DISCUSSION PAPER NO. 7

Disclaimer
Table of Contents

Capital Regional District

**Core Area and West Shore Sewage Treatment
Biosolids Management**

Issued: March 21, 2007

---

1 Objective

The objective of this discussion paper is to identify a “representative technology” for the biosolids management facility and to develop a facility concept for inclusion in the overall wastewater option analysis.

Under the options developed in Discussion Paper No. 5, there could be between one and four wastewater treatment plants. The options all assume that final biosolids processing will occur at a site remote from the plants. Dewatered sludges will be hauled by truck to this site. This is consistent with the previous planning work (Dayton & Knight, 2004) and the current LWMP.

An environmental and social review (ESR) was carried out in 2004 by the Westland Resource Group Inc. on two candidate biosolids facility sites (Westland, 2004). These two sites are termed the Millstream site (on Millstream Road in Highlands) and the Hartland site (on the north end of the Hartland landfill in Saanich). Westland evaluated potential environmental impacts on soil, water quality, plant and animal life. They also considered the social impacts due to odour, traffic and visual aesthetics on land use, neighborhoods, property values, archaeology and heritage. They concluded that the potential impacts from the construction and operation of a biosolids facility, at either location, could be mitigated to a less than significant level.

The Hartland site appears to have some advantages in that it is contiguous to the landfill, has space availability, appropriate zoning and good access points. It also appears to offer opportunities for the co-treatment of biosolids, with source-separated organics to be diverted from the landfill. However, the feasibility, costs and benefits of co-management of biosolids and source-separated organics at Hartland need to be fully evaluated in a separate study.

For the purpose of this discussion paper, we have thus assumed that the biosolids management facility would be located at the Hartland site.

2 Treatment and Resource Recovery Technologies

Discussion Paper No. 3 - Technology Assessment - included consideration of several biosolids analysis, primarily because they are currently still unproven at the required scale for the CRD application. The technologies that passed the initial pass/fail analysis were then subjected to a second evaluation, based on a weighted scoring over several different criteria. These options were ranked for suitability as Very High, High, Medium, Low and Very Low.

For the purpose of this discussion paper, we have considered technologies options that were ranked as High or Very High in DP 3 in the development of the “representative technologies”. These technologies are listed in Table 7-1.

Table 7-1
Biosolids Management Options Remaining for Further Consideration

Technology	Ranking in DP 3
Waste Biological Sludge Reduction Processes	Very High
Thermophilic Anaerobic Digestion	Very High
Mesophilic Anaerobic Digestion	High
Biosolids stabilization using landfill bioreactors	High
Digester or biogas gas utilization in internal combustion engines	High
Biosolids land application	High

These technology options are discussed further in Section 3 of this discussion paper.

3 Estimated Biosolids Quantities

Sludges generated at the various plants considered in the five wastewater management options are handled in various ways. The decentralized plants are assumed to be “liquid stream treatment only” plants. Sludges generated from the primary and secondary treatment processes are thus discharged into the downstream sewer system. Similarly, the sludges from the Clover Point wet weather plant are returned to the downstream sewer. In both cases, these dilute sludges are mixed with the raw wastewater flow and ultimately treated at the Macaulay Point plant.

For the purpose of developing biosolids quantities, we have assumed a unit generation rate based on a per capita approach. The mass of sludge generated is thus independent of the transport of sludge in the conveyance system.

The base data is as follows:

Biochemical Oxygen Demand (BOD) generation rate:	80 g per capita / day
Total Suspended Solids (TSS) generation rate:	70 g per capita / day

TSS removal in primary treatment (average):	50%
BOD removal in primary treatment (average):	20%
BOD removal in secondary treatment:	90%
BOD conversion to TSS cell yield in secondary treatment:	65%
Dry solids in dewatered undigested sludge:	30%
Ratio of maximum month to average conditions:	1.4

The calculations yield the following results:

Year	**Total Sludge Production (dry tonnes/day)**	**Dewatered Sludge Volume (cubic metres / day)**
2015	26.8	85.2
2030	31.4	99.6
2045	36.0	114.2
2065	42.1	133.5

