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Maintaining and Troubleshooting Advanced Onsite Systems: Git 'er Done!

T.R. Bounds; Grant Denn; N. Tristian Bounds[1]

Abstract:
Regular, proactive servicing of onsite wastewater treatment systems optimizes the treatment process and reduces operation and maintenance costs. Service providers need to have a solid understanding of the system's configuration, components, and component functions; treatment processes; performance expectations at each stage in the treatment process; routine maintenance procedures; performance indicators (including but not limited to effluent sampling); and troubleshooting strategies. In addition, maintenance of recirculating systems requires an understanding of the performance impacts of recirculation ratios, dosing, and mass balancing. And maintenance of nitrogen-reducing systems requires an understanding of the delicate relationships between alkalinity, ammonia, nitrate, BOD_5, dissolved oxygen, pH, fats and oils, etc. Ultimately, in order to "git 'er done," service providers must become alert to in-field indicators (effects) and skilled in — and committed to — discovering their cause.

Keywords: maintenance, troubleshooting, service provider, primary treatment, secondary treatment, advanced treatment, pump out intervals, hydraulic flows, waste strength, effluent, sampling, recirc ratios, dosing, mass balancing, denitrification

INTRODUCTION:

All onsite wastewater treatment systems require servicing, from the simplest of standard stone-trench systems to the most complex tertiary treatment systems. Regular servicing optimizes the treatment process and reduces operation and maintenance costs. Many of us probably remember the commercial for Fram oil filters: "You can pay me now, or pay me later."

Consequently, onsite system operators and service providers (in partnership with system users) play a crucial role. Property owners, neighbors, regulators, designers, installers, manufacturers, and dealers rely on the service provider to ensure efficient and effective system performance.

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Whether servicing individual onsite systems or multiple "clustered" systems, service providers must begin with a mindset committed to proactive servicing and preemptive troubleshooting. This requires more than simple book knowledge and classroom teaching. It requires a high degree of alertness to details and indicators in the field, an understanding of "cause and effect" (because every effect is provoked by a cause), and a willingness to take appropriate action to remediate the causes.

Much has been written about the importance of regular maintenance, developing maintenance protocols, creating maintenance districts, developing maintenance manuals and checklists, etc. This article touches on a few of those O&M essentials but primarily offers both **basic and advanced guidelines for evaluating system performance in the field and troubleshooting when indicators signal that something may be amiss**, especially with regards to recirc ratios and nitrogen reduction, key performance features of secondary and advanced treatment systems.

DISCUSSION:

Operation and maintenance of any onsite treatment system requires an understanding of the following information:

#1) The system's configuration, components, and component functions
#2) Basic treatment processes
#3) Performance expectations (norms) at each stage in the treatment process
#4) Routine maintenance procedures and frequencies
#5) Effluent sampling and other indicators
#6) Basic troubleshooting and diagnostic tips
#7) Advanced troubleshooting and diagnosis — recirculating processes
#8) Advanced troubleshooting and diagnosis — nitrogen and denitrification

In each of these areas, there are things that service providers can do to be detail-oriented and proactive about system maintenance and troubleshooting.

#1) System Configuration, Components, and Component Functions

Service providers should have copies of and be familiar with all the system's manuals (installation, operation, and maintenance) and be trained and authorized by the system manufacturer or manufacturer's rep.

Providers should have a schematic of each system's configuration as shown in Figure 1 and should always keep a copy at the site (e.g., inside the control panel), as well as in the office files.

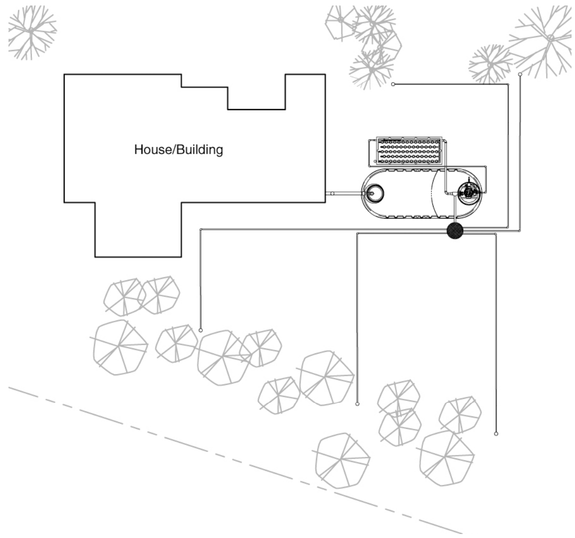

Fig. 1. Site Layout and Process Configuration

Ideally, the service provider would also be involved in the system's installation to ensure that consideration has been given to post-installation servicing requirements. For example, the service provider can ensure that all components are accessible for servicing from "ground" level, with no excavation required. The service provider can also ensure that effluent filters are visible from tank access openings and that the filter can be removed, without obstructions, for cleaning.

During installation, the service provider and installer can consider whether observation ports in filters and dispersal fields might be useful (Figure 2). Observation ports can be extremely beneficial in assessing the need for preventive action to head off clogging events. White PVC is preferred, especially for deeper locations, since it does a better job of reflecting light, thus making it easier to detect water levels. Two or four ports may be installed in a filter or dispersal field depending on size and need. For the greatest effectiveness, locate observation ports in or near the middle third of the filter and both upstream and downstream of the dispersal field. (Observation tubes must be secured to keep them from moving.)

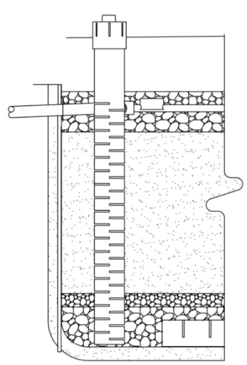

Fig. 2. Observation Port

Similarly, the installation of appropriate sampling ports (Figure 3) is extremely beneficial in applications that require continual or extensive monitoring. Sampling ports need to be located at the inlet and outlet of each treatment unit or process step and should be positioned to allow good visual access. With sampling ports, sampling time can be cut in half, and the accidental contamination of samples (by inadvertent contact with surfaces where biofilms attach) can be more easily avoided.

