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Starting with a product in mind – biosolids management design based on beneficial use goals

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Abstract

Biosolids generators across the United States are beginning to reevaluate their processing and management programs, to consider new technologies and products. As part of this, they are considering new regulatory requirements, more flexible outlets, and the concept of biosolids as a product. Their focus is no longer technology centered, but rather on product quality and the best use for it. As part of their Long-Term Biosolids Master Planning effort, Howard County Department of Public Works fulfilled their goal of selecting a solids processing technology that reduces volume and generates a Class A exceptional quality biosolids product that could be use locally in agricultural or non-agricultural markets. In this case, product quality characteristics were important in entering local markets. Key aspects of the selection process are discussed, including establishing County goals, identifying and surveying local beneficial use markets, selecting a solids management alternative, and ultimately selecting the dryer technology fulfilling the County's objective.

Key words: biosolids product quality, market preferences, management alternatives, regulatory environment

INTRODUCTION

Howard County Department of Public Works (DPW) owns and operates the Little Patuxent Water Reclamation Plant (LPWRP), an enhanced biological nutrient removal wastewater treatment facility in a highly developed area in Savage, Maryland. It is contained by the Little Patuxent River, two major highways, and an industrial park (Figure 1).

The average daily influent rate of LPWRP is 75.7 million liters per day (Ml/d) (20 million gallons per day [mgd]) with an ultimate build-out design capacity of 107.9 Ml/d (28.5 mgd). Influent treatment processes at LPWRP include raw wastewater screening and pumping, grit removal, primary clarification, three-stage activated sludge biological nutrient removal, secondary clarification, denitrification filters, ultra-violet disinfection, and post-aeration. Solids handling includes gravity thickening for primary solids, dissolved air floatation thickening for waste activated solids, centrifuge dewatering, and Class A pathogen and vector attraction reduction using an advanced lime stabilization process (the RDP process).

RDP EnVessel pasteurization uses supplemental heat and lime to generate a product that meets Class A exceptional quality (EQ) standards. The LPWRP installation currently uses lime at the rate of 40%, dry weight basis, to process biosolids. Approximately 880 wet metric tonnes (~50 truckloads) of stabilized EQ biosolids are applied as fertilizer to agricultural land in Maryland, Virginia, and occasionally Pennsylvania, each week.

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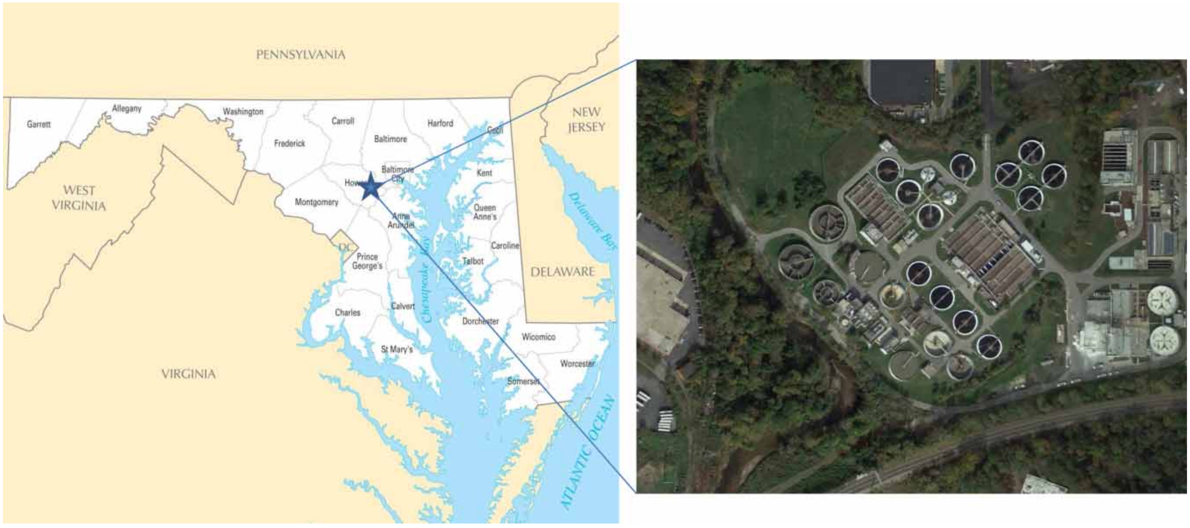

Figure 1 | LPWRP.