These figures can be put into perspective by considering the number of truck haul trips from a plant site. The largest wastewater treatment plant site being considered is the single regional plant site under Option 1-2. This secondary treatment plant, which would treat the entire wastewater flow from the Core Area and West Shore would have a secondary design capacity of 320 ML/d. Based on the use of 27 cubic metre covered sludge trucks, this size of plant would require, on average 5 one-way truck trips per day, to haul the dewatered sludge to the biosolids management facility. Under maximum month generation conditions, the number of trucks could increase to 8. For options that utilize the Macaulay Point plant as the “centralized” plant, the truck haul numbers would be similar since the sludge, from the “liquid treatment stream only” plants, is transported to Macaulay Point through the conveyance system

For some options, developed in Discussion Paper No. 5, it may be feasible to pump unthickened liquid sludge, from the wastewater treatment plant to an intermediate dewatering site, located a few kilometres from the plant site. This would reduce the amount of truck traffic through residential areas, adjacent to the wastewater treatment plant. The intermediate dewatering facility would be located on the trunk sewer system, so that the centrate from the dewatering operation could be returned to the wastewater treatment plant. The dewatered sludge cake would then be trucked from the intermediate dewatering facility to the biosolids management facility.

4 Selection of Representative Technologies

Section 2 of this discussion paper summarized six technologies that were ranked High or Very High for consideration in biosolids management. Additional discussion on each technology is provided below with a conclusion on its inclusion as a representative technology for the biosolids management facility.

4.1 Waste Biological Sludge Reduction Processes

Primary solids are comprised of inorganics and organics. The organics in primary sludge are relatively easy to degrade further in a digester or composting system. Primary sludge also contains the types of anaerobic and facultative anaerobic bacteria that do the bulk of the digestion in an anaerobic digester.

The solids in secondary sludges are mostly bacterial cell matter resulting from the conversion of soluble and colloidal organics in the primary effluent to bacterial cells. The contents of the cells can easily be degraded in a digester but getting the contents out of the cell membrane can take time. As a result, if there were processes to improve the breaking open of the cell membranes, digestion could proceed quicker and with better biogas production. There are two relatively new methods that can be used to break open the bacterial cells in waste secondary sludges. These are ultrasonic lysing and high pressure lysing.

While both these technologies look promising, the difficultly in the CRD situation is that the primary sludges and secondary sludges are combined prior to being trucked to the biosolids management facility. The ultrasonic lysing technology could be still be used to precondition a portion of the sludge stream, once it reaches the biosolids processing facility. This would provide greater efficiencies in the digestion process, due to the cell breakdown, yet still retain an adequate seed in the untreated sludge stream for the digestion process. This technology is thus retained as part of the representative technology matrix.

4.2 Anaerobic Digestion

Anaerobic digestion is one means by which the treatment plant sludges can be treated to create a product that can be beneficially used as a soil amendment in land application programs. Anaerobic digestion, as the name implies, occurs in the absence of oxygen, in warm liquid slurry of about 3% dry solids. There are two main temperature options for anaerobic digestion of sludge: mesophilic digestion and thermophilic digestion.

Mesophilic digestion occurs at 37 ^{o}C, or approximately normal human body temperature. Mesophilic digestion requires in the order of 21 days hydraulic retention time to adequately stabilize the sludge by reducing the organic content of the sludge. Provided that the metals content in the raw sludges are low enough, mesophilically digested sludge, like that from the GVRD’s Lulu Island treatment plant, will typically meet the BC Organic Matter Recycling Regulation (OMRR) Class “B” requirements for pathogen content and organic stabilization. This allows land application of the biosolids but with restrictions regarding access by the public and animals. In contrast, thermophilic digestion occurs at warmer temperatures, i.e. 55 ^{o}C, and at shorter detention times, 10 to 15 days, to accomplish the same degree of sludge stabilization. Thermophilically digested sludge can typically meet the OMRR Class A requirements for pathogens.

While the main focus of the anaerobic digestion is to decrease the organic content of the sludges and, thereby, stabilize them against further degradation in a land application program, the digestion process also creates a methane-rich biogas. Biogas from an anaerobic digester is about 60% to 65% methane and, as a result, has a significant calorific value. Methods of recovering energy from digester biogas include boilers, internal combustion engines, microturbines and fuel cells.

This process is selected as part of the technology mix for the biosolids management facility.

