" refers to rainfall or snowmelt that is not absorbed by the ground, but rather flows off impervious surfaces such as road, roofs, and parking lots. Urban stormwater flows into storm drains that are typically routed directly to receiving water bodies (EPA, 2020; USGS, 2020). Stormwater may contain pollutants including toxic metals, organics, nutrients and Compounds of Emerging Concern (CECs) (Erickson et al., 2007). Stormwater is a constant concern for toxicity to aquatic life and bioaccumulation of pollutants and because of this, stormwater source control systems are necessary to protect the environment (ILWRMP, 2010).

### Stormwater Management

Stormwater management refers to activities involving the connection of urban and rural drainage systems to streams. The vast majority of stormwater outfalls are directly linked to waterbodies and therefore can have significant impacts on aquatic life through the modification of water quantity and quality. In Metro Vancouver, only the oldest parts of the region convey stormwater directly to WWTPs (Moretto, J, personal communication). Discharges from new multi-lot residential subdivisions, multi-family residential developments and commercial, institutional, or industrial sites are considered stormwater system connections and require notifications that regulate their storm sewer outfall. (Ministry of Environment, 2005)

## Research Approach

The project was divided into three phases. For all phases, information was gathered from interviews of key stakeholders, available information on the internet, and literature review to fill information gaps.

1. Regulatory Review
    - Interview key players to analyze current stormwater regulations in Metro Vancouver.
    - Determine how stormwater management is regulated in Metro Vancouver.
    - Determine if there are any quantity or quality guidelines for runoff water.
    - Identify any design criteria for stormwater management source control systems.
    - Identify any quantity or quality standards for growing media used in Low Impact Development (LID).
    - Summarize local regulations for stormwater management and the applications of biosolids, Biosolids Growing Medium (BGM) and Drinking Water Treatment Residuals (DWTR) in these systems.
2. Current Practices Review
    - Identify types of LID used for stormwater source control systems.
    - Identify current practices and challenges in LID landscapes in Metro Vancouver.

- Identify currently used guidelines or standards for growing media used in LID landscapes.
- Analyze the current concerns about runoff water quality focusing on contaminant or nutrient uptake and release.
- Identify current practices that use biosolids, BGM or DWTR to address stormwater challenges.

3. Literature Review
    - Review scientific literature to assess the potential of biosolids, residuals, and BGM use in LID landscapes.
    - Identify successful methodologies, types of LID and growing media used, and residual types used and their findings and recommendations.
    - Identify common composition of tested growing media and their effectiveness in pollutant removal and water retention, and pollutant and nutrient release.
    - Identify past experiences regarding environmental effects of using residuals or BGM in the growing media in LID.

The project was developed through interviews with key stakeholders selected by chain-referral sampling. Table 1 summarizes participants in the conducted interviews and their organizations. Interviewees gave key insights about regulations, current practices, concerns, and future perspectives in LIDs for stormwater management source control and the use of biosolids and other organic residuals in these systems.

Table 1. Interviewees during the development of this project

| Name | Organization |
|---|---|
| Carrie Hightower | Liquid Waste Services, Metro Vancouver |
| Sally Brown | University of Washington |
| Dave Matsubara | City of North Vancouver |
| Joanna Ashworth / Chloe Hartley | North Shore Rain Garden Project |
| Rob Lukkes / Sylvie Spraakman | City of Vancouver |
| Wayne Change | City of Surrey / SWM Planning |
| Sheena Fisher | City of Surrey / Parks and Landscape |

Afterwards, a thorough search was conducted to gather documents including websites, guidelines, instructions, and other resources about stormwater management source control systems, their design, guidelines, objectives, and growing medium materials used. This was done with the objective to map the current practices in stormwater management source control systems using LID landscapes and identify current challenges and opportunities.

A literature review was also conducted to fill the gaps of information, and to identify experiences in the use of biosolids, growing medium containing biosolids and DWTRs as effective growing media for stormwater source control systems.

The literature review was conducted using data bases such as Google Scholar, Science Direct, and Web of Science using key words including “stormwater”, “biosolids”, “biosolids growing medium”, “low impact development landscapes”, “rain garden”, among others. The most relevant papers found included key information on the objectives of the project, presented quantitative data on biosolids quality needed for stormwater management and successful experiences of reuse of water treatment residuals in stormwater source control systems. Their principal findings were systematized in the chart included in Appendix A of this report.

# Findings

Due to rapid urbanization growth, impervious surface areas in cities are growing at an increasing rate. Increasing levels of imperviousness result in disrupted hydrological cycles and an increased amount of polluted runoff entering surface water bodies. Therefore, imperviousness becomes an indicator of ecological health, vulnerability to climate impacts and human health and well-being (City of Vancouver, 2019b; Minnesota Pollution Control Agency, 2020).

The Metro Vancouver region has 58,000 ha of impervious surface which corresponds to 20% of the Metro Vancouver area. This percentage corresponds to 50% of the Urban Containment Boundary (UCB). Figure 1 shows the percentage of impervious surface within the UCB for each member jurisdiction in 2014. Overall, urbanization growth is typically associated with increasing imperviousness and impacts to the health of watersheds (Metro Vancouver, 2019).

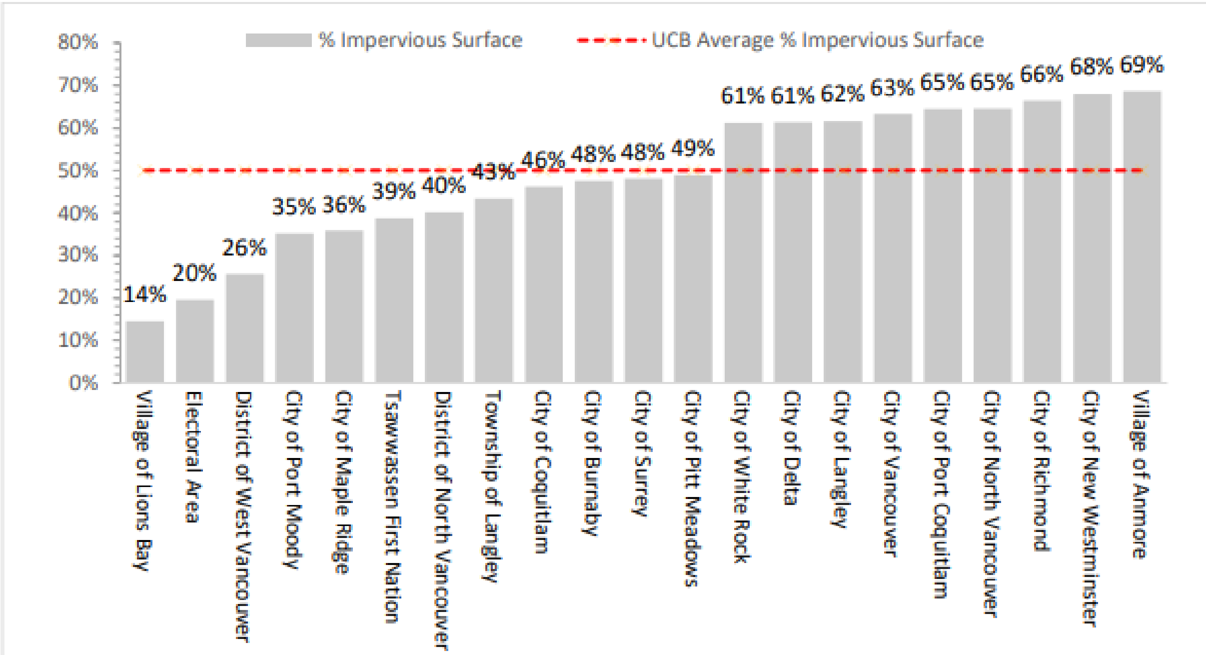



**Figure 1. % of Impervious surface within the Urban Containment Boundary by member jurisdiction (2014).** (Metro Vancouver, 2019).

Furthermore, 42% of impervious surfaces are associated with residential areas and 25% with road right of ways, being areas designated for parking are one of the main reasons for impervious surfaces (Metro Vancouver, 2019). This creates the need to give attention to the possible effects and mitigation actions of increasing impervious surfaces.

