MBBR Technology for UrbanizedWastewater Treatment

Mark Martin, Andy Westfall, Mark Steichen, Larry Bishop, and Saeed Kazemi

There are many dynamics that influence the planning and design of wastewater treatment in urbanized areas of Florida. As utilities search for the best valued solution for wastewater treatment, they must consider many non-economic evaluation factors, such as treatment objectives, process reliability, operational complexity, site constraints, community impacts, sustainability, and constructability.

These factors must be balanced against overall project and life-cycle costs. There is no one right answer that will work for all projects; instead, site-specific factors must be considered carefully to find the best valued treatment solution.

The city of Fort Myers is one of the fastest growing cities in Southwest Florida, with development occurring in the eastern portion of the city's service area. Currently, the city has two advanced wastewater treatment plants (Central and South), rated at 11 million gallons per day and 12 million gallons per day, respectively. Because of land constraints and distance from the high-growth area, it is not feasible to treat additional wastewater at the existing facilities.

Fort Myers identified the need for a new East Water Reclamation Facility (WRF) to be located east of Interstate Highway 75 to handle short-term and long-term projected wastewater flows. The city hired Black & Veatch to provide planning and conceptual design services for the new WRF.

During conceptual design, the city and Black & Veatch engaged in an evaluation of treatment technologies for the facility. During workshops, it was determined that the design of the East WRF should meet the following main project objectives:

- Be a state-of-the-art showcase facility.
- Meet site constraints and restrictions regarding physical space and neighbor friendly issues.
- Be easy to operate.
- Meet water-quality standards for reclaimed water.

With these objectives in mind, the city chose a moving bed biofilm reactor (MBBR) with a dissolved air flotation (DAF) clarifier for the East WRF. This article reviews the decision-making process used in the evaluation of treatment technologies for the facility.

During project workshops involving the city and the design team, the following secondary treatment alternatives were developed conceptually and evaluated for implementation at the East WRF:

- Alternative 1 – Membrane Bioreactor (MBR)
- Alternative 2 – Biological Aerated Filters (BAF)
- Alternative 3A – Modified Ludzack-Ettinger (MLE) with circular configuration
- Alternative 3B – Modified Ludzack-Ettinger (MLE) with rectangular configuration
- Alternative 4 – Moving Bed Biofilm Reactor (MBBR)

Conceptual process designs, process schematics, and site layouts were prepared for each secondary treatment alternative. Treatment technologies were evaluated based on both economic and non-economic factors.

The economic evaluation was based on a present-worth comparison of the alternatives. The economic evaluation focused only on costs that differed among the alternatives, so costs do not represent actual complete project costs.

Capital improvement costs were prepared for each of the alternatives based on standard costing methods, including unit costs applied to quantity take-offs specific to each alternative, labor rates in the local area, and equipment quotes from manufacturers. The following project cost factors were included: 10 percent for general requirements, 10 percent for sitework, 15 percent for electrical, instrumentation and controls, 25 percent for construction contingencies, and 20 percent for legal, administration, and engineering. While actual costs may vary from these assumptions, they provide a sound basis for uniform comparative evaluation.

Operational and maintenance (O&M) costs include power, chemicals, solids processing, odor control, preventative maintenance, and labor costs. Other O&M costs were considered to be equal for all alternatives, or believed to be insignificant, so they were not included in the cost analysis.

Power costs were calculated based on $0.09 per kilowatt hour and applied to the estimated average power draw for the alternative. Costs of membrane replacement and chemicals for membrane cleaning were included for the MBR alternative. The life-cycle cost analysis was prepared based on a rate of return of 6 percent and a 20-year project life.

A life-cycle cost analysis for each secondary treatment alternative is shown in Table 1.

This analysis indicates that Alternative 3A – MLE Circular Basin has both the lowest capital cost and present-worth value at approximately $74M and $117M, respectively. The MLE Rectangular Basin and MBBR alternatives were found to have slightly higher present-worth values, while the MBR and BAF alternatives were found to have significantly higher capital costs and higher present-worth values.

For study level cost comparisons, a cost difference of less than 10 percent is usually considered insignificant; therefore, it can be concluded from the life-cycle cost analysis that the MBR

Continued on page 40

Mark Martin is an engineering manager in the Fort Myers office of the consulting engineering firm Black & Veatch; Andy Westfall is an engineering manager in Black & Veatch's Tampa office; Mark Steichen is a process engineer in the firm's Kansas City, Missouri, office; and Larry Bishop is an associate vice president in the firm's Miami office. Saeed Kazemi is the public works director for the city of Fort Myers. This article was presented as a technical paper at the 2009 Florida Water Resources Conference.