4.3 Landfill Bioreactors

Most landfills in North America have been built with water resistant covers that help to keep moisture out of the landfill. As result, the microorganisms present in the waste often do not have the level of moisture that they need to flourish and breakdown and stabilize the organics in the landfill. Consequently, most North American landfills tend to be dry tombs for long term storage of solid waste.

Some countries, including Denmark, as early as the late 1970’s and early 1980’s, realized that the key to stabilizing the organics in their landfills was to provide adequate moisture to the landfill to allow the bacteria and fungi to flourish and rapidly degrade the organics in the landfill. The result was the first landfill bioreactors, the purpose of which was to stabilize the waste quickly and, while doing so, create landfill biogas that could be used through a biogas reuse system of some type.

Based on the above, one of the options to recover the energy from the CRD’s wastewater treatment plants would be to mix the dewatered digested or undigested biosolids or sludges in with municipal solid waste (MSW) in a landfill bioreactor and allow the anaerobic conditions in the landfill to create the biogas for energy recovery. This has the advantage of not requiring separate sludge digestion as well as having no need to rewater the dewatered sludge cakes from the treatment plants. In addition, there would only be one common gas collection, treatment and utilization system that would serve both the MSW and the biosolids and sludges. This could be especially advantageous at the Hartland Road landfill, since all of the CRD’s MSW go to this location. Landfill costs would go up because of the necessary biogas infrastructure as well as the need for a tighter final capping system to alleviate concerns about uncollected biogas (with its 60% to 65% methane content) leaking out of the landfill, causing an increase in greenhouse gas.

While this technology clearly has potential future application, the feasibility of managing all of the generated sludge in this manner is questionable. This process is not selected as the representative technology but could be considered for pilot or demonstration testing.

4.4 Biogas Utilization

At this point in time, the most likely scenario for viably treating CRD wastewater treatment sludges and recovery of energy is to digest the sludges thermophilically to create Class A biosolids with biogas capture and utilization. There are several options for energy recovery from biogas from treatment plant sludge digestion. The most common of these include the following:

- *Combustion of the biogas in a boiler with utilization of the steam as heat and recovery of heat from the boiler exhaust stack and the condensed steam.* This is a fairly common approach in medium sized wastewater treatment plants.
- *Combustion of the biogas in an internal combustion piston-style co-gen engine connected to an electrical generator or an influent pump, with heat recovery from the engine coolant system and the exhaust gas stack*. This is standard practice at many larger treatment plants including the Annacis Island WWTP and the Iona Island WWTP.
- *Combustion of the biogas in a turbine-style engine connected to an electrical generator or pump with heat recovery from the engine cooling system and the exhaust gas stack.* This is a growing trend with the cost of microturbines coming down and the efficiency of turbines improving.
- *Utilization in a fuel cell to create electricity and heat with low grade heat recovery off the fuel cell cooling water.* Fuel cells are the emerging technology for biogas utilization. At this point, their capital cost and operating costs are much higher than the boiler, internal combustion engine and microturbine alternatives.

Recent studies (WEF, 2007) have concluded the least expensive means of developing a cogen system producing electricity and heat was high efficiency internal combustion engines. For the example situation, the capital cost for the high efficiency internal combustion engines was $700,000 per 1000 kW and $14/1000 kWh for operating costs. In contrast, microturbines had a capital cost of $1,100,000 per 1000 kW with operating costs of $20 per 1000 kWh. Fuel cells, while they hold some promise, would have had a capital cost of $6,000,000 per 1000 kW with operating costs of $20 per 1000 kWh.

High efficiency internal combustion engine-drive cogen systems are thus selected as part of the representative technology for the creation of electricity and heat from the biosolids-derived biogas. The electricity could be sold to the power distribution grid. The heat could be used in the biosolids processing or sold to complimentary commercial operations, such as greenhouse vegetable production, located on adjacent properties.

4.5 Biosolids Land Application

Dewatered treated biosolids has many characteristics that can make it suitable for beneficial reuse through land application. It has moisture holding capacity very similar to peat moss so that it can help a poor soil to hold moisture. In addition, dewatered treated biosolids contain phosphorus and ammonia nitrogen that give it some of the characteristics of a slow-release fertilizer. As such, dewatered treated biosolids can be beneficially reused in many ways, especially if it is treated in a manner such as thermophilic anaerobic digestion, to reduce the pathogen content to below "Class A" requirements under the BC Organic Matter Recycling Regulations (OMRR). Some of the options for beneficial reuse of Class A biosolids include:

- Agricultural application (most likely with sub-surface injection to mitigate odour concerns)
- Forestry application to improve tree growth in existing and newly planted areas
- Decommissioning and restoration of forestry roads
- Reclamation and rehabilitation of mineral extraction mines, including large open pit mines as well as smaller gravel pits
- Creation of value-added products including top-soil substitutes through blending with other materials including sand.
- Final vegetative cover on a landfill.

