



EFFLUENT SAMPLING FOR RESIDENTIAL TREATMENT SYSTEMS

For various reasons, many wastewater treatment systems periodically require effluent sampling and characterization. Whether sampling is done to verify compliance with specific effluent limits or simply to indicate if the system is operating properly, effluent sampling must follow specific procedures and guidelines to insure accuracy. Analysis of improperly collected or contaminated effluent samples will result in data that could lead to an incorrect conclusion regarding treatment system operation. Conversely, laboratory analysis of properly collected effluent samples will generate data that can be used to evaluate actual treatment system performance. *“The objective of sampling is to collect a portion of material small enough in volume to be transported conveniently and yet large enough for analytical purposes while still accurately representing the material being sampled.”*¹ Wastewater sampling is generally performed by one of two methods, grab sampling or composite sampling. Each method has specific limitations on what tests can be performed and how the data is used.

GRAB SAMPLING

A grab sample (sometimes called an individual discrete sample) indicates that all of the test material is collected at one time. Grab samples are collected by manually removing a quantity of effluent from the flow stream at a single point in time during the flow day. As such, a grab sample reflects the effluent conditions only at the point in time the sample was collected. Therefore, by definition, a single grab sample can never be used for long term performance evaluation of a wastewater treatment system. However, there are a number of very specific places where grab sampling must be used. *“Grab samples serve to characterize variations of the waste stream over time. They also allow analysis of unstable parameters soon after sample collection. Examples of such parameters include pH, dissolved oxygen (DO), chlorine residual [and] temperature.”*²

COMPOSITE SAMPLING

Composite sampling consists of collecting, at specific time or volume intervals, a number of individual samples in one single container. Composite samples are almost always collected by the use of automated sampling and storage equipment, which will refrigerate the sample over the entire time of collection. A composite sampler withdraws a small volume of effluent periodically throughout the sampling period, usually 24 hours. This equipment is designed to automatically purge the sampling pump, transfer a programmed amount of effluent into a single storage container and purge the sampling apparatus again to remove material that could affect the results. Usually, refrigeration of the composite sample must continue during the entire time of collection and transportation to the laboratory. In order to prepare the sample for analysis, the total volume of composited effluent is thoroughly and completely mixed. Collected and analyzed in this manner, the blended composite sample represents the wastewater characteristics over the entire time or the specific volume of flow.

GRAB SAMPLING VS. COMPOSITE SAMPLING

Monthly operating reports, performance evaluations or compliance monitoring forms (used by municipal treatment systems) usually record performance data as individual daily values. In most cases, these data points represent the analysis of a composite effluent sample collected over a 24 hour period. As these results are shown by a single value, individual daily data points are frequently confused with data from grab samples. However, a composite sample consisting of a quantity of programmed individual collection events is not the same as one or more grab samples. A proper composite sample will result in one data point that represents the effluent quality over the time of collection or volume of flow. Even when the data from grab samples is averaged, that one data point represents the effluent flow only at specific moments in time when the samples were collected. Due to the differences in how the samples are typically collected and analyzed, an average of multiple grab samples does not provide valid information regarding system operation and performance the way composite sampling does.

The analysis of grab samples is necessary for certain effluent parameters, but the primary indicators of system performance including CBOD₅ (carbonaceous five day biochemical oxygen demand), TSS (total suspended solids) and TN (total nitrogen) require the collection and analysis of 24 hour composite samples. The cost and logistics of proper composite sample collection make it tempting to use grab samples for all evaluations. Performance testing by grab sampling is a blatant misapplication of technology and has no basis for use with treatment systems of any size. However, it is even more inaccurate when used with residential treatment systems. The residential sewage characteristics and flow patterns compound the degree of error when residential treatment system performance is judged by the use of a grab sample. The table on page six lists specific effluent parameters and whether grab or composite sampling is required for proper evaluation.

