Biosolids use in gravel pit reclamation

M.D. Van Ham*, M.A. Teshima* and L.M.B. Dampier

* SYLVIS Environmental, 427 Seventh Street, New Westminster, British Columbia, Canada V3M 3L2
(E-mail: mvanham@sylvis.com; mteshima@sylvis.com; ldampier@sylvis.com)

Abstract: The soil and overburden from gravel pits and aggregate mines generally lack the properties required for sustainable vegetation establishment and implementation of final land use objectives. Gravel pit reclamation projects in southwestern British Columbia (BC), Canada incorporate liquid and dewatered biosolids; biosolids amendments and biosolids soil products for soil improvement and fertilization. The form, quality and quantity of the biosolids used are dependant on the final land use objective. These BC examples present the evolution of biosolids use in gravel pit and aggregate mine reclamation, beginning with basic land application to innovative projects where biosolids were utilized in the construction of an artificial wetland, establishment of poplar plantations, development of regional park lands and, re-development of quarry operations for urban, residential and recreational land uses. Long-term monitoring of groundwater and surface water have shown that biosolids can be used in gravel pit reclamation with no adverse effects on water quality. The addition of organic matter in the form of biosolids and biosolids soil products provides soil stability and nutrient availability in a cost-effective manner. Improved soil properties created by biosolids amendments demonstrate environmental stewardship and support a variety of gravel pit reclamation objectives throughout North America.

Keywords: Gravel pit, park, poplar, reclamation, wetland

INTRODUCTION

In gravel pit and aggregate mining a surface layer of material, referred to as overburden and ranging from several centimetres to metres in depth, is removed to expose the desired raw materials, including sand, gravel and stone which are subsequently extracted, crushed, washed and sorted. The extraction and processing of aggregate materials results in the production of overburden and wash fines that are stockpiled and redistributed throughout the mine site. These materials typically lack the physical, chemical and microbiological properties to support plant growth, and are susceptible to erosion from wind and water. Without amendment or fertilization, vegetation establishment is difficult. Additionally, the coarse-textured nature of these materials facilitates the movement of water and leachable constituents through the soil profile, posing a potential adverse effect on groundwater. This problem is exacerbated in areas that experience significant precipitation, such as southwestern British Columbia (BC).

Poorly developed soils, characteristic of gravel pit and aggregate mine sites, are susceptible to colonization by invasive plant species. In southwestern BC, the establishment Scotch broom (Cytisus scoparius) on un-amended overburden and wash fines is common. Scotch broom is a legume that derives nitrogen from the atmosphere, enabling it to thrive in low-fertility soils. The spread of scotch broom can destroy wildlife habitat and shade out native grasses, shrubs and tree saplings. Further attributing to the propagation of scotch broom is its rapid growth and production of seeds that can survive in the soil for up to 30 years. Rapid establishment of native and managed vegetation minimizes the colonization of invasive/exotic species.

Chemical fertilizers are often used to supply nutrients in gravel pit reclamation. While using chemical fertilizers can facilitate quick, short term establishment of vegetation, this growth typically dissipates in successive years, particularly if fertilizer is not reapplied on an annual basis. This is due to the inability of chemical fertilizer to provide organic matter necessary for the improvement of soil physical properties. A lack of organic matter in the soil does not provide for moisture and nutrient retention, and can inhibit the establishment of soil microbial populations (Brady, 1990). Chemical fertilizers can also pose significant environmental risks to water quality.
when used in reclamation, particularly if they are over-applied (Wilden et al., 2001). Unless commercial fertilizers are treated to slowly release nutrients, their application tends to result in the development of a large pool of available, mineralized nitrogen (N). Excess mineralized N not immediately assimilated by plants is susceptible to leaching or run-off, which can lead to deleterious effects on groundwater and surface water quality.

Benefits of Biosolids Use in Gravel Pit Reclamation

In the 1970s, the genesis of biosolids use in mine reclamation was borne out of sustainability issues facing the mining industry and municipalities. Increased demand for coal through the mid-20th century and a preference for surface mining technologies resulted in vast areas of heavily disturbed land, particularly in the midwest United States. Concurrently, municipalities were faced with biosolids management challenges as populations increased and conventional disposal methods such as ocean discharge and landfilling were deemed environmentally deleterious management options (Sopper et al., 1982).

Biosolids have been used in aggregate mine reclamation to achieve reclamation objectives. The two primary benefits of biosolids are their ability to improve soil fertility through the addition of nutrients, and soil physical properties through the addition of organic matter and organic carbon (e.g. Stehouwer, 2006).