One of the main consequences of increasing impervious surfaces is the increased stormwater runoff volumes and peak flows (Barbosa et al 2012). Sustainable and integrated stormwater management considers water quality, quantity, erosion, and flood control to give a long-term solution to stormwater flows in urban landscapes. Therefore, decision-making in management practices for stormwater is a complex process that considers geophysical, social, technical, and financial factors. Moreover, engineering stormwater solutions are dependent on legislation and municipalities are increasingly seeing stormwater legislation as a “need-to-have” instead of a “want-to-have” in order to protect watersheds in their jurisdiction (Sustainable Prosperity, 2016).

## 1. Regulatory review of stormwater management in Metro Vancouver

The following regulatory review collected current regulations in Metro Vancouver and its member municipalities for planning, design, and construction of Low Impact Development (LID) landscapes as source control systems for stormwater management.

LID landscapes like soil cells, green roofs, rain gardens, etc. are encouraged, gaining wide acceptance across Canada and the US as a way to supplement existing stormwater management infrastructure (CVC, 2013). Within the province of British Columbia, Canada, Integrated Stormwater Management (ISWM) plans are adopted for rainwater management for a range of rainfall events in order to protect watersheds in each jurisdiction. The responsibility of stormwater management lies on the municipalities who can design specific bylaws for their territories (Government of British Columbia, 2002).

In Metro Vancouver, stormwater source control systems are necessary to protect the environment (ILWRMP, 2010). ISWM within the development process of the built environment is important and should not be treated only as a mitigation process, but rather using rainwater as a resource (City of Vancouver, 2019b).

Likewise, under Metro Vancouver's Integrated Liquid Waste and Resource Management Plan (ILWRMP), liquid waste management is based on three main goals including:

i) protecting public health and environment,
ii) using liquid waste as a resource, and
iii) ensuring effective, affordable and collaborative management (Metro Vancouver, 2010).

Under the plan, there are different roles and responsibilities in the management of liquid waste and stormwater. The key roles and responsibilities are outlined in Table 2.

**Table 2. Roles and responsibilities in liquid waste and stormwater management**

| Stakeholder | Responsibilities |
|---|---|
| **Federal government** | Environment Canada: regulates pollutants and protects species at risk.<br>Fisheries and Oceans Canada: protects fish populations and habitat in receiving waters and urban streams.<br>Infrastructure Canada: provides and administers infrastructure co-funding for local government projects. |

| Stakeholder | Responsibilities |
|---|---|
| Provincial Government | Ministry of Environment: regulates liquid waste and approves Liquid Waste Management Plans.<br>Ministry of Community and Rural Development: enables infrastructure financing and provides co- funding to local governments for civic projects.<br>Ministry of Health: regulates on-site wastewater treatment systems (such as septic tanks).<br>Ministry of Agriculture and Lands: encourages responsible agricultural land management. |
| Local Government | Metro Vancouver and the Greater Vancouver Sewerage and Drainage District (GVS&DD): own, maintain and operate regional trunk sewers and major wastewater treatment plants, regulate industrial waste discharges, implement required regional actions in its plans, report on plan progress, and collaborate with others as appropriate.<br>Municipal members of the GVS&DD: own and maintain collector sewers, implement municipal actions set out in the regional liquid waste management plan, manage stormwater systems, report on their progress on actions required in the plan, set local land use plans and community development. |
| First Nations | They have constitutional rights which must be taken into account in the planning process. |
| Homeowners, businesses, institutions, and crown corporations: | They own and maintain private property sewer connections and private stormwater management systems. |

Source: (Metro Vancouver, 2010)

Metro Vancouver and most member municipalities have stormwater management plans or guidelines for stormwater management systems. Metro Vancouver provides policy guidance on stormwater source control design guidelines through forums like the Stormwater Interagency Liaison Group (SILG), allowing municipalities to share knowledge and expertise in sustainable stormwater management (Metro Vancouver, 2017). In 2002, a study commissioned by Metro Vancouver reported that the wide-spread introduction of stormwater source controls could have positive long-term benefits for a watershed's health, with the potential of mitigating much of the hydrologic impacts associated with increasing watershed imperviousness (CH2M Hill, 2002). Since then, there has been continued commitment from municipalities and Metro Vancouver to design and improve guidelines for stormwater source control systems in the region. Later, in 2009, municipalities agreed to commit to updating their bylaws to require on-site stormwater source controls, either to meet their Integrated Stormwater Management Plan (ISMP) criteria or a region-wide baseline (Metro Vancouver, 2017).

Through discussions amongst SILG and their consultant (Kerr Wood Leidal), a minimum performance threshold was determined by using hydrologic models. The baseline criteria agreed on two important aspects (Metro Vancouver, 2017):

- Criterion 1: Improve rainwater runoff quality through the use of best management practices and,
- Criterion 2: Reduce the amount of rainwater runoff by limiting runoff volume to 40% of the 1 in 2-year storm of 24-hour duration.

Furthermore, there were practices established to achieve baseline criteria including:

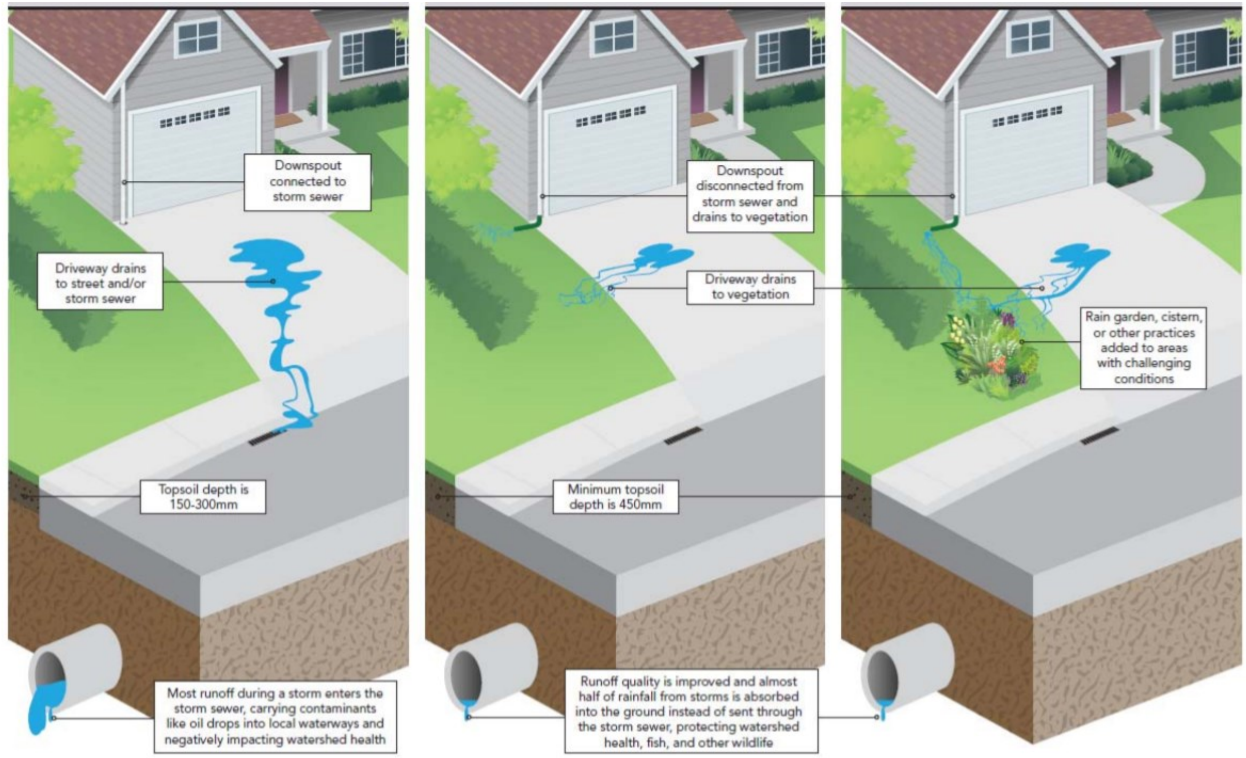
i) drain to a permeable surface, such as soil, vegetation, or gravel, or
ii) use pervious paving, or
iii) collect and drain runoff through a sump prior to discharging to storm sewer to achieve criterion 1.

