Cost Control and Risk Reduction - Precepts for Developing DCWASA's Biosolids Program in the Age of Sustainability

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ABSTRACT

The DC Water and Sewer Authority (DCWASA) is developing new plans and details for sludge and biosolids processing at the 1.4 million m³/day (370-mgd) Blue Plains Advanced Wastewater Treatment Plant in Washington DC. The program includes thermal hydrolysis of sludge followed by anaerobic digestion, and will include a major combined heat and power facility to provide electrical power for the treatment plant and steam for the thermal hydrolysis process. The resulting Class A biosolids cake product will meet all Exceptional Quality criteria and will have a much broader use than the current lime-stabilized Class B product. The quantity of product will be cut dramatically.

The development of the biosolids program has included significant risk evaluation and cost assessment work. Various potential technical and procurement risks became apparent during program and project development. These included risks from increased solids production along with system performance risks, equipment procurements, and risks concerning final product quality. Methods to control the risks were identified, evaluated, and included in the program. In some cases, risk reduction caused potential cost increase, so that almost constant cost assessment has been required to minimize scope and cost pressures.

Sustainability criteria for the program include major efforts to minimize power and energy use and to generate maximum renewable power from the digester gas. This work results in significant reduction in greenhouse gas emissions for DCWASA. Also, the program features will create maximum opportunities for long-term development of value-added biosolids products.

KEY WORDS

Biosolids, risks, costs, performance, sustainability, anaerobic digestion, thermal hydrolysis, Class A, odor control, regrowth, dewatering, greenhouse gases

PROGRAM EVOLUTION

The DCWASA biosolids program has evolved over the past decade. An evaluation of the full range of solids management options in the late 1990s led DCWASA to the conclusion that the Authority should implement anaerobic digestion at large capacity. The primary goal was to reduce the quantity of Class B biosolids material that was produced and transported off-site (EPMC IV, 2001). Minimizing product quantity was perceived then (and now) as a major help in reducing the Authority's long-term risk of biosolids program cost increases, and risks from hauling longer and longer distances over time to find acceptable agricultural land application and use sites. At an average production of 1100 wet tonnes/day (1200 wet US tons/day) of Class B, lime-stabilized cake material, DCWASA operates one of the largest land application and biosolids beneficial use programs in North America.

A major constraint at the Blue Plains AWTP is the limited available footprint for new solids processing facilities. The Blue Plains plant site is highly built-out with existing wastewater and solids processing facilities. However, a rectangular area of about 2.5 hectares (6 acres) is available adjacent to the existing solids processing area, and this is the portion of the site that has received major attention in recent years as a location for additional or modified solids processing units. A design for very large egg-shaped digesters moved forward in the 2003 to 2006 period, and this included thermophilic digestion concepts to produce Class A biosolids. However, price escalation in steel and other commodities in this time-frame, limited competition for these large tanks, and other factors resulted in unfavorable pricing and risks for DCWASA, and the egg-shaped tank procurement was suspended pending further evaluation of the biosolids program.

Biosolids Management Update (2007-2008)

In 2007, an updated evaluation of biosolids management options was initiated by DCWASA. The team included experts in a variety of biosolids management and anaerobic digestion issues. Renewed examination of solids processing alternatives included several digestion options that had advanced further in recent years – these included thermal hydrolysis and acid/gas phased digestion approaches. Thermal hydrolysis followed by mesophilic digestion had been implemented at additional (and larger) wastewater plants around the world over the 2002 to 2007 period. In addition, DCWASA had conducted bench-scale testing of the process (at Virginia Tech) and results were available by 2007 (Wilson et al, 2009).

The team recognized that producing a high-quality product or products which had Exceptional Quality status and which had multiple potential uses, was a very important goal of the DCWASA biosolids program. A program with these aspects would be less affected by changes in regulations or public perceptions, and therefore was a program that contained less risk and had more long-term sustainability.

