Biosolids growing medium: Formulations and fabrication

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Abstract: The application of biosolids as a fertilizer and soil amendment has been well established. Biosolids are used for agricultural, silvicultural and reclamation applications. Use is not limited to direct application, biosolids can also be incorporated as feedstock in biosolids products such as compost and fabricated growing medium. These retail-grade, biosolids products allow for increased application and distribution opportunities including retail sale. In British Columbia, the use and land application of biosolids, compost and fabricated biosolids growing medium is regulated under the Organic Matter Recycling Regulation. This Provincial regulation allows for production and unrestricted distribution of biosolids growing medium provided that regulatory criteria are met. The fabrication of biosolids growing medium is dictated by the final use objectives. Soil formulations, feedstock characteristics and fabrication technologies all impact the quality of the soil produced. A technical process has been developed to produce a biosolids soil product which meets regulatory requirements and client specifications. Process phases include evaluation of feedstock materials, development of formulation matrices, preparation of laboratory scale mixtures, selection of mixing technologies and assessment of soil quality with respect to regulatory criteria, fertility, physical requirements and aesthetics. This approach is demonstrated with two examples and a discussion of logistical challenges.

Keywords: Biosolids growing medium; feedstock; mixing technology; soil fabrication

INTRODUCTION

Natural soil formation is an evolutionary process which occurs slowly over a period of thousands of years. Over time, rocks, the parent material, are subject to decomposition, physical and chemical weathering, formation of secondary materials and colonisation by micro-organisms (DETR, 1999). The rate of soil formation is a function of: climate, presence of living organisms, nature of the parent material, topography of the site and the time that the parent materials are subjected to weathering. Soil characteristics such as texture, water holding capacity, vegetation establishment potential and quantity and type of clay minerals are affected by the parent materials (Brady, 1990). The same is true for fabricated soils; the parent materials influence the soil characteristics.

Fabricated soil is formed by mixing various parent materials together. The parent materials are selected and combined to ensure that the soil will meet the final use objectives. Inorganic parent or feedstock materials may be selected for their structural properties: texture, bulk density, porosity, aggregate size distribution and permeability. Organic materials may be selected for their nutrient concentrations and ability to increase the organic matter content of the soil.

The public is familiar with the benefits associated with the land application of organic matter. For several years animal manures have been applied alone or in combination with other feedstock materials for their value as a fertilizer and soil amendment. Fabricated soils are also an accepted and understood product. Fabricated soil provides an opportunity for regional biosolids utilization, increasing the awareness and understanding of biosolids concurrent with a cost effective management opportunity.
Regulatory Framework and soil quality Criteria

In BC, the use of biosolids in soil fabrication is regulated under Organic Matter Recycling Regulation (OMRR). This Provincial regulation was promulgated in 2002 simplifying the previous permitting system. The OMRR regulates both the biosolids that can be used to generate biosolids growing medium and the biosolids growing medium itself. Under the OMRR, biosolids are classified as either Class A or Class B with Class A denoting a higher quality and therefore subject to more strict process and quality criteria. Biosolids growing medium can be produced from Class A biosolids or Class B biosolids that meet the Class A pathogen and vector attraction reduction requirements (British Columbia Ministry of Water, Land and Air Protection, 2002).

The biosolids growing medium itself must meet requirements for Total Kjeldahl Nitrogen (TKN), carbon to nitrogen ratio (C:N), organic matter, foreign matter and trace elements. Biosolids growing medium which meets all the OMRR requirements can be distributed without restriction. A summary of the OMRR requirements for Class A biosolids, Class B biosolids and biosolids growing medium is given in Table 1.

