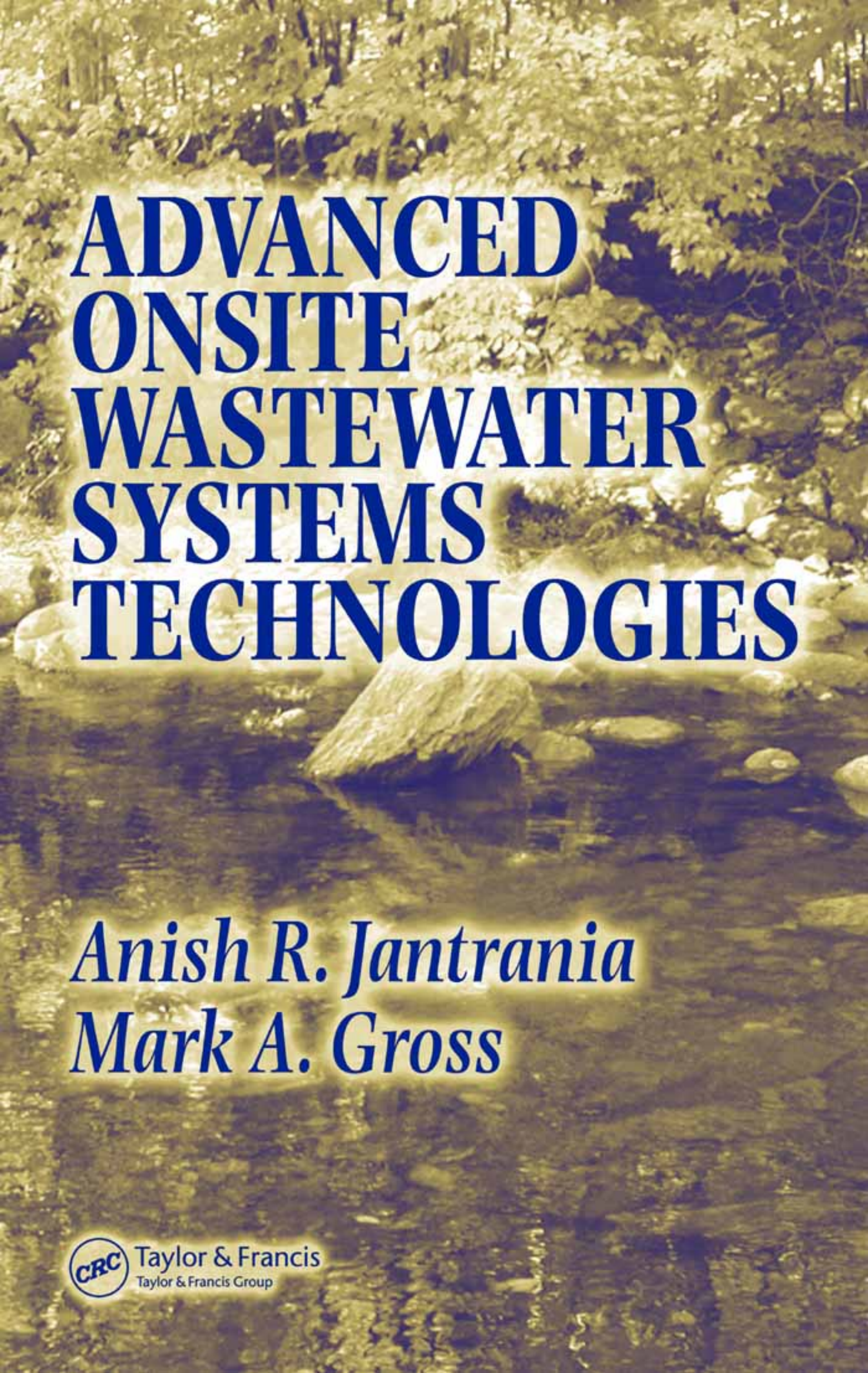

ADVANCED ONSITE WASTEWATER SYSTEMS TECHNOLOGIES

Anish R. Jantrania

Mark A. Gross

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Foreword

Issues associated with management of human waste have plagued societies throughout history. Ancient texts refer to a variety of methods to mange human waste and in the generations since societies began to develop we have developed a better understanding of the public health, environmental quality and economic impacts of waste management programs and processes. As communities developed into cities, the need to treat and manage waste became critical and when water carrying plumbing developed, the need to find effective solutions to the issues associated with waste management was amplified tremendously.

Professions developed to address these issues. Here in the United States, the Public Health Service evolved to address issues of waste management. With passage of the Clean Water Act in the late 1960's, environmental health practice and wastewater engineering practice diverged. Since the Clean Water Act, tremendous federal resource has been allocated for proliferation of the large collection and treatment systems and there has been a perception that the onsite and decentralized efforts have waned.

In truth, much of the support for the onsite and decentralized effort has come from state and local government. The research and technology development associated with the onsite and decentralized system demonstrates that these are viable options for all areas of the country. Applications of these appropriate technologies and associated management programs are evident in urban, sub-urban, and rural areas. The USEPA and state agencies recognize the value of appropriate wastewater solutions.

This text addresses planning, design operations and maintenance issues associated with those technologies required as part of a comprehensive pre-application treatment. It discusses the variety of dispersal options available to distribute treated or reclaimed water into receiving environments and describes the opportunities available for recycling and reuse. Finally, this text discusses the importance of a comprehensive planning and management approach to dealing with wastewater management issues.

Drs. Anish Jantrania and Mark Gross have many years of valuable experience and they have synthesized and assembled that experience to provide this tremendously valuable reference for all environmental health and wastewater engineering practitioners. This text provides a well developed and comprehensive assessment of technology and management solutions available to address a variety of waste management challenges. This text is an indispensable reference for all professionals involved in the planning, design, installation, operation, maintenance and management of wastewater systems.

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Preface

Onsite treatment of wastewater and onsite dispersal of treated wastewater is not a new concept. Throughout the history of civilization in this country and other places in the world, onsite wastewater systems have been and will be an integral part of the overall wastewater management infrastructure. Onsite wastewater systems are here to stay and the U.S. Environmental Protection Agency (EPA) views adequately managed onsite systems as a cost-effective and long-term option for meeting public health and water quality goals, particularly in less densely populated areas. For one out of every four homes in the U.S. wastewater is treated onsite, typically using a septic tank and a drain field system. A septic system was, and with some modifications still is, the most common method for onsite wastewater treatment. However, just like any other field, significant advances have been achieved in onsite wastewater treatment and effluent dispersal technologies. A septic tank is now viewed only as a level one treatment system, while a variety of technologies such as packed bed media filters and flow-through or sequencing batch reactor treatment system are now considered as level two, three, or even level four treatment systems. These advanced systems can treat wastewater onsite from a single home or a cluster of homes, to effluent standards similar to those achieved by large centralized treatment plants. Highly treated wastewater can now be dispersed onsite using a conventional drain field or any one of the advanced technologies such as drip, spray, filter bed, evapo-transpiration bed, and greenhouse system, on land that is typically rejected for use of septic systems, i.e., on land that doesn't *perc*.

This book has three goals: introducing readers to advanced onsite wastewater systems technologies, suggesting regulatory and management frameworks for effective use of such technologies, and proposing vocabulary to better understand the benefits of such technologies. The advanced systems can meet demands for onsite wastewater management on two main fronts—new growth that is occurring in areas not served by centralized collection and treatment plants (sewer systems), and existing homes and businesses with failing or inadequate septic systems. The advanced systems' operations can be managed using monitoring devices that send signals to a central location, allowing a trained operator to ensure treatment performance of multiple systems by offering scheduled and emergency services. Centralized management of onsite systems is now a reality and a necessity for all onsite systems. The five management models proposed by the U.S. Environmental Protection Agency (EPA) offer a good framework for initiating a global movement to bring all onsite wastewater systems into some form of recognizable management program so that their impact on public health and water quality can be measured and improved. Advanced onsite wastewater systems put more emphasis on treatment before discharge compared to conventional septic systems, thus requiring a higher degree of operational monitoring and ensuring measurable performance on a long-term basis. The onsite stakeholders are home and business owners, land developers, builders, planners, regulators, educators, trainers, consultants, designers, engineers, manufacturers, and service providers. They are intimately familiar with the use of septic systems and soil and site issues related to the *perc* test. To them, this book offers a new vocabulary of terms such as pollution scale, treatment scale, wastewater treatability, treatment levels, overall treatment levels, treatment before and after discharge, soil and site credits, performance standards, and performance matrix. The new vocabulary will improve communication among the onsite stakeholders for discussing advanced onsite wastewater systems technologies.

Advanced onsite systems should be viewed not just as an alternative to septic systems or centralized systems, but as an integral part of any wastewater infrastructure. Information in this book will complement the educational and training efforts undertaken by national organizations such as NOWRA, NEHA, NAWT, NSF, ASAE, WEF, NSFC, and regional/state associations, representing interests of onsite stakeholders. Improved knowledge and understanding of this subject matter will allow millions of home and business owners to have better access to the advanced onsite wastewater systems to meet their current and future wastewater needs. Education and training of wastewater professionals must parallel regulatory reform in order to adequately justify the newly developed professionalism and responsibilities undertaken by the certified and licensed professionals. Regulatory programs that were designed and developed for using conventional septic systems are no longer valid as the technology, management, and overall understanding of advanced onsite systems develop. Thus, there is a need for thorough evaluation and restructuring of state and local regulatory programs for onsite systems. This book offers suggestions on management and regulatory frameworks necessary for allowing the new generation of professionals to offer their services using advanced onsite wastewater systems that are currently available in the market.

Onsite systems must not be used as the tool for controlling growth in areas that are not served by centralized collection and treatment systems. Advanced onsite wastewater systems, just like technologies such as satellite television or wireless phone, neither require centralized networks of hardware nor special type of soil or site conditions for adequate onsite wastewater treatment and effluent dispersal. With the right regulatory attitude towards public health and water quality protection goals, and with the right attitude from the products and service providers, it is now possible for adequately trained and appropriately licensed onsite wastewater professionals to offer onsite wastewater services to home and business owners on a permanent basis.

We would like to thank our friends, colleagues, and mentors in the wastewater technologies field who have contributed to moving away from status quo. We are thankful to our editor and publisher for the help and support they have provided. We would like to express our heartfelt gratitude to our families for their patience, encouragement, love, and support during the entire process of getting this book ready for publication.

Views expressed in this book are our own and they do not reflect views of our past, current, and future employers.

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Dedication

We dedicate this book to our family members, friends, and peers who constantly provided much needed support and the push for starting this project and getting it to completion.

About the Authors

Anish R. Jantrania

Anish R. Jantrania is a Technical Services Engineer at the Virginia Department of Health in the Onsite Sewage and Water Program. Prior to joining the state health department in 1996, he worked for two years as an Engineering Consultant for the city of Gloucester, Massachusetts on the first national onsite demonstration projects funded by the U.S. EPA. Before that he worked as a Technical Program Coordinator at the National Small Flows Clearinghouse for four years. He received his B.E. in Agricultural Engineering from the College of Technology and Agricultural Engineering, Udaipur, India in 1982, M.S. in Agricultural Engineering from the Ohio State University in 1985 and Ph.D. in Agricultural Engineering with specialization in Environmental Systems Engineering from Clemson University in 1989. He has also received M.B.A. from West Virginia University in 1994 and is a registered professional engineer in Virginia, Massachusetts, and West Virginia. He has served on the board of directors for the National Onsite Wastewater Recycling Association (NOWRA) and has served on the technical review committee for revising the U.S. EPA Onsite Design Manual and is currently serving on the NOWRA Model Performance Code primary committee and evaluation committee.

Mark A. Gross

Mark Gross is a professor of Civil Engineering at the University of Arkansas in Fayetteville, Arkansas. He has a B.S. in Civil Engineering, M.S. in Civil Engineering, and a Ph.D. in Engineering. Dr. Gross has 20 years of experience in the decentralized wastewater field both as a teacher and as a designer. He has authored or co-authored over 75 articles in the field. His research is in the area of decentralized wastewater, currently working on phosphorus removal in soil-based systems. He maintains an active consulting practice in addition to his university duties, and is a registered professional engineer in Arkansas, Tennessee, Mississippi, Missouri, and Virginia.

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chapter one

Onsite wastewater management: an overview

Introduction

As the wastewater industry advances in the 21st century, the tools and processes used for onsite wastewater management must be evaluated. Such an evaluation should include onsite wastewater treatment and treated wastewater dispersal or reuse technologies, regulatory frameworks, operation and maintenance (management) frameworks, and community planning processes. This book presents information on advanced onsite wastewater technologies and offers a framework on how to use these technologies to solve existing onsite wastewater problems, such as failing or inadequate septic systems, and to meet future demands for wastewater treatment in areas that are not served by centralized collection and treatment systems. It also introduces concepts specific to regulatory and management framework that are necessary to further advance the efficient use of onsite systems. As the populations grow in areas not served by centralized wastewater systems, the demand for managing wastewater onsite in an environmentally sound and cost-effective manner also will grow. This book is designed to fill the information gap that currently exists among different stakeholders, such as customers, product and service providers, and regulators of the onsite wastewater industry.

The concept of wastewater management started on a small scale, focusing mainly on disposal of human waste using systems such as privies. During the early part of the twentieth century, the focus shifted to treatment of wastewater prior to disposal using large-scale, centralized collection and treatment systems in densely populated areas, and millions of septic systems in rural, typically less populated areas. Onsite wastewater management primarily focuses on adequate treatment of wastewater and dispersal of treated waste water (effluent) at or near the place of generation. Toward the end of the 20th century, numerous advanced onsite wastewater systems technologies were developed and the technological advancements are expected to continue in this century. With proper management, advanced onsite systems technologies are reliable and permanent alternatives to traditional septic systems and centralized collection and treatment systems.

The 1990 census data indicate that septic tank treatment and drain field effluent dispersal systems serve approximately 25% of the household units in the U.S. (the 2000 census did not collect this information). The number of household units that are not served by centralized collection and wastewater treatment systems has actually increased from about 19.5 million, indicated in the 1970 census data, to 25.8 million, indicated in the 1990 census data, an increase of about 6.3 million household units over the period of 20 years.

Table 1.1 contains the 1990 census data for the numbers of homes served by onsite systems and those served by centralized systems for each state in the union. Most, if not all, of these existing onsite systems are managed by their owners, who typically implement minimum or no maintenance of their systems and replace the systems when they fail. The U.S. Environmental Protection Agency (EPA) reported to Congress that approximately 37% of new development of residential and/or commercial dwellings occur in areas that are not served by centralized collection and treatment systems. At this rate of increase, the Electric Power Research Institute (EPRI) projects that there will be 8.9 million new onsite systems in the U.S. by the year 2015. Their distribution by state is shown in Figure 1.1.

In *Response to Congress On Use of Decentralized Wastewater Treatment Systems* (EPA, 1997), the U.S. EPA states that adequately managed decentralized wastewater systems are a cost-effective and long-term option for meeting public health and water quality goals, particularly in less densely populated areas. The wastewater industry will continue to move toward widespread use of advanced onsite wastewater systems with management (also called *managed decentralized systems*) in this century and in the future.

Our goals for writing this book are twofold. First, we hope to familiarize readers with the currently available advanced onsite wastewater systems technologies. Second, we hope to develop a standard vocabulary for professionals who work with these technologies as well as for the customers who depend on these technologies. This book, along with the supporting web site *www.advancedonsitesystems.com,* is designed to act as an information catalog for advanced onsite wastewater technologies and offer communication tools that will allow onsite wastewater professionals to communicate with each other and with their clients in an effective manner so as to minimize confusion and misunderstanding related to the use of advanced onsite systems on a permanent basis with management.

To the professionals offering such services as site evaluation, system selection, sizing, and design, installation, and system operation, this book serves as a resource of the technologies that they can use in their tool boxes, provides an objective method to assess the performance of such technologies, presents examples of real-world applications of advanced onsite systems technologies, and presents details on a management framework under which they can offer wastewater services using advanced onsite technologies in a

Table 1.1 1990 Census Data on Wastewater Management Methods

	Public Sewer	Septic Tank or cesspool	Other Means	TOTAL
	76,455,211	**24,670,877**	**1,137,590**	**102,263,678**
Alabama	910,782	728,690	30,907	1,670,379
Alaska	144,905	59,886	27,817	232,608
Arizona	1,348,836	282,897	27,697	1,659,430
Arkansas	601,188	382,467	17,012	1,000,667
California	10,022,843	1,092,174	67,865	11,182,882
Colorado	1,283,186	183,817	10,346	1,477,349
Connecticut	935,541	378,382	6,927	1,320,850
Delaware	212,793	74,541	2,585	289,919
District of Columbia	276,481	575	1,433	278,489
Florida	4,499,793	1,559,113	41,356	6,100,262
Georgia	1,638,979	970,686	28,753	2,638,418
Hawaii	312,812	72,940	4,058	389,810
Idaho	264,618	142,879	5,830	413,327
Illinois	3,885,689	598,125	22,461	4,506,275
Indiana	1,525,810	703,032	17,204	2,246,046
Iowa	869,056	264,889	9,724	1,143,669
Kansas	847,767	187,398	8,947	1,044,112
Kentucky	849,491	600,182	57,172	1,506,845
Louisiana	1,246,678	442,758	26,805	1,716,241
Maine	266,344	301,373	19,328	587,045
Maryland	1,533,799	342,523	15,595	1,891,917
Massachusetts	1,803,176	659,120	10,415	2,472,711
Michigan	2,724,408	1,090,481	33,037	3,847,926
Minnesota	1,356,520	467,936	23,989	1,848,445
Mississippi	585,185	387,406	37,832	1,010,423
Missouri	1,617,996	532,844	48,289	2,199,129
Montana	218,372	135,371	7,412	361,155
Nebraska	534,692	117,460	8,469	660,621
Nevada	456,107	60,508	2,243	518,858
New Hampshire	250,060	246,692	7,152	503,904
New Jersey	2,703,489	357,890	13,931	3,075,310
New Mexico	452,934	161,068	18,056	632,058
New York	5,716,917	1,460,873	49,101	7,226,891
North Carolina	1,403,033	1,365,632	49,528	2,818,193
North Dakota	204,328	66,479	5,533	276,340
Ohio	3,392,785	940,943	38,217	4,371,945
Oklahoma	1,028,594	367,197	10,708	1,406,499
Oregon	835,545	349,122	8,900	1,193,567
Pennsylvania	3,670,338	1,210,054	57,748	4,938,140
Rhode Island	293,901	118,410	2,261	414,572
South Carolina	825,754	578,129	20,272	1,424,155
South Dakota	207,996	78,435	6,005	292,436
Tennessee	1,213,934	781,616	30,517	2,026,067
Texas	5,690,550	1,266,713	51,736	7,008,999
Utah	528,864	65,403	4,121	598,388
Vermont	115,201	149,125	6,888	271,214
Virginia	1,740,787	707,409	48,138	2,496,334
Washington	1,387,396	630,646	14,336	2,032,378
West Virginia	427,930	318,697	34,668	781,295
Wisconsin	1,440,024	580,836	34,914	2,055,774
Wyoming	151,004	49,055	3,352	203,411

Source: Onsite Wastewater Treatment Systems Manual, U.S. EPA February 2002 (EPA/625/R-00/008).

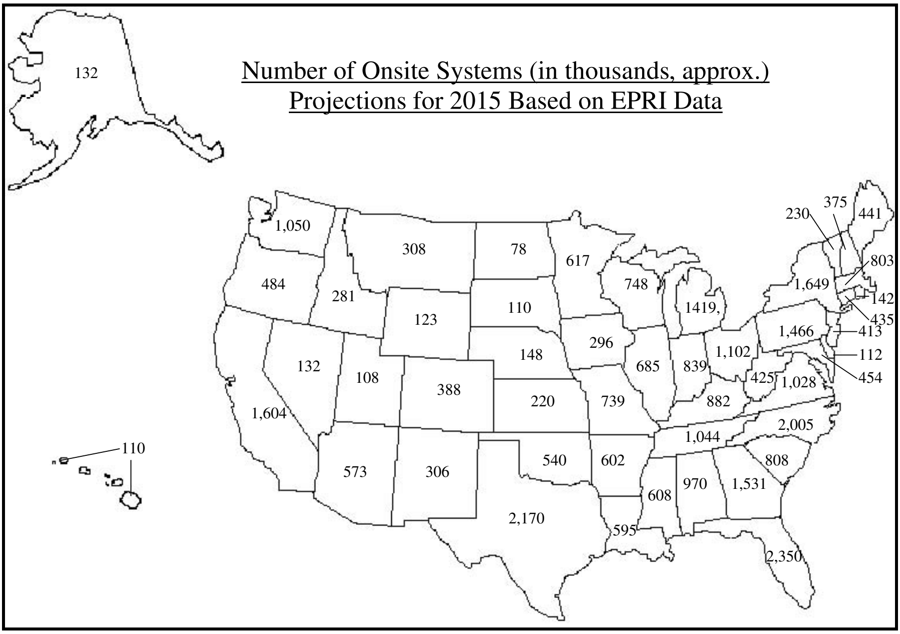

Figure 1.1 Number of onsite systems (in thousands, approx) projections for 2015 based on EPRI data.

way similar to the services offered by centralized collection and treatment systems. To the regulators, this book presents details on a solution-driven and performance-based regulatory framework that is necessary to regulate use of advanced onsite systems as a true alternative to centralized collection and treatment plants. To the community planners, this book offers guidance on how to plan for future growth with such systems. Finally, to the developers, builders, and property owners, this book gives answers to the age-old question, "What do you do when the land does not perc and the sewer is not coming?"

This book is organized as follows. The remainder of this chapter is devoted to an overview of advanced onsite systems technologies and how they compare to conventional onsite systems as well as centralized wastewater systems. Chapter 2 presents the concepts of decentralized wastewater solutions and covers topics related to wastewater characteristics, wastewater treatment basics, overall treatment levels (OTLs) for advanced onsite systems, and locations in which advanced onsite systems can be used for managing wastewater. Chapters 3 and 4 present information on various advanced onsite wastewater treatment technologies that are currently available for addressing onsite wastewater treatment needs. Chapter 5 presents information on advanced onsite effluent dispersal technologies for dispersing high-quality effluent on sites that are typically considered unsuitable for use of onsite systems. Chapters 6, 7, and 8 present information on the management, regulatory, and planning framework necessary to adopt use of advanced onsite systems technologies as alternatives to conventional septic systems and centralized collection and treatment plants. Chapter 9 presents our views on the future of advanced onsite systems technologies.

Septic systems versus advanced onsite systems versus centralized treatment

There are many technical and nontechnical differences between onsite septic systems and advanced onsite systems. One of the most important differences is the level of dependence on soil and site conditions for the application of onsite systems. As explained further in Chapter 2, this difference is mainly because the level of wastewater treatment before discharge is typically less than 20% to no more than 45% when septic tanks are used for treatment, whereas the level of wastewater treatment before discharge is typically greater than 70% when advanced onsite treatment systems are used for treatment. Higher treatment before discharge means less need for treatment after discharge, and thus advanced onsite systems are less dependent upon soil and site conditions. Complete recycling of wastewater to drinking water standards with onsite treatment is feasible.

Although many decentralized wastewater systems include dispersing effluent into soil or reusing effluent for irrigation, soil does not necessarily have to be the final medium or route for returning treated water to the hydrologic cycle. Certainly, small wastewater system technologies are just as capable of (and in some cases, more efficient at) producing exceptional quality effluent as large municipal wastewater treatment systems. Many of the small wastewater treatment systems can easily and consistently produce effluent with a total suspended solids concentration of less than 5 mg/L, 5-day biochemical oxygen demand of less than 5 mg/L, total nitrogen level of less than 10 mg/L and, with a simple, small ultraviolet disinfection unit, fecal coliform titers (or *Escherichia* coli titers) less than 200 MPN/100 ml. In addition, chemical phosphorus removal can obtain phosphorus removal levels that exceed most municipal treatment system levels. Research and development has documented, and field testing is currently underway to produce, media systems that will adsorb phosphorus by passing treated effluent through an iron-coated or iron-rich medium prior to discharge. When this medium is saturated, it is replaced. In addition, membrane bioreactors (MBRs) are available for small-scale wastewater treatment. As with large-scale municipal treatment systems, MBRs in small-scale systems show much promise for producing effluent quality that is certainly acceptable for dispersal into essentially any receiving environment. With this capability, the receiving medium need not be limited to soil. Certainly, if land area is not available, surface discharge under a National Pollutant Discharge Elimination System permit is an acceptable option.

Discussion of onsite systems commonly focuses on soil as a receiving environment, particularly because of soil's ability to accept and renovate partially treated effluent. While soil's ability to accept and renovate septic tank effluent has been the limiting factor for onsite wastewater treatment systems, advanced onsite treatment systems can overcome this limitation. Traditionally, conventional onsite systems rely on the septic tank as the only means of treatment prior to releasing effluent into the environment. This effluent could find its way into the hydrologic cycle (ground water, surface water, or atmospheric moisture) through any path having the lowest resistance (highest hydraulic conductivity), causing potential environmental degradation. Adequate renovation of septic tank effluent requires a uniform and deep soil stratum that is well drained and well aerated. If the soil has incongruities and inconsistencies, a mixture of large and small pores, and if the soil is a home for organisms ranging from the size of a nematode to an earthworm or from a mole to a groundhog (which almost all natural soil does), then natural flow channels are present that can provide preferential pathways for the septic tank effluent to flow through with little or no treatment prior to reaching ground water or surface water. Site conditions that provide preferential pathways for water movement or sites with non-uniform, shallow, not well drained, and not well aerated soil conditions can be used for dispersal of effluent from advanced onsite wastewater treatment systems.

Managed advanced onsite treatment

The U.S. EPA has proposed five models for management of all types of onsite wastewater systems. Although conventional septic system technologies are used without any formal management infrastructure, the use of advanced onsite wastewater systems technologies might only occur with the formation of a formal management infrastructure. That management infrastructure may be based upon the EPA management models 1, 2, 3, 4, or 5. Thus, a tremendous opportunity exists for managed onsite systems to be a significant part of the overall wastewater infrastructure in all communities and serve the wastewater needs of millions of customers on a permanent basis.

With recent advances in small-scale collection, treatment, and dispersal or reuse technology, as well as in remote monitoring systems, it is now possible to offer higher levels of wastewater treatment in low-density areas at a cost no more than that of traditional pipe-and-plant centralized collection and treatment systems. Today, most of the dwellings in these low-density areas are served by unmanaged onsite septic systems, which may be failing now or which will fail in the near future. Replacing the failing septic systems with managed onsite treatment systems can save communities significant amounts of money and avoid "sewer battles" within communities.

Generally, in small communities, houses are spread out and density is quite low, which makes the use of an onsite system for an individual home or a group of homes in a cluster quite a cost-effective option. Wastewater management systems for thinly populated areas can be engineered to min-

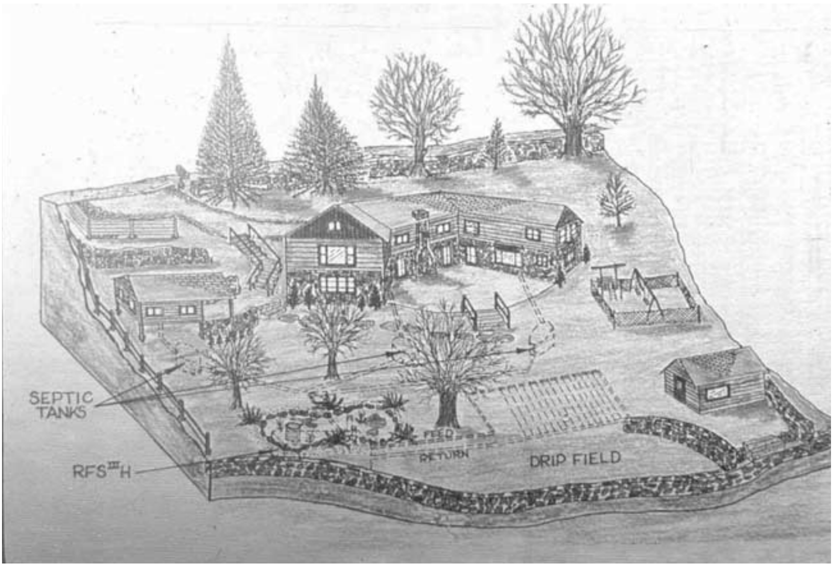

Figure 1.2 Architectural concept drawing of advanced onsite wastewater system technology (RFSIII and Drip) for a single family built on a lake front property. (Courtesy of ASHCO-A-Corporation, Morgantown, WV)

imize the collection cost, typically to less than one-third of the total project cost, by using currently available advanced onsite or decentralized wastewater treatment and land-based effluent dispersal technologies.

An architectural concept drawing of an advanced onsite wastewater treatment (RFS-^{III}H) and effluent dispersal system (drip field) is presented in Figure 1.2. With the right type of management infrastructure available, systems such as this and many others can offer wastewater solutions for existing and new homes and businesses. Examples of advanced onsite treatment systems currently in use for single-family homes are shown in Photo 1.1 and Photo 1.2.

Wastewater treatment levels and receiving environment

Two important considerations for selecting any wastewater system (onsite or offsite) are the level of treatment before discharge and the receiving environment to which the treated wastewater (effluent) will be returned to the hydrologic cycle. In this book, five treatment levels for onsite wastewater treatment (OTLs 1 to 5) are defined. Chapter 2 details these wastewater treatment levels and proposes standards for reductions in wastewater constituents at the defined levels.

Receiving environments for treated wastewater fall into three basic categories: surface water (creeks, rivers, lakes, etc.), land (area that is not categorized as water), and atmosphere. Although centralized collection and wastewater treatment plants typically use surface water as the receiving

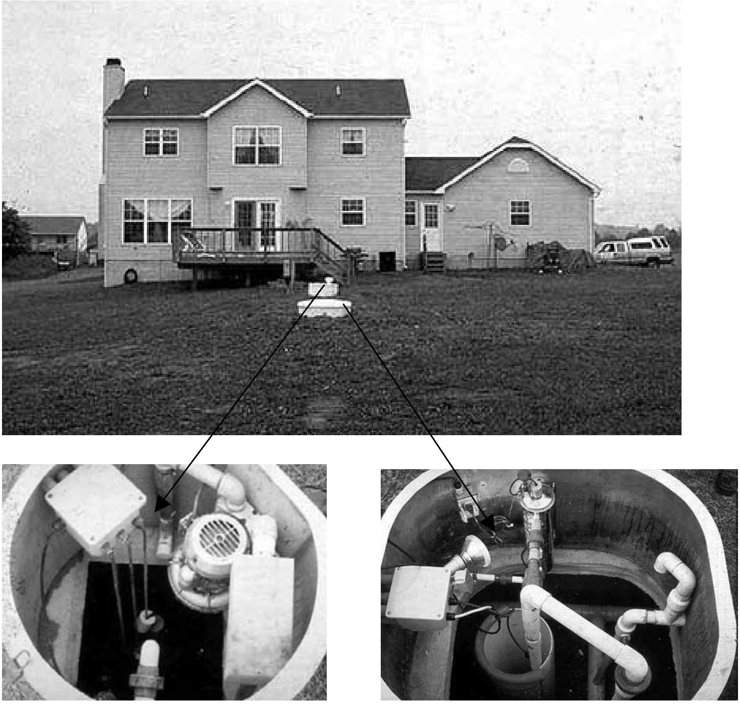

Photo 1.1 A pre-engineered and prepackaged aerobic treatment unit, recirculating gravel filter, and ultraviolet disinfection unit are installed in the backyard of this house. Both the aeration chamber and the ultraviolet disinfection unit (bottom photos) are accessible above ground.

environment, onsite wastewater systems typically use land, atmosphere, or both. Effluent from an advanced onsite treatment system can be dispersed into or on top of any land area as long as the necessary amount of area for adequate assimilation is available. Typically, one should not expect a net increase in surface runoff from the area on or under which an effluent dispersal system is operated.

Land area in the U.S. is plentiful, as shown in Table 1.2. The chances of finding a discharge point for an onsite system into surface water are far less than the chances of finding land area for dispersal of treated wastewater. This is one of the main reasons why managed advanced onsite wastewater treatment is becoming the preferred way for dealing with wastewater. The discharge of effluent directly into the atmosphere requires transformation of the effluent into humidity, which adds cost. However, the dispersal of effluent on or in land mainly requires system designers to identify limitations of the land areas and to design onsite wastewater treatment systems to treatment levels that allow dispersal of the effluent on or in the available land. Characterization of the land area to determine the required treatment level prior to discharge is one very important task that an onsite wastewater

Photo 1.2 This pre-engineered and prepackaged single pass media filtration system has an onsite wastewater treatment and effluent dispersal system installed in the front yard of the house. Note the landscaping that maintains the aesthetics of the front yard and allows for operation of the wastewater system.

system designer must undertake. When an advanced onsite treatment system is used instead of a conventional septic tank treatment system, soil and site characterization involves more than just conducting a percolation (“perc”) test. Every square-foot of land area available on a property may now be “suitable” for onsite dispersal of effluent as long as the wastewater is treated to the level necessary for the receiving environment and the onsite treatment systems are professionally managed.

Septic systems cannot do it alone

For most of the 20th century, the standard septic tank drain field system has been the primary means of onsite wastewater management. A standard water-tight septic tank system (Figure 1.3) is designed to treat wastewater to OTL 1. The first advancement in onsite treatment technology likely involved the use of a pump to overcome gravity when a "suitable" drain field site was at a higher elevation than the house.

A conventional septic system uses soil to treat primary or raw wastewater that is discharged from a septic tank. Typically, less than 45% treatment of raw wastewater can be expected from a septic tank, thus achieving OTL 1 before discharge. Thus, the subsurface drain field and soil around the drain field have to provide the rest of the treatment (typically more than 55%) before the final effluent gets mixed with groundwater or surface water (Figure 1.4). Because it is hard to collect effluent below a subsurface drain field, no one really knows what kind of treatment is actually achieved by a subsurface drain field on a long-term basis. Therefore, it is not feasible to

Table 1.2 Land Area versus Water Area

Geographic area	Population	Housing units	Area in square miles		
			Total area	Water area	Land Area
United States	281,421,906	115,904,641	3,794,083.06	256,644.62	3,537,438.44
Alabama	4,447,100	1,963,711	52,419.02	1,675.01	50,744.00
Alaska	626,932	260,978	663,267.26	91,316.00	571,951.26
Arizona	5,130,632	2,189,189	113,998.30	363.73	113,634.57
Arkansas	2,673,400	1,173,043	53,178.62	1,110.45	52,068.17
California	33,871,648	12,214,549	163,695.57	7,736.23	155,959.34
Colorado	4,301,261	1,808,037	104,093.57	376.04	103,717.53
Connecticut	3,405,565	1,385,975	5,543.33	698.53	4,844.80
Delaware	783,600	343,072	2,489.27	535.71	1,953.56
District of Columbia	572,059	274,845	68.34	6.94	61.40
Florida	15,982,378	7,302,947	65,754.59	11,827.77	53,926.82
Georgia	8,186,453	3,281,737	59,424.77	1,518.63	57,906.14
Hawaii	1,211,537	460,542	10,930.98	4,508.36	6,422.62
Idaho	1,293,953	527,824	83,570.08	822.87	82,747.21
Illinois	12,419,293	4,885,615	57,914.38	2,330.79	55,583.58
Indiana	6,080,485	2,532,319	36,417.73	550.83	35,866.90
Iowa	2,926,324	1,232,511	56,271.55	402.20	55,869.36
Kansas	2,688,418	1,131,200	82,276.84	461.96	81,814.88
Kentucky	4,041,769	1,750,927	40,409.02	680.85	39,728.18
Louisiana	4,468,976	1,847,181	51,839.70	8,277.85	43,561.85
Maine	1,274,923	651,901	35,384.65	4,523.10	30,861.55
Maryland	5,296,486	2,145,283	12,406.68	2,632.86	9,773.82
Massachusetts	6,349,097	2,621,989	10,554.57	2,714.55	7,840.02
Michigan	9,938,444	4,234,279	96,716.11	39,912.28	56,803.82
Minnesota	4,919,479	2,065,946	86,938.87	7,328.79	79,610.08
Mississippi	2,844,658	1,161,953	48,430.19	1,523.24	46,906.96
Missouri	5,595,211	2,442,017	69,704.31	818.39	68,885.93
Montana	902,195	412,633	147,042.40	1,489.96	145,552.43
Nebraska	1,711,263	722,668	77,353.73	481.31	76,872.41
Nevada	1,998,257	827,457	110,560.71	734.71	109,825.99
New Hampshire	1,235,786	547,024	9,349.94	381.84	8,968.10
New Jersey	8,414,350	3,310,275	8,721.30	1,303.96	7,417.34
New Mexico	1,819,046	780,579	121,589.48	233.96	121,355.53
New York	18,976,457	7,679,307	54,556.00	7,342.22	47,213.79
North Carolina	8,049,313	3,523,944	53,818.51	5,107.63	48,710.88
North Dakota	642,200	289,677	70,699.79	1,723.86	68,975.93
Ohio	11,353,140	4,783,051	44,824.90	3,876.53	40,948.38
Oklahoma	3,450,654	1,514,400	69,898.19	1,231.13	68,667.06
Oregon	3,421,399	1,452,709	98,380.64	2,383.85	95,996.79
Pennsylvania	12,281,054	5,249,750	46,055.24	1,238.63	44,816.61
Rhode Island	1,048,319	439,837	1,545.05	500.12	1,044.93
South Carolina	4,012,012	1,753,670	32,020.20	1,910.73	30,109.47
South Dakota	754,844	323,208	77,116.49	1,231.85	75,884.64
Tennessee	5,689,283	2,439,443	42,143.27	926.15	41,217.12
Texas	20,851,820	8,157,575	268,580.82	6,783.70	261,797.12
Utah	2,233,169	768,594	84,898.83	2,755.18	82,143.65
Vermont	608,827	294,382	9,614.26	364.70	9,249.56
Virginia	7,078,515	2,904,192	42,774.20	3,180.13	39,594.07
Washington	5,894,121	2,451,075	71,299.64	4,755.58	66,544.06
West Virginia	1,808,344	844,623	24,229.76	152.03	24,077.73
Wisconsin	5,363,675	2,321,144	65,497.82	11,187.72	54,310.10
Wyoming	493,782	223,854	97,813.56	713.16	97,100.40

Source: U.S. Census Bureau, Census 2000.

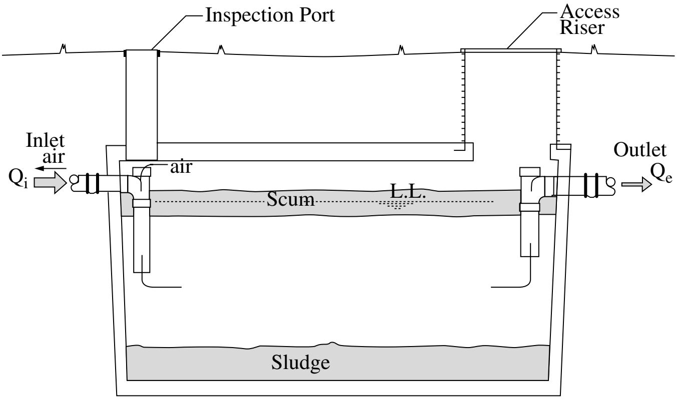

Figure 1.3 A standard water-tight septic tank treatment system.

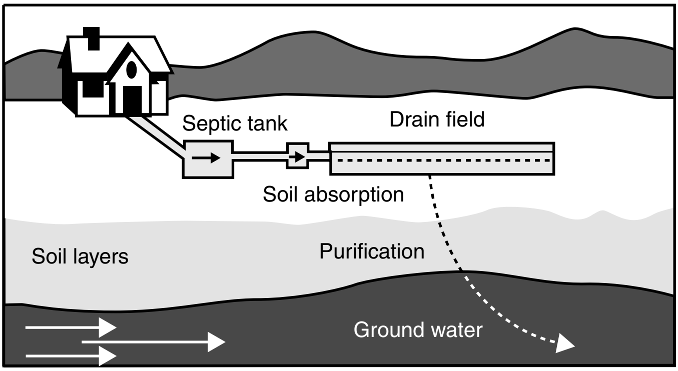

Figure 1.4 A conventional septic tank and drain field system. *Source*: *Onsite Wastewater Treatment Systems Manual*, U.S. EPA February 2002 (EPA625/R-00/008).

adequately monitor the performance of such a system. In addition, soil is not a homogeneous medium, and movement through large macropores, such as inconsistencies in the soil profile, root holes, or biopores (for example, worm channels, crawfish tunnels, or even gopher holes), provides preferential flow paths for untreated or partially treated septic tank effluent to enter the groundwater or surface water. Monitoring wells may or may not provide suitable points for collecting samples of treated water, and the samples collected from such wells may or may not represent the water quality of septic tank effluent moving into the groundwater through large macropores. Thus, unmanaged septic systems are typically viewed as a source of pollution to groundwater and surface water, contributing high levels of microorganisms (mainly fecal coliform) and nitrate contaminants.

Research studies have documented how individual drain fields work at given points in time on particular sites; however, the real impact of the operation of millions of drain fields on the environment and public health is not adequately documented. Conservative rules for locating and sizing septic systems, as specified in state and local regulations, are the primary reason why no major widespread environmental quality or public health problems have yet been associated with the use of millions of individual septic systems.

Although onsite systems will continue to be used on a permanent basis and will be needed in areas not suitable for treating primary effluent or raw sewage, we must look for onsite wastewater treatment systems that treat wastewater to a measurable higher treatment level (OTL 2 or higher) and achieve overall reduction in pollution load of greater than 70%. We also need site assimilative systems for safe dispersal of effluent into the receiving environment. Managed onsite treatment and subsurface dispersal systems can be used to meet these requirements in areas that are suitable or not suitable for treating primary effluent, i.e., septic tank effluent.

Onsite treatment to levels greater than septic tanks

The mound system (which has a drain field on top of the ground instead of in the native ground) and the low-pressure pipe system are among the most revolutionary ideas for septic tank drain fields to come out of the middle of the 20th century. It was not until the latter part of the 20th century (during the late 1970s and early 1980s) that technologies to treat wastewater onsite to a significantly higher degree than that of a septic tank were developed and brought into the market place.

As we move forward in the 21st century, the idea of treating wastewater to reduce most of the contaminants before discharging it into soil is drawing a lot of attention. Today, a number of off-the-shelf treatment systems are available to treat wastewater to a degree that allows subsurface dispersal of the effluent on any site in a manner that protects public health and the environment from such a dispersal system as long as land area is present. Chapters 3, 4, and 5 discuss such advanced onsite wastewater treatment and onsite effluent dispersal technologies. The onsite treatment technologies are grouped into two major categories — media filters and aerobic treatment units — and the technologies in each category can be designed and manufactured to treat wastewater to OTLs 2, 3, and 4 before discharge.

We are no longer limited to the availability of "percable" land, land with deep well-drained soil, for the use of onsite wastewater systems. Any site that is suitable for building a house or a business can have an onsite wastewater system, provided the owner is willing to pay for the necessary one-time capital costs associated with site assessment, engineering, and installation as well as ongoing operation and maintenance costs. Granted, if a house or business must be built on stilts due to permanently standing water, dispersal of treated effluent into soil is not practical but dispersal can be achieved directly in the permanently standing water. A wastewater solution for any site is no longer a dream; managed advanced onsite wastewater systems can make this a reality.

Use of soil for the majority of the treatment is not required

Because traditional septic systems depend mainly on soil for more than 55% of the treatment, soil evaluation has been an integral part of the onsite wastewater business. However, with the availability of a variety of treatment systems that can treat wastewater to a level greater than 70% prior to discharge, soil no longer has to do the majority of the treatment, and thus soil evaluation is no longer as critical for advanced onsite wastewater system technologies as it is for traditional septic system technologies.

As presented in Chapter 5, small and shallow trenches; filter beds; drip irrigation; spray irrigation; or minimum or zero discharge systems for dispersal of adequately treated effluent from an advanced treatment system can be installed on almost any site when an adequate amount of land is available. The performance of such dispersal systems is not dependent on soil type, soil depth, or soil color at a particular site, and the necessary hydraulic loading can be achieved by using time- and/or pressure-dosing and installing the dispersal systems at appropriate depths.

In the 21st century, emphasis needs to be on the use of appropriate onsite treatment and dispersal systems and the permanent operation and maintenance of those systems rather than on the acceptance or rejection of a lot for an onsite system based on soil evaluation and soil criteria. According to Richard Otis, Ph.D., P.E., "There are no bad sites, only bad systems selected for the sites." We can now train onsite system designers to select a system appropriate to meet the required performance standards for any given site.

In order to simplify the characterization of soil conditions, soil can now be categorized into four main groups (1, 2, 3, and 4) based on two major criteria: depth to limiting conditions and permeability/drainage. Group 1 represents soils that are deep and well drained, whereas Group 4 represents soils that are shallow and poorly drained. A simple four-quadrant approach for matching onsite wastewater treatment and effluent dispersal technologies (Onsite System Type I to XI) is proposed later in this chapter.

Assimilation: subsurface or surface dispersal of effluent

The most important consideration for subsurface dispersal from an onsite treatment system is the site's ability to assimilate adequately treated effluent (or moisture) in a manner that does not create any aesthetic or public health concerns, such as standing water (ponding) or runoff of effluent (water that has indication of quality not acceptable for human contact) from the site under normal rainfall conditions. Thus, when selecting an appropriate onsite wastewater treatment system and onsite effluent dispersal system, we need to consider such a system as a site-assimilative system (not just a soil absorption system) and we must look at the entire site and its characteristics rather than just the soil characteristics.

An onsite effluent dispersal system must not create any of the following conditions:

- A point-source discharge (i.e., surface runoff out of the effluent dispersal area)
- A public nuisance (e.g., a puddle of water on or around the area where the effluent dispersal system is operating, mainly during dry weather conditions);
- An obvious health hazard; and
- Measurable groundwater or surface water contamination due to organic, inorganic, or bacteriological contaminants that are discharged into the effluent dispersal system.

Responsible management and regulations

Centralized wastewater treatment plants are operated by a utility, public or private, where trained and licensed operators monitor and maintain the plant so that the discharge from the plant meets the necessary performance standards. Basically, homeowners and businesses pay a hook-up fee to connect to a centralized system and then pay regular usage fees, thereby transferring all the responsibility for their wastewater to the utility once the wastewater enters the utility's sewer main. Homeowners and business owners are responsible for maintaining the service line from the house or building to the sewer main. Maintenance contracts and insurance, for even the service lines, are now available in some areas.

Today, most people who use small onsite systems do not have the option of paying a sewer bill and transferring the wastewater and associated responsibilities to a utility. Public acceptance of small onsite systems can be enhanced only when such systems offer the same wastewater services as a centralized system. When onsite systems can offer people operational comfort similar to centralized systems and can offer environmental protection guarantees to the regulators, their use will be considered as equivalent to centralized systems.

We now have the technologies that can achieve both of these requirements in a cost-effective manner. However, we are still in an infancy stage in the development of an infrastructure (similar to a public utility) that can make these technologies available to people. Figure 1.5 shows typical septic system use today and the players and their roles within the onsite industry. This situation needs to change significantly, and it can change by implementing the concept of a responsible management entity (RME) within the onsite industry. Chapter 6 presents more information on the management framework and RME. Figure 1.6 shows the concept of using managed onsite systems and the players and their roles within this new, evolving paradigm.

There are a few RMEs present today that offer wastewater services to people who use small onsite systems; however, most people still have no access to such services. As we advance in this century, we need to seriously consider how to develop a regulatory system that will allow people to get wastewater services from an RME using advanced onsite systems the way they get other services, such as solid waste removal, telephone, cable, gas,

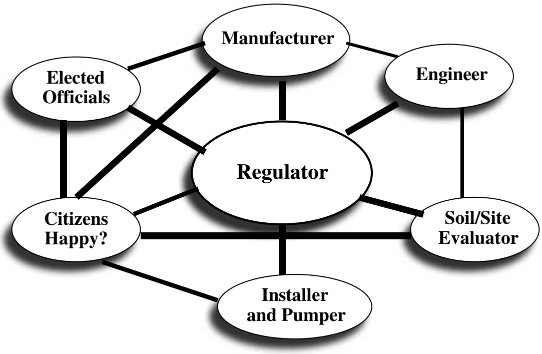

Figure 1.5 Current administrative framework for use of onsite wastewater systems.

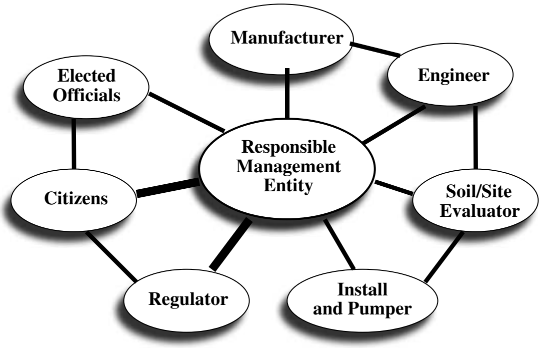

Figure 1.6 Preferred administrative framework for use of advanced onsite wastewater system technologies.

and power. We discuss in Chapter 6 the kinds of services an RME should offer and what role such a company could play within the onsite industry for new installations and replacement of existing septic systems.

When an RME is responsible for permanent operation and maintenance of an onsite system, simple issues such as access to the system's components for maintenance and inspection can be addressed in a timely manner. The current regulatory requirements for soil and site evaluation, engineering design, and multiple reviews should not apply to a licensed RME. A qualified and licensed RME should be permitted to do all the preinstallation work, such as engineering, site and soil evaluation, and selection of a wastewater system, and should be allowed to install and operate onsite systems. Such an RME should be allowed to use the best available technology for wastewater treatment and dispersal and be regulated based on the performance of the systems, both in terms of operational services to the customers and protection of the environment and public health. This model is consistent with services that provide natural gas, water, and electricity. No site survey or individual home site plat, plan review, or permit is required to set a gas, electric, or water meter or to initiate service. Homeowners are quite familiar and quite comfortable with meter readers entering their property to read and to inspect electric, gas, and water meters. Similarly in the RME model proposed here, onsite maintenance personnel would enter properties to inspect and service the wastewater systems. An additional model provides heating and air conditioning for a home. Several manufacturers and models of heating and air systems are available to the consumer, and consumers may choose to purchase long-term service plans with the heating and air provider. Service providers enter the property to inspect and maintain heating and air systems on a regular schedule.

Under the RME model for onsite systems, the role of manufacturers, engineers, soil and site evaluators, and installers can be defined in a manner that would result in the most efficient use of their services. Today, the requirements of soil and site evaluation and engineering quite often do not add any real value to the operation of individual home and small commercial wastewater systems. Most of the current regulations for onsite systems still require a soil and site evaluation to determine if the proposed site is suitable for an onsite system. Such pass/fail criteria for a site are not necessary because it is now possible to have a wastewater system for any site. Once a decision is made for development in an area that is not served by a centralized wastewater system, an onsite system RME can offer all the services necessary for adequate treatment and dispersal of wastewater. The environmental and public health regulators can then make sure that the services provided by the RME offer safe, adequate, and proper protection to the environment and public health from wastewater. Regulatory agencies can do this by making sure that the RME is using the best available technologies for wastewater treatment and dispersal and by monitoring the performance of the onsite systems and their impact on the environment.

The RME can also help the onsite industry to adequately weed out wastewater technologies that are poorly designed or manufactured. At present, no real mechanism measures the long-term performance of small wastewater treatment and dispersal systems. An RME that is responsible for acquiring, installing, and operating a wastewater system in a manner that will meet the necessary performance standards in a cost-effective way will always strive for the best possible technology. Such a company will have an interest in looking at a system's ability to meet performance standards and achieve customer satisfaction. The RME will also consider a system's long-term cost. Only with such a company can the onsite industry really judge the true potential of the various systems currently manufactured.

An RME can also educate people about the environmental impacts of wastewater and about the importance of reuse or recycling of adequately treated wastewater. There is tremendous interest in the use of environmentally friendly systems and the reuse of treated wastewater. One must, however, realize that improperly managed wastewater systems can create environmental and public health problems (as can improperly managed heating and air conditioning systems). Only under a proper management framework can people have access to environmentally friendly advanced wastewater systems. An RME can also help people get the best possible wastewater system at the least possible cost by acquiring products and services in quantity.

Today, most people who apply for an onsite system permit, typically to a health department, get most of the required preinstallation services, such as soil evaluation and design, from a health department employee, a sanitarian, or a private consultant or practitioner. Most health department employees are trained on only one type of onsite system — a septic tank drain field system. When it is determined, however, that the soil and site conditions are not suitable for septic systems, homeowners then must retain services in the private sector of a consultant familiar with alternative systems and are asked to purchase the products and services necessary to install those systems. In some cases, unfamiliarity and low comfort level in the regulatory community with alternatives to the traditional septic system make it difficult to obtain a permit for systems other than traditional septic systems. Thus, the current regulatory system is the main reason why there are so many septic tank drain fields in the country and so few advanced onsite systems that treat wastewater to OTL 2 or better quality before discharge.

The process to establish an RME model in a state must start with changes in legislation. Most importantly, we need legislation that sets a time frame to phase in the use of appropriate onsite systems under the utility model and to phase out the use of unmanaged onsite wastewater systems. Unfortunately, mere legislation will not alleviate the lack of knowledge about and low comfort level with advanced treatment systems among the regulatory community. Specialization within the regulatory community with professionals trained and tasked with specialty wastewater systems will also be required. Currently, most onsite wastewater regulatory programs are under departments of health, with environmental specialists who are the sanitarians whose workload include restaurant inspections, swimming pool inspections, and possibly even vector control in addition to onsite wastewater systems.

Onsite technology is ready for the 21st century

A number of onsite systems are available for managing wastewater from individual homes or small businesses in areas where a centralized wastewater system is not available. In addition, numerous companies offer pre-engineered, prepackaged treatment and dispersal systems for purchase and installation, with a service contract for operation and maintenance. Not all of these services are available or well developed in all parts of the U.S. Most of the public does not have easy access to such products or services, largely due to the state and local regulatory framework that currently exists in most parts of the country.

A regulatory overhaul from the ground up is needed to move the onsite wastewater industry into the 21st century and to raise the overall performance standard of onsite wastewater systems from the traditional septic system to a real treatment and dispersal system that allows for adequate maintenance and monitoring of performance. We discuss needs for changes in the regulatory framework in this chapter, and in Chapter 7, we propose concepts for regulatory programs that would really change the way onsite wastewater systems are used today and that would encourage people to start using advanced onsite systems within the frame-work of the RME model.

Advanced onsite treatment systems

Raw wastewater or septic tank effluent can be treated to treatment OTLs 2, 3, or 4 using a variety of small treatment systems currently available in the market. Such treatment technologies can be grouped into the following categories:

- Aerobic treatment units (ATUs)
    - Suspended growth: flow-through or sequencing batch reactor
    - Attached growth: trickling filter with forced aeration
    - Combination of suspended and attached growth
- Media filters — single pass or recirculating
    - Sand filters
    - Peat filters
    - Foam filters
    - Textile filters
    - Rotating biological contactors
    - Trickling filters
    - Others
- Natural systems for polishing or recycling of secondary effluent
    - Wetlands
    - Greenhouse
    - Others
- Waterless toilets and graywater systems as alternatives to flush toilets
    - Composting toilet
    - Incinerating toilet
    - Chemical toilet
- Disinfection systems for disinfecting secondary or better quality effluent
    - Ultraviolet light
    - Chlorination and dechlorination

ATUs

As described in detail in Chapter 4, ATUs offer an alternative to septic tanks. They treat raw wastewater to OTLs 2 or higher. Some ATUs incorporate a trash tank prior to the aeration tank for primary treatment. Numerous pre-engineered ATUs are currently available. They are generally used for sites that are declared unsuitable for a septic drain field system, based on soil and site evaluations. The National Sanitation Foundation (NSF) is one of the testing and certification facilities to evaluate the performance of small ATUs using the American National Standards Institute/National Sanitation Foundation (ANSI/NSF) Standard 40 for Class I effluent limits. In some states, the effluent from ATUs, after further polishing and disinfection, is sometimes discharged into a surface water body or on top of the ground, resulting in a point-source discharge instead of a nonpoint discharge into an adequately sized subsurface system.

Subsurface dispersal of secondary-quality effluent (OTL 2 and above) is technically possible on sites that are not suitable for primary effluent, such as septic tank effluent. Actually, subsurface dispersal of secondary effluent using such techniques as filter beds or drip/spray irrigation systems can reduce the impact on the receiving environment (RE) as compared to surface discharge. Nutrients including nitrogen and phosphorus can be taken up by plants when secondary effluent is dispersed into the ground at a shallow depth, typically within the top 12″ of soil. Sites that have low-permeability soil, a shallow depth to an impermeable layer or to seasonal groundwater, can be used for subsurface dispersal of effluent from adequately operating ATUs. ATUs must be operated and maintained by trained, qualified professional operators to produce high-quality effluent on a permanent basis. However, when not adequately operated and maintained, any ATU, or any other treatment system for that matter, will discharge inadequately treated effluent into the RE, which can cause problems.

Media filters

Media filters, as described in detail in Chapter 3, are primarily used for treatment of septic tank effluent; however, they are sometimes used for polishing effluent from ATUs. Although sand filters (single pass or recirculating) are the most commonly used media filters, other types of media (such as peat, synthetic foam, or textile) have been successfully evaluated for treating septic tank effluent to a better-than-secondary-quality effluent. As with ATUs, we now have access to pre-engineered, prepackaged media filters that can be easily installed and used for advanced treatment of septic tank effluent. These systems are manufactured to be as near “plug and play” units as possible. Essentially, once installed in an excavation, plumbed, and provided with electricity to the control panel, they are ready for startup. Instead of engineering a media filter or an ATU for small individual applications, it is advisable to obtain such treatment devices from companies that market them and to use engineering resources to develop subsurface dispersal systems that minimize the environmental impact. Effluent from both media filters and ATUs, after adequate disinfection and possibly color or iron and manganese removal, can also be recycled for flushing toilets or other such nonpotable uses, thus reducing the need for subsurface dispersal.

The performance of any media filter depends on the quality of the media, recirculation rate, volume of the recirculation tank, distribution system for spreading effluent on top of the media, and adequate ventilation of the media filter. Use of an effluent filter (screen) in a septic tank and regular maintenance of the tank is also necessary to get adequate performance of a media filter. Depending on the type of media used, one may need to change the media after a certain number of years. Media filters have been demonstrated to be very effective for reducing organic and bacteriological contaminants from septic tank effluent. They can also convert most nitrogen to a nitrate form (nitrification), thus maximizing the potential for plant uptake if the effluent is adequately dispersed into a shallow root zone using a shallow trench, drip or spray dispersal system. There is a potential for achieving a high degree of denitrification when recirculation through the septic tank or processing tank is designed into the system.

Natural systems

Natural systems such as wetlands are being used for treating septic tank effluent from single-family homes or from communities in some parts of the country, mainly in southern states. The performance of wetland systems depends on the design, vegetation in the wetland, climate, and operation of the system. Such systems tend to require a large land area and typically have little or no mechanism to adjust the performance to account for variation in the inflow quality. At the same time, the energy requirement for treatment is much lower than with other options. An adequately engineered wetland system can offer a cost-effective method for removing nutrients and other constituents from primary or secondary effluent.

The use of greenhouse systems, a wetland operated in an enclosed and controlled environment, can lower or eliminate dependence on climatic conditions and can offer a reliable treatment mechanism that can produce high-quality effluent on a consistent basis. Greenhouse systems can also be used for significantly lowering or eliminating discharge of effluent by using plant uptake and evapotranspiration as the primary mechanisms for assimilating effluent into the environment. Most times, natural systems can be used in a cost-effective manner for further treatment of secondary-quality effluent, discharge from ATUs or media filters, to reduce the impact of nutrient and bacteriological pollutants on the receiving environment.

Waterless systems

Waterless toilets such as composting or incinerating toilets can be used to reduce the quantity of wastewater generated from a facility and also to change the quality of wastewater. However, one needs to deal with the residual products from such a facility, either composted material or ash, for final disposal by using or recycling compost in a yard as fertilizer or by sending ash to a landfill. The remaining wastewater from the structure is called *graywater* (wastewater that comes from fixtures other than toilets and/or urinals), and it may be treated adequately using natural systems such as wetlands or other systems prior to subsurface dispersal. Typically, pollutant loads in graywater are greater than in effluent from well-maintained media filters or ATUs; hence, adequate treatment and dispersal of graywater must not be overlooked. Waterless toilets are an attractive option for remote, nonresidential areas, such as golf courses or rest areas in parks, where access to both water and wastewater facilities is costly.

Chapters 3 and 4 present information on advanced onsite wastewater systems that would allow one to use flush toilets that use water for carrying waste away from the dwelling. The authors are quite aware that most people prefer modern plumbing and modern conveniences in their homes. However, reduced-flow fixtures, such as showers and flush toilets, have been accepted by the general population, and modern washing machines and dishwashers are available that operate efficiently while at the same time requiring less water than older models. Although these fixtures are not required for using onsite and decentralized wastewater systems, they are available methods for people to effortlessly conserve water in their homes while living modern lifestyles with modern conveniences. These fixtures and measures are also positive ways to enhance the performance of a wastewater system by reducing the load on the system.

Some homeowners are willing to take more drastic measures, including non-water-carrying toilets such as composting toilets, incinerating toilets, or other types of chemical toilets. These types of fixtures are available today and can be used as alternatives to flush toilets. When such alternative toilets are used, the graywater must be treated. When properly designed and operated, advanced onsite wastewater treatment systems can be used for the treatment of graywater. Just as with treated wastewater, treated graywater can be either recycled or dispersed into the receiving environment available onsite. If the goal is to reduce the use of clean drinking water for toilet flushing, that may be accomplished by reusing the treated effluent for flushing toilets in a manner similar to using composting or incinerating toilets that do not use water for flushing waste. The first option allows the house to be constructed with conventional plumbing practices with such minor changes that allows the flush tank to be filled with recycled effluent that comes from the advanced onsite treatment system.

Disinfection systems

Effluent disinfection before discharge may be necessary when there is a potential for human contact at or near the effluent dispersal system. Typically, direct discharge of effluent into surface water or land application of effluent using spray system would require disinfection before discharge. Subsurface dispersal of secondary (OTL2) or better quality effluent may not need disinfection mainly because soil environment can be harsh on microorganisms and they typically do not last long in that environment.

Disinfection systems used before effluent discharge rely on processes that use an agent or destroy microorganisms (bacteria, viruses, etc.) by either killing them or by preventing their replication. Agents typically used for disinfection include chlorine, ultra-violet light, ozone, or of some other chemical or physical nature. The wastewater must be treated to at least secondary (OTL2) or better quality before it can be adequately disinfected. A number of pre-engineered and pre-packaged effluent disinfection systems for use in onsite systems are available.

Microorganisms in raw wastewater can be present in millions of counts per 100 milliliter, thus reducing them by 90% will still leave a large quantity in the effluent before discharge. Typically, reduction in microorganisms is reported as log-reduction rather than percentage reduction. 90% reduction represents one log reduction, while 99% reduction represents two log reductions. If the raw wastewater has 10 million fecal coliform counts (indicator microorganism) and the goal is to have less than 10 fecal coliform counts in the effluent before discharge then one need to use a disinfection system designed and tested for achieving six log reductions or 99.9999% reduction in fecal coliform count. All disinfection systems require maintenance in order to be able to disinfect the effluent in a consistent manner.

Onsite effluent dispersal systems

Small wastewater treatment systems, just like large ones, need a mechanism for returning treated effluent to the hydrologic cycle. As noted earlier, subsurface dispersal (nonpoint source discharge) is the primary mechanism used for returning effluent from small onsite treatment systems to the hydrologic cycle. Chapter 5 presents details on onsite effluent dispersal systems. The three major parameters that influence the performance of subsurface dispersal systems are effluent characteristics, method of application, and soil and site characteristics. The first two parameters are more manageable than the third. Highly treated effluent, when applied in small and frequent doses (time dosing) using various methods of application, can be adequately dispersed on a variety of soil and site conditions. The following technologies are available for subsurface dispersal of effluent from small treatment systems:

- Trenches — gravity or pressure dosed, with or without gravel
- Drip — at or below grade
- Spray — above ground
- Filter beds — raised systems on sand-lined beds
- Evapotranspiration beds — with or without storage tanks
- Greenhouses — with or without storage tanks

Since most of the dispersal technologies listed above use soil as a receiving medium for the partially treated effluent, soil evaluation has been an integral part of using onsite wastewater systems. However, with the availability of a variety of treatment systems, the necessary degree of treatment can be achieved outside the soil and thus the need for soil and site evaluation, as currently performed for septic systems, may not be necessary. Specifically, the regulatory requirements for conducting soil evaluation prior to installing a subsurface dispersal system when nonseptic onsite treatment systems are used needs changes. A variety of dispersal systems can be pre-engineered, installed, and operated on a site in a manner that provides adequate assimilation of up to 1000 gallons/day treated effluent within the zone of influence specified for that system. Based on the site characteristics and environmental sensitivity of the proposed location, an appropriate type of pre-engineered dispersal system can be selected and installed. Effluent dispersal systems should be selected and sized based on a site's assimilative capacity for the design flow and nutrient loading, rather than based solely on soil characteristics. Soil and site conditions that are viewed as limitations for septic drain fields must not be viewed as limitations for the use of effluent dispersal systems.