Land application, using one or more of these methods, is thus considered part of the representative technology for the biosolids management facility.

5 The Biosolids Management Facility

Based on the above discussion, the most likely means to both recover energy and create a product that can be used in a beneficial reuse program for the future CRD sludges would be a system comprised of thermophilic anaerobic digestion system followed by dewatering and land application of the digested biosolids and internal-combustion driven cogeneration of electricity and heat for the biosolids-derived biogas utilization. For the purposes of this exercise, it is assumed that sludge digestion would be based on receiving dewatered sludge cake at a single location with multi-stage thermophilic digesters, such as those used at the GVRD's Annacis Island WWTP.

To accomplish this digestion and energy recovery, a series of steps and facilities will be necessary. These would include the following components:

- Dewatered sludge cake rewatering and conditioning
- Primary digesters, fed in parallel
- Secondary digesters, fed in series from the primary digesters
- Biosolids dewatering
- Odour control
- Cogeneration biogas utilization

The conceptual details of these components are discussed below. It should be noted that the intent of this biosolids management facility would be that it will designed to not preclude the use of other complementary technologies in the future. For example, this could include fuel cells for biogas utilization instead of internal combustion engines.

Estimated costs for the biosolids management facility are contained in Discussion Paper No. 5. A description of the components is presented below.

5.1 Sludge Cake Rewatering and Conditioning

We have assumed that the sludges from the treatment plants would arrive at the new biosolids management facility as mixed primary and secondary dewatered sludge cake, at approximately 30% dry solids, in 27 m^3 long-haul trailers.

At the rewatering building, this cake would be discharged from the hauling trailer, into a live-bottom hopper, and then pumped or augered out and conveyed to a rewatering tank. The rewatering tank would be designed to take the sludge from 30% dry solids to about 6% dry solids, a reasonable concentration to be fed into the sludge digesters. Two tanks, 4 m high by 5 m in diameter (approximate liquid volume of 60 m^3) would be built. These tanks would each be large enough to provide two hours HRT mixing time, based on the daily maximum wet weather month sludge production rate in 2030. A third tank would be added in 2030 to accommodate up to the 2065 maximum wet weather month sludge production in 2065 with two tanks in service. Each tank would be equipped with two mechanical mixers and a water addition system. In 2030, the amount of water required for the rewatering process would be about 590 m^3/day; in 2065 it would be about 785 m^3. Where possible, some of this water would be recycled from the final sludge dewatering process. However, due to possibility of ammonia build-up through this recycling, the amount of recycled water will be restricted, forcing the need for freshwater make-up. During the wetter part of the year, this make-up water could be captured rainwater. In the dryer parts of the year, the water would have to come from rainwater storage ponds or from wells.

Following the rewatering, the liquid sludge would be subjected to grinding or screening to remove or destroy gross solids, including plastics and rubber goods. Once this is completed, the next step would be some form of treatment to break up the bacteria cells. Since the sludge cakes would be mixed and the rewatered sludges (at say 6% dry solids) would be mixed, it would not be possible to use the MicroSludge ™ process. However, as discussed previously, the ultrasonic bacterial cell lysing technology could be used on part of the sludge stream, provided that a portion of the 6% slurry is bypassed directly into the digester to provide a “seed” of bacteria for the digestion process.

The final step before the sludge solution is pumped into the digester would be to pass the sludge through a heat exchanger to increase the sludge temperature to close to the temperature of the digester. The two choices for heat source are hot water from a biogas-fueled boiler and the contents of the digester itself. Once the sludge has passed through one of the heat exchanger system, it would be pumped into the primary digester system.