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MUNICIPAL FLOW PATTERNS

Municipal wastewater treatment systems receive their flow over a 24 hour period, and the volume and strength characteristics of the incoming waste vary over the daily flow pattern. By their nature, biological treatment systems fluctuate slightly in their performance due to the growth and lag phases of the microorganisms, particularly if there are large fluctuations in the volume and strength of the influent during different periods of loading. Both of these factors result in a varying amount of impurities contained in the effluent discharged from these treatment systems over the course of the day. In municipal systems, these variations are minimized by the blending of incoming waste from a number of different homes or sources combined into one treatment system of very large capacity. Even so, the Water Environment Federation recommends that all of the primary performance indicators for municipal systems be evaluated by using composite effluent samples.

RESIDENTIAL FLOW PATTERNS

Residential treatment units receive a frequent number of short hydraulic surges throughout the day followed by intermittent periods of no flow whatsoever. Additionally, the wastewater characteristics range from nearly potable water characteristics (i.e. rinsing fresh vegetables), to graywater from doing laundry and dishes, to full strength sewage. There is little opportunity for these individual flows to be blended into a homogenous flow stream of average characteristics. The changing volume and strength of the wastewater will maximize normal fluctuations in the effluent produced by the treatment system. For example, flow surges that are present in most individual home flows will often create a washout of substantial amounts of treatment system suspended solids.

Therefore, a grab sample of the effluent taken at only one specific time throughout the daily flow pattern is not representative of system performance over the entire day. *“Failure to obtain a representative sample can produce invalid data, leading to erroneous process control decisions.”*² The type and quantity of samples collected should be determined by the data required. For example, the Code of Federal Regulations stipulates that the performance of secondary treatment systems should be evaluated by tabulating 30-day averages of system effluent. As it is impossible to judge long term treatment system performance by a single discrete grab sample, or even a single 24 hour composite sample, a 30-day regimen of proper samples must be collected, analyzed and tabulated before system performance can be evaluated.

It is wholly inaccurate, bad science and irresponsible to evaluate system performance by the analysis of data collected from one, or even several, effluent grab samples. The most widely used performance evaluation for residential treatment units (NSF/ANSI Standard 40) evaluates performance by tabulating data collected via composite

sampling techniques. Each individual daily composite sample is collected over 24 hours by withdrawing an aliquot (a measured volume of sample) of effluent at 80 separate times throughout the day. If samples were collected every calendar day, each 30-day average applied to the pass/fail criteria would actually represent 2,400 individual sampling events, collected over an entire month.

Statistically, this could present some interesting possibilities for any program requiring 30-day averages. Theoretically, an individual daily composite sample could have test results as high as 871 mg/L TSS and still compute to a 30-day average of 30 mg/L. Within the single composite sample analyzed at 871 mg/L, an individual aliquot (the equivalent of a grab sample) could contain as high as 69,601 mg/L and still be analyzed as a daily composite sample of 871 mg/L. Of course, this is a practical impossibility. However, it does demonstrate that an individual grab sample parameter could test excessively high, and yet the system could still be operating in compliance with federal standards or better. Considered individually, a number of grab samples taken from a residential treatment unit might appear to indicate a system that is not operating properly, when in reality, the average effluent could actually be of very high quality. Composite samples, while requiring electromechanical equipment and more complex sampling methods, will provide the only accurate indicator of system performance. For these reasons, professional wastewater treatment system operators and third party certifiers continue to rely on composite sampling in order to conduct evaluations that accurately measure system performance.

SAMPLING PROCEDURES

Proper collection of an effluent sample, by either technique, requires specific procedures to be followed. A grab sample of effluent must be a free falling sample, collected from a cleaned effluent pipe, in a proper sample bottle, stabilized during transport, stored for a limited period of time and analyzed by specific laboratory methods. When using a composite sampler, follow the manufacturer’s instructions to insure an accurate, representative sample is collected. An automatic sampler may require withdrawing the sample from a pipe or channel that is cleaned daily. Samples should be collected *“at points where the sample stream or tank is well mixed.”*³ This insures the effluent is moving with enough velocity to prevent the settling out and accumulation of solids. If solids are allowed to settle and accumulate, as would occur in any effluent sump, sampling previously accumulated solids mixed with the effluent is not representative of either past or current operating conditions.