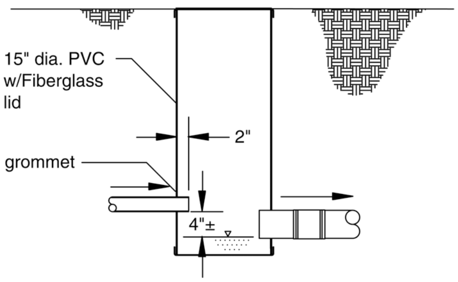

Fig. 3. Sampling Port

#2) Basic Treatment Processes

Before providing any service, all operators must have, at the very least, some basic understanding of wastewater treatment processes, the differences between processes (e.g., fixed film attached growth packed bed filters vs. suspended growth extended aeration units), and the processes for each of the systems that the provider is servicing.

Primary Treatment — Many onsite systems use a septic tank, process tank, or interceptor tank (Figure 4). As long as they are constructed and tested for watertightness, these tanks provide passive, energy-free primary treatment — the most cost-efficient method of primary treatment available for non-industrial sewage. Consequently, these tanks are often considered the single most important component used in all onsite alternatives for treatment and collection of wastewater.

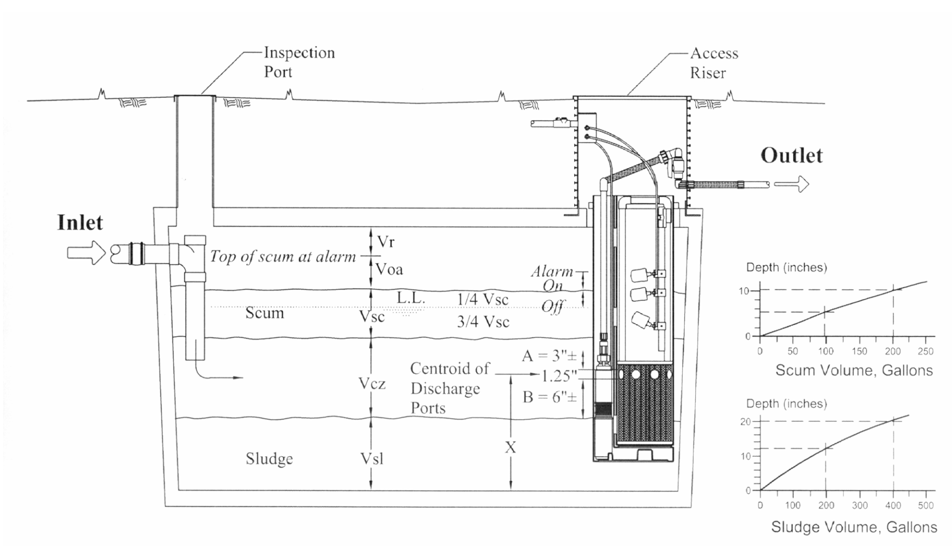

Fig. 4. Typical 1000-gal. Concrete Dosing Septic Tank with Sludge and Scum

Particles ascend or descend, and stratification develops, creating three distinct layers as shown in Figure 4. At the top, the floating layer is the *scum* layer (about 25% of the scum layer floats above the actual liquid level); on the bottom, the *sludge* layer develops; and between is the *clear zone*, which is relatively free of large solids. Under normal conditions, more than 45% of ultimate wastewater treatment can be accomplished in the septic tank; BOD_5 (biochemical oxygen demand) removals of greater than 65% and TSS (total suspended solids) removals of greater than 70% are easily accomplished (Bitton, 1994).

Secondary/Advanced Treatment — Many different kinds of processes are capable of providing secondary or advanced treatment, although there are varying levels of service and maintenance requirements relative to the different processes and products. For example, packed bed filters include a component for physical removal of wastewater constituents, and they can achieve performance norms without nutrient-rich forward flows. That means they can perform at start-up or with infrequent use. Suspended and submerged attached growth systems, however, need 20 or more days to mature. The service provider must be familiar with these differences.

Secondary/advanced packed bed filter systems may be configured to operate in a single-pass mode or recirculation modes. Forward flows and organic loading rates will vary relative to the recirculation capacity and the ability to blend and dilute influent strengths. Recirculating processes tend to allow smaller footprints than single-pass systems, but generally are more sophisticated to operate, although current technologies, such as full-time telemetry controls, help out greatly.

Final Dispersal — Final discharge practices vary per state and local regulations; however, it is highly preferable for final treated effluent to be discharged into subsurface soil dispersion system. Many subsurface dispersal options are available to onsite developers today, ranging from standard gravel systems, to chamber systems, to drip systems, to shallow (less than 10 inches deep) gravelless drainfields. Placing treated effluent as close to the surface as possible takes maximum advantage of naturally occurring scavengers (Degen et al., 1991).

#3) Performance Expectations (Norms) at each Stage in the Treatment Process

Secondary and advanced treatment processes are affected by influent flows and by influent strength. Most regulations and O&M guidelines focus on influent flows, but strength is even more important. The load on any given system is a function of "flow plus strength," which is called "mass loading."

Average flows (Q_a) are based on expected weekly discharges. Wastewater flows for single-family dwellings typically range from 40 to 60 gallons per capita per day (gpcd); **50 gpcd** is a commonly used design parameter and is the value used in the calculations in this article. Typical relationships between number of bedrooms, occupancies, and residential flows are shown in Table 1:

Table 1. Relationships between bedrooms, occupancies and flows

Bedrooms	Q_p [1] *gpd/DU*	Occu. [2] *capita*	Q_c *gpcd*	Q_a *gpd/DU*
1	200	2	55	110
2	300	3	50	150
3	375	4	50	200
4	450	5	45	225

[1] Peak day bedroom flows are based on typical administrative rules.
[2] Nominal occupancy is based on a typical usage of two occupants for the first bedroom and one occupant per additional bedroom.

With average daily flows of 40-60 gallons per capita per day, residential onsite systems should be able to meet the performance expectations shown in Table 2. Typical characteristics of residential strength wastewater influent are shown in the first line of the table. Typical characteristics of the effluent after passing through an in-tank filter or screen (in the septic tank) are shown in the second line. Typical characteristics of effluent that has recirculated through a secondary treatment system several times and blended with influent are shown in the third line. Typical characteristics of final (unblended) filtrate from a secondary treatment system are shown in the fourth line.

