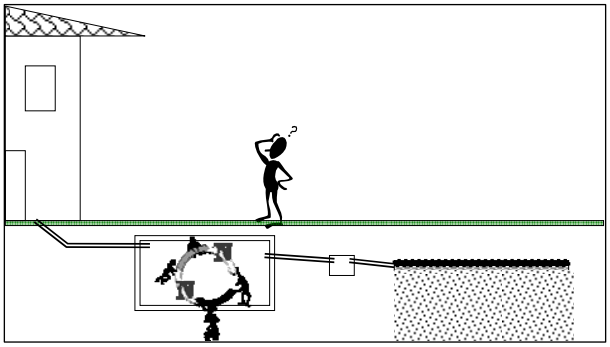
# *Monitoring Alternative Onsite Septic Systems*

## *How do we know when they are working?*
## *How can we improve performance?*

Innovative/Alternative (I/A) septic systems (also called “advanced onsite septic systems” or “advance treatment units”) are devices most often situated ahead of a soil absorption system (or leaching facility such as a trench or field) to achieve pretreatment of wastewater prior to dispersal into soils. In the Commonwealth of Massachusetts, I/A systems are most often used in remedial situations to reduce certain aspects of the soil absorption system (such as size or distance to groundwater) or in situations where there is a need to reduce target contaminants such as nitrogen, phosphorus or pathogens. Regardless of the reason for their use, there is general agreement that key requirements for their effective use include ongoing maintenance and occasional verification of their treatment through monitoring. Accordingly, the approval process in the Commonwealth requires that all I/A systems be serviced on a regular basis by qualified individuals for the life of the system. In addition, regulatory officials require that occasional performance samples be taken to verify the systems’ continued performance.

It should be understood that performance sampling is a crucial part of an overall management strategy that employs innovative/alternative onsite septic systems for the control of nutrients in watersheds. The Barnstable County Department of Health and Environment has assisted towns in Barnstable County to monitor the compliance of these systems since 1999 and has observed a disconnect between performance sampling and I/A systems operations, that represents a lost opportunity to improve overall performance of these systems. This booklet discusses the reasons for this disconnect and makes recommendations for all participants in the I/A system approval process to improve the likelihood that performance data can inform decisions and improve overall systems operations.



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COUNTY OF BARNSTABLE MASSACHUSETTS HEALTH & ENVIRONMENT

MASSACHUSETTS ENVIRONMENTAL TRUST

# Recommendations Regarding Performance Sampling of Innovative/Alternative Onsite Septic Systems

Innovative/Alternative (I/A) onsite septic systems are generally required in areas where there is a need to remove selected contaminants. When I/A use is integrated into a comprehensive wastewater management plan, these systems are "expected" to reduce overall contaminant loads. Accordingly any widespread use of I/A technologies must be accompanied by a plan to verify their performance in accordance with expected load reductions.

There is general agreement that I/A system performance can vary widely, and may be highly dependent on the level of operation, maintenance and other factors. In any event, performance monitoring is crucial to confirm that expected contaminant loads are not exceeded. In this report, we review the present methods of sampling of I/A systems in Barnstable County and make recommendations for improving various aspects of monitoring to facilitate a more accurate assessment of their efficacy.

Under the various approvals issued by the Commonwealth of Massachusetts, effluent monitoring of I/A systems is required. A sample approval letter statement is as follows:

*"All effluent samples shall be taken at a flowing discharge point, i.e. - distribution box, pipe entering a pump chamber or other location from the treatment unit approved by the Department in writing. Any required influent sample shall be taken at a dedicated location upstream of the septic tank that will provide a representative sample of the influent in accordance with Section II item 4. Influent sample locations shall be determined by the System designer and the Company and shall be selected so that the influent characteristics are not changed by the System recycle.*"(Massachusetts DEP 2008 various Approval Letters)

