Managing the "Other" Advanced Sewage Treatment Systems: An Assessment of Florida's Aerobic Treatment Units and Similar On-Site Sewage Treatment Systems

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On-site sewage treatment and disposal systems (OSTDS) serve approximately one-third of all households in Florida. While most of them are conventional OSTDS, also known as septic systems, there are some other systems that provide additional or advanced pretreatment before disposal. These systems are generally permitted as aerobic treatment units (ATU) or performance-based treatment systems (PBTS).

A property owner may need or want an advanced system because the property is located in an area where more stringent state or local regulations exist, state regulations allow advanced systems with smaller drainfields or reduced setbacks in some instances, or for protection of the environment with cleaner wastewater effluent.

Generally, advanced systems differ from conventional systems by allowing for variability in design, the need for more frequent checkups and maintenance, and production of a cleaner effluent. They are managed differently from conventional systems, with Florida's regulations (Section 381.0065 Florida Statutes and Chapter 64E-6 Florida Administrative Code) requiring that a system be inspected by the county health department inspector once a year and that a system owner contract with a maintenance entity, which in turn visits the system for maintenance twice a year. No systematic assessment of effluent quality of advanced on-site sewage treatment systems has been done in Florida since 2001, when a change in Florida statutes decreased operating permit fees; this resulted in the discontinuation of a sampling program implemented by the county health departments. A review of aerobic treatment unit sampling results gathered previously in one county showed high variability of effluent quality that was at least, in part, related to differences in sample locations (Roeder and Brookman, 2006).

This article describes an assessment of the performance and management of advanced on-site treatment system throughout Florida done by the Florida Department of Health On-Site Sewage Programs. The project was funded through an interagency agreement with the Florida Department of Environmental Protection (FDEP), via a grant from the U.S. Environmental Protection Agency Nonpoint Source Pollution program (Section 319). The study included several components, starting with a pilot project in Monroe County assessing variability of effluent quality in samples from 2007 to 2009, and continued with statewide efforts such as inventorying advanced systems in 2010 through 2011, surveying of various user groups in 2010, and assessing the operational status of systems, and sampling systems, including analyses for carbonaceous biochemical oxygen demand (cBOD5), total suspended solids (TSS), total nitrogen (TN), and total phosphorus (TP), between February and September 2011. The results of the inventory effort are summarized, some results of the survey of owners and users of advanced systems are highlighted, and results from a random sample of advanced systems are discussed.

Inventory of Advanced Systems

The objective of the inventory was to allow random and stratified random sampling for later surveys and site visits. The development of a project-specific inventory of advanced systems required the aggregation and consolidation of data from the Florida Department of Health's statewide permitting data system, a third-party web-based maintenance reporting system that is offered to county health departments and maintenance entities through a contract with the FDEP, and supplemental data obtained from county health departments and the on-site sewage programs office.

The resulting inventory, implemented in MS-Access, presented a snapshot of source databases in the second half of 2010. The consolidation steps aimed to match records from different sources and generate a list of addresses for subsequent surveys and site visits. The project report contains additional details of the database development process (Ursin and Roeder, 2011).

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The database identified nearly 16,600 addresses for advanced systems in Florida. Compared to the approximately 2.7 million on-site systems estimated to exist in the state, this indicates that less than 1 percent falls into the "advanced" categories. Advanced systems in Florida are often concentrated in certain counties, due to more stringent state regulatory or local ordinance requirements. Over 60 percent of the advanced systems in Florida can be found in five counties: Monroe, Charlotte, Brevard, Franklin, and Lee; statutory requirements have triggered the high numbers in Monroe County. Local ordinances covering parts of Charlotte, Brevard, and Franklin County explain the high numbers in these areas. In Lee County, the flexibility of allowing larger houses, and/or smaller drainfields as part of advanced systems on a given lot appears to have been the reason for the higher numbers there. The advanced systems are predominantly residential ATU systems. Just over half of the systems with known installation dates were installed within two to five years of Jan. 1, 2010, coinciding with a building boom in Florida.