Table 2. Typical residential characteristics and performance levels

	BOD_5 mg/L	TSS mg/L	TKN-N mg/L
Raw Influent[1]	450	500	70
Primary Chamber Effluent	150	40	65
Recirc-Blend Effluent[2]	15-40	10-40	
Final Effluent[3]	5-25	5-30	

[1] Source: Crites and Tchobanoglous 1998, pp. 180 and 183. Based on 50 gpcd.
[2] Will vary with recirc ratios and mode configuration. The numbers here represent a recirc ratio between 2:1 and 4:1 and mass balances between the influent and recirc strengths.
[3] Performance results, based on testing results, such as averages from NSF (National Sanitation Foundation) or other relative information on treatment performance. Performance and servicing frequencies will tend to vary relative to the mass load being treated and whether or not the system is in a stress or overload condition or otherwise. Procedures for treating excessively high loads require special engineering review.

#4) Routine Maintenance Procedures and Frequencies

Maintenance is classified as either preventive or corrective. Preventive maintenance anticipates the potential problems that cause down-time or that jeopardize the functioning of the system and includes actions taken to prevent equipment breakdowns. (Remember: "You can pay me now or pay me later.") Preventive maintenance includes equipment surveillance, servicing, lubrication, and operating a maintenance information system, which helps perform these functions efficiently.

Corrective maintenance is repair of equipment after breakdown. Corrective maintenance problems are usually unexpected and addressed as they occur. While it is impossible to anticipate the unexpected, up-to-date maintenance records will indicate the frequency of unanticipated problems and bring out those that are recurring. Problems that are recurring should be incorporated into the preventive maintenance program.

Preventive maintenance is cheaper than corrective maintenance and also provides a more efficient, reliable, and long-term operation with the least amount of annoying downtime for system users and the maximum amount of safety for operating personnel.

Manufacturers are responsible for defining preventive maintenance procedures, frequencies, and expectations (norms) for all system components: tanks (sludge and scum monitoring), screens or filters, pumps, aeration equipment, manifolds (pressure residuals or squirt heights), control panels and meters, ventilation equipment, etc. Manufacturers and/or regulatory authorities should also define procedures, frequencies, and expectations for monitoring effluent quality.

Service activities should be performed three months after start-up and then every 6-12 months, or as frequently as necessary. Typically, NSF certified systems require a minimum of four inspections with sampling during the first two years, and then annual inspections with sampling are recommended. Routine maintenance checklists are the service provider's best friend (see samples, Appendix).

At start-up (and at regular intervals thereafter), the service provider needs to get together with the system user (especially residential homeowners) to review the Owner's Manual, which should be provided by the system's manufacturer. Users need to know …

- The "Do's and Don'ts" of system use and their role and responsibilities for cost-effective preventive maintenance.
- Their responsibility for keeping their household plumbing in good (leak-free) working order.
- Their responsibility for maintaining the building sewer by ensuring that <u>nothing</u> but the building sewer is connected to the septic tank (not gutters, not downspouts, not perimeter drains, not water softener backwash lines, etc.)

These periodic meetings with the users also allow the service provider to track and record significant changes in the household (e.g., number of occupants, changes in water use, use of detergents/cleaners, disposal of cleaning compounds, etc.), which can help when assessing system performance.

While providing O&M services, the service provider must be sure to use proper personal protection equipment, such as rubber gloves and clothing, to cover parts of the body that will be exposed to sewage or effluent.

One area of routine maintenance that's commonly misunderstood — both by system users <u>and</u> by service providers — is septic tank pump-out intervals. The pump-out interval must be long enough to ensure thorough digestion of solids for solids management. Intervals that are too short not only retard anaerobic digestion, but force users to pay significantly more for service and pumping.

The length of time between tank cleanings is relative to the number of users (occupants) and the size of the tank. The septage pumping interval may be estimated by using the following curves (Figure 5).

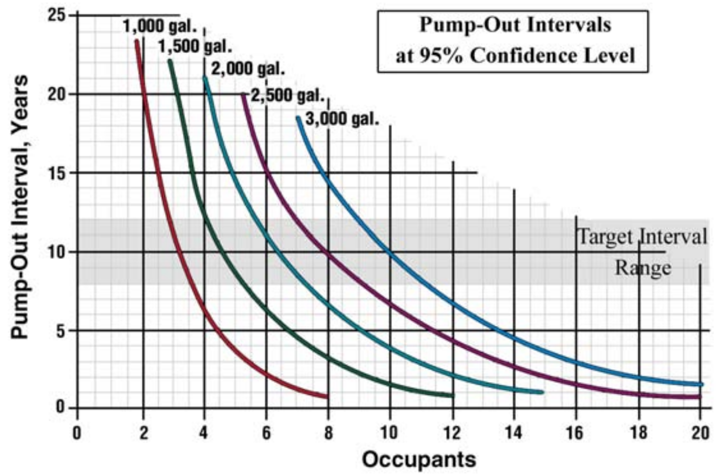

Fig. 5. Interceptor Tank Pump-Out Intervals

To achieve effective performance and minimize pump-out occurrences, recommended residential interceptor tanks should have a nominal liquid capacity of 1000 gallons for up to two bedrooms, 1500 gallons or more for three bedrooms and four bedrooms, and, for more than four bedrooms, the sizing shall be determined based on an occupancy assessment and be in accord with the graph in Figure 5.

Service providers must periodically inspect and record tank liquid depths, color of scum, and color of effluent, as well as measure and chart the sludge and scum thickness with a scum utility tool to assure adequate clear space. Measurement of the septic tank sludge and scum depths should be done after the first year of installation and approximately every three years thereafter to determine when the septic tank needs pumping.

A recommendation for pumping should be made when there is an accumulation of scum extending to a depth of about three inches above the top of the outlet ports of the pumping vault or an accumulation of sludge to a depth within six inches below the bottom of the outlet ports (Figure 4). If the tank is fitted with a pump vault, measurement will be from the top surface of the sludge layer to the bottom of the vault's inlet ports. If the tank is fitted with an effluent filter discharge assembly, measurement will be from the top surface of the sludge layer to the bottom of the filter inlet.

After removing the septage contents from the tank, whoever services the tank should refill it with water to its normal operating level, keep accurate records of the service call, and give copies to the property owners and service providers.

#5) Effluent Sampling and Other Indicators

To evaluate the operation and efficiency of all treatment and disposal facilities, service providers need to do effluent sampling on a regular basis.

Sampling Frequencies — While regional requirements vary, at a minimum, it is recommended that effluent sampling and lab testing be performed three to six months after system start-up; then, an annual field-service inspection, including sampling and lab testing, should be scheduled for late spring or in early summer: for systems needing service inspections twice or more per year, space them out (e.g., spring and fall). For groundwater sampling, the late winter, early spring, and fall are the best times for monitoring because many systems tend to show signs of stress (poor performance or infiltration/inflow problems) more readily during these seasonal changes. Observations regarding water table elevation and evidence of ponding in the subsurface should be made during all service visits.