The above-mentioned onsite treatment and dispersal technologies can be grouped into the following 11 wastewater system types; within each type, a number of different engineering designs and methods can be used to achieve the necessary performance goals on sites where the systems are used:

Table 1.3 Onsite Wastewater Systems Types

Conventional gravity septic tank effluent drain field	System type I
Pressure-dosed septic tank effluent drain field	System type II
Drip dispersal of septic tank effluent	System type III
Waterless toilets and graywater systems	System type IV
Gravity trench for treatment level 2 or better effluent	System type V
Pressure-dosed trench for treatment level 2 or better effluent	System type VI
Drip dispersal for treatment level 2 or better effluent	System type VII
Filter bed for treatment level 2 or better effluent	System type VIII
Evapotranspiration bed for treatment level 2 or better effluent	System type IX
Spray dispersal for treatment level 3 or better effluent	System type X
Greenhouse for treatment level 3 or better effluent	System type XI

Reuse systems other than the irrigation or plant watering systems mentioned above can take a variety of forms and are not classified in this list. Specifically, reuse for flushing toilets is not included in this categorization.

Two main parameters influence the functioning of a subsurface dispersal system: the depth of soil to limiting conditions (impermeable layer or seasonal water table) and the permeability of soil (percolation rate, hydraulic conductivity, or texture/structure). All sites may be grouped into four site groups based on the values of these two parameters; within each site group, parameters such as slope, landscape position, vegetation, environmental sensitivity, and others determine the type and design of wastewater systems appropriate for the given situation. Most state regulations for onsite systems specify the required limits for soil depth and permeability for the use of septic drain fields. Using these limits as a reference point, a four-quadrant matrix can be developed. Figure 1.7 presents an example of such a matrix that can be used to match wastewater system types with the site groups for a given situation. From this approach, one can see that use of certain advanced technologies is possible regardless of soil permeability and depth to limiting conditions as long as the system owner or maintenance provider is willing to take full responsibility for the system's performance and its effects on public health and environmental quality.

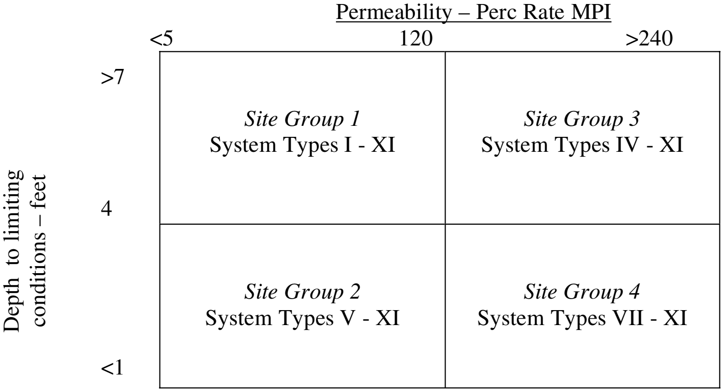

Figure 1.7 Site condition and appropriate onsite wastewater system types.

Remote monitoring system

Most of the advanced onsite wastewater systems mentioned above and discussed further in this book use electromechanical devices, such as pumps, blowers, and float switches, for achieving the necessary treatment and dispersal goals. The performance of treatment and dispersal systems depends heavily on the reliable operation of these devices on a continuous basis. In order to adequately monitor the operations of these devices on a continuous basis and detect any problems quickly, a remote monitoring system (telemetry system) should be used. Control panels capable of operating the electromechanical devices as well as reporting the conditions of these devices to a central computer using telephone lines or other means of communication are now available for small systems. Such systems can send signals to a central computer on a routine basis or to an operator during an emergency situation reporting information on various parameters, such as pump run time, duration of power outage, and high water conditions. With such remote monitoring systems, a wastewater utility can operate a number of small wastewater systems installed over a large geographical area in a cost-efficient manner. This technology is familiar to municipal wastewater collection and treatment system management entities because Supervisory Control and Data Acquisition (SCADA) systems are standard equipment and software for wastewater pumping stations and municipal wastewater treatment plants. The cost of technology has reached a level that SCADA systems are available and affordable for onsite and decentralized systems, making decentralized systems appear similar to traditional centralized systems.

Operational information gathered using remote monitoring systems can be used for preparing routine reports on the performance of the wastewater systems and to determine the amount of wastewater managed. Such reports can be useful for billing the user for wastewater management services and for the regulatory agency that is responsible for ensuring adequate operation of such systems. Routine replacement of pumps and other devices can be planned in an efficient manner based on the information gathered by remote monitoring systems, thus minimizing or avoiding serious out-of-compliance situations. Liquid and solid levels in tanks may be monitored to schedule pumping. Dissolved oxygen and turbidity may be easily monitored online and in real time to assess the treatment system's performance, to schedule maintenance, and to provide early detection of conditions that could lead to out-of-compliance performance of the treatment system. All of this monitoring of course is aimed at testing the effluent from the advanced treatment systems prior to discharge to soil. As previously mentioned, collecting a representative sample of wastewater once it has dispersed into and through soil is not feasible because it is nearly impossible to determine the treatment provided by the soil component, particularly if the soil has preferential flow paths.

Regulatory framework

Government agencies that are responsible for regulating wastewater systems must focus on two important issues: adequate treatment of wastewater, including dispersal and reuse of effluent, and environmental and public health protection from inadequately treated wastewater. Regulators must keep these two issues in focus and develop regulatory strategies around them. The science and technologies for treating wastewater and for ensuring drinking water quality are well established. Regulatory programs must be developed to allow wastewater professionals to operate in a competitive marketplace to offer wastewater services in a cost- effective and environmentally sound manner using onsite systems. Unfortunately, such a regulatory framework does not currently exist for small onsite systems. Today, regulatory agencies responsible for onsite systems are more involved with preinstallation issues that typically have less direct implications on the long-term performance of small wastewater systems. For a utility to function and offer wastewater solutions to the public, the regulatory framework must change 180 degrees. We need a solution-driven, performance-based regulatory framework with heavy emphasis on postinstallation issues such as monitoring and inspection of the system operations and the environment as well as education and training.

Figure 1.8 shows the life of a typical onsite wastewater system placed on a timeline and what we see today is that majority of the time involved by regulators and consultants is before the system is used, i.e., before the "first flush" when the risk to public health or to the environment is nil because there is no wastewater to deal with. The time required for all pre-installation activities is insignificant (a few weeks to months) compared to the lifetime of the system during which the system is expected to perform within its specifications and produce effluent. Typically, both the regulatory and the consultant community walks away from the onsite system right after the "first flush" happens and the system becomes owner's responsibility during the operation period. All onsite systems when used have potential to fail unless they are operated and maintained following the designer's and manufacturer's recommendations. Thus there is a tremendous need at least for the regulatory community to shift their involvement with the onsite system to its post-installation time period during which the system truly can have effects on public health and environmental quality. Regulatory involvement during the pre-installation period does not result into much of a value-added service to anyone.

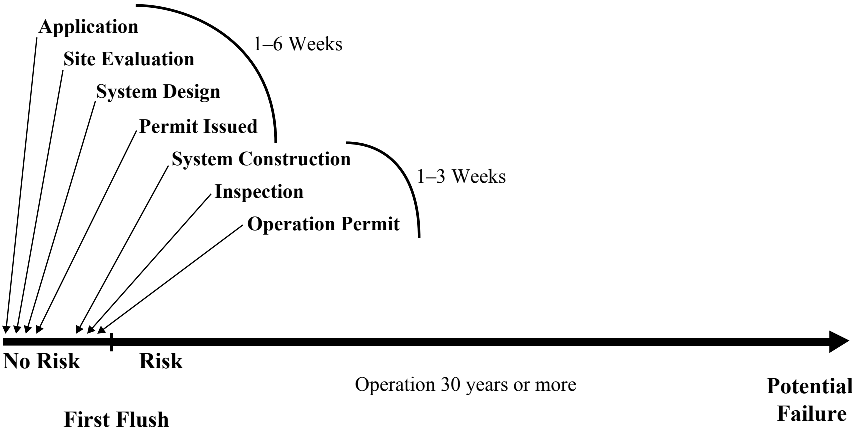

Figure 1.8 Life of an onsite wastewater system, activities performed, and time period. Source: This concept drawing was developed by Donald J. Alexander, Director, Division of Onsite Water and Sewage Services, Virginia Department of Health.

A solution-driven regulatory system means that if the regulations are used to prescribe wastewater systems, then they must lead to a set of solutions for any given site and situation, using the best available technologies for treatment and dispersal. One way to achieve such a goal is by developing a manual of practice (MOP) for all available small-scale wastewater treatment and dispersal technologies and updating the MOP as needed to stay current with technologies developed in the onsite industry. The MOP's development must be a joint effort between the public sector, state-level technical staff, and private sector wastewater professionals, engineers, and manufacturers. It should include information on sizing, layout, start-up processes, operation and maintenance requirements, operational costs, expected performance, zone of influence, and other similar issues related to the use of the technology. Such an MOP can then be used by an RME that is licensed to offer wastewater services using small-scale wastewater technologies.

Technology-performance data collected by RMEs can be used to revise or delete MOP content. Only regulated RMEs will have an interest in looking at wastewater systems' abilities on a long-term basis to meet the necessary performance standards and achieve customer satisfaction at an affordable cost. Thus, the best source for information on the long-term use of a technology can be the RMEs. Since at present very few RMEs are in operation, wastewater engineering textbooks, third-party test reports, sensible ideas and claims made by engineers and manufacturers, and information gathered from the EPA and demonstration projects are available to develop the first version of the MOP. An RME today can have more than 100 pre-engineered options available to choose from for offering wastewater management services using advanced onsite wastewater treatment systems.

A performance-based regulatory framework should be developed, starting with a clear understanding of how onsite systems need to function. Today, there is a widespread myth among regulators and soil evaluators that an onsite system would work only if deep, dry, and well-drained permeable soil (good soil) is present on a lot. This belief is based on a limited understanding of water's subsurface movement as commonly determined by percolation or saturated hydraulic conductivity tests or as estimated based on soil color and texture. In reality, subsurface movement of water is a complex phenomenon that is very hard to predict just by looking at soil characteristics, particularly since natural soil is not a homogeneous medium and has many discontinuities. Regulations need to clearly define what types of conditions must exist on and around the area where site-assimilative systems are installed and operated instead of arguing about soil hydraulic conductivity or percolation rate for individual home or other small onsite systems. The performance-based regulations should also assign effluent limits prior to effluent dispersal based on the environmental sensitivity and size of the system and should assign limits for inorganic, total nitrogen, and total phosphorus pollutants at the boundary of the site assimilative system in terms of mass loading.

The boundary around a nonpoint source discharge system can be viewed as the *zone of influence* for the site assimilative system. By defining the zone of influence, we can move away from needing regulations on soil and site criteria and setback distances and can allow the industry to develop new technologies with smaller and smaller zones of influence. A recycle and reuse system, such as flushing toilets that use effluent and recycle effluent for plant growth in a greenhouse, would have the smallest zone of influence — 0 ft. around the greenhouse. A lined "evapo-transpiration" ET bed may have a zone of influence of 0 ft. below the system and 10 ft. around the system. Water quality outside the zone of influence for any dispersal system must be no different from rain or surface water quality allowed for public contact. Adequate penalties must be enforced when predefined standards for effluent or mass loading of pollutants are violated by the utilities or RME's.

A performance standard should also include customer satisfaction in terms of the overall wastewater services offered by the RME. Customer satisfaction can be measured based on such parameters as sewage back-up in the house, odor or noise nuisance, surfacing of effluent in the yard, and unattended alarm calls that result from inadequate operation of a system. The performance-based regulations must indicate the method for establishing the violation and penalties for each violation. The penalties should include monetary fines and revocation of a license. Under a free-market model for a utility program, there would be adequate numbers of utilities available to offer dependable services to all citizens, as long as the citizens pay the fees (sewer bills) and the regulators strictly enforce performance standards. If an RME is allowed to continue to operate while violating performance standards, there will be no incentive to offer wastewater services using adequate treatment and dispersal technologies. An RME should be informed about the expected performance standards, methods for measuring performance, and the consequences for not meeting the standards. At the same time, the management entity must establish a legal framework that gives them adequate authority to collect service fees and to take actions against those who do not pay these fees.

Thus, the use of small wastewater systems to effectively recycle and reuse adequately treated effluent onsite with minimum degree of collection will be the method of choice for wastewater treatment in the 21st century. Many technologies for treatment and effluent dispersal are currently available and new ones are currently being developed. Once the infrastructure for operation and management of these technologies is established and the performance-based regulatory framework is adapted nationwide, extensive application of small-scale wastewater treatment technologies will be possible.

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chapter two

Decentralized wastewater solutions

Introduction

Society today has widely accepted the importance of adequate wastewater treatment prior to discharge as opposed to discharge of untreated wastewater. Wastewater treatment prior to discharge is necessary to ensure protection of water quality and to reduce requirements for treatment of potable water. As mentioned in Chapter 1, during the 19th and the 20th centuries, the use of centralized collection systems was viewed as a cost-effective permanent concept for wastewater treatment, while the use of conventional onsite systems, typically septic systems, was viewed as a temporary solution for areas outside the reach of centralized collection systems. By the end of the 20th century, wastewater professionals realized that centralized collection and treatment is not the only way for managing wastewater and it is impossible to extend centralized collection systems to many areas where new growth is occurring. Rural "electrification" (extending the central electric service grid to all of the populace) is no longer the model for serving the entire population of the U.S. with adequate wastewater collection, treatment, and effluent dispersal. Decentralized wastewater solutions can and will play an important role for managing wastewater in the future. Thus, advanced onsite wastewater systems technologies offer alternatives not only to conventional septic systems but also to centralized wastewater solutions.

In this chapter, we explain what the term *decentralized wastewater solution* means, how it differs from centralized wastewater and conventional septic system solutions, and how to look at wastewater within the framework of decentralized wastewater solutions.

The term decentralized

The term *decentralized wastewater solution* has several aliases, including *on-lot system, onsite system, individual wastewater system, cluster system,* and *community system.* The main idea behind decentralized wastewater solutions is to manage (treat and disperse or reuse) wastewater at or near the place where it is produced. Centralized wastewater solutions manage the wastewater in a central location that typically is far away from the place where it is produced. The other main difference between decentralized and centralized wastewater solutions is in terms of the receiving environment into which the effluent (treated wastewater) is released. Centralized wastewater systems typically release effluent into surface water bodies, such as oceans, rivers, streams, or creeks, whereas decentralized wastewater systems typically release effluent into soil or on top of land.

Why does one need to consider the use of decentralized wastewater systems? There are many reasons. For example, many old septic systems are not working correctly and sewage is seen on top of drain fields or sewage is backing up in homes. The sewer system that was supposed to arrive in a particular area just is not coming or citizens do not want it to come. Someone is planning to build a new home or develop a business in the area where you cannot get a permit to install a conventional septic system because the land does not percolate ("perc"), or poor water quality is observed in lakes or other surface water bodies resulting from a large number of malfunctioning septic tank systems that have been in use for decades.

For new developments, it is not uncommon for the nearest centralized municipal wastewater collection and treatment systems to be too far away to be economically accessible. In rapidly developing areas, municipal collection and treatment systems simply have not kept pace to provide capacity for the population growth. Decentralized systems can provide developers with wastewater collection and treatment solutions. For many developers who want to maximize lot density, decentralized solutions in the form of cluster collection treatment and dispersal systems provide a means to maximize density and meet the wastewater needs necessary to develop. In some cases, developers would like to provide "green" development by reusing water rather than flushing it down the sewer and not being able to recover any of its value. The wastewater using advanced onsite wastewater systems technologies can easily be treated and reused for irrigation of green space within the development. For areas where water is a precious commodity, and homeowners enjoy having green lawns, reusing treated wastewater effluent provides a means to achieve this goal and, at the same time, recover the value of water rather than throw it down the sewer.

In some areas of the U.S., homeowners are currently being rewarded tens of thousands of dollars to remove their lawns and replace their grass with xeriscaping in order to reduce water usage. At the same time, in these same areas, sewage is simply being dumped down the sewers and treated at great expense so that it can be disposed of into surface water bodies. In some cases, rural water districts have responded to their patrons by providing managed decentralized wastewater systems, while at the same time generating additional revenue for the water district. Areas within these districts have seen a surge in growth because developers are able to provide "city water" and "city sewers" to homeowners and developers.

If for any of the aforementioned reasons, or for other similar reasons, you want to address wastewater needs using decentralized wastewater systems, you now can do so using advanced onsite wastewater systems technologies. Use of these technologies have only two conditions: you must have an adequate management entity present in your area that can own and operate the technologies and you must have a legal and regulatory framework that recognizes the use of advanced onsite wastewater systems with management. We discuss more about the management entity and legal and regulatory framework in Chapters 6 and 7.

The decentralized wastewater management solutions are presented as positive developments for rural areas. Although the authors agree, as do most people, that successful wastewater treatment with subsequent dispersal of treated water to the hydrologic cycle is a positive and healthy goal, planning commissions have used lack of adequate wastewater collection, treatment, and dispersal as a method to prevent urban sprawl and uncontrolled development in rural and suburban areas. With the advent of feasible, easily achievable wastewater collection and treatment for decentralized systems, planning commissions can no longer use wastewater as a mechanism or an excuse to control growth. Decentralized wastewater technology has "grown up" and taken that excuse away from planners. This puts planning commissions in the unfortunate and politically unpopular position of having to pass ordinances that limit growth on its face value rather than using wastewater regulatory agencies as their enforcement department for controlling growth. We propose ideas for planning with managed decentralized onsite systems in Chapter 8.

Centralized versus decentralized solutions

The main objective of any wastewater solution (centralized or decentralized) is to adequately treat wastewater before releasing effluent into the environment. The cost of wastewater management systems is always the main issue in any public or private decision-making process. What is an appropriate cost for wastewater management? The answer depends on many factors, including the level of treatment necessary prior to discharge and the overall socioeconomic standards of the location. Typically, water and wastewater projects are viewed as public projects, and they are funded by either grant or low-interest loan funds, especially when centralized solutions are employed. The total capital cost of any such project is divided among the users and charged as connection or hook-up fees, and operating costs are charged based on usage.

Components of wastewater systems

The three basic components of any wastewater system are collection, treatment, and disposal (dispersal) systems. Of these three components, collection is the least important for treatment of wastewater. In the past, collection was a necessary and important component of wastewater systems mainly because the use of advanced treatment technologies was not cost-effective when employed for treating small quantities of wastewater. However, we now have access to wastewater treatment technologies that can treat wastewater in small quantities and meet the necessary discharge standards in a cost-effective manner, thus collection of large quantities of wastewater in one central location for treatment of an entire city's or region's wastewater is no longer needed. Wastewater solutions can now be offered using decentralized, small-scale systems with a cost-effectiveness similar to what was once only possible using a centralized, large-scale system. Granted, traditional wastewater collection and treatment systems are exactly the correct solution in areas where housing and business density and numbers makes this traditional approach economically superior; however, in less densely populated areas, the traditional approach may not be the best solution.

Categorizing decentralized and centralized systems

There are no well-defined standards for quantitatively determining whether a proposed wastewater solution can be viewed as a decentralized or centralized system. We propose that if the capital and operational costs allocated to the collection components (such as sewer lines and pump stations) of a wastewater solution system are less than 25% of the total project costs, then the solution may be viewed as a decentralized wastewater solution. By minimizing the costs associated with collection of untreated wastewater, one can maximize the capital and operational funding for wastewater treatment and effluent dispersal and reuse components of the system. If you think that the capital costs for your proposed new wastewater system are too much, we suggest that you find out the costs associated with the collection component of the entire system; if it is more than 25% of the total cost, you should consider decentralized wastewater systems to meet your demand for wastewater treatment.

The other key factor of a decentralized wastewater solution is the method by which and the receiving environment in which the effluent is released back into the environment. Decentralized wastewater systems offer alternatives to surface water discharge of effluent. This is very important for communities that rely primarily on groundwater as their source of drinking water. Treating wastewater onsite and dispersing effluent using land-based effluent dispersal systems can recharge groundwater, thus offering a sustainable source of fresh water to communities. In addition, land-based effluent dispersal technologies can reap the benefits of soil as a natural filtration medium and a buffer between the effluent and the source water, which is typically not possible when effluent is dispersed into surface water. An additional benefit for communities and other areas dependent on ground water as a source of drinking water is that, by providing measurable, effective, managed treatment of sewage (as contrasted to traditional septic tank drain fields), groundwater is protected from unknown contaminants from septic tanks. Rural water districts reap the benefits of well-head protection by providing decentralized wastewater systems to their patrons.

The science of wastewater

For both decentralized and centralized wastewater solutions, it is important to understand the science behind wastewater treatment and wastewater treatment classification schemes. Wastewater treatment is important and necessary to minimize pollution from discharged effluent into the environment. However, what is pollution? There are many technical and legal definitions of the term *pollution.* Technically, *pollution* means undesirable or adverse environmental conditions caused by the discharge of untreated or inadequately treated wastewater into an environment. Since matter can neither be created nor destroyed, from a very fundamental viewpoint, pollution is a natural resource that is misplaced.

Many states have legal definitions of the term *pollution.* For example, in Virginia, the State Water Control Law of Virginia § 62.1-44.3 states:

> "Pollution" means such alteration of the physical, chemical or biological properties of any state waters as will or is likely to create a nuisance or render such waters (a) harmful or detrimental or injurious to the public health, safety or welfare, or to the health of animals, fish or aquatic life; (b) unsuitable with reasonable treatment for use as present or possible future sources of public water supply; or (c) unsuitable for recreational, commercial, industrial, agricultural, or other reasonable uses, provided that (i) an alteration of the physical, chemical, or biological property of state waters, or a discharge or deposit of sewage, industrial wastes or other wastes to state waters by any owner which by itself is not sufficient to cause pollution, but which, in combination with such alteration of or discharge or deposit to state waters by other owners, is sufficient to cause pollution; (ii) the discharge of untreated sewage by any owner into state waters; and (iii) contributing to the contravention of standards of water quality duly established by the Board, are "pollution".

Pollution scale

In order to define the term *pollution* in a quantitative (objective) manner, rather than just a qualitative (subjective) manner as defined by any environmental law, we propose a Pollution Scale from 0 to 10 (Figure 2-1). This scale

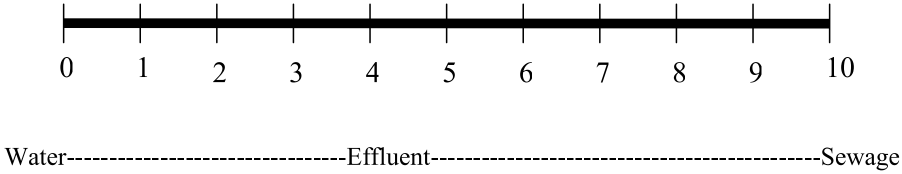


Figure 2.1 Pollution Scale from 0 (drinking water) to 10 (sewage) for differentiating between drinking water and sewage.

can be used for any water-quality related project; however, in this book, we use the scale to differentiate between drinking water and wastewater qualities.

It should be noted that the scale proposed here is in contrast to the current, subjective, somewhat loosely defined terminology of "primary," "secondary," and "tertiary" treatment. The terms *primary, secondary,* and *tertiary* seem to be fairly loosely interpreted by professionals around the U.S. and, in fact, recently, an additional term, *advanced secondary* has come into use. We propose to define treatment levels (and therefore pollution level) in terms of a measurable, quantifiable scale that ranks wastewater treatment in terms of easily identifiable values ranging from drinking water to raw sewage. We also propose quantitative values for treatment levels and a method to determine overall treatment level (OTL) for an advanced onsite treatment technology. An onsite system designer's job would be to select an advanced onsite treatment technology that would be suitable for discharge of effluent into the receiving environment present at a project site, thus minimizing the potential for pollution.

Water by its very nature cannot be found in its purest form. There are always some impurities dissolved in natural water. The U.S. Environmental Protection Agency (EPA) has established the acceptable drinking water quality standards shown in Table 2.1 (a) and (b). Note that at the present time there are 87 primary and 15 secondary standards for acceptable drinking water quality. On one extreme of the Pollution Scale, 0 indicates water that meets drinking water quality, in other words, the levels of all of the 102 contaminants are within the limits specified in Table 2.1 (a) and (b). On the other extreme of the Pollution Scale, 10 indicates untreated (raw) wastewater also called sewage. The basic idea behind any wastewater treatment scheme is to reduce the level of pollutants and move towards the left end of the Pollution Scale.

An inverse relationship can be developed between water quality on the Pollution Scale and treatment level, and terms such as *raw wastewater, effluent,* and *drinking water* can be defined as shown in Table 2.2. Note that in any wastewater treatment scheme, treatment up to some degree can be achieved prior to discharging effluent into a receiving environment (RE); the remainder of treatment can be achieved after dispersal into the environment by natural activities as well as by dilution. The treatment level necessary before dispersal depends on the characteristics of the RE and its overall assimilative capacity.

Table 2.1 EPA National Primary Drinking Water Standards

	Contaminant	MCL or TT[1] (mg/l)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Acrylamide	TT8	Nervous system or blood problems;	Added to water during sewage/ wastewater increased risk of cancer treatment	zero
OC	Alachlor	0.002	Eye, liver, kidney or spleen problems; anemia; increased risk of cancer	Runoff from herbicide used on row crops	zero
R	Alpha particles	15picocuries per Liter (pCi/L)	Increased risk of cancer	Erosion of natural deposits of certain minerals that are radioactive and may emit a form of radiation known as alpha radiation	zero
IOC	Antimony	0.006	Increase in blood cholesterol; decrease in blood sugar	Discharge from petroleum refineries; fire retardants; ceramics; electronics; solder	0.006
IOC	Arsenic	0.010 as of 1/ 23/06	Skin damage or problems with circulatory systems, and may have increased risk of getting cancer	Erosion of natural deposits; runoff from orchards, runoff from glass & electronics production wastes	0
IOC	Asbestos (fibers >10micrometers)	7 million fibers per Liter (MFL)	Increased risk of developing benign intestinal polyps	Decay of asbestos cement in water mains; erosion of natural deposits	7 MFL
OC	Atrazine	0.003	Cardiovascular system or reproductive problems	Runoff from herbicide used on row crops	0.003
IOC	Barium	2	Increase in blood pressure	Discharge of drilling wastes; discharge from metal refineries; erosion of natural deposits	2
OC	Benzene	0.005	Anemia; decrease in blood platelets; increased risk of cancer	Discharge from factories; leaching from gas storage tanks and landfills	zero
OC	Benzo(a)pyrene (PAHs)	0.0002	Reproductive difficulties; increased risk of cancer	Leaching from linings of water storage tanks and distribution lines	zero

Table 2.1 EPA National Primary Drinking Water Standards

	Contaminant	MCL or TT[1] (mg/l)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
IOC	Beryllium	0.004	Intestinal lesions	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries	0.004
R	Beta particles and photon emitters	4 millirems per year	Increased risk of cancer	Decay of natural and man-made deposits of certain minerals that are radioactive and may emit forms of radiation known as photons and beta radiation	zero
DBP	Bromate	0.010	Increased risk of cancer	Byproduct of drinking water disinfection	zero
IOC	Cadmium	0.005	Kidney damage	Corrosion of galvanized pipes; erosion of natural deposits; discharge from metal refineries; runoff from waste batteries and paints	0.005
OC	Carbofuran	0.04	Problems with blood, nervous system, or reproductive system	Leaching of soil fumigant used on rice and alfalfa	0.04
OC	Carbon tetrachloride	0.005	Liver problems; increased risk of cancer	Discharge from chemical plants and other industrial activities	zero
D	Chloramines (as Cl2)	MRDL=4.01	Eye/nose irritation; stomach discomfort, anemia	Water additive used to control microbes	MRDLG =41
OC	Chlordane	0.002	Liver or nervous system problems; increased risk of cancer	Residue of banned termiticide	zero
D	Chlorine (as Cl2)	MRDL=4.01	Eye/nose irritation; stomach discomfort	Water additive used to control microbes	MRDLG =41
D	Chlorine dioxide (as ClO2)	MRDL=0.81	Anemia; infants & young children: nervous system effects	Water additive used to control microbes	MRDLG =0.81

Table 2.1 EPA National Primary Drinking Water Standards

	Contaminant	MCL or TT[1] (mg/l)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
DBP	Chlorite	1.0	Anemia; infants & young children: nervous system effects	Byproduct of drinking water disinfection	0.8
OC	Chlorobenzene	0.1	Liver or kidney problems	Discharge from chemical and agricultural chemical factories	0.1
IOC	Chromium (total)	0.1	Allergic dermatitis	Discharge from steel and pulp mills; erosion of natural deposits	0.1
IOC	Copper	TT7; Action Level = 1.3	Short term exposure: Gastrointestinal distress. Long term exposure: Liver or kidney damage. People with Wilson's Disease should consult their personal doctor if the amount of copper in their water exceeds the action level	Corrosion of household plumbing systems; erosion of natural deposits	1.3
M	Cryptosporidium	TT3	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
IOC	Cyanide (as free cyanide)	0.2	Nerve damage or thyroid problems	Discharge from steel/metal factories; discharge from plastic and fertilizer factories	0.2
OC	2,4-D	0.07	Kidney, liver, or adrenal gland problems	Runoff from herbicide used on row crops	0.07
OC	Dalapon	0.2	Minor kidney changes	Runoff from herbicide used on rights of way	0.2
OC	1,2-Dibromo-3-chloropropane (DBCP)	0.0002	Reproductive difficulties; increased risk of cancer	Runoff/leaching from soil fumigant used on soybeans, cotton, pineapples, and orchards	zero
OC	o-Dichlorobenzene	0.6	Liver, kidney, or circulatory system problems	Discharge from industrial chemical factories	0.6
OC	p-Dichlorobenzene	0.075	Anemia; liver, kidney or spleen damage; changes in blood	Discharge from industrial chemical factories	0.075

Table 2.1 EPA National Primary Drinking Water Standards

	Contaminant	MCL or TT[1] (mg/l)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	1,2-Dichloroethane	0.005	Increased risk of cancer	Discharge from industrial chemical factories	zero
OC	1,1-Dichloroethylene	0.007	Liver problems	Discharge from industrial chemical factories	0.007
OC	cis-1,2-Dichloroethylene	0.07	Liver problems	Discharge from industrial chemical factories	0.07
OC	trans-1,2-Dichloroethylene	0.1	Liver problems	Discharge from industrial chemical factories	0.1
OC	Dichloromethane	0.005	Liver problems; increased risk of cancer	Discharge from drug and chemical factories	zero
OC	1,2-Dichloropropane	0.005	Increased risk of cancer	Discharge from industrial chemical factories	zero
OC	Di(2-ethylhexyl) adipate	0.4	Weight loss, live problems, or possible reproductive difficulties	Discharge from chemical factories	0.4
OC	Di(2-ethylhexyl) phthalate	0.006	Reproductive difficulties; liver problems; increased risk of cancer	Discharge from rubber and chemical factories	zero
OC	Dinoseb	0.007	Reproductive difficulties	Runoff from herbicide used on soybeans and vegetables	0.007
OC	Dioxin (2,3,7,8-TCDD)	0.00000003	Reproductive difficulties; increased risk of cancer	Emissions from waste incineration and other combustion; discharge from chemical factories	zero
OC	Diquat	0.02	Cataracts	Runoff from herbicide use	0.02
OC	Endothall	0.1	Stomach and intestinal problems	Runoff from herbicide use	0.1
OC	Endrin	0.002	Liver problems	Residue of banned insecticide	0.002
OC	Epichlorohydrin	TT8	Increased cancer risk, and over a long period of time, stomach problems	Discharge from industrial chemical factories; an impurity of some water treatment chemicals	zero
OC	Ethylbenzene	0.7	Liver or kidneys problems	Discharge from petroleum refineries	0.7

Table 2.1 EPA National Primary Drinking Water Standards

	Contaminant	MCL or TT[1] (mg/l)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	Ethylene dibromide	0.00005	Problems with liver, stomach, reproductive system, or kidneys; increased risk of cancer	Discharge from petroleum refineries	zero
IOC	Fluoride	4.0	Bone disease (pain and tenderness of the bones); Children may get mottled teeth	Water additive which promotes strong teeth; erosion of natural deposits; discharge from fertilizer and aluminum factories	4.0
M	*Giardia lamblia*	TT3	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	zero
OC	Glyphosate	0.7	Kidney problems; reproductive difficulties	Runoff from herbicide use	0.7
DBP	Haloacetic acids (HAA5)	0.060	Increased risk of cancer	Byproduct of drinking water disinfection	n/a6
OC	Heptachlor	0.0004	Liver damage; increased risk of cancer	Residue of banned termiticide	zero
OC	Heptachlor epoxide	0.0002	Liver damage; increased risk of cancer	Breakdown of heptachlor	zero
M	Heterotrophic plate count (HPC)	TT3	HPC has no health effects; it is an analytic method used to measure the variety of bacteria that are common in water. The lower the concentration of bacteria in drinking water, the better maintained the water system is.	HPC measures a range of bacteria that are naturally present in the environment	n/a
OC	Hexachlorobenzene	0.001	Liver or kidney problems; reproductive difficulties; increased risk of cancer	Discharge from metal refineries and agricultural chemical factories	zero
OC	Hexachlorocyclopentadiene	0.05	Kidney or stomach problems	Discharge from chemical factories	0.05
IOC	Lead	TT7; Action Level = 0.015	Infants and children: Delays in physical or mental development; children could show slight deficits in attention span and learning abilities; Adults: Kidney problems; high blood pressure	Corrosion of household plumbing systems; erosion of natural deposits	zero

Table 2.1 EPA National Primary Drinking Water Standards

	Contaminant	MCL or TT[1] (mg/l)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
M	*Legionella*	TT3	Legionnaire's Disease, a type of pneumonia	Found naturally in water; multiplies in heating systems	zero
OC	Lindane	0.0002	Liver or kidney problems	Runoff/leaching from insecticide used on cattle, lumber, gardens	0.0002
IOC	Mercury (inorganic)	0.002	Kidney damage	Erosion of natural deposits; discharge from refineries and factories; runoff from landfills and croplands	0.002
OC	Methoxychlor	0.04	Reproductive difficulties	Runoff/leaching from insecticide used on fruits, vegetables, alfalfa,	
livest ock	0.04				
IOC	Nitrate (measured as Nitrogen)	10	Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits	10
IOC	Nitrite (measured as Nitrogen)	1	Infants below the age of six months who drink water containing nitrite in excess of the MCL could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue-baby syndrome.	Runoff from fertilizer use; leaching from septic tanks, sewage; erosion of natural deposits	1
OC	Oxamyl (Vydate)	0.2	Slight nervous system effects	Runoff/leaching from insecticide used on apples, potatoes, and tomatoes	0.2
OC	Pentachlorophenol	0.001	Liver or kidney problems; increased cancer risk	Discharge from wood preserving factories	zero
OC	Picloram	0.5	Liver problems	Herbicide runoff	0.5

Table 2.1 EPA National Primary Drinking Water Standards

	Contaminant	**MCL or TT[1] (mg/l)[2]**	**Potential health effects from exposure above the MCL**	**Common sources of contaminant in drinking water**	**Public Health Goal**
OC	Polychlorinated biphenyls (PCBs)	0.0005	Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer	Runoff from landfills; discharge of waste chemicals	zero
R	Radium 226 and Radium 228 (combined)	5 pCi/L	Increased risk of cancer	Erosion of natural deposits	zero
IOC	Selenium	0.05	Hair or fingernail loss; numbness in fingers or toes; circulatory problems	Discharge from petroleum refineries; erosion of natural deposits; discharge from mines	0.05
OC	Simazine	0.004	Problems with blood	Herbicide runoff	0.004
OC	Styrene	0.1	Liver, kidney, or circulatory system problems	Discharge from rubber and plastic factories; leaching from landfills	0.1
OC	Tetrachloroethylene	0.005	Liver problems; increased risk of cancer	Discharge from factories and dry cleaners	zero
IOC	Thallium	0.002	Hair loss; changes in blood; kidney, intestine, or liver problems	Leaching from ore-processing sites; discharge from electronics, glass, and drug factories	0.0005
OC	Toluene	1	Nervous system, kidney, or liver problems	Discharge from petroleum factories	1
M	Total Coliforms (including fecal coliform and E. coli)	5.0%4	Not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present5	Coliforms are naturally present in the environment as well as feces; fecal coliforms and E. coli only come from human and animal fecal waste.	zero
DBP	Total Trihalomethanes (TTHMs)	0.10 0.080 after 12/31/03	Liver, kidney or central nervous system problems; increased risk of cancer	Byproduct of drinking water disinfection	n/a6
OC	Toxaphene	0.003	Kidney, liver, or thyroid problems; increased risk of cancer	Runoff/leaching from insecticide used on cotton and cattle	zero

Table 2.1 EPA National Primary Drinking Water Standards

	Contaminant	MCL or TT[1] (mg/l)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal
OC	2,4,5-TP (Silvex)	0.05	Liver problems	Residue of banned herbicide	0.05
OC	1,2,4-Trichlorobenzene	0.07	Changes in adrenal glands	Discharge from textile finishing factories	0.07
OC	1,1,1-Trichloroethane	0.2	Liver, nervous system, or circulatory problems	Discharge from metal degreasing sites and other factories	0.20
OC	1,1,2-Trichloroethane	0.005	Liver, kidney, or immune system problems	Discharge from industrial chemical factories	0.003
OC	Trichloroethylene	0.005	Liver problems; increased risk of cancer	Discharge from metal degreasing sites and other factories	zero
M	Turbidity	TT3	Turbidity is a measure of the cloudiness of water. It is used to indicate water quality and filtration effectiveness (e.g., whether disease-causing organisms are present). Higher turbidity levels are often associated with higher levels of disease-causing micro-organisms such as viruses, parasites and some bacteria. These organisms can cause symptoms such as nausea, cramps, diarrhea, and associated headaches	Soil runoff	n/a
R	Uranium	30 ug/L as of 12/08/03	Increased risk of cancer, kidney toxicity	Erosion of natural deposits	zero
OC	Vinyl chloride	0.002	Increased risk of cancer	Leaching from PVC pipes; discharge from plastic factories	zero
M	Viruses (enteric)	TT3	Gastrointestinal illness (e.g., diarrhea, vomiting, cramps)	Human and animal fecal waste	Zero
OC	Xylenes (total)	10	Nervous system damage	Discharge from petroleum factories; discharge from chemical factories	10

Table 2.1 EPA National Primary Drinking Water Standards

Contaminant	MCL or TT[1] (mg/l)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal

NOTES

1 Definitions

- Maximum Contaminant Level Goal (MCLG)—The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals consideration. MCLs are enforceable standards.
- Maximum Residual Disinfectant Level Goal (MRDLG)—The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.
- Maximum Residual Disinfectant Level (MRDL)—The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.
- Treatment Technique (TT)—A required process intended to reduce the level of a contaminant in drinking water.

2 Units are in milligrams per liter (mg/L) unless otherwise noted. Milligrams per liter are equivalent to parts per million (ppm).

3 EPA's surface water treatment rules require systems using surface water or ground water under the direct influence of surface water to (1) disinfect their water, and (2) filter their water or meet criteria for avoiding filtration so that the following contaminants are controlled at the following levels:

- Cryptosporidium (as of 1/1/02 for systems serving >10,000 and 1/14/05 for systems serving <10,000) 99% removal.
- Giardia lamblia: 99.9% removal/inactivation
- Viruses: 99.99% removal/inactivation
- Legionella: No limit, but EPA believes that if Giardia and viruses are removed/inactivated, Legionella will also be controlled.
- Turbidity: At no time can turbidity (cloudiness of water) go above 5 nephelolometric turbidity units (NTU); systems that filter must ensure that the turbidity go no higher than 1 NTU (0.5 NTU for conventional or direct filtration) in at least 95% of the daily samples in any month. As of January 1, 2002, for systems servicing >10,000, and January 14, 2005, for systems servicing <10,000, turbidity may never exceed 1 NTU, and must not exceed 0.3 NTU in 95% of daily samples in any month.
- HPC: No more than 500 bacterial colonies per milliliter
- Long Term 1 Enhanced Surface Water Treatment (Effective Date: January 14, 2005); Surface water systems or (GWUDI) systems serving fewer than 10,000 people must comply with the applicable Long Term 1 Enhanced Surface Water Treatment Rule provisions (e.g. turbidity standards, individual filter monitoring, Cryptosporidium removal requirements, updated watershed control requirements for unfiltered systems).
- Filter Backwash Recycling: The Filter Backwash Recycling Rule requires systems that recycle to return specific recycle flows through all processes of the system's existing conventional or direct filtration system or at an alternate location approved by the state

Table 2.1 EPA National Primary Drinking Water Standards

Contaminant	MCL or TT[1] (mg/l)[2]	Potential health effects from exposure above the MCL	Common sources of contaminant in drinking water	Public Health Goal

4 No more than 5.0% samples total coliform-positive in a month. (For water systems that collect fewer than 40 routine samples per month, no more than one sample can be total coliform-positive per month.) Every sample that has total coliform must be analyzed for either fecal coliforms or E. coli if two consecutive TC-positive samples, and one is also positive for E. coli fecal coliforms, system has an acute MCL violation.

5 Fecal coliform and E. coli are bacteria whose presence indicates that the water may be contaminated with human or animal wastes. Disease-causing microbes (pathogens) in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms. These pathogens may pose a special health risk for infants, young children, and people with severely compromised immune systems.

6 Although there is no collective MCLG for this contaminant group, there are individual MCLGs for some of the individual contaminants:

- Haloacetic acids: dichloroacetic acid (zero); trichloroacetic acid (0.3 mg/L)
- Trihalomethanes: bromodichloromethane (zero); bromoform (zero); dibromochloromethane (0.06 mg/L)

7 Lead and copper are regulated by a Treatment Technique that requires systems to control the corrosiveness of their water. If more than 10% of tap water samples exceed the action level, water systems must take additional steps. For copper, the action level is 1.3 mg/L, and for lead is 0.015 mg/L

8 Each water system must certify, in writing, to the state (using third-party or manufacturers certification) that when it uses acrylamide and/or epichlorohydrin to treat water, the combination (or product) of dose and monomer level does not exceed the levels specified, as follows: Acrylamide = 0.05% dosed at 1 mg/L (or equivalent); Epichlorohydrin = 0.01% dosed at 20 mg/L (or equivalent).

Table 2.1b National Secondary Drinking Water Standards

National Secondary Drinking Water Standards are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water. EPA recommends secondary standards to water systems but does not require systems to comply. However, states may choose to adopt them as enforceable standards

Contaminant	**Secondary Standard**
Aluminum	0.05 to 0.2 mg/L
Chloride	250 mg/L
Color	15 (color units)
Copper	1.0 mg/L
Corrosivity	noncorrosive
Fluoride	2.0 mg/L
Foaming Agents	0.5 mg/L
Iron	0.3 mg/L
Manganese	0.05 mg/L
Odor	3 threshold odor number
pH	6.5-8.5
Silver	0.10 mg/L
Sulfate	250 mg/L
Total Dissolved Solids	500 mg/L
Zinc	5 mg/L

Source: http://www.epa.gov/safewater/consumer/pdf/mcl.pdf

In this chapter, we present basics of wastewater treatment, wastewater characterization, and classification of OTLs prior to dispersal of effluent into a RE. We assume that the reader is familiar with terms that are typically used to describe the quality of untreated wastewater and effluent, such as biochemical oxygen demand (BOD); total suspended solids (TSS); fats, oil, and grease (FOG); Total Kjeldahl Nitrogen (TKN); total nitrogen (TN = TKN + nitrate nitrogen); total phosphorus (TP); and fecal coliform (FC). Literature cited at the end of this chapter offers more information on these terms.

The advanced science behind wastewater treatment is presented in a number of textbooks that are listed in the reference section of this chapter. Today, a number of pre-engineered advanced onsite wastewater treatment technologies are available in the market, each is designed based on proven scientific principles of wastewater treatment.

We will not go into details of the scientific principles and theories behind wastewater treatment. Instead, we present basic information on wastewater characterization and outline how to calculate OTLs obtained by currently available advanced onsite treatment systems.

Wastewater treatment basics

Treatability

In order to design onsite wastewater treatment systems, we must consider the nature of the wastewater. Effluent quality depends on influent charac-

Table 2.2 Pollution Scale versus Overall Treatment Levels (OTL) before Discharge

Pollution Scale	OTL Before Discharge	Treatment Level	Terms
10.0	0%		Raw Sewage
9.0	10%		Effluent
8.5	15%		
8.0	20%		
7.5	25%		
7.0	30%	1	
6.5	35%		
6.0	40%		
5.5	45%		
5.0	50%		
4.5	55%		
4.0	60%		
3.5	65%		
3.0	70%		
2.5	75%		
2.0	80%	2	
1.5	85%		
1.0	90%		
0.9	91%		
0.8	92%		
0.7	93%	3	
0.6	94%		
0.5	95%		
0.4	96%		
0.3	97%		
0.2	98%	4	
0.1	99%		Effluent
0.0	100%	5	Drinking Water

teristics. The influent characteristics, in turn, depend on the activities that take place in the dwellings or businesses that generate the wastewater. Typically, we look at the wastewater generated from a single home or a group of homes, with the main source of the wastewater being residential activities. For other types of wastewater sources, we recommend that the onsite system designer (a professional engineer or other professional educated and trained in wastewater engineering) do a detailed study on the source activities to determine what may be present in the raw wastewater. This is particularly important for commercial establishments, in which wastewater is not generated by residences.

Treatment capacity and treatment efficiency of systems are calculated based on influent concentrations and effluent requirements.

$$\text{Efficiency} = [(C_{in} - C_{out})/C_{in}]\ 100 \tag{2.1}$$

where

C in = Influent concentration (typically mg/L)
C out = Effluent concentration (typically mg/L)
Efficiency is expressed as a percentage (%)

Also, the treatment capacity over time for biochemical processes is usually modeled as a first-order equation such that:

$$C_t/C_0 = e^{-kt} \tag{2.2}$$

where

C_t = Concentration at time t (typically in mg/L)
C_0 = Initial concentration at time = 0 (typically in mg/L)
k = Reaction rate constant (typically in days^{-1})
t = time (typically in days)

For the purposes of explaining the importance of wastewater characteristics here, wastewater strength (concentration of contaminants), the availability of contaminants as a food source, and the characteristic of being easily metabolized or difficult to metabolize are all important factors to consider for designing treatment processes. Treating all wastewater as if it is residential wastewater can have disastrous results.

The source of the wastewater influences the characteristics of the waste stream. In general, we can categorize the source as residential, municipal, commercial, industrial, or agricultural. Tables documenting historically accepted values for wastewater characteristics are available for domestic wastewater. Untreated domestic wastewater has different characteristics from septic tank effluent. Septic tank effluent from a tank with an effluent screen (effluent filter) has different characteristics from unscreened effluent. Grinder pump effluent has different characteristics from any of the others. Wastewater from commercial sources, such as restaurants, schools, supermarkets, hospitals, hotels, and convenience stores with food service; car washes; beauty salons; and other types of establishments, can have characteristics specific to the wastewater-generating activities conducted as part of the business.

Typical components of raw wastewater and their concentrations are shown in Table 2.3. Once the raw sewage has undergone physical and biological treatment in a septic tank (Figure 2.2), its characteristics have been altered from those of raw sewage. Table 2.4 illustrates the characteristics of typical domestic septic tank effluent. Most of the discussion so far, along with the tables and graphs presented, has focused on the concentration of constituents in wastewater. The concentration tables may be quite familiar. However, another set of tables is available to the designer, showing typical flow rates from various establishments. Table 2.5, from the U.S. EPA 2002 *Onsite Wastewater Treatment Systems Manual,* provides information on typical residential wastewater flows from particular research projects. Most states

Table 2.3 Raw Sewage Characteristics

Component	Concentration Range	Typical Concentration
Total suspended solids, TSS	155–330 mg/L	250 mg/L
5-day biochemical oxygen demand, BOD_5	155–286 mg/L	250 mg/L
pH	6-9 s.u.	6.5 s.u.
Total coliform bacteria	10^8–10^{10} CFU/100mL	10^9 CFU/100mL
Fecal coliform bacteria	10^6–10^8 CFU/100mL	10^7 CFU/100mL
Ammonium-nitrogen, NH_4-N	4-13 mg/L	10 mg/L
Nitrate-nitrogen, NO_3-N	Less than 1 mg/L	Less than 1 mg/L
Total nitrogen	26–75 mg/L	60 mg/L
Total phosphorus	6-12 mg/L	10 mg/L

Source: Onsite Wastewater Treatment Systems Manual U.S. EPA February 2002 (EPA/625/R-00/008).

Note: mg/L = milligrams per liter; s.u. = standard units; CFU/100 mL = colony-forming units per 100 milliliters.

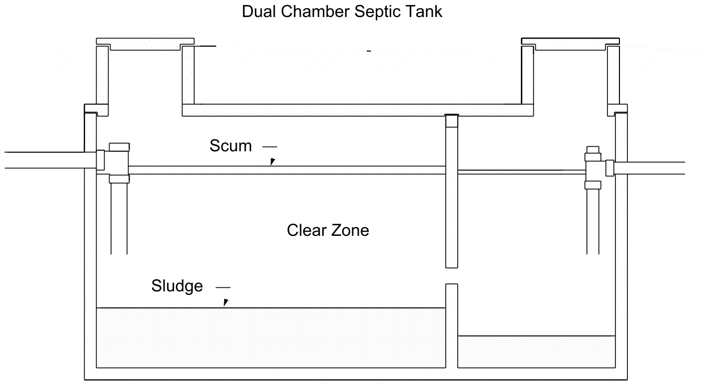


Figure 2.2 Septic Tank Profile

have tables within their own onsite wastewater regulations that prescribe flows to be used for design. For larger flows, such as from multiple dwellings, community systems, and subdivisions, the regulatory agencies generally have an estimated flow per dwelling or equivalent dwelling unit (EDU) that is used for design. Information regarding flow rates from sources other than residences is shown in Table 2.6, also taken from the U.S. EPA 2002 *Onsite Wastewater Treatment Systems Manual.*

Table 2.7 indicates the mass loads associated with domestic wastewater on an average daily basis. Note that the concept of load is simply the product of flow times the concentration, and the load to a wastewater treatment system is the mass of the constituent that is expected to be treated by the system.

Investigating the idea of load leads to a discussion of flows. Typical flows from residential sources may be obtained from references on onsite and

Table 2.4 Septic Tank Effluent Characteristics

Component	Concentration Range	Typical Concentration
Total suspended solids, TSS	36-85 mg/L	60 mg/L
5-day biochemical oxygen demand, BOD_5	118-189 mg/L	120 mg/L
pH	6.4–7.8 s.u.	6.5 s.u.
Fecal coliform bacteria	10^6–10^7 CFU/100mL	10^6 CFU/100mL
Ammonium-nitrogen, NH_4-N	30–50 mg/L	40 mg/L
Nitrate-nitrogen, NO_3-N	0–10 mg/L	0 mg/L
Total nitrogen	29.5–63.4 mg/L	60 mg/L
Total phosphorus	8.1–8.2 mg/L	8.1 mg/L

Sources: U.S. Environmental Protection Agency. "Onsite Wastewater Treatment Systems Manual," *EPA 625-R-00-008.* Cincinnati, OH: U.S. EPA Publication Clearinghouse, 2002, and Crites, R., and G. Tchobanoglous. *Small and Decentralized Wastewater Management Systems.* Boston: WCB/McGraw-Hill Companies, Inc., 1998.

Table 2.5 Residential Wastewater Flows

Study	Number of Residences	Study Duration (months)	Study Average (gal/person/day)	Study range (gal/person/day)
Brown & Caldwell (1984)	210		66.2 (250.6)[a]	57.3 – 73.0 (216.9 – 276.3)[b]
Anderson & Siegrist (1989)	90	3	70.8 (268.0)	65.9 – 75.6 (249.4 – 289.9)
Anderson, et al. (1983)	25	2	50.7 (191.9)	26.1 – 85.2 (98.9 – 322.5)
Mayer et al. (1999)	1188	1[c]	69.3 (252.3)	57.1 – 83.5 (216.1 – 316.1)
Weighted average	153		68.6 (259.7)	

[a] Based on indoor water use monitoring and not wastewater flow monitoring

[b] Liters per person per day in parentheses

[c] Based on 2 weeks of continuous monitoring in each of two seasons at each home

Sources: U.S. Environmental Protection Agency. "Onsite Wastewater Treatment Systems Manual," *EPA 625-R-00-008.* Cincinnati, OH: U.S. EPA Publication Clearinghouse, 2002.

decentralized wastewater systems, such as those cited in the reference sections of this text. Although Table 2.5 indicates the results of some of the research producing ranges for estimating residential flows on a per person, average daily basis, experience from some of the decentralized wastewater systems indicates that actual average daily flows from a single residence ranges from 150 gallons per day to approximately 200 gallons per day per residence. These values are from cluster systems with septic tank effluent

Table 2.6 Typical Wastewater Flows From Various Facilities

Facility	Unit	Flow gallons/unit/day		Flow Liters/unit/day	
		Range	Typical	Range	Typical
Airport	Passenger	2-4	3	8-15	11
Apartment/House	Person	40-80	50	150-300	190
Automobile service station	Vehicle served	8-15	12	30-57	45
	Employee	9-15	13	34-57	49
Bar	Customer	1-5	3	4-19	11
	Employee	10-16	13	38-61	49
Boarding house	Person	25-60	40	95-230	150
Department store	Toilet room	400-600	500	1500-2300	1900
	Employee	8-15	10	30-57	38
Hotel	Guest	40-60	50	150-230	190
	Employee	8-13	10	30-49	38
Industrial building (sanitary waste only)	Employee	7-16	13	26-61	49
Laundry (self service)	Machine	450-650	550	1700-2500	2100
	Wash	45-55	50	170-210	190
Office	Employee	7-16	13	26-61	49
Public lavatory	User	3-6	5	11-23	19
Restaurant (with toilet)	Meal	2-4	3	8-15	11
Conventional	Customer	8-10	9	30-38	34
Short order	Customer	3-8	6	11-30	23
Bar/Cocktail lounge	Customer	2-4	3	8-15	11
Shopping center	Employee	7-13	10	26-49	38
	Parking space	1-3	2	4-11	8
Theater	Seat	2-4	3	8-15	11

Sources: U.S. Environmental Protection Agency. "Onsite Wastewater Treatment Systems Manual," *EPA 625-R-00-008.* Cincinnati, OH: U.S. EPA Publication Clearinghouse, 2002.

pressure (STEP) sewers. When cluster systems are served by traditional gravity sewer systems, the effect of infiltration and inflow must be considered in the design flows and loads. Viessman and Hammer (1998) advise that infiltration and inflow may be as high as 60,000 gallons per day (gpd) per mile where groundwater tables are high and sewers are not tight and that, for 8″ diameter sewers, rates of 3500 to 5000 gpd per mile represent the

Table 2.7 Waste discharge by individual on a dry weight basis

	lb/capita-day		gram/capita-day	
Constituent	Minimum	Maximum	Minimum	Maximum
BOD5	0.11	0.26	50	120
COD	0.30	0.65	110	295
TSS	0.13	0.33	60	150
NH3 as N	0.011	0.026	5	12
Organic N as N	0.009	0.022	4	10
TKN as N	0.020	0.048	9	21.7
Organic P as P	0.002	0.004	0.9	1.8
Inorganic P as P	0.004	0.006	1.8	2.7
Total P as P	0.006	0.010	2.7	4.5
Oil and Grease	0.022	0.088	10	40

Source: Crites and Tchobanoglous, "Small and Decentralized Wastewater Management Systems," 1998.

Note: mass load (lb/day) = concentration (mg/l) x flow (gpd) x 8.34 x 10-6
mass load (gram/day) = concentration (gram/m3) x flow (m3/day)

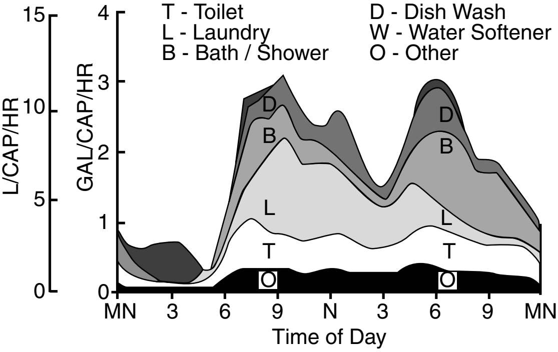
range in which most specifications fall. Photo 2.1 shows a sign where one community is facing the reality of leaking conventional sewers. Photo 2.2 shows overflowing sewer system near the pump station and you can see a standby generator next to the pump station.

Though average daily flow may be appropriate for estimating the size of a wastewater treatment system, consideration must be given to the fact that peaks occur during the course of the day. Figure 2.3 illustrates the variability and patterns typical of a day's residential flows. When sizing wastewater treatment systems, it is always advisable to consider peak flows as well as average daily flows. Even with single residential systems, these peaks may have an effect on the treatment system. In addition to daily flow variation, seasonal variations may also occur. Typically, wastewater treatment processes are sized to treat the maximum daily flow rather than simply average daily flow. Maximum daily flow is the maximum flow that occurs over the course of a single day, perhaps 450 gpd for a typical 3-bedroom home. Average daily flow is the average of flow that occurs during single days over the course of some period of time, perhaps years. This may be approximately 150 gpd. The onsite system can then be designed for all types of flow conditions.

Philosophically (if not particularly statistically rigorous), designing wastewater treatment system performance based on average daily flow would imply that 50% of the time, the system is in compliance and 50% of the time the system is out of compliance. For this reason, treatment systems are typically designed to produce the required effluent quality when treating the maximum daily flow. With cluster systems, the effect of instantaneous peaks may be dampened because of the number of homes; however, even

Photo 2.1 Infiltration and Inflow Project Sign

Photo 2.2 City sewer system facing problems due to I & I – Note the over flow of raw wastewater from the manhole and the backup power generator in the background.



Source: University of Wisconsin, 1978.

Figure 2.3 Daily indoor water use patterns for single-family residences. Variability and patterns typical of a day's residential flows.

in that case, the maximum daily flow should be considered during design of any wastewater system to compensate for the effect of increased load during the days when large flows may occur. These considerations are sound engineering principles applied to all wastewater systems regardless of whether they are decentralized or traditional sewer systems. As discussed in the following paragraph, these effects have an even greater impact when a commercial system is considered. An easily understood example is a school, in which dramatic peaks may be experienced during such periods as recess, between classes, and during and after lunch breaks, when meal preparation and dishwashing occur.

There are two concepts that need consideration while designing a wastewater system — *hydraulic loading rate* and *mass loading rate.* When considering the hydraulic loading rate, the volume of water flowing through the treatment process is the design parameter under consideration. For the concept of *mass loading rate,* the idea of the mass or weight of a particular contaminant flowing through the system over some time is considered. *Organic loading rate,* the number of pounds or kilograms of BOD per day, or *solids loading rate,* the number of pounds or kilograms of TSS per day, are common mass loading rates.

By combining wastewater characteristics determined by estimates from tables or typical residential wastewater, or perhaps by sampling and analyzing a particular wastewater stream, with the flow rate, the wastewater load may be calculated. This calculation is the product of the flow rate and the concentration as follows:

$$\text{Load} = \text{Concentration} \times \text{Flow x Conversion factor} \qquad (2.3)$$

Typically, as shown in the tables provided in this text, concentration is given in units of milligrams per liter (mg/L) and flow rate is given in units of gallons per day (gpd). Conversion to consistent units is required to produce units of mg/day, lbs/day, or other expressions of weight (or mass) of contaminants per time.

Some examples of facilities that produce wastewater that is dissimilar to residential (domestic) wastewater are listed Table 2.8. As illustrated by

Table 2.8 Nonresidential Wastewater Concerns

Source	Waste Products
Restaurants and convenience stores where cooking occurs (including service stations and truck stops)	Cooking oils, animal fats, detergents, cleansers, and other materials
Dairy bars	Milk products
Hospitals and clinics	Antibiotics, antibacterial soaps and cleansers, and pharmaceuticals
Meat processing and slaughterhouses	Blood, hair, cleaning agents (possibly acidic or caustic or both), fats, oil, and grease
Car washes	Soap, grit, particulates, "road tar," and petroleum wastes
Photography laboratories	Photographic chemicals
Beauty salon	Hair treatment chemicals and dyes, soap, and shampoo
Laundries and dry cleaners	Lint, particulate, dry cleaning agents, acidic and caustic compounds, soaps, and dyes
Schools	cafeterias that can discharge wastewater that resembles restaurant waste i.e., cooking oils, animal fats, detergents, and cleaners; chemistry and biology laboratories that can discharge chemical wastes or biological wastes; and photography and journalism laboratories that can discharge photo processing chemicals; home economics laboratories where clothes washing, cooking, or other activities may generate wastewater similar to a restaurant or a laundry i.e., cooking oils, animal fats, detergents, cleaners, bleach, clothes, lint, etc. Also, see the note above regarding TSP from "chemical dishwashers."
Mortuaries	located in rural areas served by decentralized wastewater systems may have even more particular considerations in terms of biological agents, embalming fluids, soaps, and cleansers that become part of the wastewater stream.

this table, wastewater may consist of any number of components that can influence its treatability. When considering the treatment process as a first-order reaction, an easily biodegradable component such as blood may have a very large reaction rate constant, k. A less readily degradable component such as grease may have a very small reaction rate constant. A large rate constant means that if the waste is aerobically biodegraded, the oxygen uptake rate is very rapid and oxygen must be supplied at a high rate. This affects the selection of the aeration method — whether passive aeration can be used or if mechanical aerators must be chosen and, if so, the rate at which they must supply the air. Aeration rate affects the aerator size, horsepower, and physical delivery system, such as compressors or blowers, diffusers, pipes tubes, induced draft aerators, and so forth Although the aeration rate must be high for an easily degradable waste, the reaction, or detention, time (and therefore the tank size) may be smaller than for a less readily degradable waste (one with a small reaction rate constant).

For less easily biodegradable waste (very difficult wastes are sometimes called *recalcitrant*), air may not need to be supplied as quickly; however, reaction time is longer. This translates into a larger tank volume — either more or bigger tanks — so that the wastewater can react for a longer time in order for the reaction to proceed to the same level of completion as for quickly degrading waste.

Another factor that influences reaction rate is temperature. A rule of thumb is that the reaction rate doubles for every 10°C temperature increase. This means that oxygen uptake is more rapid at warmer temperatures, requiring air to be supplied at a higher rate. Waste degrades more quickly at warmer temperatures, so it need not be held in the treatment system as long when it is warm. The converse is also true: in winter, oxygen uptake is low and air need not be supplied as fast. However, at this temperature, waste takes longer to degrade and would thus need to stay in the treatment system longer. The practical implication of this concept is that aerators are designed using summer temperatures and detention tanks are designed using winter temperatures. An illustration of the way that reaction rates affect the final concentration is shown in Figure 2.4.

Figure 2.5 shows the affect of the reaction rate upon the oxygen requirement (biochemical oxygen demand). In this illustration, k_1 is the fast reaction rate caused either by warm temperatures or by very easily degradable wastewater, and k_2 is the slower reaction rate caused by cold temperatures or by a more difficult to degrade wastewater. In both cases, the final concentration at the end of the treatment is the same. It simply takes longer for the waste with k_2 to reach the final concentration. Figure 2.5 illustrates the same two wastewaters and reaction rates, showing the rate at which the oxygen demand is exerted. The implication of this figure is that with a faster oxygen demand (i.e., a faster reaction rate), the oxygen must be supplied at a faster rate but for a shorter time. With the slower reaction rate, k_2, oxygen can be supplied more slowly but it must be supplied for a longer time. In both Figures 2.4 and 2.5, if the volume of wastewater processed is the same, the

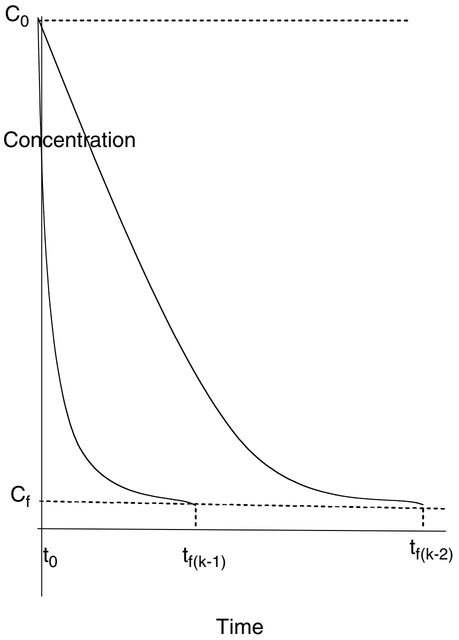


Figure 2.4 Reaction rate and time for completion of treatment

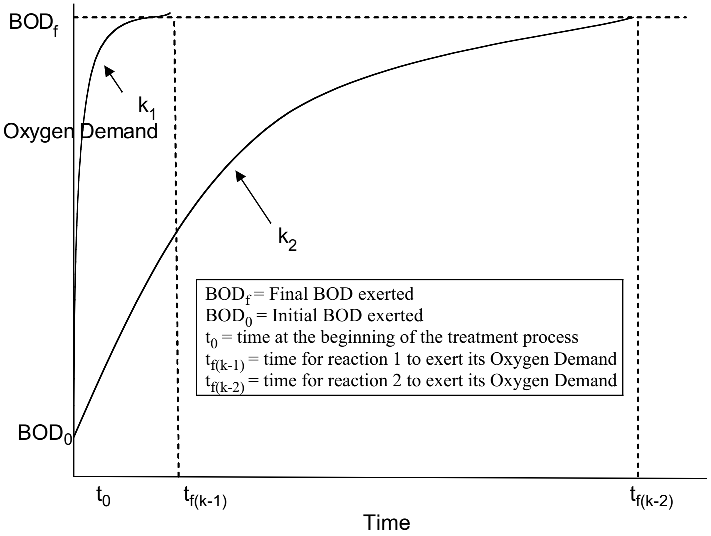


Figure 2.5 Effect of reaction rate on final concentration and oxygen uptake rate.

same amount is degraded, and the same of amount of oxygen is supplied. The waste is simply degraded over a longer period (longer detention time

= larger tank volumes), and the oxygen is supplied for a longer time and at a slower rate (fewer pounds per hour = smaller horsepower blowers) for k_2.