Maryland's 'phosphorus site index' (P-index) regulations are forcing many farmers to reduce or eliminate land application of biosolids (and fertilizers containing P) due to elevated soil P levels. Typically, biosolids and other organic fertilizers are applied to meet the crop's nitrogen needs, but when applied at this rate, they provide substantially more P than is required. As the P-index is expected to become more restrictive, many farms currently applying biosolids in the state are anticipated to be prohibited from additional biosolids application. At the least, this would increase LPWRP's costs by forcing them to transport much more biosolids into other states. If neighboring states adopt similar restrictions, land application would be eliminated completely as a viable outlet.

When the RDP process was first installed, LPWRP's minimal on-site storage caused no concern because land application of biosolids was available year-round in Maryland. In 2012, however, Maryland's Department of Agriculture (MDA) imposed a 'winter ban,' and LPWRP can no longer send biosolids for direct land application from November 16 to March 1 (105 days). All biosolids must be sent to long-term storage in Maryland, land application in Virginia or Pennsylvania, or landfill. Meanwhile, Maryland's Department of Environment limits on-farm biosolids 'staging' to 90 days, longer storage requiring permits and public notices associated with a permanent 'storage' facility. These requirements result in a period each year when beneficial use options are not available, and LPWRP must pay a large tipping fee for landfill disposal.

The seasonal biosolids application restrictions are compounded for LPWRP by loss of land area locally available for biosolids application due to high soil pH and P content. The repeated application of lime-amended biosolids on local farms has increased soil pH and/or P above the crops' optimal range on those farms involved with biosolids application for many years. This has reduced the permissible frequency of biosolids application or, in some cases, caused the termination of biosolids application.

Until recently, Class A/EQ agricultural land application has provided Howard County with a cost effective alternative for the beneficial use of the biosolids. In Maryland's current regulatory environment, therefore, Howard County engaged HDR Engineering, Inc. and Material Matters, Inc. (the Team) to develop a biosolids master plan for the reliable, cost-effective treatment and use of LPWRP's biosolids. At the start, the Team identified the need to replace the current treatment process with an alternative that would withstand the evolving regulatory environment. The alternative was to be selected on the basis of its long-term viability, and must align with the County's social and environmental objectives for biosolids management.

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MASTER PLAN

Biosolids management options were evaluated for a 20-year planning period from 2015 to 2035. It was important, from the outset, to establish goals and objectives, decision criteria, and constraints in collaboration with Howard County personnel. The goals and objectives, in turn, would be the foundation for all decisions made throughout the project. During the initial planning workshop, County staff developed a concise goal summarizing the approach to the master plan:

> *Develop a Biosolids Master Plan that provides a framework for reliable, cost-effective treatment and beneficial use of LPWRP biosolids in a changing and uncertain future regulatory environment*

Based on this goal, it was also necessary to develop specific, concrete objectives and decision criteria to guide the planning process. The six (6) objectives developed during the workshop were:

- Social and environmental responsibility – reduced truck traffic, preference for local/in- state beneficial uses, energy optimization, and greenhouse gas footprint.
- Biosolids end use – biosolids must be beneficially used, rather than disposed of.
- Biosolids product – produce a versatile, high-quality, Class A/EQ product suitable for multiple uses.
- Volume reduction – reduce the volume of biosolids generated at the LPWRP, to reduce truck haulage and other operational costs associated with the beneficial use program.
- Optimize plant processes and facilities – biosolids processing must be compatible with other plant treatment processes, and maximizing use of existing facilities is a high priority.
- Reliability – proven processing technologies and end use markets are essential.

Screening of management options

The evaluation of management options started with solids stabilization and processing technologies, biosolids products and associated markets, and product specifications.