5.2 Primary Digestion

In this situation, single stage primary thermophilic digesters would be fed raw sludge in parallel at approximately 6% dry solids content with a hydraulic retention time of between 15 and 20 days. The contents of these parallel-fed thermophilic digesters would then flow to a series of 2-day HRT thermophilic digesters, so that the possibility of short circuiting and not achieving Class A pathogen destructions, is extremely low.

It is assumed that the facility would initially be built to the 2030 capacity requirements with three primary digestion tanks, so that even with one digester out of service, there would be two primary digesters in service. At 2030, a fourth primary digester would be built to serve until 2065. Similarly, the secondary digestion tanks, in series, each with a nominal 2 day HRT minimum would include enough capacity so that with one tank out of service there would always be at least 5 days at 50 ^{o}C, with no addition of raw sludge.

Based on the design loading factors, the four primary digesters would each be 25 m in diameter and with sidewall heights of 12 m high. To improve aesthetics, the tanks would be built so that only 6 m of the sidewall is above the ground level.   These tanks would be insulated both above and below ground to conserve heat. They would also be equipped with an annular space approximately 2 m wide followed by a second, non-hydraulic, outer wall to provide space for digester piping within an enclosed, heated space.

5.3 Secondary Digestion

The secondary, series digestion tanks would be built to ensure that the digested biosolids would meet the OMRR Class A pathogen reduction requirements with 100% certainty.

The primary digesters will have already provided some initial temperature treatment, albeit with the daily introduction of raw sludges. Based on the OMRR requirements for 10 days at greater than 50° C, the design goal for this second stage of digestion would be a minimum of 10 days HRT in at least two tanks with one tank out of service. For sizing purposes, it is assumed that the primary tank digesters are able to reduce the solids content by 50%. On this basis, for the 2030 design condition, this would require three tanks, each with a volume of 4000 m^3.

5.4 Biosolids Dewatering

The biosolids dewatering building would be designed around an eventual four centrifuges. Because of their mechanical nature, the centrifuges would have approximately a 20 years operational life. On that basis, two centrifuges would be installed to provide adequate capacity to 2030, with one centrifuge down for repairs. At 2030, the first two centrifuges would be replaced and a third new one added. At 2050, the three centrifuges would be replaced and a fourth new one added so there would be adequate capacity, even with one centrifuge down for repairs.

The building would be designed with two stories, with the centrifuges on the upper level. The dewatered biosolids cake would drop through the floor to a conveyor system that would deliver the cake to one of two truck bays and distribute the cake into large long haul “cake” trucks for hauling to the land application reuse sites.

Water removed in the dewatering process (the centrate) would be recycled as much as possible back into the sludge rewatering operation. However, based on the potential for ammonia build up in the digesters because of this practice, it might be limited. There may be some possibility of using the centrate in forestry applications, as moisture and liquid fertilizer source – provided the ammonia concentration is not too strong for that application. Otherwise, the centrate could be treated in a process that removes the ammonia as magnesium ammonium phosphate crystals (known as struvite), which can be used as a slow release fertilizer. The remaining liquid could be injected into the Hartland Road landfill to assist in the degradation of the landfill organics.

5.5 Biogas Utilization

The biogas from the digesters would be first treated to remove hydrogen sulphide and siloxane to prevent corrosion in the cogeneration engines. This treatment facility would be sized to provide two redundant trains for the 2030 gas flow with a third train added in 2030 to take the system out to 2065. The generated electricity would be used locally or sold into the power grid. Surplus heat could be used in commercial operations, such as greenhouses, that would be encouraged to locate on adjacent properties.

The cogen engine systems would only be installed more or less as needed because of the relatively short life of the engines. Initially, three engines would be installed for the 2020 gas production, with replacements and additions based on a 10-year cycle.

5.6 Odour Control

The process of rewatering and mixing the raw sludge cakes and later dewatering the digested biosolids after the secondary digesters will both create odours. These odours will need to be controlled through the collection and treatment of the foul air. For the purposes of this exercise, it has been assumed that biofilters will be suitable to provide the required level of treatment.

6 References

1 Dayton & Knight Ltd. 2004. *Core Area LWMP Sludge Management Options Study*, Capital Regional District, June 2004.

2 Water Environment Federation, 2007. *Water Environment & Technology,* February 2007.

3 Westland Resources Group Inc., 2004. *Environmental and Social Review of Capital Regional District Candidate Biosolids Facility Sites, Capital Regional District*, November 2004.