An example of this is diluted blood with a BOD of approximately 150 mg/L. As a passing note, the BOD of blood is in the range of 150,000 mg/L. Diluted blood may have a BOD similar to residential-strength wastewater, but it is very easy for microbes to degrade and, therefore, the reaction rate is very fast. It is possible that a treatment system that performs perfectly well, producing a high-quality effluent with little odor or clogging when treating residential wastewater, would simply be overwhelmed and could become anaerobic and clogged if the diluted blood is processed. Even if the same flow rate passes through the treatment process and the wastewater strength is the same, the treatment unit may not be designed to provide oxygen at a rate high enough to prevent the wastewater treatment process from becoming anaerobic. The result could be odors, incomplete treatment, and clogging of the treatment unit.

Temperature and FOG

Another important wastewater characteristic, although not typically listed in tables of typical properties of wastewater, is temperature. The previous discussion illustrates the importance of temperature on the biochemical reactions for wastewater treatment; however, temperature may also have a significant effect on the physical treatment processes. One common example of this occurs with wastewater from a restaurant or school cafeteria. Wastewater from cooking and dishwashing may have high concentrations of FOG. Typically, the method for removing grease from kitchen waste is to plumb the kitchen drains through a grease trap. Conventional grease traps are simply baffled sedimentation/flotation tanks that allow wastewater to slow down long enough to let the grease float to the top. The grease trap outlet is baffled to allow liquid to pass under the floating grease and flow onto the wastewater treatment system.

In order for FOG to float (to state the obvious), it must be lighter than water. Congealed FOG tends to be lighter than water. Grease needs to cool to congeal and separate from the water carrying the grease away from the kitchen. Some considerations for allowing FOG to separate and float include the temperature of the water entering the grease trap, the temperature of the grease trap, and the length of time the wastewater is allowed to stay in the grease trap (detention time) to cool before passing onto the next wastewater collection or treatment process. A longer detention time allows the contents of the grease trap to cool and FOG to separate.

One of the ways to clean dishes more effectively is to increase the temperature of the water entering the dishwasher. Public health officials inspect kitchens and check the temperature of dishwashers as well as the time that dishes are exposed to hot water. As a result, in order to be safe, some restaurants run their dishwashers at very high temperatures. The result may be that wastewater entering the grease trap is too hot, and FOG does not have adequate detention time in the grease trap to cool and separate. FOG may be carried onto the next treatment process, and either clog or overwhelm a secondary treatment system or clog the soil absorption system. Setting the dishwasher temperature to a lower setting may allow the grease trap to operate more effectively.

Another consideration for grease trap effectiveness is that grease trap sizing criteria in prescriptive regulations are typically from old regulations written when animal fat was the main form of cooking oil used in kitchens. Modern oils include liquid oils that remain liquid at room temperature and may be more difficult to separate from wastewater than are animal fats (such as lard and suet). Again, temperature, time, and the emulsion properties of the FOG in the wastewater affect the grease trap performance and may cause poor performance or failure of a downstream treatment process. Furthermore, dishwashing detergents may keep the FOG suspended or emulsified in the waste stream, allowing it to pass through the grease trap with the water.

An additional issue is that some dishwashers now use trisodium phosphate (TSP) as an injected chemical cleaning agent. These dishwashers are sometimes called *chemical dishwashers.* Injecting TSP in the washing process allows dishwasher temperatures to be set lower to save energy. However, some anecdotal field evidence indicates that TSP emulsifies grease into smaller particles that are not removed in grease traps or septic tanks.

Pumping a grease trap is a cost that restaurant managers, hospital managers, and school maintenance personnel are likely to want to decrease or eliminate. Chemical grease removal products for introduction to the grease trap itself are available to keep the grease in suspension, allowing it to pass through the grease trap and giving the illusion that the grease has "gone away." The grease may well be passing through the grease trap rather than being trapped. Although this method may cut costs in the short term by reducing or eliminating the cost to pump the grease trap (and thereby improving the manager's profit and loss sheet), the long-term cost may well be repair or replacement of expensive downstream wastewater treatment equipment or the soil absorption system. Wastewater characteristics may be modified by adding seemingly helpful agents that result in poor performance and possibly damage to wastewater treatment processes.

Determining wastewater characteristics

Since not all wastewater is residential wastewater, some effort may need to be exerted to determine wastewater characteristics. Tables 2.3 and 2.4 are reasonable and reliable methods for estimating residential wastewater strength. For wastewater generated by establishments other than homes, some extra effort may be needed to determine wastewater characteristics.

If a system is in place and wastewater is already being generated but a new process or a modification is being designed, the waste stream can be sampled and analyses can be performed to determine the wastewater characteristics. When sampling to determine wastewater characteristics, some understanding of wastewater-generating processes and patterns is helpful to design the sampling program. For example, if the wastewater is from a school, it may be helpful to sample during the time that lunches are being prepared and served and also during the time that dishes and the kitchen are being cleaned. In addition, it may be helpful to sample during recess at elementary schools. Possibly, a 24-hour composite sample would be helpful if the process has the potential for being designed with equalization tankage for a large detention time, allowing for mixing of waste. If the waste is processed in batches as it is generated, with little or no equalization, fluctuations in wastewater characteristics may be very important and sampling in discrete increments may be the most effective way to gather information for design. Automatic sampling equipment eases the task of sampling in timed increments as well as collecting a 24-hour composite. Samplers are available that can provide refrigeration while the sample is being collected and stored inside the sampler.

If a wastewater-generating facility is not already in place and estimates must be made for future wastewater treatment, similar installations (schools, convenience stores, truck stops, restaurants, etc.) may be sampled and analyzed to provide a comparison for estimating wastewater characteristics.

Once wastewater samples have been properly collected, simple analyses for BOD, TSS, pH, acidity or alkalinity, FC, nitrogen, and nutrients may or may not be adequate for characterizing the waste. Some wastewater may contain compounds that are very difficult to treat or that are toxic to the microbes typically populating wastewater treatment systems. Some laboratories have the capability to perform treatability studies. Essentially, the wastewater is processed in bench-scale treatment systems, and the rate of oxygen demand is measured. This is a simplification of the treatability study, but the goal is typically to determine the rate constant, sludge production rate, oxygen uptake rate, and other parameters for designing the treatment process. Examination of the wastewater under a microscope is also a common way to see if microscopic life exists in the wastewater. If no life is observed, there is a concern that a toxin is present in the wastewater.

The number of constituents present in any wastewater will vary and will depend on the source that is generating the wastewater. For the purposes of discussion in this book, we will consider the following six constituents of interest in wastewater that any advanced onsite wastewater treatment system will be designed to treat: BOD_5, TSS, FOG, TN, TP, and FC.

A simple look at wastewater treatment

As wastewater moves through a treatment system, physical and biochemical processes occur. The physical process of settling is expected to occur in septic tanks, trash tanks, interceptor tanks, and processing tanks of onsite septic systems, aerobic treatment units, STEP systems, and recirculating media systems. Some digestion, either anaerobic as in septic tanks or aerobic in some processing tanks, also occurs, degrading and digesting large organic molecules and organic nitrogen forms, resulting in more easily digestible organic acids and other small carbon compounds as well as ammonium nitrogen.

As these substrates pass into aerobic treatment mechanisms within the secondary treatment system, microbial growth is stimulated. Organic compounds are used as a source of food by the microbes and converted to carbon dioxide and water, as illustrated by this equation:

$$\text{organic matter} + O_2 + \text{microbes} \rightarrow CO_2 + H_2O + \text{new microbes (e.g. biomass)} \qquad (2.4)$$

This is the ideal situation, in which all organic matter is completely oxidized to carbon dioxide and water and returned harmlessly to the hydrologic cycle. As shown in the previous equation, oxygen is required for the reaction to proceed. In well-sited and properly-functioning onsite systems, this process occurs within the boundaries of the site upon which the system is located, and wastewater is renovated within a distance that prevents contamination of groundwater or surface water.

Ammonium in wastewater is converted into nitrite and then to nitrate by processes using free oxygen (aerobic processes) called *nitrification.* First, ammonium is converted to nitrite plus hydrogen ions by a consortium of bacteria called "Nitrosomonas":

$$\text{Step 1: } NH_4^+ + {}^3\!/_2 O_2 \rightarrow NO_2^- + 2H^+ + H_2O \qquad (2.5)$$

Then nitrite is converted to nitrate by a consortium of bacteria called "Nitrobacter".

$$\text{Step 2: } NO_2^- + {}^1\!/_2 O_2 \rightarrow NO_3^- \qquad (2.6)$$

As with microbial degradation of organic matter, the nitrification reaction requires the presence of free oxygen. Thus, the system must be aerobic in order for this process to proceed. Also, this process, known as *nitrification,* requires 7.1 mg of alkalinity as calcium carbonate ($CaCO_3$) for every 1 (one) mg of nitrogen. If the nitrified wastewater encounters anoxic conditions and contains enough organic compounds, the nitrate can be converted to nitrogen gas and other gases by anaerobic processes called *denitrification,* as shown in this equation:

$$NO_3 + \text{organic compound} + \text{microbes} \rightarrow N_2 \text{ (and other gases)} \qquad (2.7)$$

Phosphorus may be removed either by using chemical phosphorus removal (alum, lime, or iron sulfate compounds), by adsorption and complexation, by biological nutrient removal (typically used in large-scale wastewater treatment systems), by dispersing the treated wastewater into soil with high phosphorus affinity, or by plant uptake and harvest using irrigation methods.

Microbiological contaminants are readily removed using disinfection techniques, as mentioned in Chapter 1. These processes are explained in detail and with much greater accuracy in the wastewater treatment texts listed in the reference section.

Concept of overall treatment levels

In order to classify advanced onsite wastewater treatment technologies based on their ability to treat wastewater and reduce the constituents of interest, we define a term called *overall treatment level* (OTL) and establish a procedure to compute OTL based on the removal rates (reduction levels) for each of the constituents of interest. This approach allows manufacturers of these technologies to market them in a uniform manner and allows regulators to specify treatment levels necessary prior to discharge into any proposed RE.

The concept we present in this chapter for calculating OTL is very general and can be customized to meet specific requirements. It is important to follow the procedure presented here and, if and when necessary, customize the input information to meet your specific requirements. Onsite treatment systems are designed to reduce wastewater constituents to some extent, and the rate of reduction for different constituents can be different. Not all treatment systems are designed to reduce all six constituents; it is the job of a designer to select an appropriate treatment system that meets the necessary overall treatment requirements before dispersal into an RE. Once a designer knows the treatment level required before discharge, the treatment necessary after discharge into the RE (soil) can be determined. Thus, the designer can determine how much of the RE (land area) is needed for the proposed soil and site conditions to ensure that 100% treatment is achieved before the effluent moves out of the design boundary of the effluent dispersal system, typically the end of the owner's property and about 10′ below the ground surface.

The overall treatment level achieved by an onsite wastewater treatment system is defined as the weighted average of the removal rates for the constituents of interest that the treatment system is designed to remove, typically measured as percent reduction in mass load or concentration compared to the levels of these constituents present in raw wastewater. Thus, OTL can be computed by a simple equation:

$$\mathrm{OTL} = \sum_{n=1}^{i} \mathrm{weight}_n * \mathrm{removal\ rate}_n \tag{2.8}$$

where

constituents of interest are from 1 to i

weight_n is the relative weight given to the n^{th} constituent

removal rate_n is the percent reduction (mass load or concentration) in the n^{th} constituent achieved by the treatment system.

In order to appropriately assign weights to the constituents of interest, we propose that constituents be grouped in three groups:

- Group 1 — BOD_5, TSS, FOG
- Group 2 — TN, TP
- Group 3 — FC

The following two simple rules can be used to determine the relative weight of each constituent of interest:

- Rule 1 — All groups get equal weight, i.e., weight for each group = 1/number of groups included in the calculations.
- Rule 2 — Each constituent within a group receives equal weight, i.e., the weight for a constituent within the group = 1/number of constituents included in that group.

As indicated before, not all onsite treatment systems are designed to treat all constituents of interest. Thus, we need to define different scales to allow for fair computations of OTL for a given treatment system based on the system's treatment scheme. We propose the creation of four scales, as follows:

- Scale A — when all groups and all constituents are included in the calculations
- Scale B — when all groups are included but not all the constituents within any given group are included in the calculations
- Scale C — when not all the groups are included in the calculations, but all the constituents within the groups that are included are included in the calculations
- Scale D — when not all the groups or all the constituents within the selected groups are included in the calculations.

An example of this concept is presented in Table 2-9, along with the values for weight for the constituents of interest. Note that you can change the selection of a group or a constituent following the above-mentioned rules and recalculate the values for the weights. Once you get comfortable establishing the values for weight, the next step is to establish the values for removal rates. Currently no nationally accepted design standards for advanced onsite treatment systems exist.

Table 2.9 Weight Calculations for Different Scales

EXAMPLE

Group	*Constituent*	*Scale A*	*Scale B*	*Scale C*	*Scale D*
Group 1	BOD5	✓	✓	✓	✓
Group 1	TSS	✓	✓	✓	✓
Group 1	FOG	✓		✓	
Group 2	T-N	✓	✓		
Group 2	T-P	✓	✓		
Group 3	FC	✓	✓	✓	

Weights

Group	*Scale A*	*Scale B*	*Scale C*	*Scale D*
Group 1	0.3333333	0.333333	0.5	0.5
Group 2	0.3333333	0.333333	0	0
Group 3	0.3333333	0.3333333	0.5	0.5

Group	*Constituent*	*Scale A*	*Scale B*	*Scale C*	*Scale D*
Group 1	BOD5	0.1111111	0.166667	0.166667	0.25
Group 1	TSS	0.1111111	0.166667	0.166667	0.25
Group 1	FOG	0.1111111	0	0.166667	0
Group 2	T-N	0.1666667	0.166667	0	0
Group 2	T-P	0.1666667	0.166667	0	0
Group 3	FC	0.3333333	0.333333	0.5	0.5

The septic tank, the most common onsite treatment system in the 20th century, has been used without any well-defined standards for removal rates. However, data on septic tank effluent quality is available in the textbooks listed in the reference section of this chapter. We used that information to calculate removal rates for the constituents of interest by the septic tank treatment system.

For advanced onsite treatment systems, we propose standards for removal rates for the constituents of interest, and we hope that the industry will start designing and testing their treatment systems against these standards. We propose five treatment levels:

- Treatment level 1 — Primary treatment: typically achieved by septic tanks for which available effluent quality data are used to determine levels of reduction;
- Treatment level 2 — Secondary treatment: 90% reduction in Group 1 constituents, 30% reduction in Group 2 constituents, and 90% (one log) reduction in Group 3 constituents;

- Treatment level 3 — Advanced secondary treatment: 95% reduction in group1 constituents, 60% reduction in Group 2 constituents, and 99% (two log) reduction in Group 3 constituents;
- Treatment level 4 — Tertiary treatment: 99% reduction in Group 1 constituents, 90% reduction in Group 2 constituents, and 99.99999% (seven log) reduction in Group 3 constituents;
- Treatment level 5 — Advanced tertiary treatment: 100% reduction for all constituents contained in all Groups.

This treatment scale is intended to be comfortably related to the current, less numerically defined terms of primary, secondary, and tertiary treatment. This attempt is made in order to provide the reader and user a familiar basis for comparing the proposed scale to current terminology.

The only thing required to use the OTL concept is to develop a complete list of constituents to be considered for treatment and classify them appropriately within each of the three groups. Note that grouping follows simple rules:

- Group 1 would have constituents that relate to organic loading, such as BOD_5, TSS, and FOG.
- Group 2 would have constituents that relate to nutrients, such as TN and TP.
- Group 3 would have microbiological constituents, such as FC.

Once the groups are determined using the two rules mentioned earlier in this section, a weight can be assigned for each of the constituents. Then the aforementioned removal rates for each of the treatment levels may be used to compute the OTL for any proposed scheme. A treatment system designer may select different removal rates for the constituents of interest; in other words, some constituents may be reduced at level 2, whereas others may be reduced at level 4, based on the quality and quantity of the RE present at the project site. Following the aforementioned procedure, OTL may be computed for any treatment scheme proposed for the project. Once OTL before effluent discharge is known, the designer must make certain that the rest of treatment occurs after the effluent is discharged onsite within the design boundaries of the effluent dispersal system.

The removal rate can be calculated from the effluent data using the following equation, which is similar to the efficiency equation [Equation (2.1)] mentioned earlier in this chapter:

$$\text{Removal rate} = [(\text{In} - \text{Out})/\text{In}] \times 100 \tag{2.9}$$

expressed as % removal of mass for the constituents in Groups 1 and 2, or concentration for the constituents in group 3.

Using this relationship, removal rates that can be expected from a septic tank are computed and presented in Table 2.10. Note that the overall treat-

Table 2.10 Septic tank treatment levels for various constituents (Source: Crites and Tchobanoglous, *"Small and Decentralized Wastewater Management Systems,"* 1998)

Constituent	Raw wastewater	Septic tank without effluent filter		Septic tank with effluent filter	
		Minimum	Maximum	Minimum	Maximum
BOD5	450	150	250	100	140
TSS	503	40	140	20	55
Oil and Grease	164	20	50	10	20
TKN as N	70.4	50	90	50	90
Total P as P	17.3	12	20	12	20
Fecal Coliform	10^6-10^8	No significant reduction		No significant reduction	

Removal rates calculated using Equation 2.9 for Septic tank – Treatment Level 1.

Constituent	Septic tank without effluent filter		Septic tank with effluent filter	
	Minimum	Maximum	Minimum	Maximum
BOD5	67%	44%	78%	69%
TSS	92%	72%	96%	89%
Oil & Grease	88%	70%	94%	88%
TKN as N	29%	0%	29%	0%
Total P as P	31%	0%	31%	0%
Fecal Coliform	05	0%	0%	0%

Note: Removal rates for each constituent are calculated based on raw wastewater concentration and septic tank effluent concentration. Minimum effluent concentration from septic tank will give results in maximum removal rate and vise-a-versa.

ment level for a septic tank depends on the scale one selects and the type of removal rates one uses for computation. The overall treatment rates for advanced onsite treatment systems depends only on the scale one selects. Also, using this information, the effluent quality expected from an advanced treatment system that is designed to reduce either all or some of the constituents of interest may be calculated.

A spreadsheet can be set up to do all these calculations. We have posted such a spreadsheet on our web site that you can download and use. An example of results from such spreadsheet calculations is presented in Table 2.11. What happens when the scale is changed? The values for OTL change for each treatment level. Table 2.12 presents the values for OTL that can be expected for each of the four scales.

As shown in Table 2.12, OTL expected from a treatment level 1 system, such as a septic tank, varies from a minimum of 19% to a maximum of 45%, depending on the number of constituents included in calculations, while that for treatment level 2 systems, such as a secondary treatment system, varies from a minimum of 70% to a maximum of 90%, a significant increase compared with septic tanks. This means that the treatment necessary after discharge is significantly less for any advanced treatment system (treatment levels 2, 3, 4, or 5) as compared to septic tanks (treatment level 1).

Table 2.11 Example of Overall Treatment Level (OTL) Computation.

Select Scale (A – D):	A	Note: See discussion on the scale type in "Basics" tab of the spreadsheet			
Septic tank effluent: data type (1, 2, 3, 4)	4	Note: See discussion and calculations on septic tank effluent data type in "Removal Rates" tab of the spreadsheet.			
	Treatment Level 1	Treatment Level 2	Treatment Level 3	Treatment Level 4	Treatment Level 5
Overall Treatment Level OTL =	21%	70%	85%	96%	100%
Group Treatment Levels					
Group 1 (BOD5, TSS, Oil and Grease)	21%	30%	32%	33.3%	33.3%
Group 2 (Total N and Total P)	0%	10%	20%	30%	33.3%
Group 3 (Fecal coliform)	0%	30%	33%	33%	33.3%
Constituent	**Weight**				
BOD5	0.1111111	44.4%	90.0%	95.0%	99.0%
TSS	0.1111111	72.2%	90.0%	95.0%	99.0%
Oil and Grease	0.1111111	69.5%	90.0%	95.0%	99.0%
Total N	0.1666667	0%	30.0%	60.0%	90.0%
Total P	0.1666667	0%	30.0%	60.0%	90.0%
Fecal coliform	0.3333333	0%	90.0%	99.0%	99.99999%

[a] The values for septic tank removal rates are from the Table 2.10 for septic tank without effluent filter and minimum removal rates.

[b] The values for treatment levels 2, 3, 4, and 5 are based on proposed standards for these types of advanced onsite treatment systems.

Table 2.12 OTL versus Scale

	Treatment Level 1 by Septic Tank							
	w/o Effluent Screen		w/Effluent Screen		Treatment Level 2	Treatment Level 3	Treatment Level 4	Treatment Level 5
Scale	Max	Min	Max	Min				
A	37%	21%	40%	27%	70%	85%	96%	100%
B	36%	19%	39%	26%	70%	85%	96%	100%
C	41%	31%	45%	41%	90%	97%	99%	100%
D	40%	29%	43%	39%	90%	97%	99%	100%

A graphical representation of this concept is presented in Figure 2.6. This is the reason why we believe that the use of advanced onsite treatment with the necessary management infrastructure can be viewed as a true alternative to centralized collection and treatment plants, not just as an alternative to septic tank systems or a temporary solution until a "real" sewer arrives.

Performance testing of onsite wastewater treatment systems by third-party testing facilities is very critical to validate the design criteria and ongoing operation and maintenance requirements in order to achieve the reduction in waste load on a continuous and consistent basis. Performance of any advanced onsite treatment system needs to be tested under controlled conditions, in which the quality and quantity of influent can be controlled, as well as on a limited basis in the field where the quality and quantity of influent on a day-to-day basis cannot be controlled. A treatment system that is designed to handle peak load as well as variation in load should perform in a satisfactory manner under both controlled and field conditions.

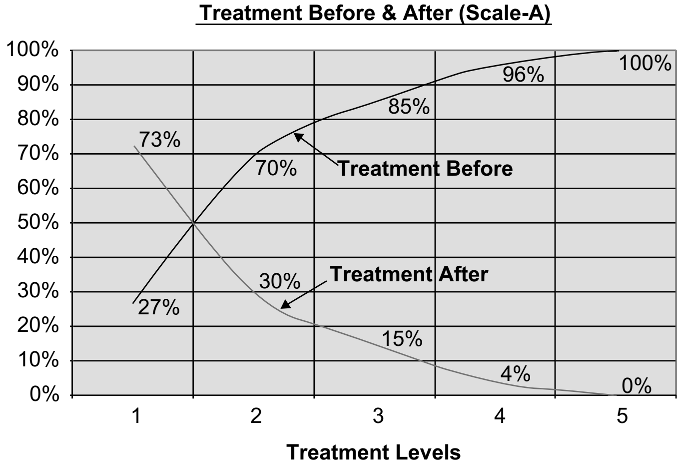


Figure 2.6 Treatment outside (before discharge) versus inside soil (after discharge).

There is some discussion that system performance may be evaluated by "operational" analyses rather than "compliance" analyses. The difference is that checking operational parameters such as pH, dissolved oxygen and turbidity, as well as sludge and scum levels and appearance may be more cost effective than chemical sampling and analysis for compliance. It is important to note that the operation and maintenance of advanced onsite treatment technologies are very important and necessary, because the majority of treatment is expected to happen before effluent is discharged into soil. Thus, management of these treatment technologies on a permanent basis is a must and details of different management models are presented later in this book.

Soil and site issues

In the 21st century, all the people involved with the use of decentralized, onsite systems should shift their focus from using soil and site criteria for acceptance or rejection of a lot to using appropriate onsite treatment before dispersal and also to operation and maintenance of the treatment systems on a permanent basis. Using appropriate advanced onsite treatment and dispersal technology, a wastewater solution can be developed for any buildable lot or site.

Installation of small, shallow trenches; filter beds; drip dispersal; spray irrigation; or minimum or zero discharge systems can be achieved on almost any site when adequate square footage of space is available. Site suitability for use of such systems is not dependent on origin (natural or fill material), type (texture and structure), depth, or color of the soil present at the site. Thus, it is very important to note here that the soil and site evaluation practices that are currently used nationwide for approving a site for a septic system will need to be significantly revised when the use of advanced onsite treatment systems is proposed.

Simply put, the purpose of a soil and site evaluation will change from determining whether the proposed site is "suitable" for installation of an advanced onsite system to determining what treatment level for various constituents of interest may be necessary to install the proposed advanced onsite system on the proposed site. Use of an advanced onsite system is possible as long as the designer can assure that the effluent dispersal system will function in a manner satisfactory to the user, and the management entity can assure that the treatment system will function in a manner necessary to meet the treatment standards on a permanent basis at a cost acceptable to the owner.

As a rule of thumb, we propose that when the use of an individual home advanced onsite treatment system is proposed under a responsible management entity, 6″ per year (about 450 gallons per day per acre) be considered in the regulatory framework as the minimum hydraulic assimilative capacity of any lot. The onsite system designer's job will then be to select an appropriate treatment system and design an effluent dispersal system that will not create any of the following conditions:

- A point-source discharge (i.e., a stream flowing out from the area)
- A public nuisance (e.g., a puddle of water on or around the area during dry weather conditions)
- A health hazard from the operation of the onsite system
- Groundwater or surface water contamination due to organic, inorganic, or bacteriologic contaminants that are discharged into the effluent dispersal system.

Since soil and site evaluation has been an integral part of the onsite industry and since most of the current regulatory programs have defined the soil and site criteria for installation of a septic tank drain field system, in Chapter 6 we propose a step-by-step approach for redefining soil and site evaluation processes in a way that assigns "credits" for use of advanced treatment and effluent dispersal system on sites that may or may not be suitable for use of septic systems. Eventually, we believe that the regulatory emphasis put on the soil and site evaluation process today will be replaced with an emphasis on performance monitoring and inspection of advanced treatment systems. The process of locating a site for an effluent dispersal system following an advanced treatment system is as simple and as independent of soil characteristics as it is for locating a site for installing the advanced treatment system itself. Typically, the distance between the wastewater source (house or commercial dwelling) and the treatment system is minimized under the concept of a decentralized wastewater system. Similarly, the distance between the effluent dispersal system and the advanced treatment system should also be minimized. Furthermore, only when effluent reuse is proposed may the effluent be transported longer distances to the sites where reuse is desired.

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chapter three

Media filters

Introduction

Media filters as discussed in this text are fixed film treatment processes designed to follow primary treatment in a septic tank and to provide more highly treated effluent. The effluent produced by these filters can be disinfected and discharged under a National Pollutant Discharge Elimination System (NPDES) permit, dispersed in the subsurface soil, or reused for irrigation or nonpotable household purposes. Media filters are one of the oldest types of treatment mechanisms for both water treatment and wastewater treatment. During their early use in England, sand filters were applied to treat water prior to use as drinking water. Sand filters continue to be used in large and small applications for water and wastewater treatment where they are used as pressure filters. In these cases, the media is completely saturated and the water is ponded on top of the filters to provide adequate head to push either the treated drinking water or pretreated wastewater through the crust, or *schmutzdecke* (dirty floor), of material that accumulates on the filter surface. These types of filters are known as *pressure filters* and, although used for filtering secondary quality treated wastewater such as settled aerobic treatment plant effluent, they should not be confused with the filters used for treating septic tank effluent.

Although media filters for wastewater treatment may perform some functions similar to pressure filters for water treatment, they should not be confused with pressure filters. The physical functions of the media filter are straining, entrapment, adsorption, and impaction. These physical phenomena may be quite effective at the beginning of the filters' operation, but they may decline and become less important as the filter matures and the biochemical processes become the prevalent method of wastewater treatment.

Media filters provide a fixed material for establishing a thin biological film by organisms living on the surface of the media. Wastewater passes through the bed and comes into contact with the attached microbial mass. The mechanism should be familiar to traditional sanitary engineers in that one commonly encountered form of the media filter is the *trickling filter.*

Another relatively well-known type of packed bed filter used for wastewater treatment is the *single-pass intermittent sand filter.* The organisms are in contact with wastewater as it percolates over the surfaces and flows slowly in an unsaturated state through the media. The process requires small, frequent doses of effluent to promote unsaturated, thin-film flow over the media surface. Air within the pores of the media provides oxygen transfer to the organisms attached to the surface. In this way, aerobic organisms digest contaminates in the wastewater as it moves slowly through the system (Figure 3.1). Aeration may be passive or active, depending on the system design or loading rate. The mode of treatment is a combination of filtration and trapping, adsorption, biological decomposition, and biochemical transformation.

Important to obtaining a well-treated effluent is the method of dosing the settled wastewater onto the filter surface. Some older design guides (U.S. Environmental Protection Agency [EPA], 1980) suggest a loading rate of 5 gallons per day (gpd) per square foot of media surface and recommend dosing by flooding the filter surface 2 in. deep with septic tank effluent. The design produced poor-quality effluent and caused the media to clog after a few months or years of service. Some of the remedies for this malfunction include rototilling the surface of the sand to break up the microbial crust and removing the media and replacing it with new media. However, without addressing the dosing problems, rototilling simply allowed the crust to reform and sometimes deepen. Media removal and replacement was costly and was merely a temporary solution until the biological clogging mat (biomat) reformed and the media become reclogged.

In this chapter, the use of small, frequent doses will be discussed. As knowledge has progressed, designers have found that using small, frequent doses keeps the filter unsaturated and aerobic and has improved performance and greatly extended the life of filters. Although current loading rates

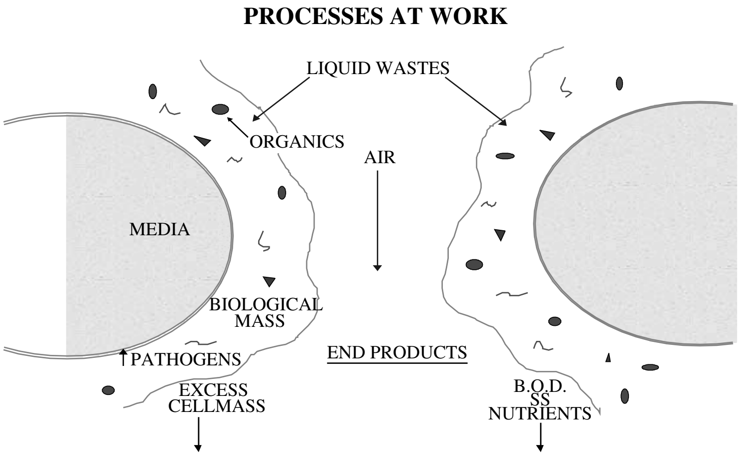


Figure 3.1 Schematic of Flow and Treatment Effects on Media Particles

Table 3.1 Typical Domestic-Strength Septic Tank Effluent And Media Filter Effluent

Treatment System	BOD mg/L	TSS mg/L	Nitrate-N mg/L	Ammonium-N mg/L	D.O. mg/L	Fecal Coliform Org./100 ml
Septic Tank	130-250	30-130	0-2	25-60	<2	10^5–10^7
Media filter	5-25	5-30	15-30	0-4	3-5	10^2-10^4

Total phosphorus (P) content depends on whether detergents with high P content are used. A media filter does not remove much P. P concentrations in septic tank effluent and PBF effluent may range from 4 to 20 mg/L (D.O. = Dissolved oxygen)

may be lower than those proposed in the 1980s, the return in terms of improved water quality and filter life more than compensates for the costs associated with increased filter size.

Media filters are a beneficial option for onsite systems in environmentally sensitive areas or areas where soils are not considered hydraulically acceptable for septic tank effluent. Media filters are used to produce effluent low in biochemical oxygen demand (BOD_5) and total suspended solids (TSS) that also has a greatly reduced concentration of pathogenic organisms in relation to septic tank effluent (Table 3.1). Media filters also transform nitrogern by the processes explained in Chapter 2 and as shown in columns 3 and 4 of Table 3.1. The increase in Dissolved Oxygen (D.O.) in the media filter effluent (as compared to septic tank effluent) is a result of the introduction of air as illustrated in Figure 3.1.

A mature media filter is not particularly effective for phosphorus removal. Although clean sand may be quite effective for removing phosphorous, over time, as the filter matures, the influent phosphorus concentration and the effluent phosphorous concentration are essentially the same (Nichols et al., 1991). Phosphorus concentrations in media filter effluent may range from 4 mg/L to 20 mg/L. Many designers and researchers believe that the resulting effluent can be discharged to soils at higher rates than septic tank effluent without developing a biomat at the infiltrative surface of the soil absorption system. Duncan et al. (1994) showed that for highly treated effluent such as that from a sand filter, a lesser depth of natural soil is required to complete the treatment process than with septic tank effluent. These examples illustrate the principle that the treatment system is less dependent on the soil when using an advanced onsite wastewater system than when using a simple septic tank for treatment prior to dispersal into soil.

Theory of attached-growth wastewater treatment systems

The media in a filter bed provides material that has a high surface area per volume and easily passes water and oxygen. Wastewater is distributed across the surface of the media. As the wastewater passes through the bed, a microbial ecosystem establishes itself on the surface of the media in the form of a fixed film. Organisms, ranging from amoeba to larvae, establish an ecosystem in the media. This is sometimes referred to as an *attached-growth process,* in contrast to the *suspended-growth process* used in extended aeration activated sludge. Fixed film reactors reduce the BOD of wastewater by exposing the organic compounds to the attached (fixed) microorganisms. Easily digestible organic material is converted to cell mass (more microorganisms), heat, water, and carbon dioxide as illustrated by equation 2.4 in Chapter 2.

A biologically active film of organisms forms on the surface of the media. Microorganisms play an essential role in treating the wastewater as it flows over the media surface. Certain bacteria, known as *primary colonizers,* attach via adsorption to the surfaces and differentiate to form a complex, multicellular structure known as a *biofilm.* The microorganisms that form the film over the media are nearly always present in the wastewater and generally do not have to be introduced to the treatment system. However, for this biofilm to form, proper environmental conditions are required. For example, a food source must be present — organic carbon and nitrogen compounds in the wastewater must be supplied. However, other conditions must also be present. A simple mnemonic for remembering the elements required for biochemical degradation is "CHONPS café" — sometimes pronounced "Chonops Café" — which refers to carbon, hydrogen, oxygen, nitrogen, phosphorus, and small amounts of calcium and iron. Sufficient moisture is also an important factor. Temperature, amount of readily available oxygen, and pH also play important roles. If these factors are present, a biofilm can form around a media particle. Typically, at temperatures near 20^0 C, a biomat may be mature enough for nitrification within 14 to 21 days. When the treatment system is receiving wastewater, adequate moisture is usually available; however, adequate air movement through the system to provide the needed oxygen has been deficient in some systems, particularly those that are organically or hydraulically overloaded, as discussed in Chapter 2. As wastewater percolates past the media and microorganisms, the biofilm grows by entrapping organic material. During rest periods, the trapped organic matter is digested.

Many different types of heterotrophic bacteria are found in these biofilm layers. Calaway (1957) discovered 14 different species of heterotrophic bacteria in different levels of a single-pass sand filter. All species were present at all times, indicating that bacteria adapted to the environment and were carrying on metabolic processes. These bacteria were in the upper layers, in about the first 12 in. (30 cm), of the sand. Insufficient food in lower levels resulted in most of the active organisms remaining in the top layer. Increasing dosing rates produced a marked increase in the number of bacterial species in the filter. Several researchers have shown that smaller, more frequent doses improve coliform removal (Emerick et al., 1997; Darby et al., 1996).

Both nitrifying bacteria (those that convert ammonium to nitrite then nitrate) and denitrifying bacteria (those that convert nitrate to nitrogen gas) are present in filter media. Although media filters are typically considered aerobic systems, the interstitial spaces within the media provide zones (microsites) of stagnation where anaerobic conditions may be present, promoting denitrification and therefore a net loss of total nitrogen. The net nitrogen reduction through an intermittent sand filter may be expected to be approximately 30 percent. With loading rates at or below the recommended design values indicated in Table 3.2, most of the BOD is removed in the first few inches of the media and most of the ammonium is converted to nitrate within the first foot or so (Calaway, 1957).

In addition, viruses have been found trapped within the first few inches of media, resulting in significant virus removal in a mature media filter (Gross & Mitchell, 1990). Deeper in the media, organism populations are reduced, oxygen may be less available, and reaction rates are lower. However, some nitrification appears to occur deeper, as evidenced by the fact that deeper filters provide more ammonium reduction (Bounds, 2003). Some recent filter designs include enhanced ventilation, drafting, or forced aeration to ensure complete air movement throughout the depth of the filter or as a recovery mechanism if biological clogging occurs.

Some media filters are manufactured to be loaded organically and hydraulically low enough to keep the biofilm in steady-state, endogenous respiration so that organisms in the biofilm are degraded and decomposed at the same rate that they are formed. This prevents clogging and sloughing of the biofilm. The lower portions of the filter media catch any material sloughed from above and maintain a consistently high effluent quality. Other media filters resemble traditional trickling filters and are designed to be loaded at a rate that causes the biofilm to occasionally slough. The enclosure in which the filter is contained provides an integral clarifier for settling the sloughed biofilm, and the resulting sludge is typically returned to the primary settling and processing tank with the recirculated effluent. Common sense would lead a designer to understand that, eventually, the degraded sludge would need to be removed from the primary settling and processing tank. This is expected to take place when the primary tank is pumped during routine maintenance.

The oxygen requirement for a media filter can be estimated using the equation:

$$O_2 = 8.34(10^{-6})\ Qi\ [1.2\ BOD_5 + 4.57\ TKN] \tag{3.1}$$

where

O_2 = pounds of oxygen required per day

BOD_5 = biochemical oxygen demand concentration reduction through the filter, mg/L

TKN = total Kjeldahl nitrogen concentration reduction through the filter, mg/L

Qi = daily (forward) flow through the filter, gpd

In some cases, the oxygen requirement is met simply by passive venting of the media filter unit through vents placed from the filter enclosure surface to the bottom of the filter. Typically, the air is supplied by a passively induced draft from the vent through sewer vent piping leading through the house and the roof vents. This mechanism is similar to the flue of a fireplace. In other cases, where the organic and hydraulic load is sufficiently high, and the passive venting does not provide adequate oxygen, a mechanically induced draft (blower) is provided to supply the oxygen demand to the media filter.

Types of natural and synthetic media used for treating wastewater

The media characteristics of interest are the surface area provided by the media upon which the biological film develops, the available pore space, and the pore space's characteristics for air movement. Characteristics of the media in several media filters, including some commonly used proprietary filters, are shown in Table 3.2.

Media filters may be classified based on the type of media used and whether effluent passes through the filter one time or is recirculated and subjected to multiple passes through the media. Following is a list of media types that have been used, classified by how the material originates, whether occurring in nature or manufactured. All of the materials listed below may be used in either single-pass or recirculation mode:

- Natural and mineral media
  - Sand or gravel
  - Expanded shale
  - Cinders
  - Limestone
  - Activated carbon
  - Peat or peat fiber
  - Manufactured products
- Textile fabric
  - Open cell foam cubes
  - Hard plastic
  - Crushed glass
  - Tire chips
  - Processed slag

The application of any of these media should be considered in terms of their life expectancy, whether they are expected to slough and produce biosolids, and their maintenance requirements. Manufacturers and suppliers have experience with and information on these factors for their particular media filters. Typically, manufacturers or their representatives work closely with design engineers to size wastewater treatment systems, including all of the tankage, pumps, clarifiers, valves, and other necessary appurtenances. The

Table 3.2 Media Filter Loading Rates, Dose Volumes, and Media Characteristics

Type	Hyd. Load, gpd/ft^2	Org. Load lb BOD/ft^2/da	Distr. System	Dose Vol. Gal/ft^2	Media Depth inches	Doses per Day	Media Void Space, %	Water holding capacity % vol.	Media Size, d_{10}, mm	Media Surface Area ft^2/ft^3
SPSF	0.7-1.2	.0007-.0021	1/8″ per 4-6 ft^2	.05-.1 (<0.5 gal/orifice)	24	18-24	30	<10	0.3–0.6	800-1000
RSF	3-5	.002-.0083	1/8″ per 4-6 ft^2	0.1-0.5 (0.5-2 gal/orifice)	24-30	48-96	30	<7	1.5-2.5 mm	500-700
Advantex^{tm} (textile)	25-35	.04-.058	1/8″/0.3 ft^2*	0.6-1.2	22	72-144	90	<25	N/A	2400-4800
Waterloo^{tm} (open cell foam)	11.2–16.8**	.013-.016**	Helical spray nozzles @ 10 psi	0.13**	36-102	80 - 140	30	50	2-in cubes	not published
SCAT^{tm} (open cell foam)	11-16	0.015-0.016 power ventilated	Helical spray nozzle @ 5-8 psi	1.2–1.5	30 (min.)	not published	30	50	2-in cubes	not published
Puraflo (peat fiber)	5.6	0.014	¼″ per 3–4 ft^2	10-12 gal/module	24	12	90-95	50-55	not published	6×10^6
Premier Tech (peat)	4-8.6	0.005-0.01	Gravity or pump to tipping bucket	0.03	31.5	20–80	>90%	85	.25-2.0	5x 10^5
PEATEC (Septisorb) Recirc. (peat spheres)	6.2	not published	Spiral nozzles	0.2-0.3	24	90-120		60	1-2 mm sphere	
Eco Pure (peat)	5.7	0.014	Gravity or pump to simulate gravity distr.	0.3	26	20 if pumpis used		50-60	not published	not published

* For the commercial unit (AX 100), distribution is by spray nozzles covering 3-4 ft^2 per nozzle.
** Values are for a 3-ft deep system. The company gives design values per ft^3 instead of per ft^2.
Note: Conversion factors: 1 gpd/ft^2=40.74 Lpd/m^2; 1 lb BOD/ft^2/day = 4.885 Kg/m^2/day; 1 inch = 2.54 cm

design engineer must supply the appropriate information, such as expected daily flows (including peaks, average, and minimum flows), wastewater strength, any particular wastewater characteristics that might affect treatment, and some idea of the trend of the system toward growth into its ultimate expected hydraulic and organic capacity in the case of phases of a subdivision or similar development. Some systems do not perform well when they are underloaded, and this may be a factor in the way that the system is designed and constructed. Most media filter systems used for decentralized wastewater treatment are constructed as modular units and, therefore, may be phased in as the wastewater capacity is required.

The most commonly used types of media filters are briefly introduced here. Design criteria and operational recommendations are discussed later.

Sand and gravel filters

Single-pass sand filters and recirculating sand filters are common types of media filters that contain natural sand or gravel particles as the media for the filter. Sand or gravel particles are screened to meet specific grain size distribution specifications. These specifications are designed to provide the required surface area for bacterial attachment, with adequate void space for passive airflow and oxygen to aerobic organisms, and sufficiently large voids to prevent rapid clogging by the combination of filtered solids and biological growth. Single-pass sand filters generally use media with an effective size in the range of 0.28 to 0.35 mm; recirculating sand filters, 2 to 5 mm. In addition, the uniformity coefficient (U.C.) of the media is important to prevent void spaces from being filled by small particles. A uniformity coefficient less than 4.0 is recommended; however, no evidence exists that a perfectly uniform media (U.C. = 1.0) would be less effective than a less uniform media.

Peat filters

Several proprietary designs of media filters utilize peat or peat fiber. This peat may be selected from specific parts of the world to provide the desirable characteristics. Peat has the high surface area and high-void volume configuration needed for efficient packed bed filter geometry. When peat is dry, it is light (lower density) compared with such mineral media as sand and can be placed into containers (called *pods*) for shipment to the site. This allows the installer to simply excavate the correct size hole, set the peat pods, plumb them, and install the appropriate electronic controls. "Plug and play" components have an advantage over sand filters in that the peat filters may be installed in their own pods without the necessity of constructing an enclosure for the media as part of the construction of the wastewater system.

Peat degrades over time and may need to be replaced after some years. The *pod* remains in place, with all plumbing, and the media is simply replaced with new peat. However, peat may provide better coliform removal than do some of mineral and synthetic media. One characteristic of peat filter effluent that may be noticed is the color. The humus in the peat may impart a slightly brownish or "tea" color to the treated effluent; however, this trait has not been found to be of any detriment to the treatment capability of the systems in terms of BOD, TSS, coliform, or nitrogen removal.

Manufactured media filters

Various manufactured media are being utilized. Examples include open-cell foam cubes, specially designed synthetic fabrics, plastic pipes, and packed tower media (typically used in air stripping towers or trickling filters). Crushed glass can be used in designs that are very similar to sand or gravel filters. Filters with several different materials are described in Leverenz et al., 2002. Other manufactured media have been tried and may be developed further for use in the future. One advantage of synthetic media is the uniform characteristics of any particular media due to manufacturing of the media to the same size and shape. In addition, synthetic media may be manufactured to provide particular hydraulic characteristics, such as conductivity, porosity, and storage capacity per unit volume. Also, the density of the media may be controlled. Given this control, the potential for manufacturing media with specific characteristics, such as lightness, provides the possibility of packaging treatment systems in modules that may be installed in an excavation as plug and play units. Then modules may be added or brought online as wastewater flow increases, thereby matching treatment capacity to wastewater flow and load.

Flow and load estimates

Crites and Tchobanoglous (1998) recommend the use of a per capita flow allowance and a peaking factor as a method of determining an appropriate design flow for a home. They use a per capita allowance of 50 gpd (200 Lpd) and a peaking factor of 2.5, resulting in a peak per capita design flow of 125 gpd (475 Lpd). For a three-bedroom home having four persons in residence, this method results in a daily design flow of 500 gpd (1900 Lpd). Wastewater system design for small systems and individual homes is highly controlled by local regulations. Each local regulation has a procedure for determining design flows or total flows for a home, or other sources of wastewater, that must be followed.

In addition, wastewater strength and load (concentration × flow) should be taken into account when designing any wastewater treatment system. In this chapter, if wastewater characteristics are not specifically mentioned, the design should be considered as applying to typical residential-strength screened septic tank effluent.

Single-pass systems

Single-pass sand filters, and most other media filters, perform best if dosed using a pressure distribution system. Test data from field monitoring of early pressure-dosed sand filters is presented by Roynayne et al. (1982). Typically, pressure distribution is in the form of a small-diameter-pipe pressure distribution system, so that the effluent can be uniformly applied in small, frequent doses (Figures 3.2a and 3.2b). Pressure-dosed sand filters, which are hydraulically loaded within recommended design limits (Table 3.2) and are not overloaded organically by wastewater of high strength, have functioned for very long periods without significant clogging at the infiltrative surface.

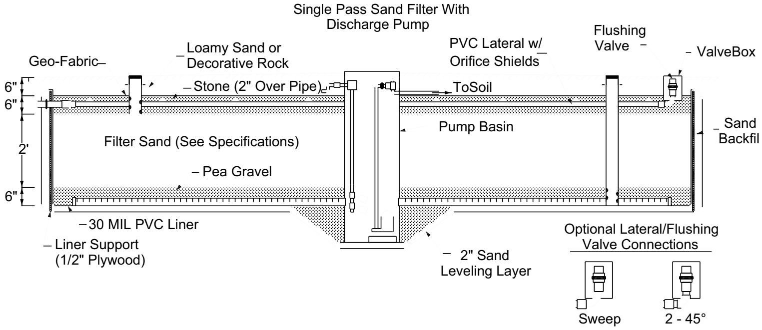


Figure 3.2a Single pass sand filter with discharge pump.

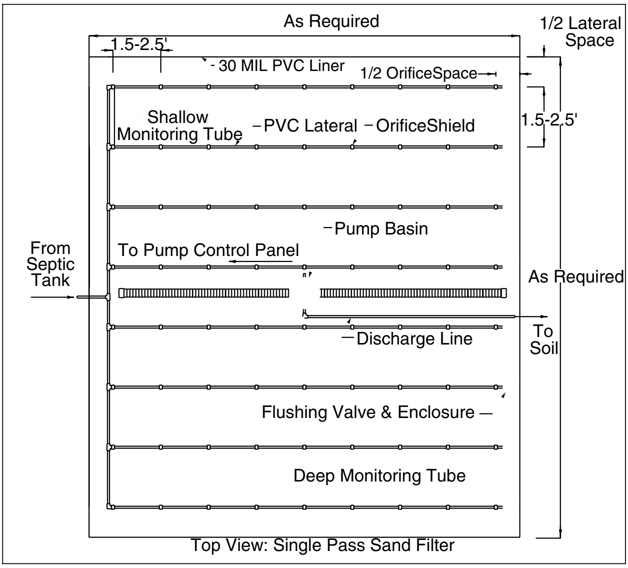


Figure 3.2b Top view: single pass sand filter

The small-diameter pipes used to apply effluent typically are imbedded in a stone layer and have discreet orifices, generally 1/8 in. (3 mm) diameter, spaced 1.5 to 2.5 ft (45 to 75 cm) apart, discharging against some form of orifice shield to avoid stones interfering with orifice discharge and also to prevent the orifice flow from jetting a hole in the media and resulting in a stream of primary treated wastewater squirting into the air over the filter surface. Orifice spacing can be reduced to improve uniformity of coverage and reduce point loading, but hydraulic and organic loading recommendations per unit area specified in Table 3.2 should not be exceeded. Reducing orifice spacing results in more orifices to be supplied with effluent, at the same time resulting in a higher flow rate requirement for the pump if the orifice size and pressure are maintained. The resulting increase in required pump flow rate can be overcome by dividing the distribution system into alternately dosed zones. As an alternative, spray nozzles may be used over a filter surface if the filter is in an enclosure to prevent odors and aerosols from escaping the treatment system. This method provides even distribution and may also supply additional aeration as the wastewater is sprayed over the surface of the filter.

When designing intermittent or recirculating media filters, it is a common mistake to specify a geotextile between the media and the underdrain. The concept is good, because it makes sense to provide a way to prevent the media from sifting into the underdrain gravel material. Unfortunately, in application, the result is that the geotextile clogs, probably with iron bacteria, and the entire filter can fail. Simply constructing a filter with moist media and a layer of pea gravel over the larger underdrain gravel allows the media to bridge over the pea gravel and the sifting problem can be avoided. The moisture content required to achieve this is not particularly critical, but forming a sand slurry is ineffective and counter productive. A simple way to determine if the moisture is adequate is that if the sand is moist enough to make a sand castle, it is about the right consistency to prevent sifting into the underdrain.

Pressure distribution systems are typically contained within pea gravel or a coarse stone layer with sufficient cover over the pipe that the applied effluent does not reach the top of the stone layer. Commonly, a shallow layer, 6 to 8 in. (15 to 20 cm) deep, of sandy or loamy sand soil is added over a geotextile fabric that is placed over the stone of single-pass sand filters. The soil is usually sod covered. Improved aeration of the sand media can be achieved if the sand filter is covered with decorative stone or some other porous covering material instead of the sod-covered soil. The stone covering is preferred from a functional standpoint.

Deep rooting plants must be kept away from the sand filter. Sand filters must be located and placed at an elevation such that they are not subject to surface water run-on. Traffic over the sand filter must be avoided so that the surface does not become compacted. Nothing that would reduce air movement into the sand filter should be placed over the surface.

Single-pass sand filter media

The media specification for sand used in single-pass sand filters is critical. Most single-pass units contain a single gradation of media in the treatment layer. However, in certain specialized situations, stratified sand layers containing different gradations of media in discrete layers may be used. The media in any sand filter must be free from fines (particles passing a number 100 sieve, a screen with 100 openings per inch). Fine sediment, if present in the media, congregates in the pores between the larger particles, reducing the hydraulic conductivity and contributing to reduced flow that may eventually result in system failure.

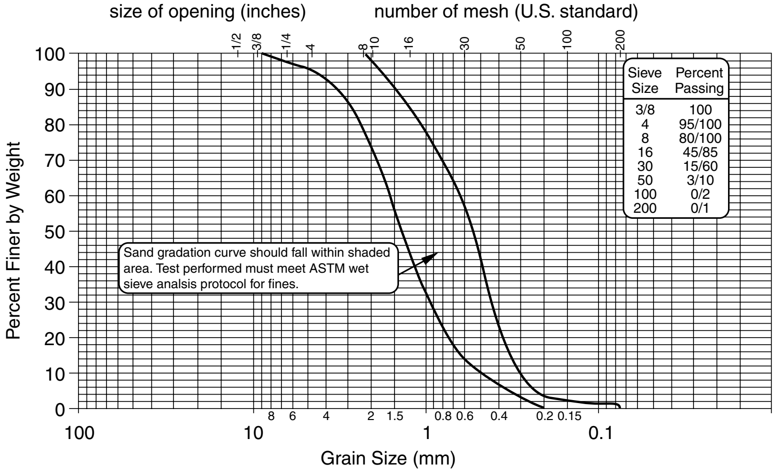
A useful, rudimentary field test for determining the presence of fines in sand filter media is the jar test. In a standard quart-size fruit jar, place 2 in. (5 cm) of the media to be tested and add water to fill the jar three-fourths full. Next, shake the material vigorously to suspend the fines. Then allow it to stand for 60 minutes to settle (Crites and Tchobanoglous [1998] say fill the jar half full of sand and let it sit for 30 minutes). If a perceptible layer of fines is visible on the surface of the media (greater than approximately 1/16 in. [1.5 mm]), the sand is not clean enough to be used in a single-pass sand filter.

Sand media are typically defined by their effective size and uniformity coefficient. Effective size is the particle size for which 10% of the particles in the mix are smaller (d_{10}). The uniformity coefficient (UC) is defined as the particle size for which 60% are smaller (d_{60}) divided by d_{10}. The formula for UC is:

$$\mathrm{UC} = d_{60}/d_{10} \tag{3.2}$$

The uniformity coefficient is an index of the degree to which particles in sand are of the same size or have a range of sizes. The larger the number, the greater the range of particle sizes. The recommended effective size (d_{10}) for pressure-dosed, single-pass sand filter media is 0.012 to 0.020 in. (0.3 to 0.5 mm), and the recommended UC is 1.0 to 4.0.

Treatment efficiency is a function of the retention time for the applied effluent within the media. Higher retention times provide greater opportunity for pathogen predation and biological processes involved in organic matter decomposition and nitrogen removal. Media containing smaller particles have greater surface areas and greater retention times for the liquid flow but have lower hydraulic conductivity and have a greater tendency to clog. Choosing media is a balance between long retention time and minimal clogging. Figure 3-3 shows a recommended grain size distribution range for a single-pass sand filter. The graph is based on conventional units with sieve size in inches for larger screens and sieve number (openings per inch) for smaller ones; particle size is given in millimeters.



Sieve Size	Percent Passing
3/8	100
4	95/100
8	80/100
16	45/85
30	15/60
50	3/10
100	0/2
200	0/1

Sand gradation curve should fall within shaded area. Test performed must meet ASTM wet sieve analisis protocol for fines.

Figure 3.3 Grain size distribution chart for single-pass filter media.

Loading rate and surface area

The design-loading rate for a packed bed filter is the design daily application rate for septic tank effluent, usually expressed in terms of gpd/ft^2 (or Lpd/m^2). The maximum expected daily flow should be used for design. Studies show that residents in homes served by septic systems typically use 50 to 65 gpd per person (200 to 250 L/c/d) as indicated as the average daily flow from residences in Chapter 2.

Various design hydraulic loading rates have been used for sand filters of different media and different loading configurations. Experience with modern pressure-dosed sand filters shows that design loading rates in the range of 1 to 1.25 gpd/ft^2 (40 to 50 Lpd/m^2) result in durable systems that provide high effluent quality (i.e. BOD$_5$ and TSS less than 10 mg/L). This text recommends designing on the basis of a maximum of 1.25 gpd/ft^2 (50 Lpd/ m^2). This would result in the single-pass sand filter for a three-bedroom home having about 280 ft^2 (26.5 m^2) surface area based on a design flow of 350 gpd (1325 Lpd). Note that this design flow is estimated as a maximum daily flow and not the average daily flow from a typical residence. As mentioned previously, it simply is not prudent engineering practice to design a treatment system for actual average daily flow if a particular effluent quality is required on a consistent basis.

Typical single-pass filter effluent has Carbonaceous Biochemical Oxygen Demand (CBOD$_5$) and TSS concentrations under 10 mg/L (often less than 5 mg/L) and usually 30% to 50% of the nitrogen in the influent is removed, with nearly all of the remaining nitrogen in nitrate form. Fecal coliform counts in the final effluent are more variable but may range from less than 50 to 10^4 most probable number (MPN)/100 ml. Typically, one can expect that a single-pass sand filter will produce at least a three-log reduction. Darby et al. (1996) showed that dosing amount and frequency could influence coliform removal.

The organic loading rate for media filters is defined as the daily loading expressed in terms of pounds of BOD_5. Typical values for design loading rates of single-pass sand filters are 0.0007 to 0.0021 Lb $BOD_5/ft^2/day$ (0.0034 to 0.010 $kg/m^2/day$). Organic loading is calculated from BOD_5 concentration and flow, as follows:

$$L = Q \times BOD_5 \times 8.34 \times 10^{-6} \tag{3.3}$$

where

L is organic load in lb BOD/day
Q is daily flow in gpd
BOD_5 is concentration in mg/L
8.34×10^{-6} is a conversion factor to convert from parts per million to pounds.

Consider the situation where design flow is 350 gpd (1325 Lpd) and the expected effluent has a BOD_5 of 130 mg/L. The organic load to be applied to a single-pass sand filter can be estimated:

$$L = 350 \times 130 \times 8.34 \times 10^{-6}$$

$$L = 0.38 \text{ lb of } BOD_5 \text{ (0.17 Kg) per day}$$

If this is applied to a 350 ft^2 (32.5 m^2) sand filter, the unit area organic loading (La) is:

$$La = 0.38/350$$

$$La = 0.0011 \text{ lb } BOD_5/ft^2/day \text{ (0.0052 Kg/m}^2\text{/day)}$$

As organic loading rate increases, the probability of failure increases. High strength wastes with BOD_5 greater than domestic strength (greater than 250 mg/L) should not be applied to single-pass sand filters on a continuous basis without pretreatment. The designer must be aware of the relationship between the design flow and the design-loading rate for media filters. A factor of safety must be incorporated into the design either by the choice of design flow, loading rate, or both. For single-home systems, the factor of safety must be high enough to assure that the actual loading rate will not exceed design even if high water users occupy the home. As more homes are clustered on a collection and treatment system, the actual water use will approach average rates and the chosen safety factor may be less.

Single-pass peat filters

Peat has been successfully used as media in media filters. A peat filter consists of a distribution system; the peat treatment media, where the removal of organic matter and pathogens takes place; and the drain. Several manufacturers market peat- or peat-fiber-based single-pass media filters as proprietary products. Peat filters typically come prepackaged in a modular unit ready to plumb from a pump with controls to dose the system appropriately. Some peat filters are gravity fed with a tipping bucket to distribute effluent and provide a dosing effect. The media comes in several varieties: peat moss or peat fiber in bulk, peat pellets, and peat bales. Each of these media has different characteristics, as shown in Table 3.2.

The peat media in peat filters is very carefully chosen and, in some cases, is processed by the manufacturer. When designers have tried to develop systems using local peat or peat from landscape firms, the filters typically failed in a short period of time.

Peat filters house a wide variety of microflora, ranging from bacteria to nematodes. Peat, being a natural biological material, deteriorates over time and needs to be replaced after years of use. Replacement times depend on the type of peat but life expectancy is estimated to be 8 to 20 years. Each company has proprietary information on their unit. and designers must follow prescribed design criteria. Used according to manufacturers' recommendations, peat filters provide excellent treatment. As with sand filters, peat filters are dosed several times per day with small amounts of effluent to provide long residence time in the media as the water moves through the peat. Peat provides a large surface area and, at the same time, a large void space for air movement to put oxygen in contact with thin films of wastewater moving over the peat media structure. It is important to follow the proprietary recommendations on sizing peat filters and designing loading amounts and frequencies. Each peat module is rated for a specific daily flow.

Peat filters have been shown to discharge effluent quality similar to sand filters over years of study (O'Driscoll, 1998). The color of the effluent may be similar to tea; however, this finding has not been correlated to any increase in normally measured wastewater parameters for wastewater treatment efficiency. The treated effluent draining from peat filter containers may infiltrate the soil by spreading into a porous matrix, such as a bed of stone directly under the containers; may be diverted to a dosing tank for pumping to the soil absorption system; or may be directed directly to a nearby soil absorption system.

Methods and benefits of recirculation

Any of the media filters discussed so far can be utilized in either a single-pass or recirculating mode. However, when recirculation is used, the media characteristics may be somewhat different from single-pass filters. One advantage of recirculation is that the unit can be subjected to higher hydraulic and organic loading rates and produce about the same quality of effluent. This results in a smaller area requirement or "footprint" for the treatment system while providing high-quality effluent. Higher loading capacities are especially beneficial in applications in which it is necessary to fit a filter into a small site or in which the system must handle larger flows. Recirculation may be advantageous in situations in which it is desirable to design for enhanced nitrogen removal through the treatment process because some of the nitrified effluent from the filter may be recirculated to an anaerobic compartment of the processing tank. Multiple-pass recirculation processes also provide operation and maintenance benefits with respect to process flexibility in treating peak hydraulic surges, greater periodic organic loads, and improved odor control. In addition, recirculation provides the flexibility to increase or decrease the recirculation ratio as the wastewater load increases, such as in the case of subdivision build-out, and also provides some flexibility for seasonal applications, such as state and national parks and recreation areas, ball fields, and other facilities that receive highly variable seasonal traffic. Unlike some of the suspended-growth processes that require adequate food to produce an acceptable effluent, media filters provide some physical treatment during startup. Also during the beginning periods of increasing loads such as the start of baseball season, or increased usage or recreational areas, the effluent quality can meet the permit limits.

Public health engineers in Illinois introduced the recirculating packed bed filter concept in the 1970s, utilizing sand as the media (Hines and Favreau, 1974). By diluting septic tank effluent with previously filtered effluent, higher application rates and smaller filter surface areas are possible with recirculating filters. Recirculating systems involve mixing septic tank effluent and effluent that has previously passed through the filter in a common tank known as the *recirculation* (or *processing*) tank. A profile view of a recirculating filter system is shown in Figure 3.4. Within this tank, a pump controlled by a timer pumps the effluent mix over the packed bed filter at a preset frequency and for a preset duration (Figure 3.5). This results in a diluted effluent

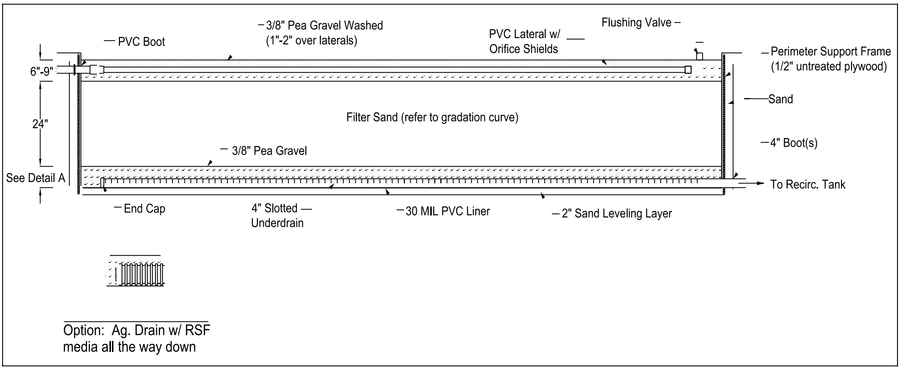


Figure 3.4 Profile view of a recirculating filter system

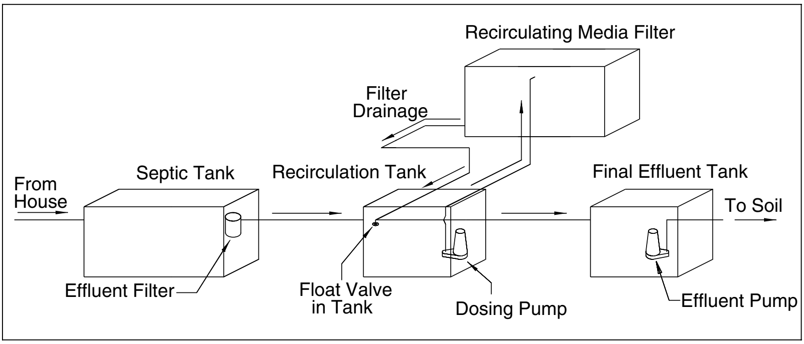


Figure 3.5 Schematic of a recirculating media filter system.

being applied frequently in equal amounts. The total daily pump run time is determined so that the total application to the filter on a daily basis is several times the daily wastewater flow coming from the septic tank. Drainage from the filter is split so that a portion goes to final dispersal or discharge (usually into soil) and a portion is diverted into the recirculation tank. It is common to use a float-based valve system in the recirculation tank to control the drainage return flow. Figures 3.6 and 3.7 show two types of splitter valves used to control the flow. Figure 3.6 shows a splitter valve that recirculates all the filter drainage back to the recirculation tank when the float valve is open. When the float valve is closed, due to a high liquid level, a portion of the flow is still recycled while some of the flow is diverted to the soil dispersal unit. With the ball closed and all of the overflow pipes open, 80% of the flow is recirculated and 20% is discharged. Overflow pipes can be capped to change this ratio. Figure 3.7 is a simple float valve that diverts all the flow coming from the packed bed filter to the soil dispersal unit or next unit in the treatment train when the recirculation tank is full. When the level in the recirculation tank drops, all the return flow is diverted to the recirculation tank to be recycled, as shown in Figure 3.8.

There are several other methods of splitting and diverting flow. Figure 3.9 shows a flow divider that returns an adjustable portion of the flow to the recirculation tank; the remainder is discharged. A disadvantage with this divider is that if there is no incoming flow to the system for a period of time, flow to the media filter diminishes to zero. The wastewater in the processing tank can become septic and, when the flow increases to cause the filter to receive wastewater again, odors can be a problem. Continual recirculation, cycling the pumps using a microprocessor timer controller, alleviates this problem.