It was decided at the initial workshop to consider only proven technologies with full-scale operating histories when evaluating biosolids processing and stabilization technologies. Several technologies were evaluated:

- Advanced alkaline stabilization (the existing process on site and the evaluation baseline)
- Mesophilic anaerobic digestion, with added processing for Class A stabilization
- Temperature-phased thermophilic anaerobic digestion
- Thermal hydrolysis process (THP) plus mesophilic anaerobic digestion
- Thermal drying, including indirect dryers, and direct drum and belt dryers
- Composting (off-site only)

These were combined with expected products and target beneficial use markets to develop nineteen (19) management options. Each option included unique combinations of solids processing, product characteristics, opportunities for energy recovery, and anticipated beneficial use markets. They were discussed in depth to produce a short-list, summarized in Table 1, for detailed evaluation. The set selected for further evaluation included beneficial use options for bulk agricultural and specialty fertilizer, turf, and soil blending.

Beneficial use market assessment

As part of the study of each management option, it was important to evaluate the markets in order to understand their available locally, the product characteristics preferred/required in each of them, and the capacity available to accept LPWRP's production volume.

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Table 1 | Summary of short-listed biosolids management options

No.	Anaerobic Digestion	Dewatering	Added Stabilization	Product	Energy Recovery	Beneficial Use
1	None	Centrifuge	RDP	EQ cake	Not Applicable	Bulk agriculture
2	None	Centrifuge	Drying	EQ granules	Not Applicable	Bulk agriculture
5	Mesophilic	Centrifuge	RDP	EQ cake	Combined Heat and Power (CHP)	Bulk agriculture
7	Mesophilic	Centrifuge	Drying	EQ granules	Dryer fuel	Specialty fertilizer, turf, soil blending
10	THP/ Mesophilic	Centrifuge/Belt Filter Press	None	EQ cake	THP, CHP	Bulk agriculture
13	THP/ Mesophilic	Centrifuge	Drying/ Screening	EQ granules	THP, Dryer fuel	Specialty fertilizer, turf, soil blending

'Bulk agriculture' and 'specialty fertilizer' were both defined for the project in order to identify target markets for surveys. 'Bulk agriculture' consists of options where biosolids are marketed in large volume truckloads only, to agricultural markets – e.g., feed/fiber/food crops – or distributed via fertilizer brokers/dealers, contractors, or a self-managed program. 'Specialty fertilizer' comprises options where biosolids are marketed to non-bulk agricultural users, soil blenders, turf farms, and wholesale/retail fertilizer distributors. In this market, biosolids may be distributed in small volume, truckloads or bagged (1 ton/tonne super sacks, 50-lb/25-kg bags, etc.) via fertilizer brokers/dealers, contractors, or a self-managed program.

A detailed product assessment for each management option was necessary, as each product has its own unique characteristics, which influence viability within any given market. For example, while options 2 and 7 both yield dried granules, undigested and digested, respectively, those associated with option 2 (no anaerobic digestion) have a higher potential to generate nuisance odors. Because of this, the product from option 7 is more likely to be suitable for beneficial use markets with close public interaction (e.g., golf courses) than that from option 2. For accurate market assessment, therefore, each product's anticipated nutrient content, percentage total solids content, production volumes, potential to generate nuisance odors, and dustiness were determined. Their characteristics were summarized on User Information Sheets given to potential customers during market interviews (Figure 2).

Once the target markets and preferred product characteristics were established, local customers in each market were identified. Phone surveys were conducted to identify the customer's current raw materials and feedstocks, products sold, on-site storage capacity, and typical transportation methods (i.e. are materials delivered to their site or do they pick them up?) to try to determine whether any of the biosolids products would fit into their operation. Follow-up, onsite interviews were pursued with those who showed interest in the product. During the latter, interviewees were given samples of biosolids derived from selected processing technologies, and asked to evaluate their suitability for replacing a raw material or feedstock currently being used. When possible, the samples provided were processed using the same digestion, dewatering and/or drying technology as that being considered for LPWRP, as each step in biosolids processing can result in different product characteristics. Examples of biosolids samples provided at interviews are shown in Figure 3; note the difference in grain size and consistency of the Exeter and OceanGro granules.