The alternatives were evaluated through economic comparisons as well as energy comparisons and climate change impacts. Other key criteria were that the processes and alternatives needed to be proven at significant scale over time, and the various options needed to be acceptable from operations and maintenance perspectives. Comparisons of biosolids product characteristics was a significant factor in evaluation, since some processes were not as proven with respect to regrowth of pathogen indicators or odor regrowth within the final cake material over time. The selected option was thermal hydrolysis with mesophilic anaerobic digestion (TH + MAD). The recommendation is defined within DCWASA's Biosolids Management Plan Update Report in December 2008.

Capacity and Cost of Recommended Plan

The recommended capacity for the selected option (TH + MAD) was determined to be 410 dry tonnes/day (450 dry US tons/day). Assuming the Cambi™ Thermal Hydrolysis Process was utilized, this would require four process trains with six reactors per train. This was sufficient capacity to process the sludge production at the Blue Plains AWTP on an average and peak month basis. However, this capacity would fall short of handling the higher peaking period solids production quantities. Therefore, the existing lime stabilization process would be required to remain in service at some capacity to handle the peak production periods. The biosolids program budget at DCWASA was adjusted to accommodate the new recommendations - total program budget was identified at $407 million. This includes engineering and construction costs, as well as construction management and startup functions.

PROGRAM DEVELOPMENT (2009-2010)

In early 2009, DCWASA's biosolids program management team began detailed work and development for the updated biosolids management plan. Several issues required further assessment to refine the concepts and approach, and there were potential technical and procurement risks that needed to be evaluated. Any significant risks would require specific activitites to make them manageable. The following sections summarize this evaluation and assessment work which was largely aimed at risk reduction while keeping costs under control.

Solids Projections

Evaluation work indicated that the Blue Plains AWTP has been accepting influent load increases over the past decade, despite reductions in plant influent flowrate. Plant flows have dropped for several reasons including the effects of water conservation and effects of constructing tighter sewers in more modern times (limiting groundwater inflow), but also because the Authority has limited the backflow of river water into the combined wastewater collection system. The affect of these measures is that greater solids production can be accommodated within the plant's design flow capacity. The solids production estimates since 2003 have steadily climbed, showing that a 20 percent increase in average solids production is now planned for the same future, 370-mgd design condition (see listing below). However, some of this increase (several percent) is caused by further treatment requirements mandated to remove additional nitrogen from the wastewater.

	Ave. Solids Production at 370-mgd flow*
Estimate made in 2003	330 dry tons/day
Estimate made in 2007	370 dry tons/day
Estimate made in 2009	397 dry tons/day

*at digester feed location, in all cases, to be comparable

Peak solids production estimates have also been modified from earlier estimates. This has been the result of more detailed examination of solids production data at Blue Plains, more complete concepts about future loads coming to the plant, better predictive tools, and additional data from other large wastewater plants with similar characteristic service areas.

The solids production estimates above do not yet include the solids that will be produced by the Long-Term Control Plan at DCWASA. This program, by 2018, will bring additional combined wastewater flows to Blue Plains for treatment during wet-weather periods, and solids will be generated by the proposed Enhanced Clarification Facility which will treat the flows. The average solids production at Blue Plains will be increased only a small amount by this program, but the peak period production could be significant. The projections above also do not include a possible Fats-Oils-Grease (FOG) program that may bring trucked FOG material to the TH-digestion facility to help increase digester gas production. These additional solids loads will be defined during the Spring of 2010.

With expected additional affects of water conservation in the future, coupled with likely potable water rate increases and greater awareness of the environmental consequences of water use and waste management practices, it is likely that the trend identified over the last decade at Blue Plains will extend to the future. Therefore, to minimize risks of inadequate space for capacity expansion for solids processing units, the development team is examining ways to handle even larger quantities of solids than are estimated by current conventional wastewater and solids planning methods.