To achieve criterion 2 and reduce runoff quantity the suggested practices included:

i) Have a maximum 70% total impervious area and,
ii) have a minimum topsoil depth of 450 mm and disconnect downspouts.

However, when practices to achieve criterion 2 and reduce runoff quantity are not possible, the municipality can determine what additional measures need to be considered (Metro Vancouver, 2017).

| Stormwater management practices before the establishment of baseline criteria. | Currently suggested stormwater management practices on single lots | Additional stormwater management practices recommended when challenging conditions exist[1] |
|---|---|---|




Source: (Metro Vancouver, 2017)

Figure 2. Comparison of stormwater management practices before and after baseline criteria implementation

The implementation of these criteria in each municipalities' bylaws is still an ongoing process. Metro Vancouver continuously works with municipalities to develop stormwater management actions of the ILWRMP, including the support in the implementation and improvement of stormwater bylaws and stormwater best management practices (Metro Vancouver, 2017). To date, only the City of Vancouver, City of Surrey, City of Burnaby, and Corporation of Delta, have specific stormwater management bylaws or policies, while other municipalities regulate stormwater within other bylaws (Metro Vancouver, 2021).

[1] Design guidelines for stormwater Best Management Practices (BMPs), adapt successful stormwater controls from regions with similar climates and soil conditions. However, a site-specific assessment could determine that a certain area has more challenging conditions like higher precipitation rate, lower infiltration rates in native soils, and other watershed and geological conditions.

### a. Stormwater management quality guidelines

Regulatory guidelines for stormwater quality in BC include the Fisheries Act, the BC Hazardous Waste Regulation, Schedule 1.2 – "Standard for discharges to the Environment" or to Storm Sewers, the BC Contaminated Sites Regulations, Schedule 6 – "Generic Numerical Water Standards", CCME Water Quality Guidelines for the Protection of Aquatic Life, BC Approved Water Quality Guidelines, and Metro Vancouver's Municipal Water Use Guidelines.

Table 3 provides a summary of the regulations and guidelines relevant to discharges to the storm sewer system.

Table 3. Regulatory guidelines for stormwater management and quality in BC.

| Regulation | Description |
|---|---|
| Fisheries Act | Provides protection of fish and fish habitat, including waters that contain or may contain fish in the future. Establishes that water for aquatic environments containing or that may contain fishes should not contain deleterious substances. |
| BC Hazardous Waste Regulation | Schedule 1.2 – "Standard for discharges to the Environment or to Storm Sewers" establishes the water quality standard for stormwater discharges from Hazardous Waste Facilities. |
| BC Contaminated Sites Regulations | Schedule 6 – "Generic Numerical Water Standards" establishes the Generic Numeral Water Standards for Aquatic Life which applies to protect freshwater and marine life. |
| CCME Canadian Water Quality Guidelines for the Protection of Aquatic Life | Intended to protect all forms of aquatic life and all aspects of aquatic life cycles, including the most sensitive life stage of the most sensitive species over the long term from anthropogenic stressors such as chemical inputs or changes to physical components. |
| BC Approved Water Quality Guidelines | Policy statement applied province wide to protect water quality and inform water management decisions in BC. |
| Metro Vancouver's Municipal Water Use Guidelines | States that it needs to be assumed that all water in the greater Vancouver region have fish present unless confirmed otherwise. Therefore, runoff water needs special attention because of the risk it represents for aquatic environments. |
| Integrated stormwater management plans (ISMPs) | Although ISMPs are not regulations or enforceable by law, developers in each jurisdiction are to comply with the requirements established in the watershed location. |

Source: Compilation based on the legislation above mentioned

### b. Materials used in LID landscapes for stormwater control

Stormwater bylaws and guidelines are based on the hydrologic cycle and mostly based on urban drainage and stormwater collection and release. Little to nothing is mentioned about materials that can be used as a growing medium for stormwater management source control or if there exists any prohibition in regards of which materials could be used for this purpose. It is in that context that Metro Vancouver wishes to assess the possibility of using residuals and Biosoldis Growing Medium (BGM) in LID landscapes as stormwater source control systems.

Stormwater management guidelines mention that for the purposes of the conducted research while establishing baseline criteria, that the definition of topsoil is a “growing medium” defined according to the Canadian Landscape Standard. There are currently no prohibitions on the use of biosolids or residuals in the growing medium. In general, guidelines recommend a performance-based evaluation, which commonly means assessing each growing medium visually to evaluate if it is in compliance with its utility of stormwater infiltration.

## 2. Current practices for LID landscapes for stormwater control in Metro Vancouver

### a. Commonly used systems for stormwater management at the source

Low Impact Development (LID) landscapes are designed as an underground recharge device and provide a permeable surface for the stormwater to soak through, mimicking the natural infiltration and percolation effects of soil (Metro Vancouver, 2012b). LID landscapes usually use soil as the filter medium, although a blended growing medium containing a mix of different materials could also be used. These engineered soils could include components such as iron coated sand, activated carbon or biochar to remove specific pollutants (Bora, 2020). Plants can also be incorporated into the systems to improve infiltration qualities, pollutant removal and for aesthetic purposes (City of Vancouver, 2016; EPA, 2016). However, there are still some challenges that need to be addressed when using this kind of source control system, as the surrounding area’s slope and soil properties need to be known and be site-specific according to the system’s needs. Plus, the risk of clogging and contamination by pollutant release should also be evaluated.

Table 4 summarizes the most common LID Systems in urban areas that use soil as a retention growing medium.

Table 4. Most common LID systems in urban areas

| System | Description | Image |
|---|---|---|
| Absorbent Landscapes | A structure that aims to reduce runoff from impermeable surfaces by creating more absorbent landscapes that intercept and retain rainwater. The objective is to maximize the area of absorbent landscape, while conserving as much vegetation and undisturbed soil as possible. |  |
| Infiltration Swales | A shallow grassed or vegetated channel designed to capture, detain, and treat stormwater and convey larger flows. Infiltration swales take surface flows from adjacent paved surfaces, hold water behind weirs, and allow water to infiltrate through a soil bed into underlying soils. Variations of swales may include an underlying drain rock reservoir. |  |
| Rain Gardens and Infiltration Bulges | Commonly a concave landscaped area where runoff from roofs or paving infiltrates into deep constructed soils and subsoils below. On subsoils with low infiltration rates, rain gardens often have a drain rock reservoir and perforated drain system to convey away excess water. |  |

Photo courtesy of Rain Dog Designs, Gig Harbor, WA.

| System | Description | Image |
|---|---|---|
| Pervious Paving | A surface layer that allows rainfall to percolate into an underlying reservoir base where rainfall is either infiltrated to underlying soils or removed by a subsurface drain. The top surface material could be porous asphalt or concrete or a plastic grid structure. The main objective is to provide a hard surface while still treating stormwater. |  |
| Green Roof | A roof with a veneer of drainage and growing media that supports living vegetation. Growing medium used in these landscapes could have different properties for water retention and pollutant removal. Green roofs should also have collection systems for drainage underneath so water can be collected. |  |
| Tree Well Structures | A well containing a large volume of soil which retains excess stormwater and helps remove pollutants from stormwater runoff. Trees within tree wells are generally healthier and reach mature height faster, which leads to more water being intercepted by the tree canopy. |  |

| System | Description | Image |
|---|---|---|
| Infiltration Trench | A sub-surface infiltration facility commonly made from rock retention trenches or crate-type facilities that hold and infiltrate water into the subsurface soils. The trench is encapsulated in filter fabric to prevent mass movement. No runoff that may contain pollutants is allowed to flow into the trench. An infiltration trench can also be installed on roofs. |  |
| Constructed Wetlands | A series of shallow ponds connected by a marsh system designed to treat contaminated stormwater through the biological processes associated with emergent aquatic plants, microbial activity, and via sedimentation. Properly constructed wetland systems provide a high level of contaminant removal through sedimentation and biological uptake. |  |
| Planter Boxes | Boxes that mimic rain gardens but are enclosed by vertical walls and perform the function of collecting and filtering stormwater runoff. They can also substantially reduce the volume of runoff entering storm sewers and can improve quality of water by filtration through soil. |  |

| System | Description | Image |
|---|---|---|
| Wet Detention Ponds | Permanent wet ponds that remove pollutants through sedimentation, filtration, absorption and adsorption through microbial and plant degradation. |  |

Source: (Bora, 2020; City of Vancouver, 2016)

It is important to mention that other types of source control systems can be used to manage stormwater (Bora, 2020; City of Vancouver, 2016). When space or maintenance cost are limiting, hard-engineering systems can be used, including:

- **Detention tanks** that reduce flooding and in-stream erosion by collecting and storing stormwater runoff during a storm event and releasing it at controlled rates to the downstream drainage system.
- **Water Quality structures** such as an oil-water separators are specifically designed to capture petroleum hydrocarbons, coarse grit, and coarse sediment. These structures may have some water quality benefits, like separating oil and grease from water but are not suitable for soluble nutrients and pollutants. These systems are also required to be cleaned out periodically in order to maintain system efficiency and effectiveness.