Bulk Agriculture – The survey results indicated that the agricultural market, which is the appropriate beneficial use for material from management options 1, 2, 5, and 10, was an 'established' market in Maryland. In other words, biosolids are commonly used as an agricultural fertilizer and minimal marketing efforts are necessary. Additionally, the agricultural sector will accept the widest range of products, and has sufficient capacity to accept the entire volume generated by LPWRP. The agricultural market preferred products with low dust potential that would spread evenly on the fields using

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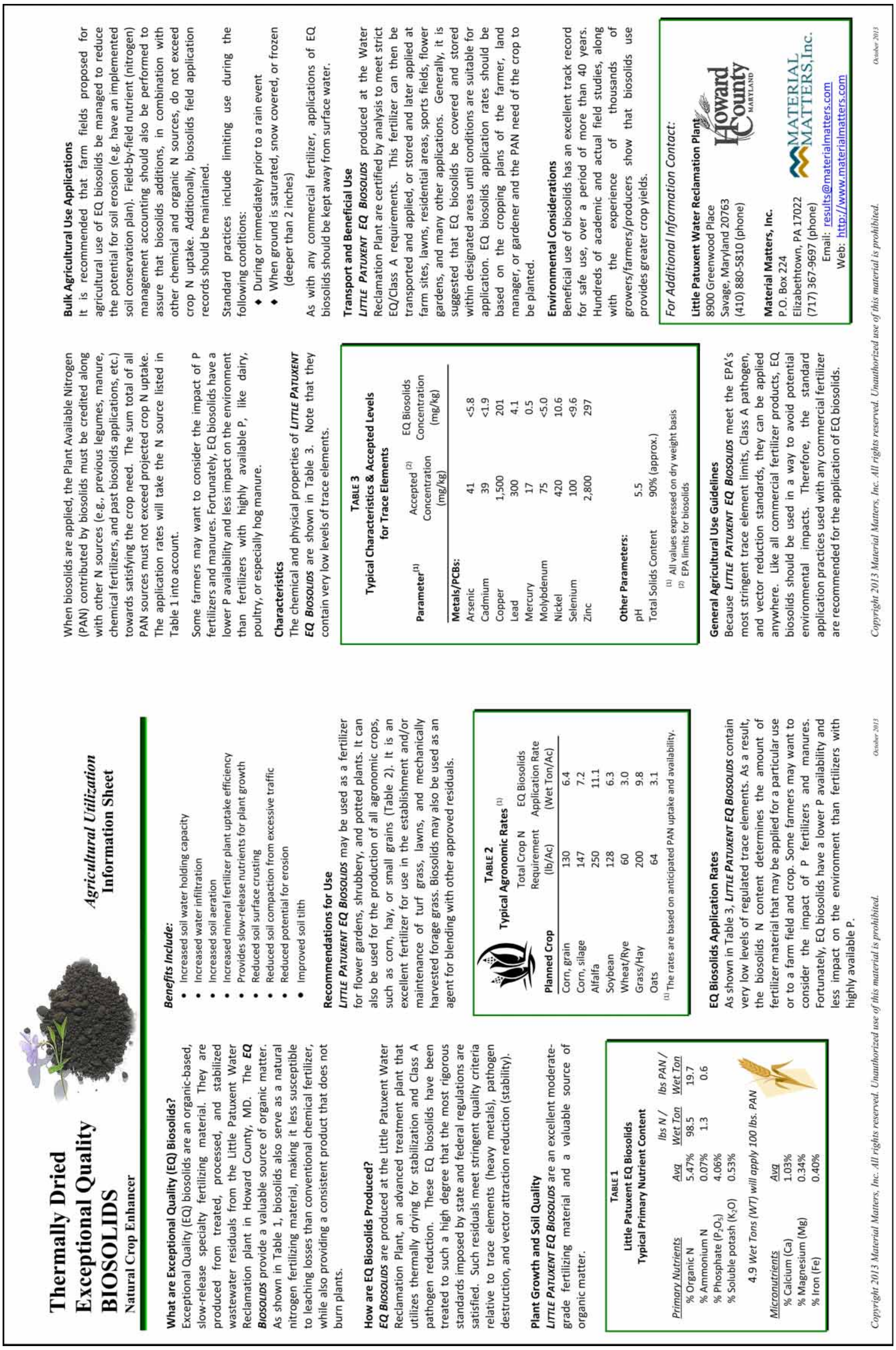