Extended aeration is the predominant technology used in Florida. Over 90 percent of the inventoried systems that included treatment technology information had extended aeration. Fixed film and mixed approaches, such as fixed activated sludge treatment, share the remainder of the market. Figure 1 illustrates the distribution of systems by different manufacturers in Florida. Each of the manufacturers offers, generally, one to three different product lines of aerobic treatment units, usually based on the same technology; Consolidated, Aqua-Klear, Hoot, Norweco, and Clearstream are the top five manufacturers used in Florida. Several manufacturers, with a combined total of less than 100 identified systems, were combined into the "other" category.

Survey of User Groups

The objective of the user group surveys was to allow a representative sample of several user groups to voice their views and opinions about the management of advanced on-site systems, as well as to measure the practices and perceptions of these user groups. Florida State University's Survey Research Laboratory (FSU-SRL) performed the survey and provided methodological expertise. Survey questions included some that were targeted to specific user groups, as well as some overlapping questions, where appropriate, to gauge differences between the groups on specific issues. The project considered six user groups: system owners/users, regulators, installers, manufacturers, maintenance entities, and engineers.

The FSU-SRL sent a total of 3,793 surveys to a stratified random sample of system owners/users, and 660 completed surveys (17.4 percent) were returned. The addresses stemmed from an intermediate development stage of the inventory database that allowed stratification as to whether the system was an ATU or a PBTS and if the facility served was residential or commercial. Most of the surveys that were returned were from full-time residents that owned the homes with the advanced system and for systems serving less than four people. Fifty-five percent reported never experiencing problems, 33 percent reported experiencing problems once or twice within the last year, and 11 percent experienced problems several times. The major sources of problems were system malfunctions such as pump failures, electrical malfunctions, faulty alarms, and bad motors. Figure 2 indicates how satisfied system owner/users were with their systems, with 79 percent being either very satisfied or satisfied.

The FSU-SRL sent surveys to all county health departments, all installers (septic tank contractors), maintenance entities, and engineers for which the department had contact information from licensing or permitting files. The response rates for installers (9 percent), maintenance entities (15 percent), and engineers (12 percent) were lower than for the owner/user group. More than half of the responding installers and about a third of the responding engineers indicated that they had not installed advanced systems. This is likely a reflection of the small number of advanced systems, and the fact that eleven (of sixty-seven) county health departments reported not having a single advanced system installed in their county.

Figure 3 compares the responses from engineers, maintenance entities, installers, and regulators regarding their overall perception of treatment performance. All of these groups predominantly indicated that both ATU and PBTS performance is either good or excellent. When comparing this result with how satisfied homeowners are (Figure 2), this seems to indicate that advanced systems are fairly well accepted among the different user groups.

Selection of Advanced Systems for Assessment, Sampling and Permit Review

The inventory allowed system selection for further permit review, site assessment,

Continued on page 48

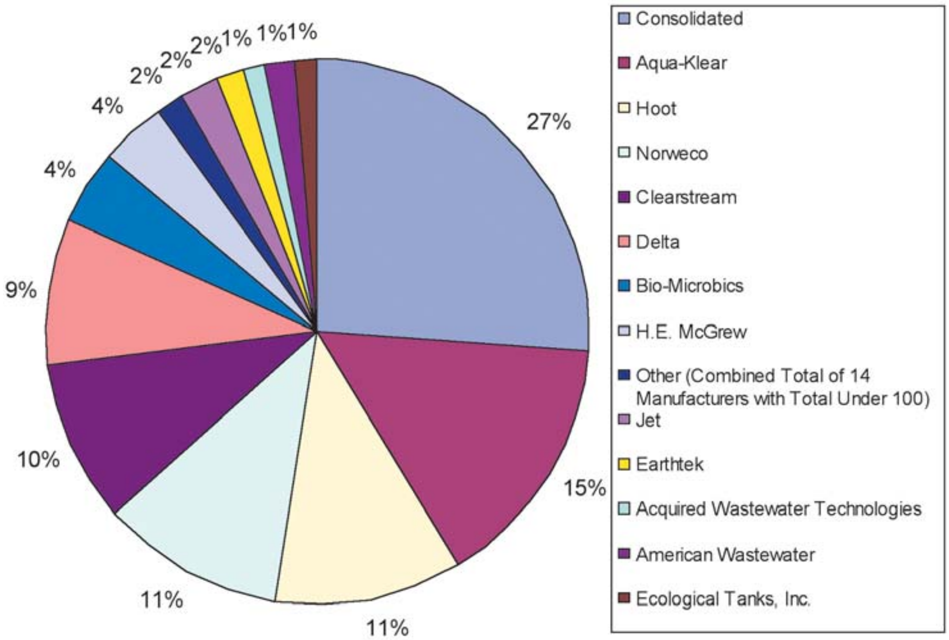

Figure 1. Distribution of Manufacturers of Advanced Treatment Systems for Which Information was Available (n=9,161)