Sampling Methods — The service provider should follow the methods for sampling, assessments, storage, and analysis defined in "Standard Methods for the Examination of Water and Wastewater," published by the American Public Health Association (APHA). (Available from the Water Environment Federation, 703-684-2400.)

Samples should be taken during normal system operation. Service providers shouldn't run pumps manually to "force" a quick sample. And it's important that providers sample carefully, so their samples aren't contaminated by biofilms growing on adjacent surfaces.

Effluent samples from each process step should be placed in a standard glass beaker or small glass container. Using a small, removable sticker placed low on the container, the service provider should note the kind of sample and the date and photograph it for future reference, in front of a common background, as shown in Figure 6. The service provider should also photograph and document the biomat accumulation on the surface of the filter media or liquid surfaces.

Fig. 6. Recirc-Blend Effluent, Filtrate Effluent, and Septic Tank Effluent (left to right)

Typical Wastewater Parameters — Parameters that are critical to a basic understanding of wastewater treatment performance are listed in Table 3:

Table 3. Wastewater parameters for testing

Essential Parameters	Secondary Parameters
Biochemical Oxygen Demand (5-day) (BOD_5)	Sulfate
Total Suspended Solids (TSS)	Phosphorus
Total Kjeldahl Nitrogen (TKN)	Temperature
Ammonia-N	Chlorides
Nitrate-N	Total Coliform
Grease and Oil Content (G&O)	Turbidity
Alkalinity	Fecal Coliform
pH	Specific Conductance
Dissolved Oxygen (DO)	Total Dissolved Solids

Inexpensive, In-Field Indicators of Treatment Performance — Between lab tests, providers can perform other simple, inexpensive in-field tests to assess system performance and maintenance needs.

Table 4. Indicators of treatment performance

Parameter	Methodology	Typical Values[1]
Clarity (Turbidity)	Visual[2]	Clear (15± JTUs or NTUs)
Odor	Sniff[3]	Non-offensive *(musty septic smell is OK; rotten egg or cabbage smell is not OK)*
Effluent Filters	Visual	No liquid level differential between inside/outside vault *(Norm: 1-2 year cleaning interval for recirculating systems)*
Oily film	Visual; *inside the pump vault*	None; *no red, blue, green, or orange sheen*
Foam	Visual; *inside tank*	None
pH	Field[4]	6-9

[1] These typical values are recommended by various sources (NSF, manufacturer's literature, etc). Effluent filter cleaning parameters are based on Orenco research and development relative to $^1/_8$´´ mesh screens and filters.
[2] To check for clarity, service providers can carry a sample bottle of typical effluent to compare against or can use a portable turbidity meter.
[3] To check for odor, service providers can simply sniff the effluent sample or can use a sulfide measuring packet or an olfactory snifter device.
[4] To check for pH, service providers can use litmus paper, a pocket pH meter, or a bench-top pH meter.

Supplemental Testing and Typical Values — If, while doing these simple in-field tests, the service provider determines that the effluent is cloudy or smells pungent or if the biomat on the textile filter appears greasy, waxy, or oily, then he or she should perform further tests of the filtrate. Table 5 gives filtrate tests that provide invaluable information for troubleshooting and diagnosing problems and causes.

Table 5. Tests on filtrate to assist in diagnosing problems

Parameter	Methodology	Typical Values
Turbidity	Grab	5 to 40 NTUs
BOD_5	Grab	5 to 25 mg/L[1]
TSS	Grab	5 to 30 mg/L[1]
TN	Grab	15 to 30 mg/L[3]
G&O	Grab	<1 mg/L
DO	Field[2]	2-6±
pH	Field	6-8±

[1] Values are based on typical values reported in university and demonstration system data, system performance records, and from NSF standards for secondary treatment

[2] To check for dissolved oxygen, use a DO meter, available from VWR Scientific, Cole-Parmer, or Hach. It's typically desirable to see a level of 2 mg/L or more in secondary effluent.

[3] Typical nitrogen reduction from packed bed textile filter systems ranges from 60-80%±, with sufficient carbon source, oxygen, and alkalinity.

When applicable, testing of additional effluent parameters such as temperature, alkalinity, chlorides, sulfate, total phosphorus, etc., may be necessary to provide a more complete picture of the characteristic properties for diagnostic clarity and troubleshooting.

Another useful test is an onsite infiltration test. Onsite infiltration tests are a supplement to the soil testing and classification of soil morphology that are typically performed before an onsite system is installed. Onsite infiltration tests provide actual measurement of a soil's absorption capacity when dosed with high-quality effluent (i.e., 10/10 BOD_5/TSS or better). This supplemental evaluation provides credible supportive information relative to the dispersal rate of clean household water into the soil. Such information may describe the soil's true infiltrative capacity better than the general regulated method for sizing drainfields, especially methods such as the perc test. Especially where soils are questionable or restrictive, there is nothing wrong with including supplemental data of this type in one's design work.

#6) Basic Troubleshooting and Diagnostic Tips

When sampling or other indicators suggest a problem with system performance, here are some useful avenues of investigation with which every service provider should be familiar.

Verify Flows and Loading Rates — Influent loading rates higher than those shown in Table 2 will result in higher effluent BOD_5 and TSS (and require greater cleaning frequencies). Service providers should investigate the cause for high flows; leaking fixtures are a common culprit.

Verify Wastewater Characteristics — Verifying wastewater strength is necessary because it's quite common to see huge variations in strength between similar facilities with similar flows, because of the differences in user practices. Typical wastewater characteristics can be found in Table 2 and in Crites and Tchobanoglous 1998. With higher influent strengths, maintenance may increase, although with a diligent service and monitoring program, performance is not expected to suffer. As waste strengths approach extremely high levels, however, *changes in user practices will need to be made or else additional process steps will need to be implemented*, such as pretreatment for high- strength waste from restaurants or food processing facilities.