Table 1. OMRR requirements for biosolids growing medium

<table>
<thead>
<tr>
<th>Parameter</th>
<th>OMRR Criteria</th>
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<tbody>
<tr>
<td></td>
<td>Class A biosolids&lt;sup&gt;1)&lt;/sup&gt;</td>
</tr>
<tr>
<td>Total Kjeldahl Nitrogen</td>
<td>-</td>
</tr>
<tr>
<td>C:N Ratio</td>
<td>-</td>
</tr>
<tr>
<td>Organic Matter</td>
<td>≤ 1</td>
</tr>
<tr>
<td>Foreign Matter</td>
<td>Arsenic</td>
</tr>
<tr>
<td></td>
<td>Cadmium</td>
</tr>
<tr>
<td></td>
<td>Chromium</td>
</tr>
<tr>
<td></td>
<td>Cobalt</td>
</tr>
<tr>
<td></td>
<td>Copper</td>
</tr>
<tr>
<td></td>
<td>Lead</td>
</tr>
<tr>
<td></td>
<td>Mercury</td>
</tr>
<tr>
<td></td>
<td>Molybdenum</td>
</tr>
<tr>
<td></td>
<td>Nickel</td>
</tr>
<tr>
<td></td>
<td>Selenium</td>
</tr>
<tr>
<td></td>
<td>Zinc</td>
</tr>
</tbody>
</table>

<sup>1</sup> Element concentrations for Class A biosolids are given in the Trade Memorandum T-4-93, Standards for Metals in Fertilizers and Supplements (CFIA, September 1997).

The OMRR is designed to ensure that biosolids and biosolids products are protective of human health and the environment. It is not intended to ensure that the biosolids growing medium will be aesthetically pleasing or contain the nutrients and physical characteristics necessary to support vegetation establishment and growth.

Additional standards, although not required when producing a biosolids growing medium, may assist the producer is fabricating a more desirable product, particularly to meet specific client or use requirements. The BC Society of Landscape Architects and the BC Landscape and Nursery Association have developed both general growing media standards and standards for the intended application. General standards are summarized in Table 2.

Table 2. BC Landscape Standards for growing medium<sup>(1)</sup>

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Growing Medium Standards</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boron</td>
<td>≤ 1.0</td>
<td>ppm</td>
</tr>
<tr>
<td>Conductivity</td>
<td>3.0 at 25°C</td>
<td>millimhos cm⁻¹</td>
</tr>
<tr>
<td>Sodium adsorption ratio</td>
<td>≤ 8.0</td>
<td>-</td>
</tr>
<tr>
<td>Total nitrogen</td>
<td>0.2 – 0.6</td>
<td>% by weight</td>
</tr>
<tr>
<td>Available phosphorus</td>
<td>20 – 250</td>
<td>ppm</td>
</tr>
<tr>
<td>Available potassium</td>
<td>50 – 1,000</td>
<td>≤ ppm</td>
</tr>
<tr>
<td>Carbon to nitrogen ratio</td>
<td>≤ 40:1</td>
<td></td>
</tr>
</tbody>
</table>

<sup>(1)</sup>BC Society of Landscape Architects and BC Landscape and Nursery Association, 2001
Developing a Biosolids Growing Medium

Several factors should be considered when fabricating a biosolids growing medium: final land use objectives, feedstock characteristics, growing medium quality and selection of mixing technologies. A soil fabrication program has been developed based on our understanding of these factors. Although this is not the only method, it has been used successfully to fabricate soil for several operational scale projects. This process is described in greater detail in the sections below.

Final Land Use Objectives

Awareness of the final use objectives is vital when fabricating a biosolids growing medium as it impacts the selection of feedstock materials, determination of mix ratios and selection of mixing technology. Uses of biosolids growing medium are as wide ranging as the use of soil itself. Biosolids growing medium uses can range from reclamation of disturbed areas, enhancement of steep slope stability and establishment of recreation fields to use in hanging planters for landscaping. The quality of the growing medium will be influenced by the end user and aesthetic characteristics as they relate to perception and acceptance. The appearance and texture of the biosolids growing medium may hold great importance for residential use but less so for commercial or industrial applications. A soil fabricated for use in mine reclamation will be distinctly different than a retail grade potting soil developed for house plants.

