Onsite Sewage Treatment Alternatives (Excerpt)

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WHY IS SEWAGE TREATMENT IMPORTANT?

Effective sewage treatment prevents a variety of ailments that can be spread by exposure to pathogens that can be present in untreated sewages, and thus helps prevent disease. Discharges of untreated sewage can contaminate groundwaters and surface waters used for drinking, recreation, and fish and shellfish fisheries (Figure 1).

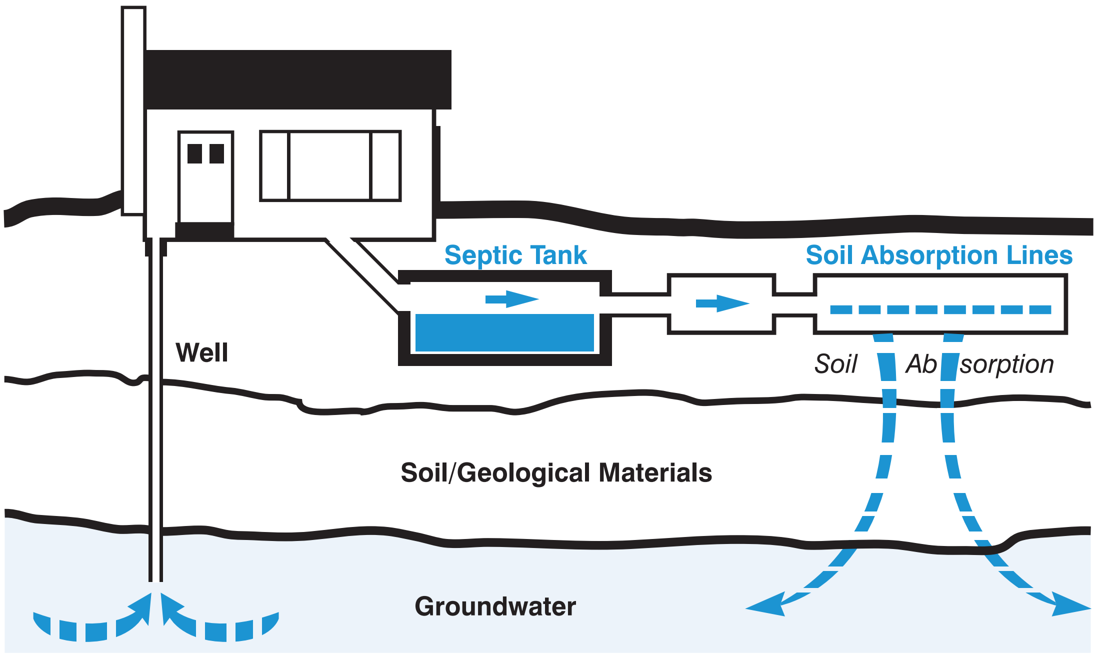

Figure 1. Many rural residences use groundwater wells as water sources, and rely upon onsite treatment systems for sewage disposal. Onsite treatment systems, such as the system represented above, disperse partially treated wastewaters in soils. When such systems are correctly sited, designed, installed, and operated, passage of wastewaters through the soil removes contaminants, which protects the groundwater from contamination. The above figure represents a conventional onsite system, similar to systems used by many rural households. Environmental factors, such as soil type and depth to groundwater, will determine the site suitability for conventional onsite systems.

Untreated sewage from failed conventional septic systems or sewage discharged directly into the environment can percolate into groundwater, contaminating drinking water wells with pathogens. The discharge of untreated sewage to streams can spread disease through direct contact, making such streams unfit for forms of recreation that involve skin contact with the water such as swimming and boating. Disease can also spread by indirect (secondary) contact such as through contact with rodents or insects that received primary exposure and, in turn, harbor the pathogens. Discharged, untreated sewage also can damage the receiving streams' ability to support healthy, living communities of aquatic organisms and can contaminate fisheries.

GENERAL PRINCIPLES OF SEWAGE TREATMENT

Raw sewage and septic wastewaters contain a variety of contaminants (Table 1). Many technologies are available to render the sewage suitable for safe discharge to the environment. These include those used in the municipal treatment works that receive sewage discharged to public sewers in the nation's developed areas; conventional onsite sewage treatment that uses a septic tank and soil absorption field commonly used in rural areas; and the alternative onsite technologies that form the focus of this publication. Most sewage treatment technologies operate by combining basic physical, chemical, and biological processes (Figure 2).

