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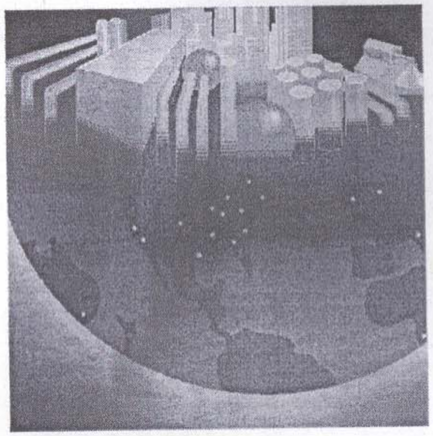

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Design and Performance of Onsite Wastewater Soil Absorption Systems

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Design and Performance of Onsite Wastewater Soil Absorption Systems

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1. Abstract

The primary system for onsite and decentralized wastewater treatment in the U.S. includes septic tank pretreatment followed by subsurface infiltration and percolation through the vadose zone prior to recharge of the underlying ground water. These wastewater soil absorption systems (WSAS) have the potential to achieve high treatment efficiencies over a long service life at low cost, and be protective of public health and environmental quality. Favorable results from lab and field studies as well as an absence of documented adverse effects suggest that system design and performance are generally satisfactory. However, the understanding and predictability of performance as a function of design, installation/operation, and environmental factors, as well as the risk of inadequate function and its effects, have not been fully elucidated. This has been due to the complex and dynamic relationships between hydraulic and purification processes and the factors that control their behaviors. As a result, the current state-of-knowledge and standard-of-practice have gaps and shortcomings that can preclude rational system design to predictably and reliably achieve specific performance goals. Moreover, the quantitative analysis of long-term treatment efficacy on a site-scale up to watershed scale is difficult, as is any formal assessment of risks and selection of appropriate management actions. This white paper describes the process function and performance of WSAS. The system performance capabilities and predictability as well as reasonably conceivable system dysfunctions are described within a risk assessment and management framework. Issues applicable to the single-site scale and to the multiple-site to watershed scales are addressed. Based on an analysis of the current state-of-knowledge, critical research needs are identified and prioritized. As described herein, critical questions and current gaps in knowledge generally relate to the absence of fundamental process understanding that enables system performance relationships to be quantified and modeled for predictive purposes. High and very high priority research needs include those that support: (1) fundamental understanding of clogging zone genesis and unsaturated zone dynamics and their effects on treatment efficiency, particularly for pathogens, (2) development of modeling tools for predicting WSAS function and performance as affected by design and environmental conditions, (3) identification of indicators of performance and methods of cost-effective monitoring, and (4) development of valid accelerated testing methods for evaluating long-term WSAS performance.

2. Introduction

Wastewater infrastructure in the U.S. includes a continuum of technologies designed for scales of application that span from small decentralized systems serving individual homes in rural and suburban areas, to large centralized systems serving municipalities in densely populated urban areas. In the past, the decentralized or onsite systems were viewed by some as a means of providing temporary service until city sewers and a centralized treatment plant became available to provide permanent service. Early versions of onsite wastewater systems (e.g., pit privy, cesspool) were often designed with simple and short-term goals of waste disposal to prevent direct human contact and to achieve basic public health and environmental protection.

In the early 1900's, some system designs evolved to include raw wastewater pretreatment in a tank-based unit (e.g., septic tank) followed by disposal through a soil drainfield, and extension bulletins and guidance materials began to appear. As modern appliances became more commonplace, high water-use plumbing fixtures resulted in increased wastewater flows and a need for more careful siting and design of onsite wastewater soil absorption systems. For many designers and regulatory officials, the systems were still often viewed temporary with relatively simple waste disposal goals. During the 1990's the rapid movement toward centralization of wastewater treatment faded for a number of reasons, including the end of construction grants funding for treatment plants and a realization that large centralized solutions were not appropriate for all situations. Continuing to evolve, classic and alternative WSAS have been increasingly viewed as *treatment systems* and they have been designed and implemented to achieve purification as well as disposal, and even considered for beneficial reuse. Recently, increasing concerns over ground water quality and the effects of hazardous chemicals and waste pollutants have elevated the attention given to proper design and performance of WSAS. Today, nearly 25% of the U.S. population is served by onsite and decentralized wastewater systems and approximately one-third of new development is supported by such systems (USEPA, 1997). This amounts to roughly 25 million existing systems with 0.2 million new systems being installed each year. These onsite systems are now viewed as a necessary and permanent component of sustainable wastewater infrastructure in the U.S. and abroad.

The most common WSAS includes intermittent delivery (by gravity or pressurized dosing) of primary treated wastewater into the subsurface with infiltration and percolation through the vadose zone and into the underlying ground water (Fig. 1). Successful application of WSAS is based on engineering design that is compatible with the environmental conditions as determined through a site evaluation (Fig. 1). In properly implemented WSAS, advanced treatment is expected and can be achieved for many wastewater constituents of concern (COC's) through removal (e.g., filtration of suspended solids or sorption of phosphorus), transformation (e.g., nitrification of ammonium or biodegradation or organic matter), and destruction processes (e.g., die-off of bacteria or inactivation of virus) (Fig. 2). For the purposes of this discussion, the boundaries of the *WSAS treatment system* include the inlet to the soil absorption unit through the lower limit of the underlying vadose zone (see Figs. 1 and 2). In these WSAS, the conditions imposed by the WSAS process design (e.g., applied effluent quality and hydraulic loading rate) in a given environmental setting (e.g., soil type, moisture and temperature) must be such that key treatment processes occur at a rate and to an extent such that advanced treatment is reliably achieved before ground water recharge occurs (see Fig. 1). This is critical since the percolate released from most WSAS enters the underlying ground water, which can migrate under natural gradients toward points of exposure for receptors of concern (e.g., humans and drinking water supplies). Depending on local and regional conditions, ground water transport/fate processes may or may not reduce percolate COC concentrations, which would be of concern if exposure occurred at the point of percolate entry to the ground water, to lower levels that are not of concern at a remote point of exposure (Fig. 3).

In contrast to the modern WSAS simply illustrated in Figure 1, the large population of onsite systems in the U.S. today is extremely heterogeneous, including an array of old and new system designs, located in varied site conditions with different environmental sensitivities, and used to treat wastewaters from residential, commercial, and institutional sources (Table 1). Moreover, this population of systems includes those that are properly designed, installed and operated as well as those that are poorly designed, incorrectly sited, and/or improperly operated and maintained. Thus, characterization of performance capability and reliability for modern WSAS (e.g., Fig. 1) that are properly implemented in a given application must not be skewed based on the performance observed for older systems (e.g., disposal-based designs) and/or inappropriate applications (e.g., poorly sited systems).

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