Recirculation ratio

The recirculation ratio (Rr) is defined as the ratio of the total recirculated flow (Qr) applied to the filter daily to the influent (forward) wastewater flow (Qi), as shown in Figure 3.10 and the following expression.

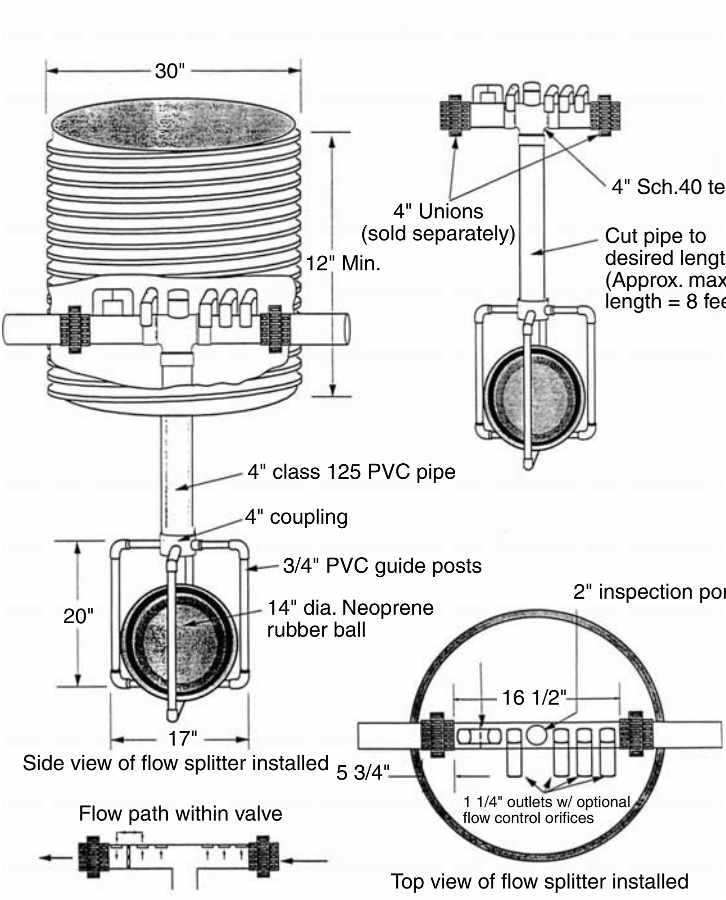


Figure 3.6 Recirculating ball value.

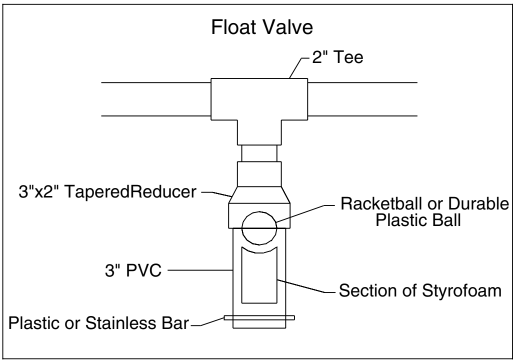


Figure 3.7 Recirculating in-line ball value.

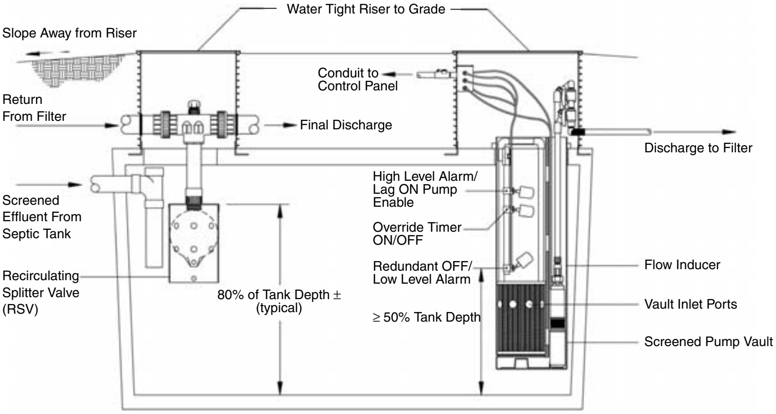


Figure 3.8 Typical recirculation tank.

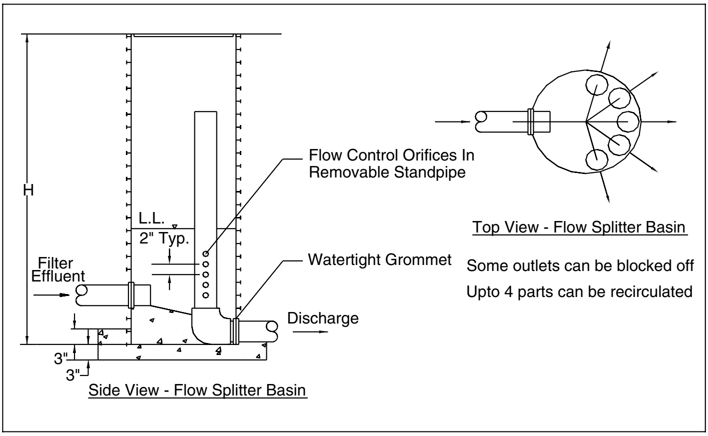


Figure 3.9 Typical flow divider.

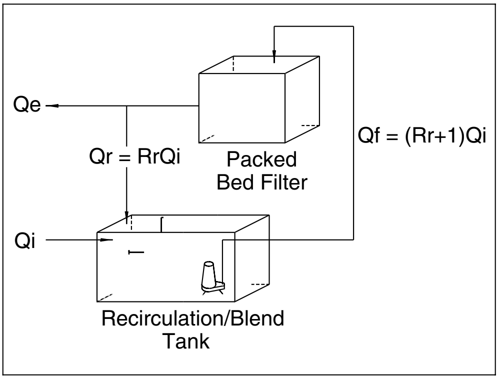


Figure 3.10 Flow distribution in a recirculating system.

$$Rr = Qr/Qi$$

$$Qr = Rr \times Qi$$

$$Qf = Qr + Qi = (Rr + 1)\ Qi \tag{3.6}$$

where

Rr is the recirculation ratio (can also be referred to as the recirc-blend ratio and can also be calculated as a ratio of Qf to Qi)
Qr is the daily flow returning to the recirculation tank
Qf is the daily flow through the filter, in gpd
Qi is the daily forward flow (i.e. daily inflow to and outflow from),
Qe is the daily effluent discharge equal to the inflow in daily flow

Rr typically ranges from 2:1 to as high as 50:1, depending on the treatment system and whether filtration of the return flow is provided to remove or reduce filamentous growth. It is important to understand that there are both high and low practical limits to Rr. Higher ratios may be preferred to prevent odor problems, but ratios of 3:1 or 4:1 (with normal strength influent at design flow) are typically sufficient for controlling odors. High recirculation ratios may affect the biology, chemistry, and life of a system. They may also elevate dissolved oxygen concentration in the recirculation tank. Under these conditions, the ecosystem becomes especially suited for filamentous microbes, which tend to cluster and overpopulate on screens and distribution pipe orifices, greatly increasing the need for maintenance. High ratios do not allow sufficient time for filtrate dissolved oxygen (DO) levels to deplete within the recirculation chamber. This tends to inhibit denitrification and cause greater nitrate concentrations to pass through, unless part of the nitrified effluent is returned back to the primary tank (septic tank) for denitrification to occur. High recirculation ratios consume more energy than necessary but may be advantageous in terms of low maintenance cost of the filter media.

With a simple float valve in the recirculation tank, the recirculation mix will vary continuously depending on the flow rate coming from the septic tank. A float valve similar to the one shown in Figure 3.6, with continuous discharge back to the recirculation tank, helps dampen out some of the variation in the recirculation mix.

The function of the Rr is as critical to process management for multiple-pass attached-growth systems as return sludge, wasted sludge, and air management are to suspended-growth processes. Proper management of the Rr assures aeration and wetting needs and, most importantly, it establishes equilibrium with respect to the desired endogenous respiration rate by maintaining appropriate food-to-microorganism (F/M) ratios relative to influent hydraulic and biological loads.

The average Rr is determined by how the timer controlling the pump in the recirculation tank that feeds the sand filter is set. If a 4:1 Rr is desired, then the pump is set to run enough minutes per day to pump five times the daily forward flow to the media filter, unless recirculation ratio is defined as flow through filter divided by forward flow. On average, one-fifth of this flow is flow from the septic tank and four-fifths is return flow from the filter. The desired flow quantity delivered to the filter per dose and the number of doses per day varies depending on the type filter media being used.

Recirculating systems generally involve pressure distribution to provide uniformity of application over the media. As discussed under single-pass systems, various application technologies are possible. The goal is to provide uniform distribution while providing flexibility in adjustment of dose volume and dose frequency.

Recirculating sand filters

Recirculating sand filters (RSFs) are used for systems as small as individual home systems up through systems for small communities. Maximum practical size depends somewhat on the relative cost of land versus the long-term cost of energy and management for more intensive systems that occupy a smaller footprint.

Recirculating gravel filters

Recirculating gravel filters (RGFs), filters containing larger media in the gravel size range of 3 to 5 mm or larger, are sometimes used for systems in which waste strength may be slightly higher or in which effluent quality is not of utmost importance. Filters using larger media are somewhat more prone to sloughing solids off the media and generally produce a poorer quality effluent in terms of BOD and TSS. However, these units can produce a high-quality secondary effluent with BOD and TSS typically in the range of 10 to 20 mg/L. In addition, larger media may provide poorer nitrification than smaller media.

Recirculation tanks

The recommended recirculation (or blend) tank volume for RSFs is equal to the daily design flow to be treated by the system. This provides adequate volume and hydraulic retention time for blending the flow as input from the primary treatment facility varies throughout the day. This size could be reduced if a very uniform incoming flow rate is expected throughout the day; however, this would be an unusual situation. In such cases, hydraulic retention time and surge capacity should be carefully evaluated. The source of the incoming flow as well as the collection system may both be factors in determining the flow variation. Commercial installations, such as restaurants, truck stops, rest areas, schools, and other establishments with similar variations in flow patterns, may require a surge capacity quite different from a residential subdivision. When gravity sewers are the collection system, or when the collection system is not watertight, infiltration and inflow (I/I) may greatly impact the volume and strength of the incoming wastewater. It is not uncommon to have inflow equal to or greater than the average daily flow of sewage from the homes. Viesman and Hammer (1998) suggest 3500 to 5000 gpd/mi of 8-inch diameter collection sewer (including the house service connections) for I/I. They also note that I/I can be as high as 60,000 gpd/mi. If I/I is taken into the design flow, I/I is often greater than the daily wastewater flow rate from the residences.

Recirculating sand filter media

The media recommended for RSFs is very coarse sand or fine gravel. The exact specification depends on the degree of treatment desired. The state of Oregon has media research-based specifications that have met the test of time and are accepted by other states as well (Roynayne, et al., 1982). Figure 3.11 illustrates the media size distribution for recirculating filter media. The fines content (materials passing a number 100 sieve) should be as low as possible, preferably less than 1% even though the above specification allows more. It is also important that the media be handled so as not to introduce any fines in the construction process and that the area immediately surrounding the filter site be protected against wind and water erosion so that fines are neither blown nor washed onto the filter. The surface of an RSF is an exposed stone surface, so any sediment deposited on the surface moves down to the infiltrative surface by rain and contributes to clogging.

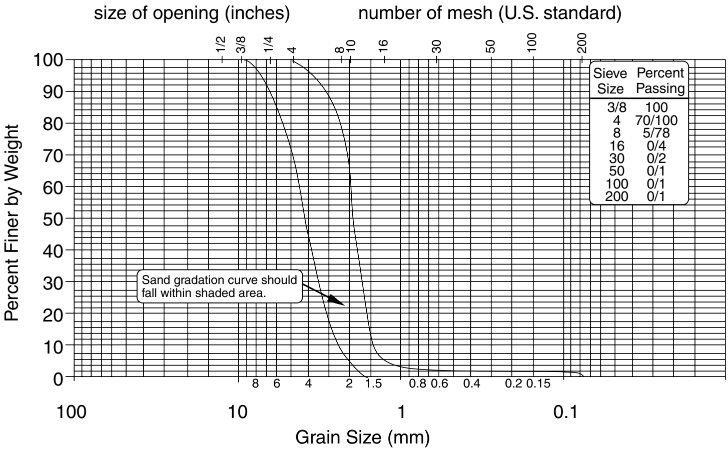


Figure 3.11 Grain size distribution chart for recirculating filter media.

Filter drain

Adequate drainage must be provided so that water can move freely away from the bottom of the filter. Typical drains are 4-in. diameter slotted pipes. Material manufactured by cutting slots in polyvinyl chloride (PVC) or slotted, corrugated polyethylene drainage pipes may be used. Drainpipes should never be surrounded by a geotextile or filter fabric. This material will clog rapidly and prevent flow from entering the drain. An "envelope" of large pea stone or coarser drain stone may be placed around the drain. This is necessary if a drainpipe with large slots is used. If agricultural drainage tubing with smaller slots is used, neither a gravel envelope nor a coarse bottom layer is necessary as long as the media meet the normal RSF specification.

A ball valve on the drain outlet is recommended so that the drain can be closed and the sand filter cell used as a temporary holding cell, if necessary to lower the level of the water in the recirculation tank to work on components in the tank, such as the recirculation valve. In addition, this valve allows for flooding the filter completely and introducing air into the system to provide water saturated with dissolved oxygen as a means of degrading biological clogs if they occur. Measures such as this (and also installing an air coil in the bottom of the filter) provide designed-in recovery techniques in case the system clogs. A sampling sump at the drain outlet is useful for obtaining samples to judge filter performance. The drain outlet must not be submerged. Air must freely move into and up through the drain to assist the treatment media aeration process.

Recommended RSF treatment media depth is 24 to 36 in. (60 to 90 cm). If only 24 in. of treatment media depth is used a 6 in. (15 cm) layer of pea stone or coarse drain rock should be placed in the bottom of the filter to facilitate lateral drainage and maintain at least 24 in. of unsaturated treatment media throughout the filter. If the same size media is continued all the way to the bottom liner, there will be slightly more capillary rise from the saturated zone in the bottom up into the media than if there is a distinct media gradation discontinuity as provided by a courser layer in the bottom of the filter. Thus, the recommendation of 6 in. more media is appropriate.

An alternative to pipe drains is to utilize drain field chambers, or some other method of forming a cavity in the bottom of the RSF, and utilize the volume in this cavity as the recirculation and mixing zone. This eliminates the need for a recirculation tank. One or more small pump chambers are used outside the filter to accept filter drainage and pump it back over the filter or to final dispersal. This design option is shown in Figures 3.12a and 3.12b.

Loading rate and surface area

The surface of an RSF must be free from any soil cover so that the unit permits free air movement. The surface area of the filter should be sized

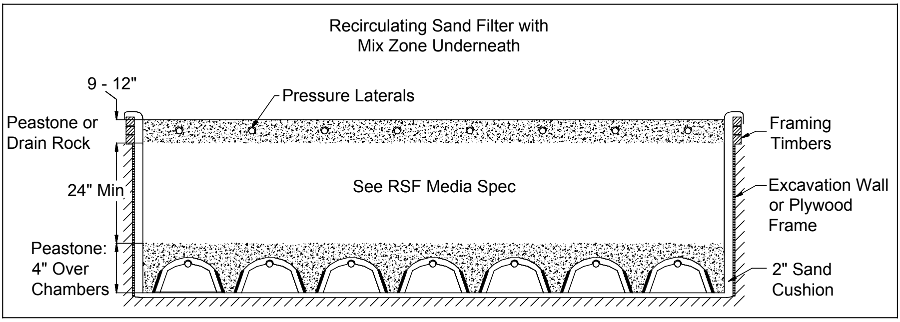


Figure 3.12a Chambers used as filter drains - cross section.

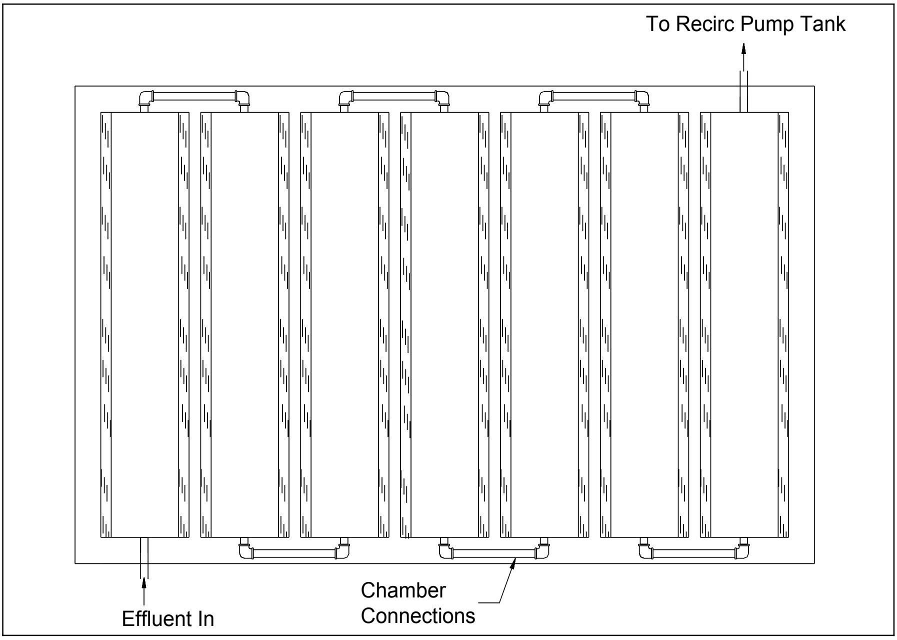


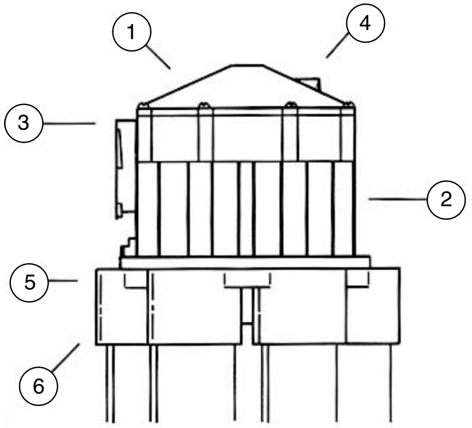
Figure 3.12b Top view of RSF that uses chambers in the bottom.

based on a forward flow loading between 3 and 5 gpd/ft^2 (120 and 200 Lpd/m^2) based upon daily design flow. For systems in warmer climates receiving domestic effluent from screened septic tanks expected to have TSS levels below 70 mg/L and BOD$_5$ below 150 mg/L, the higher loading rate can be used. For systems in colder climates or those in which effluent quality is less certain, it is wise to design for loading rates in the lower part of the range. It is also important to consider organic loading on the filter along with hydraulic loading. Whenever available, the actual effluent characteristics should be used for designing the filter. When effluent strength exceeds typical domestic effluent quality, the filter must be designed on the basis of the organic load, typically expressed in terms of Lb BOD/ft^2/day (kg BOD/m^2/day). Insufficient research has been done to define recommended organic loading rates well. Typical values for RSFs range from 0.002 to 0.008 Lbs BOD/ft^2/day (0.01 to 0.04 kg/m^2/day). High recirculation rates are recommended as organic loading approaches the upper portion of this range. Maintenance personnel should be alerted to watch for the development of media clogging where higher organic loading rates are anticipated.

Distribution system design

The most common distribution system design for RSFs is small-diameter pipe with 1/8 in. (3 mm) orifices spaced approximately 2 ft on center and 2 ft (60 cm) between distribution pipes. These configurations balance reasonable distribution against required flow quantities and therefore pump sizes. Simpler designs such as a use of "tipping" tray and a distribution plate with holes for gravity distribution have also been used successfully by a peat filter system's manufacturer. Some designers have successfully used orifice spacing as low as 15 in. (38 cm) to spread the applied effluent more uniformly over the surface area of the filter. It is recommended that a minimum residual head at the far end of the most distal lateral be maintained at 5 ft (150 cm) of water head. There should be no more than a 10% differential in flow between any two orifices in the system (i.e., between distal orifices and those nearest the pump). The use of pumps with steep characteristic curves is recommended. A steep curve means that, as orifices begin to clog and the flow demanded from the pump drops slightly, the pressure increases rapidly. This results in the system being somewhat self-cleaning, as higher pressures help keep orifices open. Pumps with steep curves typically have low maximum flow capabilities in the lower horsepower range. In order to keep pump sizes in the half horsepower range, it is recommended that the distribution system be divided into zones that require no more than 50 gallons per minute each. An automatic hydraulically operated sequencing valve (Figure 3.13) can be utilized to sequentially feed the distribution zones of the system.

Pressurized pipe with orifices may be mounted directly in distribution stone (although this set-up is not recommended), may be mounted in stone with orifice shields over each individual orifice, may be inserted in a larger pipe sleeve that is perforated to release the water into surrounding stone, or may be mounted in chambers with the jet from each orifice impinging on the chamber surface to break into droplets and provide distribution (Figure 3.14a). In some media filters, such as open-cell foam filters and textile filters, spray nozzles are utilized to distribute effluent more uniformly over the surface of the media. The nozzles typically used are helical, spiral, nonclog nozzles mounted with the spray directed downward onto the media. These nozzles can also be utilized in chambers with the plumbing mounted in the top of the chamber and the nozzles directed downward to provide uniform distribution of effluent over the base of the chamber (Figure 3.14b). They



1. Valve Top: A high strength metal die cast top which is secured to the valve body by eight stainless steel screws.

2. Valve Body: A high strength metal die cast housing.

3. Inlet Female: 1_" NPT inlet for connection to water source.

4. Vacuum Breaker Port: Used to prevent back-siphon of water to source.

5. Valve Bottom: High strength ABS plastic bottom which is secured to valve body with 6 stainless steel screws.

6. Outlets: Allows to slip and glue connection to 1_" PVC pipe.

Figure 3.13 Automatic hydraulically operated sequencing valve.

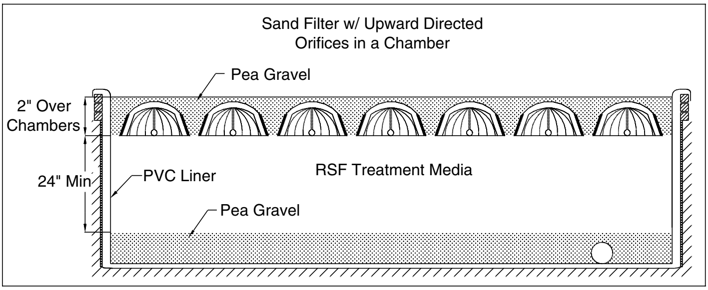


Figure 3.14a Sand filer with upward directed orifices in a chamber.

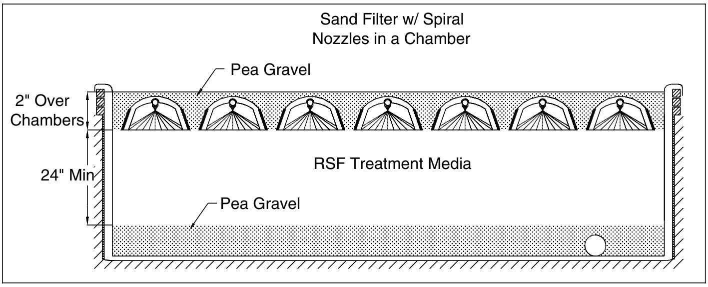


Figure 3.14b Sand filter with spiral nozzles in a chamber.

are also used in applications where the entire packed bed filter is housed in a container specially built for the unit.

All of these distribution methods have proven successful, although orifice configurations provide application at discreet points rather than uniform distribution over the surface of the media. In the case of single-pass sand filters and RGFs, discreet point application results in only a portion of the media receiving effluent unless the media starts to clog. With only a portion of the media utilized, the surrounding media always contains air with higher oxygen concentrations, which can diffuse into the zone of treatment to provide the necessary oxygen for organisms. However, with good ventilation, this may not be needed. Orifice spacing of 24 in. × 24 in. (60 × 60 cm) on single-pass sand filters and RGFs have been common, but spacing as low as 9 in. × 9 in. (22 × 22 cm) has been utilized (Piluk and Peters, 1994). Regardless of orifice spacing, recommended loading rates per unit area should not be exceeded or extensive maintenance problems may result.

Pumping systems for recirculating sand filters

The pumps that feed RSFs should always be timer controlled. Timers should be set so that the dose volume from each orifice does not exceed two gallons per orifice per dose cycle. The flow rate from a 1/8 in. (3 mm) orifice subjected to 5 ft (150 cm) of head is 0.43 gpm (1.6 Lpm). Therefore the maximum allowable pump run time per dose at 5 ft (150 cm) of head is less than 6 minutes except for very long pipe runs that take a long time to fill and come to pressure. Pumps can be cycled frequently, but the number of pump cycles per day should not exceed the pump manufacturer's recommendations. This is typically either 100 cycles per day or 400 cycles per day for vertical turbine pumps. Some pump manufacturers may have other recommendations.

If low head effluent pumps are used and orifices begin to clog, the pump may not move enough effluent out of the tank and a high water alarm condition may result, signaling to the operator that maintenance is required. Orifice cleaning can be as simple as opening cleaning ports on the ends of the distribution laterals and pushing a bottle brush or a "snake" through the distribution pipes. It is important, as mentioned previously in the sections on Filter Drains and in the "Nature of Fixed Films" section, and in the section on large Recirculating Sand Filters", to design for maintenance and potential "recovery" of the filter systems.

An alternative method of distribution on a packed bed filter is to use drip irrigation tubing with its specially manufactured emitters. Drip emitters are capable of discharging very low rates of flow — literally drips, as the name implies. With drip tubing, the space between the points of application can be minimized and the application rate to the filter minimized as well. Use of drip tubing requires special filtration and regular flushing of lines, but these processes can be automated.

Large recirculating sand filters and recovery techniques

Large RSFs should be designed in cells so that, if maintenance is necessary, one cell can be shut down and the others remain operational while cell maintenance is accomplished. Systems should be designed with maintenance in mind. Every cell should have observation ports at one or more locations that extend from the surface of the cover media to the surface of the treatment media, so that it is easy to monitor for clogging and ponding at the infiltrative surface. Observation ports that extend to the bottom of the filter should also be provided so that, if a clog in or around the drain begins to cause an abnormal level of ponding in the bottom of the cell, it can be detected easily and early. Clogging can be remedied by flooding the filter, forcing air into the bottom to raise the dissolved oxygen level in the cell, and stimulating aerobic organisms to digest the organic materials that may have formed. This necessitates a piping system that can effectively serve as an air distribution system when the cell is flooded. The drainage system may be used for this purpose, or an optional air coil may be installed during filter construction.

Textile filters

The use of geosynthetic fabrics, commonly called *geotextiles* or *geofabrics*, as media in media filters has been a subject of considerable research and development over the past decade. Geofabrics offer characteristics that are consistent with the media characteristics desired in a packed bed filter — namely, they provide both large surface area and large void volume per unit bulk volume of material while maintaining a high water-holding capacity. These materials have been used in two configurations: (1) small squares about 2 in. × 2 in. (5 cm × 5 cm) of 1/4 to 3/8 in. (6 to 9 mm) thick fabric randomly packed in a container with capillary breaks between 4 to 6 in. (10 to 15 cm) thick layers and (2) hanging curtains of fabric about 1/2 in. (12 mm) thick. In residential applications, the filter typically is placed over or next to the septic tank or a recirculation tank. The filter drainage returns to the recirculation tank if BOD_5 and TSS removal is the main goal. If maximum nitrogen removal is desired, the drainage is directed to the inlet end of the septic tank. Filter drainage is controlled by the liquid level in the tank and, at any given moment, it is either all going into the tank or all going on to the next unit in the treatment system. Figure 3.15 is an illustration of this type of packed bed filter set up in recirculating mode with recirculation back to a septic tank. Vertical sections of fabric about 2 ft long are hung side by side so that they are touching. Photo 3.1 is a photograph of a typical individual home system showing the textile sheets. Wastewater is applied over the top of the fabric in small, uniformly distributed doses several times per hour. This keeps the fabric wet and provides maximum residence time for the water within the fabric. Table 3.2 shows the characteristics of fabric filters in comparison with other packed bed filter media.

A textile filter operates in the recirculating mode, much like a recirculating sand or gravel filter. Due to the increased surface area of the media, loading rates can be much higher (5 to 15 times) than RSFs and thus filter size can be smaller for a given wastewater flow. Aerobic conditions are maintained due to the large volume of pore space through which air can

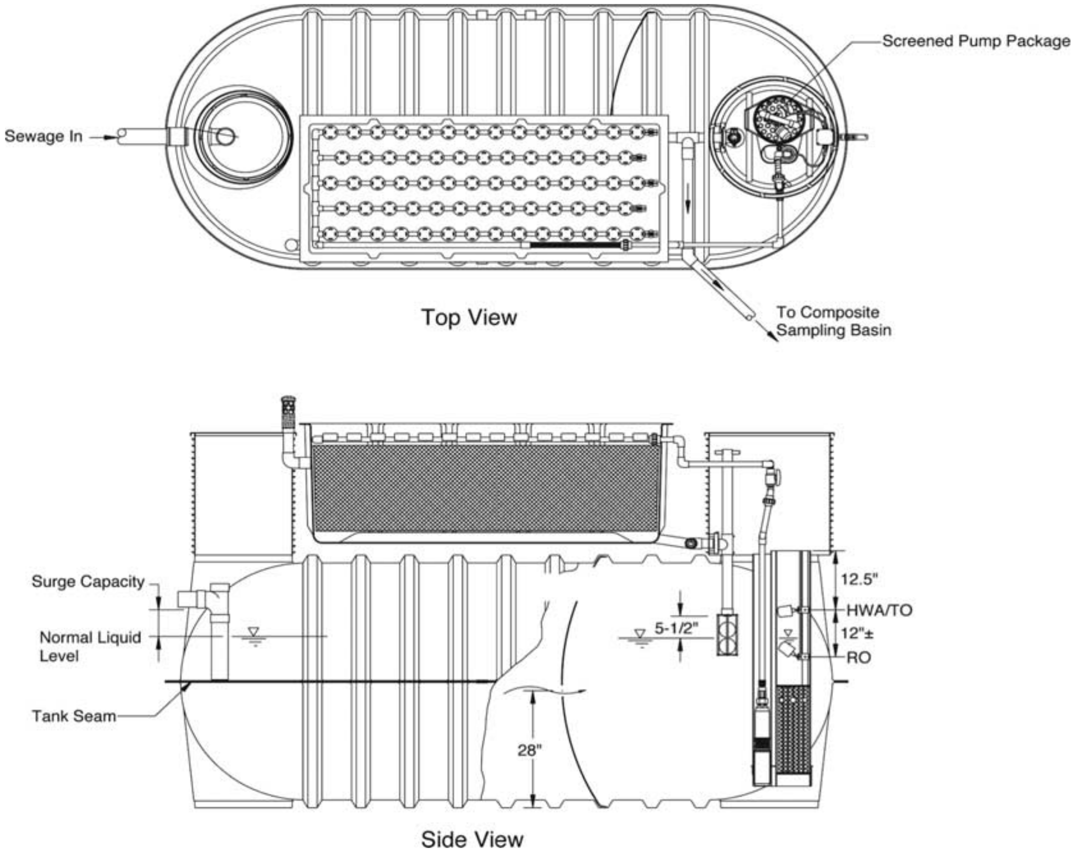


Figure 3.15 Recirculating textile filter.

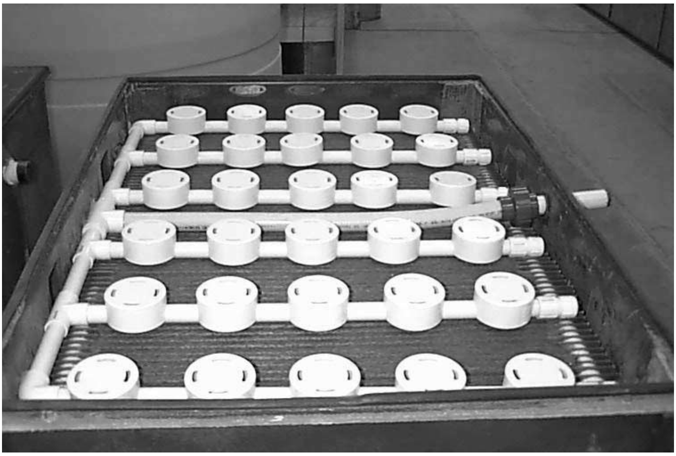


Photo 3.1 typical individual home textile filter.

flow, even while the material is wetted to its drained upper limit of moisture content. A biofilm develops on the upper surface of the media. Organic matter, measured in terms of BOD and TSS, is efficiently removed. Ammonium nitrogen is nitrified to nitrate by the same type of biological processes that occur in sand filters. Nitrogen removal is enhanced by recirculating the filtrate back to the carbon-rich septic tank to increase denitrification.

If necessary, the biomat that builds on the top of the textile configuration can be periodically removed with a hose or individual hanging curtains can be removed for more complete cleaning. As with all media filters, periodic maintenance by a trained service provider is critical to maintaining high-quality effluent from the filter.

Open cell foam filters

Media filters that utilize a polyurethane foam material in 2 in. cubes randomly placed in a prefabricated container are available as a proprietary product. The absorbent filter media combines large surface areas for microbial attachment and long retention times with high void volumes and separate flow paths for wastewater and air, thereby enabling loading rates 10 times greater than that for sand filters. Design loading rates are shown in Table 3.2. These units are used in either single-pass or recirculating modes. Field trials with domestic strength effluent have shown removal rates of 97.8% BOD, 96.1% TSS, and 99.5% fecal coliform bacteria, with hydraulic loading rates in the range of 12 gpd/ft^2 (490 Lpd/m^2). Surge flows up to four times this loading rate have been handled for short periods with little effect on effluent quality (Jowett, 1997). Overall treatment is better with forced airflow than with natural convection. Cold influent and plugging by freezing may cause poor treatment.

Septic tank effluent or blended effluent from a recirculation tank is applied to foam filters in small doses of 0.1 to 1 gal/ft^2 (4 to 41 L/m^2) per dose using helical spray nozzles for uniform distribution. Manufacturers' recommendations vary, but usually dosing is controlled by a timer to provide uniform application throughout most of a day regardless of water use patterns within the facilities being served.

Open cell foam filters are more easily maintained than sand-based media filters. Any clogging due to biomat development usually occurs within the top few layers of foam cubes. These cubes can be removed and replaced or cleaned and returned. Being in a container and having much less surface area contributes to easier maintenance as well.

Controls

Control systems for pumps and dosing are critical to the operation of media filters. All media filters should be pressure dosed to assure uniform distribution of effluent. This can be done using either pump systems or, in some cases, siphons for dosing. In general, pump systems may be demand controlled (demand dosing) or timer controlled (time dosing), but time dosing has proven to be more effective for media filter systems.

Level sensors set to provide a predesigned dose volume control demand dosed systems. With demand-dosed systems, the filter receives a dose of effluent whenever a sufficient quantity of water has been used at the source to generate one dose. The filter is therefore dosed frequently during periods of high water use and does not receive doses if no water is being used at the source. Therefore, demand-dosed systems sometimes suffer from the tendency to be dosed too frequently while sometimes allowed to be unfed for fairly long periods when no wastewater is being generated, such as overnight. In addition, it is more difficult (as compared to time dosing) to control the dose volume with demand-dosed systems because dose volume is a function of tank cross-section and the ability to adjust on/off level of floats, or other level control devices, for a small enough change in tank level during a pump cycle is limited.

Research has shown that treatment is enhanced with small, frequent doses (Emerick et al., 1997; Darby et al., 1996). Time dosing provides the ability to apply small, frequent doses. The timers themselves can be float controlled so that when the water level in a supply tank reaches a certain minimum, a level sensor turns the timer off and the timer remains off until the water level starts to increase. The timer is reactivated and operates to provide dosing until the minimum level is again reached. Timers can be overridden by a high level sensor such that if the level in the tank reaches a predetermined high level, the system can become level controlled (demand dosed) until the level again is down to the top of the range in which the timer operates. Some controls can also increase the frequency of dosing when the high level is reached rather than reverting to demand dosing. An alarm can be activated when this happens or a separate level sensor can be set just above the timer override level so that an alarm is only actuated if the timer override does not keep up with the rate of wastewater inflow. Figure 3-17 shows a pump in a recirculation tank with floats to turn the timer on and off. If the level in the tank reaches a preset high level, a second pump is activated; if the tank has only one pump, the pump runs on the float until the level is reduced to the normal range.

Simple, small, and relatively inexpensive programmable logic controllers (PLCs), similar to the one shown in Photo 3.2, provide the flexibility and multiple functions available for media filter system operation and processing tank and flow variation management. The microprocessors can safely be mounted in watertight, weather-resistant enclosures within sight of the pump system and in an unsightly manner to avoid being a detriment to a residence or a commercial establishment.

Level sensors

The sensors most commonly used with packed bed filter control systems are floats. Some floats are mechanical while others contain mercury switches. Due to environmental concerns with mercury, manufacturers are moving away from the use of mercury switch floats. Level sensors should be mounted on a specially designed mounting system separate from the pump and discharge pipe, which simplifies service. Sensors mounted on the discharge pipe of a pump are also subject to vibration and may become loose and move. Sensor mounting systems allow for level sensors to be easily removed as a group and adjusted outside the tank without disturbing the pump. In addition, the pump can be pulled for service without disturbing the adjustment of the level sensors.

All pump chambers should be equipped with a secure lid and a riser to grade. Sufficient cord for each level sensor and the pump should be retained in the riser so that pumps and sensors can be easily removed from the tank for service without disconnecting anything. This cord slack should be neatly coiled and tied off in a convenient location in the riser. It is sometimes convenient to have an electrical junction box in the riser over the pump tank to connect the manufacturer-provided cords on pumps and level sensors to wires leading to the control box. A junction box (classification NEMA 4X) in the riser is permissible for pumping systems serving no more than five dwellings (National Fire Protection Association [NFPA] Standard 820). Such facilities are unclassified by NFPA 820 because they are expected to vent through the plumbing systems of the dwellings. Systems that serve more than five dwellings are not automatically covered by this unclassified designation. Wire connections in a junction box mounted in a riser are in a very moist and corrosive environment. Wire splices should be done using sealed, waterproof connections and waterproof cord grips must be used where the cords penetrate the junction box. A better solution may be to avoid the junction box altogether by specifying pumps and controls with sufficient cord to be run all the way to the control panel location without any splice.

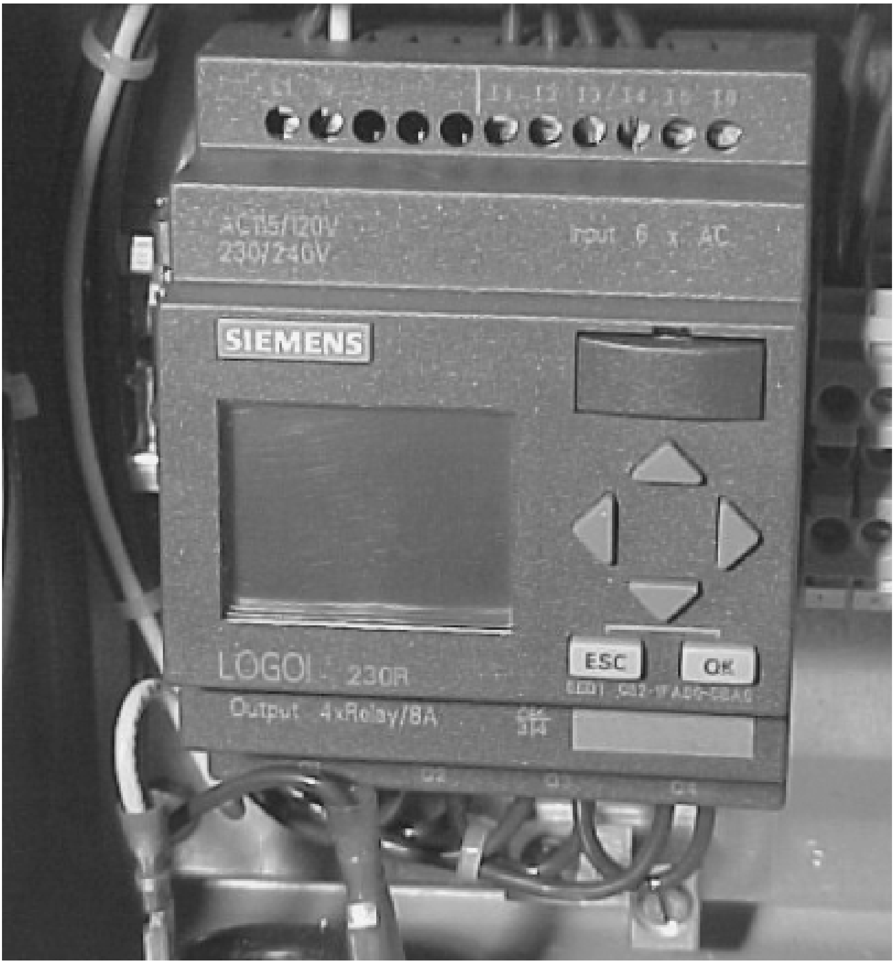


Photo 3.2 Programmable logic controller

Determining timer settings

Pump timers should be set so that the total flow anticipated can be pumped to the packed bed filter on a 24-hour basis. To allow for peak periods of use, a general practice is to set timers so the quantity of effluent generated in the typical 24-hour day can be pumped to the filter in about 18 hours of time-dosed pump operation. In the case of single pass systems, this means that under normal flow conditions, the pump shuts down for several hours every night. However, if the incoming flow is greater than the anticipated average daily flow, the pumps will operate more hours. If the flow exceeds the average flow for which the system is adjusted by more than 33% (6/18 × 100%), a high water alarm will occur.

In recirculating systems, the recirculation pumps run based on timer settings rather than on liquid level in the recirculation tank. When the inflow decreases at night, the water-level activated recirculation-splitter valve opens and returns all the filtrate to the recirculation and processing tank. Therefore, no filtrate is discharged during low inflow periods. The packed bed filter, though, is continually dosed to keep the dissolved oxygen level from depleting completely in the recirculation tank during low inflow periods, which causes anaerobic gas products to generate and periodic odors to occur when the recirculation pump comes back on. This means that adequate surge volume is considered in the recirculation and processing tank design to accommodate peak daily usage. In addition, the recirculation valve opens during low flow periods, returning all the filtrate to the recirculation tank. The controls may include a feature that provides a high-level-timer override, which increases the dose frequency in the event of extremely high flow occurrences. Controls can also be set up to alert the service provider when the flow exceeds normal peak flow.

Dosing frequency (DF) is typically reported as the number of doses or dosing events per day, but more specifically represents the time span between doses (the time measure is generally in minutes) or, in control terminology, the *cycle time.* There are two components to the cycle time: the "on" (dosing) time and the "off" (resting) time, as shown in the following expression:

$$CT = DF = Td + Tr \tag{3.7}$$

Also:

$$DF = 1440 \text{ min per day}/nd \tag{3.8}$$

where:

nd is the number of doses per day to the filter

$$nd = (Rr + 1)Qi\ /(Td)(qd) \tag{3.9}$$

$$DF = 1440\ (Td)(qd)/(Rr + 1)Qi$$

And, from Figure 3.10:

$$Rr = (Qf/\ Qi) - 1 \tag{3.10}$$

where:

CT is the dose cycle time in minutes
DF is the dose frequency time in minutes
nd is the number of doses per day
Tr is the rest time in minutes ("off")
Td is the dose time in minutes per dose ("on")
qd is the dosing flow rate to the filter, gpm

Qi is the daily inflow (or forward flow), gpd
Qf is the daily filter hydraulic load, gpd
Rr is the recirculation (recirc-blend) ratio

The dosing frequency is related to the Rr as well as to particular features of the media, such as its texture, void ratio, and water-holding capacity. Considerable academic work has been done to establish relative dosing frequencies for various media. It is well recognized that small, frequent doses improve filter performance. Increasing the dosing frequency (number of occurrences over a given time period) reduces the volume of wastewater applied per dose and increases coliform removal (Darby et al., 1996).

For example, determine the Rr for an RSF receiving 500 gpd if the dose flow rate to the filter, qd, is 30 gpm, the dose frequency is 10 minutes, and the dose time, Td, is 30 seconds.

$$DF = Td + Tr$$

$$Td = 0.5 \text{ min}$$

$$Tr = 10 \text{ min} - 0.5 \text{ min} = 9.5 \text{ minutes}$$

$$Qf = nd\ Td\ qd = (1440/DF)\ Td\ qd$$

$$Qf = 1440\ (0.5 \text{ min})\ (30 \text{ gpm})\ /\ 10 \text{ min} = 2160 \text{ gpd}$$

and:

$$Rr = (Qf/Qi) - 1 = (2160/500) - 1 = 3.32$$

Or, if the Rr is set at 3 and the dose time is 30 seconds:

$$Tr = [1440\ Td\ qd\ /(Rr + 1)Qi] - Td$$

$$Tr = [1440\ (0.5)\ (30)\ /\ (3 + 1)\ (500)] - 0.5$$

$$Tr = 10.3 \text{ minutes (rest or “off” time)}$$

And:

CT = 10.3 + 0.5 = 10.8 minute cycle time (or dose frequency every 10.8 minutes)

Event counters and run-time meters on pumps are very helpful in documenting the operation of the system. They can be utilized to determine the total quantity of flow handled by the pump over a specified period and can be used to determine whether the pump frequently operates in the demand mode as compared to being operated mostly by the timer. The PLC illustrated in Photo 3.2 can easily be programmed to provide pump cycle counts and pump run time. Knowing the pump flow rate allows the operator to calculate the total flow from each pump instrumented in this way.

Pump selection

Two basic types of submersible pumps are commonly utilized to feed media filters: submersible centrifugal effluent pumps and submersible centrifugal turbine (high head) pumps (Photo 3.3). Self-priming centrifugal suction pumps mounted outside the tank can also be used, but these pumps are much less common. Effluent pumps are low-pressure pumps with the capacity for handling some solids. Solids handling is not necessarily a desirable feature of pumps feeding media filters, but the general flow and head capabilities of effluent pumps and their wide availability and dependability makes them a common choice. Turbine pumps have a capacity to generate higher pressures but lower flows than effluent pumps. Turbine pumps are desirable for feeding pressure distribution systems on media filters because of their steep discharge curves, which result in rapid pressure increases as the flow drops by small amounts. This helps keep orifices open and the system functioning with complete, uniform distribution. Where effluent pumps are utilized, greater care may be necessary in monitoring and maintaining the distribution system to assure that the entire system is functioning at all times. Both types of pumps have long service lives and are designed for the effluent environment. All but the smallest suspended solids should be removed in the septic tank or filtered out using effluent screens (< 1/8-in. openings) prior to pump intake. It is recommended that pumps be continuously submerged to avoid potential corrosion problems. It is the designer's responsibility to assure that the proper pump is chosen for the specific application.

Photo 3.3 Submersible turbine pump.

Other fixed film processes

Similar concepts in wastewater treatment that are used in larger systems include traditional trickling filters and rotating biological contactors (RBCs). Although both of these systems involve organisms attached to media, the processes involved are somewhat different than those involved in media filters. Trickling filters and RBCs are subjected to much higher, continuous loading. One important operating difference is that these traditional systems are designed to slough solids where, in contrast, media filters are designed based on endogenous respiration, meaning that most of the biofilm or organism buildup that occurs is consumed by the organisms present and little sloughing or loss of solids out of the system occurs.

System monitoring and maintenance

All wastewater treatment systems should be constructed so that maintenance personnel can easily monitor their performance and conduct routine maintenance. In the case of proprietary media filters, some manufacturers provide monitoring recommendations. Some states require particular discharge limits that may depend on whether the treated effluent is dispersed to the subsurface environment (soil-based dispersal) or is discharged to surface water under an NPDES permit or other permit.

Monitoring tubes

In the case of both single-pass and recirculating sand filters, it is recommended that monitoring tubes be placed to the bottom of the stone around the distribution pipe, terminating at the infiltrative surface of the treatment media. These should be placed in strategic locations so that if ponding begins to occur on the infiltrative surface, it will be observed. Monitoring tubes should also be installed to the bottom of the filter, terminating at the surface of the liner, for determining if the level of ponding in the base of the filter is normal. Monitoring tubes located at the maximum distance from underlying drains are recommended for this purpose. The monitoring tube is a 3 in. or 4 in. pipe, which is perforated in the bottom few inches and placed during construction. Support options for monitoring tubes are shown in Figure 3.16. Monitoring tubes should be capped with an easily removable cover. The use of valve boxes over the tops of monitoring tubes is recommended. If other forms of cover are used, such as slip caps, the bottom of the monitoring tube must be anchored when it is installed with a flange, tee, or rods through the pipe to render it secure so that it does not pull out when the cover is removed. Valve box covers are not directly connected to the monitoring pipe and do not present this problem.

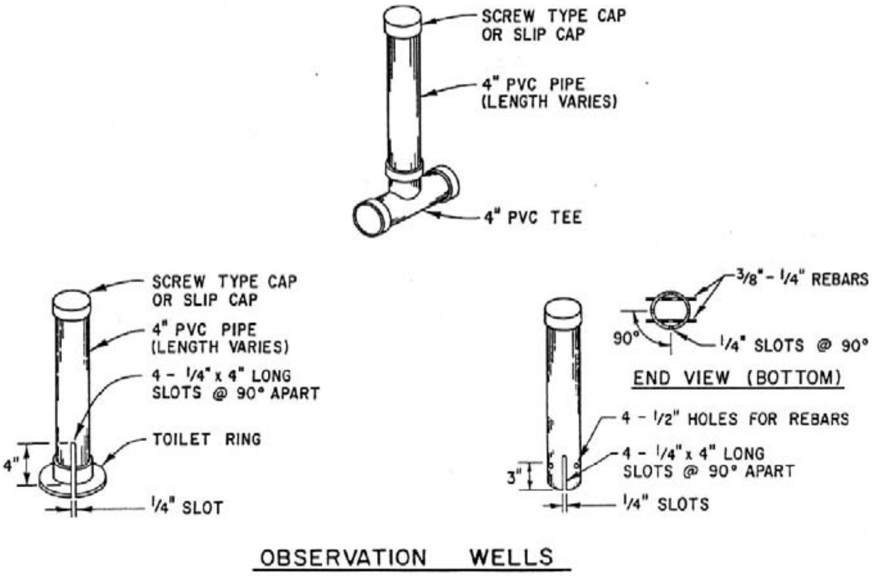


Figure 3.16 Support options for monitoring tubes.

Remote monitoring

Equipment and technology are available for providing remote monitoring of water levels, pressures, flows, and pump-run events. Data can be sensed and stored on a local data logger for periodic downloading to a monitoring computer or can be automatically downloaded and accessed over the world wide web via a server or dial-up modem. These types of systems can be programmed to recognize parameters that are out of range and alert maintenance personnel. Maintenance personnel can troubleshoot the system from a remote computer and often determine and fix a problem without visiting the site. If the problem is occurring because a timer is not correctly adjusted to accommodate the flows occurring, it can be reset from the remote location. The sophistication and cost of remote monitoring and graphical user interfaces make them attractive alternatives for many systems. Designs for commercial systems, community or cluster systems, and remote or sparse systems — where access for maintenance is time consuming and expensive — should incorporate remote monitoring. Designers are recommended to continue tracking the development of remote monitoring technologies and incorporate them where feasible.

Monitoring routine

For a proprietary product, the manufacturer should provide a maintenance routine along with an operations and maintenance manual. In the case of sand filters without remote monitoring, a complete monitoring visit should be made in the first few weeks of operation, with a second visit about 6 months later. Monitoring visits must occur at least annually thereafter. Twice per year is highly recommended until the maintenance provider is comfortable that use patterns and filter performance warrant reducing the frequency to annual visits. Commercial systems should undergo monitoring visits at least twice per year.

A typical maintenance visit should include:

1. Check sludge and scum levels in the septic tank to assure adequate clear space.
2. Check septic tank effluent screen and pump vault screen, or in-line filter, and clean if necessary.
3. Flush packed bed filter distribution laterals.
4. Check pressure at the distal end of the lateral and compare with design recommendations or pressure monitored at the last visit. If pressure has increased since the last measurement, it may be necessary to use a bottlebrush, pressure jet, or other orifice or nozzle cleaning process.
5. Note readings on pump run-time meter and event counter and compare with previous readings.
6. Check pump voltage (off and while pumping) and amp draw while pumping.
7. Check pump control floats for proper operation and proper elevation adjustment.
8. Check for ponding at the media infiltrative surface and at the bottom of the filter through observation tubes.
9. Collect and observe the final effluent in a clear sample bottle, checking for clarity and odor.
10. Collect a sample of effluent for laboratory analyses of BOD_5, TSS, and fecal coliform, at a minimum, and for any other parameters required under the permit.
11. Check for wetness around the drain field and observe ponding in observation tubes.
12. If the treatment system includes disinfection, check chlorine levels (for chlorinators) or check the intensity of the ultraviolet radiation (for UV disinfection units), and add chlorine or change the UV tube as necessary.
13. Check and record pump run times and pump cycle times and compare the actual flow rates to the design flow rates.

Monitoring User Inputs

When performing a monitoring operation, it is always a good idea to visit with the owner or operator of the system to determine whether anything has changed in terms of water inputs or problems noted with the operation of the system. Remind the owner of cautions in use of the system, including water conservation. Certain inputs can influence the operation of the system, including strong drugs (chemotherapy or dialysis in particular), chronic use of drain cleaners, input of water softener backwash to the system, and improper inputs, such as paint thinner and antifreeze. The owner should be cautioned against discharge of such substances to the system.

In some cases, lack of alkalinity in the source water may influence the ability of the system to remove nitrogen. Typically, 7.14 mg of alkalinity as calcium carbonate ($CaCO_3$) is required for nitrification of 1 mg of nitrogen as N.

Soil dispersal of media filter effluent

High-quality effluent, such as that from a well-maintained media filter, is not likely to develop much, if any, bio-mat in soil absorption systems and can therefore be applied to soil at hydraulic loading rates higher than those for septic tank effluent. The major consideration is applying at rates that will result in adequate retention time in the soil to complete the treatment process. Packed bed filter effluent contains nitrate and phosphorus that needs to be removed by soils, and some residual level of pathogen removal is also required. Soil loading rates in slowly permeable soils can be three to five times higher than loading rates for septic tank effluent, assuming that septic tank effluent loading rates are very conservative. In rapidly permeable soils, it may be desirable to utilize loading rates only one to two times the hydraulic loading rate used for septic tank effluent to encourage maximum treatment in terms of pathogen and nutrient removal. Because highly treated effluent from media filters is not likely to form a bio-mat in the soil absorption system to enhance distribution, this effluent should always be dispersed to the soil using pressure distribution to minimize the chance of rapid flow through soil macropores.

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chapter four

Aerobic treatment units

Introduction

Although aerated wastewater treatment has been used since the 1800s in the form of media filters, suspended growth aerated treatment is relatively modern. The first activated sludge treatment plant began operation in 1916 in San Marcos, Texas. A channel aeration treatment system was constructed in Sheffield, England in 1921 (Dinges, 1982).

Naturally occurring microorganisms are the workhorses of wastewater treatment. Sometimes mistakenly considered to be "merely bacteria," the ecosystem of a suspended growth aerated treatment system includes bacteria, fungi, protozoa, rotifers, and other microbes. These organisms thrive on many of the complex compounds contained in domestic wastewater. Secondary-treatment activated sludge processes are highly engineered bioreactors. These bioreactors are designed to provide microbes with the optimum conditions to assist in the renovation of domestic wastewater. With the mechanical addition of dissolved oxygen, aerobic and facultative microbes can rapidly oxidize soluble, bioavailable organic and nitrogenous compounds.

Onsite and decentralized wastewater management systems take advantage of this technology. Aerobic treatment units can be an option when insufficient soil is available for the proper installation of a traditional septic tank and soil absorption area. Increasingly, homes and small commercial establishments are being constructed in rural areas with no central sewer and on sites with marginal soils. In these situations, wastewater must receive a high level of pretreatment before being discharged into the soil environment. Depending on local regulations, the use of an aerobic treatment unit may allow for a reduction in the required infiltration area or a reduction in depth to a limiting soil layer. This ability to produce high-quality effluent may open sites for development that were previously unsuitable because of soil limitations (U.S. Environmental Protection Agency [EPA], 2000).

Although all wastewater treatment devices that are engineered to maintain aerobic conditions are considered "aerobic treatment units," the community of onsite wastewater management professionals divide these devices into two classifications: saturated (with wastewater) and nonsaturated. Whether suspended-growth or attached-growth, any unit that maintains saturated and aerobic conditions is generally referred to as an ATU — the acronym for "aerobic treatment unit." In this chapter, the term ATUs refers to an engineered, suspended growth, high-rate wastewater treatment process. In nonsaturated, attached-growth systems, atmospheric oxygen is passively transferred into a dissolved state as the water moves around or through the media. Trickling filters (such as those found at smaller municipal wastewater treatment plants) and most packed-bed filters typify this type of biological process.

The classical expectation of an ATU is to reduce the concentration of soluble organic compounds and suspended solids. Like manufacturers of media filters, manufacturers of ATUs are actively developing new treatment systems that incorporate enhanced disinfection and nitrogen and phosphorus removal as parts of the treatment train.

Theory of biochemical wastewater treatment using aerobic treatment processes

Most people consider bacteria and other microorganisms undesirable disease-causing components of wastewater. In fact, only a small fraction of the microbes found in wastewater are truly pathogenic. Aerobic wastewater treatment encourages the growth of naturally occurring aerobic microorganisms as a means of renovating wastewater. Such microbes are the engines of wastewater treatment plants. Organic compounds, high-energy forms of carbon, are the fuel that powers these engines. The work of the engines is to oxidize organic compounds to a low-energy form (carbon dioxide). The final products of the process are carbon dioxide, water, and more microorganisms. One way to represent this process is:

$$\begin{gathered}\text{Organic carbon + oxygen + microbes} \rightarrow \\ \text{carbon dioxide + water + more microbes}\end{gathered} \tag{4.1}$$

Understanding how to mix aerobic microorganisms, soluble organic compounds, and dissolved oxygen for high-rate oxidation of organic carbon is one of the fundamental tasks of wastewater engineering.

Microorganisms responsible for the oxidation of complex organic compounds are called *decomposers.* These organisms return simple forms of carbon back to the soil, water, and atmosphere. When high concentrations of organic pollutants are available, these decomposers flourish. Because these same microorganisms exist in natural water bodies, wastewater being discharged back into surface water bodies must have a very low organic strength. Natural aquatic systems must have an ample concentration of dissolved oxygen to support advanced life forms, such as fish and macroinvertebrates. Most decomposing microbes prefer aerobic conditions to anaerobic conditions. When dissolved oxygen is available, the aerobic decomposition of organic compounds consumes dissolved oxygen out of the water. If the rate of re-aeration is not equal to the rate of consumption, the dissolved oxygen concentration falls below the level needed to sustain a viable aquatic system. As mentioned in Chapter 2, this is another consideration of the receiving environment. The level of treatment and the receiving environment should be considered as a holistic system of evaluation when choosing an appropriate treatment system to suit a site.

The concentration of soluble, bioavailable organic compounds in water is often measured as biochemical oxygen demand, or BOD. As previously described, oxygen demand is the result of aerobic microorganisms consuming dissolved oxygen as they decompose organic carbon and nitrogen compounds. In the engineered biochemical oxidation of wastewater, oxygen is supplied to aerobic microorganisms so that they will consume the substrate (organic carbon and nitrogen compounds) to fuel their metabolism. The result is the conversion of organic pollutants into inorganic compounds and new microbial cells as illustrated in Equation 4-1. The net production of cells (creation of new cells versus the die off of old cells) forms an accumulation of biological material.

Organic materials that are typically found in residential strength wastewater include carbohydrates, fats, proteins, urea, soaps, and detergents. All of these compounds contain carbon, hydrogen, and oxygen. Domestic wastewater also includes organically bound nitrogen, sulfur, and phosphorus. During biochemical degradation, these three elements are biologically transformed from organic forms to mineralized forms (i.e., NH_3, NH_4, NO_3, SO_4, and PO_4).

Microbial metabolism

Metabolism is the sum of the biochemical processes that are employed in the destruction of organic compounds (catabolism) and in the buildup of cell protoplasm (anabolism). These processes convert chemically bound energy into energy forms that can be used for life-sustaining processes. Catabolism is an oxidative, exothermic, enzymatic degradation process that results in the release of free energy from the structures of large organic molecules. Some of the released energy is available for construction of new cellular material. Anabolism is a synthesis process that results in an increase in size and complexity of organic chemical structure (Benefield and Randall, 1985).

Fermentation and respiration

Aerobic and anaerobic heterotrophic microorganisms use the fermentation process to reduce complex organic compounds to simple organic forms. Heterotrophs are microorganisms that use organic carbon for the formation of new biomass. These organisms are consumers and decomposers and therefore depend on a readily available source of organic carbon for cellular synthesis and chemical energy. They are the primary workhorses in the oxidation of soluble BOD in wastewater treatment. In comparison, autotrophic microorganisms can create cellular material from simple forms of carbon (such as carbon dioxide). These organisms are at the bottom of the food chain. They do not depend on other organisms for the creation of complex organic compounds. Autotrophic microorganisms are important for the removal of nitrogen from wastewater.

As shown in equation 4.2, fermentation is an exothermic, enzymatic breakdown of soluble organic compounds and does not depend on the presence of dissolved oxygen. Fermentation is often described in two stages: acid fermentation and methane fermentation. End products of the acid fermentation process include volatile fatty acids (VFAs) and alcohols. Little reduction in BOD occurs because most of the carbon is still in organic form. During methane fermentation, a portion of the acid-fermentation end products are converted to methane and carbon dioxide gases. The result of this conversion is a reduction in BOD. *Anaerobic microorganisms are limited to the fermentation process*. This is why methane can only be produced with anaerobic conditions.

$$\begin{array}{c}\text{COHNS}\\ \text{organic compounds}\end{array} \xrightarrow[\text{microbes}]{\text{heterotrophic}} \begin{bmatrix}\text{volatile}\\ \text{fatty}\\ \text{acids}\end{bmatrix} + CO_2 + H_2O + CH_4 + \text{energy} + \text{residuals} \tag{4.2}$$

Through the process of respiration, aerobic microorganisms can further transform VFAs (and other bioavailable organic compounds) into carbon dioxide, water, and additional energy (Lehninger, 1973). As shown in equation 4.3, respiration requires the presence of oxygen, typically dissolved oxygen in the mixed liquor of a suspended-growth (activated sludge) system. Oxygen acts as an electron acceptor for the catabolic degradation of VFAs. Because aerobic microbes can readily convert bioavailable organic carbon into inorganic carbon, aerobic systems can provide high-rate wastewater treatment.

$$\begin{bmatrix}\text{volatile}\\ \text{fatty}\\ \text{acids}\end{bmatrix} + O_2 \xrightarrow[\text{microbes}]{\text{aerobic}} \text{energy} + CO_2 + H_2O + \text{residuals} \tag{4.3}$$

Biosynthesis

According to Lehninger (1973), biosynthesis is the most complex and vital energy-requiring activity of all living organisms. As shown in equation 4.4, biosynthesis is the formation of characteristic chemical components of cells from simple precursors and the assembly of these components into structures, such as membrane systems, contractile elements, mitochondria, nuclei, and ribosomes. Two kinds of ingredients are required for the biosynthesis of cell components: precursors that provide the carbon, hydrogen, nitrogen, and other elements found in cellular structures and adenosine triphosphate (ATP) and other forms of chemical energy, which are needed to assemble the precursors into covalently bonded cellular structures.

$$\underset{\text{precursors}}{\text{simple}} \xrightarrow[\text{energy}]{\text{microbes}} \underset{\text{new cells}}{C_{60}H_{87}N_{12}O_{23}P} \tag{4.4}$$

As seen in equation 4.4, cell composition can be represented as $C_{60}H_{87}N_{12}O_{23}P$. If phosphorus is not considered, basic cell composition is often written $C_5H_7NO_2$. It is important to reinforce the point that the cellular components are being taken from a wastewater stream and thus, many wastewater constituents are converted into new cells. Table 4.1 lists the typical composition of bacterial cells.

Endogenous Respiration

Under substrate-limited conditions, microbes feed on each other at a higher rate than new cells can be produced. The aerobic degradation of cellular material is endogenous respiration (Equation 4.5). Endogenous respiration is not 100% efficient and thus slowly degradable cellular material and other residuals accumulates (Reynolds, 1982). ATUs employed in the decentralized

Table 4.1 Percent Elemental Composition of Cellular Material

Carbon	50.0	Potassium	1.0
Oxygen	22.0	Sodium	1.0
Nitrogen	12.0	Calcium	0.5
Hydrogen	9.0	Magnesium	0.5
Phosphorus	2.0	Chlorine	0.5
Sulfur	1.0	Iron	0.2
Other trace elements including Zn, Mn, Mo, Se, Co, Cu, and Ni:	0.3		

Source: Adapted from Metcalf & Eddy, Inc. (2003).

wastewater management industry operate in the endogenous respiration phase. Referred to as *extended aeration,* this process provides plenty of aeration to ensure that microbes will start feeding on each other once food is consumed. This effect minimizes the accumulated biomass that must be removed by the maintenance provider.

$$\underset{\text{cellular material}}{C_{60}H_{87}N_{12}O_{23}P} + O_2 \xrightarrow[\text{microbes}]{\text{aerobic}} CO_2 + H_2O + PO_4 + NH_3 + \text{residuals} \tag{4.5}$$

Environmental factors

In order to provide high-rate oxidation of organic pollutants, microorganisms must be provided with an environment that allows them to thrive. Temperature, pH, dissolved oxygen and other factors affect the natural selection, survival, and growth of microorganisms and their rate of biochemical oxidation.