Detention tanks and water quality structure systems do not require the use of soil, they are designed to retain stormwater and release it at lower rates for flow control.

### b. LID construction practices – Growing medium requirements

Currently, construction guidelines for LID are designed in terms of performance. Available construction guidelines (City of Vancouver, 2019a) and standards for stormwater management systems (Salmon Safe, 2018) or any of the municipality's ISMPs, require specifications in terms of performance, based on the baseline criteria established.

None of the construction guidelines specify the materials that can or cannot be used in the fabrication of a growing medium as a native soil alternative. However, there are some common recommendations for preparing growing media for LID landscapes. In general, the recommendation is to use soil that is suitable for landscaping and gardening. Authors (GVRD, 2006; Salmon Safe, 2018) recommend using landscaping soil with a high infiltration rate. They also recommend the addition of composted materials to add organic matter to the soil. They also discourage the use of non-composted materials such as untreated cow manure because of potential impacts to the stability of the soil and microbes. The addition of foreign soil with highly concentrated organic amendments could interfere in the development and performance of the system because it requires some time to stabilize (GVRD, 2006). The addition of any material to the soil would require being previously stabilized so nutrients are slowly released into the soil and the water (Brown, S. personal communication).

According to the BC Land Development Guidelines, biofilters are vegetated filter strips, swales and rain gardens that remove deleterious substances including particulate contaminants through a combination of biotic and abiotic removal processes. During LID construction, the guidelines recommend that disturbances to the surrounding native soil should be limited. Also, measures must be taken to prevent the release of silt, sediment, sediment-laden water, raw concrete leachate, or any other deleterious substance into any water course, stream or storm water sewer system (Department of Fisheries and Oceans Canada, 2009).

According to the Canadian Landscape Standards (CLS), growing medium shall be from a source approved by the authority[2] and should satisfy the requirements for texture and organic matter given in tables T-6.3.5.2 T-6.3.5.3 and T-6.3.5.4 (See Appendix B) of the standard. Furthermore, CLS states that growing media should be virtually free from subsoil, wood including woody plant parts, invasive and noxious plants and their reproductive parts, plant pathogenic organisms, organic or inorganic materials, toxins, stones over 30mm, and debris and foreign objects (CSLA & CNLA, 2016).

A common practice among municipalities is to use a vendor for the supply of landscaping soil. Some municipalities state they have used Nutrifor Landscaping Soil (Metro Vancouver markets its BGM product to municipalities as Nutrifor Landscaping Soil) for park area landscaping. To Metro Vancouver’s knowledge, Nutrifor Landscaping Soil has not yet been used in stormwater source control systems, and member municipalities use other landscaping soils.

While there isn’t a specific standard or guideline for growing medium in stormwater source control systems, some member municipalities have their own common practices that are detailed in the following table.

[2] The Canadian Landscape Standard defines authority as the owner who uses the standard. The authority having jurisdiction is any governmental body having regulatory powers with regard to such work and its locations (CSLA & CNLA, 2016).

Table 5. Common practices in LID landscapes growing media of member municipalities.

| Municipality | Common Practices for growing media in stormwater management systems |
| --- | --- |
| City of North Vancouver (CNV), interview with D. Matsubara | • Construction of rain gardens is common if there is a lot of space available and low rain intensity, although the biggest opportunity is in street trees.<br>• Soils are inspected visually as the materials are unloaded. Turf soil purchased from vendors is normally used which complies with the Canadian Landscape standards for landscaping soil.<br>• CNV has used Nutrifor Landscaping soil (Metro Vancouver's BGM) previously in parks projects but has not used it in rain gardens or other LID landscapes. |
| City of Vancouver, interview with Sylvie Spraakman | • City of Vancouver is developing Supplementary Specifications for bioretention soil to add to their construction specifications (Currently under revision).<br>• These guidelines include directions on size, location, building foundations, requirements for design, materials that can be used, and standards for soil media.<br>• City of Vancouver uses a standard for Turf Soil described in their construction specifications (City of Vancouver, 2019a). Standards are based on what has been done previously and are currently being updated.<br>• Landscaping soil is normally bought from their supplier, Veratec Group. Other acceptable suppliers are Harvest Power Canada Ltd and Eco-Soil Recycling.<br>• Vancouver Board of Parks and Recreation Parks Development Standards Growing Medium Specifications allow for the use of Biosolids Growing Medium and soil containing biosolids as a growing medium in stormwater management (City of Vancouver, 2015). |

| | |
|---|---|
| City of Surrey, interview with Sheena Fisher | • City of Surrey has general soil specifications including % of organic matter, E.C., pH, particle size and fertility for parks application. Currently, Stormwater management systems use these same specifications for soil.<br>• City of Surrey periodically tests the soil to determine any variations from city specifications and the soil laboratory provides direction to City staff on how to correct soil quality – i.e. apply lime, rinse thoroughly, add fertilizer etc. Once the quality is corrected, these soils are then used. |

### c. Post construction monitoring practices

Post construction activities include the monitoring of the system to ensure performance. Usually, adaptive management tools are used to reduce costs[3]. Common activities during field monitoring include conducting a visual inspection on infiltration rates in order to ensure the goals of the development are being reached. These activities also determine if stormwater capture is met and provide real data of performance and effectiveness to municipalities, practitioners, and developers for decision making (Metro Vancouver, 2012b).

According to the Metro Vancouver Stormwater Source Control Design Guidelines (Metro Vancouver, 2012b), post-construction monitoring consists of checking rainfall and groundwater levels, as well as flow downstream of the constructed source control system. These activities can be conducted directly by developers or by a third party. Extra requirements by voluntary certifications, such as the Salmon Safe Certification, also include monitoring of irrigation or water use, water quality and habitat monitoring, especially if the risk of overfertilization (high nitrogen release) is occurring in fertilized areas (Salmon Safe, 2018).

Monitoring is often a costly activity and requires significant effort from municipalities. Member municipalities that participated in the interviews for this project stated that most monitoring in stormwater source control systems is done visually to analyse infiltration rates and ensure that baseline criteria is being met (CNV, interview with Dave Matsubara). Some municipalities, like the

[3] Adaptive management refers to the process of continuously improving management policies by learning from the outcomes of operational programs (Province of British Columbia, n.d.). In the context of stormwater management, adaptive management responds to watershed health (for example, water quality sampling results) and actions can include engineered infrastructure and non-structural measures like enhancement of riparian areas, retention of tree cover, reducing impervious surfaces, education and outreach, identification of sources and source controls, etc. (Metro Vancouver, 2014).

City of Surrey, do soil testing in parks in order to ensure the quality of the soil meets their specific criteria. This allows them to make corrections to the soil if needed (City of Surrey, interview with Sheena Fisher). However, when landscaping soil comes from a known supplier, most municipalities do not perform soil testing (North Shore Rain Garden Project, interview with Chloe Hartley; City of Vancouver, interview with Sylvie Spraakman).

Water quality monitoring of runoff, city outfalls and creeks is conducted before discharging into the natural watershed. However, this practice is difficult for identifying pollution hotspots or non-functioning systems because sampling points are typically too far downstream of individual systems to identify the source (City of Vancouver, interview with Sylvie Spraakman). Therefore, some initial monitoring activities should be performed at the outlet of each system until the performance of the system is stabilized and its performance is ensured.