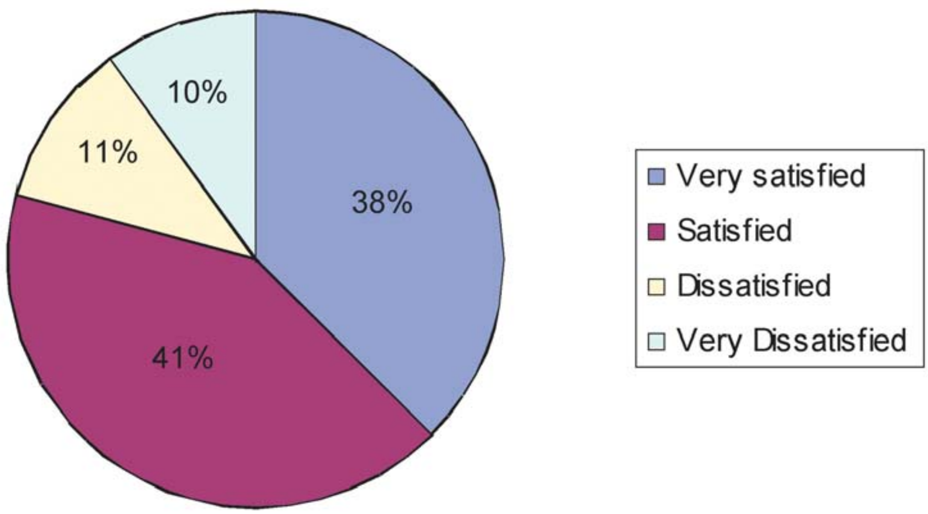

Figure 2. System Owner/User Satisfaction (Question: How would you describe your overall satisfaction with your advanced onsite sewage system [septic system])

Continued from page 47
and sampling. Most sites were selected as a random sample from the inventory, while others were chosen to ensure that a variety of technologies were part of the sample population. For purposes of this article, only the 901 sites that were selected as a random sample are included in the subsequent discussions and calculations. The distribution of these sites generally aligned with the distribution of advanced systems in the state, with counties that have the most advanced systems having the highest representation in the random sample.

Following the selection of sites, project staff performed a detailed review of construction and operating information. The information was complemented by the subsequent site visits. This review resulted in the determination that about 30 percent of sites were not active advanced systems. The most common reasons for the difference were: the system had been abandoned, that is, the property had connected to the sewer (10 percent); the information stemmed from operating permits for other purposes (9 percent); or the property was served by a conventional on-site system (7 percent). These review steps left 629 advanced systems in the random sample as targets for a field assessment. Applying the 30 percent exclusion rate to the number of systems in the database results in 11,600 as the estimated number of active advanced systems as of mid-2011.