Biosolids are a significant source of micro and macronutrients. Due to the high organic matter and treatment processes, the macronutrients in biosolids such as N and phosphorus are primarily in organic forms unavailable to plants. However, upon application, these organic sources of nutrients are mineralized to plant available forms. The “slow-release” properties of the nutrients within organic residuals prevent the release of excess, mobile nutrients that can leach into adjacent water features and present toxicity concerns (Sarkar et al., 2005). This rate of release is controlled by the forms of nutrients and the forms of carbon in the organic residuals which regulates the rate of availability of the nutrients over time. The addition of organic residuals to soil can also increase the microbial activity in the amended soil (Rogers and Smith, 2007), which can lead to improved soil respiration and microbial decomposition rates, enhancing biogeochemical nutrient cycling.

Biosolids also improve physical properties of disturbed soils by increasing the organic matter and organic carbon content of the soil. Research has demonstrated that organic carbon provided through the addition of biosolids improves soil aggregate stability and decreases in bulk density (García-Orenes, et al., 2005). Further to the benefits related to physical properties provided by biosolids, Basta et al. (2005) discusses the ability of biosolids to reduce the phytoavailability of trace metals through their adsorption by organic matter and metal oxide surfaces that comprise a substantial component of biosolids. These sorptive properties of biosolids have generated interest in evaluating the use of fabricated or ‘tailored’ soils incorporating biosolids to amend contaminated soils containing elevated concentrations of copper, lead and zinc.

In addition to the aforementioned benefits, biosolids are microbiologically diverse media and can provide soils with beneficial microorganisms that assist in the degradation of organic matter, suppression of plant diseases (Loschinkohl and Boehm, 2001) and cycling of nutrients. Finally, the use of organic residuals in reclamation provides a regionally sustainable and environmentally protective alternative to non-beneficial biosolids management options.

SOUTHWESTERN BC BIOSOLIDS RECLAMATION EXPERIENCES

Four case studies related to biosolids use in gravel pit and aggregate mine reclamation are provided in the following section. The programs are presented to demonstrate the evolution of biosolids use in gravel pit and aggregate mine reclamation from basic land application to innovative and creative uses of biosolids in high profile reclamation projects.

Due to the generally coarse textured soils present on gravel pit and aggregate mine sites, and high winter rainfall in southwestern BC, leaching losses of plant essential nutrients and the movement of these constituents into groundwater is of concern. Groundwater and surface water quality monitoring programs accompany some of these reclamation programs to ensure that biosolids use remains protective of the aquatic environment.
Resort Municipality of Whistler – Emerald Forest

In 2001, the Resort Municipality of Whistler (RMOW) identified two significant reclamation and restoration projects. One of the projects the RMOW identified was the reclamation of one of two orphaned gravel pits. This location was recognized as a priority reclamation area within the designated RMOW conservation lands, as its revegetation would contribute towards the completion of an important wildlife corridor in the Whistler valley bottom. The disturbed areas of the gravel pit were composed of nutrient deficient, coarse textured sand and gravel, and were highly compacted in areas subjected to repeated vehicle traffic. Anthropogenic use of the gravel pit perpetuated the disturbance, preventing the establishment of pioneer colonizers in all but the perimeter of the disturbed area.

Class A biosolids produced by the RMOW were identified as a suitable organic residual to amend the underdeveloped soils for establishment of vegetation. The biosolids were mixed with ground yard waste at the Municipality’s landfill to create a fabricated biosolids amendment. Prior to application, the orphaned gravel pit was contoured. While the site was very permeable, a berm was created around the perimeter of the gravel pit to prevent any overland flow from leaving the application area during incorporation and vegetation establishment.

In October 2001, 109 dry tonnes of biosolids and 497 dry tonnes of yard waste were mixed together, transported to the gravel pit and evenly applied and incorporated to a depth of 0.15 m. Following application, volunteers from the community assisted with the planting and seeding of native trees, shrubs, grasses and wildflowers. The use of biosolids and ground yard waste resulted in the restoration of the gravel pit and the development of urban parkland.

“Pit to Park” – Aldergrove Lake Regional Park Gravel Pit Reclamation

In 1969, the Greater Vancouver Regional District (GVRD) purchased a portion of land for inclusion in the Aldergrove Lake Regional Park, located approximately 60 km east of Vancouver. Despite owning the land, the GVRD did not possess mineral/resource extraction rights to the site, and these were subsequently purchased by Valley Gravel Sales. Prior to excavation of the property, the GVRD developed a partnership with Valley Gravel Sales to ensure that site development would proceed in a manner that would not compromise the long-term objectives of the land (i.e. establishment of parkland). This partnership also required that Valley Gravel Services restore the site to a desired grade and place native topsoil on the site following completion of its extraction operations. The GVRD was responsible for park planning and supplying biosolids.