## 3. Challenges and opportunities of using LID landscapes for stormwater management

In an ever-growing urban environment, stormwater management represents important challenges and opportunities. In this context, the materials that are used in source control systems also present different concerns and opportunities.

Some of the main challenges are around water quality and how quality may be impacted by the growing medium used in source control systems. Acting as a filter or as a sponge, growing media can remove or release pollutants into the runoff water (Metro Vancouver, 2012b). If using a native soil, there is little concern on how the soil could affect water quality or affect the natural balance of compounds in water sources. However, considering that runoff water may come into contact with road pollutants before being discharged to receiving waters, and fabricated or foreign growing media can chemically interact with water affecting its quality, there are common concerns with stormwater source control systems.

First, Compounds of Emerging Concern (CECs) in rainwater runoff have been a constant concern in the last few years. The presence of xenobiotic organic compounds in water and their relationship with the carbon cycle, aerosols and human health risk is still partially known (Fairbairn et al., 2018; Polyakova, Artaev, & Lebedev, 2018). Additionally, there may be concerns with using biosolids that come from domestic wastewater treatment and potentially contain antibiotic and other medicine metabolites from households (Canadian Municiapal Water Consortium & Ryerson University, 2015). In that sense, there is a concern among researchers and practitioners that stormwater source control systems could turn into a source of contamination for underground water or soil adding CECs to the environment. However, researchers from the University of Washington have proved that the level of risk to people from the exposure to biosolids compost is minimal. For instance, compared to a one therapeutic dose or a 1 day home exposure, the exposure to pharmaceuticals and personal care products from the use of biosolids on agricultural soils and urban areas, is significantly lower (Brown, Kennedy, Cullington, Mihle, & Lono-Batura, 2019). This means that if biosolids compost is stabilized and the concentration of CECs are kept below the detection limit, the risk of using biosolids compost amendments in urban soils is very low.

Another concern from municipalities is the public's perception and potential concerns of using residuals and growing media containing biosolids (Whitehouse, 2018). Adding biosolids and other residuals to growing media can create odours and have a negative public response. Public perception and experience are especially important when developing source control systems in public spaces like parks or near shopping malls. The public has to be taken into account when considering biosolids or any other residue as a soil amendment or as part of the growing media in source control systems.

Bioretention soils are often considered to be good pollutant removal filters, especially for some hydrocarbon and toxic metals contaminants (Jay et al., 2019). However, the are some concerns about the adsorption capacity of bioretention soils. The quantity of pollutants that can be adsorbed into the soil mix is an important parameter to keep in mind in order to be sure that LID landscapes will not turn into contaminated sites in the future (The North Shore Rain Garden Project, interview with Chloe Hartley).

Water interaction with the growing medium could also result in the release of nutrients like nitrogen (N) and phosphorus (P) to the runoff water, resulting in the degradation of receiving water quality. Increasing amounts of compost in growing medium can increase the release of N and P (Jay et al., 2019) but the effect of these could change according to the composition of the feedstock used in the prepared compost, as well as the composition of the growing medium. However, results could be enhanced by adding aluminum/iron-rich Drinking Water Treatment Residuals (DWTR) or other sorbent materials to the mix that would reduce N and P leaching (Ordonez, Valencia, Elhakiem, Chang, & Wanielista, 2020; Yue, Li, & Johnston, 2018).

There is a concern that the organic fraction of growing medium could be a facilitator in the mobility of toxic metals to plants or water. However, it has been shown that even if increasing mobility, especially with metals like copper, organic-copper complexes are less toxic than free copper ions and therefore, bioretention systems could help reduce the harmful effect of pollutants in stormwater (Chahal et al., 2016).

Source control systems that use soil as a retention media have several opportunities for stormwater management. A survey in Seattle, WA (USA) showed that 87% of landowners in Seattle with a rain garden stated that they have positive feelings about their rain gardens (Chrys & Clark, 2017). This vision is often accepted under the idea that rain gardens can beautify yards and neighborhoods, prevent floods, and create more welcoming neighborhoods. In addition, it is commonly accepted that rain gardens help the environment by keeping more pollution out of the water (Chrys & Clark, 2017; SFU, n.d.).

Stormwater source control systems increase urban environmental resilience integrating cross-collaboration among land-users (Deksissa, Trobman, Zendehdel, & Azam, 2021). The use of organic residuals as soil amendments to recover nutrients and enhance soil activity is a common practice in the agricultural sector. There is growing interest in bringing these circular economy principles into the urban environment (Brown, Ippolito, Hundal, & Basta, 2020). Several member municipalities within Metro Vancouver have already tried different organic residuals in their growing media mix, so there is an opportunity to incorporate alternative materials, like biosolids and DWTR, into LID landscapes.

## 4. Organic residuals as soil amendments

Organic residuals, such as biosolids and compost, are commonly applied as a soil amendment to supply carbon and nitrogen (N) needs to crops. The application of biosolids in replacement of artificial N fertilizers, has demonstrated a positive effect in soil quality and has shown to be a low-cost alternative to enhance microbial soil communities and plant development (Cogger, Bary, Kennedy, & Fortuna, 2013).

The Organic Matter Recycling Regulation (OMRR) of BC governs the construction and operation of compost facilities, as well as the production, distribution, storage, sale, and use of biosolids and compost (BC Government, n.d.). This regulation establishes the conditions under which organic residuals, like biosolids, can be recycled and used on land.

According to the regulation (Reg 18/2002 OMRR), biosolids that may be composted into Class A or Class B compost are "stabilized municipal sewage sludge resulting from a municipal wastewater treatment process or septage treatment process which has been sufficiently treated to reduce pathogen densities and vector attraction to allow the sludge to be beneficially recycled in accordance with the requirements of this regulation."

The OMRR also establishes requirements for compost and Biosolids Growing Medium (BGM) quality. Schedule 4 of the OMRR states the quality requirements for Class A compost, Class B biosolids and compost and BGM, and is summarized in the following table.

Table 6. Quality criteria according to OMRR

| Max Concentration of Substance (µg/g dry weight) | Class A compost | Biosolids Growing Medium | Class B biosolids Class B compost |
|---|---|---|---|
| Arsenic | 13 | 13 | 75 |
| Cadmium | 3 | 1.5 | 20 |
| Chromium | 100 | 100 | 1 060 |
| Cobalt | 34 | 34 | 150 |
| Copper | 400 | 150 | 2 200 |
| Lead | 150 | 150 | 500 |
| Mercury | 2 | 0.8 | 15 |
| Molybdenum | 5 | 5 | 20 |
| Nickel | 62 | 62 | 180 |
| Selenium | 2 | 2 | 14 |
| Zinc | 500 | 150 | 1 850 |

In addition to concentrations shown in Table 6, retail-grade organic matter (Class A compost and BGM) and managed organic matter (such as biosolids and Class B compost) must have foreign matter content less than or equal to one (1) percent dry weight, and no sharp foreign matter, such as glass or metal shards, in a size and shape that can cause injury.

Furthermore, OMRR states that BGM must be derived from Class A or Class B biosolids that meet pathogen and vector attraction reduction requirements established in Schedules 1, 2 and 3 of the regulation and the next following standards: a) substance concentration according to quality criteria; b) Total Kjeldahl Nitrogen (TKN) $< 0.6$ percent by weight; c) carbon to nitrogen ratio, (C:N) ratio must be $> 15:1$; and d) organic matter content must not exceed 15 percent dry weight.

The BC Code of Practice for Soil Amendments (CoPSA) (BC Reg. 2010/2007) which regulates Drinking Water Treatment Residuals (DWTR) states that residuals can be used as a soil amendment if they comply with the quality criteria in Table 7 and have less than 1% foreign matter by dry weight. For this matter, CoPSA defines, among other, residuals from the treatment of water for domestic use or use in industrial processes as viable soil amendments.