Temperature

The rate of bio-oxidation is a function of temperature. Various microbial species have optimal temperatures for survival and cell synthesis:

- Psychrophilic microorganisms thrive in a temperature range of -2° to 30°C (28° to 86°F). Optimum temperature is 12° to 18°C (54° to 64°F).
- Mesophilic microorganisms thrive in a temperature range of 20° to 45°C (68° to 113°F). Optimum temperature is 25° to 40°C (77° to 104°F).
- Thermophilic microorganisms thrive in a temperature range of 45° to 75°C (113° to 167°F). Optimum temperature is 55° to 65°C (131° to 149°F).

Overall, as temperature increases, so does microbial activity. Generally speaking, decentralized ATUs are buried and the soil acts as a sink for the heat generated by the exothermic activity within the treatment unit. The microbial population in a buried ATU consists of a mixture of psychrophilic and mesophilic organisms.

Food-to-microorganism ratio

The food-to-microorganism ratio (F/M) represents the mass of bioavailable organic compounds (substrate) loaded into the aeration chamber each day in relation to the mass of microorganisms contained within the aeration chamber. Typically, this ratio is expressed in terms of mass of soluble BOD per day per mass of microbes in the treatment unit (Crites and Tchobanoglous, 1998). Microbial populations are dynamic and respond to changes in life-sustaining parameters. A time lag occurs between sudden changes in organic loading and changes in the microbial population. However, if all other factors are constant, the population can rapidly increase in response to increased organic loading. To effectively treat an increased organic load, the hydraulic retention time of the basin must correspond to the time required for the population to increase. However, increased organic loading is often associated with increased hydraulic loading. If a means of flow equalization has not been provided, then effluent will not have the same residence time or be exposed to the same concentration of microbes.

Acid concentration

The pH of influent has a significant impact on wastewater treatment. Benefield and Randall (1985) report that it is possible to treat organic wastewaters over a wide pH range; however, the optimum pH for microbial growth is between 6.5 and 7.5. It is interesting to note that bacteria grow best under slightly alkaline conditions. Conversely, algae and fungi grow best under slightly acidic conditions. The response to pH is largely due to changes in enzymatic activity.

Aerobic treatment unit operation

ATUs are high-rate oxidizers of soluble organic and nitrogenous compounds. From a biological perspective, ATUs used for individual homes and decentralized systems do not employ any processes that are not currently utilized in large-scale municipal wastewater treatment plants. The technology unique to ATUs is the design and packaging of these systems for small-flow situations. These devices are essentially miniature wastewater treatment plants. In addition to reducing of BOD via aerobic digestion and the conversion of ammonia by nitrification, many commercially available ATUs have additional chambers that promote the removal of nutrients, suspended solids, and pathogens from effluent. Other unique aspects to the design of ATUs are the ease of installation at remote locations and the ease of maintenance for semiskilled maintenance providers. ATUs installed at home sites and small commercial locations must be dependable and maintenance-friendly.

Process description

Primary treated wastewater enters the aeration unit and is mixed with dissolved oxygen and suspended or attached microbes, or both. Primary treatment is provided by a “trash tank,” which is essentially a septic tank that is sized for a shorter detention time than a standard septic tank. Aerobic microbes convert organic compounds into energy, new cells, and residual matter. As the water moves through the clarifier, a portion of the biological solids is separated out of the effluent and retained within the ATU. These biological solids settle back into the aeration chamber, where they serve as seed for new microbial growth. Settled biomass and residuals accumulate in the bottom of the chamber and must be periodically removed.

Because biomass creates an oxygen demand, clarification is an important part of generating high-quality effluent. The soluble BOD of effluent is generally below 5 mg/L, but the biomass solids that carry over may produce an effluent BOD of 20 mg/L or greater (Benefield and Randall, 1985). Many ATUs have a cone-shaped clarifier to promote separation of the biomass. As the cross-sectional area of upflow increases, fluid velocity decreases. Once the settling velocity of the biomass is greater than the fluid velocity, the biomass will no longer move upward (Eikum and Bennett, 1992). During periods of no flow, the biomass will settle back into the aeration chamber. Other ATUs may incorporate inline filters to separate the biomass from the effluent. Such filters require periodic maintenance to remove the buildup of solids.

In the aerobic process, organic nitrogen and ammonia are converted to nitrate. Under anoxic conditions (no molecular oxygen), this nitrate is denitrified to nitrogen gas. Some ATUs are designed to provide denitrification as part of their operation. Design modifications include intermittently supplying air and recirculating the nitrified wastewater into the anoxic regions within the treatment unit.

Typical ATU configurations

Most ATUs operate as intermittent-flow, complete mix tank, constant volume reactors. The flow is intermittent because influent flow is not continuous. The contents of the aeration chamber are thoroughly mixed to maximize contact with dissolved oxygen, microbes, and wastewater. Effluent moves out of the aeration chamber and into a clarifier. The rate of discharge is directly related to the rate of inflow. The exception to this generalization is sequencing batch reactors. As described later in this section, this treatment device operates in batch mode.

Extended aeration

Most commercially available ATUs operate as extended aeration units. Extended aeration is characterized by long-term aeration, long detention times, low F/M ratio, and low biomass accumulation. As shown in Figure 4.1, by providing plenty of dissolved oxygen and minimal soluble organic matter, the microbes will be forced into the endogenous phase of growth and will readily consume bioavailable organic carbon, including biomass. The goal is to balance the mass of new cells synthesized each day with the mass of cells endogenously biochemically degraded each day. The American Society of Civil Engineers (ASCE, 1977) suggests that, for a treatment unit

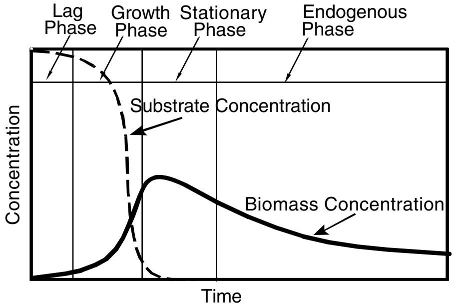

Figure 4.1 Kinetics of aerobic digestion.

to operate in extended aeration, 2000 cubic ft of air should be injected in the water per pound of BOD_5 removed.

As shown in Figure 4.1, kinetics of aerobic digestion, as substrate increases, biomass increases. These curves represent a batch-style application of substrate, in which biomass concentration changes in response to changes in substrate concentration. Intermittent-flow, complete mix systems only operate over a small range on these curves because the concentration of substrate tends to be relatively constant.

Suspended-growth bioreactors

As shown in Figure 4.2, suspended-growth ATUs are scaled-down activated sludge plants. Activated sludge is a heterogeneous microbial culture composed mostly of bacteria, protozoa, rotifers, and fungi. The bacteria are responsible for assimilating most of the organic material, whereas the protozoa and rotifers (serving as predators) are important in removing the dispersed bacteria that would otherwise escape in ATU effluent (Benefield and Randall, 1985). The biomass is thoroughly mixed with biodegradable organic compounds. Individual organisms clump together (flocculate) to form an active mass of microbes called *biological floc* (Davis and Cornwell,

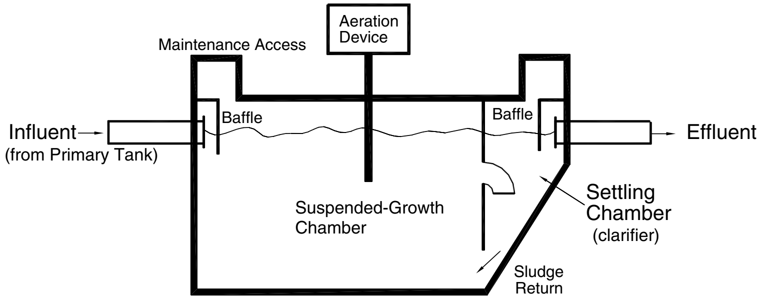

Figure 4.2 Schematic diagram of a suspended-growth ATU.

1991). This slurry of biological floc and wastewater is called *mixed liquor* (Reynolds, 1982). The concentration of microorganisms in mixed liquor is measured as mg/L of mixed liquor volatile suspended solids (MLVSS). That is the *volatile* suspended solids concentration in the aeration basin contents.

Reynolds (1982) wrote that the term *activated* is used to describe the reactive nature of biological solids. As wastewater enters the aeration chamber, suspended floc adsorbs organic solids and absorbs soluble organic compounds. Through enzymatic activity, the organic solids are solubilized. Once in solution, the soluble organics are oxidized by biochemical oxidation. At the inflow of the ATU, the capacity of the biological solids to adsorb and absorb substrate is rapidly filled. As the mixture moves into the clarification zone, the biological solids (or "activated" sludge) are re-activated as the oxidation process proceeds. Near the downstream end of the ATU, the biological solids are substrate limited and are therefore highly reactive to the remaining suspended and dissolved organic solids. The extended aeration process has been shown to run properly at a F/M ratio of 0.042 to 0.153 Lb of BOD per Lb of MLVSS. Functionally, MLVSS should not fall below 2500 mg/L or exceed 6000 mg/L. Organic loading is typically about 15 Lb BOD per 1000 cubic feet of volume per day.

Attached-growth bioreactors

Another broad category of ATUs is attached-growth systems. Often called *fixed-film reactors*, these systems contain an inert medium for microbial attachment (Figure 4.3). As wastewater flows through or across the media, fine, suspended, colloidal and dissolved organic solids are absorbed by the biological film. Wastewater and dissolved oxygen are brought in contact with the attached microorganisms by either pumping the liquid past the media or by moving the media through the liquid.

Coupled contact aeration

Treatment units are available that combine attached growth in the same basin as suspended growth. Referred to as *coupled-contact aeration*, the combination of attached-growth and suspended-growth processes enhances the performance and capacity of aeration units (U.S. EPA, 2002). This dual-system approach provides a higher degree of microbial population stability, and lower effluent suspended solids and BOD. Attached-growth areas are submerged and large channels are provided for turbulent water to flow over the surfaces. These large channels allow suspended-growth microbes to flourish. Aeration is provided by directly injecting air or by circulating the water to the air-liquid interface. Excessive attached growth sloughs off and settles to the bottom of the chamber. These solids accumulate and must be removed as part of periodic maintenance procedures.

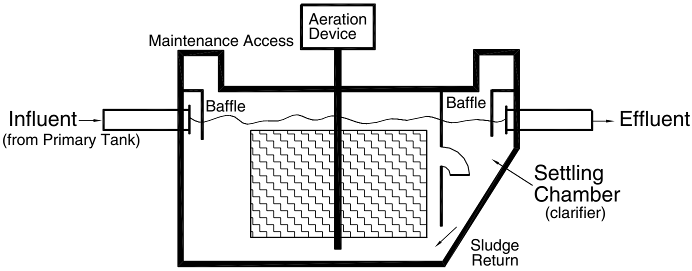

Figure 4.3 Coupled contact aeration system.

Rotating biological contactor

Rotating biological contactors (RBCs) combine suspended-growth and attached-growth bioprocesses. In RBCs, a series of closely spaced circular disks are mounted on a common shaft and are slowly rotated (Photo 4.1). The shaft is located either just above or just below the water surface. This location allows the surface of the disks to be exposed to both air and wastewater while rotating. A typical disk is made of an inert material such as polystyrene or polyvinyl chloride. A fixed-film biological growth attaches to the disks and, when submerged, the organisms are exposed to food. In rotation, the reactor carries the fixed film into the air, where it absorbs oxygen. Excess dissolved oxygen mixes with the bulk liquid as the contactor surface moves back through the wastewater (ASCE, 1977). As the thickness of attached biomass on the disk increases, some of excess biomass is sheared off the disk. This biomass is kept in suspension by the rotation of the disks. Ultimately, the flow of wastewater carries the solids out of the reactor chamber and into the clarifier.

Photo 4.1 Rotating biological contactor.

Generally, about 35 to 45% of a disk's surface is submerged in a RBC that is designed with the shaft just above the water surface. A system that has the shaft submerged in the water produces about 70% to 90% submergence (Crites and Tchobanoglous, 1998). A higher degree of organic removal and nitrification may be obtained by arranging sets of disks (or other inert media) in series, because each subsequent stage receives an influent with a lower organic concentration than the previous stage. The tank construction usually consists of reinforced concrete or steel and is enclosed to maintain environmental controls and to confine any nuisance odors. RBCs can be scaled down for single-family homes or scaled up to provide secondary treatment at municipal wastewater treatment plants (Metcalf & Eddy, Inc., 2003).

Sequencing batch reactor systems or periodic processes

In sequencing batch reactor (SBR) systems, flow equalization, aeration, clarification, and biomass wasting processes are carried out sequentially in the same tank (U.S. EPA, 1986, 1992). Because most SBRs require the system to be closed to influent during the treatment cycles, two reactors operating in parallel are required in order to maintain continuous flow. However, with new inlet designs, single-tank reactors can be used to maintain continuous flow. The SBR process can provide flow equalization and tends to modulate the quantity and strength of wastewater inflow.

SBR process description

One cycle of SBR operation has five basic modes:

- ***Fill*** — Raw wastewater that has been through primary treatment is added to the reactor. During this phase, aeration may or may not be supplied to provide alternating periods of high and low dissolved oxygen. This mode may occupy 25% of the total cycle time.
- ***React*** — Aeration is provided in an effort to obtain rapid biodegradation of organic and nitrogenous compounds. This mode typically consumes about 35% of the total cycle time.
- ***Settle*** — Aeration is shut off to allow the wastewater to become anoxic (for denitrification) and to allow for quiescent conditions that permit very effective liquid-solid separation. Clarification usually takes about 20% of the overall cycle time.
- ***Draw (also called "decanting")***— Clarified supernatant is removed. Decanting is accomplished using adjustable weirs, floating weirs, and submersible pumps. Excess biosolids must periodically be removed. Decanting generally takes about 15% of the total cycle time.
- ***Idle*** — Time is allowed for the first reactor to complete its full cycle, and then switch the flow into the second reactor for parallel operation.

This cycle is illustrated in Figure 4.4.

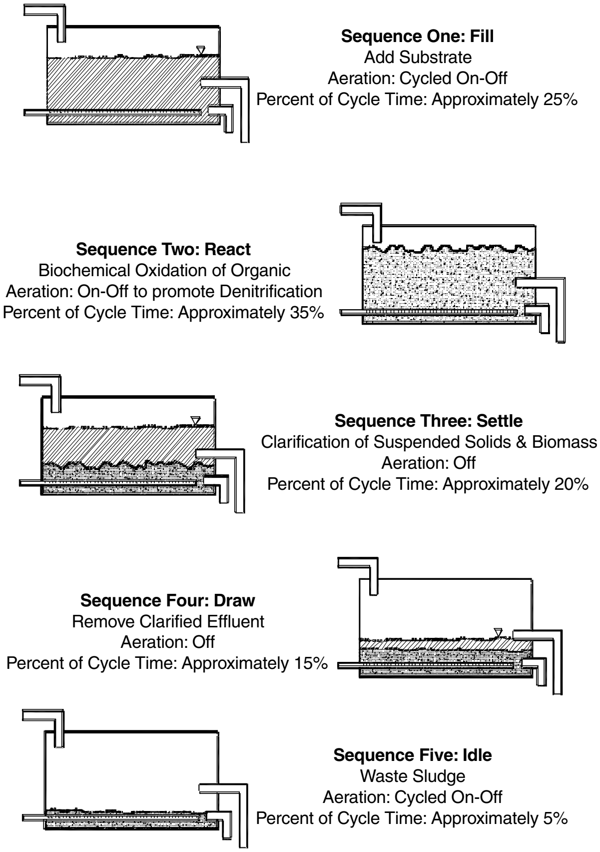

Figure 4.4 Sequencing Batch Reactor (SBR) cycles.

An important element in the SBR process is that a tank is never completely emptied; rather, a portion of settled solids are left to seed the next cycle (Henry and Heinke, 1996). This allows the establishment of a population of organisms uniquely suited to treating the wastewater. By subjecting the organisms to periods of high and low oxygen levels, and to high and low food availability, the population of organisms becomes very efficient at treating the particular wastewater (Henry and Heinke, 1996).

Nitrogen removal in SBRs

During aeration, organic and ammonia nitrogen present in the wastewater are converted to nitrate. When aeration is suspended and the remaining dissolved oxygen is consumed, denitrifying bacteria strip the oxygen out of the nitrate molecule, converting nitrate to nitrogen gas (denitrification). While other ATUs can be designed to provide denitrification, the SBR sequence can provide denitrification conditions without adding additional unit processes.

Typical applications of SBRs

With the development of reliable automatic control systems, SBR package plants have become competitive with more traditional ATUs. The process is flexible and efficient and can accommodate large fluctuations in hydraulic and organic loads. The process is particularly applicable to small communities, because of easy installation, simple operation, lower maintenance, and higher energy efficiency (U.S. EPA, 1992).

Other Process Considerations

Oxygen transfer

Large quantities of oxygen must be provided to maintain aerobic conditions. If influent to the ATU has an ultimate BOD of 100 mg/L, then 100 mg of dissolved oxygen per liter of influent must be provided to satisfy the oxygen demand. The primary function of the aeration system is to transfer oxygen to the liquid at such a rate that dissolved oxygen never becomes a limiting factor. Oxygen is only slightly soluble in water. Natural aeration cannot meet the demand of this high-rate unit process and, therefore, oxygen transfer must be engineered into the treatment unit in order to maintain a minimum residual of 1 mg of dissolved oxygen per liter of water.

The passage of oxygen from the gas phase (air) into the liquid (wastewater) phase is absorption. The driving force of oxygen transfer is the concentration gradient between the atmosphere and the bulk liquid. This gradient is created when there is a difference in the equilibrium concentration in the two phases. Thus, the force required to obtain equilibrium drives the transfer of atmospheric oxygen into the water. The saturated concentration of dissolved oxygen changes with temperature, barometric pressure, and salinity and with the concentration of water impurities. Designers of ATUs must maximize the contact interface (surface area) between the gas and liquid phases in order to maximize the opportunity for oxygen transfer. In other words, systems must be designed so that the concentration gradient between the gas-liquid interfaces is high and, therefore, the rate of transfer will also be high.

Aeration units are evaluated on the mass of oxygen transferred per unit of air introduced to the water. This is known as an *efficiency rating*. The goal is to maximize the mass of oxygen transferred per unit of energy consumed by the device. The most common method of maximizing energy efficiency is to combine mixing with aeration. Turbulent mixing is required to maximize the opportunity for microbes to come in contact with both soluble organic compounds and dissolved oxygen. If steady-state conditions can be maintained, the rate of oxygen transfer is equal to the rate of consumption by the microorganisms. Dissolved oxygen in the mixed liquor should be maintained at 1 to 3 mg/L. For residential-strength wastewater, Metcalf & Eddy, Inc. (2003) reports that 2 to 7 g/day of dissolved oxygen is needed for each gram of MLVSS.

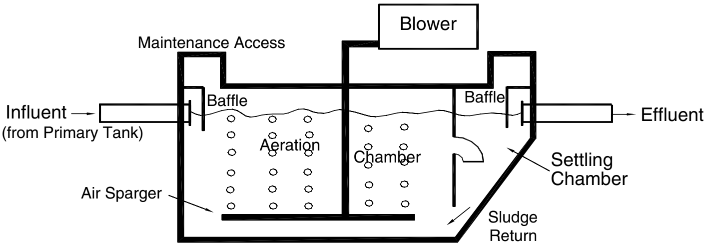

Figure 4.5 Aeration in an ATU by air spargers.

For most ATUs, the actual oxygen mass transfer efficiency is proprietary information. Manufacturers market specific ATU models based on organic and hydraulic loading. For a given unit, the aeration device is rated to provide sufficient dissolved oxygen for the given range of input oxygen demands (organic loading).

Basically, manufacturers of ATUs utilize two types of aerators: diffused air systems and mechanical aeration systems. Diffused air systems use submerged devices (spargers) to inject air into the bulk liquid. As shown in Figure 4.5, air injected below the surface has continuous contact with the liquid as it rises to the surface. The smaller the bubble, the greater the oxygen transfer rate. Additionally, bubbles formed deep within the chamber have more hydrostatic pressure to drive the oxygen transfer and more time-of-contact with the air-water interface. Another method of creating small bubbles involves porous ceramic diffusers. The small, interconnected passageways inside the ceramic matrix create a tremendous loss of air pressure and many points of outflow. This combination produces streams of small bubbles over the surface of the ceramic diffuser. A second method of injecting air is to precisely drill orifices into pipes and plates. Many large-scale aerobic digesters use jet aerators. Streams of air serve to transfer oxygen and to provide vigorous mixing of basin contents.

A third type of diffused aerator is an aspirated mixer. As shown in Figure 4.6, a mixing-propeller attaches to a hollow shaft that vents to the atmosphere. This propeller is located near the bottom of the aeration chamber. As the shaft spins, a venturi effect creates a vacuum down the shaft and injects air into the water. The mixing devices must balance the need for

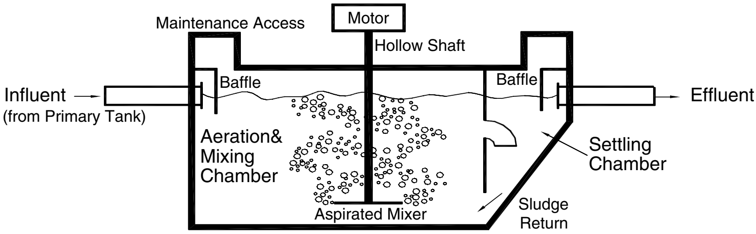

Figure 4.6 Aspirated mixer for aeration of an ATU.

agitation while minimizing the shearing of floc. If shear is excessive, poor settling conditions in the clarifier can result.

Several ATU manufacturers employ a cycled-aeration approach. Cycling the aeration system provides some energy savings and promotes nitrogen removal (temporary anoxic conditions). Care must be taken, however, because this technique can produce a poor settling biomass due to gas flotation and nonflocculating microbes.

ATU influent

Influent to an aerobic treatment chamber typically passes through primary treatment, provided by either a septic tank or some other type of primary tank. ATUs that can receive raw wastewater directly from a house and do not require primary tanks are also available. When used, primary tanks can provide separation of easily settleable and floatable solids before the influent enters the ATU. A large portion of these solids are likely nondegradable or slowly degradable. Manufacturers of ATUs provide guidance regarding the required size of a primary tank for their aerobic treatment devices. Primary tanks also provide an element of dilution that minimizes the effects of chemical shocks on the microbial population in the ATUs. Medications, such as antibiotics and chemotherapy drugs, are highly toxic to the microbial population. Most manufacturers list products that should not be added to the wastewater stream. In some manufacturers' literature, this list includes water softener brine backwash.

Hydraulic and organic loading

The specifications of an ATU are based on both hydraulic and organic loading. Hydraulic loading is the rate that water passes through the device; it provides information about the length of time that wastewater will be exposed to microbes. For example, if a basin has a volume of 1000 gal and the wastewater flow is 500 gal per day (gpd), the hydraulic detention time is 2 days. Organic loading refers to the food (incoming colloidal and soluble BOD) as compared to the microbial population available to consume the food (F/M ratio). Organic load is typically expressed in pounds per day. Used in this way, *load* is the product of flow and concentration, as indicated in Equation 4-6. If there is more food than microbes, the effluent quality will be poor. If there are more microbes than food, then the effluent quality will be high. As previously mentioned, the population of microbes is dynamic in an ATU.

$$\text{Load (Lb per day)} = \text{Flow (gpd)} \times \text{concentration (mg/L)} \times 8.34 \times 10^{-6} \quad (4.6)$$

If a system has been upset due to heavy laundry water loads that are low in soluble BOD, the microbial population may be reduced because of a lack of food. Additionally, wash-out of microbes can occur if hydraulic loading is greater than the designed outflow rate of the clarifier. When the next heavy dose of organic material enters the tank, the microbial population may be insufficient to complete the digestion of BOD during the hydraulic detention period. This phenomenon has been observed in seasonal applications, such as baseball fields and state parks. Furthermore, if an ATU is designed for a subdivision at ultimate build out, the F/M may not be adequate when only a few homes have been built in the subdivision during the early stages of development.

Flow equalization

ATUs are designed to work within a range of hydraulic and organic loads. Variations in flow rates and constituent concentrations that are outside of the design specifications seriously complicate the treatment process. Municipal plants have the advantage of serving large populations, which tend to balance their daily organic and hydraulic loading rates. However, during storm events, municipal plants must deal with tremendous inflow and infiltration problems. Municipal plants commonly use offline equalization basins or bypass aerobic treatments in order to prevent wash-out of microbes. Likewise, residential ATUs must be designed to handle days with high flows and still be able to provide sufficient biochemical treatment to discharged wastewater. Ideally, flow equalization would dampen the variations, so that there would be a constant or near-constant flow rate into the ATU. Equalization can be achieved with storage, float switches, pumps, and timers. Generally, additional storage in the primary tank is the most cost-effective method to accomplish flow equalization because tankage is usually the least costly portion of the overall expenses (Bounds, 2003). Most ATUs are not designed to provide flow equalization and, therefore, equalization must be provided just prior to the ATU.

Nitrogen and phosphorus in wastewater

The presence of nitrogen in wastewater results from the degradation of proteinaceous matter in feces and from urea, the chief constituent in urine. Nitrogenous compounds undergo various biotransformations in response to the presence or absence of dissolved oxygen. ATU influent, having just exited from a septic tank or other primary treatment system, contains nitrogen in organic or reduced-ammonium ion form. In the aerobic environment of an ATU, most of the ammonium will be oxidized to nitrate (NO_3), which is the most highly oxidized form of nitrogen. While in the ATU, a fraction of nitrogen may be removed by sedimentation, volatilization, and denitrification. Unless process modifications are made to the ATU, no reliance on net nitrogen removal can be expected. Nitrogen removal is highly dependent on specific performance of individual ATUs to create denitrification conditions.

Because phosphorus is often a limiting nutrient in natural ecosystems, eutrophication can occur when excess phosphorus is discharged to a surface water body. In wastewater, phosphorus can be bound in organic compounds or can be in soluble phosphate form (PO_4). Typical phosphorus concentrations in septic tank effluent range between 6 and 12 mg/L. Bacteria assimilate a small portion of the orthophosphate during their growth process. Conceptually, this amount of phosphorous could be removed by sedimentation. Because residential ATUs operate in the endogenous phase, very little sludge wastage (and thus very little phosphorus removal) occurs. When a higher degree of phosphorus removal is needed, a more advanced wastewater treatment system, such as chemical precipitation or a wastewater treatment plant designed for biological nutrient removal, would be required.

Operational issues

Start up

Start up involves the establishment of a sufficient population of microbes within the ATU to digest the soluble organic and nitrogenous components of influent. In most applications, a sufficient population of microbes enter the ATU with the wastewater to start the process. If needed, one method of inoculating the system is to add a few gallons of mixed liquor from an operational ATU such as a municipal wastewater treatment plant. While the biomass concentration is increasing, microbes tend to be dispersed and do not form floc that will settle in the clarifier. Until the biomass becomes more flocculated and can settle more readily, there is a greater potential for solids carry over, especially with high hydraulic loads. If solids build up in the clarifier, gas forms in the biosolids (as a result of anaerobic conditions within the solids) and cause solids to rise to the surface and form a scum layer. The quality of activated sludge offers a good measure of how well the process is proceeding. Generally, good quality activated sludge has a golden-brown color and an earthy smell if kept aerated. Microscopic examination also reveals a relatively varied population, with a healthy population of rotifers and other motile organisms.

Typical problems

Sludge bulking is a phenomenon that develops in the aeration tank when a growth of filamentous bacteria (primarily *Sphaerotilus)* attaches to the floc particles and impedes settling (Crites and Tchobanoglous, 1998). Such microorganisms can tolerate large changes in dissolved oxygen and nutrients, a situation that frequently occurs in small ATUs. These conditions cause a carryover of solids into the effluent. This phenomenon is particularly troublesome to smaller plants that may have considerable fluctuation in organic loading and lack of technical support.

When excessive growth of *Nocardia* (a hydrophobic bacterium) occurs, foaming and frothing on the liquid surface in the aeration chamber (and the clarifier) may result. The problem is exacerbated by the fact that the baffles in the clarifier trap the foam and foster more growth (Crites and Tchobanoglous, 1998). Some ATU manufacturers provide froth spray pumps. The froth spray reduces the surface tension of the water and breaks down the froth (Ohio EPA, 2000).

Biomass (sludge) wastage

Although ATUs use the extended aeration process, endogenous degradation cannot completely prevent accumulation of old biomass. Biomass and non-biodegradable solids commonly accumulate in a low areas of ATUs and, periodically, a maintenance provider must remove a portion of these solids. During removal, it is important to leave some of the solids in the aerobic chamber to serve as seed to repopulate the biological floc.

Performance certification

The National Sanitation Foundation (NSF International) and the American National Standards Institute (ANSI) publish a standardized procedure for independent evaluators to certify the performance and reliability of aeration units. NSF/ANSI Standard 40-2000, "Residential Wastewater Treatment Systems," establishes minimum materials, design and construction, and performance requirements for residential wastewater treatment systems having single, defined discharge points and treatment capacities between 400 and 1500 gpd.

Mechanical evaluation

Design and construction requirements of the NSF/ANSI Standard ensure that structural integrity is maintained when a system is subjected to earth and hydrostatic pressures. An *in situ* visual evaluation of the structural elements is performed during and after the performance testing period. The system is tested to ensure that it is watertight (i.e., no infiltration of groundwater or exfiltration of wastewater occurs). Water tightness is evaluated by filling the tank with tap water to the level of the high-level alarm. This level is then monitored for 24 hours.

All ATUs have moving parts. These parts operate in very corrosive environments and therefore require periodic maintenance and replacement. During the certification procedure, all mechanical components are evaluated to determine the frequency of required maintenance and the ease by which maintenance can be performed by a service provider. Inspections are conducted to ensure that all electrical components are protected by safety devices that meet or exceed ANSI/National Fire Protection Association (NFPA) Standard 70. ATUs must have mechanisms or processes capable of detecting failures of electrical and mechanical components that are critical to the treatment processes and detecting high water conditions. These mechanisms must be capable of delivering visible and audible signals to notify owners when electrical, mechanical, or hydraulic malfunctions occur.

All units must have ground-level access ports for visual inspection, periodic cleaning, replacement of components, removal of residuals, and sampling. Access to ports must be protected against unauthorized intrusion via padlocks, covers requiring the use of special tools, or covers weighing a minimum 65 Lb (29 kg).

Performance evaluation

NSF performance testing and evaluation of a specific type or model of treatment system is conducted for 26 consecutive weeks, with 16 weeks of design loading followed by 7.5 weeks of stress loading, and another 2.5 weeks of design loading. Design loading consists of operating 7 days per week with a wastewater volume equivalent to the daily hydraulic capacity of the unit. The 30-day average carbonaceous BOD_5 ($CBOD_5$) and total suspended solids (TSS) concentrations of wastewater entering the system should range between 100 and 300 mg/L and 100 and 350 mg/L, respectively. Stress loading is designed to simulate four nondesign conditions: laundry day, working parents, power or equipment failure, and vacation.

Performance testing and evaluation are conducted during 96 data days, with no interruptions for routine service or maintenance. Unless otherwise specified, all sample-collection and analysis methods must be in accordance with the current edition of the American Public Health Association's Standard Methods for the Examination of Water and Wastewater. During periods of design loading, daily composite effluent samples are collected and analyzed 5 days per week. During stress-loading conditions, influent and effluent 24-hr composite samples are collected on the day each stress condition is initiated. Afterwards, samples are taken to monitor the recovery of the treatment unit. Twenty-four hours after the completion of the wash-day, working-parent, and vacation stresses, influent and effluent 24-hr composite samples are collected for 6 consecutive days. Forty-eight hours after the completion of the power/equipment failure stress, influent and effluent 24-hr composite samples are collected for 5 consecutive days.

Residential wastewater treatment systems are classified as either Class I or Class II, according to the chemical, biological, and physical characteristics of their effluents. A Class I certification indicates performance to EPA Secondary Treatment Guidelines for three parameters: $CBOD_5$, solids, and pH (U.S. EPA, 1996). During the first calendar month of performance testing and evaluation, a unit is allowed to exceed 1.4 times the effluent limits for $CBOD_5$ and TSS sample concentrations without losing Class I status. A system can be designated Class II if 10% (or less) of its effluent $CBOD_5$ and TSS sample concentrations are greater than 60 mg/L and 100

Table 4.2 NSF/ANSI Standard Number 40-2000 Performance Classifications

Parameter	Class I 30 day average shall not exceed	7 day average shall not exceed
$CBOD_5$	25 mg/L	40 mg/L
TSS	30 mg/L	45 mg/L
Color	Individual samples shall be less than 15 NTU units	
Threshold odor	Nonoffensive	
Oily film	None visible other than air bubbles	
Foam	None	
pH	The individual effluent samples shall be between 6.0 and 9.0	

Class II

Not more than 10% of the effluent BOD_5 values shall exceed 60 mg/L and not more than 10% of the effluent TSS values shall exceed 100 mg/L.

mg/L, respectively. Table 4.2 provides the criteria for Class I and Class II performance standards.

As shown in Table 4.2, the performance bases of NSF/ANSI Standard 40 are organic carbon and suspended solids in the effluent. However, there is increased interest in evaluating treatment units for their capacity to remove nitrogen, phosphorus, and pathogens. Standard 40 provides procedures for evaluation of the removal of these constituents. However, specific performance of the removal of these constituents is not required in order to receive certification (Converse, 2001). The primary function of saturated ATUs is the digestion of soluble and colloidal organic compounds and removal of solids. Additional unit processes are added to the treatment train to provide denitrification, phosphorus removal, and disinfection.

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chapter five

Effluent dispersal and recycling systems

Introduction

All onsite wastewater treatment systems need a mechanism for treated effluent to be dispersed and returned to the hydrologic cycle. Subsurface dispersal (nonpoint source discharge) is the primary mechanism used for releasing effluent from onsite treatment systems. For most of the 20th century, onsite wastewater options were limited to only septic systems, so the choice for wastewater management was either sewer or septic. One of the unintended adverse impacts of having limited onsite wastewater choices is devaluation, or even condemnation, of tracks of land for development when traditional municipal sewer systems are not accessible and soil and site conditions do not meet the regulatory requirements for septic systems. It is widely believed that the rules governing the operation of septic systems are used as de facto zoning tools, mainly because if land is deemed unsuitable for installing a septic system (i.e., no perc), then no one can build a home or any other structure on it that has potential to generate wastewater.

Research conducted and field experience obtained over the past several decades indicate that soil and site conditions necessary for treatment and ultimate dispersal of septic tank effluent are not necessary for the treatment and ultimate dispersal of secondary or better quality effluent. Hence, we need to look at soil and site conditions in a totally different manner when advanced onsite wastewater systems are considered and soil and plant systems are used mainly for "polishing" secondary or better quality effluent rather than for reduction of organic waste load. This is the concept mentioned in Chapter 1 in which soil is not required to remove biological oxygen demand (BOD) or total suspended solids (TSS) and does not serve as a medium for mineralization of nitrogen from organic to inorganic forms. Instead, those functions are performed by an advanced treatment system for which the conditions and the material of construction can be controlled, leaving soil to be used for what soil is best for — recycling residual nutrients and polishing the microbiological quality of effluent.

Alternatives to conventional septic systems are needed in areas where soil and site conditions are not suitable for treating septic tank effluent or when use of septic systems is not cost effective or not desired, or where desired lot density cannot be achieved by using traditional septic systems. Such systems can also be used for rejuvenating septic tank effluent drain fields that are failing due to age and accumulated biomat. Introduction of aerobic effluent into an old drain field breaks down the biomat and allows the assimilation of aerobic effluent into the subsurface environment, thus in some cases, offering an effective and efficient repair option for old septic systems.

Dispersal of advanced secondary effluent

Aerobic treatment of wastewater to secondary or better quality effluent should be a key component of any permanent managed onsite wastewater infrastructure. Subsurface dispersal of secondary effluent can be achieved in an environmentally sound manner on any buildable site that is currently viewed as unsuitable for a septic system, as long as adequate land area is available for hydraulic assimilation of the secondary or better quality effluent and reduction in nutrient or bacteriological contaminant load.

Because a secondary treatment system reduces organic waste load (typically measured as BOD_5; TSS; and fat, oils and grease [FOG]) prior to introducing the effluent to the soil dispersal system, performance of an effluent dispersal system for secondary or better quality effluent is not influenced by biomat formation. In traditional septic systems, the formation of a biomat in the drain field is considered an important part of the treatment for removal and reduction of bacteriological contaminants. Therefore, a question typically arises among regulators about what happens to those contaminants when a biomat is not formed in the dispersal systems that receive secondary or better quality effluent. Dispersal of aerobic effluent into a subsurface soil environment allows the soil to retain aerobic conditions (unlike the dispersal of septic tank effluent) and thus enhances removal (neutralization) of bacteriological contaminants even without the formation of a biomat. Whenever necessary, aerobically treated effluent can be disinfected using a variety of advanced onsite disinfection technologies, such as ultraviolet or ozone disinfection systems. When chlorination systems are used, effluent should be dechlorinated prior to subsurface dispersal mainly to prevent any adverse impact of the residual chlorine on soil microorganisms.

Effluent dispersal technologies

Technologies available for dispersal of secondary or better quality effluent can be grouped as follows:

- trenches or beds filled with gravel or other media (gravity fed or pressure dosed)
- gravelless trenches or beds with chamber systems (gravity fed or pressure dosed)
- at-grade or above-grade (shallow trench, filter bed, mound, capping fill, etc.)
- drip dispersal (subsurface or surface)
- spray dispersal (above ground)
- minimum or zero discharge (evapotranspiration or greenhouse)
- point source discharge into surface water or on the ground
- existing onsite dispersal systems after removal of accumulated wastewater from them.

Photos 5.1 through 5.10 show various projects that use advanced effluent dispersal systems. Information on many other projects that use such dispersal systems is available on our web site. Designing, sizing, and layout of these types of effluent dispersal systems can be done using common sense understanding of soil and site conditions and the owners' requirements.

Adequately treated effluent can be safely released into the environment using any of the above effluent management systems, including existing onsite disposal systems (such as cesspools, trenches, seepage pits, infiltration galleries, or beds) that are failing due to excessive build up of a biomat. Highly treated effluent can also be used for flushing toilets or other nonpotable applications prior to release into the environment, thereby reducing the net amount of liquid discharge.

Since septic systems depend mainly on soil for the treatment of primary effluent, soil evaluation has been an integral part of the onsite wastewater business. However, with the availability of a variety of treatment systems, we no longer need to depend on soil for treating septic tank effluent. The installation of small, shallow or deep trenches, filter beds, drip, spray, or minimum or zero discharge systems for adequately treated effluent can be achieved on almost any site where adequate square footage of space is available. Performance of such dispersal systems does not depend on type, depth, or color of soil present at the site. In the 21st century, emphasis needs to be put on the use of appropriate onsite treatment and dispersal systems and on the permanent operation and maintenance of those systems rather than on the acceptance or rejection of a lot for an onsite system based on soil evaluation and soil criteria.

With the availability of pre-engineered and prepackaged treatment and effluent management systems in the market today, engineers now have more than 500 different ways of developing onsite solutions for wastewater systems. Soil and site characteristics as well as environmental sensitivity typically determine which onsite system may be used for a given project. However, a designer may decide to standardize onsite wastewater solutions using a small number of system categories that address most of the soil and site conditions in a given region.

Photo 5.1a Installation of a small (10-ft long and 1-ft wide) trench on a slope. Note that the backhoe is digging in the trench just by scratching the ground surface.

Photo 5.1b Close view of the small and shallow trench. Notice the fiberglass cover placed on typical four inch perforated drain pipe placed in the trench. There is no gravel used in this trench.

Photo 5.1c Side view of the small and shallow trench before covering the trench with soil material removed from the area.

Photo 5.1d Side view of the same trench after covering the trench with the top soil that was removed from the area.

Photo 5.1e Looking at the house from the bottom of the slope. The small and shallow trench is located between the house and the shrub.

Soil and site evaluation: then and now

Soil and site evaluation has been an integral part of the onsite wastewater business and its regulation. With the availability of various treatment systems, the use of soil for treatment of primary effluent or raw wastewater (septic tank effluent) is not necessary. When the use of advanced onsite wastewater systems is proposed, subsurface effluent dispersal systems can be adequately sized, designed, installed, and operated for any soil and site conditions; thus, there is no need to have regulatory requirements for soil and site conditions to determine whether a proposed site is "suitable" for an onsite system.

The soil and site evaluation that is typically done for septic systems generates such information as a soil description and the depth to limiting conditions. This information is not needed for sizing of a dispersal system for secondary or better quality effluent. A simplified approach for developing regulatory requirements for using advanced onsite systems is proposed later in this chapter along with a proposal for set-back requirements and sizing criteria. Some of the other factors associated with site evaluation would remain important, including determining slopes; location and distance to environmentally sensitive areas; location of water supplies; location of surface water bodies; location of utilities and easements; availability, location,

Photo 5.2 Small and shallow placed gravel-less trench that is used for dispersing up to 1,000 gallons per day effluent from an advanced onsite treatment system. Note that the trench is between Dr. Craig Jowett and Dr. Kevin Sherman.

and type of power (115 VAC, 230 VAC, single-phase or 3-phase); access to site for construction purposes; and location of existing underground utilities.

Currently, for designing onsite systems, most of the site evaluation factors required for choosing the appropriate advanced onsite wastewater technology are simply ignored and a "site evaluation" is essentially a description of the sidewalls of some pits dug on the property, which is typically done for soil mapping purpose. A true site evaluation includes many more factors for locating and choosing the appropriate wastewater treatment system and focuses less on two pits excavated or four auger holes bored on the property. A site evaluation for use of onsite systems should not be an exercise in soil mapping. The owners of onsite wastewater systems are not interested in knowing the color, texture, and structure of individual soil stratum, but they are interested in making sure that their onsite systems work on their properties and meet their needs for adequate wastewater management. A site evaluation process that truly results in meaningful information that a designer needs and can use for selection, design, and layout of an onsite system can be justified and will be accepted by the onsite professional; but a site evaluation process that simply meets the regulatory requirements for obtaining a permit cannot be justified and will not be accepted by onsite wastewater professionals.

Photo 5.3a A 5-ft wide and about 100-ft long trench that was dug down to about 10-ft depth to the sand layer and filled up with gravel. The "L" shaped trench is used to disperse about 5,000 gallons per day effluent from an advanced onsite treatment system that serves a service station. Photo courtesy of Mr. Daniel Pavon of Aquarobic International, Winchester, VA.

A variety of dispersal systems for individual home or small (less than 1000 gal per day [gpd]) commercial systems can be pre-engineered with little knowledge of soil characteristics and can be installed on a site in a manner that allows for adequate assimilation of effluent. Based on the site characteristics of the proposed location, an appropriate type of pre-engineered dispersal system can be selected and installed. It is possible to educate and train installers of onsite systems to install such pre-engineered dispersal systems with the availability of onsite engineering and other design expertise when needed. Effluent dispersal systems should be selected and sized based on a site's assimilative capacity for the design flow and the nutrient loading, rather than just based on soil characteristics. Soil and site conditions that are

Photo 5.3b Chambers were used to cover the four inch perforated pipes placed in the trench. Photo courtesy of Mr. Daniel Pavon of Aquarobic International, Winchester, VA.

Photo 5.3c Final view of the area where the trench is now dispersing the effluent from a SBR treatment system. Note that one end of the "L" shaped trench is at the white observation pipe and the other end is next to the dumpster.

Photo 5.4a Drip dispersal system for an individual home. Note that the drip tubing is installed in five feet wide trenches. Trenches are open and the system is being tested before covering the trenches.

Figure 5.4b Drip dispersal system area a few months after installation. Note that the grass is established and under the grass cover, effluent from an advanced onsite system is dispersed using drip lines.

Photo 5.5a Drip system for effluent dispersal installed in open area using a vibratory plow. Source: Photo courtesy of Mr. Robert Mayer of American Manufacturing, Inc., Manassas, VA.

Photo 5.5b Drip system for effluent dispersal installed in wooded area using a vibratory plow.

Photo 5.6a Spray irrigation system installed in the front yard used for dispersal of effluent from an advanced onsite wastewater treatment technology that serves a single family home.

Photo 5.6b Spray irrigation system installed in wooded area, back yard of a house, used for dispersal of effluent from an advanced onsite wastewater treatment technology that serves a single family home.

Photo 5.7a A filter bed system for dispersal of effluent from an advanced onsite wastewater treatment technology that serves a single family home. Note this picture was taken a few days after the installation was completed.

Photo 5.7b Same filter bed system a few years after it was installed. Note the happy homeowner standing between the two weeping-willow trees planted within the filter bed system.

Photo 5.8a Effluent dispersal area with a sign to restrict any vehicular traffic within the area.

Photo 5.8b Picnic area over and around a large effluent dispersal area. Note that the effluent is dispersed in subsurface environment with no adverse impact on the ground.

Photo 5.9a Evapo-transpiration beds for dispersal of effluent from an advanced onsite wastewater treatment technology that serves three individual family homes. Note the picture is taken few months after the installation.

Photo 5.9b Evapo-transpiration beds about four years after the installation. Note the plant growth within the beds.

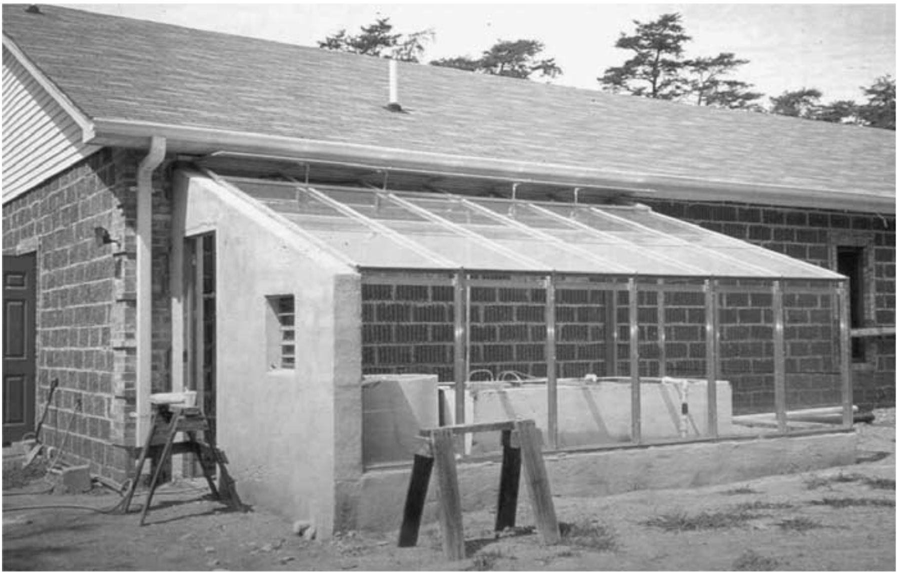

Photo 5.10a A wetland treatment system installed within a greenhouse for dispersal of effluent directly into atmosphere in form of humidity. This system serves a community center. Note the picture is taken just before the system went online.

Photo 5.10b The wetland system within the greenhouse a few years after the system went online. The final effluent from this treatment system is disinfected using Ultra-violet light disinfection system and the disinfected effluent is reused for flushing toilets inside the community center.

viewed as limitations for septic drain fields must not be viewed as limitations for effluent dispersal systems because soil is no longer required as a treatment medium for the wastewater, but instead is merely a medium for effluent dispersal and return to the hydrologic cycle in most instances.

The site's ability to effectively absorb and move effluent away from the dispersal site with minimum movement of pollutants is the only issue of concern when highly treated effluent is discharged into a subsurface dispersal system. Installation of at- or above-grade filter beds, drip, spray, or minimum or zero discharge systems can be achieved on almost any site when adequate square footage of space is available and the owner is willing to pay for the appropriate system to fit the site conditions —in terms of both capital costs and ongoing operation and maintenance costs. Performance of such systems does not depend on type, depth, or color of soil present at the site. Photos 5.1a through 5.1d demonstrate this fact in real world application. Note that a small (10 ft long and 6 in. wide), shallow trench is adequate to accept all the flow generated from the house that it serves. Flow monitoring for this house indicated that average flow measured over a 2-year period was about 150 gpd. No soil evaluation method, percolation test, or hydraulic conductivity test would have suggested a true hydraulic loading rate of 30 gpd per square feet of trench bottom area! Actually, the trench system shown in these photos was sized independent of soil characteristics. The photographs of other effluent dispersal systems indicate the same concept: sizing and design of effluent dispersal systems for advanced onsite treatment has more to do with site characteristics and method of application than with soil characteristics. Public access to the site within the zone of influence should be restricted if and when necessary. Photo 5.8a shows a large dispersal area where vehicle traffic is restricted, but the area is a park- like area for unlimited access to people for recreation. Photo 5.8b is a large drain field where the park-like setting is being utilized as a picnic area for the restaurant being served by the dispersal system. One of the persons having lunch at the picnic table is the director of a state onsite wastewater program. Once the zone of influence for a dispersal system is established on a given site, it is important to regulate the environmental conditions outside that zone, not within the zone. When necessary, samples of shallow groundwater can be collected from outside the zone to ensure that no pollutants escape in excess of allowable limits from the treatment zone.

Assimilation: subsurface dispersal of effluent

At the present time, sizing a subsurface dispersal system for septic tank effluent and aerobic effluent is heavily dependent on soil hydraulic conductivity or percolation rates. A most recent approach (Tyler, 2001) shows soil loading rates for secondary effluent as influenced by soil texture and structure. However, this approach indicates that certain types of soil texture and structure do not have conductivity, thus the soil loading rate is zero. The approach also indicates that, at the minimum, 8 in. of infiltration distance (soil between the bottom of the system and limiting conditions) are needed to determine linear loading rate. Thus, on sites where minimum infiltration distance is not present, this approach suggests that an effluent dispersal system cannot be designed because the linear loading rate is assumed to be zero. This approach is developed based on a theory that certain soil types are not suitable for installing any type of onsite wastewater system. However, our field experience suggests that both of the limitations, low conductivity and lack of infiltration distance, can be overcome by designing aerobic effluent dispersal systems following basic principles of soil physics. An engineered effluent dispersal system can be developed such that it can overcome resistance to water movement that is offered in extremely low permeability soils.

The most important consideration for a subsurface dispersal system's adequate treatment of effluent is the site's ability to assimilate the water (or moisture) in a manner that does not create any aesthetic or public health concerns, such as ponding or runoff of effluent containing a concentration or mass load of pollutants in excess of the specified performance limits from the site under normal rain conditions. Thus, we need to consider such a system as a site assimilative system (SAS) and not just a soil absorption system. Determining the operational adequacy of any SAS is a challenge. The intent of regulations for onsite systems is to protect public health and environmental quality and, keeping this intent in focus, we can develop understandable and measurable performance standards for any SAS.

Any SAS installed on any site in any area must not create any of the following problems:

- Point-source discharge (i.e., a stream flowing out of the area where the SAS is installed)
- Public nuisance (e.g., a puddle of water on or around the area where the SAS is operating, mainly during dry weather conditions)
- Health hazard
- Groundwater or surface water contamination due to organic, inorganic, or bacteriological contaminants that are discharged into the SAS.

Once such an agreement is reached among the regulatory agencies and wastewater professionals working in the private sector, developing monitoring requirements and performance standards for any onsite system will be relatively easy. People will then have adequate access to all the available technologies for managing wastewater onsite. Such a performance-based monitoring and regulatory system can also help "weed-out" inappropriate wastewater systems that may be in the market. There are technologies that sound good but simply do not perform adequately. With the current regulatory approach focusing mainly on preinstallation issues and typically ignoring ongoing performance monitoring of onsite systems, it is usually hard to separate the bad apples from the good apples until it is too late.

New concept for effluent dispersal system design

With recent advances in the onsite treatment systems industry and acceptance of the notion of managed onsite wastewater systems, can we take some of the mystery out of the "soil test"? Is it possible for professional designers to confidently say that if some minimum amount of land area is available in relationship to expected flow rates on land that is suitable for building a home or business, an onsite effluent dispersal system can be designed for any given soil and site conditions? The answer to both of these questions is "yes." The onsite industry should recognize the true potential of onsite aerobic treatment systems and a site's ability to adequately absorb and assimilate aerobic effluent under all types of soil and site conditions. Such a system can help streamline the processes for designing onsite wastewater treatment and effluent dispersal systems as long as an adequate amount of land area is available.

As a starting point, we propose a 6 in. per year loading rule for determining if a proposed site would be suitable for installation and operation of an onsite system with the appropriate management level (see Chapter 6 for more discussion on management). This rule says that as long as the volume of effluent generated on a property on an annual basis is no more than 6 in. per year, an onsite wastewater system can be designed, installed, and operated in a manner that protects public health and environmental quality. Six inches per year equals about 446 gpd on an acre of land. A typical household generates about 250 gpd of wastewater. Six inches also represents about 10% of void volume on 10 ft depth of soil profile on sites where the permanent water table is at a depth greater than 10 ft from the ground surface and soil with 50% void space.

In this chapter, a concept is presented for designing a land-based effluent dispersal system for small systems (typically for individual homes or small commercial facilities) and for assessing performance of such a design in field conditions. The current approach for regulating individual home and small onsite systems should be revised significantly. In Chapter 7 an approach is proposed for developing a solution-driven and performance-based regulatory framework for managed onsite systems that would allow use of advanced onsite technologies whenever and wherever they are needed or desired.

Because soil is porous, water movement through soil should be viewed as movement through a porous media that offers resistance to such a movement. With adequate design to overcome such resistance, water is expected to move in the subsurface soil environment. Water moves in soil in response to an energy gradient (Brady and Weil, 1999) either under saturated flow or unsaturated flow conditions. Although water movement in soil can also be achieved in gaseous (water vapor) form, this form of water movement may not be significant in onsite systems.

For a typical individual home onsite system, the question always is very basic: can the site adequately accept and move the quantity of effluent generated from the dwelling? The rule that typically defines adequate acceptance and movement of effluent by soil is that the effluent does not surface to the ground and it does not back-up in the house. If an effluent dispersal system can be designed to function in a hydraulically acceptable manner under all soil conditions, then the polishing and treatment of the effluent after discharge can also be adequately addressed by using treatment technologies to reduce pollution load before discharge.

When designing small systems, typically individual home onsite systems, the size and depth of installation determination can be simplified when the following three conditions apply:

- Aerobic effluent with BOD_5 and TSS less than 30 mg/L (greater than 90% reduction in group 1 contaminants) and effluent dissolved oxygen greater than 5 mg/L on a consistent basis (95th percentile or higher) is guaranteed.
- Quantity of effluent meets the 6-in. rule.
- The onsite treatment system is managed by a responsible management entity.

Experimental design example

Under these conditions, the size of an effluent dispersal system can be determined using a standard linear loading rate of 10 gpd per linear foot and the installation depth can be fixed at 5 ft below the lowest elevation on the property. The dispersal system could be a traditional trench (with or without gravel), drip, or pipe installed underground using a horizontal or vertical boring or drilling mechanism. Effluent must be pumped into any of these systems under pressure and a check-valve must be used to prevent backflow. The big unknown at present is what pressure should be maintained to ensure that effluent is released into the subsurface environment under dry, moist, and wet soil conditions. Overall pump run time per day for the experimental pre-engineered effluent dispersal system should be limited to no more than 4 hours per day. The size of any pre-engineered effluent dispersal system should be such that its installation requires minimum disturbance of ground, thus minimizing the cost for landscaping after installation. Since drip emitters' discharge rates typically are less than 2 gal per hour, the use of pressurized tanks (like the ones used for individual home water wells) to operate drip lines may be necessary to minimize the pump run time.

Soil physics indicates that when all pore spaces are filled with water, water moves in soil under saturated conditions and the quantity of water per unit of time Q that can flow through a soil layer can be expressed by Darcy's law (Brady and Weil, 1999), as follows:

$$Q = \frac{K_{sat} A \Delta P}{L} \tag{5.1}$$

Although this relationship is used in the onsite industry to indicate that water movement through soil is heavily dependent on saturated hydraulic conductivity (Ksat) and water movement through soil is not possible when the measured or estimated values for Ksat is 0, it is not clear if this relationship can be used to determine the hydraulic force (ΔP) driving the water into or through the soil. Typically, water movement through soil is influenced by gravitational force and capillary force. However, water movement into soil may be influenced by the pressure exerted by a pump that is pumping effluent into the drain line. In order to use the Darcy's equation to calculate the pressure head, values for the rest of the variables are required.

Soil physics also indicate that air and water, along with mineral and organic matter, are the critical components of any soil. Typically, 50% of soil volume is filled with matter, whereas the other 50% is occupied by air and water. Space that can be occupied by air and water in soil is referred to as the *void* or *pore space,* and values for void space can range from as little as 25% in compacted subsoil to as high as 60% in well-aggregated, high-organic-matter surface soil. The following formula is used to calculate the percentage of pore space in soil (Brady and Weil, 1999):

$$\%\text{Porespace} = 100 - \left(\frac{\text{Bulk density}}{\text{Particle density}} \times 100 \right) \tag{5.2}$$

One can expect to have a lower value of pore space in soil when the bulk density is low and the particle density is high. Conceptually, lower values of pore space mean lower capacity for holding and transmitting water in and through soil and possibly higher resistance to water movement, for example, lower hydraulic conductivity. Particle density (mass per unit volume of soil solids) for most soils varies between 2.60 to 2.75 mg/m^3, whereas bulk density (mass of unit volume of dry soil) for most soil varies from 0.1 mg/m^3 for Histosols to 2.0 mg/m^3 for Vertisols when dry. Thus, in Vertisols, one can expect to have a minimum pore space of about 42% for low bulk density of 1.6 mg/m^3 and high particle density of 2.75 mg/m^3. One cubic meter of Vertisols can hold up to 0.42 m^3 (or about 111 gal) of water in the pore space (or about 3 gal/ft^3 of Vertisols).

Subsurface application of 446 gpd on a 1-acre lot that primarily has Vertisols, would saturate 150 ft^3 of soil around the dispersal system. If the dispersal system configuration is a cylinder about 50 ft in length (i.e., a 50 ft pipe inserted in the ground and covered by soil), then the radius of the saturated cylinder would be about 1 ft and the surface area (A) of such a cylinder through which water has to move would be about 314 ft^2. Brady and Weil (1999) indicate that saturated hydraulic conductivity (Ksat) even for clay soil is more than 10 cm/day (equal to about 2 gpd/ft^2). With this information, Darcy's equation can be solved for the hydraulic force (ΔP) equal to about 35 ft of head. Similarly, we can solve the equation for a trench-type dispersal system that is 3 ft wide and 1 ft deep and the value for ΔP will be about 45 ft of head. Does this mean that if pressure is maintained equal to or greater than 45 ft of head in the pipe, effluent can be released into clay soil all the time? A field evaluation of such a standardized dispersal system installed on sites with worst possible soil conditions (very low conductivity and seasonal saturation conditions) can help answer this question.

Field Evaluation

The process for performance evaluation and verification of an onsite treatment system is quite formalized in the country today based on the standards developed by the American National Standards Institute (ANSI) or National Science Foundation (NSF) Environmental Technology Verification (ETV) programs. However, no formalized process or approach is available to evaluate or verify performance of an effluent dispersal system. Two basic rules apply to determine successful functioning of such a system:

- No back-up in the house or in the treatment component
- No surfacing of effluent on or around the area where system is operated.

Since the main issue in evaluation is measurement of pressure and flow through the system, incorporating in-line instruments to measure these parameters during operation can assists in evaluation of the concept design. In-line pressure measurement may be achieved using pressure sensors and data loggers available from Pace Scientific (*www.pace-sci.com*) or other companies that offer such instruments. Cumulative flow can be measured by installing a flow meter in line and by keeping records. With this type of information, one can determine if the pump used in a system is capable of maintaining the hydraulic gradient necessary to introduce effluent into soil. A check valve must be installed to ensure that backflow does not occur after the pump shuts down. Pressure readings should be obtained on both sides of the check valve.

Sites that are declared "unsuitable" for installing onsite wastewater systems due to such soil conditions as poor conductivity, shallow depth to impervious strata or seasonal saturation, and poor drainage or flooding conditions should be selected for field evaluation of this experimental design concept. Several sites in Virginia have been identified and are being considered for installation of this type of effluent dispersal system. At this time, system installation is planned but funding for installation must be secured and an installer capable of installing the concept design must be found. The 6 in. per year rule will be used to determine the amount of effluent that can be dispersed on the lot selected for this project. Under this rule, an acre lot will be rated for a 447-gpd system, which should be adequate for a typical individual home.

An onsite treatment and dispersal system should be installed on a lot such that adequate access to the critical components is possible for maintaining the system and taking samples and reading monitoring and control equipment. The effluent dispersal system should be installed keeping in mind that effluent will be released into soil under pressure; hence, there should be no weak spots in the system. If the system is installed using horizontal-boring techniques, then at least 5 ft on each side should be sealed using bentonite or another sealant material. If the system is installed using vertical-boring techniques, at least the top 5 ft of the bore must be adequately sealed. If a trench system is installed, the top of the gravel should be sealed in a similar manner to prevent effluent surfacing through weak spots. The holes or slots in the discharge line should face downwards in the trench or horizontal bore to prevent soil from accumulating in the pipe. The length of the pipe or trench necessary for dispersal should be determined based on the linear loading rate of 10 gpd per linear foot. When a drip system is proposed, the number of drip emitters necessary should be such that the entire daily flow can be discharged in no more than 4 hours per day. Thus, if the discharge rate per emitter is 1 gal per hour and the design flow is 400 gpd, then about 100 emitters will be needed. The length of drip tubing will depend on the spacing between the emitters. Use of a pressure-tank may be advisable to minimize the pump run time for operating the drip system.

A year-long evaluation period should be sufficient to assess the adequacy and effectiveness of this conceptual design. Critical places to make observations during the evaluation period include the pump tank (to make sure that the effluent is leaving the tank and not accumulating in the tank) and the area on and around the dispersal system (to look for surfacing or wetness caused from dispersal). Within 1 week, one may be able to determine if the system size is adequate to handle the design flow. One should consider time dosing of effluent, with 24 doses per day. Pump run time during a dose cycle will depend on the discharge rate. Assuming a typical discharge rate of 10 gal/min and the required ~20 gal per dose (447÷24), the pump run time should be set for 2 min and off time should be set for 58 min. This example's calculation is based upon dispersing 447 gpd. However, if the actual observations indicate that the pump is discharging at a rate less than 10 gal/min, then increase the run time and decrease the off time accordingly. The pressure reading recorded during the pump on and off cycle should indicate the degree of actual resistance to flow through soil.

Based on field observations, one can adjust the initial sizing parameters, mainly the linear loading rate, to either increase or decrease the length and the residual pressure to select a better pump, if necessary. Ideally, field evaluation of this concept should be conducted on sites that have clay or plastic clay soils with measured or estimated hydraulic conductivity values of very low or none in the top 5 ft of soil and where soil-limiting features are present in the top 5 ft of soil. The idea is to demonstrate that if such a pre-engineered effluent dispersal system can be operated on "tough" sites, then it should work on any site as long the assumptions used in this design apply. Selection of the pump to run this type of system depends on the amount of resistance offered to the movement of water through the soil and may vary based on soil texture; however, the variation may be insignificant. Field evaluation of several hundred systems is necessary to demonstrate that operation of such a pre-engineered system for dispersing secondary or better quality effluent on sites with different soil conditions is possible.

Nitrogen reduction and the effluent dispersal system

Use of subsurface soil and plant environment for dispersal of aerobically treated effluent can be beneficial for reduction of nutrient content, nitrogen, and phosphorus. Although reduction of phosphorus depends mainly on the soil's ability to adsorb the phosphorus via cation exchange capacity and complexation with metal oxides and calcium on the soil particles, reduction of nitrogen can be achieved by two primary processes: denitrification and plant uptake. We will focus mainly on nitrogen reduction in this chapter.

Reduction in mass loading of total nitrogen in an onsite wastewater system can occur in a treatment system as well as in an effluent dispersal system. The dilution that occurs from mixing with infiltrated rainwater reduces the concentration of total nitrogen but not the mass loading of total nitrogen. Typically, the rules and regulations address the *concentration* of nitrogen only and thus dilution can play a greater role in the process of reducing nitrogen impact from onsite systems. However, the design engineering community and the regulatory community could put more emphasis on reduction in mass loading and less on dilution in order to minimize adverse impacts on groundwater and surface water quality from nitrogen present in effluent. Figure 5.1 shows the transformation of various forms of nitrogen in an onsite treatment and dispersal system.

In an onsite treatment system, reduction in total nitrogen occurs by two principal mechanisms: by assimilation of nitrogen into cell mass and by denitrification of nitrate nitrogen into nitrogen gas. Nitrogen can be removed by assimilation into plants and by denitrification of nitrate nitrogen into nitrogen gas. Nitrogen removal in the treatment system can be achieved on a more predictable and reliable basis than that in the dispersal system. However, with adequate research and field data collection, design standards for onsite effluent dispersal systems may be developed such that nitrogen reduction can be predicted with confidence similar to that for onsite treatment systems.