1. Primary treatment removes solid chunks and particles from raw sewage through gravity separation and/or screening. A septic tank is the most common primary treatment device in onsite systems. In alternative systems, the septic tank is commonly outfitted with an outlet filter, to capture solid particles that are too small or too light to settle. When used with conventional septic systems, an outlet filter will extend system longevity and improve performance. The partially-treated liquid discharged from primary treatment is called *primary effluent*.

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Table 1. Sewage contaminants and modes of treatment

Component	Description	Mode of Treatment
Solids (includes particulates)	Primarily carbon-based, slowly biodegradable organic compounds	Most are removed by primary treatment (settle by gravity and/or separated by screening or outlet filter).[a]
"BOD" (biochemical oxygen demand)	Biodegradable organic carbon compounds, in particulate and soluble forms	Particulate BOD is removed by primary treatment. Soluble BOD is consumed by native bacteria in the soil absorption field[b] and/or secondary treatment process that transform carbon-chain organic compounds to CO_2 via matabolic processes. Advanced treatment (if present) removes additional BOD.
Bacterial, viral, and protozoan pathogens	Disease-causing agents, contaminants of fecal matter	These organisms, well adapted to the oxygen-poor environment of the human gut, are not well adapted to well-aerated environments. When pathogens are present, some perish in secondary treatment, but some remain in secondary affluent. Pathogens perish in the soil absorption field[b] and/or disinfection processes.
Nitrogen (N)	N as organic and ammonium (NH_4^+) forms	N associated with solids is removed via primary treament Some N is volatilized and lost to the atmosphere. Secondary treatment converts much of the remaining N to the nitrate (NO_3^-) form. Advanced treatment can be installed to remove additional N prior to discharge.
Phosphorous (P)	P as organic and inorganic phosphate chemical forms	P associated with solids is removed via primary treatment and in secondary clarifier, if present. P binds to soil particles, and is not highly mobile in most soil environments. Advanced treatment can be installed to remove additional P prior to discharge.
Household chemicals	Cleansers, detergents, etc.	Minimal treatment: disposal with septic wastewater should be minimized.

[a] Primary treatment tanks (septic tanks) must be cleaned out periodically to maintain system function.
[b] Absoption field soils must be well aerated to function effectively.

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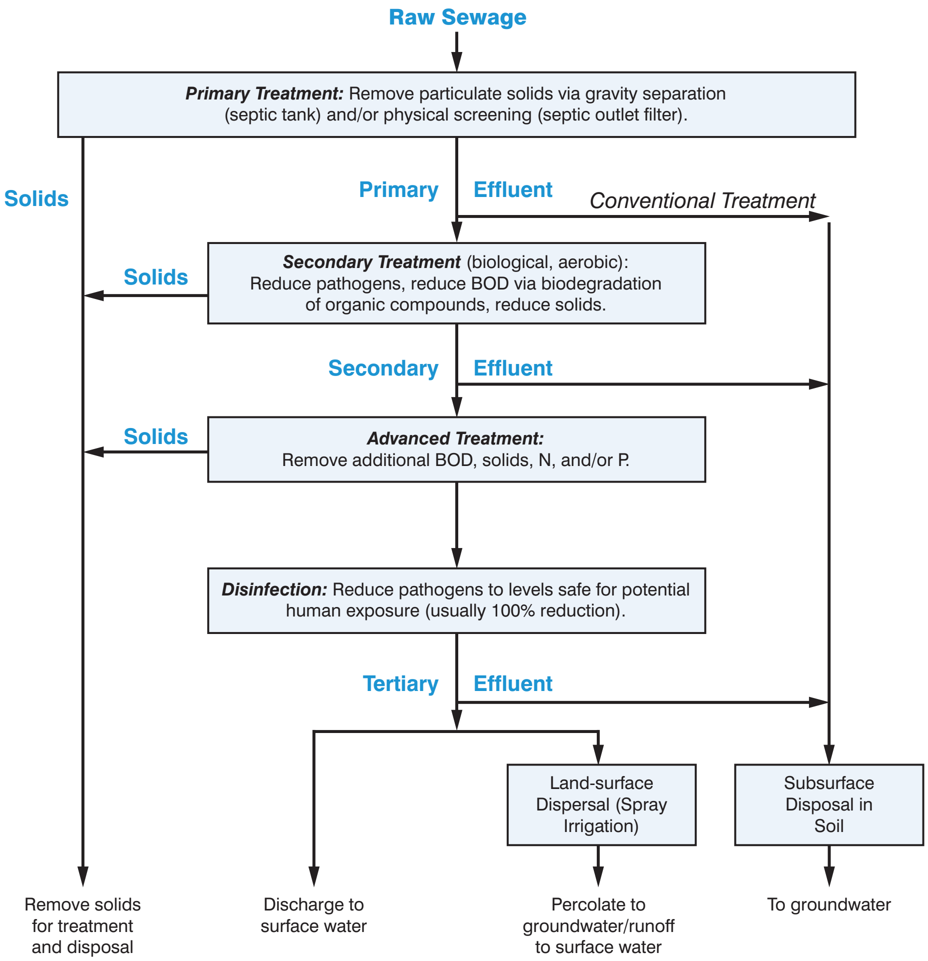