Table 7. Quality criteria for application of soil amendments to land

| Substance | Max. Concentration (µg/g dry weight) |
|---|---|
| Arsenic | 75 |
| Cadmium | 20 |
| Chromium | 1 060 |
| Cobalt | 150 |
| Copper | 2 200 |
| Lead | 500 |
| Mercury | 5 |
| Molybdenum | 20 |
| Nickel | 180 |
| Selenium | 14 |
| Zinc | 1 850 |

Under OMRR and CoPSA regulations, biosolids, BGM and DWTR are eligible for application as soil amendments or as recycled organic matter to land. During wastewater treatment, biosolids are generated from the removal of organic matter and nutrients from wastewater. Biosolids thus contain nutrients such as nitrogen (N) and phosphorus (P), that can be beneficial for soil microbiota and plant growth and help reduce or even eliminate the need for synthetic fertilizers under a circular economy perspective (Brown et al., 2020). Biosolids application, by increasing organic matter content in soil, also improves soil aggregate stability, increase infiltration rate and water capacity (Tsadilas, Mitsios, & Golia, 2005).

Consequently, biosolids are nutrient-rich and can be utilized as a soil amendment to improve physical, chemical and biological properties of soils. The use of biosolids in land may replace the use of slow-release fertilizers, offering a cost-effective solution for soil remediation and improvement (Lu, He, & Stoffella, 2012).

Metro Vancouver follows a rigorous quality control program that exceeds the OMRR requirements for process and quality criteria. Throughout the treatment process, Metro Vancouver tests wastewater that will be turned into biosolids. Once biosolids have been produced, biosolids are tested again before leaving wastewater treatment plants. This testing confirms that biosolids meet the OMRR and can be used as a soil amendment. Test results show that Metro Vancouver biosolids are consistently within the limits established by the OMRR.

## 5. Experiences in using biosolids and water treatment residuals in LID landscapes

Having been successfully applied in agricultural activities as a fertilizer and soil amendment, biosolids have the potential to be used in the urban environment landscapes including Low Impact Development (LID) landscapes for stormwater source control management. Additionally, there is increasing interest from academia to evaluate the safety of this practice and to address concerns of biosolids-stormwater interactions.

Research in this topic mainly aims to assess the removal of metals and nutrients in growing media amended with biosolids or Drinking Water Treatment Residuals (DWTR). Most relevant research has been conducted to address the challenges in using biosolids in growing media or bioretention soil for stormwater management. The University of Washington and the University of Maryland participate actively in this kind of research.

Most research tries to replicate stormwater conditions and source control systems at a laboratory scale in order to assess removal and release of contaminants and nutrients. Gardina, C (2016)[4] tested different bioretention soil media in columns using synthetic stormwater. Results showed Nitrogen (N) and Phosphorus (P) release for all treatments as high as 300mg-N/L and 4.6 mg-P/L in outlet water and therefore, Gardina did not recommend the use of biosolids-derived compost in bioretention media.

These concerns have led other cities in the US Pacific Northwest to have stricter guidelines when designing, constructing, and maintaining LID landscapes for stormwater management. In the US, the primary source for stormwater system BMPs is the Stormwater Management Manual for

[4] Gardina, Colleen. Water Quality Impacts due to the Addition of Biosolids-Derived Compost to Bioretention. Restricted access until August 2022. https://doi.org/10.13016/M28R47

Western Washington (SMMWW). The SMMWW specifies that bioretention facilities must be sized to treat 91% percent of the runoff draining to the area and establishes construction criteria including quality criteria for compost in terms of organic matter content, carbon to nitrogen ratio, pH, and presence of beneficial fungi and bacteria. Furthermore, biosolids or manure are prohibited for use in bioretention facilities (Chrys & Clark, 2017; Washington State Department of Ecology, 2019). Even though, experts at Washington State University have mentioned that this prohibition could be more based in preventing possible risks than based on actual scientific facts and risks analysis (Brown, S., personal communication).

Other authors have found that different soil mixtures can lead to different water quality performances and the effect of using biosolids compost in growing medium can vary according to the type and quantity of biosolids and residuals included in the soil mix (Jay et al., 2019). Table 8 summarizes the composition and characteristics of tested media by Brown et al. (2016) and Jay et al. (2019).

It is important to note that mixtures were prepared in terms of % of volume, following Stormwater Management Manual for Western Washington best practices recommendations of maintaining sand to organic matter proportion to 60%/40% or as close as possible (Washington State Department of Ecology, 2019). Guidelines in the US (Washington State Department of Ecology, 2019) and Canada (Campbell et al., 2013) recommend a minimum of 25mm/hr infiltration rate for better system performance in rain gardens, and (Government of British Columbia, 2002) classifies 50mm/hr infiltration rate as “good”. The recommendation is based on the notion that rainwater can drain rapidly after a storm event and at the same time, it will have enough time for the particles to interact with the contaminated water for contaminant removal (Campbell et al., 2013; Hinman, 2005). Media tested by Brown et al. (2016 and 2019) had higher infiltration rates but still managed to successfully remove contaminant metals (Table 9). However, increasing compost proportions increased N and P concentrations in leachate from 40 to 80%.

In general, growing media containing biosolids were a source of N and P, and all growing media adsorbed Copper (Cu), Zinc (Zn), and Polycyclic Aromatic Hydrocarbons (PAHs) from stormwater with different levels of efficiency. However, it was noticed that contaminant removal was not related to infiltration rate and therefore, there is not a specific soil mixture that would outperform the others across all categories. This means that growing media containing biosolids could be tailored to different needs by adjusting compost rates, additives and the type of compost itself (Jay et al., 2019).

Table 8. Description of 13 bioretention soil mixture (BSM) analyzed.

| Sample Code | C FY 40 | C BY 40 | C BY 35 WTR 5 | C BY 80 | C BY 20 | C BY17.5 WTR2.5 | C BY 15 S5 | C BY 15 O5 | B FE 20 C 30 | B FE 51 | C BFE 51 | B FE 13 S 85.5 | B FE 23 S75 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mix (% volume) | | | | | | | | | | | | | |
| Biosolids-yard compost | - | 40 | 35 | 80 | 20 | 17.5 | 15 | 15 | - | - | - | - | - |
| Food-yard compost | 40 | - | - | - | - | - | - | - | - | - | - | - | - |
| High-Fe Biosolids | - | - | - | - | - | - | - | - | 20 | 51 | 51 | 12.9 | 23 |
| Sand | 60 | 60 | 60 | 20 | 80 | 80 | 80 | 80 | 49 | 49 | 49 | 1.2 | 3 |
| Sawdust | - | - | - | - | - | - | 5 | - | - | - | - | 85.5 | 75 |
| Oyster Shells | - | - | - | - | - | - | - | 5 | - | - | - | - | - |
| Water Treatment Residuals | - | - | 5 | - | - | 2.5 | - | - | - | - | - | - | - |
| Loamy clay | - | - | - | - | - | - | - | - | 30 | - | - | - | - |
| Mineral fines | - | - | - | - | - | - | - | - | - | - | - | 1.4 | - |
| Characterization | | | | | | | | | | | | | |
| pH | 6.7 | 5.8 | 6 | 5.2 | 6 | 6.5 | 5.6 | 6.6 | 6.5 | 6.3 | 6.7 | 5 | 6.5 |
| C:N | 15.7 | 17.8 | 20.5 | 19.3 | 21.9 | 18.3 | 26.8 | 35 | 6.8 | 6.7 | 6.8 | 151 | 13.1 |
| Infiltration rate (mm/hr) | 1320 | 2100 | 3120 | 102 | 420 | 7980 | 1860 | 7980 | 1440 | 18 | 150 | 7440 | 900 |

Source: (Brown, Corfman, Mendrey, Kurtz, & Grothkopp, 2016; Jay et al., 2019)