Document Usage of Household Chemicals — A wide variety of detergents, disinfectants, and other household cleaning compounds are discharged into the wastewater stream daily. Under normal usage, these compounds are diluted and don't generally retard septic tank performance. A study (Gross, 1987) was conducted at the University of Arkansas at Little Rock Graduate Institute of Technology. The study investigated quantities of specific household chemicals that caused destruction or degradation of septic tank performance. The study also monitored the rate of microbial recovery following the excessive chemical overloads and concluded that natural recovery periods typically range between 30 and 60 hours, without the aid of any special additive. Service providers need to ensure that users are informed about the impact of household chemicals on their septic systems and are encouraged to practice care in this regard.

Determine if Low-Flow Fixtures are Affecting Performance — Low-flow fixtures tend to reduce the hydraulic load to the system, as well as the benefits of dilution, which cause elevation of wastewater constituents (i.e., higher concentrations of BOD_5, TSS, TKN, etc.).

Assess Integrity of System Components — The quality of materials used is critical to the successful operation of any equipment, and onsite wastewater systems are no exception. Service providers must be alert to the differences in controls, motors, pumps, etc., as well as critical subcomponent details, like impeller quality and resistance to wear and tear. Poor quality products result in unnecessary service calls and component replacements, thus increasing long-term costs. Proper equipment selection will extend the time between service calls and will result in lower operation and maintenance costs.

Corrosion is a condition that is inherent to any wastewater application and, because of their designs, onsite and pressure sewer systems tend to enhance corrosive conditions. Attack from this environment may destroy a component or impair its performance; therefore, selecting equipment constructed of corrosion-resistant materials improves system performance. For example, high-strength plastics and stainless materials are more inert to wastewater degradation than bronze, and bronze is more inert than brass, and brass is more inert than cast metals.

Be sure to regularly exercise all valves. (And also make sure the valves are back in their proper positions before leaving the site.)

Relation Between Liquid Levels and Filter Cleaning — Generally, when the liquid level difference between the inside and outside of the vault is two inches or more, that's a sign that the in-tank filter or screen may need to be cleaned. (That relationship should fall within the typical inlet and outlet liquid level differential.) However, you may need to check with the manufacturer of the filter. If the tank's filter can't be checked, you should consider replacing the filter with one that can be.

Filters will occasionally clog, but when that happens it is viewed as a success rather than a failure, because the filter is keeping excessive solids from discharging into the dispersal system. There are some unusual problems that will cause premature clogging, like excessive sludge or scum accumulation, high infiltration or inflow rates, high water usage, leaky tanks that allow the scum level to drop too low, lint from heavy wash loads (such as those from laundry facilities or nursing homes), excessive grease and oil from food processing facilities, disposable diapers, disposable wipes, rags, cigarette butts, excessive use of garbage grinders, drug manufacturing, and other improper disposal practices. The screened system will soon expose the problem and set the stage for correction.

<u>Investigate Odors</u> — When complaints of odors occur, the service provider should request help from the user to identify the following:

- When odors are predominantly noticed (e.g., during dosing events, at night, all the time, etc.)
- What the odor smells like (e.g., sulfurous egg-type, skunk type, strong septic type, etc.)
- Where the odor is strongest and appears to originate from (e.g., the filter, recirculation tank, vent, dispersal field, ponded areas, etc.)

Identify the discharge location/method and measure DO levels at the critical process discharge locations. Look for evidence of clogging or excessive solids accumulation. Odors are a concern in any wastewater application and need attention, but it is not uncommon to discover that the source of the odor is something other than what was originally thought.

<u>Assess Biomats</u> — The service provider should note the character and color (brown, black, white) of biomats and whether there appears to be excessive solids accumulation or ponding over the biomat. With a textile filter, the biomat can be cleaned as necessary, but the biofilms are alive with active and healthy microbes and should only be cleaned as much as necessary to eliminate any concerns relative to clogging.

Ponding of the drainfield is generally an indication that the biomat build-up has become excessive. This could be caused by hydraulic overload (excessive flows) or biological overload (excessive strength), or it could simply be because the drainfield is too small.

<u>Consider High-Tech Assistance</u> — Advanced telemetry controls allow service providers to monitor and troubleshoot systems remotely, from an office computer, saving time and money. Controls that signal alerts as well as alarms allow the operator sufficient time to respond to a problem, even before the user is aware there is one. Additionally, Bluetooth wireless technology has made it easy for service providers to download panel data in the field, run pumps or tests, or even shut systems down, all while sitting in their service vehicles, out of the rain, snow, or heat!

<u>Save Time with Parts Inventory</u> — Service providers who keep an adequate inventory of spare parts and supplies in their truck are more likely to practice preventive and corrective maintenance, since

they can do what needs to be done without making a second trip to the site. Spare pumps and control panels, as well as small parts (level controls, electrical parts) should be readily accessible, as well as any tools that the provider has found to be particularly useful.

Keep Good Records — The importance of maintaining adequate documentation should not be underestimated, and it cannot be said too often**.** Clear and thorough records with dates, flows, wastewater strengths, program settings, sludge and scum monitoring, effluent quality monitoring, manifold pressure residuals, special events, etc. build a valuable history of the system's operation, which will save everyone time and money in the long run.

#7) Advanced Troubleshooting and Diagnosis — Recirculating Processes

Recirculation Ratios — Typical multiple-pass recirculating filter design criteria rely on optimizing the Recirculation (recirc-blend) Ratio (R_b). The Recirculation Ratio (R_b) is defined as the ratio of the daily flow returned (Q_r) to the recirc-tank to blend with the daily inflow (influent or forward wastewater flow) (Q_i) as shown in the following expression:

$$R_b = Q_r/Q_i$$
$$Q_r = R_b\, Q_i$$

where:
R_b is the recirculation (recirc-blend) ratio
Q_r is the daily flow returned to the recirc-tank, gpd
Q_i is the daily inflow (or forward flow), gpd

Typically, the R_b control range is between 2:1 to 6:1. It's important to understand that there are both high and low R_b limits to watch for. Higher ratios may be preferred to prevent odor problems, but generally should not exceed 6 or 7; ratios of 2 or 3 – with normal strength influent – are typically sufficient for controlling odors and providing secondary treatment.

High R_bs — those exceeding 7 or 8 in typical residential applications — can have many adverse effects on the biology, chemistry, and performance of a system. High R_bs can deplete the base alkalinity concentration sufficiently to cause the pH to fall below acceptable levels. The ecosystem then becomes especially suited for filamentous microbes, which tend to cluster and overpopulate on the pump screens, accelerating cleaning needs. In addition, high ratios don't allow sufficient time for filtrate dissolved oxygen (DO) levels to deplete within the recirc-chamber. This tends to inhibit denitrification and cause greater nitrate concentrations to pass through. Not only do high ratios increase maintenance demands and degrade effluent quality, they also consume more energy than necessary. In sum, excessively high R_bs are not beneficial and, in fact, when not properly controlled, cause process degradation, regardless of the growth process (suspended or attached).