Process Modelling and Plant Process Development

Process modelling for the entire Blue Plains plant is underway to examine changes being made in both liquid and solids processing. Modelling involves use of the Biowin platform and modeling experts in both North America and Europe are involved in this work. For the biosolids program, new Biowin modules have been developed for thermal hydrolysis and anaerobic digestion and are currently being refined and reviewed. The objectives of this work for the solids program include the following:

- Confirm expected performance of the thermal hydrolysis and anaerobic digestion processes under various operating scenarios.
- Expand the understanding of solids production quantities at Blue Plains, especially for peak production periods
- Assist in defining digestion conditions (especially loading rates and conditions within the tanks) and digester sizing for adequate residence times

- Improve prediction of ammonia concentrations for digestion performance and for filtrate treatment needs (ammonia removal).

Process modelling work is helping to confirm several important considerations for the biosolids program. This is giving the design teams greater confidence in these future conditions with TH + MAD, so that solids and recycle facilities are sized and engineered for best performance within budget limitations.

The thermal hydrolysis process results in the production of small amounts of hard-to-degrade or even non-degradable dissolved organic nitrogen (DON). This is of concern because of the stringent total nitrogen effluent discharge requirements for the Blue Plains plant. Research and testing showed that this recalcitrant DON could be reduced by operating the TH process at 150° C instead of 170° C. The Cambi TH-digestion plant in Brisbane, Australia operates in this manner for this purpose. Additional removal of this DON is being evaluated through collection of data from other TH + MAD plants, partial removal within the liquid treatment system, and partial potential removal within the final dewatering or final dewatering recycle treatment facilities. Even if all the recalcitrant DON material was recycled and discharged with the effluent, it would not, by itself, cause violation of the effluent requirements, but if some of it is not removed, it will place additional pressure on achieving greater nitrogen removal within the plant's denitrification treatment system. The objective is to find the right mix of DON reduction or treatment techniques that minimizes costs and risks, does not place high burden on plant operations and maintenance, yet retains very high reliability in achieving NPDES discharge requirements.

Feedstock Characteristics

The characteristics of the feedstock to the TH + MAD system have been shown from previous projects to be a critical issue. Grit removal at the headworks has been improved in recent years at Blue Plains, and the adequacy of this system is being confirmed. Debris removal from sludge is highly preferred prior to discharge to thermal hydrolysis reactors because of limited-size piping. Essentially all existing TH + MAD plants have used sludge screening processes to remove debris, and this is being developed for the DCWASA program to minimize or eliminate this risk. Debris removal also improves the quality of the final biosolids product, thus making the final product more amenable to the creation of value-added biosolids materials.

The pre-dewatering system needs to produce a cake material that has at least 16.5 percent solids to insure the proper capacity within the thermal hydrolysis process. Centrifuge dewatering has proven to be a good technology to meet this need, and to provide consistent cake solids content, thus minimizing swings in solids/moisture content that would then limit the performance of the thermal hydrolysis system. DCWASA has tested its existing centrifuges for the ability to produce cake solids in the range of 16 to 20 percent solids and the testing work indicated the units could perform well. This work shows confidence that similar machines to these will provide the necessary feed characteristics for the thermal hydrolysis process. Fine-tuning the performance of the pre-dewatering centrifuge system will have benefits to insure maximum throughput and cost-effectiveness of downstream processing.

Nitrogen content of feedstsock material affects ammonia concentration in digestion. This is significant in TH + MAD plants because of the higher-than-normal organic loading rate and high-solids thickness of digestion feedstocks. There may be little, if anything, that can be done to control the nitrogen content of primary or waste biological sludges, but dilution of the high-strength feedstock prior to digestion is almost always used to limit ammonia content in digestion to the range of 2500 to 3000 mg/l (the term 'ammonia' here includes both ammonium ion and molecular ammonia). Ammonia content above this range, for common mesophilic temperatures, has been shown to begin to inhibit biological activity within anaerobic digestion. Digestion, therefore, needs to accommodate the volume required for adequate hydraulic retention time, which is typically in the range of 12 to 15 days minimum, and preferably towards 18 to 20 days at average conditions. Analytical work on existing sludge at DCWASA is being completed to make the best predictions for future digester ammonia levels and the strength of recycle streams. DCWASA will require final-dewatering recycle treatment since, otherwise, the recycled ammonia would represent about 25 percent additional plant ammonia load.