Table 9. Concentration of Cu, Pb, Zn, N and P in effluent from BSM columns

| Sample Code | Total Cu (ug/L) | Total Lead (Pb) (ug/L) | Total Zn (ug/L) | Total N (ug/L) | Total P (ug/L) |
|---|---|---|---|---|---|
| Stormwater | 39.8 | 4.2 | 172 | 1.8 | 0.08 |
| C FY 40 | 12.9 | <20 | 15.6 | 10.3 | 2.1 |
| C BY 40 | 32 | <20 | 26.2 | 25.4 | 13.1 |
| C BY 35 WTR 5 | 19.3 | <20 | 26.3 | 12.3 | 4.7 |
| C BY 80 | 38 | 21 | 78 | 20.6 | 12.8 |
| C BY 20 | 21.2 | <20 | 13.6 | 10.1 | 6.4 |
| C BY17.5 WTR2.5 | 7.8 | <20 | 9.1 | 4.7 | 4 |
| C BY 15 S5 | 17 | <20 | 15.9 | 4.8 | 4.9 |
| C BY 15 O5 | 10.9 | <20 | 11.2 | 5.5 | 4.1 |
| B FE 20 C 30 | <4 | <20 | 15 | 21.5 | 4.7 |
| B FE 51 | 6 | <20 | 9.7 | 31.6 | 4.1 |
| C BFE 51 | 7 | <20 | 15 | 36.3 | 3.1 |
| B FE 13 S 85.5 | 25.8 | <20 | 40 | 2.1 | 2.1 |
| B FE 23 S75 | 32.3 | <20 | 90 | 21.9 | 4.2 |

Source: (Jay et al., 2019)

Other authors also identify how the variability of biosolids compost quality and type used in the system results in different N and P leachates and that their presence can decrease during successive storms (Chahal et al., 2016). Variability of compost materials used in retention media makes it difficult to assess the performance of a system based only on its composition. Again, it is necessary to prepare specific media and evaluate specific water quality needs to properly evaluate the media used. Unfortunately, there is no current known recipe that would address completely all stormwater quality challenges in a unique system. However, some researchers are trying to develop key indicators for the performance of stormwater management and have identified the Phosphorus Saturation Index[5] as a possible predictive tool for system performance (Brown et al., 2016).

[5] The P Saturation Index (PSI) has been used as a measure of the ratio of environmentally relevant P and the ability of a soil to bind P through adsorption onto Fe and Al oxides. It is calculated by the equation [PSR=P/(Fe+Al)] represented by extractable molar concentration of each element (Maguire and Sims, 2001). PSI has been studied to predict the leaching of P from agricultural soils and has been recommended to predict P leaching from Biorention Soil Mixtiures (O'Neill and Davis, 2011). However, studies on testing PSR in bioretention context are limited (Jay et al., 2017).

Nitrogen and phosphorous release are a major concern due to the risk of eutrophication of receiving waters. Some sources of N and P in urban stormwater are from fertilizers, detergents, and automobile exhaust (USGS, n.d.). Although N and P are important nutrients for soil and plant growth, leaching or runoff from these elements can lead to algae bloom in water bodies that may have other adverse effects such as loss of biodiversity and poor water quality (USGS, n.d.). This challenge can be addressed by modifying growing media in order to meet the requirements of water quality. For example, Liu & Davis (2014), successfully added 5% by mass of DWTR (obtained from Rockville drinking water treatment plant in Potomac, MD, USA) to create an enhanced P-removal media (Liu & Davis, 2014). Meanwhile, O.A. Knowles et al. (2011) successfully tested the incorporation of biochar into biosolids-amended soils to mitigate nitrate leaching and delay the release of this nutrient (Knowles, Robinson, Contangelo, & Clucas, 2011), a technology that could also be applied to stormwater control systems.

Speciation[6] is another important factor to consider when evaluating the efficacy of stormwater source control systems. Organic matter from residuals can interact with metals in the soil changing their bioavailability which can influence metal release to runoff water and potentially plant uptake. Regularly, literature shows that growing medium containing biosolids acts like sinks for metals and pollutants (Brown et al., 2016; Jay et al., 2019) and a typical 90% of removal is reported. However, in the cases when retention soil can release metals, specifically copper, it has been shown that the released organic-bond copper is less toxic than free copper and therefore does not represent a risk for humans or plants (Chahal et al., 2016).

Overall, literature shows that biosolids can be used in rain gardens and other LID landscape without representing a risk to people and the environment (Brown et al., 2019). Nevertheless, different mixtures will perform differently in terms of contaminant retention, and nutrient release since different combinations have different results with no direct correlation found. Literature does show the potential use of biosolids as a soil amendment or as a component of growing media successfully in stormwater management. However, specific-case analysis is needed in order to make local decisions.

[6] Chemical speciation refers to the distribution of an element amongst chemical species. Chemical species can de defined by isotopic composition, electronic or oxidation state, and/or complex or molecular structure (IUPAC).

## 6. Opportunities for using biosolids and water treatment residuals in Metro Vancouver LID landscapes

In order to assess the applicability of biosolids, Biosolids Growing Medium (BGM) and Drinking Water Treatment Residuals (DWTR) in stormwater source control systems in Metro Vancouver, it is important to assess the compliance of the chemical composition of the materials to the Organic Matter Recycling Regulation (OMRR).

According to the information presented previously in Section 4, the following table compares the characterization of Metro Vancouver biosolids and BGM to the OMRR. Results show that biosolids and BGM comply with the OMRR and therefore can be used in land application.

Table 10. Comparison of Metro Vancouver biosolids and BGM composition to OMRR

| Substance | Class A compost | Class A biosolids | Class B biosolids Class B compost | Annacis Island WWTP Biosolids (Class A biosolids) (2020 average) | Biosolids Growing Medium | MV BGM (May 2021 12-month average) |
|---|---|---|---|---|---|---|
| Arsenic | 13 | 75 | 75 | 5 | 13 | 3.2 |
| Cadmium | 3 | 20 | 20 | 2 | 1.5 | 0.2 |
| Chromium | 100 | - | 1 060 | 64 | 100 | 27.1 |
| Cobalt | 34 | 150 | 150 | 4 | 34 | 6.4 |
| Copper | 400 | - | 2 200 | 690 | 150 | 56 |
| Lead | 150 | 500 | 500 | 37 | 150 | 5.5 |
| Mercury | 2 | 5 | 15 | 1 | 0.8 | 0.1 |
| Molybdenum | 5 | 20 | 20 | 10 | 5 | 1 |
| Nickel | 62 | 180 | 180 | 27 | 62 | 27.6 |
| Selenium | 2 | 14 | 14 | 7 | 2 | 0.4 |
| Zinc | 500 | 1850 | 1 850 | 1300 | 150 | 107.6 |

Note: OMRR standard in blue, sample results in yellow.

It is worth noticing that the OMRR quality standards for BGM are stricter than standards for Class A compost for most parameters. The objective of the OMRR is to ensure the safe use of organic residuals for land application. In BC, class A compost is already used as a constituent in many growing media in stormwater management source control systems. All of this is a clear indication that using BGM would not represent a higher risk of contamination than using Class A compost for land application, including the addition of these residuals to stormwater source control systems.

To compare, the following table summarizes the standards used for landscape soil and bioretention media used in Metro Vancouver and it is compared to the available information about BGM. This table compares the quality of the soil commonly accepted for landscape developments, including stormwater source control systems such as detention ponds or rain gardens.

According to the presented data, BGM meets the quality criteria for the Canadian Landscape Standard, as well as the City of Vancouver and City of Surrey growing medium specifications for C:N, %OM, acidity, and nitrogen. Additional analyses for the remaining parameters may be required to ensure ongoing compliance of the material with all the established criteria. The application of biosolids and BGM in bioretention soil mixtures could potentially be an alternative to improve plant growth, reduce potential for erosion and increase infiltration rates.