***A Note About Influent Sampling***

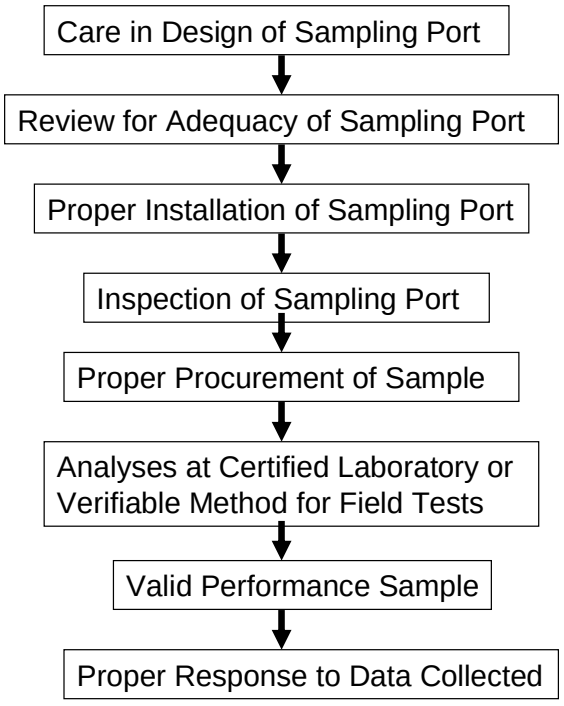
*Influent sampling at small I/A septic systems (<2000 gal/day) is notoriously difficult. This is due to the fact that most process trains in small I/A systems recycle a portion of final effluent back to the headworks or beginning portion of the system. This means that most locations on the influent end of the system are not raw untreated wastewater, but rather a mix of raw untreated wastewater with recycled effluent. Samples taken at this point are hence not representative of the true influent wastewater. Intercepting the influent line before the treatment system also has inherent problems. The raw influent from the house is highly variable and contains large solids intermittently (fecal matter, toilet paper, food, etc), thus obtaining a representative sample is not possible without extreme compositing measures that not practical in most situations.*

While the requirement stated above appears simple, our observations at numerous installations suggest that more guidance for designers, installers and samplers is warranted.

The ultimate procurement of a good representative sample from an I/A septic system begins with care taken at both the design and installation phase and ends with the collection of a good representative sample that will indicate performance and inform decisions regarding adjustments to the operation that might be necessary.

## Design and Construction Considerations

In order to eliminate any confusion, the first critical point in the process of ultimately obtaining representative samples begins with the design of the sampling port. A septic system design plan should contain all the details and specifications necessary for the proper installation of the septic system. With I/A systems this should also include adequate detail on the proper placement of sampling and observation ports. Sampling ports should have access covers that are brought to grade and secured against unauthorized entry. A common omission in septic system plans is the degree of detail necessary to ensure that, following all final grading and filling, the observation or sampling port is accessible and can be sampled.




Among the most common deficiencies observed regarding sampling ports involves the distribution box. Most I/A systems with gravity discharge intend to use the distribution box as a sampling port. The most common observation in our study has been that the distribution box is buried, providing no immediate access for sampling. In these instances, the distribution box must be excavated each time sampling is required. In reality however, this does not happen and the sampler will attempt to obtain a sample from an accessible location on the system that may or may not provide a representative sample.

All septic plans that require sampling at the distribution box must specify that the access to the distribution box shall be at grade and be supplied with covers to

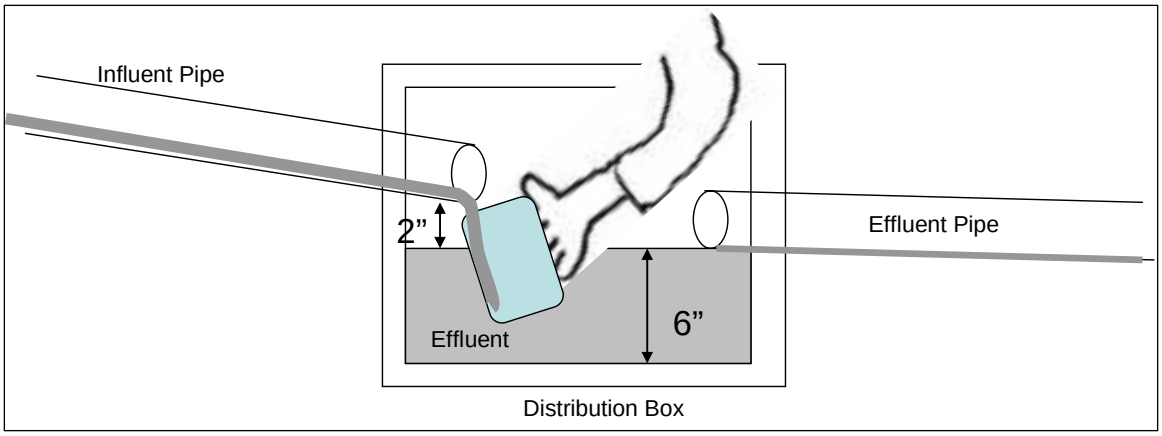



**Figure 1**. Illustration of method to obtain a grab sample from a distribution box when the system relies on gravity for distribution of effluent.