Since the onsite systems used for single homes typically use subsurface nonpoint source effluent dispersal systems, such as trenches, beds, or drip systems, most of the remaining nitrogen is assimilated by the soil and plant system. This final step in an onsite system can act as an additional safety factor for limiting the adverse impact of nitrogen on groundwater or surface water. Nitrogen is essential for plant growth, and plant roots take up nitrate nitrogen when it is available. Also, anoxic conditions and the carbon source

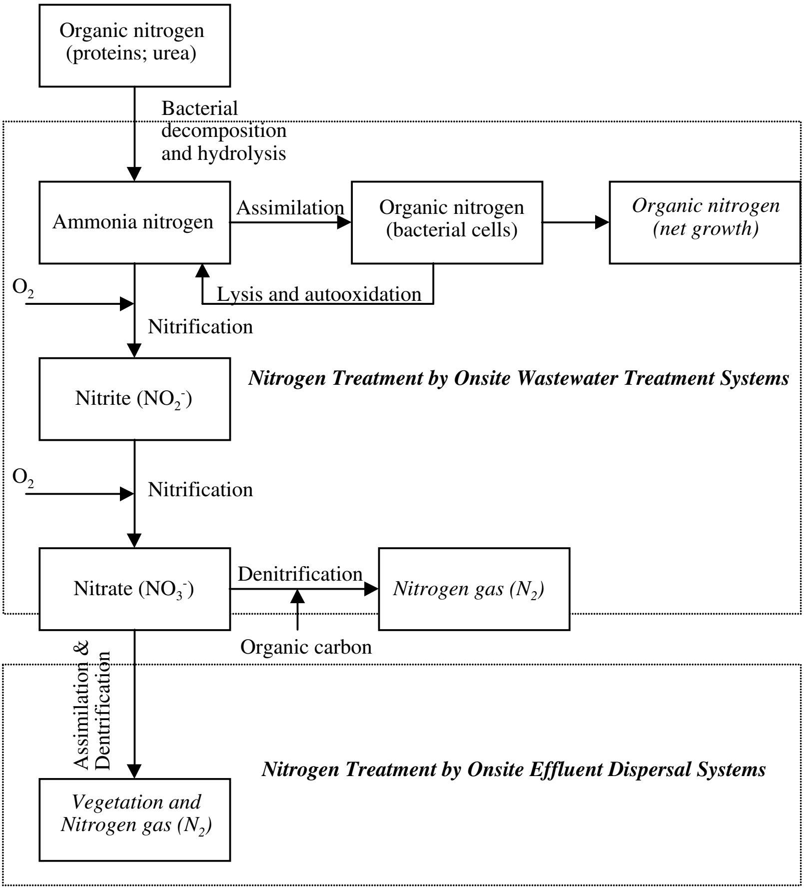

Figure 5.1 Transformation of various forms of nitrogen in an onsite wastewater treatment and effluent dispersal system. Source: Crites and Tchobanoglous, *Small and Decentralized Wastewater Management Systems*, 1998, with minor modifications.

present in soil denitrify nitrates to some degree (Wolf et al., 1998). However, any excess nitrate or other form of nitrogen has a tendency to migrate to groundwater or surface water.

Nitrogen model

When effluent from advanced onsite wastewater treatment technologies is dispersed into subsurface environments using any of the aforementioned effluent dispersal systems (except a greenhouse), the effluent mixes with rainwater that is infiltrated into the ground. This mixture of effluent and infiltrated rainwater is called *recharge water* and it eventually moves to groundwater. The nitrogen concentration in recharge water can be calculated using the mass-balance approach and the mathematical model proposed by Hantzsche and Finnemore (1992). This relationship can be explained in simple terms as:

Recharge water = Effluent (E) + Rainwater (R) that infiltrates into the ground

and

Nitrogen concentration in recharge water = (Nitrogen concentration in leftover in effluent + Nitrogen concentration in dilution water)/Total quantity of recharge water.

The mathematical equation proposed by Hantzsche and Finnemore (1992) is:

$$N_r = \frac{IN_w(1-d)+RN_b}{(I+R)} \tag{5.3}$$

where:

Nr = nitrogen concentration (mg/l) desired in the recharge water (the value should be the discharge limit set for nitrogen for groundwater, typically drinking water standards)
Nw = nitrogen concentration in effluent from the onsite treatment system (mg/l)
Nb = nitrogen concentration in rainwater (mg/l)
R = amount of rain infiltrated into the ground (inches per acre per year); could be determined using the runoff equation R = (1 – Runoff)
I = amount of effluent applied to the ground (inches per acre per year)
d = nitrogen removal fraction in the soil and plant system

and

$$I = \frac{0.01344W}{A} \tag{5.4}$$

where:

W = flow in gpd
A = gross area in acres
0.01344 = conversion factor.

These equations indicate that nitrogen impact on groundwater is related to effluent quality, removal of nitrogen in the soil, and the land area (or rainwater available for dilution). These equations can be used for many purposes, including determining the amount of land area necessary to achieve dilution to meet groundwater standards. Hantzsche and Finnemore

(1992) rearranged the equation for calculating gross area requirements as follows:

$$A = \frac{0.01344W(N_w - dN_w - N_r)}{R(N_r - N_b)} \tag{5.5}$$

We have developed and posted on our web site a spreadsheet solution for such parameters as Nr, Nw, A, d, and R using this mass-balance approach. These equations can also be used to determine necessary treatment levels for nitrogen reduction prior to subsurface dispersal of effluent for a given property or project. As proposed earlier, the design engineer must shoot for a reduction in mass-load of nitrogen as much as possible (greater than 66%) and use dilution with rainwater as little as possible (less than 33%). One of the biggest unknowns at this time is the value for "d," the fraction of nitrogen expected to be removed in the soil and plant system.

There is very little research conducted in this area to suggest how much nitrogen may be removed by denitrification and plant uptake using different effluent dispersal technologies and different layout schemes. The findings of one field study done in Virginia suggested that almost all nitrate/nitrogen was removed at the bottom of a sand-lined filter-bed system installed and operated for an individual home (Reneau et al., 2001). Projects such as this indicate that it is possible to achieve high levels of nitrogen reduction using onsite effluent dispersal systems. In Table 5.1, a scheme is proposed for assigning values for "d" for different effluent dispersal systems. These values are proposed as a starting point, but field studies should be conducted to confirm their validity.

Total maximum yearly load (TMYL)

Sizing criteria for onsite effluent dispersal systems are a critical and often debated issue in the onsite wastewater industry. What should be the soil loading rate for a particular set of soil and site characteristics and for a particular effluent quality? When advanced onsite systems are used, the size of an effluent system mainly depends on site conditions and a designer should have all the freedom necessary for sizing and designing an effluent dispersal system that would work and would minimize the installation and operational costs for the system. Thus, no loading rate tables for effluent dispersal system are proposed here. Instead, a new concept — total maximum yearly load in terms of inches per year (TMYL) — is proposed. This value may be specified by regulators or planners in the areas where advanced onsite wastewater systems are proposed. It is important to note that the value of TMYL as zero proposed by regulators or planners would only suggest that onsite systems being used as a zoning tool to control new growth. We recommend a minimum value of TMYL to be 6 inches per year; a maximum value depends on many factors, including the presence of a

Table 5.1 Values of "d" for various types of effluent dispersal system and design parameters

Probable Values for "d" for Nitrogen Model					
Dispersal System		**0.2**	**0.4**	**0.6**	**0.8**
Trench or Drip					
	Effluent Quality	Primary, Ammon-N > 2.0	Secondary or better, Ammon-N <= 2.0	Secondary or better, Ammon-N <= 2.0	Secondary or better, Ammon-N <= 2.0
	TBA Loading Rate (gpd/sq.ft.)	Based on Ksat	1.0 - 10.0	0.1 - 1	< 0.1
	Drip Linear Loading Rate (gpd/lf)	< 0.1	1.0 - 5.0	0.1 - 1	< 0.1
	Installation Depth	18" or more	18" - 36"	< 18"	< 18"
	Veg Cover	Grass	Grass	Grass & Trees	Grass & Trees
	Management Level	1, 2, 3, 4, or 5	3, 4, or 5	4 or 5	4 or 5
Filter Bed					
	Effluent Quality	Primary, Ammon-N > 2.0	Secondary or better, Ammon-N <= 2.0	Secondary or better, Ammon-N <= 2.0	Secondary or better, Ammon-N <= 2.0
	Basel Loading Rate (gpd/sq.ft.)	N.A.	> 1.0	0.1 - 1.0	< 0.1
	Installation Depth	N.A.	< 18"	< 18"	< 18"
	Veg Cover	N.A.	Grass	Grass & Trees	Grass & Trees
	Management Level	N.A.	1, 2, 3, 4, or 5	3, 4, or 5	4 or 5
Spray					
	Effluent Quality	Primary, Ammon-N > 2.0	Secondary or better, Ammon-N <= 2.0	Secondary or better, Ammon-N <= 2.0	Secondary or better, Ammon-N <= 2.0
	Application Rate (in/wk)	N.A.	> 1.0	0.5 - 1.0	< 0.5
	Veg Cover	N.A.	Grass	Grass & Trees	Grass & Trees
	Management Level	N.A.	1, 2, 3, 4, or 5	3, 4, or 5	4 or 5
ET Bed or Green House					
	Effluent Quality	Primary, Ammon-N > 2.0	Secondary or better, Ammon-N <= 2.0	Secondary or better, Ammon-N <= 2.0	Secondary or better, Ammon-N <= 2.0
	Management Level	N.A.	1, 2, 3, 4, or 5	3, 4, or 5	4 or 5

responsible management entity that can own and operate onsite systems on a permanent basis.

A simple relationship exists between TMYL, gallons per day flow from a home, and the gross area necessary to build a home. That relationship is as follows:

$$A = \frac{0.01344W}{TMYL} \tag{5.6}$$

where:

W = flow in gallons per day per home
TMYL = total maximum load in inches/year
0.01344 = conversion factor.

Equations 5-5 and 5-6 can be used for permitting individual and cluster home onsite systems that use advanced onsite treatment systems with minimum information on soil and site conditions. With this approach, licensed designers, engineers, and others will be able to design systems that adequately trained and certified installers can install and a certified management entity can operate on a permanent basis. Also, developers who plan to develop land using advanced onsite systems can confidently do so without having to worry about whether the land will "perc." A solution-driven and performance-based regulatory program will allow a responsible management entity to offer wastewater solutions using advanced onsite systems in areas where sewer extensions are not practical or not desired and in areas where conventional septic systems are failing. Equations 5.5 and 5.6 can serve as the primary tools to determine how much total land area is necessary for adequate assimilation of aerobically treated effluent. Details on actual loading rates (gallons per day per square feet or per liner feet) should be left to designers and should not be included in regulations.

A wastewater system that works in an acceptable manner throughout its life span is needed for managing wastewater onsite, as is a regulatory system that focuses on the performance of a wastewater system rather than on details of site evaluation, design, and system installation. At the same time, value-added engineering services resulting in the most efficient use of pre-engineered advanced onsite treatment and dispersal systems are needed. Engineering services that truly add no value to the project and are provided simply to meet regulatory requirements should be discouraged and eliminated in order to allow the public to use advanced onsite treatment systems. Even the current regulatory approaches for engineering and technical review requirements for small onsite systems should reformed. Any regulatory review that results in no value-added comments or improvement in the proposals (engineering report, plans, and specifications) should not be required. With the availability of pre-engineered onsite treatment and dispersal systems, regulatory reviews of individual home onsite systems and even large-scale onsite systems should be conducted only when such reviews result in value-added responses. Currently, enforcement of onsite systems is generally on the permitting end. By not allowing onsite systems simply because regulators are unfamiliar with them or have biases toward different solutions, a de facto enforcement occurs. By enforcing on the performance end and requiring accountability from the responsible management entity (with the key word here being "responsible"), systems must perform regardless of their configuration and placement on the property. When performance-based regulation and enforcement are the rule, the regulatory review of an individual plan and specification set becomes obsolete. Enforcement focuses on performance rather than permits. There is tremendous need for developing a utility infrastructure that can offer wastewater services in the same manner as centralized systems using advanced onsite treatment and dispersal systems.

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chapter six

Management framework for using advanced onsite wastewater systems technologies

Introduction

Technically, the onsite wastewater treatment industry is already into the 21st century; however, technology is just one of many different areas of any industry. Other areas need to progress in order for the industry as a whole to progress and be effective and competitive. The establishment of a utility infrastructure is one of the most important areas to address in order to be successful in this century.

Today, most homes that use onsite systems have conventional septic tank drain field systems. These systems are generally installed and forgotten about unless they start showing problems, such as sewage surfacing on the ground or backing up into the house. These systems are not operated or maintained by any wastewater utility companies — public or private — and most problems can be avoided by regularly pumping out the septic tanks or occasionally by installing additional drain fields. However, advanced onsite wastewater systems require a bit more oversight.

Also, in the 21st century, a wastewater system, no matter how small, ought to treat wastewater to secondary or better quality before discharging it into groundwater or surface water. Depending on soil for treatment of raw or primary quality wastewater (septic tank effluent) is not an environmentally sound idea and is not a sustainable concept. Soil may in fact be the most effective method for removing and recycling phosphorus and possibly even nitrogen. Mostly because of its unpredictable and nonhomogeneous physical properties, soil is not the most effective or the most reliable medium for removal of suspended solids, aerobic decomposition of organic carbon, and transformation (mineralization) of organic nitrogen to ammonium and nitrification of ammonium to nitrate.

Centralized versus onsite wastewater systems' management

Centralized wastewater treatment plants are operated by a utility, typically a public utility although privatization of the operation and management function is becoming more common. Trained and licensed operators monitor and maintain the treatment plant so that discharge from the plant meets the necessary performance standards. The utility or operations firm is responsible to the regulatory agencies for meeting permit requirements. Basically, a homeowner pays a hook-up fee to connect to a centralized system and then pays regular user charges, transferring all responsibility for sewage to the utility. Today, most people who live with onsite systems are responsible for operation and maintenance of their own systems. If a system goes out of compliance or becomes a nuisance to the neighbors, the homeowner is responsible for all litigation, penalties, and repair costs for the system.

Although just released and in its infancy stage, a new program is available on the market to provide a "bumper-to-bumper" warranty for onsite wastewater systems. This is the first program to include the soil component — the drain field — under any service contract or warranty (Carmody, 2004). The cost of the warranty program is borne by the individual homeowner; however, ongoing maintenance, repair, and compliance issues are borne by the warranty company. This program is one more step toward making onsite systems "invisible" to the homeowner or user of the system, and therefore allowing the user to pay a fee (similar to a monthly sewer charge paid to wastewater utilities) for their wastewater services to be provided by an outside professional entity.

Public acceptance of onsite systems can be enhanced only when onsite systems offer the same wastewater services as centralized sewage systems. When onsite systems can offer such operational comfort to people and offer an environmental protection guarantee to regulators, their use can be considered equivalent to centralized sewage systems. The technologies are now available to achieve both of these requirements in a cost-effective manner. However, the industry is still in an infancy stage regarding the development of an infrastructure similar to a utility that can make these technologies available to people.

EPA management models

The U.S. Environmental Protection Agency (EPA), in its 1997 Response to Congress (EPA 832-R-97-001b), identified lack of management programs as one of the five barriers to widespread use of advanced onsite wastewater systems. In 2003, the U.S. EPA published "Voluntary National Guidelines for Management of Onsite and Clustered (Decentralized) Wastewater Treatment Systems" (EPA 832-B-03-001). Since ongoing management (operation and maintenance) of traditional onsite systems (septic systems) is typically left up to system owners, proposing and promoting use of onsite systems under responsible management to the system owners is a tall order. Thus, the EPA outlines five models for management that recognize the fact that current onsite system owners may want to continue to own and operate their systems with clearly defined responsibilities (models 1 and 2) and that new owners may want to contract out the management to responsible management entities (RMEs) while owning their systems (models 3 and 4) or may not even want to own their systems (model 5). (*Note:* The EPA estimates that 33% of new development uses decentralized systems.)

The U.S. EPA defines an RME as "a legal entity responsible for providing various management services with the requisite managerial, financial, and technical capacity to ensure the long-term, cost-effective management of decentralized onsite or clustered wastewater treatment facilities in accordance with applicable regulations and performance criteria." An important idea here is to recognize the fact that in order for any and all onsite wastewater treatment systems to perform according to their design expectations and to protect environmental quality and public health from poor operation of such systems on a permanent basis, management is a must and someone has to be responsible for the system's performance and the required management.

Centralized wastewater treatment plants are managed (operated and maintained) by RMEs (public or private), thus management of onsite systems should not be viewed as a new concept. However, until the end of the 20th century, most onsite systems were conventional septic tank drain field systems without any electromechanical components (such as pumps or blower or float switches) and their use was viewed as temporary until the sewers come, thus no major emphasis was placed on their management. In addition, once systems are constructed, little enforcement takes place. Certainly little or no performance monitoring occurs, so if systems are contaminating the receiving environment, it is unknown.

Responsible Management Entity (RME)

An RME would be a company that offers comprehensive wastewater services using the latest and most appropriate advanced onsite systems for any site conditions to meet the needs of the home or the establishment generating the wastewater. Such a company would be responsible for selecting treatment and dispersal or recycle and reuse systems for the soil and site conditions and wastewater quantity and quality characteristics, installing these systems, and operating and monitoring the systems on a permanent basis such that public health and environmental quality are protected from the operation of these onsite systems. All the engineering, site evaluation, and other services necessary for adequate operation of onsite systems could be and should be offered by the RME. The manufacturers of various onsite treatment and dispersal or recycle and reuse systems and the private sector engineers and site evaluators would offer their products and services to the RMEs rather than to individual homeowners, as is done today. Also, RMEs would approve or disapprove an onsite technology based on its performance in the field, instead of evaluation of the systems by regulators, as is done today. This approach will weed out inefficient and inadequate onsite systems in timely manner and thereby encourage manufacturers, engineers, and designers to develop efficient and adequate treatment systems that would have a guaranteed market and that would be operated under adequate supervision of well-trained operators.

The advanced onsite wastewater treatment systems presented in this book are designed and manufactured to treat wastewater to a significantly higher degree than conventional septic tanks, thus routine operation and maintenance of these systems is more important and necessary to ensure their performance. Although there is nothing to operate in a conventional septic tank, the maintenance of even a septic tank (cleaning of the effluent screen or pumping out) must be considered important in order for such a system to be considered as a legitimate part of the wastewater infrastructure. Performance of any unmanaged (ignored) onsite wastewater system cannot be guaranteed, thus it cannot be considered a legitimate part of the wastewater infrastructure. If a system owner decides to keep the ownership of the system and take responsibility for operation and maintenance of the system, he or she must be registered as an RME for that system and must be regulated in a manner similar to an RME that owns or manages more than one system. During the permitting phase, the applicant (system owner) should be given a chance to opt into a private or public RME; if the applicant chooses not to do so, then the system owner by default becomes the RME for the system. At any time, the system owner should be allowed to join an RME if and when it is possible to do so, thus moving all or partial responsibilities of management from the owner to the RME. In order to join an RME, however, the system must be evaluated in terms of its ability to properly treat wastewater. It is quite conceivable that a system would not be taken on by an RME if the system is inadequate or if it has been abused. Also, RMEs may choose to set rates based on a particular system's liability in terms of being able or unable to function properly. This is part of the weeding out process mentioned earlier. Inefficient, unreliable systems would require higher maintenance fees than more reliable systems.

Recognition of the importance of onsite system management needs to start at the permit application process. An example of a simple application form is presented later in this book. Note that for onsite systems, the permit applicant typically is not the system owner. For example, a builder typically applies for and obtains a construction permit for an onsite wastewater system for a residential or commercial dwelling. The homeowner's name (if it is a custom-built home) may appear on the permit application. The dwelling then gets sold and is occupied by the owner, who may or may not have any idea about the onsite wastewater system from a technical or management perspective. It is important to have laws that require filing detailed information (application form, construction permit, and operation permit) for an onsite wastewater system that serves the dwelling with the deed document for the dwelling, making the information accessible to the owner who purchases the property. For onsite systems, the minimum evaluation may be for the lending agency, and if the home is vacant, little performance information is available. A simple site visit when no water has been used may reveal little information about the system's ability to function properly. Typically, when a dwelling is served by a centralized collection and treatment system (sewer systems), information on the sewer connection and sewer bills are present and property owners are required to sign statements noting that they have received all the information on their sewer system. Similar legal requirements should be implemented for onsite systems. Only then can use of onsite systems with management become reality.

In this book, we use the term "utility," which should be viewed as similar to the term "responsible management entity" as defined by the U.S. EPA.

Who can be an RME?

Because onsite systems have historically been used without any formalized long-term management programs, introduction of the concept of using these systems with formalized long-term management programs and the concept of forming RMEs has generated fear among some stakeholders in the onsite industry. Some of the main concerns and questions are: who can become an RME; how can a developer, homeowner, county, or community work with an RME; and what would be the role in the industry that promotes use of onsite systems with management? The players within the onsite industry who are competent about their roles and work typically have no fear about the concept of an RME. As a matter of fact, these stakeholders prefer to see their products and services being used with responsible management rather than with no management.

Anyone acting as a site evaluator, system designer, engineer, manufacturer, installer, pumper, or even a regulator can become and act as an RME as long as the organization they are working for is ready to take responsibility for all 13 program elements that the U.S. EPA lists in their guidelines for management of onsite systems. These program elements include:

- Planning
- Record keeping
- Inventory and reporting
- Site evaluation
- Financial assistance and funding
- Construction
- Design
- Training
- Certification
- Residuals management

- Inspection and monitoring
- Corrective action
- Performance
- Operation and maintenance
- Public education and participation.

There are ways in which firm that are currently specialized only as engineering firms offering consulting services or as soil and site evaluation firms but are interested in becoming RMEs can do so by developing and adapting a business model in which all 13 EPA-required elements are adequately addressed. Even a firm that only does installation work or pumps septic tanks can become an RME if interested and qualified. Manufacturers of advanced onsite treatment systems can start offering all the services necessary before, during, and after installation of their systems, thus becoming an RME. If and when necessary, even local regulatory agencies can act as RMEs, thus filling the void for services that an RME can offer in their community. An RME does not have to do all the activities within its business; however, an RME takes full responsibility for all the activities that are necessary to offer wastewater services on a permanent basis using advanced onsite wastewater systems.

One of the existing public sectors that typically does not get involved with onsite systems is the public works or public utility department present in localities (towns, cities, or counties) that is responsible for operating centralized water and wastewater treatment plants. However, that is not always the case. In at least one instance in the U.S., a large municipal water and wastewater utility provides decentralized wastewater services to outlying developments that are too far from the city to make conventional gravity sewer and lift stations economically feasible. The city provides water service, because transporting water to the developments was more cost effective, and the municipality was able to generate water revenue. By using a combination central water service and decentralized wastewater service, the municipality has been able to generate a revenue stream from both water and wastewater while optimizing their capital costs for infrastructure. These agencies are acting as RMEs for centralized systems and they can do the same for decentralized systems, thus expanding their rate-payer base without extending the sewer pipe.

Utility/RME system concept

It is time to seriously consider the use of onsite systems under a utility concept. Few management entities present today in the country offer wastewater services to people who use onsite systems. Even when these services are available, the soil component of the system is not included in the management agreement and is never included in the system manufacturer's warranty. Serious consideration should be given to development of a regulatory system that allows people to access wastewater services from a utility the way they get other services, such as telephone, cable, gas, or electricity service. There is also a need to define the kinds of services a utility should offer and the role such a company should play in the onsite industry.

When a utility is responsible for permanent operation and maintenance of an onsite system, simple issues such as access to the system's components for maintenance and inspection can be addressed in a timely manner. A qualified utility should be licensed to do all pre- and post-installation work, such as engineering, site and soil evaluation, and wastewater system selection. The qualified RME should be licensed to provide installation and operation of onsite systems on a permanent basis. Such a utility should be allowed to use the best available technology for wastewater treatment and dispersal and should be regulated based on the performance of the onsite system, both in terms of operational services to the customer and protection of the environment and public health.

Under the utility model for onsite systems, the roles of manufacturers, engineers, designers, soil and site evaluators, and installers can be defined in a manner that would result in the most efficient use of their services. Today, the requirements of soil and site evaluation and engineering design quite often do not add any real value to the operation of individual home and small commercial onsite systems. Most of the current regulations for onsite systems still require soil and site evaluations to determine if the proposed site is suitable for an onsite system. Such pass/fail criteria for a site are not necessary because it is now possible to construct a wastewater system for any buildable site.

Of course, onsite systems generally are scattered over a large area, making it a challenge to offer operation and maintenance services in a cost-effective manner. However, with advances in the area of remote monitoring systems, it is now possible to keep a constant watch on the operation of a large number of scattered onsite systems from a central location. This is not unlike cities that have multiple sewer lift stations with Supervisory Control and Data Acquisition (SCADA) systems as part of the infrastructure. If a pump fails in a municipal sewer lift station, the SCADA system informs operators, and they make service calls as necessary. Most aerobic treatment units (ATUs) and media filters use a pump or a blower for treatment. Performance of such systems, (i.e., the effluent quality) mainly depends on the performance of the component that operates the system (i.e., the pump, blower, etc.). With a control panel that is designed to operate the components as well as to send electronic signals about the status of these components to a centralized computer system on a routine basis or to the operators in emergency, it is now possible to operate a large number of systems professionally on a cost-effective basis in a manner similar to operating conventional municipal sewer systems.

Public acceptance of onsite systems can be enhanced only when such systems offer wastewater services that are just like centralized sewer systems. For a typical homeowner, it is important that sewage does not backup in the house, there are no "sewage alarms" to worry about, there is no odor from the sewage system, and the sewage system does not interfere with the expansion or resale of the property. When onsite systems can offer such operational comfort to homeowners and offer environmental protection to regulators, their use can be considered equivalent to centralized sewer systems. Technology is now available that can achieve these requirements in a cost-effective manner. However, we are still in an infancy stage of the development of an infrastructure similar to a utility that can make these technologies available to citizens on a large-scale basis, and we are in a similar stage in terms of the regulations that govern the use of onsite systems by citizens.

Once a decision is made to develop a land area that is not served by a centralized wastewater system, an onsite system utility can offer all the services necessary for adequate treatment and dispersal of wastewater. The environmental and public health regulators can then make sure that the services provided by the utility offer safe, adequate, and proper protection to the environment and public health.

Value-added services

Under the current regulatory system for septic systems, a homeowner has to deal with an engineer or other designer, a soil and site evaluator, an installer, a manufacturer, and a regulator and must spend a lot of money, especially when the lot is not suitable for a conventional septic tank drain field system. Soil and site evaluations are sometimes done by public and private sector soil scientists; similarly, engineering for single-family home onsite wastewater systems is done by public and private sector engineers. This approach typically leads to a slow and expensive duplication of work. For a commercial system, it is not uncommon for an owner to have to deal with multiple divisions within an agency and to also have to deal with more than one state agency. For example, in Arkansas, systems over 5000 gal per day (gpd) with subsurface dispersal must go through:

- A soil review from the Environmental Health Division of the Department of Health
- An engineering review from the Engineering Division of the Department of Health
- Subsurface discharge permit application and review by the Water Division of the Arkansas Department of Environmental Quality.

If the site is on a Corps of Engineers Lake, the U.S. Army Corps of Engineers may also have a role in the permit application. In one case, two divisions of one state agency, one division of another state agency, and two divisions (real estate and environmental divisions) of the U.S. Army Corps of Engineers were involved in permitting a 1000 gpd onsite system. Most of the agencies required payment of a review fee. In that particular case, a U.S. senator's office also participated and a public hearing was required. This event actually happened within the past 8 years.

In contrast, under the utility model, the necessary preinstallation work can be done by the utility in an efficient manner. Adequate installation of onsite systems is very important for the long-term use of such systems. Under the utility model, well-trained installers can install systems, and soil and site evaluators and engineers can offer value-added services when needed. Manufacturers of onsite systems can also be assured that their products will be installed and operated in a professional manner, according to the manufacturers' recommendations, and on a permanent basis.

Redefining the roles

Only a utility company (public, private, or some combination) can correct the current situation with onsite systems. Today, a regulatory agency is involved in all aspects of the onsite industry. In most states, a health department, state or local, is given the task of regulating the installation of onsite systems, mainly septic systems. Most of the resources of the regulatory program are allocated to preinstallation issues, such as soil and site evaluation and review of engineering work submitted by the private sector. The performance of the system is taken for granted, and there is no monitoring of the system's performance or the system's impact on the environment.

With advancement in technologies for individual home wastewater treatment and dispersal systems, it is time for regulatory programs to shift their emphasis from preinstallation to postinstallation issues. It is time for regulatory programs to move away from dictating where people can live, how many bedrooms people can have in their houses, how many seats a restaurant can have, and what kind of wastewater systems they need. Instead, a utility could be involved that is licensed to offer wastewater services in a cost-effective and environmentally sound manner.

Preinstallation could be provided by utilities that are licensed by the appropriate regulatory agencies to offer wastewater services to citizens who do not have access to centralized sewage systems. Such a utility must move away from using conventional septic tank drain field systems and consider onsite systems that discharge at least secondary or better quality effluent into the environment. Regulatory agencies can then focus on monitoring the performance of wastewater systems and their environmental impact. Performance monitoring may be required in environmentally sensitive areas or in areas where public health issues, such as proximity to drinking water sources, may exist. An RME would be equipped to perform the necessary sampling and analyses required to monitor those systems' performance and to cooperate with regulatory agencies to provide performance reports. This model is already in place with the National Pollutant Discharge Elimination System program and with management entities and laboratories routinely monitoring and reporting to regulatory agencies. Sampling and analysis are performed and discharge monitoring reports are submitted based on a schedule set in the permit.

If and when needed to meet higher environmental standards, the utility may be asked to upgrade the systems that are operating in its service area. This is unlikely, however, if the utility starts with an onsite system that uses a media filter or an ATU to achieve advanced treatment and a shallow trench, drip, spray, filter bed, or evapotranspiration type system for adequate dispersal of treated effluent.

Helping the onsite industry

A utility company can also help the onsite industry adequately "weed out" wastewater technologies that are poorly designed or manufactured. At present, there is no mechanism that can measure the long-term performance of small wastewater treatment and dispersal systems. A utility company that is responsible for acquiring, installing, and operating wastewater systems in a manner that meets the necessary performance standards in a cost-effective way will always strive for the best possible technology. Such a company will have an interest in looking at a system's ability to meet performance standards and achieve customer satisfaction and will also look at the system's long-term cost. Only with such a company can the onsite industry really judge the true potential of the various systems currently on the market.

Serving the people and the environment

A utility company can also educate people about the environmental impacts of wastewater and about the importance of reuse or recycling of adequately treated wastewater. There is tremendous interest in the use of environmentally friendly systems and the reuse of treated wastewater. One must, however, realize that improperly managed wastewater systems can create environmental and public health problems. Only under a proper management framework can people have access to environmentally friendly, advanced wastewater systems.

A utility company can also help people get the best possible wastewater system at the least possible cost by acquiring products and services in quantity. Today, most people who apply for onsite system permits (typically to a health department) get most of the preinstallation services, such as soil evaluation and design, from a health department employee, a sanitarian, or a private practitioner licensed by the health department. Many of these employees and practitioners are trained on only one type of onsite system — a septic tank drain field system. When it is determined, however, that soil and site conditions are not suitable for a septic tank drain field system, the homeowners are asked to retain the services of someone in the private sector for the use of alternative systems and are asked to purchase the products and services necessary to install those systems. Thus, the current regulatory system is the main reason why there are so many septic tank drain field systems in the country and so few alternative systems that treat wastewater to secondary standards or better before discharge.

The onsite industry should seriously reconsider the current approach by which regulators are allowed to "sell" one type of onsite system — a conventional septic tank drain field system. This approach creates a situation in which companies that manufacture packaged treatment and dispersal systems have to compete with government employees who are authorized to sell generic systems. At the same time, the regulatory agency is not held responsible for the long-term consequences on the environment or public health from the operation of the systems that they require. As one can see, this is not a good approach by any means.

If, however, a utility is allowed to offer wastewater services, the onsite industry will definitely benefit in terms of offering well-engineered, advanced wastewater treatment and dispersal systems that can protect public and environmental health on a permanent basis in a cost-effective manner.

Long-term cost

As indicated in Chapters 3 and 4, numerous companies offer a variety of onsite treatment and disposal technologies. It is hard, however, for the public to really evaluate which system may be suitable for each situation. A wastewater system has three types of costs: capital cost (the cost of getting a system installed); operating cost (the cost of power to operate the system and the cost to maintain it); and replacement cost (the cost to replace some or all components of the system at the end of their useful lives). Some systems may be less expensive from a capital cost point of view but may require high operation costs, whereas some may be the other way around. Some systems simply are not sustainable or have components that are not durable and must be replaced within a short time. It is important for the homeowner and the designer to consider the long-term cost of a system.

Typically, however, homeowners and developers are not interested in the long-term costs of a wastewater system because they may not use the system on a long-term basis. Thus, only the utility that is required to operate the system on a permanent basis and is responsible for its performance can really judge the true cost of a wastewater system. An onsite wastewater system, just like a centralized system, must be for the structure that it serves and not for the people who live in that structure or use the structure for commercial purposes.

Under a utility model, the cost of offering wastewater services using onsite systems will be no different than what is typically charged to people who have access to central sewer systems; in fact, it may be even less. It is important to keep in mind, however, that most centralized systems are subsidized by public funds. During the construction grant program in the 1980s, billions of dollars were spent to subsidize the construction of centralized collection and treatment systems. Therefore, one must look at the real cost of connecting to a centralized system and not the subsidized cost.

Under a utility model, a residential onsite system could be made available to individual homeowners for less than $20,000 in construction cost, with an operating cost of less than $10 per thousand gallon of usage. Of course, greater cost effectiveness could be achieved with economies-of-scale. The bottom line is the fact that if connecting to the nearest sewer system is less expensive than installing onsite systems, then that is the way to go unless people want to pay more to have decentralized systems for some environmental quality reasons. Typically, when all the real costs (cost without government subsidies) associated with connecting to an existing sewer system (cost of collection and treatment) are included in the cost analysis, use of advanced onsite wastewater systems typically comes out as a cost-efficient solution from the capital cost view point; however, one must also consider the cost of management and look at a 30 to 50 year cost analysis for comparing costs between connection to an existing centralized system and onsite systems.

Among the costs to compare are the maintenance costs. A common misconception is that conventional gravity sewers are maintenance free. A drive through most cities would reveal this to be untrue. A sewer vacuum or jetting truck cleaning the sewer mains is a common sight in most cities. Even conventional gravity sewers must be cleaned and maintained at great expense in terms of manpower and equipment. These costs must be considered when a comparison is made to other types of collection systems such as pressure sewers.

Regulatory changes needed

The process that could establish such a utility model in a state must start with changes in legislation. There needs to be a legislative mandate to change the current regulatory framework for onsite systems from a prescriptive to a solution-driven, performance-based system and to allow utilities to offer wastewater services to people who are not on a central sewage system. The revised regulatory framework must not limit the use of the latest technologies available for addressing wastewater treatment challenges under the utility concept. Most importantly, legislation is needed that sets a time frame to phase in the use of the most appropriate onsite system under the utility model and to phase out the use of conventional septic tank drain fields. Chapter 7 includes details on a new concept for the regulatory framework.

Examples of utility programs

Although the current reorganization for management of onsite systems by the U.S. EPA has developed new interest in the onsite industry, some examples of management programs were established in 1970s and are still in use. The textbook *Small and Decentralized Wastewater Management Systems* (Crites and Tchobanoglous, 1998) lists several of these management programs, including details on some of the oldest management programs, such as Georgetown and Stinson Beach, CA. Environmental impacts of onsite wastewater systems used in environmentally sensitive areas, such as along coastlines or near drinking water supply areas, were recognized and area-wide management programs were implemented to prevent contamination of groundwater or surface water bodies from the use of onsite systems.

Thus, it is a well-established fact that onsite systems can be used on a permanent basis for meeting wastewater treatment needs when a responsible management program such as an RME is in place. Without a management program, none of the advanced onsite wastewater systems discussed in this book can offer wastewater solutions on a permanent basis. Use of advanced onsite wastewater systems should be allowed and encouraged in any area only when an RME is formed to serve that area. There are a number of private and public sector entities present today that are offer wastewater services using advanced onsite systems in areas that are not served by centralized collection and treatment systems. While a public sector RME may have a fixed and limited service area, a private sector RME can serve the area that is not served by the public sector RME. Loudoun County Sanitation Authority, which serves Loudoun County, VA, and Charles City County Public Works Department, which serves part of Charles City County, VA, are a couple of examples of public sector RMEs that operate today in the Commonwealth of Virginia. Northwest Cascade Inc. and Pickney Brothers Inc. are a couple of examples of private sector RMEs that are ready to work on a national level to offer wastewater services.

Examples of other RMEs are listed on our web site, with information on how you can reach these entities to determine if they can offer services in your area. As the wastewater industry and the public in general become more familiar and comfortable with the idea of using onsite systems under a utility model, more RMEs will form. Like other utilities, such as electricity, gas, telephone, and cable, some RMEs will stay in business longer than others. The important thing to remember is that the need for advanced wastewater treatment systems will be there as long as human activities generate wastewater (i.e., as long as humans occupy this planet) and there will always be an RME ready to manage an advanced onsite wastewater system as long government rules and policy allow RMEs to function. Thus, when one RME for some reason closes down its business, its customers can be picked up by another RME that is willing to fill the gap.

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chapter seven

Regulatory framework for using advanced onsite wastewater systems technologies

Introduction

Wastewater solutions for any buildable lot or area using small onsite systems are now possible; however, the lack of an adequate regulatory framework makes it hard for the public to effectively use such systems. From a technology point of view, the onsite industry is already into the 21st century; however, from the perspective of managing onsite systems and the regulatory framework for managed onsite systems, the industry is still quite behind. There is much discussion about the importance of permanent operation and maintenance for onsite systems. Can this goal be achieved today by the formation of onsite management entities? Currently, the regulatory framework necessary for such entities to offer wastewater services using onsite systems does not exist. Regulations are needed that are progressive and effective, and regulators are needed who are held accountable for their actions and inactions while regulating the onsite industry.

Making changes to regulations is a challenging process that is affected by many factors. However, if a logical approach is taken that considers the benefits of advanced treatment systems prior to discharge and the benefits of having responsible management entities (RMEs), currently used regulations for septic tank drain field systems can be updated such that the revised regulations will allow onsite wastewater professionals to address wastewater needs using advanced onsite wastewater systems in a cost-effective manner.

In this chapter, a concept is presented for a solution-driven and performance-based regulatory framework that is necessary for the public to use advanced onsite wastewater systems under an adequate operation and maintenance (management) infrastructure that can be offered by RMEs. The proposed regulatory framework could be used for regulating use of advanced onsite wastewater systems with the following distinct features:

- Onsite systems that use the nonpoint subsurface concept for dispersal or recycle and reuse effluent at or near the place where wastewater is generated
- Wastewater systems that put more emphasis on adequate treatment of wastewater and dispersal of effluent than collection (collection and transport cost is less than one-third of the total project cost)
- Wastewater management in relatively small quantities, typically less than 0.1 million gallons per day (MGD) per system, by which one can minimize the cost for the collection and transport system component.

These three features should separate onsite, decentralized systems from large centralized wastewater systems that normally collect and transport sewage through hundreds of miles of pipelines and discharge effluent into surface water bodies under the National Pollutant Discharge Elimination System regulatory framework.

Under the current regulatory framework for onsite systems, those who get a permit for installing septic systems may be misled into believing that their wastewater system will protect environmental quality and public health on a permanent basis, whereas those who do not get permits are led to believe that there is no option for managing their wastewater onsite. Either way, the public is getting the wrong signal. The challenge to regulatory agencies is to determine how to do their jobs so that onsite and decentralized systems are used wherever they are appropriate under permanent operational oversight provided by RMEs.

Governmental agencies that are responsible for regulating the use of onsite wastewater systems must focus on two important issues: (a) adequate treatment and disposal, dispersal, or reuse of wastewater using the best available technologies for any project, and (b) environmental quality and public health protection on a permanent basis from the operation of onsite wastewater systems. The regulators must keep these two issues in focus and develop regulatory strategies around them. The science and technologies for treating wastewater and for ensuring drinking water quality from the operation of nearby effluent dispersal systems are well established.

Regulatory programs can be developed to allow RMEs to function in a competitive marketplace, offering wastewater services in a cost-effective and environmentally sound manner in areas that are not served by sewers. The regulatory program should also allow single-family homeowners who do not wish to obtain wastewater services from RMEs to take full responsibility for the operation and maintenance of their own onsite wastewater systems and to be held accountable for the overall performance of their systems, in ways similar to RMEs.

No matter how small, wastewater systems need ongoing operation and maintenance to achieve adequate public health and environmental protection on a permanent basis. Establishment of a management entity that can offer such services on a permanent basis is long overdue. However, such an entity may not be able to operate adequately under the current method of onsite wastewater system regulation. The main reason is that the prescriptive nature of the regulatory framework and the heavy emphasis on regulating preinstallation aspects, such as soil and site evaluation, design, review and rereview, makes it too time consuming to get a construction permit for a small system, thus costing time and money to both the service entity and the owner. Also, most of the current regulatory requirements are rigid — for example, they specify a limited number of solutions for given soil and site conditions.

In this chapter, a concept is proposed that would allow regulators to move forward with the use of advanced onsite treatment systems by offering reasonable and appropriate "credits" towards soil and site conditions when higher levels of treatment are proposed for onsite systems. Before an RME can function and offer wastewater solutions to the public, the regulatory framework must change and use a solution-driven, performance-based concept with heavy emphasis on postinstallation issues, such as monitoring and inspection of system operations and the environmental impacts, as well as on education and training.

Regulatory framework for use of septic systems

A traditional septic tank drain field is the most widely used onsite system in the country today. At the end of the 20th century, more than 25 million septic tank drain field systems were in use in areas not served by sewers. With recent advances in small-scale onsite treatment devices, an onsite system means much more than a septic tank drain field system. As a matter of fact, some of today's onsite systems, such as greenhouse systems, do not even use septic tanks or drain fields. However, the current regulatory framework for onsite systems is deeply rooted in septic drain field systems, and instead of regulating onsite systems as wastewater systems, the current regulatory system regulates all onsite systems as unmanaged septic systems.

Use of septic tank drain field systems requires certain types of soil, mainly unsaturated, well-drained, and deep soils. Certain minimum distances (setback distances) must also be kept between septic drain fields and such environmentally sensitive areas as wells and streams. The requirements for soil and site conditions for unmanaged septic systems have been used as a basis to form regulatory requirements for all onsite systems. However, today such regulatory requirements actually prohibit the use of soil-based dispersal systems for highly treated effluent in many areas, even when such systems can protect environmental and public health. This regulation is happening mainly due to a misconceived and inadequately defined understanding of soils, subsurface assimilation of effluent, and its impact on the environment. For example, the presence of seasonal water table is identified based on the presence of "gray mottles," but what is the meaning of "gray mottles" in the top 12 in. of soil and how would their presence influence operation of a dispersal system for secondary or better quality effluent?

Today, the regulatory system puts much emphasis on subjective assessment of soil's ability to accept and move effluent and percolation (perc) tests, saturated hydraulic conductivity tests, or determination of soil texture and structure. Conductivity values are assigned based on that soil information. However, there is no effective method of evaluating the validity of such subjective or objective assessments for different types of effluent dispersal methods that are available today for dispersal of effluent from advanced onsite treatment systems. Onsite subsurface effluent dispersal methods can be very effective in minimizing or eliminating nutrient loading into surface and groundwater if only by looking beyond the current regulatory requirements for soil and site evaluation based on soil color, texture, structure, permeability, or perc rate. We have been involved in many projects in which effluent dispersal systems have been installed and utilized on sites where, under conventional soil evaluation methods and regulations, the soil and site conditions are considered as unsuitable for onsite systems. Details on such projects are posted on our web site, which will be updated as we do more projects.

Prescriptive regulations for septic systems have also been misused and even abused for zoning and controlling development based on soil and site characteristics in areas where sewers are not present or are cost-prohibitive. In the current regulatory environment, if a site is not good for a conventional septic system, it is considered not good for residential or commercial building regardless of all the other potentials the site may have for building. A regulatory approach that only allows use of a septic tank drain field system is inappropriate and is actually quite detrimental for environmental protection from the operation of onsite systems. The concept of predefining soil and site conditions and setback distances may be appropriate for the use of septic drain fields without any oversight after installation, but it is inappropriate for the use of nonseptic systems with permanent oversight after installation by an RME.

With the advancement in small-scale wastewater treatment and dispersal technologies, one can now design an onsite wastewater system for any particular soil and site conditions; thus the regulatory requirements for such issues as set-back distances and loading rates must be specified in relationship to effluent quality and not just soil and site characteristics. Unfortunately, the current regulatory framework for onsite systems is "stuck" with the procedures that are necessary for the use of septic systems only. The current approach can lead to rejection of large lots (5 acres or more) for building homes, while leading to acceptance of much smaller lots (1 acre or less) for individual home septic systems in a subdivision with hundreds of homes. Moreover, in many states, regulators actually are the primary service providers for preinstallation work, such as soil evaluation and septic system design, and thus influence the land-use planning process. This approach has led to the current situation, in which local public health officials and sanitarians have been vested with power to declare a lot or an area unsuitable for development due to a lack of "suitable soil" for any type of wastewater system. At the local regulatory levels, there generally is no interest in looking beyond the use of septic drain fields.

A proposed lot or site should be declared unsuitable for development based on wastewater issues only when the total cost (capital, operation, and maintenance) associated with the use of an adequately managed advanced onsite wastewater system is not affordable to the developer or builder. For this to happen, the current regulatory framework must be changed. Regulators must be asked to focus on a wastewater system's performance and its impact on public health and the environment once its operation begins. Regulators must be asked to change their role from preinstallation service providers to regulators of the onsite system management entities that provide wastewater services. Such a change requires that clearly define how an onsite system needs to function in terms of operational and treatment aspects. This change is needed to protect the environment from widespread and indiscriminate use of conventional septic drain fields. This change is also needed because of the current potential for developing public and private management infrastructures to offer wastewater solutions using small-scale advanced onsite wastewater technologies. Resistance to change at the regulatory level helps no one — not the public, not the environment, not the onsite industry, and not the regulators.

Regulatory framework for use of advanced onsite systems

What is needed today is a regulatory system that is solution driven and performance based. A system that allows an RME to offer wastewater services using the best available wastewater treatment and dispersal or recycle and reuse technologies and will hold it financially and criminally responsible for violating requirements for environmental quality and public health protection from the operation of any onsite wastewater systems.

Solution driven system

A solution-driven regulatory system means that *if* regulations are used to prescribe wastewater systems (they do not have to be used), then they must lead to a set of solutions for any given site and situation, using the best available technologies for treatment and dispersal. One way to achieve such a goal is by developing a manual of practice (MOP) for all available small-scale wastewater treatment and dispersal or recycle and reuse technologies and updating the MOP as needed to stay current with technologies developed in the onsite industry.

The development of an MOP must be a joint effort between the public sector (state-level technical staff) and private sector wastewater professionals (engineers, soil evaluators, manufacturers, and operators). It should include information on sizing, layout, start-up processes, operation and maintenance requirements, operational cost, expected performance, zone of influence (ZOI), and other similar issues related to the use of the technology. Such an MOP can then be used by any onsite management entity that is licensed to offer wastewater services using advanced onsite wastewater technologies.

Technology and performance data collected by the onsite management entities can be used to revise or delete MOP content. Only the management entities will have an interest in looking at wastewater systems' abilities on a long-term basis to meet the necessary performance standards and achieve customer satisfaction at an affordable cost. Thus, the best source for information on the long-term use of a technology would be the management entities. Because there are currently very few such entities, the current knowledge as presented in this and some other textbooks, proposals made by onsite management entities, third-party test reports, sensible ideas and claims made by engineers and manufacturers, and information gathered from the U.S. Environmental Protection Agency (EPA) and other demonstration projects should be used to develop the first version of the MOP for a state that wants to regulate onsite management entities.

The MOP should include information on all the technologies that are currently offered by the onsite industry, as presented in earlier chapters in this book. At least five types of pre-engineered, prepackaged media filters (granular material, peat, foam, textile, and plastic); dozens of small aerobic treatment units; and several methods for dispersal of treated effluent (existing dispersal systems, shallow or deep trenches, drip or spray systems, filter beds, evapotranspiration beds, and greenhouses) are available today. In fact, more treatment and effluent dispersal technologies may be developed by the time you read this book. Thus, a homeowner or an RME has more than 100 pre-engineered, prepackaged options available to choose from to manage wastewater onsite. Sizing criteria such as flow rates and loading rates must be developed by the RMEs based on their understanding of the project and the site characteristics. All onsite wastewater systems must be designed and installed to handle actual flows from the dwellings that they serve.

RMEs should be allowed to use their own understanding of advanced onsite systems listed in the MOP, offer wastewater solutions to their customers, and gather performance information from the application of the wastewater solutions. Such information could then be used for future revision of the MOP by regulators and other involved parties. Each state's technical staff, mainly wastewater engineers and environmental specialists, should be required to keep the MOP current by updating the information at least once a year and should be required to make the latest information available on the state's web site.

Performance-based framework

A performance-based regulatory framework should be developed, starting with a clear understanding of how an onsite system needs to function. Today, there is a widespread myth among regulators and soil evaluators that an onsite system would work only if a lot has deep, dry, and well-drained permeable soil ("suitable soil"). This belief is based on a limited understanding of water's subsurface movement as commonly determined by percolation or saturated hydraulic conductivity tests or as estimated based on soil texture. In reality, subsurface movement of water is a complex phenomenon that is very hard to predict just by looking at soil characteristics. As proposed in Chapter 5, discussion should focus on site assimilative systems (SASs) instead of just soil absorption systems. A SAS for secondary effluent considers all possible means for assimilating hydraulic and pollutant loads, including plant uptake, evaporation and transpiration, lateral movement, runoff, and storage of effluent within the ZOI. A ZOI for a SAS must be defined by the management entity, and performance standards within and outside the zone can then be defined by regulatory agencies. Public access within the ZOI for large SASs may be restricted, if and when necessary.

For single-family home onsite systems, the owner's property could be viewed as the ZOI. When an RME is involved with an onsite project, there is no need to regulate soil characteristics and site conditions within the ZOI because that is the area that a management entity can use to assimilate the effluent. It should be up to the management entity to collect the soil and site information necessary for sizing the assimilative system such that the pre-defined performance standards can be achieved on a permanent basis. As mentioned earlier in this book, all professionals working with onsite systems can agree that an onsite effluent dispersal system must not create:

- Point source discharge (e.g., a stream flowing out of the area where the system is installed)
- Public nuisance (e.g., a puddle of water on or around the area where the system is operating)
- Health hazard (e.g., a condition that suggests someone is becoming ill because of such systems)
- Groundwater or surface water contamination due to organic, inorganic, or bacteriological pollutants discharged into the system.

In addition to defining the operating conditions on, around, and under SASs, the performance-based regulations should also assign effluent limits prior to discharge (treatment level 2 or higher, based on environmental sensitivity and the size of the system) and assign limits for discharge of total nitrogen and total phosphorus at the boundary of the SAS in terms of mass loading. Concepts used under the TMDL (Total Maximum Daily Load) program can be used to define mass loadings for nitrogen and phosphorus.

Both effluent quality and mass loading of nutrients at the boundary need to be assigned based on the environmental sensitivity of the area. The boundary around the system can also be viewed as the ZOI for the SAS. By defining the ZOI, we can move away from needing regulations on soil and site criteria and setback distances and allow the onsite industry to develop new technologies with smaller and smaller ZOIs. Recycle and reuse systems, such as flushing toilets using effluent and recycling effluent for plant growth in a greenhouse, would have the smallest ZOIs – 0 ft around the greenhouse; whereas a lined evapo-transpiration (ET) bed may have a ZOI of 0 ft below the system and approximately 10 ft around the system. Water quality outside the ZOI for any dispersal system must be no different from rainwater or surface water quality allowed for public contact. Adequate penalties must be enforced when predefined standards for effluent or mass loading of pollutants are violated by RMEs.

A performance standard should also include customer satisfaction in terms of the overall wastewater services offered by management entities. Customer satisfaction can be measured based on parameters that result from inadequate operation of the systems, such as sewage back-up in houses, odor or noise nuisance, surfacing of effluent in yards, and unattended alarm calls. The performance-based regulations must indicate the method for establishing the violation and penalties for violating each standard. Penalties should include monetary fines and revocations of licenses.

Under a free-market model for a management program, an adequate numbers of onsite management entities would be available to offer dependable services to all citizens, as long as the citizens pay the fees (sewer or wastewater bills) and the regulators strictly enforce performance standards. If a management entity is allowed to operate while violating performance standards, there will be no incentive to offer wastewater services using adequate treatment and dispersal technologies. A management entity should be informed about the expected performance standards, methods for measuring performance, and the consequences for not meeting the standards. At the same time, the entity would need to establish a legal framework that gave them adequate authority to collect service fees and to take action against those who do not pay those fees. Such an authority should be similar to areas served by centralized sewer systems.

Regulatory programs need to emphasize providing value-added services for citizens. Current preinstallation regulatory requirements for installing an individual home or small (<1000 gal per day [gpd]) wastewater system, such as soil and site evaluation and engineering design and review, add no real value to the ultimate use of that system. A regulatory framework should be developed in which such small systems can be installed, repaired, or upgraded by licensed onsite management entities that can submit "as built" drawings to regulatory agencies within 30 days of their start-up to "register" their systems and to obtain operating permits with a finite life. There should be no need for licensed management entities to contact regulatory agencies prior to installation of onsite wastewater systems for individual homes or small businesses. Thus, replacing the current construction, repair, and upgrade permit approach for small systems with a registration and operating permit approach.

The main reason for regulatory involvement must be to evaluate the environmental sensitivity of the area and to determine if the proposed engineering design can be improved in terms of treatment efficiency and reduction of environmental and public health impacts from operation of a system. At present, technical reviews for small systems are done primarily to determine if an engineer′s proposal meets the design prescribed in the regulations. However, once a MOP is in place that indicates the recommended engineering practices, public sector (regulatory) engineers may just audit the work submitted by private sector engineers instead of checking on minute details. Adherence to the specifications covered in the MOP must not be required, as long as any deviation is specified and reasoned for by the private sector engineers.

At present, regulators are responsible for approval of pre-engineered, prepackaged treatment and dispersal and reuse technologies. However, this approach makes no sense because no matter how good a technology is, it will not function on a permanent basis without adequate operation and maintenance. Thus, only a management entity responsible for permanent operation of a technology can judge its real effectiveness both in terms of long-term cost and performance. Therefore, instead of regulators, management entities should approve or disapprove a technology. The technical staff of a regulatory agency may offer their cursory evaluation and recommendation for improvements of a technology if asked by the entity or the manufacturer or engineer.

The regulatory framework for onsite systems needs to change to a more efficient, accountable, result-oriented, and value-added system. The future regulator for onsite systems will be one who focuses primarily on operation monitoring of systems, education and training of service providers, and enforcement of performance standards. Onsite system regulators in the 21st century will:

- Recognize onsite systems managed by RMEs as true alternatives to centralized wastewater systems
- Focus on environmental and public health impacts from systems′ operation
- Focus on the education and training of users and service providers of these systems
- Conduct cursory reviews for technologies and, when asked, make recommendations to the manufacturers or engineers for improvement
- Monitor groundwater and surface water quality in areas near these systems
- Take strict enforcement actions against service providers who violate performance standards

- Find solutions for adequately managing wastewater onsite when the private sector fails to do so
- Create regulatory conditions under which private sector site evaluators, designers, engineers, manufacturers, and service providers can compete on a level playing field
- Educate the public about the importance of wastewater treatment and its impact on public health and environmental quality.

Onsite system regulators in the 21st century will not**:**

- Decide which lots or areas are suitable for onsite systems or how many homes or what size businesses can be developed in a given area
- Determine how people live or conduct business on their property
- Take sole responsibility for approving or disapproving wastewater technologies
- Allow the use of onsite systems as a de facto zoning tool
- Interfere with technological advancement in the onsite industry
- Act as experts or specialists in wastewater management without having the proper education and professional licenses to do so
- Promote one type of wastewater system over another
- Interfere with citizens' efforts to improve quality of life by improving their indoor plumbing and wastewater systems.

Funding for the regulatory program should be directly linked to the fees collected from the renewable operating permits issued for onsite systems and fines collected from service providers for performance violations. Such a direct link to the operation of onsite systems ensures that the regulatory agency is as interested as the private sector in seeing that onsite systems are appropriately used whenever necessary.

Building a foundation for performance-based regulations

A new regulatory system is needed to establish a "level playing field" for the widespread use of various onsite technologies. A concept for building a foundation for performance-based regulatory programs should allow any state or locality to develop regulatory details based on quantitative parameters. The regulatory agency could then adopt a regulatory program that puts more emphasis on postinstallation issues than on preinstallation issues. The primary logic behind performance-based regulations is that technologies and knowledge are now available for addressing wastewater needs under any soil and site conditions as long as the technologies are operated, maintained, and monitored after installation. The proposed foundation for such a regulatory system uses wastewater system size and environmental impact as the guiding parameters for developing various monitoring and inspection requirements as well as penalties for violating the predefined performance requirements. Since the foundation is not based on a type of wastewater technology, it should offer an unbiased framework to the onsite industry and allow the industry to promote existing and new technologies within an efficient and accountable regulatory framework.

The process of developing performance-based regulations should begin with establishing measurable performance goals for onsite systems and logical classification of such systems. Performance expectations from any onsite system can be grouped into three main categories:

- Customer satisfaction;
- Public health protection; and
- Environmental protection.

Within each category, performance expectations can be explained using subjective or qualitative terms, such as:

- Customer satisfaction
  - No unattended sewage-related complaints from the neighbors or the owners
  - No backup of sewage inside the building
  - No odor- or noise-related complaints
  - No legitimate complaints about the rates for managing the sewage system (utility issues)
  - No complaints about wet spots or standing water on or around the system
  - No complaints about service interruption of sewage services
  - No other complaints about the area where the onsite system is installed
  - No health-related complaints from the use of the onsite system
- Public health protection
  - No water quality sample showing any fecal coliform of human origin from the area where the subsurface dispersal system is operating on a prolonged basis
  - No sample with fecal coliform of human origin in sample taken from monitoring wells at the boundary of the ZOI, such as 1 ft below and 10 ft down-gradient from the subsurface dispersal system, on a prolonged basis
  - No change in the total nitrogen and total phosphorus concentrations from groundwater monitoring wells installed on the up-gradient and down-gradient sides of the dispersal system about 50 ft away from the dispersal area or outside the ZOI as specified by the RME
  - No health hazard conditions anywhere in the area where the subsurface dispersal system is in operation
  - No unattended complaints of odor or other type of nuisance that may have an impact on public health

    - Any other public health parameters that were agreed on by the RME for the use of onsite systems in certain areas based on a risk assessment analysis
- Environmental protection
    - No degradation in environmental quality outside the predefined ZOI for the subsurface dispersal system
    - Parameters of concerns to be predefined based on the environmental sensitivity in the given area (typically this will be total nitrogen and total phosphorus)
    - The background level must not change outside the ZOI once the onsite system is installed and operated

Performance parameters can be developed for each project in quantitative, objective terms, and achieving those values can be the requirement for renewing the operating permit for the project. Although this concept sounds simple, such an exercise is not currently done by most of the governmental agencies responsible for regulating use of onsite systems. Some states, such as North Carolina, have developed requirements for operation and maintenance based on the complexity of onsite systems. However, such an approach promotes the use of so-called simple onsite systems — gravity drain fields for septic tank effluent — that actually may have adverse long-term impacts on the environment when used under relaxed operating requirements. Instead being classified as simple or complex, onsite systems should be classified based on their size and the potential environmental impact from their operation.

Onsite system classifications

Onsite wastewater systems are classified into five categories based on the size of the system (gpd flow) and into three categories related to environmental impact (Table 7.1). Environmental impact is measured based on the quality of effluent prior to discharge (secondary, advanced secondary, and tertiary) and the density of systems measured as gallons per day per acre of undeveloped land. Environmental impact is considered "low" when high-quality effluent is dispersed over a large area (rather than low-quality effluent dispersed over a small area). Thus, an onsite system dispersing effluent from a treatment level 3 system over an acre lot would have lower environmental impact than an onsite system dispersing effluent from a treatment level 2 system on the same lot.

The environmental impact (***L, M, H***) from the operation of an onsite system for any soil and site conditions can be determined based on the overall discharge density of the system, calculated in terms of gallons per day flow discharged per gross acreage of open land (land not paved or not under any structure) and the effluent quality (OTL3) prior to discharge. This concept is presented in Table 7.2. Note that this is a concept and the values

Table 7.1 Onsite system classification scheme.

Size of an Onsite System (gallons/day flow - gpd)	Environmental Impact
Extra Small (ES) – Single Family System up to 1000 gpd	Low (L)
Small (SM) – Other Systems up to 1000 gpd	Medium (M)
Medium (MD) – 1,001 to 10,000 gpd	High (H)
Large (LG) – 10,001 to 50,000 gpd	
Extra Large (LG) – greater than 50,001 gpd	

Note: Flow should be viewed as gallons per day per system and not the gallons per day per project. That means that a project managing 1 MGD total flow using 1000 small systems, each managing 1,000 gallons per day, the rating will be either ES or SM.

Table 7.2 Environmental impact related to effluent quality and the density of subsurface systems.

Effluent Quality Gpd/Ac	OTL 2 Secondary	OTL 3 Advanced Secondary	OTL 4 Tertiary
< 500	**M**	**L**	**L**
501 - 1000	**H**	**M**	**L**
1001 - 2000	**H**	**H**	**M**
> 2001	**H**	**H**	**H**

Note: gpd/ac means the flow managed by a system and the total area on which the effluent is dispersed on, not just the area covered by the dispersal system.

associated with gpd/Ac can be changed if and when necessary for a given region or a given state. The logic, however, must not be changed.

The environmental impact category *can* be changed for a project based on the actual observations of the flow data (gpd) or the effluent quality. This means that, at the initial phase, a project with a "designed gpd per ac" value of 1000 and effluent of advanced secondary quality (OTL3) may have been assigned ***M*** category, but if the actual flow data and the actual effluent quality at the end of the year indicates that the actual gpd/Ac is 950 and the actual effluent quality is secondary (OTL2); the impact rating will change to ***H*** for the following year and the system will be regulated differently in terms of the monitoring and inspection (M&I) requirements. On the other hand, if the actual flow data indicates that the actual gpd/Ac is 450 and the actual effluent quality is advanced secondary, the impact rating will change to ***L*** and so would be the regulatory requirements.

Performance monitoring requirements matrix

The performance monitoring of an onsite system is the most important aspect that would allow the use of such systems on a permanent basis as a true alternative to centralized systems. Requirements for these items should be developed based on the classification scheme presented in Tables 7.1 and 7.2. Any wastewater system will go out of compliance once in a while, but it is critical to bring the system back into compliance as soon as possible. Monetary penalties must also be developed for a system that stays out of compliance for longer than an established period. There is also a need to clearly define what constitutes "out of compliance" for onsite systems. Tables 7.3 through 7.9 show a proposed monitoring and inspection matrix and monitory penalties for operating systems in out-of-compliance status for various parameters based on system size (ES, S, M, L, EL) and environmental impact (***L, M, H***). Such a scheme may be used for systems operating in areas with deep, well-drained soils. Requirements may be adjusted upward (more stringent) if the proposed project is not in an area with deep, well-drained soils. Again, no standards currently exist for onsite system performance monitoring, and the following standards are proposed only as a starting point. Any such effort must consider the potential risk from operation of onsite systems on public health and on the environmental quality and make the requirements logical, meaningful, achievable, and affordable; otherwise they will be ignored.

Table 7.3 Number of samples required per year prior to subsurface discharge.

Impact Size	L	M	H
ES	0.1	0.5	1
SM	0.5	0.75	1
MD	0.75	1	1.5
LG	1	2	4
EL	2	4	6

Note: Sampling frequency 0.1 per year means one sample per 10 years. Sampling frequency for any system in the first few years of operation may be greater than the values indicated in this table, mainly to determine the system's reliability.

Like centralized systems, all onsite systems must be operated and maintained by adequately trained and licensed operators. Currently, there is a widespread misunderstanding that operation of an onsite system can be left to the owner with no need for a licensed operator. Education, training, and certification programs are now available in many states for onsite system operators. Regulations should follow, requiring that the operation of onsite systems be performed by licensed onsite system operators. Then onsite systems can be a true alternative to centralized wastewater systems.

Table 7.4 Number of samples required per year prior to subsurface discharge.

Impact Size	L	M	H
ES	0|0	0|0	0|0
SM	0|0	1|0.1	2|0.5
MD	1|0.1	2|0.5	4|1
LG	2|0.5	4|1	8|2
EL	4|1	8|2	16|4

Note: Sampling frequency 0.1 per year means one sample per 10 years. Sampling frequency for any system in the first few years of operation may be greater than the values indicated in this table, mainly to determine the system's reliability.

Table 7.5 Number of deep monitoring wells (to permanent groundwater) per 5 acres and number of sample per well per year.

Impact Size	L	M	H
ES	0|0	0|0	0|0
SM	0|0	0|0	1|0.1
MD	0|0	1|0.1	2|0.5
LG	1|0.1	2|0.5	4|1
EL	2|0.5	4|1	8|2

Note: Intensity for monitoring of permanent groundwater should be less than that for shallow seasonal groundwater mainly for two reasons: (a) it is expensive to install deep monitoring wells, and (b) if appropriate steps are taken to operate treatment and dispersal systems based on monitoring results from shallow monitoring system then protection of permanent groundwater can be assured.

Table 7.6 Number of site visits (walk over) per year to determine the operating conditions of the system to be submitted by an RME.

Impact Size	L	M	H
ES	0.2	0.5	1
SM	0.5	0.75	1
MD	0.75	1	1.5
LG	1	2	4
EL	2	4	6

Note: 0.2 walk over means a site visit once every five years and 1.5 walk over means three site visits in two years

Table 7.7 Number of site visits (walk over) per year to be conducted by the regulatory agency to double check on the RME reports.