Figure 2. The figure is a generalized flow chart of the sewage renovation process used in onsite treatment. In addition to the processes shown, some removal of nitrogen, phosphorous, other nutrients, and other contaminants occurs due to primary and secondary treatment.

2. Secondary treatment processes (also called *microbial digestion*) receive primary effluent. Most secondary treatment processes move the effluent through an aeration process environment that is favorable to aerobic microorganisms, those that thrive in atmospheric oxygen (O_2) environments. The following wastewater renovation processes occur during this treatment:

   - Pathogenic microorganism populations are reduced. The vast majority of microorganisms found in sewage thrive within the human digestive system, an environment where oxygen does not occur as O_2. Consequently, these organisms are not well adapted to aerated environments. Within secondary treatment devices, some microorganisms (including most pathogens) perish as a result of exposure to O_2.

     Other organisms, including predators that consume pathogens, do thrive in an aerobic environment, sustained by the rich mix of O_2 with H_2O, biodegradable organic compounds, and essential nutrients that comprises sewage. Where the effluent passes through secondary treatment media with small pores (such as a sand filter, or natural soils), pathogen numbers are also reduced via physical straining.

   - Biodegradable organic contaminants, such as dissolved organic substances and organic particles remaining in the effluent after primary treatment, are removed.

     The microorganisms in the aerated secondary treatment medium consume and metabolize biodegradable organic compounds, deriving energy by breaking the carbon-carbon bonds and converting the organic carbon to carbon dioxide (CO_2).

   - Small particulate contaminants are removed. Where the filtration media are comprised of mineral particles with small pores (such as a natural soil or a sand filter), particulate contaminants are removed via physical screening; biodegradable components of the particles captured in the fine pores are consumed by the resident aerobic bacteria.

     The partially-treated liquid discharged from secondary treatment is called *secondary effluent*.

3. Advanced treatments are optional processes that may be applied to remove additional contaminants from secondary effluent prior to dispersal. Advanced treatment is usually included only in systems intended to discharge directly to the land surface or to surface water streams. Advanced treatment processes designed to remove additional nitrogen and phosphorous from the effluent are sometimes necessary to protect water quality in streams receiving treated effluent discharges.

4. Disinfection systems often rely on chlorination, ozonation, or ultraviolet light. Systems that discharge treated effluent where there is a potential for direct human exposure (i.e., discharge to surface waters or the soil surface) are often required to disinfect the effluent so as to eliminate potential hazards due to human exposure.

   Effluent that has been disinfected, and has received advanced treatment is called *tertiary effluent*.

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Treated effluent must be discharged to (or dispersed in) the environment. Secondary effluent is commonly dispersed in soils below the surface, while tertiary effluent may be discharged to flowing waters (such as a surface water stream) or on the soil surface. Surface discharge or dispersal typically requires a permit from an agency responsible for protecting surface water quality as well as an onsite septic system permit.

CONVENTIONAL ONSITE TREATMENT OF DOMESTIC SEWAGE

The conventional means of treating sewage with onsite systems is with a septic tank and soil absorption field (Figure 3).

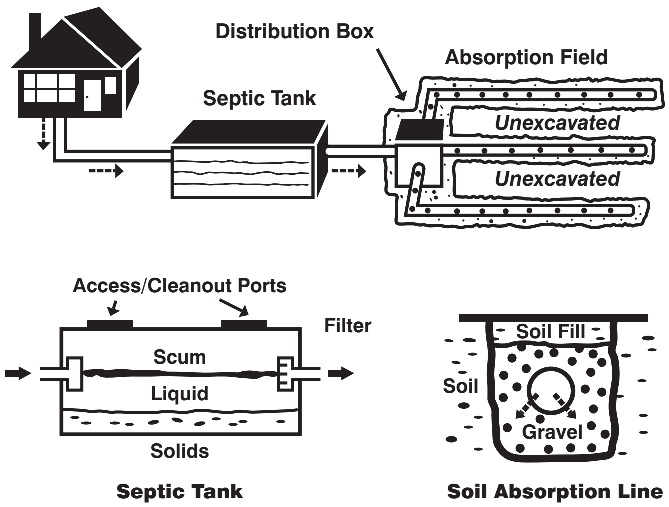

Figure 3. Conventional onsite wastewater treatment systems (above) include a septic tank (lower left) to perform primary treatment and an absorption field. Effluent from the septic tank is directed by gravity through a distribution box to an absorption field which contains multiple soil absorption lines (lower right) to disperse effluent to the soil where additional treatment occurs. Soil absorption lines are commonly constructed in gravel-lined trenches, but other methods of construction are also possible.