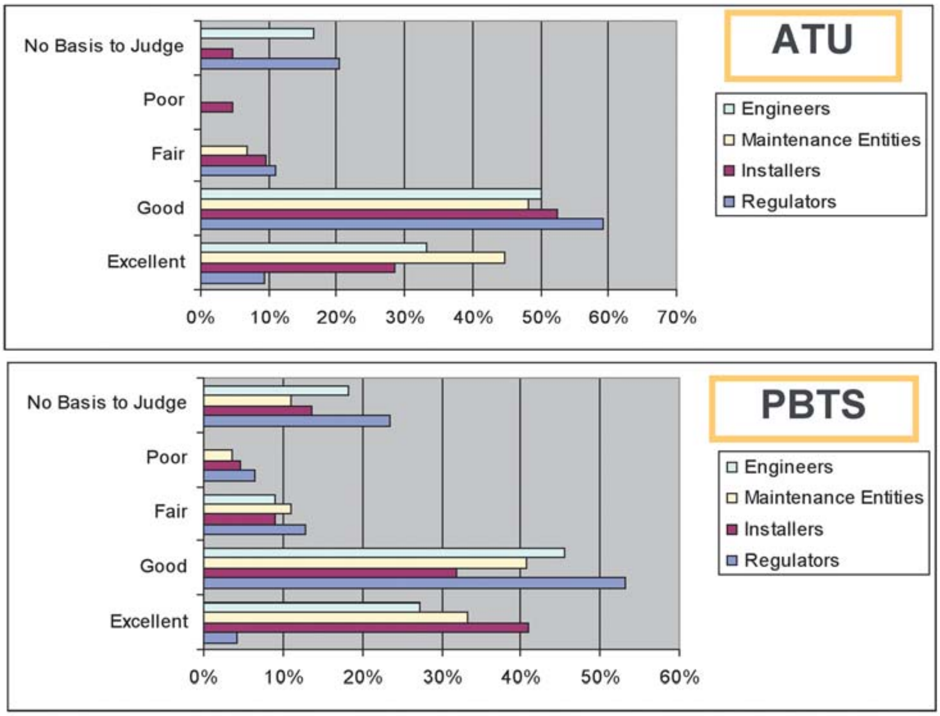

Figure 3. Comparison of the Perceptions of Overall Treatment Performance of Advanced Systems Among Groups (Question: How would you rate the OVERALL TREATMENT PERFORMANCE of the advanced systems you are involved with?)

Table 1. Distribution of Issues for Non-Properly Working Systems

Issue	Number of Observations			Relative Frequency of Issue	
	Total	Vacant	Not vacant	Of all determinations	Of not vacant determinations
Overall not operating properly	142	50	92	30 percent	24 percent
Aerator not working	84	42	42	22 percent	13 percent
Aeration not working	77	21	56	23 percent	19 percent
Power switched off	65	44	21	15 percent	6 percent
Power not on per indicator	56	25	31	24 percent	16 percent
Alarm on	21	3	18	5 percent	5 percent
Surfacing/Breakout	11	1	10	3 percent	3 percent
Broken/Missing Cover	7	2	5	2 percent	1 percent
Ponding	5	0	5	1 percent	1 percent

Assessment and Sampling of Advanced Treatment Systems

Project staff visited sites throughout Florida to perform field assessments, usually combined with sampling. Logistical challenges and time constraints prevented site visits in about 10 southern Florida counties and kept the completion rate in Monroe County low, so that only 469 of 629 targeted advanced systems were assessed with a site visit. Due to denial of entry by owners or obstructions to access, the data gathered for some systems was limited. The detailed field assessments encompassed an initial assessment, similar to annual inspections that county health departments perform and, where feasible, field measurements and sampling. Laboratory samples were packed in ice and sent overnight to a laboratory certified by the National Environmental Laboratory Accreditation Program (NELAP).

The field assessment included field observations to see if the system was operating properly: power was on, no sanitary nuisance existed, aerators were working, aeration resulted in bubbles and mixing of sewage, and alarms were not on. During data analysis, these observations were summarized to determine if the system appeared to be operating properly. These operational assessments provide a general indication that could be applied to the larger population of advanced systems. Qualitative field observations during the site visits indicated that 83, or about 18 percent, of the visited advanced systems served vacant houses or lots. For the largest counties, the vacancy rates ranged from 11 percent (Brevard) to 24 percent (Lee).

Thirty percent of the sites visited were considered not to be operating properly (142 out of 469 systems); the main reason for a system not operating properly was related to the aeration system (Table 1). The most common nonfunctional conditions were that the aerator was not working, the aeration in the aeration tank was not working, power was switched off, or the power indicator was not on. These three observations overlap: not all systems included identifiable power indicators, and for some systems the aerator was not operating, even if there was power. Compared to the frequency of inoperable aeration, other issues were relatively rare among the determinations; these include: alarms were on (5 percent), evidence of surfacing or breakouts of sewage (2 percent), broken or missing covers or lids (2 percent), and indications of soil saturation and ponding in the drainfield area (1 percent). From a water quality protection perspective, it appears useful to distinguish between systems without discharge (vacant) and with discharge (not vacant). Table 1 also provides data comparing issues for occupied (not vacant) and vacant properties separately. When focusing on not-vacant properties, the frequency of issues overall is reduced to a quarter and the power related issues decrease noticeably; in particular, the fraction of systems switched off decreased from 15 percent to 6 percent. It is reasonable to expect this difference in that a vacant property is much more likely to have had the power turned off to the entire property. The field assessment was valuable at vacant properties to determine system issues unrelated to power. Ponding—the accumulation of water in and above the drainfield—was never observed at vacant houses, consistent with a lack of water use.