secure from unauthorized entry. In addition, the access risers to the distribution box should be carefully planned for size. Distribution box sampling requires that a clean sampling bottle be placed below the wastewater stream of a discharging system. Within a standard distribution box, there is only two inches of vertical drop between the inlet pipe and liquid contained in the distribution box. This requires that the sampler carefully immerse the sampling bottle *without allowing it to fill from the contents of the distribution box* and hold it below the incoming wastewater stream until it is filled with sufficient volume (Figure 1). Ideally, the actual sampling bottle should be used, however due to the configuration and the size requirement of some samples (< 1 liter), a transfer vessel must often be used.

When planning for sampling in a distribution box, the following points should be remembered during the design and installation phase of the project.

- If the distribution box is too deep and the access is too narrow, it is difficult to orient a buoyant sampling container beneath the incoming stream of septic effluent from above.
- Distribution box access should be brought as close as possible to final grade so that dirt and debris do not enter the distribution box during excavation.
- All distribution box access covers should be secure from unauthorized entry by either a cover of sufficient weight or proprietary locking mechanisms (such as screws with specialized heads or latches that lock).

The second most common sampling point in an I/A system is the point at which the treatment unit drains into a pump chamber. This location is typically a freefall pipe (most commonly fitted with a tee). In this instance, a sampling bottle or transfer vessel is simply placed below the pipe while flow is occurring. The most common problem observed with this configuration is that the inlet side of the

pump chamber is not equipped with an access cover[1]. This is due to the fact that the most common maintenance item in the pump chamber, the pump itself, is usually situated at the discharge end of the pump chamber, and under normal circumstances, this is the only location that actually needs and access cover. For sampling purposes, however, access to the inlet side of the pump chamber is necessary.

When planning for sampling in the pump chamber of an I/A system, the following points should be remembered during the design and installation phase of the project.

- Pump chamber inlet access should be brought as close as possible to final grade so that dirt and debris do not enter the distribution box during excavation.
- All pump chamber inlet access covers should be secure from unauthorized entry by either a cover of sufficient weight or proprietary locking mechanisms (such as screws with specialized heads or latches that lock).

In short, the design plan should clearly indicate the location of the sampling port(s), **specifying all materials that should be used to secure the port and ensure its accessibility for sampling**. The designer should bear in mind all potential difficulties (such as discharge stream depth, adequacy of room to maneuver sampling vessels, etc.) when designing the sampling location. All materials necessary to secure the sampling port from unauthorized entry, such as weighted covers or proprietary fasteners or locking devices, **should be clearly specified on the plan.**

The installing contractor should discuss the features of sampling locations with the designer to ensure all appropriate materials and features are installed.

The reviewing authority should ensure that designer has taken into consideration all factors that are required to allow for proper sample collection. The attached review sheet may assist regulators in this task.

## Sampler Considerations

The purpose of sampling is generally twofold. Foremost, sampling is for the confirmation of system performance. Just as important, however, is the goal of enabling the diagnosis of problems when systems are not meeting performance standards. This section references sampling considerations for nitrogen performance standards.

[1] 310 CMR 15.231: Dosing Chambers and Pumps (5) only requires that one manhole be brought to grade. This requirement was presumably to accommodate pump servicing. For sampling, however a manhole should be brought to grade over the inlet side of the pump chamber also.

The first consideration for any sampler should be proper collection, storage and transport of samples. Regulatory approval letters for systems purporting to remove nitrogen in residential setting where the vendor is seeking approval to discharge 660 gallons per day per acre, simply state that:

*"the System shall not exceed 19 milligrams per liter (mg/L) total nitrogen (TN) concentration in the effluent measured as the total TKN (total Kjeldahl Nitrogen), NO3-N (Nitrate nitrogen) and NO2-N (Nitrite nitrogen).*"[2]

From this statement, a sampler should conclude that at least two samples need to be taken. TKN samples are taken in acid-preserved bottles, while the nitrate and nitrite samples are generally procured in another bottle having no chemical preservative. Both samples, once taken should be preserved on ice (or held as close as possible to $4^{o}$C), and transported to a certified laboratory within the specified holding times. Holding times for all parameters can be found in the latest edition of Standard Methods for Examination of Water & Wastewater, a joint publication of the American Public Health Association (APHA), the American Water Works Association (AWWA), and the Water Environment Federation (WEF).