Table 1 - Secondary Treatment Cost Summary

	Alt. 1 [1] MBR	Alt. 2 BAF	Alt. 3A MLE (Circ.)	Alt. 3B MLE (Rect.)	Alt. 4 MBBR
Capital Cost	$ 107,890,700	$ 87,429,600	$ 73,764,000	$ 81,547,100	$ 85,035,000
Annual O&M	3,811,300	$ 3,459,900	$ 2,916,600	$ 2,993,500	$ 3,003,800
PW of O&M	$ 56,702,500	$ 51,474,600	$ 43,391,600	$ 44,535,700	$ 44,689,000
Total PW	**$ 168,070,800**	**$ 138,904,200**	**$ 117,155,600**	**$ 126,082,800**	**$ 129,724,000**
Capital Cost $/gal	**8.99**	**7.29**	**6.15**	**6.80**	**7.09**
% above lowest	**43.46%**	**18.56%**	**0.00%**	**7.62%**	**10.73%**

(1) PW of O&M includes two membrane replacements at years 7 and 14.
(2) Costs are based on a 12 mgd facility, but do no represent full project costs since the evaluation focused on costs which differed between the alternatives

Continued from page 38
and BAF alternatives are not as economical as the other three alternatives. Significant non-economic advantages will have to be identified to justify the selection of these two technologies.

The non-economic factors believed to be important for the treatment technology selections are summarized in Table 2, along with their respective weightings that define their relative importance to the overall selection. These weightings were determined in workshops between the city and the design team.

Non-economic criteria are more subjective than economic criteria, but they are also important to the overall evaluation process. The use of these criteria in the evaluation process helps identify alternatives that best address the city's primary concerns.

A methodical scoring system was used to help compare the alternatives based on the non-economic criteria. The weighting system was used to establish the relative importance of a criterion. Using this method, a composite benefit score was developed for comparing the alternatives using the Criterium Decision Plus® (CDP) software.

Figure 1 shows a comparison of the benefit scores and how each criterion contributed to the overall score, as generated by the CDP software for the secondary treatment alternatives.

The benefit scores for the MBR and MBBR alternatives are similar at approximately 0.80, while the benefit scores for the other three alternatives are notably lower. The MBR and MBBR alternatives have a higher benefit score primarily because they scored much higher than the other alternatives on criteria that are focused on neighborhood impacts.

Although the MBR and MBBR total benefit scores are similar, it is evident the MBR alternative scored higher on neighborhood impact criteria, while the MBBR scored higher on process and mechanical reliability criteria. The BAF alternative was given the lowest benefit score with relatively low contributions in all categories other than criteria addressing infrastructure factors.

The benefit scores for each alternative were divided by the respective present-worth values and normalized to the highest life-cycle cost alternative to generate a benefit/cost ratio comparison of the alternatives. Figure 2 shows the benefit/cost ratio comparison of the alternatives.

The MBBR and MLE Circular Basin alternatives have the highest benefit/cost ratio, indicating that these two alternatives provide the best value for the overall life-cycle cost. The benefit/cost ratio for the MBR and BAF alternative were considerably lower, while the MLE Rectangular Basin alternative was found to have a somewhat lower benefit/cost ratio.

Based on the results of the secondary treatment technology evaluation, it was recommended that Alternative 4 – Moving Bed Biofilm Reactors (MBBR) be implemented at the East WRF. This alternative was found to be competitive economically with the other alternatives with a present-worth value within approximately 10 percent of the lowest present-worth alternative (Alt. 3A – MLE Circular Configuration).

The non-economic evaluation concluded the MBBR alternative is also attractive based on the selected non-economic criteria, with a total benefit score nearly matching that of the MBR alternative. The MBBR alternative was also found to have a high benefit/cost ratio, nearly equaling that of the MLE Circular Configuration alternative, indicating that the MBBR alternative will provide good value for the overall life-cycle cost.