Impact Size	L	M	H
ES	0.1	0.25	0.5
SM	0.25	0.375	0.5
MD	0.375	0.5	0.75
LG	0.5	1	2
EL	1	2	3

Note: The frequency for walk over or inspection by regulatory agency should typically be half of the frequency for RME. Once again, a frequency of 0.1 indicates one inspection every ten years.

Table 7.8 Wastewater operator's class requirements (I – V) for onsite systems.

Impact Size	L	M	H
ES	V	V	V
SM	V	V	IV
MD	V	IV	III
LG	IV	III	II
EL	III	II	I

Note: Higher the classification means lower the requirements for operator certification and smaller the system they can operate. Thus, to become a class I operator, one needs to learn and know more about wastewater technologies than to become a class V operator; and a class I operator should be able to manage any size system while a class V operator can manage only SM or ES system with L or M impact.

Table 7.9 Monetary Penalties for Each Unattended "Out-of-Compliance" Status

Impact Size	L	M	H
ES	$5	$10	$30
SM	$10	$30	$90
MD	$30	$90	$270
LG	$90	$270	$710
EL	$270	$710	$2100

Note: The amount of penalties can be adjusted up- or down-ward, but the logic to set the amount should remain the same as presented in this table.

A definition is needed for the "out-of-compliance" standards for these systems. An onsite system will be considered "out-of-compliance" when any of the following conditions happen:

- Annual flow exceeds the rated or design capacity
- Alarm conditions prevail for more than 48 hours
- More than three complaints are made per year (not related to cost) by the user of the system
- Any grab sample exceeds the effluent limits
- Effluent quality is not brought into compliance within 7 working days
- Subsurface water or groundwater sample total nitrogen is greater than 5 or 10 mg/L for two consecutive sampling periods
- Any parameters on the field observation form are not met
- Other items agreed upon and listed in the permit.

A time limit by which any out-of-compliance situation needs to be remedied must be specified in the operating permit. Such a limit needs to be short for larger and high impact systems. For example, an ES system operating in an L impact classification must not operate out-of-compliance for more than 1 week, whereas the limit for an EL system operating in an H impact classification may be less than 1 day. If the system is not brought under compliance within the specified time limit, then a financial penalty must be assessed based on the criteria shown in Table 7.9.

Once a state-level regulatory framework is established on the performance-based concept, onsite wastewater professionals can start working on addressing wastewater needs using onsite systems in a cost-effective manner. Another key component to all these ideas is a wastewater service provider, or RME, that can own and operate onsite systems in the same manner as centralized systems are operated today.

The main objective for this concept is to promote the use of advanced systems for treatment and effluent dispersal in a way that allows for the lowest possible environmental impact by developing monitoring and inspection requirements that offer adequate incentives. At present, regulatory requirements typically discourage the use of advanced systems by imposing inappropriate and undue monitoring requirements. The approach used by some states to classify monitoring requirements based on technology type is not adequate because it discourages people to use advanced technologies. Instead, using a classification scheme based on the size of a system and its environmental impact potential should promote the use of advanced and appropriate technologies for any given project. By doing so, the onsite wastewater industry can offer wastewater solutions and assure long-term environmental protection from the use of onsite systems.

Approval process for advanced onsite technology

State and local level regulatory agencies recognize that there are number of technologies and components being developed in North America that can be used for onsite wastewater treatment and effluent dispersal. A product verification protocol with respect to both marketability and performance assurance is necessary to allow stakeholders to reasonably expect that the approved technologies and components will satisfy their needs for onsite wastewater treatment and effluent dispersal. The protocol proposed in this section allows a vendor of onsite wastewater technology to apply for approval at various initial levels, depending on the amount of performance data available, and it allows the vendor to effectively move through the approval process to obtain the final approval.

Technologies that are not listed in the current regulations are typically called *alternative* or *experimental* systems. By using this terminology, advanced technologies that often have measurable and consistent treatment capabilities receive a stigma that they are not quite as good as the "conventional" septic tank and drain field system. In some states, the homeowner or builder is required to sign a memoranda stating that he or she is aware of the experimental nature of the system. Interestingly enough, the traditional septic tank and drain field system does not receive the same scrutiny and no one must sign any memorandums stating that the treatment capability of the traditional septic system is unknown in the soil component and that no feasible way exists to measure the treatment in the drain field. Because of this approach to permitting advanced onsite systems, homeowners and builders may be frightened away from using systems that provide significantly better treatment than a septic tank.

The need for such a system arises primarily when someone cannot (or does not want to) install technologies that are recognized and approved under current regulations. Since the use of onsite systems at the present time is influenced by soil and site conditions, newer advanced onsite technologies are developed to overcome the soil and site limitations associated with traditional septic tank systems. The degree of flexibility or credit given to a technology in terms of soil and site conditions should be primarily based on the level of treatment achieved for the constituents of interest prior to discharge, the operational reliability of the technology, and the level of long-term (permanent) management accepted and used by citizens for that technology.

Performance verification protocol

The issue is how to approve new technologies or components for use in onsite systems in an effective and efficient manner using an approval process that is simple and meaningful. The protocol proposed in this section offers a process by which performance of new technologies can be adequately evaluated by state regulatory agencies. Since the use of newer technologies is proliferating in all the states within the U.S. and in the provinces of Canada, the performance of such technologies is being evaluated in different parts of North America. A technology in any given state can be approved at one of three initial approval levels (Approval Level 1, 2, or 3) and in-state field evaluations of the initially approved technologies should be conducted following different paths, as outlined in Figure 7.1 of this protocol. Figure 7.1 presents the overall concept of the Approval Levels and Evaluation Paths

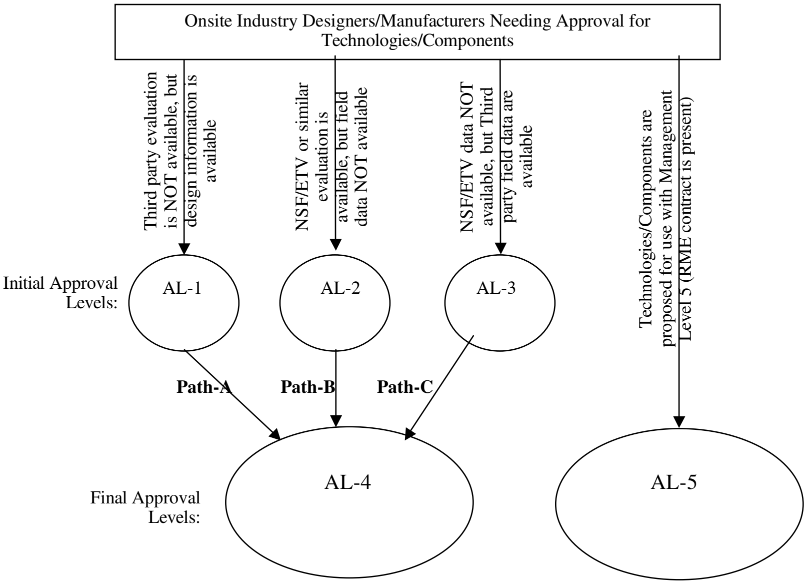


Figure 7.1 Approval Levels and Evaluation Paths

that a manufacturer or designer of an onsite technology may use for obtaining state-wide approval for their technology or component. Only those technologies and components that receive initial approval and can successfully complete the evaluation process can receive the final Approval Level 4 and should be allowed for use as advanced systems in that state. Technologies and components that are approved at final Approval Level 5 should be allowed for use only when permanent enforceable contracts with users of onsite systems and RME are presented to the approval agency.

The approval process presented in this protocol allows a designer or manufacturer of an advanced onsite treatment and effluent dispersal system to enter a state at any one of three initial approval levels (Approval Level 1, 2, or 3), depending on the amount of performance evaluation information available for the technology.

A technology that is designed based on accepted scientific and engineering principles but the performance of which has not been evaluated by a third party would be approved at Approval Level 1. A technology whose performance has been evaluated by a third party would be approved at Approval Level 2 or 3, depending on the type of performance data available for the technology. The ultimate goal of the approval process presented in this protocol is to determine if technology initially approved at Approval Levels 1, 2, or 3 could be included (listed) in the advanced technology list (MOP as noted earlier) at Approval Level 4 based on the performance information gathered within the state. The operational and management requirements approved for long-term use of the technologies in the state are determined based on the information gathered during the approval process.

The scope of such an approval process should be limited to only those advanced onsite technologies that are proposed for use within the state with minimum to adequate operational oversight of the system after installation by the system's owner following the EPA's Management Model 1, 2, or 3 or a similar management level. States should recognize that the use of advanced onsite systems under a responsible management program is becoming a reality and the approval process for a technology or component that is considered for use by an RME should be different from the approval process for an unmanaged, unmonitored system. When a technology or component is proposed for use in onsite systems that are managed by a state-recognized RME, the state may not get involved in the approval process and the technology may be approved at final Approval Level 5, which requires the user to join the RME for use of that technology. The RME would own and operate the onsite system, thus allowing for system repair or upgrade in a timely manner when or if necessary.

The primary objective of any advanced onsite treatment system is to reduce the pollutant load present in raw wastewater. There are number of ways pollutant load in raw wastewater can be assessed and there are number of different constituents that can be used to determine pollutant load. The performance assessment process outlined in this protocol primarily focuses on the reduction in mass loading (or reduction in concentration of fecal coliform) of six constituents (5-day biochemical oxygen demand [BOD_5]; total suspended solids [TSS]; fats, oil, and grease [FOG]; total nitrogen [TN]; total phosphorus [TP]; and fecal coliform) that are grouped as group 1, 2, and 3, as indicated in Chapter 2. A state may consider a larger or smaller number of constituents within each of the three groups.

Advanced onsite wastewater treatment technologies are categorized into four groups based on the overall treatment level they provide for treating wastewater. The minimum treatment levels for each of the constituents of interest in groups 1, 2, and 3 are defined in Chapter 2. At the present time, dissolved oxygen (DO) is not included in this protocol for determining the overall treatment level. However, if necessary, DO can be added to the list of parameters for which the performance is evaluated. One must note that, unlike other constituents, as a result of aerobic treatment, DO in effluent is greater than that in raw wastewater. The overall treatment level is calculated based on the weighted average of treatment levels of the constituents of interest. Equal weight is given to each of the groups and to each of the constituent within the group to calculate the overall treatment level. This number (the OTL) may be used by the manufacturer or designer of the technology for marketing the system. The state may exclude TN and TP (group 2 constituents) from calculations of overall treatment levels by assigning a value of 0 to the weight for group 2. Details on weight assignment for each group and constituents within a group are presented in Chapter 2. A computer spreadsheet (*ProductVerficationCalculations.xls*) is available on our web site to support this protocol; it allows a designer or state regulatory agency to mix and match reductions in mass loading of each constituent

Table 7.10 Matrix for Soil and Site Credits during and after Evaluation

	Site is approvable for a septic tank system	Site is not approvable for a septic tank system
Reduction in drain field size (Treatment for Group 1):		
TL 2 + AL 1	25%	0%
TL 2 + AL 2	33%	25%
TL 2 + AL 3	33%	25%
TL 2 + AL 4	50% or more	33% or more
TL 3, 4 + AL 1	33%	25%
TL 3, 4 + AL 2	50%	33%
TL 3, 4 + AL3	50%	33%
TL 3, 4 + AL 4	66% or more	50% or more
Reduction in horizontal separation distance (Treatment for all groups)		
TL 2, 3 + AL 1	0%	0%
TL 2, 3 + AL 2	33%	0%
TL 2, 3 + AL 3	33%	0%
TL 2, 3 + AL 4	33%	0%
TL 4 + AL 1	0%	0%
TL 4 + AL 2	33%	0%
TL 4 + AL3	33%	0%
TL 4 + AL 4	50%	33%
Reduction in vertical separation distance (Treatment for all groups)		
TL 2, 3 + AL 1	N.A.	33%
TL 2, 3 + AL 2	N.A.	50%
TL 2, 3 + AL 3	N.A.	50%
TL 2, 3 + AL 4	N.A.	66%
TL 4 + AL 1	N.A.	33%
TL 4 + AL 2	N.A.	66%
TL 4 + AL3	N.A.	66%
TL 4 + AL 4	N.A.	100%

Note: TL = Treatment Level; AL = Approval Level.

(concentration reduction for fecal coliform) and calculate the overall treatment level of the system based on the weights given to each group.

As state and local regulatory agencies focus on the performance evaluation process for onsite treatment technologies, the manufacturers of these technologies are interested in knowing what kind of credits their treatment technologies may receive during the performance evaluation process and at the successful completion of the evaluation process (i.e., if or when the technology is approved at the final approval level). A matrix is developed and presented in Table 7.10 based on soil and site credits that indicates the relationship among the type of soil and site credits given for the treatment, the treatment level the technology offers, and the approval level assigned to the technology. It is important to note that long-term permanent operation and maintenance oversight (management) is absolutely necessary for any technology that is approved following the approval process outlined in this document and receives soil and site credits.

States will indicate the level of management necessary (management levels 1, 2, 3, or 4) for all technologies that receive final approval level 4 based on the operating experience gathered during the field evaluation process and the input from the approved technology manufacturer or designer. A higher level of treatment prior to subsurface effluent dispersal and permanent management is viewed as an alternative to optimum soil and site conditions.

Technologies or components seeking approval under this process will need a performance bond during the evaluation period and after the evaluation is completed. The amount for such a bond will be determined based on the level of approval desired, assumed failure rate, and the cost to repair the failed system. The performance bond will act as assurance against failure during the evaluation period. In case of failure, the money from the performance bond will be used to replace the failing system with one that will work under the given conditions. In general, inability of the technology to operate and treat wastewater at an acceptable level on a consistent basis will be viewed as failure.

The amount of performance bond necessary for the desired number of permits during the evaluation process depends on three basic factors: initial level of approval (1, 2, or 3); the risk factor; and the cost of repair. Values for the risk factors and cost of repairs can be assumed by a state and presented in the protocol. These values can be changed by the state based on experienced gained during the implementation of this protocol. The amount of performance bond ($) necessary for obtaining approvals is determined based on the following formula:

$$\$ = \mathrm{N} \times \mathrm{F} \times \mathrm{C} \tag{7.1}$$

where:

$ is the amount of performance bond (or other instruments) required
N is the number of permits desired
F is the failure rate assumed
C is the cost of repairing an individual failure.

Note: This concept for determining the amount for a performance bond was developed by Allen Knapp, Program Manager, Division of Onsite Water and Sewage Services, Virginia Department of Health, and incorporated in a policy that approved the use of gravel-less drain field systems in the Commonwealth.

Suggested values for F and C that can be used for various approval levels are presented in Table 7.11. Thus, knowing the numbers of permits desired by the company seeking approval for their technology, the state's approval agency can determine the amount of performance bond needed. The following examples explain this concept.

Table 7.11 Values for Financial Bond Calculations

System's Approval Level	F	C
1	50%	\$15,000
2	25%	\$15,000
3	25%	\$15,000
4	5%	\$15,000
5	NA	NA

> *Example 1.* A company is seeking approval for an effluent dispersal system at level 2 and wants to install at 50 sites to go from approved level 2 to 4. The cost of the system is approximately \$15,000 per site, and the estimated failure rate is 25%. The required financial assurance (bond) is:
>
> $$\$ = 50 \times 0.25 \times 15000 = \$187{,}500$$
>
> *Example 2.* The same company seeks approval at level 1 and wants to install at 50 sites to move from approved level 1 to 4. The required financial assurance will be:
>
> $$\$ = 50 \times 0.5 \times 15000 = \$375{,}000$$

Thus, an applicant seeking initial approval for the technology or component at Approval Level 1 will require a higher amount of financial assurance than that required at Approval Level 2 or 3. The technology or component that is approved at final Approval Level 4 may still require some amount of financial assurance depending on the overall performance and failure rate observed for the technology or component during the evaluation process.

In order to recover the cost of processing applications and the recurring cost of maintaining approvals, states could assess fees, such as one-time application and ongoing approval maintenance fees. The ongoing approval maintenance fees could depend on the evaluation path taken by the applicant for moving to Approval Level 4 from the initial approval level. The levels of initial and ongoing fees recommended in this protocol are: a \$1500 one-time fee, a \$1000 fee for the technologies that were approved following paths A and C, and about \$500 for the technologies that were approved following path B. Details on the approval paths A, B, and C are shown in Figures 7.2 through 7.4. The ongoing maintenance fees for paths A and C

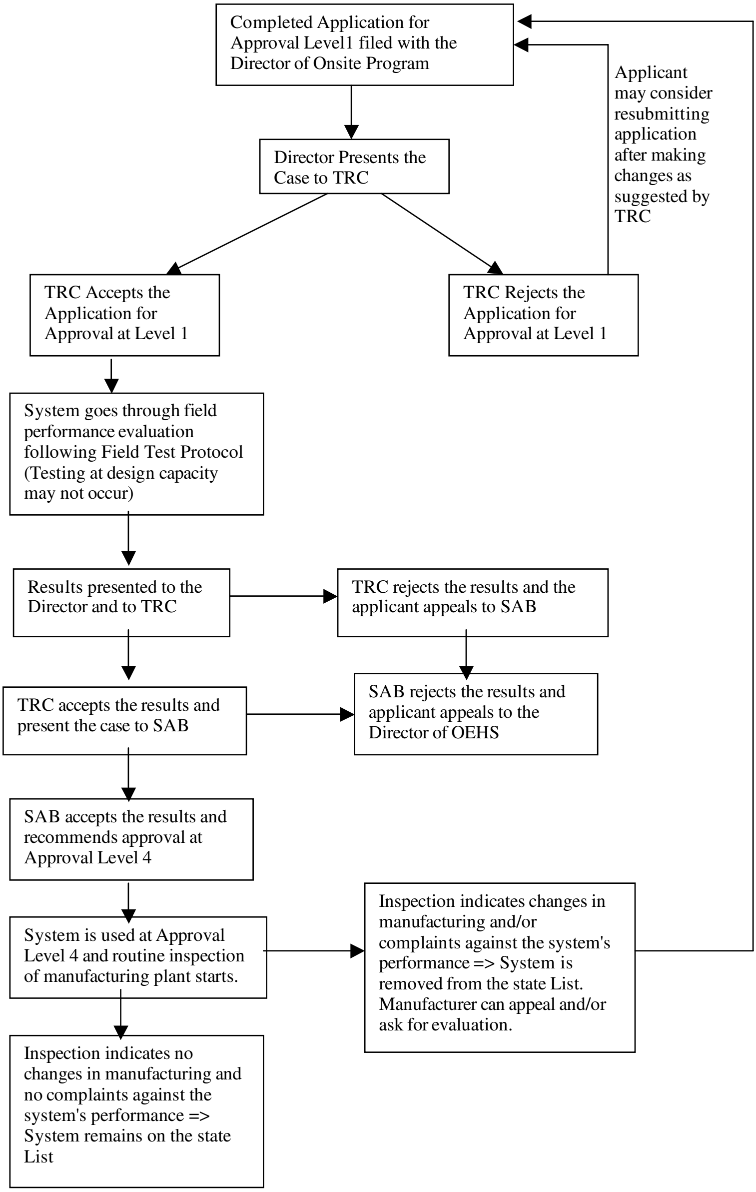


Figure 7.2 Evaluation Path A for initial approval Level 1 to final approval Level 4. *Note*: TRC = Technical Review committee; SBA = Sewage Advisory Board; OEHS = Office of Environmental Health Services.

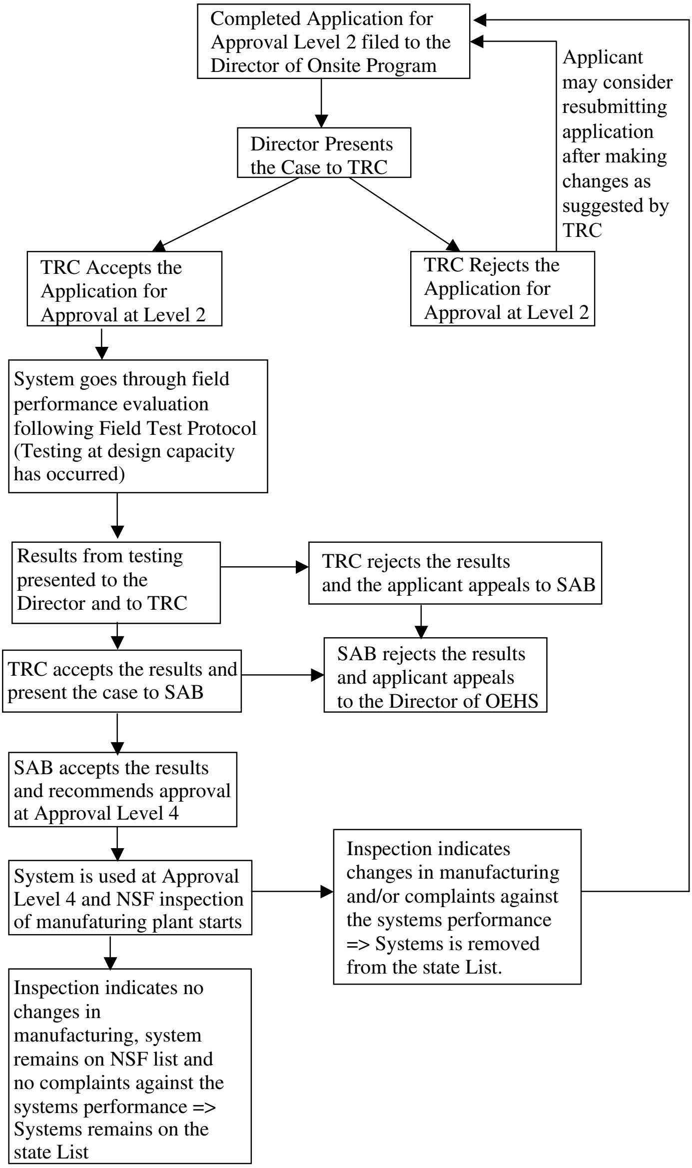


Figure 7.3 Evaluation Path B for initial approval Level 2 to Final Approval Level 4. *Note*: NSF = National Sanitation Foundation (www.nsf.org).

are higher than for path B, mainly because the role that a third-party performance verification entity typically plays in ensuring that technologies are manufactured in a consistent manner, thus precluding the state from having to do that. Note that the actual amount for approval fees must be assessed by each state based on the cost incurred for conducting this activity.

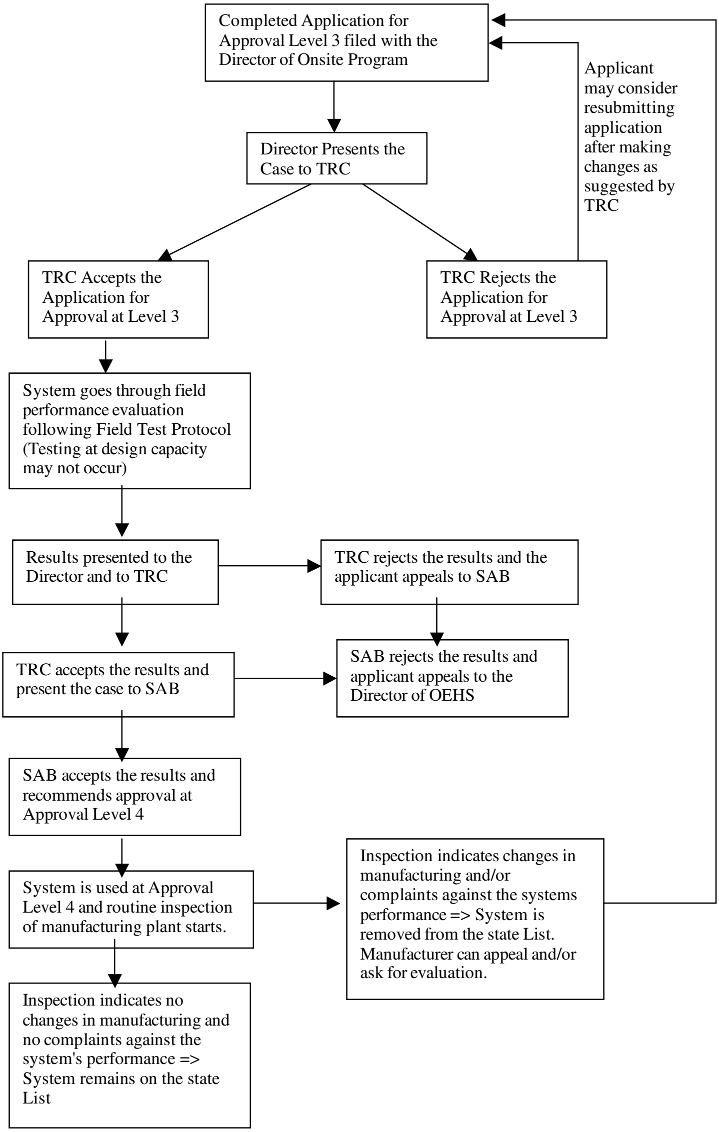
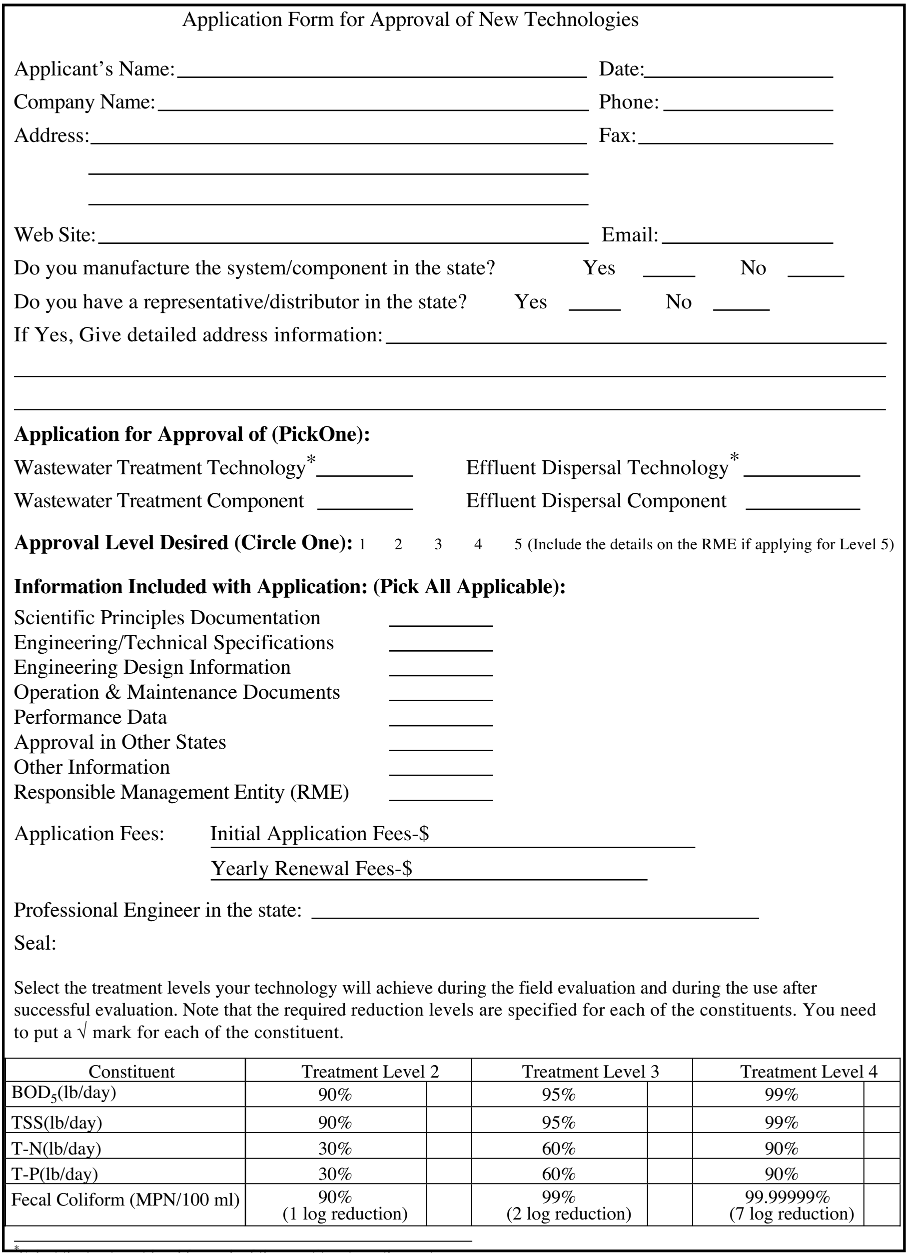


Figure 7.4 Evaluation Path C for initial approval Level 3 to final approval Level 4.

Approved process

The typical approval process for a technology should begin by submitting the completed application form (Figure 7.5) to the director of the onsite program in any given state. It is assumed that, at the state level, the director of the onsite program works with an advisory board (typically called a “sewage advisory board”) and a subcommittee of that board (typically called a “technical review committee”) during the approval process. A professional



Application Form for Approval of New Technologies

Applicant's Name: ______________________ Date: ____________
Company Name: ______________________ Phone: ____________
Address: ______________________ Fax: ____________
____
____
Web Site: ______________________ Email: ____________
Do you manufacture the system/component in the state? Yes _____ No _____
Do you have a representative/distributor in the state? Yes _____ No _____
If Yes, Give detailed address information: ______________________
____
____

Application for Approval of (PickOne):

Wastewater Treatment Technology* ________ Effluent Dispersal Technology* ________
Wastewater Treatment Component ________ Effluent Dispersal Component ________

Approval Level Desired (Circle One): 1 2 3 4 5 (Include the details on the RME if applying for Level 5)

Information Included with Application: (Pick All Applicable):

Scientific Principles Documentation	________
Engineering/Technical Specifications	________
Engineering Design Information	________
Operation & Maintenance Documents	________
Performance Data	________
Approval in Other States	________
Other Information	________
Responsible Management Entity (RME)	________

Application Fees: Initial Application Fees-$ ____________
Yearly Renewal Fees-$ ____________

Professional Engineer in the state: ______________________
Seal:

Select the treatment levels your technology will achieve during the field evaluation and during the use after successful evaluation. Note that the required reduction levels are specified for each of the constituents. You need to put a √ mark for each of the constituent.

Constituent	Treatment Level 2		Treatment Level 3		Treatment Level 4	
BOD_5(lb/day)	90%		95%		99%	
TSS(lb/day)	90%		95%		99%	
T-N(lb/day)	30%		60%		90%	
T-P(lb/day)	30%		60%		90%	
Fecal Coliform (MPN/100 ml)	90% (1 log reduction)		99% (2 log reduction)		99.99999% (7 log reduction)	

---

*

Figure 7.5 Application Form

engineer licensed to practice engineering in that state must sign and seal the application package for a technology, mainly to ensure that the technology is designed based on accepted engineering principles and the performance data (when available) are classified following the data classification scheme shown in Table 7.12.

Table 7.12 Performance Data Classification Scheme

Data Source	Sewage Source	Lab used for Analysis	Performance Data Class
1st Party	Not Similar	Not Certified	A
		Certified	B
	Similar	Not Certified	C
		Certified	D
2nd Party	Not Similar	Not Certified	E
		Certified	F
	Similar	Not Certified	G
		Certified	H
3rd Party	Not Similar	Not Certified	I
		Certified	J
	Similar	Not Certified	K
		Certified	L

Note: Data collection includes sample collection and sample analysis.

The office of the onsite program director will process the application for approval of a technology or component when all the information required in the application form for approval is available. The approval process for an individual component is assumed to be more straightforward and less time consuming than the approval process for an onsite wastewater treatment or onsite effluent dispersal technology. The director, with input from the onsite and decentralized wastewater advisory committees present in the state, will be able to approve a component at final Approval Level 4 without conducting a field assessment as long as adequate information (both technical and experience) is made available to the state for review. However, for approval of the technology (wastewater treatment or effluent dispersal system), the director would present the application to the advisory committees for their consideration. If the committees recommend acceptance of the application, the technology would receive initial approval at one of the three levels (1, 2, or 3) and the technology's performance would be evaluated in the state based on the performance evaluation path (A, B, or C) appropriate for that technology. Note that the director and the committees may reject the application if the information submitted is not scientifically sound and does not have technical merits or if available data suggest to the state that the technology has not performed adequately outside or inside the state.

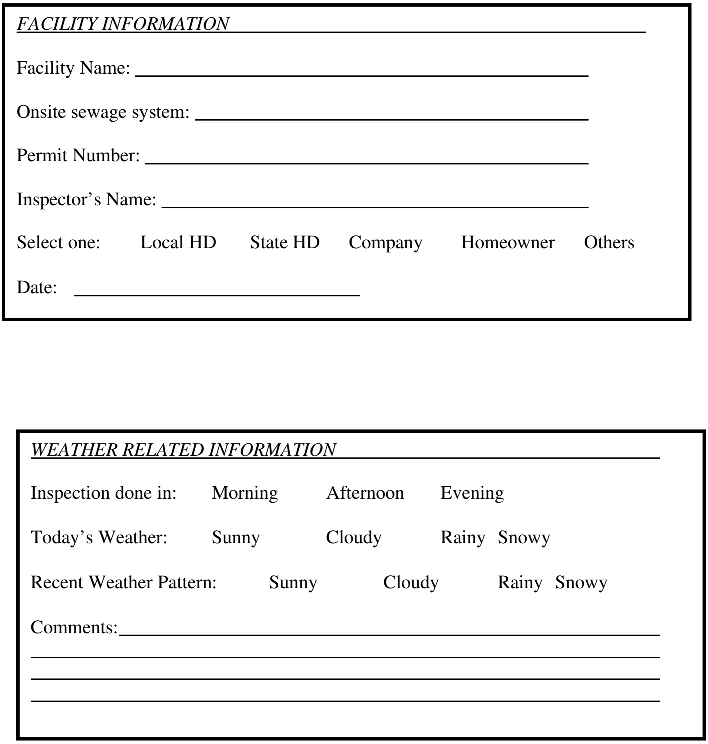
The state should recognize the importance of third-party evaluation of a technology at its design conditions (both hydraulic load and pollutant load) along with the field evaluation. It is important that an approved technology operates as expected under field conditions. A technology that is designed based on appropriate scientific and technical principles using reasonable assumptions should operate adequately under field conditions as long as the production and manufacturing of the approved technology remains consistent without any significant changes and with professional ongoing operation and maintenance.

At present, performance testing centers such as the National Sanitation Foundation (NSF) conduct regular inspections of manufacturing plants of the technologies that are certified and listed by the NSF to ensure ongoing consistency in manufacturing. In order to offer similar performance assurance for the technologies that are approved following paths A or C, the state will have to implement regular inspection of the manufacturing facilities to ensure ongoing consistency in manufacturing. It is expected that the state will charge a fee to cover the ongoing cost of such inspection and manufacturers will pay the fee in order to remain on the list of approved systems in the state. Technologies that are approved following paths A or C may or may not have third-party test data collected at the design flow and mass loading conditions. When this information is not available for a technology, the state will indicate this fact in their approval listing so that designers who recommend the use of the technology are aware of this fact.

Performance assessment for a treatment technology will be based on effluent quality samples collected "at the end of the pipe" before discharge into a subsurface dispersal system. Performance assessment for dispersal technology will be based on effluent quality samples collected from underneath and around the dispersal system. Such sampling processes are more complex than the sampling process for a treatment technology. Influence of soil and site conditions on subsurface movement of the effluent will have to be adequately considered for selecting sampling positions. Effluent quality (or more correctly called "soil solution") samples may be collected using a monitoring well (for saturated soil conditions) or suction lysimeter (a device that allows sampling of soil moisture even when soil is not saturated). Depending on the soil and site conditions, it is possible that horizontal wells could be required for an integrated soil solution sample. The location of sampling points, number of sampling points, and details on sample collection process would be presented by the applicant for review and approval prior to stating the performance assessment process for both the treatment and dispersal technologies.

Every company whose technology is approved at levels 1, 2, or 3 would develop a detailed field evaluation protocol for testing the performance of its technology in the state, and the state would approve the protocol before field evaluation begins. The company would involve a professional engineer licensed to practice engineering in the state for preparing and presenting the testing protocol to the state. Evaluation protocols will specify how the performance of a wastewater treatment or effluent dispersal technology will be evaluated during the field testing period and who will be responsible for conducting the test. All the results obtained during the testing program would be reviewed and approved by the professional engineer who was involved in preparing the testing protocol. The overall objective of the field evaluation process is to gather as much information related to field experience as possible within the state without requiring the company to duplicate work that may already have been done outside the state.

An Onsite System Inspection Form is presented in Figure 7-6 as an example of a data collection tool. The form is divided into four sections, sections A, B, C, and D. Information contained in the first two sections (A and B), must be collected from all the sites included in the evaluation process. If the company has documented effluent quality data from sites out of state that are acceptable to the state, then information collection for sections C and D of the form may not be required for all the sites included in the evaluation process.



FACILITY INFORMATION

Facility Name: ______________________________

Onsite sewage system: ______________________________

Permit Number: ______________________________

Inspector's Name: ______________________________

Select one: Local HD State HD Company Homeowner Others

Date: ____________________

WEATHER RELATED INFORMATION

Inspection done in: Morning Afternoon Evening

Today's Weather: Sunny Cloudy Rainy Snowy

Recent Weather Pattern: Sunny Cloudy Rainy Snowy

Comments: ______________________________

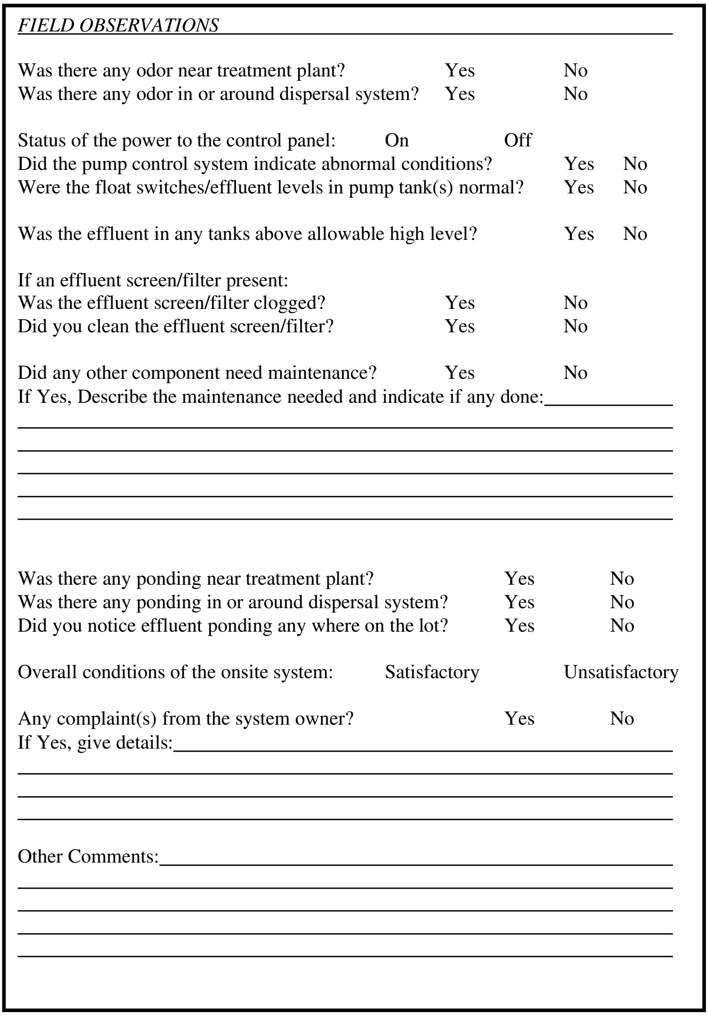
____

____

____

Figure 7.6a Onsite System Inspection form: Section A

The total number of effluent quality data necessary for a treatment technology to obtain final Approval Level 4 should be the same for all states, and the recommended number is 150 data points collected by a third party meeting the performance data class L (Table 7-12). A standardized Onsite System Inspection Form (Figure 7-6) should be used for recording field observations (sections A and B) and for recording effluent quality data collection process (sections C and D). The 150 data points for effluent quality should be collected from 30 sites (selected with input from the state), with



FIELD OBSERVATIONS

Was there any odor near treatment plant? Yes No
Was there any odor in or around dispersal system? Yes No

Status of the power to the control panel: On Off
Did the pump control system indicate abnormal conditions? Yes No
Were the float switches/effluent levels in pump tank(s) normal? Yes No

Was the effluent in any tanks above allowable high level? Yes No

If an effluent screen/filter present:
Was the effluent screen/filter clogged? Yes No
Did you clean the effluent screen/filter? Yes No

Did any other component need maintenance? Yes No
If Yes, Describe the maintenance needed and indicate if any done:

Was there any ponding near treatment plant? Yes No
Was there any ponding in or around dispersal system? Yes No
Did you notice effluent ponding any where on the lot? Yes No

Overall conditions of the onsite system: Satisfactory Unsatisfactory

Any complaint(s) from the system owner? Yes No
If Yes, give details:

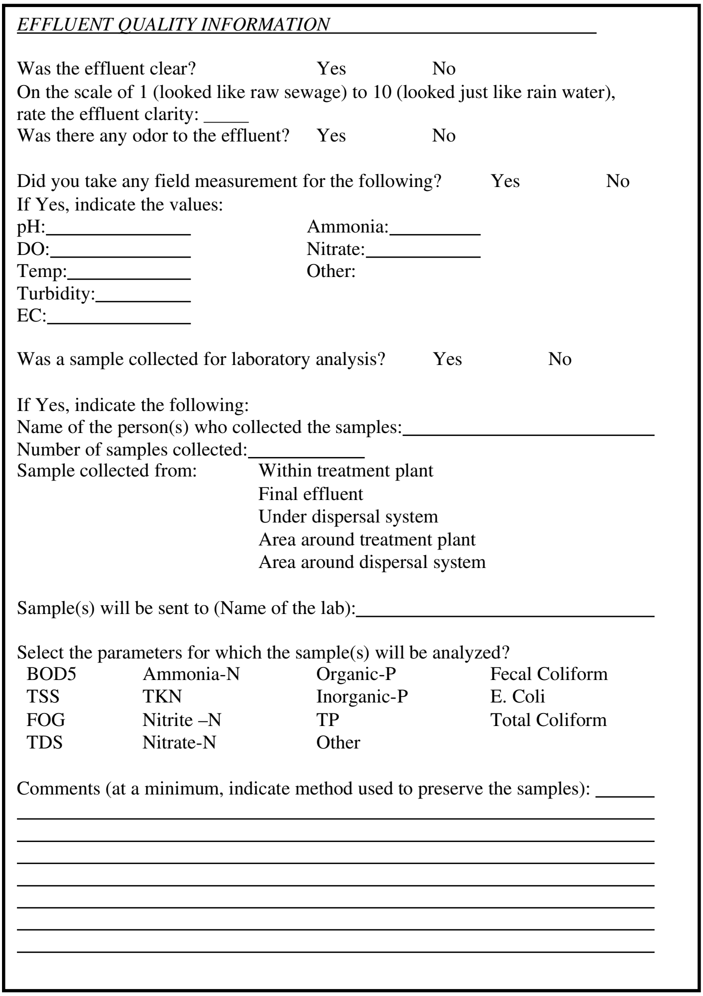
Other Comments:

Figure 7.6b Onsite System Inspection form: Section B.

quarterly sampling conducted for a period of five quarters or following another sampling schedule that is acceptable to the state.

The cost of the evaluation process will be passed on to customers, thus all approving agencies should be very careful about asking for performance-related information and should make sure that the information required is valuable and meaningful in decision making.

The laboratory used for effluent sample analysis should be certified by the state if the state has a wastewater laboratory certification program. Data collected outside the state that meets the requirements of the performance data class L and laboratory certification may be accepted by the state toward the 150 data required for final approval. When a technology receives initial



EFFLUENT QUALITY INFORMATION

Was the effluent clear? Yes No

On the scale of 1 (looked like raw sewage) to 10 (looked just like rain water), rate the effluent clarity: _____

Was there any odor to the effluent? Yes No

Did you take any field measurement for the following? Yes No

If Yes, indicate the values:

pH:______________
DO:______________
Temp:____________
Turbidity:_________
EC:______________

Ammonia:_________
Nitrate:___________
Other:

Was a sample collected for laboratory analysis? Yes No

If Yes, indicate the following:

Name of the person(s) who collected the samples:_________________________
Number of samples collected:___________

Sample collected from:
- Within treatment plant
- Final effluent
- Under dispersal system
- Area around treatment plant
- Area around dispersal system

Sample(s) will be sent to (Name of the lab):_____________________________

Select the parameters for which the sample(s) will be analyzed?

BOD5
TSS
FOG
TDS

Ammonia-N
TKN
Nitrite –N
Nitrate-N

Organic-P
Inorganic-P
TP
Other

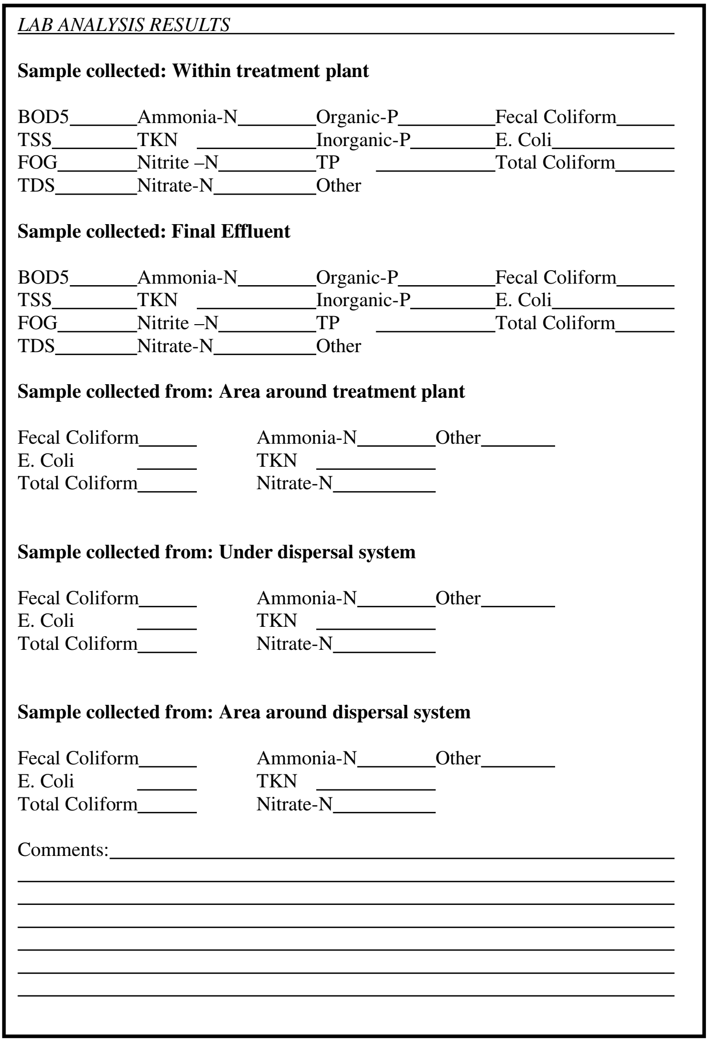
Fecal Coliform
E. Coli
Total Coliform

Comments (at a minimum, indicate method used to preserve the samples): ______
____
____
____
____
____
____
____

Figure 7.6c Onsite System Inspection form: Section C.

approval at level 2 or 3 and the company produces the all the required effluent quality data from outside the state, the field evaluation may be limited to sections A and B of the Onsite System Inspection Form, which mainly shows subjective assessment of the field performance.

Field performance of onsite wastewater treatment or effluent dispersal systems could be evaluated based on grab samples collected during the evaluation period. Effluent samples should be analyzed for the constituents of interest that are relevant to the approval of the technology. Note that sections C and D of the Onsite System Inspection Form contain a comprehensive list of constituents; however, during the evaluation period of a technology, effluent samples would be analyzed for only those constituents that are expected to be treated by the technology. Three pieces of information



LAB ANALYSIS RESULTS

Sample collected: Within treatment plant

BOD5______ Ammonia-N______ Organic-P______ Fecal Coliform______
TSS______ TKN ______ Inorganic-P______ E. Coli______
FOG______ Nitrite –N______ TP ______ Total Coliform______
TDS______ Nitrate-N______ Other

Sample collected: Final Effluent

BOD5______ Ammonia-N______ Organic-P______ Fecal Coliform______
TSS______ TKN ______ Inorganic-P______ E. Coli______
FOG______ Nitrite –N______ TP ______ Total Coliform______
TDS______ Nitrate-N______ Other

Sample collected from: Area around treatment plant

Fecal Coliform______ Ammonia-N______ Other______
E. Coli ______ TKN ______
Total Coliform______ Nitrate-N______

Sample collected from: Under dispersal system

Fecal Coliform______ Ammonia-N______ Other______
E. Coli ______ TKN ______
Total Coliform______ Nitrate-N______

Sample collected from: Area around dispersal system

Fecal Coliform______ Ammonia-N______ Other______
E. Coli ______ TKN ______
Total Coliform______ Nitrate-N______

Comments:______

Figure 7.6d Onsite System Inspection form: Section D.

are necessary for evaluating the performance of any onsite wastewater treatment or effluent dispersal technology: effluent quality, flow, and influent quality. A spreadsheet should be used for data analysis and to determine whether the desired performance is achieved.

Water quality samples should be collected for analysis by a third party that is acceptable to both the applicant and the state, and the laboratory performing the water quality analysis must be certified by the state for doing such analysis if the state has a wastewater laboratory certification program. The duration of testing can be determined by the applicant and approved by the state.

The number of sites necessary for testing and the number of samples collected from each site will be determined by the applicant and must be approved by the state before the performance evaluation can start. Careful consideration should be given by the applicant for selecting the sites for the performance evaluation such that testing is conducted in a manner that is representative of the overall marketplace for onsite wastewater systems in the state. The applicant would present details on the characteristics of the sites selected for testing in the field evaluation, and the details in the protocol must be approved by the state before the applicant can proceed with testing.

Once the performance evaluation for a technology starts at a site, the evaluation process may be terminated only if the dwelling becomes unoccupied during the test period or if the applicant and the state mutually agree to terminate testing. If the testing on a site is terminated prior to completion of the test period, the data gathered from that site may not be used for the overall performance assessment of the technology. The applicant must select another site or sites with approval from the state in order to gather the necessary data for completing the field evaluation.

In order to allow the manufacturers of the treatment technologies to market their systems during and after the evaluation period, the state may offer credits in soil and site condition requirements, when wastewater is treated to treatment levels greater than 1. The credits given will depend on the treatment level the technology is expected to achieve before discharge, the constituents that are treated by the technology, the initial level of approval the technology has received in the state, and whether the site is suitable for installing a septic tank system. Technologies that successfully complete the field performance evaluation in the state and are accepted as alternative technologies will get the maximum credits for soil and site condition requirements.

As a starting point, all treatment technologies that receive initial approval (1, 2, or 3) will be allowed for onsite treatment systems on sites that are not acceptable for septic tank systems as long as the requirements presented in Table 7-10 are met. This means that the sites that are rejected for installation of a septic system may be reassessed to determine if newly approved treatment systems can be used for onsite wastewater management on those sites. Requirements for reserve areas for subsurface drain fields might be waived for treatment technologies that receive initial approval at levels 1, 2, or 3.

Soil and site conditions credits are grouped into four major categories:

- Size of the drain field
- Horizontal separation to natural and man-made features
- Vertical separation to limiting conditions, such as seasonally high ground water table, rock, and others
- Lot size.

The relationship among the various aspects of soil and site credits is presented in Table 7-10. The state reserves the right to update the soil and site credits values (upward or downward) presented in Table 7-10 as field experience is gathered from widespread use of advanced onsite treatment and effluent dispersal systems. The credit (percentage) granted may be up to the levels listed in Table 7-10 based on site-specific evaluations.

When all states in the U.S. and provinces in Canada implement a uniform approval process based on the practices recommended in this section, the manufacturers of advanced onsite wastewater technologies will have a better mechanism for obtaining approval at the state levels and the stakeholders will have better access to these technologies. An approval process that uses the performance information already available for the technology and conducts necessary steps to gather detailed or general performance information within the state (field experience), will allow the onsite industry to offer onsite wastewater services using the most current technologies and tools that the industry can offer to the public.

Soil and site issues

One of the characteristics of an onsite system is that the effluent may be discharged into the environment using a land-based (as opposed to surface-water-based), nonpoint-source (as opposed to a point-source) effluent dispersal system. Thus, soil becomes an integral part of an onsite system. At the present time, certain soil and site conditions are often considered "limitations" to the use of an onsite system, mainly because most of the current onsite (septic) systems require soil to treat primary (Treatment Level 1) effluent. In much of the country, soil and site conditions are not suitable for the use of septic systems, mainly due to lack of adequate soil conditions (deep, well-drained soil) necessary to adequately treat primary or less than primary quality effluent. However, once wastewater is treated to Treatment Level 2, 3, or 4, an onsite dispersal system can be used in any area if an adequate amount of land is available to assimilate the effluent from hydraulic and nutrient points of view. Wastewater treatment and effluent dispersal technologies are available to adequately design onsite wastewater systems to achieve the necessary performance standards for public health and environmental quality protection. Soil and site issues in dealing with onsite systems can be grouped into three major categories:

- Soil loading rates for sizing an effluent dispersal system and gross area requirements
- Separation and setback distances, horizontal and vertical, from an effluent system to topographic features and soil limiting conditions
- Site conditions.

Soil loading rates and gross area

Many research studies have been done and are still being done to establish the relationship between soil characteristics and loading rates appropriate for sizing a subsurface effluent dispersal system. Most of the research is done for the dispersal of primary quality effluent (Treatment Level 1). At the same time, a number of actual field projects have been completed that indicate that high-quality effluent can successfully be discharged into soils at much higher rates than are allowed for septic tank effluent. Most of these projects are done at homes or commercial facilities where old septic tank effluent drain fields have failed, causing untreated wastewater to surface on top of the ground.

Soil characteristics (texture, structure, and saturated hydraulic conductivity or percolation rate) are only one of many parameters that determine a site's ability to accept effluent discharge. The topography, vegetative cover, and method of effluent dispersal may have more influence on a site's ability to accept secondary or better quality effluent than simply soil characteristics. Soil loading rate recommendations can be developed based on soil characteristics; however, this should be done by offering a wide range of the rates and not making these rates regulatory requirements. An onsite system designer should be allowed to size an effluent dispersal system based on his or her judgment and to make the system operate in a manner satisfactory to the regulators and customers. Soil loading rates for secondary or better quality effluent (Treatment Level 2, 3, or 4) can be presented in a simplified manner, as shown in Table 7.13. However, these rates must be used only when an adequate amount of gross (total) area, as calculated based on nitrogen loading and allowable total maximum hydraulic load (TMYL; see Chapter 5), is available for the onsite system project. Soil scientists may assign loading rates of 0 gpd/ft^2 for certain soil textures and structures. However, instead of 0 gpd/ft^2, it is possible to use a small number such as 0.1 gpd/ft^2 as a minimum loading rate for any soil type. With the currently available effluent dispersal technologies, adequately treated effluent can be dispersed on any site at this low rate.

One of the design objectives of any onsite wastewater project should be to have as much gross area set aside for effluent dispersal and assimilation system as possible, thus minimizing the overall impact of such systems on the environment. A spreadsheet can be developed to calculate the values of gross area requirements for nitrogen assimilation, using the mass-balance approach for different treatment levels and different soil and plant assimilative capacities on a given site, and the minimum gross area requirements based on the allowable TMYL.

Separation and setback distances

In order to develop a systematic method for soil and site evaluation for projects that propose to achieve wastewater Treatment Level 2, 3 or 4 prior

Table 7.13 Soil Loading rates for treatment level 2, 3, or 4 effluent quality: simplified approach.

Soil Texture and Percolation Rate (mpi)	Loading rate for sizing effluent dispersal system (gallons per day per square feet)
Sand (< 10 mpi)	10 to 20
Between Sand and Clay (10 – 50 mpi) (Loamy sand, Sandy loam, Loam, Sandy clay loam, Silt loam, Clay loam, and Silty clay loam)	1 to 10
Clay (> 50 mpi)	0.1 to 1

to discharge, appropriate credits should be assigned for treatment level prior to discharge and dispersal methods used for dispersal of treated effluent. The quality of secondary or advanced secondary effluent is much better than that of primary effluent. Pressure distribution of treated effluent in small and frequent doses allows more efficient dispersal than gravity distribution in demand doses. Thus, adequate credits for such improvements over conventional gravity septic tank effluent drain field systems can be assigned. This can mainly be done because most states have adapted soil and site requirements, as well as design standards, for conventional septic tank effluent drain field systems and have accepted those standards as adequate to offer public health and environmental quality protection. Logic would suggest that if public health and environmental quality are protected today from widespread use of septic systems following the adapted set-back standards, then reduced set-back standards could be adapted when advanced onsite wastewater treatment and effluent dispersal systems are used without causing adverse impacts to public health or environmental quality.

It is typically hard to develop and adapt regulatory requirements for setback distances for advanced onsite systems because no systematic method is available. We propose the concept of "system equivalency," which simply says that advanced onsite systems can offer public health and environmental protection equivalent to what is accepted from septic tank effluent drain fields even when the separation and setback distances are reduced proportional to the additional treatment achieved from such systems. Of course, in order to achieve the public health and environmental quality protection from onsite systems at a level similar to that of centralized treatment plants, RMEs are required to own and operate the onsite systems, as indicated in Chapter 6. The separation and setback distances for advanced onsite systems can be developed using a multiplication factor (multiplier) assigned to indicate the credit for higher level of treatment and adequate dispersal of the highly treated effluent into the environment. These distances must be adjusted upwards if the available model for management is less rigorous than Model 4, as proposed by the U.S. EPA.

Two types of separation distances are currently used by all regulatory agencies for the use of septic tank effluent drain field systems:

- Vertical separation between the bottom of the drain field and the limiting condition
- Horizontal setback between the area where the drain field is installed and a variety of topographic features and structures.

Of these two, the vertical separation typically is hard to predict and enforce mainly because it requires determination of limiting conditions, such as seasonal water table, rock, and restricting soil, based on soil characteristics. Quite often it is hard to accurately make determinations of the depth at which the limiting conditions are occurring because they vary greatly by area. Also, no matter how a site is selected for a septic tank effluent drain field system, there is always a good chance that the drain field area would be saturated at some time in a given year, especially in areas where seasonal water table is within a few feet from the ground. The adverse impact caused by a septic tank effluent (Treatment Level 1) drain field used in an area that remains saturated 1 day per year is no different than the impact caused by a secondary effluent (Treatment Level 2) drain field used in an area that remains saturated 10 days per year, by an advanced secondary effluent (Treatment Level 3) drain field used in an area that remains saturated 100 days per year, or by a tertiary (Treatment Level 4) drain field used in an area that remains saturated year-round.

Vertical separation is necessary for the use of a septic tank effluent drain field system because the septic tank effluent (Treatment Level 1) needs a certain amount of relatively dry and uniform soil strata for adequately treating the effluent before it is released into the subsurface or surface water. However, once the wastewater is treated to Treatment Level 2, 3, or 4, unsaturated soil is not needed for treatment of bacteriological contaminants. Just as with surface water (stream) discharge, if an onsite system treats wastewater to Treatment Level 2, 3, or 4, a vertical separation requirement is not necessary and should not be required in regulations. Secondary quality effluent is allowed to be discharged into a stream allowing the steam to assimilate the waste load within certain allowable stream length and, if necessary, tertiary quality effluent is achieved prior to stream discharge. Similarly, for onsite systems, secondary or advanced secondary effluent should be allowed to discharge into subsurface systems on sites where vertical separation is not possible and, if necessary, tertiary quality effluent should be achieved prior to discharge.

Horizontal setback distances between an onsite effluent dispersal system and various topographical features, such as streams, shellfish waters, and drainage ditches, and various structures, such as property lines, building foundations, and wells, are required mainly to offer adequate travel time for the effluent. The requirements for separation distances must be different for different treatment levels, especially when advanced treatment and effluent dispersal systems are used with an adequate level of operation and maintenance oversight, for example, Management Levels 3, 4 or 5.

A common-sense approach is proposed to develop a multiplier that accounts for the improvement achieved due to higher treatment, adequate dispersal, and reduction in volume due to evapotranspiration and used to determine horizontal separation distances for advanced onsite systems. Table 7.14 presents this concept and the multiplier factor for the improvements over conventional septic tank effluent drain field systems. The credits given for advanced treatment systems are based on the difference between the overall treatment levels for advanced treatments and that for Treatment Level 1, as calculated using scale A. The credits given for effluent dispersal systems are mainly based on an educated guess and can be changed if necessary for any area based on input from the public and private sectors. However, once such credits are established, they should be used for at least 10 years before being changed and any change to the credits system must be based on actual performance and impact data collected from the field. It is now possible to monitor the environmental impact from the use of onsite systems using a variety of monitoring tools. The hydraulic separation distance or the travel time between a drain field and a well can be measured using a tracer. Once a performance-based

Table 7.14 Credits and Multiplier for Adjusting Horizontal Separation Distance when Advanced Onsite Treatment and Effluent Dispersal System Is Used

Technological Improvement Over Septic Tank Effluent Drain Field	Credit (Improvement)	Multiplier = 1–Credit		
		Multiplier-T (for Treatment)	Multiplier-D (for Dispersal)	Multiplier-Q (for Quantity Reduced)
Treatment Level 2	50% (0.50)	0.50	*1.0*	*1.0*
Treatment Level 3	65% (0.65)	0.25	*1.0*	*1.0*
Treatment Level 4	76% (0.76)	0.24	*1.0*	*1.0*
Shallow trench time- or pressure-dosing	10% (0.10)	1.0	0.90	*1.0*
Sand-lined filterbed	30% (0.30)	*1.0*	0.70	*1.0*
Drip	15% (0.15)	*1.0*	0.85	*1.0*
Spray	30% (0.30)	*1.0*	0.70	*1.0*
ET bed (assuming 75% reduction in volume due to ET losses)	75% (0.75)	*1.0*	*1.0*	0.25
Greenhouse (assuming 90% reduction in volume due to ET losses)	90% (0.90)	*1.0*	*1.0*	0.10

regulatory system is established in any state and onsite systems are used based on the concepts proposed in this chapter, within 10 years, adequate information should be collected from the field to fine tune the numbers proposed here.

The overall multiplier (OM) for a combination of treatment and effluent system should be determined by multiplying all the applicable multipliers (multiplier-T × multiplier-D × multiplier-Q) for the proposed system. Table 7.15 gives examples of OMs for a few advanced onsite systems that can be

Table 7.15 Overall Multiplier (OM) for Advanced Onsite Systems

Onsite System Type	Multiplier-T	Multiplier-D	Multiplier-Q	OM
Conventional septic tank effluent drain field	1	1	1	1
Pressure- or time-dosed shallow trench for Treatment Level 1	1	0.90	1	0.900
Drip for Treatment Level 1	1	0.85	1	0.850
Conventional drain field for Treatment Level 2	0.50	1	1	0.500
Pressure- or time-dosed shallow trench for Treatment Level 2	0.50	0.90	1	0.450
Drip for Treatment Level 2	0.50	0.85	1	0.425
Sand-lined filterbed for Treatment Level 2	0.50	0.70	1	0.350
Conventional drain field for Treatment Level 3	0.25	1	1	0.250
Pressure- or time-dosed shallow trench for Treatment Level 3	0.25	0.90	1	0.225
Drip for Treatment Level 3	0.25	0.85	1	0.213
Spray for Treatment Level 3	0.25	0.70	1	0.175
ET Beds for Treatment Level 2	0.50	1	0.25	0.125
Greenhouse for Treatment Level 3	0.25	1	0.10	0.025
Any other system combination	???	???	???	???

Note: You can determine values for any other onsite system type using the Table 7.14, knowing how the system is going to be managed, and applying the logic presented in this chapter.

utilized in areas not suitable for conventional septic tank effluent drain fields or even in areas suitable for septic tank effluent drain fields to achieve better environmental quality protection.

In order to account for adequate long-term operation and maintenance issues, development of one more adjustment factors (AFs) is required to incorporate an adequate safety factor into horizontal setback distances for advanced onsite systems. The following values for AF are proposed in relation to the level of management available for a given project:

- EPA Proposed Management Model 1 or 2 AF = 2
- EPA Proposed Management Model 3 AF = 1.5
- EPA Proposed Management Model 4 or 5 AF = 1

The horizontal setback distance from an advanced onsite system and various topographical features or structures can be determined by multiplying the setback distance requirements for a conventional septic tank effluent drain field with the OM and AF. All the horizontal setback distances should be rounded up to the nearest 10th feet. Using this logical approach, a regulatory agency can now develop a spreadsheet for horizontal separation distance requirements for a variety of advanced onsite systems based on current setbacks used for conventional septic tank effluent drain field systems. It is important to mention here that horizontal set back distance for advanced onsite wastewater systems technologies can be zero feet if necessary.

Site conditions

The limitations on site conditions that are assigned to conventional septic tank effluent drain fields are not needed and should not be used for onsite systems that use secondary or better treatment system and advanced effluent dispersal systems. A site that is considered suitable for habitation is suitable for an onsite wastewater system as long as adequate area necessary for nitrogen assimilation and based on allowable TMYL is available and an appropriate treatment and effluent dispersal system is installed and operated in a safe manner by a professional management entity.

Site restrictions such as slope, rock outcropping, wetness, drainage way, flood plains, and sink holes could be adequately addressed during the planning and design phase of an onsite system. It should be the job of an onsite system designer to carefully assess the site's limitations and strengths to decide the level of treatment necessary prior to discharge and the method of effluent dispersal necessary to address the site conditions.

As presented in Chapter 1, sites can be grouped into four basic categories, ranging from deep, well-drained sites to shallow, poorly drained sites. For each site group, an onsite system designer can select a type of treatment and effluent dispersal technology based on detailed site evaluation and cost issues. The regulations must not restrict a designer's ability to propose an onsite solution based on the site conditions unless the gross area requirements as determined by nutrient or TMYL requirements are not met. Of course, successful long-term use of any onsite system will depend on the level of management available in the given area.