Operational reclamation of the gravel pit was initiated in 1999. Shortly before application, 930 bulk tonnes of GVRD biosolids and 3,918 bulk tonnes of compost were delivered to the site, and mixed with native soil at a volume ratio of 1:1:4 compost:biosolids:native soil. This mixture was applied to 11 hectares of the mine site, incorporated to a depth of 0.15-0.30 m and seeded with a sports turf seed mixture. The reclamation of the mine included the establishment of a lake used for canoeing and providing habitat for waterfowl, amphibians and other wildlife (Figure 1).

Figure 1 Aldergrove Lake Regional Park created using biosolids and compost
A component of environmental monitoring at the Aldergrove Lake Regional Park reclamation program was the monitoring of five water sampling sites for two years following the first application of biosolids. The five water sampling sites consisted of three residential groundwater wells, a groundwater well on the reclamation site, and a surface water site in the canoeing lake created using the fabricated biosolids soil. Sampling was conducted every three months for the first year and every six months for the second year.

Park development objectives were achieved with no adverse water quality impacts. The biosolids and compost applications did not have a negative effect on the water quality of the canoeing lake. The concentrations of the analyzed constituents did not exceed the aquatic life and drinking water quality standards. Although nitrate concentrations varied throughout the sampling period, they were always well below regulatory limits. These fluctuations were likely due to natural seasonal cycles. Nitrate concentrations rose during the cooler parts of the year when photosynthesis and nitrate reduction rates decrease dramatically. The park well monitoring did not reveal any negative impacts to groundwater resulting from biosolids applications. The water quality from the residential wells remained unchanged throughout the sampling period in comparison with pre-application concentrations (SYLVIS Environmental, 2001).

Producers Pit – Biosolids Soil Fabrication

Producers Pit is a 200 hectare sand and gravel mine owned and operated by Lehigh Northwest Materials, and is located approximately 20 km southwest of Victoria, on Vancouver Island in British Columbia. As the mine nears its scheduled closure, there existed a need to develop and implement a reclamation program that was in theme with the unique final land use objectives. Rather than typical reclamation objectives of returning the land to native vegetation, the mine will be developed into a subdivision. This comprehensive development includes residential properties, greenways, two schools, ten parks and waterfront village center, and will be home to up to 10,000 people.

Reclamation objectives are two-fold – to establish permanent vegetation on portions of the mine site in transition to parks, greenways and playgrounds, and to establish temporary vegetative cover to minimize erosion and improve visual quality prior to subsequent development. The mine identified the opportunity to use biosolids in their reclamation activities; however, due to the proximity of the mine to residential and commercial properties and major thoroughfares, the land application of biosolids alone was not a feasible option. The development of fabricated soil using biosolids was proposed. Incorporating biosolids as part of a fabricated soil prior to land application would reduce odour concerns for nearby residents, and would allow the uniform distribution of a fertile, aesthetically appealing soil throughout reclaimed areas of the mine site.

Wood waste from land clearing, wood shavings and sawdust were used as carbon sources; biosolids from the Capital Regional District’s Saanich Peninsula Wastewater Treatment Plant and Nanaimo’s French Creek Water Pollution Control Centre were used as a nutrient source, and sand and sedimentation pond fines from Producers Pit were used as a structural material. The objective of soil development was to fabricate soils using high quality feedstocks to produce growing media that comply with biosolids growing medium standards. Compliance with the Organic Matter Recycling Regulation (OMRR) (British Columbia Ministry of Water, Land and Air Protection, 2002), the regulation governing biosolids use in BC, allows for the distribution and application of biosolids-based fabricated growing media without permit, approval or volume restrictions.

An iterative approach was utilized in the testing and refinement of biosolids growing media. Over forty fabricated soils were blended in an initial product development phase. These soils underwent a primary evaluation based on visual aesthetics, odour, colour and texture. Soils with the best aesthetic properties underwent a secondary evaluation which included analysis for quality based criteria to assess fertility and the ability of the soils to meet regulatory requirements stipulated in the OMRR. Of the soils developed, three were selected for operational production.

A soil mixing facility on the mine site includes a covered building for storage of biosolids, stockpile areas for other feedstock and dedicated soil mixing equipment. In 2006, approximately 4,000 bulk tonnes of biosolids were recycled in the production of 14,000 m$^3$ of soil for use in mine reclamation activities. An estimated 50,000 m$^3$ of biosolids soil will be required to fulfill final redevelopment objectives.
Sechelt Mine Organic Reclamation Program

Located on BC’s Sunshine Coast, Construction Aggregates Limited’s Sechelt mine is the largest sand and gravel mine in Canada, occupying in excess of 250 hectares and producing 5-7 million tonnes of product per year. Aggregates extracted and processed at the mine site are shipped by barge to depots on the BC mainland, or shipped to international destinations by ocean-going freighters. After identifying reclamation as a significant challenge and important component of their operation, the Sechelt mine explored the opportunity to use biosolids in their reclamation activities.