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Whether collecting a grab sample or preparing a composite sample for analysis, proper procedures must be followed:

- 1) Personal safety should be the first consideration in any sampling protocol. The same safety precautions exercised in any area of wastewater treatment should be taken during effluent sample collection. Proper eye protection and disposable gloves should be worn. Always wash hands thoroughly following any sample collection and especially before handling any food. The use of hand sanitizing lotion is recommended.
- 2) A properly sized and cleaned sampling bottle must be prepared before going to the site. The bottle, cap and sampling equipment must be sterilized if the sample is to be analyzed for bacteriological activity.
- 3) The effluent sample should be tested at the time of collection for the presence of chlorine. If the testing laboratory needs to analyze chlorinated effluent, the presence of chlorine should be noted on the sample bottle. Prior to analysis, only sufficient dechlorination agent should be added to reach the chlorination endpoint. In past practice, many laboratories used prepared sample bottles with a dechlorination agent already present in the bottle. It has since been discovered that if the amount of dechlorination agent exceeds the chlorine demand in the effluent, false positive BOD₅ and CBOD₅ readings can result.
- 4) For the parameters that require collection of a grab sample, several considerations must be followed:
 - a) The location of sample collection is extremely important. A grab sample must be free falling from the end of the effluent pipe or taken at a point where the flow stream is uniform with enough velocity to prevent the deposition of solids in the line. *"Where samples are to be collected from flowing pipes, keep the sample line as short as possible."*²
 - b) The effluent pipe in a gravity flow residential treatment system will rarely flow full of effluent. Typically, the effluent flows through only a small section of the bottom of the pipe. The remainder of the pipe above the normal flow line is exposed to all types of environmental factors. Dust, leaves, plant spores, insects and small animals may have access to a partially full effluent pipe. This foreign material can, and routinely does, collect in the pipe during a low flow/no flow period and could be washed into the sample bottle when routine flow is present. For this reason, the interior and exterior of the pipe in the vicinity of the sampling area must be cleaned and sterilized prior to collection of an effluent sample. This will include removal of grass or weeds around the effluent pipe and cleaning the inside and outside of the pipe with soap and water followed by a disinfectant (i.e. bleach or peroxide).
- c) A residential treatment system can be effectively sampled only when there is an effluent flow. Due to intermittent residential flow patterns, there may not be effluent flow at the time designated to collect a grab sample. Hydraulic flow may be induced into the treatment system in order to generate effluent for grab sampling. With detention time designed into any wastewater treatment system, water flow introduced into the system inlet or pretreatment chamber in order to generate effluent, will undergo full treatment before reaching the system outlet. Remember that the effluent grab sample is not representative of the average flow and therefore can not be used to evaluate long term system performance. Also, keep in mind that the induced flow must be typical of the normal incoming flow rate. A surge flow into most wastewater treatment systems will create a washout of solids that can be carried into the sample container. This effect will skew certain test results dramatically.
- d) Once the effluent is free flowing and the prepared sample bottle is in position to collect the effluent, carefully place the mouth of the sample bottle directly into the falling stream of effluent and collect the sample. Be careful not to touch the effluent pipe with the mouth of the sample bottle. Fill the sample bottle nearly to the top. Leave an airspace above the sample liquid of approximately 1% to 5% of the container volume to allow for thermal expansion during shipment.
- 5) Extreme care must be used when handling an open sample bottle to prevent contamination from environmental factors. Airborne dust, insects, blades of grass or any material coming in contact with the sample bottle or cap, other than free falling effluent, will contaminate the sample. Even a properly collected sample can easily become contaminated if the container is allowed to touch the sides of a basin or access riser, or if dirt or other material is allowed to enter the bottle.
- 6) The volume of sample required for proper analysis varies according to the test performed. Refer to the table on page six for sample volume guidelines.
- 7) Minimum sample sizes are recommended by Standard Methods for the Examination of Water and Wastewater, and other sources. However, laboratory experience, familiarity with the treatment system being tested and the number of analyses required for a given effluent may allow collection and submittal of smaller volume samples. The minimum sample size indicated in the table on page six considers only the volume required for an individual parameter. Confer with a local laboratory to establish the volume requirements needed based on the total number of parameters requiring analysis.