The sampler should understand that TKN is a measure of nitrogen that may have high dependence on the suspended solid characteristic of the sample. Accordingly in all sampling scenarios, care should be taken to take the sample from the flowing discharge of the treatment system. If, for instance, a sample is taken from the standing liquid in a distribution box, or from the standing liquid in a pump chamber, it may not be representative of the discharge concentration. In one instance, if either of these structures allow for settling of solids from the effluent, the TKN value will be lower than the true value of the effluent. In another instance, where taking of the sample disturbs the liquid and resuspends solids, the TKN value will be higher than the normal effluent level of TKN. As stated, both of these biases can be avoided by taking the sample directly in the effluent stream as it is being discharged. ***Care should be taken when sampling with acid-preserved sampling bottles. Wear protective gloves and eyewear when sampling.***

Once samples are taken, the sampler should immediately place the samples on ice and transport them to the appropriate laboratory facility.

[2] Sample statement from a residential system claiming nitrogen reduction and seeking to obtain approval for the discharge of 660 gallons per day per acre (DEP Provisional Use Approval Letter, Bio-Microbics, Inc., December 2008)

## Consideration of Sampling Parameters

The DEP Approval Letter implies that only TKN, nitrate and nitrite are required for proper sampling. While this true, the sampler should consider additional parameters that can assist in diagnosing problems in performance. These parameters are dissolved oxygen, pH, alkalinity and BOD of the effluent.

The reactions necessary for removal of nitrogen from wastewater can be simply expressed as:

- Conversion of protein in wastewater to ammonium (occurs in the septic tank)
- Conversion of ammonium to nitrate (*nitrification*; requires oxygen and alkalinity and occurs in aerated portion of I/A system)
- Reduction of nitrate to nitrogen gas and its release to the atmosphere (*denitrification*; occurs in an anoxic portion of the system with sufficient BOD for the denitrifying organisms).

One of the most sensitive steps in the process is the conversion of ammonium to nitrate. This step requires a narrow range of pH (generally not less than 6.5 and not more than 8.0), and other requirements outlined below.

### Oxygen and Alkalinity

Sufficient oxygen and alkalinity are essential to the conversion of ammonium to nitrate (the precursor for *denitrification)*. The bacterial organisms responsible are both sensitive and slow growing. Low measured oxygen or alkalinity can be diagnostic for I/A systems that are not meeting the nitrogen reduction requirements.

The presence of oxygen can be measured in-situ with a dissolved oxygen meter. A crude estimate of oxygen requirement is that 6 mg of oxygen is required to oxidize 1 mg of nitrogen. Thus, it is important as a diagnostic tool to measure the dissolved oxygen

***A Note about Field Test Kits and Instrumentation***

*All field instruments require regular calibration. Common field instruments, such as turbidity, pH and dissolved oxygen meters should be calibrated daily against standards (dissolved oxygen meters should at minimum be checked at 100% air saturation). Operation manuals for all meters should be reviewed and manufacturers' recommendations for calibration, sensor or membrane replacement, interference factors, etc. should be adhered to. A field meter measurement is only as good as the calibration indicates. Following initial calibration and use in the field, all meters should be "closed out" by comparing the closing values with a standard. If during this process you observe significant deviation between the meter value and the standard at the close of the day, all meter readings that day are suspect for inaccuracy.*

*Rapid field tests for other parameters should be used with caution. The sampler should understand all possible interferences that may affect results. While field kits, such as ammonium, nitrate and nitrite tests, have their place in a rapid diagnosis mode, they should not be substituted for certified laboratory analyses to be used in performance monitoring. The results of many field kits can be altered or interfered with by compounds in wastewater that are not typically measured. Consult the manufacturers' literature for all possible factors that interfere with the test accuracy.*

in the aerobic portion of the system. Very low (<3 mg/L) dissolved oxygen in the aerobic portion of the system should generally be addressed by adjusting those features that control the flow of air through the system.

