ONSITE INDUSTRY FEATURE

Three Perspectives on the Use of Soil in Wastewater Treatment

1 The Power of Soil: Using it to Our Advantage

By Judith Sims and Richard Otis, Ph.D., P.E., DEE

The soil environment is the most effective water-treatment system on earth! For millions of years, it has protected the earth's pristine groundwater resources from pollutants that collect in water percolating from the surface. It sustains the quality of our ground water; it permits us to use ground water as our drinking water without additional treatment.

In our industry, we depend on the soil environment's purification power to sustain groundwater quality as onsite and cluster systems return "used" water safely to the groundwater for recycling and reuse. However, the purification power of soil has limitations that vary from location to location. Without having a good understanding of those limitations and without knowing how to identify and accommodate them when we site and design drainfields, we run the risk of overloading the soil's purification power at the expense of the quality of our groundwater resources.

The soil environment provides a variety of physical, chemical, and biological treatment processes. Among them are sedimentation, filtration, adsorption, precipitation, ion exchange, hydrolysis, biodegradation, nitrification, denitrification, and predation. The effectiveness of each of those processes will vary from soil to soil, so to use the treatment capability of the soil to its maximum extent, a system's pretreatment processes must be selected to complement the treatment capability of the soil. Understanding the relationship between the soil's characteristics and its treatment capability also can be used in modifying the soil characteristics to create favorable conditions for desired treatment capabilities. This requires that a thorough site and soil evaluation be conducted to estimate not only the soil's capacity to accept and disperse the wastewater's hydraulic load but also to treat the wastewater by retaining, transforming, and/or removing pollutants of concern. Such an evaluation requires that we consider the soil as a treatment component that can provide various treatment processes depending on its characteristics and conditions.

The most important soil characteristics and conditions to observe during the site evaluation are:

- Permeability
- Moisture potential
- Unsaturated depth
- Mineralogy

Permeability. The permeability of the soil is not only important in the water's ability to disperse into the receiving environment and ultimately percolate to the water table but also in allowing air to diffuse into the soil, which is necessary to support aerobic treatment processes in the soil. The soil's permeability is a function of the size distribution and continuity of the pores in the soil. Soils with mostly fine pores will provide greater treatment potential than those with coarse pores, but they will hinder the rate at which water can percolate through the soil and disperse into the receiving environment. Thus, treatment and dispersal are competing objectives where soil permeability is high or space is limited.

Soil characteristics that determine soil permeability are the soil's texture and structure. Also, soil color is a good indicator of how well a soil allows water to move.

The **texture** of a soil is defined by the relative proportions at which the soil particulates—sand, silt, and clay—occur within the soil. Some common soil-texture classifications—in order of large to small particulates—are sand, sandy loam, loam (primarily silt), silt loam, clay loam, and clay. The various sizes of the individual particulates in a soil and their arrangement, or "packing," create a variety of pore sizes that impact permeability. Water flows between the particles, and, in most cases, the larger the particles, as with sand, the more quickly the water moves through the soil. Soil with a mixture of the various particulate classes, such as sandy loam, will have fewer large pores and is more effective in filtering out bacteria, viruses, and other potential pathogens from the applied wastewater.

A soil's **structure**, which is the combination or arrangement of individual soil particulates into aggregates or peds, affects how well the soil can absorb and move water. The structure will often impact soil permeability to a greater extent than does the texture. Also, macro pores, such as channels created by

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worms or by decayed roots, are common in structured soils. Well structured soils with large spaces between the aggregates transmit water more quickly than soils of the same texture with little or no structure. Water percolates very slowly through fine-textured ("massive") soils with little structure, while fine-textured soils with strong structure can provide rapid water movement.

The **color** and color patterns of soil can be used to estimate the soil's moisture regime. The colors of soils that are seasonally "wet" or permanently saturated differ from the colors of well drained soils. Soils that experience extended wet periods often exhibit redoximorphic features including mottling or "gleying." Mottling within the soil matrix appears as spots of different shades of color resulting from the alternating periods of reduction and oxidation that accompany seasonal cycles of saturation and dryness. Gleyed soil usually is a uniform grey color that is the result of extended periods of intense reduction indicative of permanently saturated soil. Bright yellow or red soils indicate a good drainage environment.