Feedstock Characteristics

Fabricated soil is produced from a mixture of feedstock ingredients. The quality of biosolids used as a feedstock ingredient is regulated under the OMRR as is the quality of the fabricated soil. The final soil quality requirements influence the selection of other feedstock ingredients.

A variety of feedstock materials can be used in the production of biosolids growing medium. These materials can be divided into two sub-groups: inorganic feedstock such as sand, clay, lime mud or other mineral based materials; and organic, or carbon based, feedstock such as wood waste, yard waste (leaves), pulp sludge or compost. Appropriate feedstock materials will be free of foreign matter such as glass, metal, plastics, or other materials not normally found in soil.

The addition of an inorganic component to a biosolids growing medium is multi-purpose. Inorganic feedstock materials serve to provide structure. This structural component is important for ensuring the soil has the appropriate texture, aeration, drainage and slope stability characteristics. The inorganic material also functions to moderate the high organic matter content of the other feedstock materials to ensure that the final biosolids growing medium complies with regulatory standards.

The use of organic feedstock materials also serves several functions. Biosolids typically have a low C:N ratio which affects their nutrient release characteristics. The introduction of higher carbon organic matter such as wood chips, sawdust, primary pulp and paper mill sludge or de-inking sludge increases the C:N ratio and moderates the nutrient release. The C:N ratio differs among feedstock materials so the mix ratio will require adjustment accordingly.

Feedstock materials will also affect pH, trace element and nutrient concentrations in the final product. If the feedstock material contains a lower concentration of a given parameter than the biosolids, the feedstock may serve to “dilute” the concentration in the biosolids. The reverse is also true. Feedstock material may also be selected to improve the aesthetics of the biosolids growing medium. Compost is sometimes used for this purpose.

Knowledge of final use objectives is necessary in determining the appropriate expenditures for feedstock materials. Some feedstocks such as wood waste and compost can have high market value depending upon local economies. The local availability of feedstock is also a consideration as the cost of transporting the material can be significant. Ideally there should be a reliable, consistent feedstock source close to the location where the biosolids growing medium will be fabricated.
**Biosolids Growing Medium Quality**

In addition to the OMRR regulatory requirements, fertility, physical requirements and aesthetics are important considerations. The OMRR requirements for biosolids growing medium require that the TKN concentration is less than 0.6% and the organic matter content not exceed 15%. The regulated low organic matter presents a soil quality objective challenge as client specifications for fabricated soil often exceed 15%.

The physical structure of the biosolids growing medium should support the intended application. For example a biosolids growing medium being applied to a slope may require more structural cohesiveness than that being used on flat land. In general, the biosolids growing medium should be uniform, consistent and friable. It should also be free draining while still providing moisture retention. The soil should have structure, adequate porosity and aeration, and withstand the moderate compaction associated with placement without sealing.

Characteristics which can detract from the aesthetics of the biosolids growing medium include excessive plasticity, visible wood or sand, a heterogeneous mixture containing clumps of biosolids or other feedstock ingredients, discoloration caused by the selection of feedstock ingredients or an imbalance in the mix ratio and odour. Selecting appropriate feedstock ingredients and mixing technologies can alleviate these issues. An appropriate biosolids growing medium looks, feels, smells and performs like similar fabricated soils.

**Initial Assessment**

Upon determination of the final use of the growing medium and sourcing of the feedstock materials, representative samples are collected of each of the feedstock materials. These samples are analyzed for macro and micronutrients, pH, electrical conductivity and the OMRR parameters. Data generated from these analyses are used in an optimization model which has been developed for the purpose of determining soil formulations. The model estimates the final soil concentration of various parameters (nutrients, trace elements) in the biosolids growing medium which are then compared to the OMRR criteria. Altering the ratio of feedstocks in the model allows different formulations to be “tested” and the quality of the biosolids growing medium predicted. The model enables the selection of fabrication ratios which will result in a soil that meets the OMRR criteria and has an acceptable level of nutrients. This model provides a starting point for initial mixes to determine regulatory compliance. Some fertility parameters (e.g. pH) will change based upon feedstock interaction during fabrication.