Primary treatment (the removal of solids from the sewage) occurs in the septic tank. If the septic tank fails to perform, solids will enter the distribution box and soil absorption field in large quantities. The accumulated solids will render these components ineffective. When a soil absorption field or a distribution box begins to “clog” with solids, a typical result is unequal distribution of the effluent and the overloading of nonclogged absorption areas, which then tend to clog at an accelerated rate. Untreated or partially treated effluent may emerge on the surface in such situations. A septic tank outlet filter, essentially a screen that captures small particles, can help to ensure against this result.

Some removal of organic contaminants occurs in the septic tank. Its oxygen-poor environment promotes some decomposition by anaerobic microorganisms, but this process has only a minor effect.

The distribution box allocates the effluent equally among several soil absorption lines. The distribution box is usually situated below the septic tank outlet, so effluent can move to the distribution box via gravity flow. Because flow through the distribution box also occurs via gravity, the box is leveled during installation to achieve equal distribution of effluent among the soil absorption lines.

The soil absorption lines distribute the effluent to the soil where biological treatment can occur. Effluent moves through soil pores and encounters resident microorganisms. Each absorption line is laid out with a low pitch (generally 1/8 to 1/4 vertical inch per horizontal foot). The low pitch helps distribute effluent evenly along each absorption line’s entire length. Most soil absorption lines are perforated 4-inch PVC pipe laid in gravel-lined trenches, although soil infiltration chambers . . . may also be used.

Effluent emerges from each pipe and percolates through the gravel to the bottom of the trench. Although less common, other absorption-line configurations, including soil infiltration chambers, may be used. State regulations require consideration of soil type and other environmental conditions when an onsite system is designed and includes the amount of trench bottom required for each 100-gallons-per-day of wastewater system design capacity.

Although the distribution boxes and soil absorption lines are intended to distribute effluent evenly throughout the soil absorption field, it rarely occurs in practice because of the lack of precision in building field systems that depend on gravity for effluent distribution. Therefore, soil absorption fields are commonly larger than would be necessary if precise and even effluent distribution were assured.

The most common cause of conventional septic system failure is inadequate cleaning of the septic tank, which leads to movement of solids into the absorption lines where they accumulate and impair drainfield function–a condition known as *clogging*. A qualified septic system contractor should be employed by the homeowner periodically to remove solids from the septic tank, which will minimize this problem.

Other causes of septic system failure can include:

- Improper installation, leading to excessive effluent accumulation in one area of the soil absorption field
- Installation of a system that is too small to handle the household’s wastewater production
- Installation in soils with inadequate capacity, or
- Home usage patterns that produce wastewaters in excess of the absorption system’s treatment capacity.

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SUSPENDED GROWTH SYSTEMS

Aerobic Treatment Units
A number of stand-alone treatment systems are available for purchase on the open market. Aerobic treatment units (ATUs), or package plants, are modular sewage treatment units that can be purchased through and installed by a commercial contractor (Figure 7).

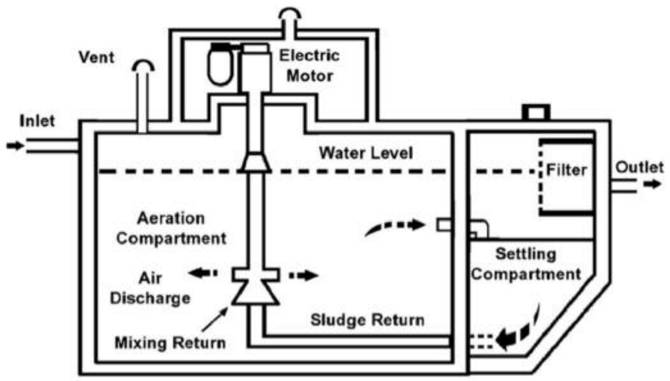

Figure 7. An aerobic treatment unit is a mechanical system that treats effluent using natural processes that require oxygen. The system consists of an aeration chamber, a mechanical agitator, and a sludge settling compartment. Secondary treatment takes place in the aeration chamber. Some units also include a disinfection device (not shown).