One means to provide an assessment of the performance of advanced systems is to compare effluent to influent data. For the purposes of this project, the influent to the advanced system was obtained by drawing from the clear zone of a pretreatment compartment or trash tank of systems, when feasible. These samples represent sewage that has already undergone some settling and anaerobic pretreatment. In this way, the samples are also comparable to septic tank effluent, although septic tanks tend to be larger by a factor of about three. Effluent samples were obtained wherever it was feasible, generally by drawing from dosing tanks, sampling ports between the treatment unit and the drainfield, or clarifiers, in this order of preference if more than one sampling location existed. The sampling emphasized nonvacant lots in order to obtain representative sewage samples.

Influent Concentrations

In reviewing the influent data, several samples showed high nitrate/nitrite nitrogen values. Samples with values above 5 mg/L ni-

Continued on page 50

Table 2. Influent Data Summary From the Random Sample of Systems

Influent (mg/L)		cBOD5	TSS	TKN	NOx	TN	TP
Parameter	Valid	41	42	42	42	42	41
	Missing	1	0	0	0	0	1
Mean		115.7	76.0	51.1	0.313	51.4	8.7
Std. Deviation		97.9	670.9	37.6	0.715	37.3	5.7
Minimum		2.0	7.0	0.1	0.008	3.0	0.1
Maximum		393.0	434.0	181.0	3.080	181.0	33.5
Percentiles	10	15.4	17.9	11.2	0.019	11.2	2.2
	25	42.3	28.0	22.1	0.034	22.5	5.7
	50	95.2	66.0	45.3	0.034	45.3	7.9
	75	166.0	110.5	74.3	0.184	74.6	10.5
	90	250.6	140.7	102.2	1.119	102.2	14.3

Continued from page 49

trate/nitrite were excluded as inconsistent with an anaerobic pretreatment step (five of 47 samples). Possible causes are a misidentification of compartments in the field or interaction between aeration treatment and pretreatment compartments. Table 2 summarizes the results of the influent sampling. The data show considerable and somewhat skewed variability, with an interquartile range that is larger than the median value for all parameters other than TP.

The median value for cBOD5 (95 mg/L) is much lower than the median for septic tank effluent (216 mg/L) that has been recently reported (Lowe et al., 2009), while the median value for TSS (66 mg/L) was similar to the 61 mg/L reported (Lowe et al., 2009). The median values for TN (45 mg/L) and TP (7.9 mg/L) in this study were both somewhat lower than the 60 mg/L and 9.8 mg/L, respectively, reported by Lowe et al. The concentrations can also be compared to results from a pilot study in Monroe County (Roeder, 2011). In that study, influent concentrations of advanced treatment systems that appeared to be most representative for pretreatment tank effluent showed median concentrations of 99 mg/L, 64 mg/L, 76mg/L, and 10 mg/L for cBOD5, TSS, TN and TP, respectively. Again, the current study showed lower nutrient concentrations. Perhaps this could be related to differences in water usage, but this was not part of the study data collection.

Effluent Concentrations and Treatment Effectiveness

The effluent concentrations based on one effluent sample each for 309 sites are shown in Table 3. The median concentrations for cBOD5 (5.5 mg/L) and TSS (19 mg/L) show substantial removal, as compared to the influent concentrations. The Total Kjeldahl Nitrogen (TKN) and nitrate-nitrite (NOx) concentrations indicate that there is a wide variability among systems as to the extent of nitrification. The TN concentrations (30 mg/L) show some removal and the TP concentrations are less than 1 mg/L lower than before the aeration step. The effluent concentrations can be compared with results from a review of ATU-inspection results from Monroe County during 2000 and 2001 (Roeder and Brookman, 2006). The median effluent results for cBOD5 and TP were within 10 percent of each other, and TN concentrations (26 mg/L), somewhat lower. The TSS concentrations in that study were 32 mg/L, somewhat higher than here.