Final Product Characteristics and Uses

One of the major drivers of the new biosolids program is to produce biosolids product(s) that will have maximum potential use in the marketplace, and products that are versatile in moving from market to market over time, thus reducing long-term risks of limited outlets or cost increases in one use sector or another. Initially, the Class A digested cake product from the new facilities is likely to be used in agricultural land application. However, DCWASA's vision is to develop higher-valued products over time and products that are more likely to be bought and sold through marketing and distribution systems. This could involve further processing of the biosolids in many different ways to produce drier products, products with more aerobic characteristics, blended products, products with higher or different nutrient content, products more appealing to the public, and products with significant energy content.

The cake product that would be the basis for further processing should be well-digested, stable, pathogen-free, have limited odor and limited odor regrowth, not be subject to pathogen or pathogen-indicator regrowth, contain minimum extraneous debris and moisture content, and have good nutrient content. Therefore, much of the assessment of optional processing methods for the DCWASA wastewater sludge over the last several years, has involved research and data-gathering that would help steer the recommended processing system toward one that would provide the desired product characteristics. The decisions to install thermal hydrolysis and anaerobic digestion were made with final product uses in mind. These decisions also involved the need for sludge screening to remove debris.

The specific technology for final dewatering of the TH/digested biosolids was also evaluated in detail because of biosolids product issues. Data on TH/digested/dewatered cakes in the UK indicated there was little concern for pathogen or pathogen-indicator regrowth even with use of centrifuges. However, there was concern for product odor regrowth in such cakes depending on the dewatering technology. Testing of both centrifuge and belt filter press cakes from TH/digested biosolids at TH-MAD plants in the UK and Europe showed that there is likely to be less odor from belt filter pressing.

High solids cakes (about 30 percent solids or higher) can be provided by either technology because of the TH process prior to digestion. This is one of the major advantages of the TH + MAD process – the ability to achieve a very well-dewatered product with relatively low energy use and reasonable polymer dose. The resulting final cake is readily handled by bulk loading equipment, and is easily stored in piles inside buildings, or on open pads, or within storage piles in agricultural fields prior to land spreading. Product risk is additionally reduced because the well-dewatered nature of the cake makes the product attractive as an energy product.

Re-Assessment of Dewatering Options

The additional future solids production quantities caused re-examination of how to utilize the 14 existing centrifuges at the Blue Plains plant. It became apparent that 10 to 14 centrifuges were required to remain in service for sludge dewatering and lime stabilization service during peak production periods. Therefore, retaining the existing 14-centrifuge system for lime stabilization service became an option that needed to be evaluated.

Several alternatives were developed to assess use of either centrifuge or belt press systems for final dewatering. The assessment also included options for pre-dewatering centrifuges since either existing or new machines might be used for this purpose. The development of the options was highly dependent on the increased solids production quantities and the revised peaking factors which had been developed for the biosolids program. This resulted in more-costly options for both pre-dewatering and final dewatering. Capital, operation and maintenance, and life cycle costs were developed to compare the options.

The life cycle costs for combined options of pre-dewatering and final dewatering varied somewhat, but not widely. Several non-economic criteria were identified as being of major importance in the assessment of these options - these included construction staging and startup sequencing, especially for final dewatering. The analysis showed that a new final dewatering facility had major advantages in its ability to be phased in as the TH-digestion system was brought on-line over some period of time. The use of belt press technology was determined to have advantages in final dewatering, not only because of cake odor and product quality benefits, but also the lower energy use of the technology. Costs for dewatering odor control (for both the belt press and centrifuge options) were included in the evaluation.