Thermally Dried Exceptional Quality BIOSOLIDS
Natural Crop Enhancer

Agricultural Utilization Information Sheet

What are Exceptional Quality (EQ) Biosolids?
Exceptional Quality (EQ) biosolids are an organic-based, slow-release specialty fertilizing material. They are produced from treated, processed, and stabilized wastewater residuals from the Little Patuxent Water Reclamation plant in Howard County, MD. The *EQ Biosolids* provide a valuable source of organic matter. As shown in Table 1, biosolids also serve as a natural nitrogen fertilizing material, making it less susceptible to leaching losses than conventional chemical fertilizer, while also providing a consistent product that does not burn plants.

How are EQ Biosolids Produced?
EQ Biosolids are produced at the Little Patuxent Water Reclamation Plant, an advanced treatment plant that utilizes thermally drying for stabilization and Class A pathogen reduction. These EQ biosolids have been treated to such a high degree that the most rigorous standards imposed by state and federal regulations are satisfied. Such residuals meet stringent quality criteria relative to trace elements (heavy metals), pathogen destruction, and vector attraction reduction (stability).

Plant Growth and Soil Quality
Little Patuxent EQ Biosolids are an excellent moderate-grade fertilizing material and a valuable source of organic matter.

Table 1
Little Patuxent EQ Biosolids
Typical Primary Nutrient Content

Primary Nutrients	Avg	lbs N / Wet Ton	lbs PAN / Wet Ton
% Organic N	5.47%	98.5	19.7
% Ammonium N	0.07%	1.3	0.6
% Phosphate (P_2O_5)	4.06%		
% Soluble potash (K_2O)	0.53%		

4.9 *Wet Tons (WT) will apply 100 lbs. PAN*

Micronutrients	Avg
% Calcium (Ca)	1.03%
% Magnesium (Mg)	0.34%
% Iron (Fe)	0.40%

Benefits Include:
- Increased soil water holding capacity
- Increased water infiltration
- Increased soil aeration
- Increased mineral fertilizer plant uptake efficiency
- Provides slow-release nutrients for plant growth
- Reduced soil surface crusting
- Reduced soil compaction from excessive traffic
- Reduced potential for erosion
- Improved soil tilth

Recommendations for Use
Little Patuxent EQ Biosolids may be used as a fertilizer for flower gardens, shrubbery, and potted plants. It can also be used for the production of all agronomic crops, such as corn, hay, or small grains (Table 2). It is an excellent fertilizer for use in the establishment and/or maintenance of turf grass, lawns, and mechanically harvested forage grass. Biosolids may also be used as an agent for blending with other approved residuals.

Table 2
Typical Agronomic Rates [1]

Planned Crop	Total Crop N Requirement (lb/Ac)	EQ Biosolids Application Rate (Wet Ton/Ac)
Corn, grain	130	6.4
Corn, silage	147	7.2
Alfalfa	250	11.1
Soybean	128	6.3
Wheat/Rye	60	3.0
Grass/Hay	200	9.8
Oats	64	3.1

[1] The rates are based on anticipated PAN uptake and availability.

EQ Biosolids Application Rates
As shown in Table 3, *Little Patuxent EQ Biosolids* contain very low levels of regulated trace elements. As a result, the biosolids N content determines the amount of fertilizer material that may be applied for a particular use or to a farm field and crop. Some farmers may want to consider the impact of P fertilizers and manures. Fortunately, EQ biosolids have a lower P availability and less impact on the environment than fertilizers with highly available P.

When biosolids are applied, the Plant Available Nitrogen (PAN) contributed by biosolids must be credited along with other N sources (e.g., previous legumes, manure, chemical fertilizers, and past biosolids applications, etc.) towards satisfying the crop need. The sum total of all PAN sources must not exceed projected crop N uptake. The application rates will take the N source listed in Table 1 into account.