Cape Cod and much of southeastern New England has water with low alkalinity. Alkalinity is crucial to the ability to nitrify the ammonium in raw wastewater. A crude estimate of need is that ~7 mg/L of alkalinity (expressed as $CaCO_3$) is needed to oxidize 1 mg of ammonium to nitrate. In instances where there is not enough alkalinity, effluent samples will have a high percentage of the nitrogen as ammonium, *despite sufficient oxygen to oxidize the ammonium.* Insufficient alkalinity can also result in low pHs that can inhibit nitrification.

### Biochemical Oxygen Demand

Biochemical oxygen demand (BOD) is often used as a surrogate measure of available carbon that bacteria use for the construction of cells. In many I/A systems, once the wastewater nitrogen has been nitrified, it is directed to an anoxic portion of the system. When there is no atmospheric oxygen available, some organisms use the oxygen on the nitrate molecule as an electron acceptor (necessary for them to complete their metabolic pathways and live). This use frees the nitrogen as nitrogen gas (hence denitrifying the wastewater). Essential in this stage, however, is the presence of sufficient carbon for the denitrifying bacteria to build cell mass, reproduce, live and be available for more denitrification. Unfortunately, at this point in most process trains, the carbon has been used by other organisms and little may be left for the denitrifiers. This "problem" is addressed in various ways by each technology, but it is sufficient to mention that non-detectable BOD measurements at the discharge of a system, accompanied by high nitrate values can be diagnostic of insufficient carbon sources for the denitrifiers.

### Dissolved Oxygen Again

In contrast to the need for dissolved oxygen in the aerobic phase of wastewater nitrification, dissolved oxygen is actually counter-productive at the denitrification step. The majority of organisms that denitrify wastewater will not do so in the presence of available oxygen. Thus a measure of dissolved oxygen in the anoxic portion of the system > 1.0 mg/L probably inhibits denitrification.

## System Troubleshooting Using Sampling Data

While not meant to be an exhaustive list of strategies, Table 1 presents a list of common problems that have been observed in Barnstable County and the diagnostic actions an operator might consider to resolve the problem.

It is important to remember that, besides standard chemical parameters, a good operator needs to know and understand operational parameters in order to optimize the performance of a system. Water usage in the residence may significantly impact the concentration of certain contaminants and require system operational adjustments. Operators/samplers should also make note of any of the following items in the event that the samples taken reveal performance problems:

- Strange or different odors or chemical smells to the effluent or system,
- Strange or different color or characteristic of the effluent or intermediate flow,
- Changes to any counters or run time meters that would indicate abnormal operation of the system,
- Testimony of system owners regarding problems or abnormal observations they have had since the previous visit.

Although it is not explicitly stated in approval letters, the system sampling is meant to be integrated closely with the operational oversight of the system. System performance samples should inform the operator to optimize system performance. Often, however, sampling data is merely collected and not reviewed. If I/A systems are to be seriously considered as a means to achieve nitrogen reductions, **we strongly recommend that a management district of sorts be formed with responsibilities that include regular review of sampling data, consistent contact with operators regarding these data, and follow up communication to ensure that the system operations are optimized in accordance with the data collected.**

## Other Troubleshooting Considerations

Although water chemistry can help diagnose a problem, an operator should also consider other factors that exert influence on system performance.

- Water use. If possible, water use values should be recorded and used to assist in estimating the relative strength of the wastewater. If the home is on a private well, consider requiring the installation of a water meter as part of the septic plan. Good water use data can help determine treatment strategy and estimate contaminant loads.
- Occupancy. It is always a good idea to interview the occupants of a residence being served by an I/A system. Foremost, it is an opportunity to educate the residence on the do's and don'ts of wastewater disposal (not flushing toxic materials, moderation in use of bleach and antimicrobial soaps, spacing laundry loads, etc.). In addition, an interview might reveal a pattern of use that can aid in I/A system adjustments.
- Chemical use. Many of the water treatment steps are negatively affected by use of certain chemicals. An operator should always be observant for

any signs of chemical use (old containers, odd odors, testimony of occupants). The occupants should be made aware that their septic system is a biological treatment unit that can be upset by use of certain medicines, toxic materials and antimicrobial compounds.