The final recommendation was to construct new belt filter press final dewatering facilities. This solved what was otherwise becoming a major construction staging and startup sequencing risk and also had advantages for product quality and for minimizing energy and polymer use. The construction cost of this option was only slightly higher than other options. Another advantage was that this option provided space for expanding the dewatering systems if and when additional TH and digestion capacity was needed.

Solids Processing by TH-Digestion and by Lime Stabilization

The new TH-digestion system capacity and biosolids program budget was established within the updated management plan in 2008. This biosolids plan provided an upper limit on the ability of the TH-digestion system to handle expected quantities. When sludge and solids production at Blue Plains exceeds the TH-digestion system capacity, the overage will be processed through the existing dewatering and lime-stabilization system. Some improvements and changes to the cake conveyance and lime system will be implemented by the program. Since the dewatering and lime stabilization system has capacity in the range of 350 to 450 dry tonnes/day (400 to 500 dry US tons/day), this system has high capability to process peak sludge production quantities at Blue Plains. This concept provides a major risk and cost reduction strategy, since capacity-redundancy and backup equipment within the TH-digestion system can be minimized.

Meeting Air Emissions Requirements and Insuring Adequate Steam Supply

The biosolids program must meet air quality and air permitting requirements, and the portion of the project that has the greatest potential for air permitting challenges is the Combined Heat and Power facility (CHP). The CHP must provide the steam requirements for the thermal hydrolysis process, and can produce electric power to offset major power purchases needed for the Blue Plains AWTP. NOx production is perhaps the greatest permitting challenge for a project of this type located within the Washington DC Metro area which is a non-attainment area for ozone.

Different prime movers and steam generation systems were evaluated in the development of the biosolids program, and the decision to utilize combustion gas turbines was highly influenced by the low NOx emissions that these units can achieve. The turbines would be used with Heat Recovery Steam Generators (HRSGs) to produce the steam requirements. Steam at about 12-bar (180 psi) is required for thermal hydrolysis, and about one ton of steam is required per ton of solids throughput. Gas turbines are highly reliable if proper digester gas quality and consistent supply is provided. Siloxane treatment of the digester gas will be needed. Footprint for digester gas storage is being allocated, but may not be installed initially. The steam to power energy ratio is good for the needs of this program as long as highly efficient turbine systems are utilized. The turbine and HRSG system can also utilize natural gas at startup and whenever digester gas is not available or is in short-supply.

A decision has also been made to provide a backup steam boiler as part of the CHP, to insure high reliability of steam supply. The boiler could be operated on either digester gas or natural gas. Therefore, in the manner described above, the risks for air permitting problems have been kept to a minimum, and the overall energy output is maximized.

Power Production and Greenhouse Gas Reductions

Between 10 and 14 megawatts of power will be produced on a regular basis from the combined heat and power (CHP) facility. As indicated above, combustion gas turbine technology has been selected for power production. For more detail on this portion of the program, the reader is referred to the paper by Cooper et al, 2010.

The Blue Plains AWTP typically utilizes about 30 megawatts of electric power. This amount of power is likely to be reduced in the future with several energy-based improvements underway, although new facilities being constructed will add new power loads at the plant. CHP power production will provide a significant portion of the plant power load, thus offsetting major power purchases with the use of renewable energy. The CHP can also provide sufficient power to keep the most essential plant processes operating even with total power loss from the power utilties, thus providing improved reliability for essential plant treatment functions.

An analysis of the plant's carbon footprint and the impacts from the biosolids program are summarized in Willis et al, 2010. The overall greenhouse gas (GHG) emissions reduction in DCWASA's utility-wide inventory, from implementation of the biosolids program, is between 28 and 39 percent, depending on the assumptions used. The production of renewable electric power (reducing fossil fuel-derived power) represents the majority of these GHG reductions. However, other GHG reductions also occur due to vast reduction in lime usage and the reduced quantity of biosolids product trucked off-site (i.e., fuel reductions). Various changes in GHG emissions will also occur because of nutrient issues and CH4 and N2O emission differences. Overall, the biosolids program will have a very positive effect in reducing DCWASA's GHG emissions and in providing "green", renewable energy.