Some farmers may want to consider the impact of P fertilizers and manures. Fortunately, EQ biosolids have a lower P availability and less impact on the environment than fertilizers with highly available P, like dairy, poultry, or especially hog manure.

Characteristics
The chemical and physical properties of *Little Patuxent EQ Biosolids* are shown in Table 3. Note that they contain very low levels of trace elements.

Table 3
Typical Characteristics & Accepted Levels for Trace Elements

Parameter [1]	Accepted [2] Concentration (mg/kg)	EQ Biosolids Concentration (mg/kg)
Metals/PCBs:		
Arsenic	41	<5.8
Cadmium	39	<1.9
Copper	1,500	201
Lead	300	4.1
Mercury	17	0.5
Molybdenum	75	<5.0
Nickel	420	10.6
Selenium	100	<9.6
Zinc	2,800	297
Other Parameters:		
pH	5.5	
Total Solids Content	90% (approx.)	

[1] All values expressed on dry weight basis
[2] EPA limits for biosolids

General Agricultural Use Guidelines
Because *Little Patuxent EQ Biosolids* meet the EPA's most stringent trace element limits, Class A pathogen, and vector reduction standards, they can be applied anywhere. Like all commercial fertilizer products, EQ biosolids should be used in a way to avoid potential environmental impacts. Therefore, the standard application practices used with any commercial fertilizer are recommended for the application of EQ biosolids.

Bulk Agricultural Use Applications
It is recommended that farm fields proposed for agricultural use of EQ biosolids be managed to reduce the potential for soil erosion (e.g. have an implemented soil conservation plan). Field-by-field nutrient (nitrogen) management accounting should also be performed to assure that biosolids additions, in combination with other chemical and organic N sources, do not exceed crop N uptake. Additionally, biosolids field application records should be maintained.

Standard practices include limiting use during the following conditions:
- During or immediately prior to a rain event
- When ground is saturated, snow covered, or frozen (deeper than 2 inches)

As with any commercial fertilizer, applications of EQ biosolids should be kept away from surface water.

Transport and Beneficial Use
Little Patuxent EQ Biosolids produced at the Water Reclamation Plant are certified by analysis to meet strict EQ/Class A requirements. This fertilizer can then be transported and applied, or stored and later applied at farm sites, lawns, residential areas, sports fields, flower gardens, and many other applications. Generally, it is suggested that EQ biosolids be covered and stored within designated areas until conditions are suitable for application. EQ biosolids application rates should be based on the cropping plans of the farmer, land manager, or gardener and the PAN need of the crop to be planted.

Environmental Considerations
Beneficial use of biosolids has an excellent track record for safe use, over a period of more than 40 years. Hundreds of academic and actual field studies, along with the experience of thousands of growers/farmers/producers show that biosolids use provides greater crop yields.

For Additional Information Contact:

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Savage, Maryland 20763
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Web: http://www.materialmatters.com

Figure 2 | Example User Information Sheet developed for use in market surveys.

typical fertilizer or manure spreading equipment. However, due to Maryland's evolving land application regulations, it is expected that most future agricultural application sites are likely to be located in Virginia or Pennsylvania. It was also confirmed that the agricultural market is restricted

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Figure 3 | Biosolids product samples provided during interviews.

for portions of the year due to cropping and weather limitations, so that off-site storage must be considered. In general, the agricultural market is a low-value option as it has low potential to generate revenue, and is likely to require management fees for farming services.

Specialty Market – The specialty market surveys indicated that the high-quality biosolids associated with options 7 and 13 provide the flexibility needed to enter multiple markets, including soil blending, fertilizer blending and turf production. All three are 'novel' in Maryland, as biosolids use is not common in the region, and more marketing and pilot testing is necessary to demonstrate that biosolids will benefit them. Every interviewee in the specialty market indicated that only the granular product would suit their operations, and the product must meet strict specifications quite different from the agricultural market and including: low nuisance odor, consistent – i.e., uniform – size, zero inorganics content, and low dust. Interviewees from specialty markets indicated that they had no storage capacity or structures available, so that storage would be needed at LPWRP.