Moisture Potential. The energy status of water in soil may be described in terms of a "moisture potential" index. When the soil is saturated (all the soil pores are filled with water), the moisture-potential index is zero (at atmospheric pressure) or greater than zero (under positive pressure). When the soil is not saturated, the larger pores are devoid of water while the smaller pores hold water under tension by capillary action—the moisture-potential index is less than zero.

As more water leaves the soil, higher moisture tension ensues, only the smallest pores hold water, and the moisture-potential index becomes more negative. That situation has two beneficial effects for treatment: 1) The larger pores remain open allowing air to diffuse into the soil where oxygen can support aerobic biochemical reactions to meet the oxygen demand of the percolating wastewater, and 2) water is forced to flow in the smaller pores, improving filtration, and slowing percolation. Concurrently, the residence time of the water in the soil increases, allowing ample time for biochemical reactions and more contact with the soil matrix where chemical adsorption reactions can occur.

Soils with shallow water tables and low areas that can receive storm water runoff should be avoided. However, in any soil, the moisture-potential index will vary with the applied water, but high moisture tensions can be achieved by controlling the rate of wastewater application to the soil. High moisture tensions are necessary to ensure good removal of the biochemical oxygen demand (BOD), filtration of suspended solids and bacteria, and ammonia removal via nitrification,

Unsaturated Depth. A depth of soil that will remain unsaturated and provide active aerobic treatment sufficient to ensure good removal of BOD and fecal coliform must be present during wastewater applications. Studies have shown that 18 to 24 inches of unsaturated soil with a texture of at least fine sand or with a moisture-potential index maintained at a large negative value is adequate to achieve good removal of those pollutants. However, the specific depth of suitable soil is usually dictated by regulatory codes that require a minimum of 3 to 4 feet of unsaturated soil. Those minimums were established to ensure acceptable pathogen removal and to provide an ample factor of safety, but such depths will prevent the formation of soil conditions that can support biological denitrification, which is often required.

Movement of nitrogen in soil is becoming an increasing concern with onsite wastewater treatment. As nitrogen moves through an onsite treatment system, biological processes (primarily in the septic tank) convert it from organic nitrogen to ammonia nitrogen. Then, below the drainfield biomat in the underlying unsaturated soil, the ammonia nitrogen is adsorbed to soil particles and then biologically converted to a soluble and mobile form of nitrogen—nitrate. Nitrate, which is associated with the "blue baby" syndrome and vilified as an aquatic plant nutrient in marine waters, can move with percolating water through the soil to ground water. Without a zone of saturated soil with organic matter present to provide a source of carbon and an anoxic environment, nitrate will not be removed.

Mineralogy. The soil's mineralogy is important in controlling the pH of soil water, removing cations through ion exchange, and offering adsorption sites for various pollutant ions. Of these reactions, the removal of phosphorus through adsorption and precipitation reactions is of the most interest in onsite treatment near surface waters, because phosphorus is a limiting nutrient in aquatic plant growth. To maximize removal of phosphorus, the volume of soil contacted by the percolating water is important. Attaining adequate contact can be achieved best by locating systems away from lake shores and extending the application of wastewater along the site contours.

In the process of determining what system design would be appropriate for a proposed building site, the local regulatory authority, which is often a health or planning and zoning department or district, usually specifies procedures and policies to be followed when site and soil conditions are evaluated. The results of the evaluation should be sufficient to enable the system designer to select the most appropriate system design for the site. To ensure that the evaluations are performed correctly, they should be conducted by soil scientists, environmental health scientists, or other appropriately trained and licensed professionals.

The objective of the site evaluation is to determine the site's capacity to hydraulically accept and adequately treat the wastewater to be applied. The scale and detail of the site evaluation will depend on the raw wastewater characteristics (quantity and quality) and the environmental sensitivity of the site. A thorough site evaluation includes the following steps:

- **Wastewater Characterization and Treatment Requirements.** The site evaluation process begins with obtaining a reasonably accurate estimate of the daily volume of wastewater to be treated, its constituent concentrations, and the stipulated treatment goals. From this information, the site

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evaluation focuses on delineating a sufficient area for the treatment site, an estimate of the soil required to retain, transform, and/or remove constituents of concern, and whatever additional pretreatment, if any, is needed to meet the stipulated treatment goals.