Program Procurement and Delivery

Significant risks are often acknowledged in the procurement of large, complex public works programs such as this one. These include risks of commodity price increases, cost/price creep due to additional scope added during design, unclear bidding documents, limited bidders, risks from long construction and commissioning periods, risk allocation (between owner and builder) not properly defined, risks of inadequate coordination between projects or between elements of a large project, and overly strict terms and conditions placed on bidders. These risks and more have been evaluated, and continue to be evaluated, as the projects unfold.

Decisions about procurement of the major elements of the program were made during 2009 and are the subject of a paper by Braswell et al, 2010. The decision to utilize a range of procurement methods was driven by specific needs of the program and the desire to implement the program in a time-frame that takes advantage of the current economic downturn and perceived advantageous bidding climate. The procurement team included experts in alternative delivery methods to assess the specifics of this biosolids program, and make appropriate recommendations. The use of performance-based contracting for major elements of the program is new to DCWASA, but has advantages in delivering projects with specific performance objectives and delivering them more quickly. Risk reduction and cost control were major drivers in these decisions.

DCWASA sole-sourced the Cambi Thermal Hydrolysis Process in 2009 for its biosolids program. This was completed after considerable due diligence work in evaluating the competing technologies in this field. Cambi is now under contract to the biosolids program to define the system and the interfaces required between the TH process and all pertinent process elements. The sole-sourcing of Cambi is proving advantageous in designing specific interface systems, making layout decisions, and locking in the scope, cost and delivery schedules pertinent to Cambi facilities.

Equipment Selection

A major risk for performance-based contracting (i.e., design-build) is that the specific equipment to be provided is often determined by the design-build team, and yet the owner will be providing operation and maintenance of the system. The pressure to provide a low-price bid-proposal may bring less-than-desirable equipment into the project. Fortunately, there are ways to reduce the risk of this situation. One of these is to more-directly prescribe the equipment that must be provided. For the DCWASA design-build procurement, the owner will pre-qualify certain equipment, thereby limiting the design-build teams to perhaps two or three options for a specific item, yet still providing equipment and cost competition. Other methods are under review to help insure that the equipment provided will meet the O&M expectations of DCWASA.

Risk Management Teams

The DCWASA biosolids management program has established two risk management teams:

- Technical risk management and risk reduction team
- Procurement risk management and risk reduction team

These teams are meeting to both assess and define risks in these broad categories and then to proceed to develop risk reduction methods for each risk identified. The teams are composed of representatives from various departments at DCWASA. Each team is developing a risk-reduction log to keep track of its deliberations and recommendations.

Cost Control

Cost control during program development and design is often synonymous with scope control. There may be many good reasons to expand the biosolids program with more capacity, greater redundancy, or increased flexibility for operations. However, budget constraints are real. Frequent cost-assessment updates have been used in the biosolids program to examine proposals for additional or modified scope - these are examined carefully to determine if alternate approaches can be used to meet a need rather than increase the scope. Also, all construction cost estimating has been centralized within the biosolids program so that consistent cost estimating methodologies and assumptions are used.

SUMMARY

Substantial risk evaluation work has been completed as the DCWASA biosolids program has developed. Because of higher-than-anticipated fugure solids loading, changes in system configuration have been required and new final dewatering facilities proved to be a good approach. Final product characteristics were deemed very important in terms of program risk control. Cost control has been necessary on an almost continuous basis during program development.

This is not a program demanded by regulatory requirements, but rather a program that makes sense from the standpoint of economics, risk reduction, public awareness and sustainability. Factors involving renewable energy production, minmizing energy use, and reduction in greenhouse gas emissions have become important considerations for the new program.

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