Table 2 – Criteria Weighting

Fort Myers, East WRF	Criteria Weighting Category	Sub-criteria
Reliability	20%	
Proven performance		40%
Operational flexibility		20%
Ease of operations		40%
Total (100)		*100%*
Impacts on Neighbors	35%	
Reduces odor potential		35%
Minimizes truck traffic		10%
Aesthetics		20%
Public safety and acceptance		35%
Total (100)		*100%*
Implementation and O&M	20%	
Ease of permitting		50%
O&M Requirements		25%
Constructability / Schedule		25%
Total (100)		*100%*
Sustainability	20%	
Flexibility to accommodate future treatment requirements		20%
Hydraulics, flow control, and yard piping		25%
Effluent water quality		30%
Equipment has good safety record		25%
Total (100)		*100%*
Infrastructure Factors	5%	
Land use		30%
Hydraulics, flow control, and yard piping		50%
Green technology		20%
Total (100)		*100%*
	100%	

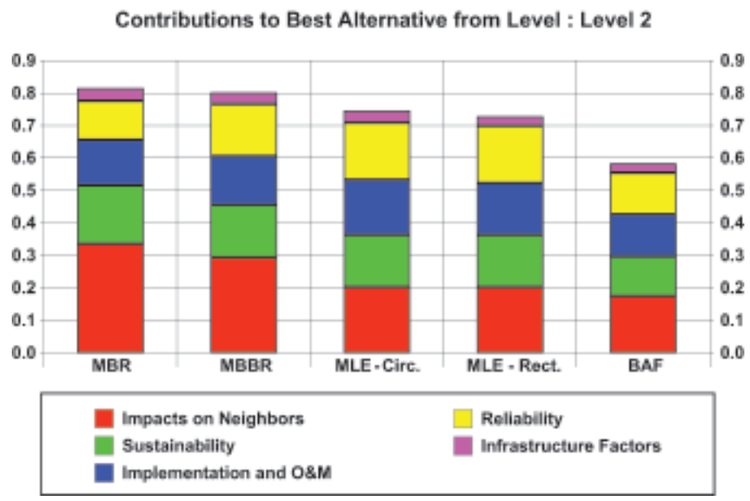

Figure 1 – Secondary Treatment Alternatives – Benefit Score Contributions

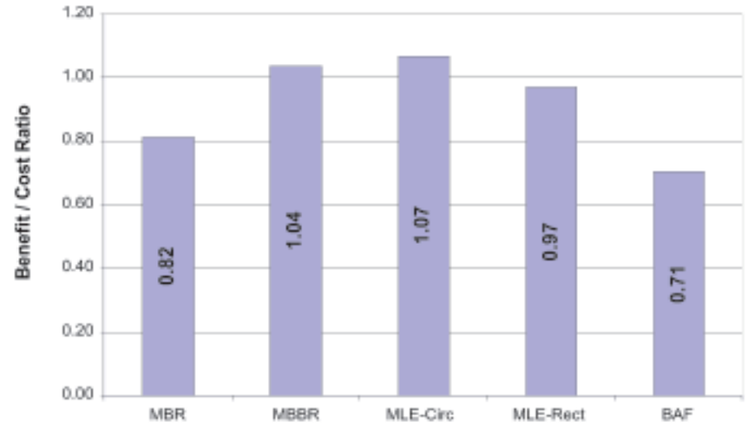

Figure 2 – Secondary Treatment Alternatives – Benefit / Cost Ratio

The MBBR alternative will provide a reliable high-quality effluent that when filtered will be very similar to an MBR effluent. Compared to MBR technology, the MBBR process has a similar small footprint and has significantly less mechanical equipment, instrumentation, and controls. The MBBR process is also very simplistic from an operational perspective, with fewer operational control parameters than the other activated sludge alternatives.

Although the MBR technology may be perceived by some in the industry as the "cutting edge" technology, the proposed MBBR alternative is an innovative solution that is well suited for the specific treatment and site requirements for the East WRF. The city of Fort Myers and other project stakeholders will save an estimated $38M over a 20-year period by implementing MBBR rather than MBR, based on the results of the life-cycle cost analysis.

Although the present-worth value of the MBBR alternative is approximately 10 percent greater than the MLE circular configuration alternative, there are a number of other factors that support implementing the MBBR alternative. This technology will reduce the footprint of the secondary treatment process by approximately 50 percent, and a WAS thickening facility will not be required which will further reduce the overall footprint of the East WRF.

By reducing the overall size and footprint of the WRF, the MBBR process will provide a more neighbor-friendly facility that has a lower odor potential and is more visually appealing to the community. The MBBR process is also a "state-of-the-art" technology that is completely different than the activated sludge processes at the existing wastewater treatment facilities in Fort Myers, which are not perceived as neighbor-friendly facilities. The operational simplicity of the MBBR process will also reduce staffing requirements for the East WRF.

Finally, it is important to remember that for study-level cost comparisons, a cost differential of less than 10 percent is usually considered insignificant, so the cost differential between these two alternatives is only approaching the point at which it should be considered significant.