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- 8) Once the sample has been collected, carefully remove the bottle. Be sure not to touch the mouth of the bottle against any other surface. The sample can then be analyzed for field parameters, if required, or capped and stored as necessary.
- 9) The sample bottle containing the grab or composite sample should be carefully labeled to include the following information:
 - a) A unique sample identification number
 - b) The source/location of sample collection (i.e. final effluent, discharge pipe, etc.)
 - c) The date and time the sample was collected
 - d) The name of the technician who collected the effluent sample
 - e) The name of the treatment system owner where the sample was taken
 - f) Whether a grab or composite effluent sample was collected
 - g) The presence or absence of chlorine in the effluent sample
 - h) All parameters requiring analysis, such as CBOD₅, TSS, etc.
 - i) Listing of any required preservative added (see the table on page six)
 - j) The results of any analysis that needed to be performed onsite
- 10) For parameters not requiring immediate testing, the analysis should be performed as soon as possible, using proper storage and sample preservation during transport. This almost always involves cooling the sample to inhibit further biochemical reactions occurring during transport and storage. Chilling the liquid to the required temperature and maintaining it during all transport and storage time is essential for sample integrity. Icing down the sample is preferred as rapid chilling takes place without expensive mechanical refrigeration equipment, and there is no danger of over-chilling and freezing the sample.
- 11) Invalid data will result if the sample is held for a longer period of time than the guidelines permit. For this reason, travel time, laboratory operating hours, weekend or holiday schedules all need to be considered with any sampling program.
- 12) Sampling for the level of chlorine, coliform bacteria or for the performance of dechlorination equipment requires some special considerations:
 - a) Due to the unstable nature of chlorine, samples collected for this parameter must be analyzed immediately. Storing samples in an open container allows the chlorine to volatilize into free air. Samples stored in a closed container can continue chemical reactions that can change the chlorine into other compounds.
 - b) Samples collected to test for the presence of coliform or other bacteriological examinations must be collected in a sterile bottle and immediately checked for the presence of chlorine. Any chlorine present must be removed or stabilized prior to storage or transport of the sample. Storing a bacteriological sample with chlorine present allows additional "contact time" and may result in a false positive indication of disinfection efficiency. Conversely, stabilizing or removing the chlorine allows the process of bacterial regrowth to begin. Therefore, stabilized samples must be immediately cooled to 4° C and stored for a maximum of 6 hours, before significant bacterial regrowth occurs.
 - c) The point of sample collection is also critical. If a contact chamber is designed for effective bacteriological reduction and is followed by a dechlorination system at the contact tank outlet, bacteria regrowth due to environmental exposure can begin to occur in a long outlet pipe and could be significant in a downstream component, such as a post-aeration chamber. Therefore, samples for bacteriological analysis must be taken at the end of contact time, but upstream of any other treatment or storage process.
- 13) Special precautions and record keeping are required for any samples taken for compliance with an NPDES (National Pollutant Discharge Elimination System) permit or other regulatory requirement. Be sure to have the analysis performed by a laboratory certified for the specific testing required. Analytical data must be logged in the required format and on the form appropriate to the proper agency.
 - a) Where legal action or other serious considerations are dependent on the results of sampling to determine system performance, chain-of-custody procedures to track possession of the sample are required. These procedures usually require a sample bottle to be closed with a tamper-evident seal immediately after collection. A written record on the chain-of-custody form requires each person transporting or handling the sample to certify the specific period of time that the sample is in their possession. The completed form insures that proper handling of the sample has been documented. The chain-of-custody record should remain with the sample during laboratory analysis and be filed with the permanent log of lab results.