Specialty markets are generally of higher value than agricultural markets, and distribution to them is likely to generate revenue. The findings show that the fertilizer blending market is likely to generate the highest unit revenue but, because biosolids contain phosphorus, use in the fertilizer market is expected to be limited, as Maryland's regulations limit fertilizers containing P. In contrast, the soil blending market is not subject to P regulations, if biosolids are incorporated in a soil blend as a soil amendment (for micro-nutrients, organic matter, etc.). Thus, soil blending is the most promising market, despite generating lower unit revenue.

Selecting a management option

The regulatory evaluation and market surveys completed during development of the master plan helped Howard County personnel to select option 7 – anaerobic digestion and heat drying – for long-term biosolids management at LPWRP. Several other options met some of the County's objectives and/or had a lower estimated cost than option 7, but did not meet the objective of a versatile, high quality product with local beneficial use possibilities. For example, options 1, 2, and 5, with bulk agriculture as the only potential outlet, had lower estimated costs but would expose the County to the risk of increasing and uncertain regulatory restrictions on bulk land application in

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Maryland. The regulatory review and market survey results demonstrated that the need to meet the local use and reduced truck traffic objectives would probably not be realized with any of them. Similarly, option 10 – thermal hydrolysis and anaerobic digestion – had a slightly lower estimated cost for producing Class A/EQ dewatered cake, but Howard County felt it offered too much risk to be pursued. Thermal hydrolysis is new to the United States and survey feedback indicated little demand for the product.

Option 7 was selected because it met all six of the County's objectives. It significantly reduces production volumes and truck traffic, and eliminates the use of lime (social and environmental responsibility and volume reduction). In addition, the technology is well-established in the USA in meeting the goal for reliability, and produces high-quality, Class A/EQ biosolids. It also maximizes existing infrastructure use at LPWRP, including the current anaerobic pretreatment tanks, pumps, piping, etc., with manageable added process complexity and impacts on other processes. Ultimately, however, the decision to select this option was most heavily influenced by the market survey results, which proved local demand for the product. Potential customers in many local and regional markets supported a low-dust, low-odor, dried granule product. In other words, the product from option 7 has potential for local use in high volume.

Development of the biosolids master plan set the stage for the Preliminary Engineering Report (PER), which refined the technology and process decisions to the level of a specific dryer type and manufacturer.

PRELIMINARY ENGINEERING REPORT

Option 7 includes mesophilic anaerobic digestion, centrifuge dewatering, and thermal drying to produce a granule for use in specialty markets. As these markets are being developed, it is intended that the granules will be used (beneficially) in bulk agriculture, with the advantage of significant volume reduction compared to that from the existing process. Howard County authorized the Team to proceed with a PER to expand upon the Biosolids Master Plan, and further refine the process and equipment concept plan.

As part of the PER, three (3) dryer technologies were evaluated; one (1) rotary drum dryer and two (2) types of belt dryer. Of the latter, 'Belt A' uses screening and product recirculation; and 'Belt B' involves neither. The relevant issues were the products' characteristics for each dryer type and manufacturer, and their suitability for the local beneficial use market.

Drum dryer technology (Figure 4) is well-established and produces a hard, rounded, relatively uniform product. Plants often have post-processing oil sprays to reduce dust, so that the product is

Figure 4 | Drum dryer and typical product.

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preferred by fertilizer distributers and blenders. Drum dryers recirculate and screen their product to achieve high uniformity. They also have high evaporation potential and comprise, therefore, the most commonly used drying technology for larger wastewater treatment plants (>56.8 Ml/d or 15 mgd).

Belt dryers (Figure 5), while widely used in Europe, are relatively new in the United States. In general, they have a lower evaporative capacity than drum dryers, and therefore, are typically used at smaller plants (<56.8 Ml/d or 15 mgd). In such systems, the biosolids are fed onto a slow moving belt in a low-temperature vessel, resulting in a granular, friable, product that is less uniform than that from a drum dryer. Recirculation and screening equipment can be added to belt dryers to improve product uniformity.

Figure 5 | Single pass belt dryer – i.e., no recirculation – and typical product.