The function of the R_b is as critical to process management for multiple-pass attached-growth packed bed filter systems as return sludge, waste sludge, and air management are to suspended-growth processes. Proper management of the R_b assures aeration and wetting needs, but most importantly it establishes equilibrium with respect to the desired endogenous respiration rate by maintaining food-to-microorganism (F/M) ratios relative to influent hydraulic and biological loads. The recirculation ratio is well documented in textbooks and design manuals.

The Importance of Dosing — Dosing and pressurized distribution are practices commonly used in most secondary treatment processes and have become a common practice in onsite treatment technologies. As the hydraulic loading rate (HLR) increases, removal of bacteria and viruses decreases (EPA, 1977; Dymond, 1981). Increasing the dosing frequency (number of occurrences over a given time period) reduces the volume of wastewater applied per dose and increases coliform removal (Mohammed, 1991). The value in dosing comes from its *intermittent* nature. Eliassen (Sproul, 1975) observed that increased loading rates resulted in decreased removal of viruses in soil mediums. Therefore, by keeping the dosing periods short, the instantaneous hydraulic and organic loads are reduced.

Short doses followed by extended resting periods spread uniformly throughout the day increase the liquid-to-media contact time, which enhances microbial activity and improves treatment. The value of pressurized distribution is also in its ability to improve treatment and site longevity by spreading the load in smaller, discrete volumes, more uniformly over the treatment area. Managing influent surge with dose feed controls is especially critical in maintaining a balanced ecosystem for the mixed liquor in high strength applications, regardless of the type of process, PBF or suspended growth. High-strength aerobic processes in particular should incorporate dose feeding to ensure a more stable, suspended growth population/process.

The Importance of Mass Balancing — It's important to understand mass balancing when dealing with processes that incorporate recirculation and mixing of filtrates and influent streams. By adjusting the R_b, the dilution and blend concentrations within the recirc-chamber (process tank) can be balanced, as shown by the following expression.

$$Q_i\, S_i + Q_r\, S_e = Q_{r+i}\, S_b$$
$$Q_i\, S_i + Q_i R_b S_e = (R_b + 1) Q_i\, S_b$$
or
$$S_i + R_b\, S_e = (R_b + 1) S_b$$

where:
Q_i is the daily inflow (or forward flow), gpd
Q_{r+i} is the daily filter hydraulic load, gpd or $Q_{r+i} = (R_b + 1)\, Q_i$
Q_r is the daily flow returned to the recirc-tank, gpd
S_i is the inflow substrate concentration, mg/L
S_e is the filtrate substrate concentration, mg/L
S_b is the blended substrate concentration, mg/L

Typical screened residential septic tank wastewater characteristics (substrates) are shown in Table 2.

By varying the recirc-blend ratio (R_b) within the limits of the application's wastewater characteristics, optimization of the HRT and substrate concentrations within the recirc-chamber can be accomplished. Biological respiration rates tend to adjust according to the available food and oxygen. Therefore, to ensure the best performance and sustain the most efficient working environment, service providers should use the substrate equation (above and below) and Figure 7 to establish programmed timer settings that maintain R_b within an acceptable range.

The recirc-tank's blended substrate concentration may be determined directly by the following expression and as illustrated in Figure 7.

$$S_b = (S_i + R_b S_e) / (R_b + 1)$$

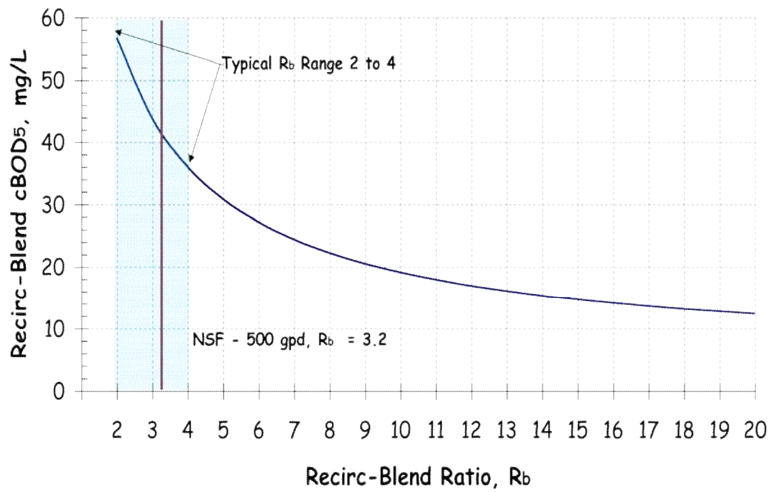

Fig. 7. Recirc Blend Ratio vs. Blended cBOD$_5$

Varying Recirculation Rates — Varying recirculation rates is an important operational tool to optimize and control nutrient levels/reduction, microbial growths, screen cleaning frequencies, etc.

The following is a field test example, performed on a recirc filter treatment unit, to demonstrate the effects of varying recirc-ratio settings. In this example, a 1500-gallon primary interceptor tank receives wastewater from a commercial facility consisting primarily of restrooms with low-flow fixtures:

Test Period 1
Recirculation ratio: 7.7:1
Average forward flow for four-month period: 240 gpd
Filter-loading rate: 12 gpd/ft^2 (20 ft^2 filter)
Timer settings: 2.2 min "ON" / 12.8 min "OFF"

	BOD_5	TSS	TKN	NH_3-N	NO_3-N	pH	Alk	DO
Influent	227	73	135	134	3	7.4	434	0.2
Recirc-Blend	21	13	50	45	41	6.7	90	0.5
Filtrate	6	6	48	43	49	5.8	47	3.9

Test Period 2
Recirculation ratio: 3.4:1
Average forward flow for four-month period: 230 gpd
Filter-loading rate: 11.5 gpd/ft^2 (20 ft^2 filter)
Timer settings: 1 min "ON" / 14 min "OFF"

	BOD5	TSS	TKN	NH_3-N	NO_3-N	pH	Alk	DO
Influent	253	74	186	173	1.7	7.3	522	0.15
Recirc-Blend	29	27	-	76	21	7.1	202	0.4
Filtrate	4	12	-	59	35	7	125	3

At the higher recirc-ratio, the nitrification process through the filter shows that most of the alkalinity is consumed and the pH has dropped to a level below 6. At the lower recirc-ratio, the pH held to a more consistent level, even though the total nitrogen reduction was about 20% greater based on ammonia and nitrate. Maintaining a filtrate alkalinity level of 70 or 80 mg/L generally will keep the pH from dropping too low. The nitrification process appears to be converting more ammonia to nitrate through the filter at the higher recirc-ratio, although, during the second test period, the nitrification performs equally well and converts a greater total quantity of ammonia to nitrate without sacrificing pH. The lower recirc-ratio, also, appears to be denitrifying much better (greater reduction of TN), which is probably a result of the increased food available in the recirc-blend (a direct result of reducing the dilution ratio coupled with a longer hydraulic retention time).