Biosolids use at the Sechelt mine began in 1997. The initial research and demonstration project involved the application of biosolids and other residuals to retaining berms visible from the town of Sechelt. The results of this demonstration project were two-fold. The project demonstrated to mine staff, the community and other stakeholders the benefits of biosolids use in improving physical and chemical properties of soil and subsequent vegetation establishment, and increased stakeholder support of the use of biosolids through visual evidence, education and awareness.

The Sechelt mine’s reclamation program is nationally recognized, serving as model not only for biosolids recycling, but also for regional sustainability. The mine utilizes all regionally provided biosolids and can also use locally produced pulp and paper sludge and lime residuals in reclamation activities.

Based upon a decade of local experience, two innovative projects utilizing biosolids have been recently implemented at the mine. Over the spring of 2004, a wetland was established using biosolids fabricated soils, and in spring of 2004 and 2005 two poplar plantations were established that utilize liquid and dewatered biosolids as fertilizer and a source of irrigation.

Due to the large volume of impermeable clay that settles out of the process wash water, a decommissioned sedimentation pond can form an artificial water table and depressions in the surface can fill with water. During the spring of 2004, one water-filled depression was transformed into a wetland habitat. The formation of the wetland was initiated by contouring the slopes leading into the depression. Undulations and slope discontinuities were established using mine site overburden. This overburden serves to elevate the surrounding riparian zone from the water table. An island was created by excavating a deep trench around a shallow edge of the basin. To address the fertility deficiencies evident in the applied overburden, and to improve the establishment of a functional wetland, a biosolids amendment was fabricated for use around the wetland. This fabricated soil was placed in and around the pond. Large stumps and rocks were placed throughout the planting zone to improve slope stability and create micro-habitats for both flora and fauna. The area was planted with a variety of native trees, shrubs and herbaceous plants and seeded to grass and wildflowers. Aquatic vegetation was established through transplants, willow cuttings and cultured native plants.

The pond retains water during the dry summer months and has a fixed overflow to maintain a constant water level during the winter rains. Surface water drainage from adjacent roadways is directed into the wetland. The wetland serves to moderate, and effectively filter surface run-off. The wetland is the centerpiece of a planned wildlife corridor that will span the width of the mine site, allowing animals to safely traverse the property. Water quality monitoring after biosolids product placement and planting identified minor increases in total organic carbon and electrical conductivity. There was no mineral nitrogen detectable in the water and phosphorus concentrations were low.

Elsewhere on the mine site plantations of fast-growing hybrid poplar have been established. These poplar plantations provide education and employment opportunities for the Sechelt Indian Band and other community members. The plantations are irrigated and fertilized with liquid and dewatered biosolids; the rapid growth and nutrient requirements of these trees enables repeated applications of biosolids. The maintenance of the plantations provides education and employment opportunities, and will provide an economic return upon harvesting in 12-15 years. To date, approximately 10,000 poplar trees have been planted in two plantations over 23 hectares of the mine site.
An extensive environmental monitoring program at the mine ensures biosolids and other organic residuals are used in an environmentally protective manner. The water monitoring sites on and adjacent to the mine site include groundwater wells and surface water monitoring from a creek at locations upstream and downstream of the mine site. Water is sampled on a quarterly basis and analyzed for nutrients, trace elements and microbiological parameters. The long-term monitoring program has not identified any deleterious effects of biosolids use on surface or groundwater features.

SUMMARY
Regionally, local market development and cost-effectiveness have made the use of biosolids in gravel pit and aggregate mine reclamation an increasingly attractive option for biosolids management. The projects presented above provide examples of several different methods by which biosolids can be utilized to achieve reclamation objectives. Class A and Class B biosolids as both dewatered cake and liquid, can be used alone, or in combination with other organic residuals and high quality feedstock to create soil amendments and fabricated growing medium. The use of biosolids in these capacities has facilitated the achievement of reclamation objectives ranging from the establishment of agronomic grasses to the development of wetland habitats.

The prudent management of biosolids, as with any amendment of fertilizer is important in the protection of aquatic resources. It is important, however to consider biosolids use in comparison to other amendments. It is possible that minor increases in nitrate may be observed in water resources for a short duration. Under appropriate management these increases will be minor, within regulatory limits and not atypical of nitrate concentrations found in water bodies in the natural environment.

Biosolids use in gravel pit and aggregate mine reclamation in southwestern BC has developed substantially over the past decade. The evolution of biosolids utilization results from building upon education and experiences, both good and bad, and the development of projects made possible through prudent biosolids management, diligent environmental stewardship and ongoing education and consultation with stakeholders. The aggregate mine reclamation projects at the Producers Pit and Sechelt sites currently represent the leading edge of regionally supported, cost effective and innovative use of biosolids in aggregate mine reclamation and research.

REFERENCES