## Summary

This project reviewed information collected by the Barnstable County Department of Health and Environment over the years 1999 – 2009 and makes the following recommendations on issues relative to performance sampling of I/A septic systems.

### Group: Designers

**Recommendations:** Specify all aspects of sampling ports on design plans in consultation with system vendors. Specify that sampling ports shall be accessible and at grade, and provide detail on access covers to include any proprietary products desired to be used. Consider the process of sample collection in all designs and allow for procurement of sample from the wastewater stream while flowing. Avoid deep sampling ports that prohibit reasonable maneuvering of sampling vessels.

### Group: Installers

**Recommendations:** Review all plans prior to construction and ask designer for clear detail on sampling port features such as size of riser (if applicable), access cover, product suppliers, etc. Make sure all access covers for sampling ports are at grade.

### Group: Regulators (regulatory review of plans)

**Recommendations:** Review plans for thoroughness of detail. Use checklist (Appendix A) for the review of plans in regard to sampling ports.

### Group: Samplers/Operators

**Recommendations**: Review data collected and adjust system operations as indicated. If systems are non-compliant, investigate means of correcting operation. Consider using suggested strategies outlined above. Discuss actions with local regulator.

| | Total Nitrogen | TKN | Nitrate | Nitrite | BOD | Recommend |
|---|---|---|---|---|---|---|
| System 1 | high | high | low | low | > 50 mg/L | Check for proper aeration in aerobic portion of system with dissolved oxygen meter (should be >3 mg/L), adjust air as necessary. Possible lack of nitrification, check for adequate alkalinity to achieve nitrification (~7 mg/L for each 1 mg/L of Total Nitrogen). If alkalinity insufficient, consider trial period of adding baking soda (Sodium bicarbonate) or other alkalinity source. |
| System 2 | high | low | high | low | <5 mg/L | System is apparently oxidizing ammonium, but not denitrifying. BOD in effluent diagnostic of carbon starving of denitrifiers. Check for oxygen concentration in anoxic portion of system, if high (>1 mg/L) consider downward adjusting recycle rate of effluent. |
| System 3 | high | low | moderate | high (>5 mg/L) | 15-20 mg/L | System diagnostic of a start up system. Non-completion of nitrification may be diagnostic of toxicity issue for second stage nitrifier. Check harsh chemical or quaternary ammonium excess use in residence. |
| System 4 | high | high | low | low | >50 mg/L | Check for aeration elements (blower operation, recycle rate, etc.). Check daily water usage in residence as system may have concentrated wastewater that requires system operational parameter adjustment. |

**Table 1. Hypothetical sample results from innovative/alternative septic systems with possible measures to correct operation. This is not meant to be an exhaustive diagnostic list.**

# Suggested Regulatory Review Sheet
# Addendum for Sampling Port Designation on Septic System Design Plans

Sampling Port Checklist for Plan

| | Yes | No |
|---|---|---|
| **Sampling Ports located on plan** | | |
| Influent | | |
| Effluent | | |
| If sampling port in distribution box, is cover at grade and accessible? | | |
| If sampling port in pump chamber, is inlet of pump chamber at grade and accessible? | | |
| If sampling port otherwise sited, is its location clearly indicated on plan? | | |
| If sampling port otherwise sited, has vendor agreed that it provides a representative sample? | | |
| **Is there adequate detail on the following aspects of the sampling port to ensure that a proper sample can be taken?** | | |
| Depth from surface of ground to sampling withdrawal point ? | | |
| Width of opening at ground surface adequate ? | | |
| **Are the following aspects of sampling port adequately detailed on plan?** | | |
| Access risers noted to be sealed to prevent drainage entry? | | |
| Access cover materials' specification adequate? | | |
| Means to secure access from unauthorized entry adequately specified? | | |

| **Other Checklist Items for I/A Systems** | | |
|---|---|---|
| Are adequate control panel event counters and run-time indicators specified on the plan? | | |
| Did the applicant submit an operation manual for the technology to the approving authority?. | | |
| Did the applicant provide the Approval Letter for the technology so that approving authority can verify all sampling requirements? | | |
| Are access requirements to all maintenance items for the technology clearly indicated on the design plan? | | |
| Is the technology specified on the plan designed/intended to address the contaminant removal expectations of the Board of Health? | | |
| It's the installer certified to install the specified technology? | | |
| | | |
| | | |