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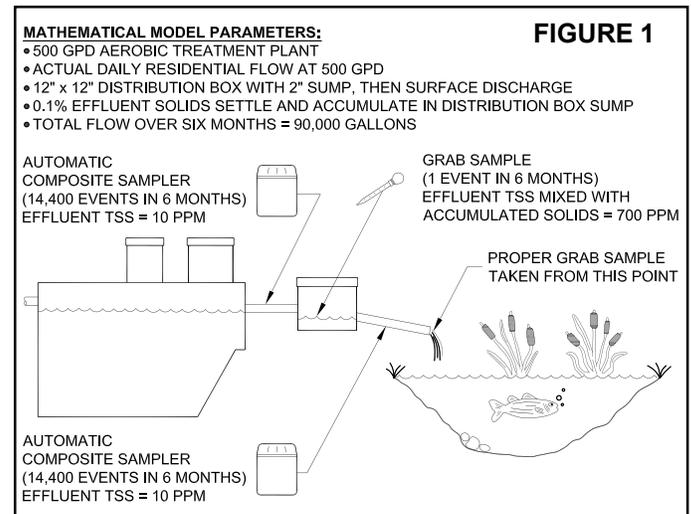
LOCATION OF SAMPLE SITE

While the limitations of analyzing effluent collected by grab sampling have been discussed, the use of grab samples for evaluation of a residential treatment unit is further compromised if the grab sample is not collected from effluent with sufficient velocity to keep solids in suspension. *“Avoid taking samples at points where solids settling occurs or floating debris is present. These situations occur normally in quiescent areas, where the velocity of the flow has decreased.”*³ For this reason, under no circumstances should system performance be evaluated by a grab sample of effluent taken from a pump chamber, distribution box or any device that contains a sump. Especially due to the intermittent flow patterns that are typical of individual residences, effluent solids tend to settle out in a sump when allowed enough time and a low velocity. Even the few solids present in a high quality treatment system effluent can settle out in a sump during a no flow period. If only a very few solids settle out in the sump during a no flow period today, they can remain and accumulate with additional solids settling out over successive days. This will result in an amount of solids accumulated in the sump that are a gross misrepresentation of what the treatment system effluent has in suspension during any given flow day.

Using a mathematical model will allow us to put these considerations into perspective (see Figure 1). At 500 GPD, a residential treatment unit will discharge approximately 90,000 gallons of effluent over the six month period between routine service inspections. In our mathematical model, this treatment system is generating a high quality effluent of 10 mg/L CBOD₅ and 10 mg/L TSS. In the flow path of this model, the treatment system effluent passes through a common 12" by 12" distribution box containing a 2" sump below the effluent discharge pipe.

In our mathematical model, we will assume that due to the intermittent flow pattern of a residential treatment unit, 0.1% (0.001) of the total effluent suspended solids will settle out and accumulate while effluent passes through the sump. (While it is likely that a higher percentage of solids will settle out, especially during an overnight period of no flow, we will consider that on the average, only 1 out of each 1,000 effluent solids will settle out in the distribution box. Therefore, 999 out of every 1,000 effluent solids will stay in suspension and are carried out with the flow.) In this model, these parameters will remain in a steady state for six continuous months, corresponding to the period between service visits. After six months of operation, the sump in the bottom of the distribution box has accumulated 1 out of each 1,000 effluent solids that were contained in the 90,000 gallons of high quality effluent that has passed through the distribution box. If the contents of the sump in the bottom of the distribution box are then mixed, collected and analyzed as a grab sample, the data will show an effluent containing more than 700 mg/L of total suspended solids. This obviously erroneous data would seem to indicate that

the effluent contains more suspended solids than typical residential influent flow. In reality, this treatment system is actually discharging an effluent of 10 mg/L total suspended solids. With this model, it is easy to understand that judging treatment system performance by dipping into any effluent sump and stirring the contents (effluent and accumulated solids) is totally invalid.