The selected feedstock materials at the determined ratios are used to fabricate soil in the laboratory. The feedstock ingredients are mixed in a bench scale tub mixer according to the desired ratio. The fabricated soil is then assessed for texture, colour, odour, aesthetics, plasticity and structure. If these are suitable, the fabricated soil is analyzed to confirm that the OMRR requirements are met and the fertility levels are acceptable. Once these data are received, operational fabrication of the biosolids growing medium can commence. Additional samples are collected after operational mixing to ensure product quality and ongoing samples are collected as per the OMRR criteria which requires one sample to be collected for every 1,000 tonnes dry weight of organic matter or once per year, whichever occurs first.

**Mixing Technology**

There are several considerations when selecting a mixing technology for the fabrication of a biosolids growing medium. Many standard technologies are designed to sift and separate soil from unwanted materials or for use in agricultural applications. These systems do not work well for fabricating biosolids growing medium due to the cohesive properties of biosolids.

Dewatered biosolids have a high plasticity and tend to form balls if the mixing technology is inappropriate. Technology used to fabricate biosolids growing medium should produce a high quality product that is homogeneous, consistent, free of foreign matter and uncontaminated by oil and grease. A heterogeneous final product is challenging to sample and may result in data that does not comply with the regulatory criteria. It is also aesthetically less desirable. Consequently the mixing technology must produce an appropriate mechanical force to intimately mix the biosolids with the other feedstocks.
Due to the increased amount of industrial scale organic matter recycling over the last several decades, there are a variety of mixing technologies which can be adapted to fabricate biosolids growing medium. Screens, hammer mills, tub mixers and bottom buckets are some of the separation and mixing technologies that can be used.

A bottom bucket can be used to produce biosolids growing medium and remove any unwanted large aggregates simultaneously. The hammer mill technology, used in bottom buckets, effectively breaks up large clumps of biosolids and can produce an even mix if processed several times. This technology is relatively inexpensive and robust, easily separating unwanted foreign matter that may be present in the feedstock. Consistency in fabricated mixtures is difficult to achieve as feedstocks are first batched by volume and then mixed. Bottom buckets may not be appropriate for a large scale soil fabrication as multiple handling of the material leads to a longer processing time.

To meet the operational demands of large scale production, different technologies are required. It has been found that large horizontal auger tub mixers are capable of producing a consistent, homogenous mixture effectively and efficiently (Figure 1). This technology is not capable of removing foreign matter which must be excluded from the feedstocks to avoid severe equipment damage. The shearing forces in a horizontal auger tub adequately mix the biosolids. The order of feedstock mixing can impact mixing operations and final soil quality.

![Figure 1 Horizontal auger tub mixer used to fabricate soil](image)

The removal of finished product is a limiting factor when using a large tub mixer. A side casting conveyor is the most common system for discharging the finished soil product. The production efficiency is increased with a stacking conveyor. This system can be operated on a batch or continuous basis depending on the set-up. A batch system has been used with good success in fabricating biosolids soil products for landfill closure, mine reclamation and residential use.

The unique characteristics of biosolids present challenges in the production of a high quality biosolids growing medium. Available processing technologies are not specifically designed to meet the demands of producing a biosolids growing medium, and the development of efficient systems has been an ongoing process. Beyond product quality other production factors include machine maintenance and overall efficiency. Knowledge acquired from previous experience coupled with new developments in technology has led to the production of biosolids growing medium becoming progressively more efficient.
BC BIOSOLIDS GROWING MEDIUM PROGRAMS

Biosolids growing medium have been developed at the City of Abbotsford and at Lehigh Northwest Material’s Producers Pit near Victoria, BC.