Based on the median effluent concentrations relative to influent concentrations, the typical removal effectiveness of the advanced treatment units is 94 percent for cBOD5, 72 percent for TSS, 84 percent for TKN, 33 percent for TN, and 6 percent for TP. The removal effectiveness for cBOD5, TN, and TP is consistent with expectations for such treatment systems. The removal effectiveness of TSS is somewhat lower than expected and suggests that perhaps there was entrapment of inert solids during the sampling process.

Comparisons of effluent concentrations were performed, using the Kruskall-Wallis Test. The relative small number (12) of sampled vacant systems showed significantly lower concentrations (level of significance <5 percent) in cBOD5, NOx, and TN than nonvacant systems. Of particular interest were differences between well- and poorly-operating systems. Effluent concentrations from systems with one or more aspects of an unsatisfactory operational status (power switched off, power off or aerator not working, diffusers not working, overall unsatisfactory status) were compared to effluent concentrations from systems with a satisfactory operational status. Using several measures of unsatisfactory operation yielded similar results: the systems that appeared operational performed significantly better than the nonoperational ones for cBOD5, TKN, and TN, but not significantly different for TSS and TP.

The highest removal rates based on median concentrations were estimated for systems for which the power was on and the aerator was working (95 percent for cBOD5, 73 percent for TSS, 89 percent for TKN, 36 percent for TN, and 7 percent for TP). The apparent lack of aeration in treatment systems resulted in samples with median concentrations, which indicated lack of nitrification, no nitrogen removal, and reduced cBOD5 removal (only 60 percent).

The substantial fraction of low cBOD5 effluent concentrations in samples from nonoperational treatment systems and the measurement of high nitrite/nitrate concentrations in some of these samples indicate that the power operational status at the time of the visit is not completely predictive of effluent concentrations. One reason could be the hydraulic residence time in the treatment unit, which is typically several days. Effluent from a system that is not operating now due to a power failure, but was operating a day to several days ago, would still show the effect of treatment in the effluent.

Conclusions

Advanced OSTDS are utilized in Florida for various reasons. These systems require more maintenance and management than a conventional OSTDS. Most advanced systems are located in counties where state or local regulations require them.

The inventory of advanced systems developed during the project initially estimated 16,600 advanced systems in Florida; this estimate was revised to 11,600 systems in mid-2011 based on permit file review. Less than 1 percent of on-site systems fall into the advanced system categories. By far the most common treatment technology in these systems is extended aeration.

A survey of user/owners of advanced on-site systems and other stakeholders found largely positive opinions about systems. More than three quarters of owners or users of such systems were very satisfied or satisfied with the operation of their system.

During site assessments of 469 randomly selected advanced systems, approximately one-third were found to be not operating properly. The main reason for this was an apparent lack of power to the system or aerator malfunction. Lack of power was much more common in vacant houses.

Influent concentrations, as measured in nonaerated pretreatment tanks, indicated wide

Table 3. Effluent Concentration Summary for the Random Sample of Systems

Effluent (mg/L)		cBOD5	TSS	TKN	NOx	TN	TP
Parameter	Valid	301	309	309	309	309	308
	Missing	8	0	0	0	0	1
Mean		24.7	36.8	21.3	16.661	38.0	8.0
Std. Deviation		51.4	57.1	32.2	21.6	33.4	4.4
Minimum		2.0	3.5	0.1	0.008	0.5	0.0
Maximum		450.0	484.0	252.0	108.000	290.0	29.0
Percentiles	10	2.0	3.5	0.1	0.019	7.4	2.9
	25	2.2	6.5	1.4	0.219	16.4	5.3
	50	5.5	18.7	7.4	6.850	30.3	7.5
	75	24.1	42.0	27.7	26.250	51.5	10.0
	90	62.2	92.0	68.9	49.500	77.0	13.0

variability in strength. Median cBOD5, TN, and TP concentrations were lower than reported in other recent studies.

Median effluent concentrations indicated over 90 percent removal for cBOD5, about three-quarters removal for TSS, one-third for TN, and nearly none for TP, compared to the median influent concentrations. These are generally consistent with the treatment technology employed, while the lower-than-expected TSS removal may be in part related to the sampling process.

Advanced treatment systems assessed as operational, either as overall assessment or based on power supply and aerator operation, perform significantly better than nonoperational ones with respect to cBOD5, TKN and TN removal.

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Notice

The information contained within this article does not necessarily reflect the official opinion of the Florida Department of Health, and no official endorsement should be inferred.

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