It is understood that under absolute conditions, some degradation of the accumulated solids will occur during the length of time the solids are retained in the sump. Also, some of the organic material processed in the treatment system is converted into suspended solids, prohibiting an exact solids mass balance to be performed. While it would be scientifically impossible to ascertain the exact degree of bio-degradation or conversion of organic matter, neither process will be of enough significance to affect the conclusion. It is absolutely certain that stirring or mixing the contents of a sump and analyzing this mixture will result in data showing effluent solids that are hundreds, if not thousands, of times greater than data from samples collected by proper composite sampling techniques. These same principals hold true whether the effluent sample is taken directly from a distribution box, a pump chamber, a chlorine contact chamber, a post-aeration chamber, a roadside ditch or any structure that retains effluent below the flow line. Even a small sump, such as a 4" diameter pipe cross capped at the bottom, will accumulate effluent solids over a short period of time. Use of this pipe cross in conjunction with a composite sampler designed for automatic operation will still require the cross to be flushed clean each day. This is usually done when the operator is collecting the daily sample and checking the equipment operation.

When properly performed, effluent sampling is the most important tool available to evaluate treatment system performance, make operational adjustments, protect the environment and insure the health and safety of all. However, the proper techniques for collecting and analyzing any effluent sample must be followed before an accurate, informed conclusion can be made.

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GUIDELINES FOR SAMPLE COLLECTION, STORAGE AND ANALYSIS

EFFLUENT PARAMETER	MINIMUM SAMPLE SIZE	SAMPLE TYPE	PRESERVATION REQUIRED	MAXIMUM HOLDING TIME
Carbonaceous 5 Day Biochemical Oxygen Demand (CBOD ₅)	1,000 mL	Composite	Refrigerate, 4°C	6 hrs./48 hrs.*
Total Suspended Solids (TSS)	200 mL	Composite	Refrigerate, 4°C	7 days
pH	50 mL	Grab	Analyze immediately	0.25 hrs.
Dissolved Oxygen	300 mL	Grab	Analyze immediately	0.25 hrs.
Temperature	N/A	Grab	Analyze immediately	0.25 hrs.
Total Residual Chlorine	500 mL	Grab	Analyze immediately	0.25 hrs.
Ammonia Nitrogen	500 mL	Composite	Analyze as soon as possible or add H ₂ SO ₄ to pH <2, refrigerate	7 days/28 days*
Nitrate Nitrogen	100 mL	Composite	Analyze as soon as possible, refrigerate	48 hrs. (28 days for chlorinated samples)
Total Kjeldahl Nitrogen (TKN)	500 mL	Composite	Add H ₂ SO ₄ to pH <2, refrigerate	7 days/28 days*
Oil & Grease	1,000 mL	Grab	Add H ₂ SO ₄ to pH <2, refrigerate	28 days
Total Phosphorus	100 mL	Composite	Add H ₂ SO ₄ to pH <2, refrigerate	28 days
Fecal Coliform	N/A	Grab	Add 0.008% Na ₂ S ₂ O ₃ **, cool to 4°C. All collection utensils and techniques must be sterile	6 hrs.

*First value is maximum storage time recommended by "Standard Methods." Second value is maximum holding time allowed by Code of Federal Regulations⁴, but the code also indicates that samples should be analyzed as soon as possible after collection. In any case, the second value listed is the maximum time that samples may be held prior to analysis and still be considered valid.

**Should only be used in the presence of residual chlorine.

REFERENCES

1. American Public Health Association, American Waterworks Association, Water Environment Federation. *Standard Methods for the Examination of Water and Wastewater*. 20th Ed.
2. Water Environment Federation. *Operation of Municipal Wastewater Treatment Plants*. Manual of Practice No. 11, 5th Ed.
3. Water Environment Federation. *Wastewater Sampling for Process and Quality Control*. (1996) Manual of Practice No. OM-1.
4. U.S. Environmental Protection Agency. *Rules and Regulations 40CFR*. (1998) Part 136.3.

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