The City of Abbotsford operates the Joint Abbotsford Mission Environmental System (J.A.M.E.S.) Water Pollution Control Centre, which provides secondary wastewater treatment resulting in the production of dewatered Class A biosolids. The City selected biosolids growing medium production as an environmentally sound and local opportunity to diversify their biosolids management program by producing a biosolids based fabricated soil for retail markets. Feedstock ingredients included J.A.M.E.S. biosolids, two types of sand and three carbon sources: composted bark, sawdust and a combination of woodchips and sawdust. Based on the results of the soil optimization model, a series of 24 fabricated soils were produced on a pilot scale (Figure 2). Nine of the 24 mixtures, were selected for their aesthetic qualities and potential to meet the OMRR requirements and analyzed for trace elements, nutrients and physical parameters. Based on soil aesthetics and data generated from the pilot scale fabrication, composted bark and processed sand were selected as the preferred feedstock (SYLVIS, 2003). A bottom bucket was used to fabricate the soil. Product branding and marketing were developed concurrent with development of the biosolids growing medium. The biosolids growing medium, marketed under the name Val-E-Gro™ is sold to commercial landscapers and is used by the City of Abbotsford in the City’s parks and planters.

Figure 2 Pilot scale biosolids growing medium formulations

Lehigh Northwest Material’s Producers Pit is a large sand and gravel mine located southwest of Victoria, BC on Vancouver Island. As the mine is nearing the end of its operational life, the owners retained SYLVIS to fabricate biosolids growing medium for use in vegetation establishment and conversion of the mine site to residential and recreational uses. Feedstock ingredients were sourced and over 40 different soil blends were fabricated based on the ratios established by the optimization model. Evaluation of selected mixtures identified those that met the OMRR requirements and were suitable for the final use objective. A covered biosolids storage facility and asphalt mixing area were established on site in 2005. In 2006, approximately 4,600 wet tonnes of biosolids were recycled, generating approximately 13,000 m³ of biosolids growing medium. The biosolids growing medium facility is a partnership between Lehigh Northwest Materials, local regional districts (the biosolids generators) and SYLVIS Environmental.
CONCLUSIONS
Biosolids growing medium is a biosolids soil product derived from the combination of biosolids with inorganic and organic feedstock materials. Both the biosolids used to produce biosolids growing medium and the biosolids growing medium itself must meet quality criteria regulated under the BC OMRR. Biosolids in other jurisdictions meeting unrestricted use and distribution criteria could be used in a similar manner.

The OMRR requirements for biosolids growing media are designed to be protective of human health and the environment. They are not designed to ensure vegetation establishment. An OMRR compliant biosolids growing medium may not resemble what is typically thought of as a productive soil for vegetation establishment.

Before attempting to fabricate a biosolids growing medium it is essential that the final use objectives be established. Knowledge of final use objectives is required to develop a biosolids growing medium that will have the characteristics necessary to meet the objectives.

Developing a suitable biosolids growing medium requires identification and characterization of feedstock ingredients, determination of the correct proportion of these ingredients, and selection of appropriate mixing technologies. To determine appropriate feedstock ingredients the materials are analyzed and a computer model used to assess different formulations and the potential to meet regulatory compliance. Development of laboratory scale mixtures and regular sampling and analyses ensure that the biosolids growing medium meets the regulatory criteria, as well as nutrient and fertility requirements needed to sustain vegetation.

Existing mixing technologies proved difficult to adapt for use with biosolids. Based on experience and ongoing technology development, optimum product quality was achieved with a modified horizontal auger mixer.

Knowledge of regulatory criteria, final soil use objectives, soil fertility and physical requirements, feedstock characteristics, formulations and mixing logistics are essential to ensure the production of an aesthetically acceptable biosolids growing medium that meets regulatory requirements and client specifications.

Biosolids growing medium provides a unique biosolids management option. It provides a local, cost effective opportunity to use biosolids as a feedstock in an existing product that is accepted and understood. It also provides an opportunity for ongoing public education in local initiatives thus furthering awareness and understanding of biosolids.

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