- **Site Screening and Reconnaissance.** Screening of potential treatment sites should begin with a review of soil and topographic maps prior to the site visit. When first at the site, the topography, landscape position, vegetation, and cultural features should be identified to locate the most promising areas for a treatment site.
- **Detailed Site Investigation.** At a minimum, a good site evaluation should include topographic mapping and detailed morphologic soil-profile descriptions. In sensitive environments, it might be necessary to consider deep borings, soil permeability measurements, groundwater mounding analyses, or other tests. This investigation should establish the size of the drainfield and its bottom elevation with respect to an established benchmark.
- **Preliminary System Layout.** Finally, a preliminary layout of the system with elevations should be sketched. It should consider any required setback distances from property lines, surface waters, wells, and other features to ensure that the selected system design will fit on the selected treatment site.

A site and soil evaluation is the first step toward installing an appropriate onsite wastewater treatment and dispersal system. The evaluations determine the characteristics of the building site and the ability of the soils present at the site to treat and dispose of wastewater. When conducted well, it provides enough information about the area to select the correct onsite system from the possible options available. ■

For more information and guidance on site and soil evaluations, consult NOWRA's *Guidance for Estimating the Treatment and Dispersal Capacity of the Unconfined Soil Treatment Component,* which is a supplement to NOWRA's *Model Code Framework for Decentralized Wastewater Infrastructure,"* to be published in 2008.

2 Soil Treatment: Model Code Tools-to-Come

By Anthony Smithson, R.S.
Model Code Committee Chair

I will start with four confessions: (1) I am a regulator—a Director of Environmental Health in a relatively urbanized county of suburban Chicago—with a career-long fascination with soil as a wastewater-treatment medium. (2) My personal inclinations, my education, and my training provide just about enough knowledge to make me dangerous if I did not have good friends and good staff who help me. (3) It is important to me that things make sense; I want to know "why" and in regulating onsite wastewater I often ask myself "why not." (4) I do not hesitate to stir-the-pot; I will challenge regulatory issues and decisions (including my own), and I do not mind making my fellow regulators uncomfortable.

Our prescriptive onsite wastewater regulatory codes can have a huge impact on our citizens. Notwithstanding the historical benefits to public health and environmental protection that "regulating" onsite systems have had, we can deprive citizens reasonable uses of their property, interfere with the business practices of other professionals and manufacturers, and cost everyone involved significant resources—all as a result of one or another requirements of our respective codes. I have calculated, for instance, that Illinois' prescriptive requirement for a design flow of 200 gpd/bedroom costs Illinois' citizens $7.3 million per year, although other states consider a 120 gpd/bedroom flow to be perfectly satisfactory. That $7.3 million gets divided among thousands of installations, of course, so apparently it goes unnoticed by an unsuspecting public. We believe, probably sincerely, that we are only being appropriately conservative.

It is our tendency as regulators and code writers to be "conservative" without asking, or demanding to know, what is "too conservative." This attracted me to participate in NOWRA's Model Performance Code project in the first place. A diverse group of participants challenged and debated these kinds of prescriptive requirements over a period of several years. In the end, NOWRA has produced some extraordinary documents that can guide us, if we are so moved, toward more "reasonable" regulation of decentralized wastewater systems. (See www.modelcode.org.)

However, the resolution of issues relating to soil, even the simple ones like horizontal/vertical setbacks and system sizing), has become elusive. A "soil" subcommittee of preeminent "soil minds" dug deeply (no pun intended) into the various treatment capabilities of soil, looking at the constituents designated by the Model Code Committee—BOD, TSS, fecal indicator organisms, nitrogen, and phosphorous. While some marvelous information resulted (unpublished to date), the level of complexity, the limitations of supporting data, the extent of extrapolation, and the scope of some implications proved to be too much to swallow. Still, the "Soil Guidance Appendix" to the

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Model Code Framework is purported to be, by most interested parties, a much anticipated and welcomed achievement. So, a role for the simple minded (me) has surfaced.