Table 11. Landscape and bioretention soil standards in Metro Vancouver

| | Canadian Landscape Standard | | | City of Vancouver | | City of Surrey | MV BGM (May 2021 12-month average) |
|---|---|---|---|---|---|---|---|
| | Level 4/Level 5-3L | Level 2- 2L | Level 2- 2P | Turf Soil (Park Turf Mix) | Bioretention Soil (Under revision) | Growing Medium properties | |
| C:N | <40:1 | <40:1 | <40:1 | 20:1-10:1 | 30:1- 10:1 | <40:1 | 20.2 |
| %OM | 2-10% | 3-10% | 10-20% | 10-20% | 8-17% | 8-12% | 11.50% |
| All gravel | 0-10% | 0-5% | 0-5% | - | - | 0 | - |
| %Sand | 30-70% | 50-70% | 40-80% | 70-85% | 60-70% | 30%max | - |
| %Silt | 15-50% | 10-25% | 10-25% | 5-15% | 5-40% | 50%max | - |
| %Clay | 15-30% | 0-25% | 0-25% | 0-15% | 0-15% | 30%max | - |
| Total Silt and Clay | 60%max | 35%max | 35%max | 20%max | 40%max | 60%max | - |
| Acidity (pH) | 6.0-7.0 | 6.0-7.0 | 4.5-6.5 | 4.5-8 | 5.5-8.0 | 6.0-7.0 | 6.3 |
| Max Particle Size | 75mm sieve | 75mm sieve | 75mm sieve | 0.5" sieve | 12.77mm sieve | - | - |
| Nitrogen | 0.2-0.6% by weight | 0.2-0.6% by weight | 0.2-0.6% by weight | 4 | 0.2-0.6% by weight | - | 0.3 |
| Phosphorus (ppm) | 20-250 | 20-250 | 20-250 | 324 | 20-250 | - | - |
| Potassium (ppm) | 50-1000 | 50-1000 | 50-1000 | 1956 | 50-1000 | - | - |
| Electrical Conductivity | <3 | <3 | <3 | n/a | <2.5 | <3 | - |
| Sodium Adsorption Ratio (SAR) | <8 | <8 | <8 | 2.22% | <4 | - | - |
| Minimum saturated hydraulic conductivity (mm/hr) | 25 | 25 | 25 | - | 25 | - | - |

# Conclusions and Recommendations

As impervious surfaces in Metro Vancouver continue to grow, and as the trend continues towards more intense rain events due to climate change, Low Impact Development (LID) landscapes offer a solution to deal with increasing volumes of rain runoff water.

Stormwater source control systems like raingardens, bioswales, retention ponds, etc. are favoured in urban areas; with advantages of increased stormwater infiltration and decreasing surface runoff through traditional media like sand, soil, or compost, with plants growing in the media guaranteeing urban resilience and watershed protection.

The application of organic residuals like biosolids, Drinking Water Treatment Residuals (DWTR) and Biosolids Growing Medium (BGM) to land for soil quality improvement has been long studied and it has been shown that biosolids can act as an adsorbent filter for the removal of toxic metals, sediments, and organic pollutants from stormwater runoff, while increasing infiltration rates. However, some researchers and practitioners remain concerned about the use of biosolids in bioretention soils due to the potential release of nutrients like nitrogen (N) and phosphorus (P) that may cause eutrophication in receiving waters. More research in this area is needed in order to address the use of biosolids in stormwater source control systems.

Some research has been conducted on the use of biosolids compost and other organic residuals in bioretention soil mixtures for LID. These studies have tried to address water quality concerns by adding iron-rich water treatment residuals to control P release, or adding biochar to control N release. It is important to test different combinations of growing media to address project specific water quality and infiltration needs.

A more detailed assessment on the possible release of nutrients from BGM and the possibility of adding DWTR or biochar to improve water quality, would be a next step. This information could help alleviate concerns from municipalities, the public and other stakeholders, who may be hesitant to use these residuals in stormwater source control systems in Metro Vancouver.

By applying the principles of circular economy into the recovery of nutrients from wastewater treatment residuals and incorporating those materials into the urban landscape, there is an additional potential for carbon sequestration, increasing urban resilience and beautification.

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# Appendix A

Electronically attached to this report in the file "2021– 17 – Information Systematization.xls" which summarizes the main notes of the interviews conducted, the main sources of information used in the elaboration of this report and the main literature pieces analyzed for this project.

# Appendix B – Canadian Landscape Standards

| | Table T-6.3.5.2 | Table T-6.3.5.3 | Table T-6.3.5.4 |
|---|---|---|---|
| Name | "Well-Groomed" Areas | "Groomed" and "Moderate" Areas | "Open Space/Play", "Background" and "Service & Industrial" Areas |
| Description | Level 1 area: Intensive, high standard of maintenance is anticipated. Irrigation is necessary in all areas that are "on-slab" or under cover. The textural classification for these growing media by the Canadian system of soil classification is "sand" to "loamy sand". Plan selection, irrigation requirements and maintenance intensity should consistently respond to the exceptional nature of the growing medium. Note: treen and large shrubs areas may also have type 1L growing medium. | Levels 2 and 3 areas: Routine, high to moderate standard of maintenance anticipated. Automatic irrigation is recommended, however such areas can de adequately irrigated through consistent use of manual irrigation equipment. The textual classification for these growing media by the Canadian system of soil classification is "loamy sand" to "sandy loam". These growing media accommodate a suited to moderate normal maintenance practices. "On-slab" areas should be treated as level 1 areas, with corresponding increase in sand content and decrease in silts and clays. Note: trees and large shrubs areas may also have Type 2L growing medium. | Levels 4, 5 and 6 areas: High standard of maintenance is neither anticipated nor required. Irrigation may be provided, but more frequenty only temporary watering is done for establishment maintenance. The textural clasification for this growing medium by the Canadian system of soil classification is "sandy loam" to "loam". These soils provide a high-quality growing medium, albeit with reduced percolation and resistance to compaction. These may be imported soils, however, existing soils may meet these requirements or it may be possible to amend them to meet the requirements. Plant selection must respond to the limitations of the growing medium and to modest maintainance expectations. If growin medium must be imported to augment existing site topsoil (due to insufficient volumes on site or damage to on-site topsoil by costruction activities), the imported growing medium should be similar to the on-site soil and should be mixed with it. Different soil types should not be layered. Note: trees and large shrub areas may also have type 3L Growing Medium. |

| | Table T-6.3.5.2 | | | Table T-6.3.5.3 | | | Table T-6.3.5.4 | |
|---|---|---|---|---|---|---|---|---|
| Growing Medium Types | 1L | 1H | 1P | 2L | 2H | 2P | 3L | 3P |
| Applications | Low traffic Lawn areas, Trees & Large shrubs | High traffic lawn areas | Planting areas | Low traffic Lawn areas, Trees & Large shrubs | High traffic lawn areas | Planting areas | All Lawn areas, Trees & Large Shrubs | Planting areas |
| Texture | Percent of Dry Weight of Total Growing Medium | | | | | | | |
| Coarse Gravel: Larger than 19mm Smaller than 40mm | 0 – 1% | 0 – 1% | 0 – 1% | 0 – 1% | 0 – 1% | 0 – 1% | 0 – 3% | 0 – 3% |
| All Gravel Larger than 2mm Smaller than 40mm | 0 – 5% | 0 – 5% | 0 – 5% | 0 – 5% | 0 – 5% | 0 – 5% | 0 – 10% | 0 – 10% |
| Texture | Percent of Dry Weight of Growing Medium Excluding Gravel | | | | | | | |
| Sand: Larger than 0.05mm Smaller than 2mm | 50 – 70% | 70 – 90% | 50 – 70% | 50 – 70% | 70 – 90% | 40 – 80% | 30 – 70% | 30 – 70% |
| Silt: Larger than 0.002mm Smaller than 2mm | 10 – 25% | 5 – 15% | 10 – 25% | 10 – 25% | 0 – 15% | 10 – 25% | 15 – 50% | 15 – 50% |
| Clay: Smaller than 0.002mm | 0 – 20% | 0 – 20% | 0 – 20% | 0 – 25% | 0 – 15% | 0 – 25% | 15 – 30% | 15 – 30% |
| Clay and Silt Combined | Max. 25% | Max. 25% | Max. 25% | Max. 35% | Max. 15% | Max. 35% | Max. 60% | Max. 60% |
| Organic Content (weight) | 3 – 10% | 3 – 5% | 10 – 20% | 3 – 10% | 3 – 5% | 10 – 20% | 2 – 10% | 5 – 20% |
| Acidity (pH) | 6.0 – 7.0 | 6.0 – 7.0 | 4.5 – 6.5 | 6.0 – 7.0 | 6.0 – 7.0 | 4.5 – 6.5 | 6.0 – 7.0 | 4.5 – 7.0 |
| Drainage: | Percolation shall be such that no standing water is visible 60minutes after at least 10 minutes of moderate to heavy rain or irrigation. | | | Percolation shall be such that no standing water is visible 60minutes after at least 10 minutes of moderate to heavy rain or irrigation. | | | - | |