Samples of granules produced by the three types of dryers being considered were obtained from wastewater treatment plants across the United States. Samples of product from 'Belt B'-type dryers with post processing 'crushed' and 'crushed/pelletized' options were also obtained (Figure 6). They were sent to the same interviewees surveyed during development of the master plan, to confirm

Figure 6 | The Belt B dryer products – left to right: dried/non-pelletized, dried/pelletized/not cut, dried/pelletized/cut, and dried/non-pelletized/crushed.

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detail of the product characteristics preferred by each industry. Interviewees were also asked to rank by preference the products from each dryer/post-processing technology.

RESULTS AND DISCUSSION

The final market study revealed that, although the drum dryer's product has proven successful in the high value, bagged fertilizer market elsewhere in the country, interest in markets local to Howard County was limited because of Maryland's P-fertilizer regulations. The local soil blending market, which can use large volumes of product beneficially and is not impacted by the P-fertilizer regulations, prefers the granular/irregular product from the belt dryer to the sub-rounded pellets from the drum dryer. It was also determined that the belt dryer's product is suitable for the bulk agriculture market, which is likely to continue to be available for parts of the year.

Table 2 | Product and market preferences

Product			Market		
Dryer	**Digestion**	**Post-Processing**	**Soil Blender**	**Fertilizer Blender**	**Bulk Agriculture**
Drum	Anaerobic	None	+	++	++
Belt A	Aerobic	None	++	–	++
	Anaerobic	None	++	–	+
Belt B	None	None	–	–	–
	None	Crushed	++	–	+
	None	Crushed, pelletized	–	–	+
Ranking of Maryland Market Availability			1	3	2

Key: ++ = preferred; + = usable, but not preferred; – = not usable.

Market preferences and availability are summarized in Table 2. Interviewees were given samples from each dryer/post-processing combination and asked to (1) identify which product(s) could be used in their business and (2) rank the products in preference order. No 'Belt B' product with digestion was available for distribution, but it is thought that digestion would improve the product odor quality and thus increase acceptability.

The results of the PER final market survey led to Howard County selecting belt dryer technology. During the PER evaluation, county staff continued to focus on the objectives defined at the start of master plan development. In particular, they recognized local market demands when deciding which dryer technology was most suitable for LPWRP. The PER survey showed that Maryland's soil blending market has significant interest in and capacity for dried biosolids, and is, therefore, the most suitable primary target for LPWRP. It also indicated interest in agricultural land application in adjacent states. In contrast, Maryland fertilizer blenders, who had indicated a preference for products like the drum dryer's pellets, had little interest in biosolids products due to phosphorus-limiting regulations. Therefore, Howard County selected a belt dryer to meet their goals, to produce a high-quality product that would be in demand locally in many markets and remain viable despite Maryland's evolving regulatory environment.

CONCLUDING REMARKS

The methodology used in the Howard County project is distinctive in its strong focus on connecting technology decisions with the long-term viability of the biosolids product in the local market.

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Regional regulations and local market requirements were critical throughout the project, when considering solids processing technology. For example, Howard County determined that Maryland's regulations made the management options associated with bulk land application of biosolids cost-prohibitive or unavailable in the long-term. However, a regulatory review and market survey for a different state may find that bulk land application is cost-effective, locally available, and in high demand by the local farming community.

This project also highlights the significance of establishing concrete objectives and focusing on product quality, to set the foundation for decisions made throughout the process. Every decision made took account of the goals established at the outset to: 'develop a biosolids master plan that provides a framework for reliable, cost-effective treatment and beneficial use of LPWRP biosolids in a changing and uncertain future regulatory environment'. Whereas the product or beneficial use outlet has not been considered, historically in relation to solids processing technology, Howard County consistently focused on a management option optimizing beneficial use, from the start of solids processing to final sale/distribution. By identifying the final product generated from each option and presenting the product to the potential customers, the County reduced the risk associated with poor product quality and identified a likely demand for it. This project serves as an excellent example demonstrating that evaluating regulatory pressures and market availability, is critical to identifying reliable and sustainable biosolids management solutions.

The authors thank Howard County DPW for allowing their data and experiences to be shared in this paper.