As current Chair of the NOWRA Model Code Committee, I have been attempting to find a way to complete this project. It seems to me that, among those who have been intimately invested in this effort, the main disagreements tend to be at the margins—we do not have enough perfect information to develop perfect solutions. Meanwhile, we regulators, who hold the key to promoting rational, performance-based regulation, continue to impose soil-related prescriptions that we cherish as gospel, often by virtue of nothing other than their historical perpetuation from generation to generation. We assume there is solid scientific support for our prescription, and pretend not to notice the vast differences in the prescriptions from one jurisdiction to another. We tend to resist considering what our requirements cost others. I wonder how many of us actually understand that soil is, or can be, a predictable wastewater *treatment* component capable of being effectively manipulated.

Ultimately, for NOWRA's Soil Guidance to be of benefit to the decentralized community, regulators must challenge, reevaluate, and realign their views of soil as a component of wastewater systems. Regulators have said to NOWRA that they want better tools for evaluating the role of soil, but they must be prepared to give something in return—a dedication to participation and contribution of their own thinking on the subject. Are regulators in fact willing to think of soil as a dynamic treatment component, or are they expecting only a "better set of tables"? Are they dedicated to evaluating and monitoring successful and unsuccessful applications of our current knowledge to extend our understanding?

What I have learned while participating in this process is that soil has inherent and definable (to a significant extent) capacities and limitations with respect to treatment and transport. Every other aspect of a wastewater system (sourcewater, flow volume, pretreatment, distribution methods, construction practices, O&M, etc.) enhances or restricts the ability to access treatment and transport capacity and sustain the "system" as required by the receiving environment and the long range plans for the site.

New understandings and new technologies make almost anything possible. But, it is *NOT* possible to establish a setback, a separation, a size reduction, or a set of "unsuitable" characteristics that apply to a soil/site without taking into account the unique characteristics and design options for that soil/site. Let's be clear: When it comes to soil, it is not possible to do legitimately what we, as regulators and code writers, have always done. Setbacks cannot apply to all soils on all slopes; loading rates cannot be reduced by the same factor for all soil textures with effluent quality improvements; vertical separation does not accomplish the same thing for different distribution methods; some soil conditions heretofore considered miserable can be desirable.

The Onsite/Decentralized community has many opportunities ahead. The advantages of soil-based options will eventually gain more and more favor. While progress has been slow (and will likely continue to be slow), NOWRA will produce a Soil Guidance tool by drawing on the knowledge of superb scientists who continue to investigate that fascinating natural resource—soil. There will be gaps in the knowledge, and those gaps will be acknowledged and targeted for future investigation. It remains to be seen whether we, as regulators, will continue to pretend that there are not gaping holes in the processes we currently embrace or whether we will welcome the opportunity to harness the benefit that soil as a treatment medium can offer society. I hope the latter is the case. I do not want the regulatory community to have to admit someday that (with due attribution to Walt Kelly and Pogo) "we have met the enemy, and he is us." ■

3 Soil: Part of a Decentralized Solution

By Jerry Stonebridge, NOWRA President

All the components of a decentralized wastewater treatment system are integral to the success of the system's meeting its performance goals—each component in the treatment train must meet or exceed its design expectations for the whole to operate as intended.

In most cases, a component can be tested easily—though sometimes at considerable cost—at its flow-output point to determine how well it is performing. The data collected can be analyzed and the O&M service provider can tweak the parameters affecting the in-flow and out-flow to advantageously alter the outcome.

However, the extent to which the soil component is upholding its piece of the design performance criteria has always been open to question There needs to be a standardized method for confidently measuring the performance of the soil, the final component in the treatment train before the flow is dispersed into the environment.

The industry (i.e., everyone involved with the onsite decentralized/distributed wastewater field) needs to participate in establishing and then comprehensively applying a Standard for measuring the performance of the soil as it relates to its design purpose, i.e., to influence the quality of the effluent as it reaches the ground water or whatever other intended dispersal point.

I believe that with the collective wisdom of the wastewater field and NOWRA's leadership, we can develop a simple, inexpensive method for validating the soil component. ■

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