Household scale ATUs are commonly purchased, delivered, and installed as self-contained modules containing some level of primary treatment (in some cases, only a screen), secondary treatment (generally, a suspended media biological treatment process), a procedure (called *polishing*) to remove additional contaminants, such as small particles or nutrients, as required to meet water quality standards, and disinfection.

Many ATUs are designed for discharge to a surface water stream and are rated by the quality of effluent they will produce if operated correctly. If direct access to a surface water stream is not available, surface water discharge is not an option. High quality effluent from an ATU can also be discharged to a soil dispersal system, either above or below ground.

Although the term "package plant" implies ease of operation, some user care is required. Filters and screens must be cleaned periodically, and pumps must be maintained and replaced. The suspended growth treatment process requires a pump, mechanical agitator, or similar device that cycles on and off several times during each operating day. These devices can require maintenance as can the disinfection mechanism (if present). Depending on location, it may be possible to purchase maintenance services from a commer-

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cial contractor. Because experience has shown that self-maintenance by homeowners often results in system failure, the state agency may require a maintenance contract as a condition of permit approval. Like most other onsite treatment alternatives, operation of a package plant requires electric power.

Where effluent is discharged to the surface, a surface discharge permit must be obtained. Generally, such a permit will include *effluent limitations*, or numerical limits on the amount and/or concentration of contaminants that can be released in the effluent to the stream. An ATU's ability to meet water quality standards should be considered by homeowners making purchase decisions.

Editor's Note:
As demonstrated by the University of Wisconsin-Madison and National Sanitation Foundation (NSF) research on the effects of water softeners on septic tanks, the volume of discharge from a softener's regeneration cycle is roughly 50 gallons[†]*. While this amount is often less than the volume of wastewater generated by a residential clothes washing machine, homeowners with onsite wastewater treatment systems are cautioned against washing numerous loads of laundry in a single day to avoid exceeding the system's capacity. Specifiers of any point-of-use and point-of-entry water treatment equipment that generates a waste stream must take into account both the capacity of the waste drain and the onsite treatment system, along with water usage patterns.*

[†] "Onsite Wastewater Treatment Systems Special Issues Fact Sheet 3: Water Softeners", USEPA Risk Management Research, August 13, 2010.

QUIZ 2: "Onsite Sewage Treatment Alternatives Excerpt" (0.25 CPD)

1. **Why does sewage need to be treated?**
   a. To reduce space in landfills
   b. To extract reusable minerals
   c. To provide black water for reuse
   d. To prevent disease
2. **Which technique is used at the primary treatment stage to remove solids?**
   a. Septic tank
   b. Gravity separation
   c. Effluent discharge
   d. Centripetal force
3. **In addition to destruction by oxygen, what other methods can be used to remove pathogens in secondary treatment?**
   a. Digestion by acid
   b. Physical straining
   c. Ultraviolet disinfection
   d. Chlorination
4. **Which contaminants are removed in the advanced treatment process?**
   a. Nitrogen compounds
   b. Dissolved gasses
   c. Pathogens
   d. Hardness ions
5. **Which stage of treatment must be completed before effluent may be dispersed below the surface?**
   a. Primary
   b. Secondary
   c. Tertiary
   d. Advanced Treatment
6. **What are the two components of a conventional onsite sewage system?**
   a. Advanced treatment unit and pump chamber
   b. Aerobic digestion and filtration
   c. Anaerobic digestion and filtration
   d. Septic tank and solid absorption field
7. **What's the most common cause of septic tank failure?**
   a. Inadequate cleaning of the tank to remove solids
   b. Presence of microorganisms in the soil absorption field
   c. Presence of wastewater from a water softener
   d. Use of a too large soil absorption field
8. **Since onsite sewage treatment systems are sized based on usage patterns, how could peak use volumes that exceed capacity impact operation?**
   a. If average monthly use within design capacity, no impact
   b. Peak use over capacity leads to clogging and system failure
   c. If the composition of waste is within design parameters, no impact
   d. Peak use over capacity only impacts efficacy of secondary treatment
9. **What discharge options do aerobic treatment units offer that conventional units do not?**
   a. Direct discharge to sanitary sewer
   b. Below ground soil dispersal
   c. Direct to black water collection tank
   d. Direct to surface water stream
10. **Which level of treatment is not included with conventional units, but is standard with aerobic treatment units?**
    a. Primary
    b. Secondary
    c. Tertiary
    d. Quaternary