#8) Advanced Troubleshooting and Diagnosis — Nitrogen and Denitrification
Nitrogen is a tell-tale performance indicator and a critical parameter to monitor and observe. As processes become overloaded or saturated, or as they begin to clog, oxygen transfer tends to suffer. Nitrifying microbes show the first signs of this. In packed bed filters, degradation in the nitrification process can be detected months before turbidity, BOD_5, or TSS show any signs of distress.

<u>The Process</u>
Nitrogen removal (or "nitrification/denitrification") is a biochemical process in which ammonia is converted to nitrate (nitrification) ($2NH_3$ converts to $2NO_3$ + $3H_2O$) and then reduced through bacterial action (denitrification) to nitrogen gas, which can be released harmlessly to the atmosphere.

During the nitrification process, about 9 parts oxygen are consumed in converting 2 parts ammonia to nitrate. Therefore, depending on the concentration of ammonia, a considerable amount of air may be needed. Other processes, like biological (BOD_5) reduction, may occur simultaneously and further elevate the demand for aeration, especially if the organic level is high.

In an abundance of air, all the aerobic or facultative microbes compete for their share of oxygen. When the organic concentration is high, the microbes that oxidize organic matter, primarily the heterotrophic bacteria, are aggressive and tend to outcompete other microbes for the available free oxygen in solution. The oxidation of ammonia is accomplished by autotrophic bacteria, which do not have as aggressive a growth rate, so if there isn't an abundance of oxygen, nitrification suffers. Consequently, the nitrification process usually lags until the organic concentration is depleted or until sufficient oxygen is present. At a 2.5:1 BOD_5/TKN ratio, the nitrifiers may only make up about

10% of the microbial population. At 0.5:1 BOD_5/TKN, the nitrifiers make up about 35% of the population.

In a filtering process, the filter column must be deep enough, or the filter media must be efficient enough at filtering organic particles, to deplete organic concentrations to a level in which a sufficient population of nitrifiers will be sustained. The physical (dimensional) features of the filter will vary depending on the media's characteristics — void ratio, moisture holding capacity, and effective surface area per unit volume ratio. Tankage, surge capacity, application rates, and loading characteristics are other design considerations that play a role in the sizing of the filter unit.

Performance Indicators

Typical nitrification in single-family residential systems is expected to be in the 98-99% range. You'll want to investigate if the process appears to degrade by 5 percentage points or more.

To judge the nitrogen-reducing performance (or potential) of any wastewater treatment system, be sure to check the following performance indicators:

Clear, Odorless Effluent — Simple, "see and sniff" tests can be performed easily in the field. Effluent from advanced onsite systems that are performing well should be clear (with turbidity ≤20 NTUs±) and odorless.

Tests for Ammonia and Nitrate Nitrogen — If your system is oxidizing ammonia to nitrate (nitrifying), lab tests should measure relatively low ammonia levels and relatively high nitrate levels in the filtrate. Because nitrification responds to many and varying conditions within the aerobic treatment processes, ammonia and nitrate nitrogen levels in the filtrate are the most ideal constituents to watch for any changes in performance. Start-up times can be plotted, optimum recirc ratios can be gauged, cleaning frequencies can be predicted, and nonvisible clogging or saturation detected by watching either of these constituents. As simple in-field indicators, ion selective electrodes, color meter kits, and test strips are available that will give estimates for NH_3 and NO_3.

BOD_5 — The nitrification process requires oxygen, which is why nitrification is enhanced when BOD_5 is extremely low. Measures of filtrate BOD_5 should be <15 mg/L, although higher BOD_5 may not necessarily correlate with low levels of nitrification.

Typical influent characteristics are shown in Table 2. When BOD_5 is high, there is a greater organic demand for oxygen, which may hamper the nitrogenous demand for oxygen. Increasing the recirc ratio should help establish oxygen balance.

Dissolved Oxygen — Dissolved oxygen also provides critical information with which to diagnose how well a system is performing. Measures of dissolved oxygen should be in the range of 2.5 to 6 mg/L. If the DO level drops, the degree of nitrification will normally drop as well, which could be a sign of blinding or saturated flow conditions — anything that might inhibit free air from flowing into the system. (Nevertheless, it's quite possible to have low filtrate DOs and still have high effluent quality, as measured by BOD_5 and TSS levels.)

Biological Growth on Filter — With "fixed film" treatment systems, biological growth on the filter media is natural. The biomat should appear light-brown to dark-brown in color and gelatinous in texture.

Influent Characteristics — Influent characteristics (see Table 2) will greatly affect the amount of nitrogen reduction that is possible from any wastewater treatment system. High solids and/or fats and cooking oils increase the oxygen demand and accumulation of material on and within the media, affecting the available oxygen for nitrification.

pH — For normal residential nitrogen loads, pH is typically maintained between 6 and 8.

Alkalinity — The nitrification process releases hydrogen ions into solution, which tends to lower the pH level. Alkalinity is essential for nitrification. For each part ammonia that is nitrified, 7.14 parts alkalinity are consumed (buffering the acidity caused by the release of hydrogen ions). Consequently, if the degree of nitrification is less than expected, it could simply be a lack of sufficient alkalinity to support more. Typical residential nitrification requires alkalinity above 250± mg/L for recirculating processes and double that for single-pass processes. Many wastewater streams do not have sufficient alkalinity to support complete nitrification.

Wastewater streams without sufficient alkalinity to support complete nitrification may, depending on the type of process, cause a depletion in the alkalinity to the point where its ability to buffer stops. The pH correspondingly drops to a level that retards the microbial activity (<6±). Recirculating the effluent helps, since half the alkalinity can be restored in the recirc or process tank, wherever denitrification occurs (and adjusting the recirc-ratios may also bring the pH back to preferred operating levels). But wastewater streams that are alkalinity-starved can't provide for 100% nitrification.

The use of low-flush fixtures requires special consideration. Low-flush fixtures tend to reduce hydraulic loads, which causes elevation of wastewater constituents (i.e., higher concentrations of BOD_5, TSS, TKN, etc.). In this case, the available alkalinity in the water supply may not be adequate to accomplish the full level of nitrification desired.

These constraints exist for all wastewater treatment operations, regardless of whether the operation involves a suspended growth contact stabilization process or an attached growth packed bed filter. Packed bed systems will perform better, especially if they have a large attached growth surface area per unit volume ratio, because the micro-sites near the attached side of the biomat, where denitrification typically occurs, return some of the alkalinity. Textile packed bed filters, because of their large surface area per unit volume ratio, tend to perform even better. Nevertheless, additional buffering may be necessary to accomplish the level of nitrification desired. In low alkalinity conditions, pH adjustment can be made with the addition of quick or hydrated lime, soda ash, or caustic. (Note: at process points preceding sedimentation zones, lime adjustment — buffering — would be preferred. Soda ash and caustic both contain sodium, which is a dispersant.)

CONCLUSIONS:

Servicing wastewater systems is not a glamorous occupation, but it can be a challenge and can be genuinely rewarding when approached with a mindset that is detail-oriented, proactive, and investigative. From a broader perspective, service providers who do good work help to ensure that onsite systems, which are the most environmentally sound method of managing wastewater currently available, are viewed by the public as a sustainable technology. That's why it's so important to remember the words of Larry, the Cable Guy, and just "Git 'er done."

Field Maintenance Report Form

Person Calling: ______________________
Date/Time Called: ______________________
Address: ______________________
Phone: ______________________

Operator Responding: ______________________
Date/Time Responded: ______________________
Total Field Time: ______________________
Total Travel Time: ______________________

Service Calls

Type of System: ______________________

Meter Readings (refer to ETM/CT Log & Worksheet)
Days Since Last Reading: ______________________
Today's CT: ______________________
Today's ETM: ______________________
Frequency (CT/Days): ______________________
☐ Normal ☐ High ☐ Low
Duration (Min./Cycle): ______________________
☐ Normal ☐ High ☐ Low
Typical average daily flow: ______________________
Typical average weekly flow: ______________________

Pump Test
Pump #1: Tank Pump
Voltage at Rest: ______________________
Voltage while Pumping: ______________________
Amps while Pumping: ______________________
Pumping Head (Ft.): ______________________
Shutoff Head (Ft.): ______________________
Drawdown Time (Min. & Sec.): ______________________
Drawdown Depth (Inches): ______________________
Pump #2: Discharge Pump
Voltage at Rest: ______________________
Voltage while Pumping: ______________________
Amps while Pumping: ______________________
Pumping Head (Ft.): ______________________
Shutoff Head (Ft.): ______________________

Odor
Normal: ☐ Musty ☐ Earthy ☐ Moldy
Pungent: ☐ Sulfite ☐ Cabbage ☐ Decay
Method of Detection: ______________________

Squirt Height: ______________________

Valve Position at Departure
Hose & Valve Assembly: ☐ Open ☐ Closed
End of Laterals: ☐ Open ☐ Closed

Control/Alarm Switch at Departure
MOA: ☐ Manual ☐ Off ☐ Auto
CB: ☐ On ☐ Off

Repair: ______________________
Replace: ______________________

Alarm Call Addendum

Conditions Leading to Call
☐ Alarm ☐ Tank Overflow
☐ Odor ☐ Surface Runoff
☐ Noise ☐ Sewage Backup
☐ Other: ______________________

Odor
Normal: ☐ Musty ☐ Earthy ☐ Moldy
Pungent: ☐ Sulfite ☐ Cabbage ☐ Decay
Date/Time Discovered: __________/ __________
Method of Detection: ______________________

Alarm
☐ High Liquid Level
☐ Low Liquid Level
☐ Off

Pump
☐ On
☐ Off

Tank Liquid Level
☐ Normal
☐ High
☐ Low

Circuit Breaker
☐ On
☐ Off
☐ Tripped
☐ Switched

Cause of Malfunction

Mechanical	Physical or Process-Related
☐ Control Panel	☐ Power
☐ Pump	☐ Back Pressure
☐ Float Switch	☐ Air Bound
☐ Screened Vault	☐ Sludge & Scum
☐ Hose & Valve	☐ Clog
☐ Check Valve	☐ Infiltration/Inflow
☐ Building Sewer	☐ Exfiltration
☐ Service Line	☐ Siphoning
☐ Other: __________	☐ Other: __________

Repair: ______________________
Replace: ______________________

Observation: ____
Action: ____
Comment: ____

Field Sampling Report Form

Date: ____________________
Inspector: ____________________
Address: ____________________
System Type: ____________________

The following effluent tests can be easily and routinely performed in the field. Perform annually, or as frequently as necessary per the methodology indicated. For AXN systems, there is to be a minimum of four sampling events the first two years and then annual sampling thereafter. Record your results/observations in the space provided:

Parameter	Methodology	Typical	Field Observations	Pre-Test Lab Concurrence
Clarity	Visual[1]	Clear (15± JTUs or NTUs)	________	________
Odor	Sniff[2]	Non-offensive (no smell of rotten eggs or cabbage; a musty, earthy, or moldy odor is normal)	________	________
Oily film	Visual; inside tank	None (no red, blue, green, or orange sheen)	________	
Foam	Visual; inside tank	None	________	
pH	Field	6-9	________	
			Date ________	Date: ________
			________ Signature Field Sampler	________ Signature Lab Technician

[1] *To check for clarity, service providers can carry a lab-prepared sample bottle or bottles with known turbidities of 15 JTU s and 30 JTUs, to compare against, or can use a portable turbidity meter. Always put effluent sample in a clear glass container or beaker to evaluate clarity. Using a small, removable sticker, write the date, place it low on the beaker, and photograph for documentation.*

[2] *To check for odor, service providers can simply sniff the effluent sample with the assistance of an olfactory snifter device and/or sulfide odor measuring packet. Whenever possible, interview system users about odor occurrences and request user's assistance in verifying or detecting odors.*

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