Building agreement

One of the biggest challenges faced by the onsite wastewater industry is how to change the state and local level regulatory programs. Agreements among professionals are needed at four different levels, starting at the top level and moving down as many levels as possible. Agreement at the top level is a must, and building agreements at lower levels will be hard but achievable under a performance-based regulatory program that allows professionals to try new ideas and allows regulators to measure the impacts on public health and environmental quality, thus assessing whether the top level agreement is kept. Agreement need to be built at the following four levels:

- Philosophy
  - Concept (general description, function)
    - Approach (steps involved in the process)
      - Numbers (equations, standards, tables with numbers)

Philosophy

A safe, adequate, and proper onsite wastewater system is needed that will protect public health and environmental quality from poor or inadequate operation of onsite systems on a permanent basis. Onsite wastewater systems, if not properly selected, adequately designed, properly sited, adequately installed, or properly operated will adversely affect public health and environmental quality.

Concept

Selection and design of an onsite system are functions of the following conditions:

- Area (gross or total area of the property and the footprint area used for the onsite system)
- Soil and site conditions (within the footprint area available for installing the dispersal system)
- Quantity of wastewater (flow — predicted and actual)
- Quality of effluent prior to discharge (primary, secondary, advanced secondary, tertiary or treatment level 1, 2,3, 4 or 5)
- Effluent dispersal system (trench, bed, drip, mound, spray, evapotranspiration)
- Management level (Levels 1 to 5 or combinations of these levels)

Therefore, mathematically the concept can be presented as:

Onsite system selection and design = f {area,
soil and site conditions,
quantity of wastewater,
quality of effluent,
effluent dispersal system,
management level}

Regulations should allow a designer to evaluate all the above-mentioned parameters (factors) before rejecting the proposal. As much as possible for values of the first three parameters, regulations should allow designers to develop recommendations for the last three parameters and design an onsite treatment and dispersal systems that meet the needs.

Approach

We propose the following eleven step approach for developing a regulatory procedure to permit use of small onsite system for single family homes:

1. Determine the gross or total land area where the use of an onsite system is proposed and the footprint area available for installation of the system. (*Note:* Gross or total area can be used in nitrogen models and for separation distances, while footprint area is used in hydraulic models.)
2. Determine the management models feasible and available for the project.
3. Determine the quantity of wastewater (gpd flow) and the type of wastewater (residential, commercial, combination).
4. Determine the soil and site characteristics within the area available (footprint) for the system, including depth to limiting conditions (seasonal saturation, impervious strata, bedrock); hydraulic conductivity classes of horizons in the top 5 to 10 ft; the slope; the proximity to surface water; and the approximate depth to permanent groundwater.
5. Determine the level of treatment necessary before discharge that will match the total land area and the footprint available for the dispersal system with the quantity and quality of effluent.
6. Use the site quadrant approach to select an appropriate onsite system group (treatment and dispersal) for the given site (4 quadrants and 11 system groups). Note that there is more than one system group available for each quadrant, thus choices are available.
7. Determine if reduction in flow is needed prior to discharge, by either reducing the quantity of wastewater using low flow devices (make sure the treatment can handle the higher strength) or reducing the quantity of effluent by reusing the treated effluent for toilet flushing

or by installing evapotranspiration systems, such as a greenhouse or evapotranspiration bed.

8. Develop a treatment and effluent dispersal scheme and design for the system that can be constructed by the installers present in the area.
9. Develop operation and maintenance requirements for the treatment and effluent dispersal system and determine the necessary level of management.
10. If the owner agrees with the requirements for installation and operation of the proposed treatment and effluent dispersal system and the required management model for the system is available in the area, then apply for and obtain the construction permit from the regulatory agencies.
11. Install the system and operate it within the scope of the project on a permanent basis following the requirements specified in the renewable operating permit.

Numbers (equations, standards, tables, "must not change" values)

Once the agreement is build on the regulatory approach; we propose the following items for developing details on numeric values for various design parameters necessary for sizing an onsite system as well as for other issues related to system construction.

- Estimate and predict flows — Use the formula for residential homes, tables from engineering textbooks for other structures, actual data from the water meter, or another proposal made by a professional engineer as long as it can be monitored after the systems are installed and the engineer takes full responsibility for the proposal.
- Soil and site conditions — Use the quadrant approach as a starting point for determining the treatment and dispersal system. Use a soil morphological assessment for estimating hydraulic conductivity, thus the hydraulic footprint. Use four factors (indicators of seasonal saturation, rock [hard, soft, fractured, coarse fragments, etc.], impervious strata, and drainage class) as tools for determining if primary effluent can be discharged. Use of the top 5 ft of strata for the dispersal system (i.e., evaluate only the top 5 ft from the ground surface for decision making purposes).
- Assess relationships among soil texture, structure, and saturated hydraulic conductivity ranges that are presented in soil textbooks or that are proposed by the system designer. Note that there is no such thing as a zero loading rate for any soil type.
- Conduct saturated hydraulic conductivity tests using a variety of meters, an Orenco infiltration test kit, or another tool to determine the field value of permeability and conductivity for a large project or projects that propose dispersal of more than 1000 gpd effluent per acre of total land area.

- Follow commonsense construction practices for dispersal systems — Allow installation of the dispersal system within the footprint based on recommendations of the system designer. Aerobic effluent dispersal systems can be installed in a drainage way, under or around parking lots, under the house, or in any such place where a septic drain field may not be allowed. Do not restrict the use of the land area for installing dispersal systems for aerobic systems; installing a large effluent dispersal system over a large area would be much better than installing a small system within a small area that appears to have "suitable" soil. Also, use land area that is useable for nothing else for a highly treated effluent dispersal system, thus minimizing the cost of land area and benefiting from using otherwise valueless property.
- Don't be "picky" about the soil conditions within the area available for effluent dispersal on the property. Relatively dry, deep, well-drained soil should considered "desirable" conditions for the footprint and should not be considered "required" conditions for the footprint necessary for dispersal of aerobic effluent. As long as a designer assures the desired performance of the dispersal system after installation, regulations should not be "picky" about soil conditions. If and when the dispersal system does not perform in a desired manner, then the designer must address the problem. It does not make sense to presume how soil will behave when the dispersal system is used because soil science is not exact (as said by many soil scientists) and there is no exact way to predict how soil will behave when aerobically treated effluent is introduced into a dispersal system.
- Use gross area requirement tables based on TN mass balance analysis and a minimum area necessary for hydraulic assimilation of the effluent — The value of rainwater dilution and soil and plant reduction for nitrogen can be determined based on mutually agreeable engineering standards. A table must be developed and used for determining the area required for 100 gpd flow rates and used to calculate the area for the given flow rate.

When regulators and onsite wastewater professionals reach agreements at most or all of these levels — philosophy, concept, approach, and numbers — implementing a regulatory program for use of advanced onsite systems will not be the tedious and unpleasant task that it is today.

chapter eight

Planning with advanced onsite systems technologies

Introduction

Typically, water and wastewater services are key elements in planning for new growth. Unlike other utilities, such as electricity, gas, heating oil, telephone, television, and internet services, people generally look to the local government for offering water and wastewater services. Centralized water and wastewater systems are generally considered the preferred way for providing drinking water and managing wastewater for a community. However, by the end of the 20th century, it became quite obvious that local government would have to depend on decentralized approaches for offering water and wastewater services in areas that are currently not served by centralized systems.

In many cases, growth has outstripped the local community's water and wastewater capacity. Hence, planning communities at all levels of the government must become familiar with and learn to plan with the use of decentralized wastewater systems and not rely solely on conventional septic tank systems to control growth in areas not served by centralized wastewater systems. Particularly, private developers have learned of the decentralized approach, and they are using modern methods to provide sewage collection, treatment, and dispersal for their developments. In some cases in which larger towns are unable to provide wastewater collection or treatment capacity, the developers exercise the option to de-annex their property from the town and build their own wastewater systems. The result is that, in many cases, the nearby town loses the tax base that otherwise could have been provided by the homes within the development.

"Capacity" is becoming a valuable commodity, and if local towns cannot or will not provide capacity in terms of water and sewer services, advanced wastewater collection, treatment, and dispersal technology, coupled with modern data collection and transmission systems used by responsible management entities (RMEs), provide a method for developers to create their own capacity, bypassing the larger towns. When the planning community really learns the basics of decentralized wastewater systems and understands the benefits they offer in terms of long-term environmental quality protection, they will become advocates for the use of these systems.

Some basic questions for planning purposes always include what building density (homes per acre or commercial dwellings per acre) can a decentralized wastewater system support and how should the overall capacity of decentralized wastewater systems be determined. When it comes to treatment capacity, the decentralized wastewater infrastructure allows one to follow the concept "build as you need," unlike the centralized wastewater infrastructure, which requires one to build to capacity and then expect that the growth will occur to pay for that capacity. In the current economy, where the "just-in-time" (JIT) concept has helped businesses to be more efficient in delivering their services to their customers, the planning community should consider a decentralized wastewater infrastructure as one that can offer wastewater services JIT, whenever and wherever they are needed, thus saving millions of dollars of upfront dead investment in laying miles of sewer lines or building millions of gallons of treatment capacity at a centralized wastewater treatment plant. Cost benefits, along with environmental benefits achieved mainly by eliminating inter-basin transport of water (taking water from one watershed and discharging treated wastewater into another watershed), ought to make decentralized wastewater infrastructure the preferred option for any community.

Integrating the use of advanced onsite systems in planning

Wastewater management systems come in different sizes and forms, ranging from the basic aerobic treatment system that treats wastewater to treatment level 2 standards followed by a small, gravity, demand-dosed drain field system to a complex nutrient reduction and disinfection treatment and subsurface drip dispersal system or an above ground spray dispersal system for either a single home or for a group of homes or a business. We have come a long way from using outhouses or cesspools or even conventional septic drain field systems in areas that are not served by centralized wastewater management systems.

Proprietary treatment and dispersal systems are available on the market that can treat and return wastewater to the environment in an ecologically sound manner on sites that have challenging soil and site conditions normally unsuitable for operating conventional septic drain field systems (i.e., no "percable" land). Today it is possible to develop a wastewater treatment and dispersal system that can address both customers' needs (i.e., quantity and quality of sewage to be managed) and environmental protection requirements (i.e., adequate assimilation of pollutants) for any site.

Technologies are also available for remote monitoring of the operation of complex wastewater systems. Just a few years ago, such options were not available for managing wastewater on a small scale. Now communities have a number of options available for managing wastewater in a cost-effective and environmentally sound manner. Selecting an appropriate option is a challenge from both technical and socioeconomical points of view. Quite often, debates on the selection of wastewater systems get off track and issues not related to wastewater (such as good soil or bad soil, zoning, and growth) get in the way of the planning process. During the planning phase of a wastewater system in any community, the focus must be on three important issues: the wastewater (quantity and quality); the needs of the citizens in terms of current and future requirements; and the environmental quality (groundwater and surface water resources) that must be protected from the poor or inadequate operation of wastewater management systems.

Onsite versus centralized wastewater systems

The three basic components of any wastewater system are collection, treatment, and disposal (or dispersal). Of these three components, collection is least related to treatment and dispersal of wastewater. Common sense says that pipes do not treat sewage. However, the majority of the cost (typically more than 60% of total cost) of a centralized system is allocated to the collection system (i.e., to collect and bring millions of gallons of wastewater to a central location for treatment and disposal). Unfortunately, gravity sewers leak, even ones constructed using modern materials and techniques. Infiltration and inflow rates may be as high as 60,000 gal per day (gpd) per mile of sewer mains and house service connections (Viessman and Hammer, 1998). Because of this, using conventional gravity sewers with conventional manholes and solids-handling lift stations may result in paying a very high price for a transmission system that transports wastewater as well as groundwater during periods of high seasonal water tables. The result is that the expensive sewers bring an excess hydraulic load to the treatment system that must be built into the treatment capacity (another added expense) or a bypass or surge (equalization basin) must be designed and constructed. Using conventional sewers to collect and transport wastewater from communities located many miles apart is neither the most cost-effective nor the optimum alternative when decentralized solutions are available for which an RME can provide professional management services.

Specifically, in a small community where the total quantity of wastewater generated is less than one million gpd, the cost of just collecting sewage could be more than $20,000 per connection when conventional sewers are utilized. Onsite and decentralized systems are wastewater management systems that can be used for treatment and dispersal of wastewater at or near the locations where wastewater is generated. With the availability of small-scale treatment and dispersal technologies, collection of large quantities of wastewater is *not* necessary. The collection system can be minimized or eliminated by using advanced onsite wastewater system technologies in areas that are not currently served by a centralized wastewater system.

Two major differences between onsite systems and conventional centralized systems are the extent of the collection systems and the type of dispersal systems. A typical onsite system can serve a single residence or a nonresidential entity (such as a school, office building, or restaurant) or a small group of individual facilities with a relatively small collection system. The primary objective of the onsite system should be to keep the collection component of the total wastewater system as small as possible and to focus mainly on necessary treatment and dispersal of wastewater. Also, a typical onsite system uses a land-based (not soil dependent) subsurface dispersal system (also known as nonpoint-source discharge), as opposed to a typical centralized system, which uses surface water discharge (also know as point-source discharge) of treated effluent. Discharge in surface water is also an option for small-scale systems; however, it is typically not necessary and it should be used only when no land is available for subsurface dispersal (for example, a house on a lake with no backyard or front yard) or where land is so valuable that surface discharge with rigorous monitoring can be provided by an RME. As much as possible, small onsite systems should consider nonpoint-source discharge for final dispersal to minimize the adverse environmental impact of nutrients. Another option for managing treated effluent at a small scale includes recycling and reuse, thus minimizing the need for discharge. Concepts that would allow recycling and reuse of treated effluent include irrigation (subsurface or surface drip or above-ground spray); evapotranspiration or a greenhouse (plant uptake of moisture and nutrients); use of effluent for nonpotable purposes, such as flushing toilets; and use of composting toilets with appropriate graywater irrigation and dispersal systems.

Wastewater management at small scale

At a small community level, decision makers normally are not aware of all the options available for onsite wastewater management. There is a widespread misunderstanding that the only way wastewater may be managed in an area that is not served by a central sewer system is by using a septic system (i.e., a septic tank gravity drain field system). However, the use of conventional septic systems heavily depends on soil and site characteristics. There is normally a long list of soil and site criteria presented in the septic system regulations (either state or local regulations) that specify what site and soil conditions are necessary for the approval of a site for installing a septic system. When such conditions are not present on a lot or in an area, that lot or area is normally declared unsuitable for a wastewater system (i.e., no "perc" land) and thus not inhabitable or buildable even for nonresidential purposes, unless and until a centralized sewer system is made available for managing wastewater.

Another misconception is that if alternative technology is available, it is less desirable or less permanent than conventional gravity collection systems with solids-handling sewer lift stations and large activated sludge sewage treatment plants. Some engineers remember the days of innovative and alternative (I & A) technology, when 100% federal funding was available for the I & A portion of the sewer system. Some of the less-than-reliable and sometimes downright goofy technologies foisted upon communities in those days have left an impression that modern decentralized technology is simply another in a long line of technologies that will not work over the long run. In fact, some of the technology used in decentralized systems is technology that survived the test of time from the I & A technology days and has been improved to provide reliable, sustainable, durable solutions for a community's wastewater collection and treatment needs. Unfortunately, this may provide a basis for the misunderstanding and mistrust (however misplaced) perpetuated in the engineering community.

Typically, installing a conventional centralized wastewater system (gravity sewer, solids-handling lift stations, and a treatment plant) requires a large quantity of wastewater in order to be cost-effective. Centralized collection and treatment becomes a more appropriate choice than decentralized systems in urban settings where users are quite densely distributed and the volume of flow is sufficient to make the economics of scale feasible. Hence, a centralized system is normally not considered for remote, small-scale operations, such as small shopping centers or subdivisions. Thus, lack of exposure to and lack of understanding of the various small-scale onsite wastewater systems (also called "alternative" onsite systems) available have led to misuse (or abuse) of onsite systems regulations as growth control or de facto zoning tools. Decision makers in small communities should know that onsite systems, although most of the soil based, are *not* soil dependent or limited. In addition, soil and site conditions that are not suitable for one type of system, such as a septic drain field, are suitable for a number of other onsite wastewater systems currently available.

So, how does one evaluate wastewater management options for a small community? There are at least five important factors to consider while planning for a wastewater system:

- Wastewater: quality, quantity, and variability
- Receiving environment (RE): soil and site characteristics; groundwater and surface water conditions
- Wastewater management technologies: collection, treatment, dispersal, recycle, or reuse
- Operation and maintenance infrastructure: availability of a public or private utility system
- Costs of managing wastewater: cost-effectiveness and affordability issues that affect the rate-setting procedure.

For each of these factors, there are several subfactors that must be considered during the planning phase. An <u>appropriate</u> (not an alternative or a conventional) wastewater system that meets the current demands for wastewater management, that is expandable to meet future demands, that is affordable in both capital and operational costs, and that can protect the RE (the environment into which the effluent is discharged) from bacteriological and nutrient pollution *can* be selected by adequately addressing all of the above-mentioned factors. On the other hand, a system that is selected without adequately addressing one or more of these factors will not serve the community in a satisfactory manner. In some cases, serving part of a community with a centralized system and serving part with a decentralized system may in fact be the most appropriate solution. Also, combinations of technology can be used. It is not necessary to construct a pressure sewer or an effluent sewer to use some of the treatment technology generally associated with decentralized solutions.

It is, however, important to honestly evaluate all components. Infiltration and inflow (I/I) should be no surprise to designers of conventional gravity sewers, so they should design for them using appropriate flow values. In some cases, combinations of gravity sewers and pressure sewers are the most appropriate solutions. In this case, if effluent sewers are discharged to gravity sewers, odors should be expected when the sewage is septic, and the designer should realistically design for odor reduction or removal. Dumping an effluent sewer into a gravity sewer manhole in front of an historic bed and breakfast (B&B) in a picturesque village with no odor control measures is probably not the best way to win over opponents of decentralized technology — or the guests of the B&B for that matter. Using land valued at nearly a million dollars per acre for a soil-based dispersal system rather than treating the effluent to an extremely high quality and discharging to an adjacent stream under an National Pollutant Discharge Elimination System (NPDES) permit is also probably not the best choice of technology or regulatory process. Choosing the appropriate technology for the situation should be the approach and the underlying principle pursued and chosen by all designers, regulators, and maintenance providers.

Wastewater and the receiving environment

Whether considering a centralized multimillion gal per day wastewater system or a single-family home wastewater system, it is important to know that you are dealing with wastewater, and you must know the quantity and quality of wastewater to be managed along with the variability (daily or seasonal) in wastewater quantity and quality. For a large-scale system, a good understanding of wastewater quantity, quality, and variability is developed at the beginning stage — at least for the amount of wastewater generated by the users. In most cases, unfortunately, the amount of I/I is discounted or minimized, resulting in undersized pumping and treatment facilities. However, sometimes very little or no attention is given to this very important factor for an onsite systems. There is great deal of difference between the quality (i.e., the strength) of residential wastewater and restaurant wastewater. There is a great deal of difference in the flow patterns of residential wastewater and a school's or church's wastewater. Many times, onsite wastewater systems for restaurants are specified and installed following the requirements of a residential septic system (septic regulations). The result is not pretty. Factors to consider in order to adequately understand the wastewater that needs to be managed using onsite systems include:

- Source of wastewater: residential or nonresidential
- Daily average flow based on an annual usage: estimate or real data
- Peak flows during a day, week, or month based on the activities that generate wastewater
- Characteristics of the wastewater: detailed analysis if and when necessary
- Seasonal variability in both the quantity and quality of wastewater.

Knowlng the wastewater is just the beginning of the planning phase, the second important item to understand is the RE, the environment into which the treated wastewater (effluent) will be released via an onsite effluent dispersal system. The dispersal system can be a trench or a bed with or without gravel; a dispersal or recycling system, such as drip or spray irrigation; or a reuse or zero or minimum discharge system, such as an evapotranspiration bed or greenhouse system, along with reuse for nonpotable purposes or a point-source discharge into surface water bodies, such as an outfall into a creek, river, or ocean.

One needs to understand the assimilative capacity of the RE in order to determine how much treatment is necessary before releasing effluent into the environment. The *assimilative capacity* is the ability of the RE to assimilate pollutants without causing any long-term degradation in environmental quality. Use of such a measure is common for establishing discharge standards (i.e., NPDES permits) for large wastewater treatment plants. It is not uncommon to perform long-term (multiseasonal) stream studies prior to setting discharge limits for large treatment plants. The objective is to determine the assimilative capacity of the receiving stream, and the assimilative capacity is determined, with discharge limits set to result in conditions to meet particular objectives, such as fish habitat or downstream water users' needs. The objective of any wastewater management system must be to release the treated wastewater into the RE in a manner that allows quick and effective assimilation of the pollutants that are remaining in the effluent without exceeding the assimilative capacity of the RE, thus minimizing the degradation of the quality of the RE and movement of the residual pollutants.

Determining the assimilative capacity of the RE, or even determining what the RE is for an onsite system, is a scientific and technical challenge. The debate over this issue can go on forever. Meanwhile, for no real reasons, some communities are asked to spend enormous amounts of public funds to install new sewer lines or to extend existing sewer systems in areas that have either failing septic systems or have no systems. Currently, assessment of assimilative capacity for onsite systems is done primarily by *subjective* evaluation of soil characteristics, such as texture, structure, and color. Use of the "perc" test is still quite common to evaluate sites and to determine the size of drain fields. The current system for evaluating assimilative capacity for onsite wastewater systems is merely evaluation of the soil to accept and transmit septic tank effluent. This is very different from determining the assimilative capacity of a site to renovate and transmit wastewater treated to a particular quality prior to dispersal into the RE. Some states are now moving toward the use of other techniques to conduct *objective* evaluation, such as conducting an infiltration test or even conducting a test that simulates operation of a small trench (Orenco Infiltration Test Kit) in an area where the actual trench would later be installed and dosed in a similar manner in which the simulation was conducted. Use of a real infiltration test is a better way of determining a site's ability to move water (i.e., the soil's permeability and conductivity) than just relying on the subjective evaluation of soil color and texture.

Soil's ability to move the effluent away from the dispersal area is one of the major factors in determining how big of area is needed to install a subsurface dispersal system. Movement of nutrient and bacteriological pollutants in the subsurface environment are other major issues that should be addressed while evaluating the carrying capacity of an RE Nutrient and bacteriological pollutants can now be removed from wastewater quite effectively prior to subsurface dispersal, thus minimizing adverse impacts on the RE from such pollutants. Use of natural systems, such as plant uptake of effluent in evapotranspiration beds, greenhouse systems, and wetlands, can be considered for minimizing any potentially adverse impact of nutrient and bacteriological pollutants when the RE is determined to be sensitive to such pollutants. The RE is required to assimilate the wastewater, and this process includes both transmission as well as renovation components. When designing a surface-discharging municipal wastewater treatment system, the receiving stream is evaluated for its assimilative capacity to determine discharge limits — the level that the wastewater treatment must achieve. Decentralized systems using soil-based REs must apply the same methodology to determine the assimilative capacity of REs in order to determine the treatment level for wastewater being applied and the land area required to complete the functions of transmission and renovation.

Evaluation of an RE is important for installing and operating any wastewater treatment and dispersal system, be it a small onsite system or a large centralized system. However, common sense and risk assessment should to be used to determine the amount of time and resources that should be spent on the evaluation of the RE. The extent of evaluation must be based on the type of treatment and dispersal technologies proposed for managing wastewater onsite and the degree of risk associated with the operation of systems on the RE. Evaluating an RE such as a delicately balanced ecosystem in a salt pond in New England would require significantly more effort than evaluating a lawn adjacent to a pesticide-contaminated rice field bayou with propanyl barrels floating in it in east Arkansas.

Quite often, standard subjective evaluation of the soil and site is performed regardless of the type of wastewater treatment and dispersal technologies proposed for an onsite system and regardless of the risk associated with the use of the proposed technologies on the RE. Such an approach has no real benefits either to the protection of the RE or to the citizens who need cost-effective and environmentally sound wastewater systems. A better approach is to conduct a necessary evaluation of the RE to determine the type of treatment and dispersal system necessary for the site or to conduct the necessary evaluation of the RE to determine if the proposed treatment and dispersal systems are adequate for operation on the proposed site.

One must consider the *value* of any type of detailed and potentially costly evaluation of the RE before requiring such an evaluation for an onsite system. Most of the current regulatory requirements for onsite systems in terms of soil and site evaluation do not add any real value to the overall operation of the wastewater project. Quite often, regulations require money to be spent on soil and site evaluation for onsite systems when that money could be better spent on use of advanced treatment devices, such as media filters and ultraviolet disinfection.

Appropriate treatment and dispersal of wastewater is not cheap; however, it does not have to be outrageously expensive. With adequate planning and value-added engineering, affordable wastewater systems can be made available to every citizen not served by centralized systems. The capital and operation and maintenance costs and the replacement cost of a wastewater system must be considered in the planning stage. Onsite systems, when adequately evaluated, can lower both the capital and operational costs compared to the true cost of hooking into an existing centralized system or the true cost of a newly installed centralized system when the density dictates that a decentralized approach is more cost effective. With the tools available today, an onsite system that can treat wastewater to tertiary standards and dispose of effluent with no adverse impact on the environment or public health can be installed for less than $20,000 for a typical residential home and can be effectively operated at the cost of less than $10 per 1000 gallons of wastewater treated. However, many changes need to occur in the current regulatory framework and other aspects of both the public and private sectors before widespread use of appropriate onsite systems can become a reality. Some of the needed changes have started occurring at the national, state, and local levels and, within the next few years, communities will have better access to the use of onsite wastewater systems.

Operation and management infrastructure

Without a management program, no wastewater system can offer wastewater solutions on a permanent basis. It is not uncommon to be asked by friends who are manufacturers' representatives to evaluate new equipment or treatment systems and provide advice regarding their performance. Some of these manufacturers' representatives also sell large municipal or commercial systems. One of the first questions asked during an evaluation of small systems technology is "Does this individual home treatment system come with an operator?" Of course the answer is always "No," and the follow up question is "Would you sell a municipal sewage treatment plant to someone who plans to bury it and expect it to work a year or a month later?" The answer to this question is again "No." The point of the enquiry is to clarify that no mechanical collection or treatment system should be expected to operate with no maintenance, monitoring, or operation program. Use of advanced onsite wastewater systems should be allowed and encouraged in any area only when an RME is formed to serve that area. A number of private and public sector entities currently offer wastewater services using advanced onsite systems in areas that are not served by centralized collection and treatment systems. Although a public sector RME may have a fixed and limited service area, private sector RMEs can serve areas that are not served by public sector RMEs. Loudoun County Sanitation Authority, serving Loudoun County, VA, and Charles City County Public Works Department, serving part of Charles City County, VA, are a couple of examples of public sector RMEs that are in operation today in the Commonwealth of Virginia. Northwest Cascade Incorporated and Pickney Brothers Incorporated are examples of private sector RMEs that are ready to work on the national level to offer wastewater services.

Many RMEs are currently available in the U.S., and some of these management entities have been in operation for more than 50 years (National Environmental Services Center, 2004). Although the U.S. Environmental Protection Agency (EPA) has developed voluntary guidelines for management of decentralized systems (U.S. EPA, 2003), it is uncommon to find a management entity that fits perfectly into one of the five levels of the model. Although designers and engineers may use the model with its five levels as a guide, creativity is encouraged in evaluating each project or community on its own merits and developing a management entity that best suits the situation. Each community or project has its own factors to consider and its own political, sociological, and technological aspects. Some projects may be located within the boundaries of rural water districts. Some projects may be located such that a municipality may be interested in managing the onsite and decentralized systems. Some projects may require the formation of a sewer improvement district or other political subdivision to manage the systems. In some cases, a for-profit RME may be available, and contracting with that RME may be the simplest and best option.

When an engineer, planner, or designer begins the process of evaluating an area for wastewater collection, treatment, and dispersal, the site conditions are generally the first consideration. Although this is a very important aspect of the process, just as important is evaluating the availability of an RME. The process of finding an RME may be quite different for new construction than it is for an existing community. In practice, this may be an unfamiliar process to engineers, designers, and land planners because it is not so much a technical, calculation-oriented process as it is a political, legal, regulatory, and sociological process. A few questions to ask as the evaluation begins are:

- Who currently provides water to the community, home, or development?
  - A rural water district?
  - A water authority?
  - A nearby or adjacent community?
- Who currently provides electric service to the community, project, or home
  - A rural electric district, cooperative, or association?
  - A for-profit electric utility?
- Is there a nearby wastewater service that may be interested in taking on the project?
  - A nearby town or community wastewater utility?
  - A nearby or adjacent sewer improvement district?
- Who will hold the permit?
  - If the permit is held by the owner but the owner contracts with a for-profit RME, who is responsible for penalties for noncompliance?
  - If the permit is held by the RME and repairs are need to bring the system into compliance, who is responsible for the cost of the repairs?

As may be discerned by this limited list of questions and considerations, forming an RME involves more than just forming a political subdivision or business enterprise and calling it a "responsible management entity." The key word in this term is "responsible." If an RME is going to be responsible, where does its responsibility begin and end? The definitions specifically delineating the RME's responsibilities must be worked out before contracts are signed between the service provider and the entity receiving the services of the RME. In many cases, this process requires legal assistance; an attorney experienced in working with rural water and wastewater systems can be invaluable to the process. Although most small water and wastewater systems have attorneys on retainer, few of them are well versed in the political, technical, funding, engineering, and public relations aspects of decentralized water and wastewater systems. The engineer or designer commonly takes on the role of advisor as well as educator for the project.

For new construction, it is quite often the desire of the developer to simply form a property owners' association (POA) as a measure to show some political subdivision that would nominally own, operate, and manage the wastewater systems within its boundaries and jurisdiction. In practice, this usually means that the developer is the POA until the lots are all sold; then the developer leaves with no real management authority and with no real process to collect sewer bills and maintain the wastewater system and with no real plan for making the system sustainable. The result is that regulatory agencies are faced with failing decentralized systems scattered around their states, and the conclusion is that "decentralized wastewater systems don't work." In fact, no wastewater system should be expected work and be sustainable with no management, so it is not the fault of the treatment technology but rather failure to manage the wastewater system.

POAs have successfully taken on the role of RMEs when they are organized in such a manner that they have the power to collect sewer bills, employ or otherwise obtain the services of licensed wastewater operators, and have been given the authority to enforce nonpayment of sewer bills by members of the association. With this model, however, when the developer has disappeared from the picture, enforcement for violation of permit requirements means that multiple homeowners (POA members) are parties to the enforcement action. The regulatory agency may in fact have to take action against many individual homeowners in order to force compliance. In low- to moderate-income communities and developments, the homeowners simply may not have the resources to pay the costs to repair or replace the treatment system to get it back into proper operating condition to meet the permit requirements. POAs can be RMEs, but caution must be used and careful consideration of the functions of the RME must be taken when a POA is organized as the RME.

As previously mentioned, several models are available for engineers, planners, and designers to follow when new construction is planned. A rural electric cooperative may take on the role of RME in some areas and provide wastewater service to the patrons it is already serving with electricity. The National Rural Electric Cooperative Association and the Electric Power Research Institute have both been very involved in the decentralized wastewater industry, and member cooperatives are provided with assistance to enter into decentralized wastewater RME roles.

Some states allow water districts or associations to enter the wastewater business. In this case, the transition is particularly smooth, because it is common for water operators to also hold wastewater operators' licenses. State regulatory agencies are generally familiar with the water district manager, and a trust has already been established, with confidence in the performance of the water district. The water district provides a single point of contact for the enforcement branch of regulatory agencies so the problem of enforcement against multiple homeowners or an absent developer is not applicable as it would be in the case of a POA. The water district already has a mechanism of generating bills for water, so adding wastewater customers to the monthly bill is a relatively simple task. The water district may be able to generate revenue from the wastewater service. It has been the experience of some water districts that when wastewater service is provided, development increases and more customers (both water and wastewater) are generated, increasing revenue. A motto for some of the water districts that have provided wastewater service is, "If you build it, they will come." Although they do not typically build "fields of dreams," when managed wastewater service is available, patrons of the district desire the service and developers are often able to develop land that was not approved for septic systems. The water districts also reap the benefit of removing old, unmanaged septic systems from their service area (and possibly source recharge areas) and can provide themselves with wellhead protection by eliminating inadequately treated wastewater from entering their source water. Water districts have access to public funds and therefore can borrow from state revolving funds (SRFs) and have typically mastered the process of working with SRF administrators. Water districts may also have the track record and ability to borrow private funds and encumber bonded indebtedness to pay for infrastructure expansion. In addition, water districts actually have a reason to continually encumber federal indebtedness from such sources as the U.S. Department of Agriculture Rural Utility Service since the water district can protect its territory under federal law 1932(b) when the district has federal debt. Rural water districts have access to technical services through the National Rural Water Association circuit rider program, by which technicians from state rural water associations visit local water districts to provide technical assistance to the operators and managers.

For existing construction (existing onsite systems or existing community systems), the picture can be quite different. New construction is nearly always easier in terms of planning and designing wastewater systems as well as in terms of finding acceptable and willing RMEs to manage the proposed wastewater systems. In some cases, an existing community may be purchasing water (as a wholesale customer) from an adjacent or nearby town. The nearby town may hold the smaller community hostage with the water service and can require unreasonable technology to be used in the wastewater management infrastructure. Existing small communities may not have the wastewater operators available for managing wastewater service. Costs to enter into a managed onsite or decentralized wastewater arena may be more than the small community is willing to encumber. Even when developers are willing to build the infrastructure and give it to the community, the community may not be prepared to accept the role of an RME.

If existing onsite systems are the chosen form of treatment and dispersal, one of the first steps in forming the RME is simply finding and inventorying the existing systems. Once the systems are located and a database is developed to simply tabulate the systems' physical locations, the systems must be evaluated for their viability. Not all of the treatment systems may be functional and some may need to be repaired or replaced in order to make them acceptable for management under an RME.

Another major part of the management process is to obtain billing addresses for the system owners and to purchase or develop billing software or a billing system so that monthly bills can be sent. Commercial billing software can be purchased from companies that provide billing software for water systems. Water system software is easily adaptable for wastewater systems. As part of the billing and accounting structure within the RME, a cost analysis must be performed and coupled with a rate study to determine an appropriate and affordable monthly rate to cover the costs of operating and managing the systems. The rate study and evaluation should include the costs previously discussed — capital cost (or debt retirement), ongoing operation and maintenance costs, and the replacement cost at the end of the system's useful or design life. Simple engineering economic analyses can be applied to determine these costs, using a reasonable system life and interest rate for the amortization of both the capital costs and the replacement costs. Within the analysis, a schedule should be developed for replacement or repair of components based on when particular components, such as pumps, media, filters, and floats, should be replaced within the life of the system. These costs can be scheduled into the amortization and rate structure so that the funds will be available when those costs are incurred. If the RME is a for-profit entity, profit must be factored into the monthly rates.

For most municipalities, sewer charges are linked to water usage. For decentralized systems, public water service may or may not be available and not all rural water service is metered. In some cases, water rates are based on flat fees. In these cases, sewer rates could also be based on flat fees, or if remote monitoring systems are installed with the onsite systems, sewer charges may be generated based on usage determined by measuring sewage flow from the wastewater system and transmitting the flow to a centrally located computer via the World Wide Web or by telephone modem.

Although the current reorganization for management of onsite systems by the U.S. EPA has developed a new interest in the onsite industry, there are examples of management programs that were established in the 1970s and are still in use. The textbook *Small and Decentralized Wastewater Management Systems* (Crites and Tchobanoglous, 1998) lists several of these management programs and gives details on some of the oldest management programs, such as Georgetown and Stinson Beach, CA. Environmental impacts from onsite wastewater systems when used in environmentally sensitive areas, such as along coastlines or near drinking water supply areas, were recognized and area-wide management programs were implemented to prevent contamination of groundwater and surface water bodies from the use of onsite systems. Thus, it is a well-established fact that onsite systems can be used on a permanent basis for meeting wastewater treatment needs when a responsible management program is in place.

Examples of other RMEs will be listed on our web site, with information on how you can reach these entities to determine if they can offer services in your area. As the industry and the public in general become more familiar and comfortable with the idea of using onsite systems under a utility model, more RMEs will be formed. Just like other utilities (electricity, gas, telephone, cable), some of these RMEs will stay in business longer than others. However, when one RME closes down its business, its customers can be picked up by another RME that is willing to fill the gap. The important thing to remember is that the need for advanced wastewater treatment systems will be there as long as human activities generate wastewater — in other words, as long as humans occupy this planet — and there will always be RMEs ready to manage these advanced onsite wastewater systems as long as government rules and policies allow these RME to function.

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chapter nine

The future of advanced onsite systems technologies

Introduction

Our needs for clean water and adequate wastewater treatment will never end, and as we move forward in the 21st century, the decentralized wastewater management concept will play a greater role in meeting the needs for adequate wastewater treatment than it has in previous centuries. The best way to predict the future for onsite systems is for all of us involved in the onsite industry to participate in making and shaping that future. The future is bright for addressing wastewater treatment needs using advanced onsite wastewater systems technologies under a utility management concept such as the one presented in this book. There are plenty of business, education, and regulatory opportunities for all the players involved in the onsite industry and in this century we will make the use of decentralized wastewater systems an integral part of our wastewater infrastructure.

In order for onsite systems to have a bright future, we must make adjustments to our vocabulary and start incorporating the word "management" or "managed" every time we say "onsite systems." We must also focus on wastewater treatment levels necessary prior to discharge such that, once installed, effluent dispersal systems can be used on a permanent basis. We are not opposed to discharge of primary treated (overall treatment level [OTL] 1) effluent into the subsurface environment. However, with the advances in onsite treatment technologies and with the information available and endorsed by the U.S. Environmental Protection Agency (EPA) on management programs, it is time to stop using soil for the treatment of primary effluent and start using the soil and plant system for polishing and final treatment of secondary or better quality effluent. In this way, the concept of assimilative capacity of the receiving environment is applied to decentralized wastewater treatment. With effort, the concept will be applied more successfully than it has been applied in the conventional surface discharging municipal system realm. We must look at the lessons learned from the operations of large treatment plants that used to discharge primary effluent into the surface waters of our nation prior to the Clean Water Act; we cannot wait until federal laws are enacted that will prohibit discharge of primary effluent in soil. It is not uncommon to see soil scientists with bumper stickers that say "Stop treating our soil like dirt." In the world of decentralized wastewater treatment, the soil is part of the hydrologic cycle and has a finite ability to transmit and renovate wastewater.

The 1997 report to Congress by the U.S. EPA recognizes the fact that extending central collection systems to all dwellings in our nation is neither a practical nor an achievable goal and thus onsite systems will remain an integral part of the nation's wastewater infrastructure and must be managed in a responsible manner. Protection of natural resources, such as land and water, and protection of protection of public health from operation of all wastewater systems must be ultimate goals for regulatory as well as professional entities of our industry. We must keep these ultimate goals in mind at every step we take while conducting preinstallation and postinstallation activities related to the use of onsite systems. Only then we can secure a bright future for our product and our vocation — serving wastewater needs using managed onsite systems.

Managed onsite systems

In its executive summary for the Report to Congress (1997), the U.S. EPA states, "Adequately managed decentralized wastewater systems are a cost-effective and long-term option for meeting public health and water quality goals, particularly in less densely populated areas" (Response to Congress on Use of Decentralized Wastewater Treatment Systems, April 1997). Population density, although a critical factor in determining cost-effectiveness of wastewater system solutions for a given area, is not the only factor that should be considered. In many cases, a less densely populated area today may become a more densely populated area tomorrow if the area offers potential opportunities for economic growth. Does this mean that adequately managed decentralized wastewater systems are not cost-effective or a long-term option for wastewater systems?

The answer is "NO." Adequately managed decentralized and onsite wastewater systems can be used in areas that are less densely populated today but offer potential for future growth. One of the best characteristics of onsite systems is that they are "expandable" to meet the future needs, thus communities do not have to predict the future needs or build systems for future needs. Adequately managed decentralized systems can be installed and operated wherever and whenever wastewater management services are needed. These systems offer viable alternatives to centralized collection (sewer) and wastewater treatment plants or publicly owned treatment works as well as to conventional onsite septic tank drain field systems. Use of these systems can help communities fix their existing problems associated with failing septic systems or lack of wastewater systems for existing homes and businesses as well as address the future needs for wastewater management. These systems also allow communities to grow where conventional collection and treatment system infrastructures have not kept pace with population growth. In some communities served by large municipalities, the larger towns have shortsightedly allowed the population to outgrow the collection and treatment capacity. The smaller, surrounding communities are held hostage by the larger community's lack of planning and failure to provide capacity. These systems can also provide a means for cities, communities, rural water districts, and other entities to generate revenue by providing decentralized wastewater solutions for outlying suburban or rural areas. At the same time, responsible management entities (RMEs) serve the needs of the suburban and rural population for adequate wastewater management.

In order to introduce citizens to the idea of permanent management of onsite wastewater systems, careful study of the voluntary management guidelines that the U.S. EPA has proposed (US EPA 832-B-03-001) is recommended. (A copy of these guidelines can be obtained from the U.S. EPA's website (http://cfpub.ep.gov/owm/septic/guidelines.cfm#7489) or by calling 1-800-490-9198). Initial public resistance to the concept of management for their onsite systems, especially to the recurring costs associated with this management, is quite understandable and should be expected. That is why the U.S. EPA presents five models for management programs. At the least, all users of onsite systems must be made aware of the fact that wastewater treatment and effluent dispersal systems are installed on their properties and these systems must be operated and maintained such that environmental quality and their own health, as well as the public health in general, and the investment in their property are protected on a permanent basis. Implementation of such an awareness program is needed immediately in every community that relies on onsite systems for part or most of their wastewater management needs.

The use of advanced onsite wastewater systems must be considered only in communities that are serious about management of such systems and only for those users who are not afraid to pay on an on-going basis for operation and maintenance of their wastewater systems, just like people do today if their homes and businesses are connected to centralized wastewater collection and treatment systems. There are many benefits of recognizing and accepting management for onsite systems. First and most importantly, the list of options available for onsite wastewater treatment and effluent dispersal or reuse is a long one, thus offering customized solutions for your wastewater management needs. For most of the 20th century, a conventional septic tank for wastewater treatment and drain field for effluent dispersal was the only technology listed as an onsite wastewater solution. However, with management, a wide range of currently available pre-engineered and prepackaged onsite wastewater treatment systems can treat wastewater to rainwater quality (OTL 4) – or better than some of the acid rain and nitrogen-rich rain of the industrial northeast US. An onsite system designer can design an effluent dispersal or reuse system that can offer the protection necessary for environmental quality and public health standards.

The currently available advanced onsite system technologies can be used to serve one home (small or large), one business (anything from a restaurant to a funeral home — small or large), or a cluster of dwellings (residential or businesses combined), or an entire community with any density that is present or expected in the future. It is important to note that although the U.S. EPA proposed that management models 1, 2, or 3 may be adequate for small onsite systems serving individual dwellings, larger systems (clustered or community) that serve multiple dwellings must be used where RMEs are present and ready to take full responsibilities for operation, maintenance, and ownership of the onsite wastewater systems.

Why treat beyond the septic tank?

In order to adequately answer this question, one must first understand what a septic tank is, how it treats wastewater, and most importantly how much treatment can be expected from it. Although there are no set standards for septic tank performance, it is widely accepted that a septic tank is a primary treatment system in which heavy material present in wastewater settles downward and light material floats upward, thus removing and storing these materials in the tank where the material undergoes anaerobic decomposition (break down). Effluent is discharged from a septic tank every time influent (wastewater from the source) enters the tank. Thus, a septic tank is a flow-through treatment system that treats raw wastewater to a primary treatment level, OTL 1. In Chapter 2, we have proposed a method for calculating OTLs for any type of onsite treatment system and when you consider majority of the constituents present in raw wastewater and consider the effluent quality that is typically reported for septic tanks, the overall treatment level of a septic tank would in the range of 20% to 45%.

Septic tank effluent is not clear like rainwater; it is gray to black in color and has a strong odor that is typically associated with ammonia and hydrogen sulfide gas. Use of an effluent screen (also called *effluent filter*) must be considered if a septic tank is expected to achieve primary treatment on a regular basis. The screen prevents discharge of settled or floated material out of tank during peak flows or when accumulated to the maximum capacity. The effluent screen also prevents discharge of any materials that may be neutrally buoyant in the wastewater, for example, a saturated cigarette butt. Readers may (or may not) use their own imaginations to form other examples. The effluent screen must be designed and installed such that it reduces or stops the flow of effluent out of the tank, thus alarming the owner by creating sewage back-up inside the dwelling and creating the need for pump-out (i.e., removal of the solid and liquid content from the tank). Without regular inspection and maintenance, a septic tank cannot be viewed as an onsite treatment system because it lets raw wastewater exit out to a drain field, which is designed for the treatment of primary effluent and not raw wastewater.

When a septic tank is used as an onsite treatment system, the majority of wastewater treatment (i.e., removal of contaminants) occurs in the subsurface soil environment that surrounds the drain field. The soil acts as a medium that treats septic tank effluent as it flows through the gravel and the soil pores. The treatment principles are similar to the one used for designing a single-pass media filter, as explained earlier in this book. However, the important differences between a subsurface drain field and a single-pass media filter are reliability, sustainability, and accountability of the treatment system. Since drain fields are installed under ground (subsurface), it is practically impossible to look at the quality of the effluent that exits the soil-based treatment system. Natural soil is seldom if ever homogeneous and free from large macropores, which provide preferential flow paths to allow partially treated wastewater to move into groundwater or surface water. Thus, there is no telling whether final effluent quality meets the discharge standards. Also, the biomat that grows at the gravel and soil interface (or at the soil interface when nongravel systems such as chambers or drip lines are used) can neither be inspected nor maintained on a regular basis.

The unmanaged biomat eventually develops resistance to the movement of the effluent out of the drain field, causing the effluent to surface. At this point, the septic system is considered "malfunctioning" at best and "failed" and inoperable at worst. For this very reason, we believe that subsurface discharge of effluent must be preceded by a treatment system that reduces the organic load (mass loading of biochemical oxygen demand; total suspended solids; and fats, oil, and grease) to at least 90% (OTL 2), thus minimizing or stabilizing formation of biomat at the soil interface. Doing so will allow the drain field to operate on a permanent basis and will allow soil to treat other constituents, such as nutrient or bacteriological parameters. Column studies conducted in controlled environments by several researchers show that when the majority of organic waste load is reduced from the wastewater, clogging of soil does not occur and aerobic conditions are maintained under and around the effluent dispersal point. The aerobic conditions maintained in the subsurface environment act as a natural disinfection system that reduces the microbiological content in effluent. It is also observed that such conditions allow for a reduction in total nitrogen and total phosphorus as the effluent moves away from the dispersal system. Thus, treatment beyond the septic tank using advanced onsite wastewater systems technologies with management is the key for ensuring a bright future for onsite wastewater systems.

Fixing current problems and addressing future needs

If you live in the area that is not served by a centralized wastewater collection and treatment system, chances are you know about a failing septic system, about someone using an outhouse, or about someone that has no wastewater treatment system. In many cases, quality of life has suffered and is still suffering due to lack of adequate wastewater systems for residential dwellings. There are places where economic growth has been halted just because of the lack of a necessary wastewater system. Use of advanced onsite wastewater systems can offer the necessary services to adequately manage wastewater, improve quality of life, and allow growth to occur.

As noted earlier, some believe that a conventional septic tank drain field has a finite life, typically less than 30 years. A clogged drain field can be rejuvenated and put back to work for effluent dispersal if the conventional onsite treatment system (septic tank) is replaced or augmented with an advanced onsite treatment system and the raw wastewater is treated to OTL 2, 3 or 4. Introduction of aerobic effluent starts decomposition of the biomat and helps the soil interface recover its ability to assimilate the effluent. The only question is how long it takes before a failing drain field becomes operational again. It may take anywhere from a few weeks to a few months for a drain field to start working again if most of the accumulated wastewater is removed from the drain field and an advanced system is designed such that treated effluent is released into the drain field in small and frequent doses (time dosing). One should also consider replacement of the distribution box with the currently available gravity flow splitters or even a pressure manifold or pressurized distribution. The idea is to allow the flow of effluent from the advanced treatment system to the entire drain field system and the old distribution box will not allow that to occur.

The owners of existing failing systems should consider not only replacement of their treatment systems but also a maintenance contract from the service provider or the manufacturer of the treatment system in order to ensure their investment in their new onsite system. The owners of conventional septic system should consider obtaining service contracts with RMEs as soon as they become available, thus avoiding some of the risk of the unpleasant conditions that would occur at the end of the life of their existing drain field. It should be noted that, to our knowledge, no service provider includes the soil component of the septic system in its service contract, and no manufacturer includes the soil component of a wastewater treatment system in its warranty. An RME may decide to upgrade the system right away and charge for the upgrade as a one time sign-up fee or may consider charging an extra fee for the future upgrade of the onsite system along with the fee for the routine operation of the existing system. Either way, current owners of onsite systems may really save some headaches and loss in their property values due to failing onsite systems by allowing RMEs to take operational responsibilities for their onsite systems. Users of onsite systems should ask their permitting agencies about the presence of an RME in their area and, if none are present, consider forming one.

With the presence of RMEs in areas that are not served by centralized wastewater systems, addressing future needs for wastewater systems becomes very easy and quite cost effective. The management entity can work with developers just like other utilities work to offer their services. Selection, design, installation, and operation of the wastewater system for new growth that occurs in any area not served by a centralized wastewater system can be done by the RME from day one. This concept is here to stay and, for that reason, the future is quite bright for the advanced onsite systems.

Performance monitoring is now possible

As relatively newer advanced wastewater treatment and effluent dispersal systems for onsite wastewater management become available, the interest among regulatory agencies in monitoring the performance of these systems in the field is rising. Wastewater treatment using aerobic treatment devices or media filters is not new from a scientific point of view. Scientific theories for aerobic and anaerobic treatment of wastewater are well tested and are used extensively in large-scale wastewater treatment systems. Such theories are now employed for developing onsite wastewater treatment systems using technologies such as media filtration with enhanced recirculation, flow-through or sequencing batch reactions with efficient air diffusing systems, and ultraviolet light disinfection systems.

Unlike large-scale wastewater treatment plants, most small onsite systems currently are not required to have on-going performance monitoring and reporting of effluent quality as a condition for their operating permits. At the same time, long-term field performance and the environmental impact from the use of many of the onsite systems are still not well established. An adequate monitoring protocol for onsite systems is needed for both short-term field evaluation of new systems and for long-term performance monitoring of such systems.

Tools that allow for easy and adequate access to various points within the treatment and dispersal system scheme of an onsite system for collecting samples are very important parts of the monitoring program. Such tools should be incorporated during the installation of the system to be monitored. A list of monitoring tools used includes: a water meter to record the flow data; a sampling port or faucet to collect an effluent sample from a treatment device; a groundwater sampling well to collect free-water samples underneath or around the dispersal area; a suction lysimeter to collect soil moisture samples when free-water is not present in the dispersal area; a tensiometer to measure the soil moisture potential (i.e., wetness indicator); and a remote data sensor to automatically record the depth of free-water in evapotranspiration beds and store the data on site. Other tools available on the market can also be easily used for monitoring the performance of onsite systems.

With advances in control systems, it is now possible to remotely monitor the performance of pumps and other mechanical devices used in onsite treatment systems. Telephone lines or internet cables can be used for transferring data from the field to a central location on a routine basis or whenever necessary. Flow data can be recorded onsite and can be monitored from a distance location using advanced control systems. With the use of appropriate sensors, it is possible to remotely monitor such qualitative parameters as dissolved oxygen, turbidity, and pH in the effluent prior to discharge. Data can be stored onsite and downloaded easily with handheld personal data assistants and then transferred to office computers for analysis and synthesis. Such parameters can indicate the overall performance of the treatment system and allow operators to optimize site visits for maintenance purposes. Since onsite systems are typically scattered over a large area, advances in remote monitoring are quite valuable for those who want to develop operation and maintenance infrastructures for these systems. When the performance of an onsite system is closely monitored, its maintenance becomes quite cost effective. An appropriate onsite system that is professionally operated and well maintained can protect public health and the environment as well as the owner's and the community's property values and financial standing on a permanent basis, regardless of where it is installed.

Monitoring of onsite systems is still a relatively new concept that is gaining momentum as advanced treatment and dispersal systems are developed and proposed for use in areas that are not suitable for septic systems or where the use of septic systems is not desired. However, long-term monitoring of onsite systems should be considered by regulatory agencies if onsite systems are to be used as true and equivalent alternatives to centralized wastewater systems. With the monitoring tools currently available, it is possible to monitor the performance of a large number of scattered onsite systems using remote monitoring techniques. An adequately monitored onsite system can be operated and maintained by professional wastewater operators in a cost-effective manner. A permanent operation, maintenance, and monitoring infrastructure (utility) is needed for all onsite systems in order to protect public health and the environment from the operation of such systems. When such a utility is established, an onsite system can be made available to all the citizens who do not have access to a centralized wastewater system.

Regulating use of onsite systems online

There is a move among government agencies to incorporate use of the internet in their day-to-day operations and interactions with the public. Just like advances in technologies for onsite wastewater treatment and onsite effluent dispersal systems, advances in information systems today can offer many tools to regulate widespread use of advance onsite wastewater systems in a manner that can save a significant amount of time and resources, both in the public and private sectors. Of course, it is very hard to make any changes to any existing regulatory programs, especially changes to current regulations or implementation of a new regulatory framework. However, we believe that these changes are necessary in order for the public to truly recognize benefits of using onsite wastewater systems as an alternative to centralized systems.

The internet has changed the way we do business. Next it will change how we access government services, and then it will change how government regulates an industry and its service providers. The E-Government Act of 2002 outlines the internet architecture and objectives to implement web-based government services, including permitting processes. This architecture includes specific regulatory frameworks and objectives. How can these changes be implemented in order to maximize benefits and minimize costs and pitfalls? What will be the impact on regulators who regulate the onsite industry and on landowners and developers who rely on onsite systems? What are the costs and benefits? How will these changes affect the current state of onsite regulations? Can the onsite industry influence how these changes are implemented? What can we as industry leaders do to prepare others and ourselves for these changes? How can our needs and interests be incorporated into the onsite well and septic E-government concept?

The E-Government initiatives will start to manage information in support of strategic water quality and resource management. In order to reap the benefits, it is time to prepare for the changes ahead. State and local regulators will be expected to define regulations in a manner that is less subjective and not open to wide interpretation. Now is the time to define all our regulatory criteria and permitting workflow such that they are e-government compatible. New technologies for onsite treatment and effluent management have been introduced by the onsite industry that are not well supported by current regulatory processes.

What does industry need from the regulatory process in order to maximize the benefits and manageability of these new technologies? In order for onsite wastewater solutions to gain new recognition in the 21st century, new ways of implementing regulations must be assessed and implemented as soon as possible. It is about time that we take most of the myths out of permitting programs for onsite systems and adopt a regulatory framework in which permit applications are processed and decisions are made in an "open," meaningful, consistent, and justifiable manner for all who are affected by the process.

The U.S. EPA identifies inventory of onsite systems as a key element in the model 1 management program. Since permitting of onsite systems typically is a responsibility at the local level, all data on the system location and other basic information related to the system (inventory) are currently stored in paper form at the local health department or other local permitting agencies. Very rarely such information is kept in an electronic form, such as a database. It is widely believed that there is no use for this information outside the local or regional area. But, this belief is wrong. In order to understand long-term effects on public health and environmental quality, one needs to know where onsite systems are installed, what kind of systems are there, and what the performance of those system is in terms of their ability to treat wastewater and disperse effluent onsite to the levels for which they were designed. Current technologies, such as web-based data collection, analysis, and reporting, can offer powerful tools to regulators and to the onsite industry for assessing the long-term impacts of the operation of these systems in a manner similar to what is done for centralized wastewater systems.

Today, people are getting used to obtaining services from private sector businesses on a 24/7 basis (24 hours per day, 7 days a week) using telephone- and internet-based tools. Interacting with government agencies on the internet appears to be the choice of people who typically use the internet for other purposes. A 2002 federal government report called "E-Government Strategies" indicates that more than 60% of all internet users interact with government web sites and indicates that government web sites should be designed and implemented to simplify delivery of services to citizens. The report states, "Government needs to reform its operation — how it goes about its business and how it treats the people it serves." Three key elements for reforming government agencies proposed in the report are:

- Citizens-centered, not bureaucracy centered
- Results-oriented, producing measurable improvements for citizens
- Market-based, actively promoting innovation.

Most of the people who have dealt with or are dealing with the state or local permitting agencies responsible for regulating use of onsite systems in their area would agree with the ideas proposed in this report and with the idea that not only do the regulations need changing but also the process of implementing the revised regulations needs to be changed. Use of electronic permitting is possible today and should offer the changes necessary in the process of implementing regulations for use of onsite systems.

Permitting programs for onsite systems deal with two major types of activities: ongoing day-to-day permitting (construction or operation) of individual systems based on existing rules and approval of newer technologies or designs that are not in the existing rules. All these regulatory activities must be based on the rules or policies that are developed and implemented based on public input. Once the rules are in place, they can be coded into a computer program and the computer program can be used online to accept and process applications for permits.

Five steps to E-government for onsite systems

The current paper-based regulatory program can be changed to a web-based regulatory program following a five-step process. The main reason for breaking the process down in five steps is to allow current regulators to take the time necessary to make the changes with the available resources. At the present time, most state level regulatory agencies are at the first step but have a desire to move forward.

Step 1: Creating web sites and posting current information on them

This is the beginning of the process of moving toward E-Government. It is now possible for any government agency (no matter how small or large) to develop and host a web site that people can access on a 24/7 basis. Once a web site is developed, all the information related to permitting processes and general information on use of onsite wastewater systems can be posted on the web site. Applicable rules, regulations, and policies can be posted on the web site along with the forms and a list of the fees necessary for the application for installation and operation of onsite systems. An explanation of the rules and basic requirements for obtaining a permit can be posted along with a list of frequently asked questions related to the permitting process. The main idea at this step is allow regulators to make the information as readily available to the public as possible by offering it online, thus minimizing the time spent on giving such information to the public on a daily basis.

Interaction with the web-based system at this step would be just a one-way communication — from the regulators to the public — and the information posted on the web would most likely be in a static form, not being able to be changed by anyone other than the staff of the regulatory agencies. All the information, including the information on authorized service providers for various services related to the use of onsite systems (soil evaluators, system designers, service providers, manufacturers, etc.), at this step can be entered and updated only by the staff of the regulatory agencies.

Information posted on the web site can be searched but only on a limited basis. For example, at this step, a person cannot determine how many onsite systems are present in a given area, what kinds of systems are typically used, how old the systems are, and so forth. Despite these limitations, step 1 is a good starting point for moving toward the ultimate goal of this process.

Step 2: Limited online interaction with users

Once a regulatory agency starts the process of moving toward implementing the E-Government concept, interest will build among all the users of such a system. Local regulatory agencies should consider moving all relevant information associated with existing onsite systems (such as permit numbers, locations, sizes, types, soil/site conditions, installation dates, installers, and inspectors) into a database or an information base that can be linked to the web site. Operational history (i.e., the information gathered from the system users [complaints, etc.]) can also be added to the database. A database should be designed such that it can be searched based on various criteria and the public interested in this information can access it and get the information they are interested in on the web.

Another useful service that can be added at this step is information on the service providers available within the area that is served by the regulatory agency. Even though most of the services required for obtaining a construction permit for an onsite system are typically offered by the staff of the regulatory agencies, movement toward allowing private sector professionals that are licensed or certified by the regulatory agencies to offer the services necessary for determining location and designing an onsite system has begun. This means that regulatory agencies will have to develop and maintain a current list of certified or authorized professional with their contact information and the type of services they offer. Such a list should be present on the web site, and people who need services should be able to search for professionals based on the services they offer and should be able to see the performance history of the service providers. At the same time, professionals who are certified and listed on the web site should be given access to their own information so that they can keep their own contact information current, thus minimizing or eliminating the workload for regulators.

Thus, at step 2, the web site hosted by the regulatory agencies starts the process of two-way communication with the public and private sector professionals. Information stored on the web site now becomes more dynamic in nature, and keeping the information current becomes the responsibilities of both regulators and the professionals that are listed on the web site.

Step 3: Applying for a permit online

The application forms that are posted on a regulatory agency's web site can be made "active" instead of "passive," thus allowing applicants to actually complete and submit the application, along with the fees necessary for accepting and processing the application, online. At this step, the regulatory agencies start the process of moving toward online permitting. The permit application is typically required to be done by the owner of the onsite system. However, an agent for the owner is also allowed to make an application as long as the agent is working on the owner's behalf. The owner has to sign the application form. In the current paper application process, regulatory agencies rely on the applicant's signature, along with the agent's signature when necessary, to ensure that only the legitimate people are applying for the permit for an onsite system.

In order to implement step 3, the regulatory agencies responsible for onsite systems must work with the building and planning agencies that are typically responsible for keeping records of land ownership. A process to authenticate the identity of online applicants will have to be developed; there are many models currently used by private sector businesses, such as those in the banking industry, that can be used to develop such a process. User identification can be processed and established for all certified professionals who can act as agents for owners. Similarly, user identification can be processed and established for all property owners who own land in the area that is not served by a public wastewater infrastructure, thus knowing that those land owners will need to apply for permits for onsite systems when they are ready to develop their land. Once an individual's identity is authenticated, he or she can access the online permitting system by logging into the system and providing the information necessary to complete the application forms.

Typically, the application for an onsite system requires two types of information: information that is general for the property, such as name, address, and contact information of the owner; directions to the property; and other legal description of the property, including Geographical Information System (GIS) information, and information specific to the onsite system, such as the type of the dwelling (residential or commercial), quantity and quality of the wastewater expected to be managed by the onsite system, soil and site conditions, whether the application is for a new system or for repair of an existing system. Although the owner should be able to provide general information, specific information related to the design of the onsite system must be developed and provided by the professionals who are authorized to offer this service. So, the application form must be completed based on information that is provided by the property owner and information provided by an authorized professional. The online permitting system should be developed such that it can allow interaction between the property owners and the authorized service providers.

With the current tools and technologies available for development of interactive, web-based software, it is possible to achieve this goal. The online application forms should be designed such that the general information entered is quickly checked to determine if it meets the required format, such as the date, phone number, and so forth, and that the design information entered by the professionals is checked against applicable rules. For example, typical regulations specify the flow rates for all types of dwellings for which a permit is required; thus based on the information about the dwelling, the flow rate entered by the applicant can be checked against the flow rate required by the rules, and if there is a difference in the values, the applicant can be warned and asked for correction. Collection of the application fees can also be done online using a variety of services that are currently available and used by other utilities, including the centralized water and wastewater services offered by local and regional public works.

Step 4: Processing permit applications online

Once the permitting agencies puts the application forms online in an "active" manner and allow the authorized users to fill out the information necessary for the processing of the application forms, the next logical step would be for the agencies to develop a rule-based computer program that can review the information and offer guidance to the regulators about the status of the application, (i.e., whether all the information necessary for making a decision is available and comments on whether the information submitted meets the regulatory requirements). Such a rule-based system can be developed using advanced information processing tools available today and used by many private-sector businesses. A rule-based system must include all the regulations and policies that are in effect at any given time that are used by the regulators for making decisions about permit applications. A rule-based application processing system must be developed in a manner such that it can be easily updated by the state-level regulators who are responsible for setting rules and policies.

In any industry, in order for service providers and manufacturers to offer their services and products to the customers in a timely and cost-effective manner, it is very important for regulatory agency employees to follow their rules and policies in a consistent and uniform manner. Humans, and especially regulators, by nature are not designed to conduct their daily work in a consistent and uniform manner. Moreover, regulations governing installation and use of onsite systems are voluminous and sometime hard to follow. Laws, regulations, rules, and policies are implemented at both state and local levels. It is practically impossible for a field-level regulator to keep up with all of this information and use the information in a uniform and consistent manner. Hence, it is absolutely important and necessary for state-level regulatory agencies to move toward a web-based computer program that can collect information and process the information to assist every regulator to make regulatory decisions in a consistent manner following all the state- and local-level rules and policies. With this tool, citizens can be reassured that everyone is playing the game following the same rules and no one is getting any special treatment. Also, authorized professionals and manufactures of the onsite industry can be reassured that they are all being regulated in a consistent manner and rules are applied uniformly to all.

Another important benefit of moving to step 4 is the significant reduction in personnel time that can be achieved in the process of reviewing the permit applications. Currently, it takes anywhere from a few days to a few months to obtain a construction permit for an onsite wastewater system. The permit processing time varies from locality to locality and from the one treatment system to another. Typically, newer technologies proposed for use take more time for permit approval than conventional technologies. This approach penalizes those who wish to use advanced technologies for better treatment and better environmental protection. However, if the approval criteria for all approved technologies are computerized and such a system is made available to all local- and field-level regulators, their ability to process permit application in a timely and uniform manner will significantly improve. The review time can be reduced for all onsite systems to less than a day.

Of course, no computer program can prevent authorized users from submitting false information (in an acceptable format!). The only way regulators can determine if the information submitted electronically for a given property, or for a proposed use, or for soil and site conditions, is to conduct random field checks. A computer system can be developed for selecting the permit applications for field checks in a random but consistent manner following predefined and accepted rules. For example, at the state level, the rules for selecting permit applications for field checks can be defined such that per year a fixed percentage of all the application submitted by authorized users, for a locality, and for a technology can be selected. The value of the percentage can be adjusted up- or downward based on the results obtained from the field check. By doing so, field checks can be minimized for those professionals who are doing in field what they say they are doing on paper, i.e., not lying on their application forms, while focusing the field checks on those who may be doing something different in field compared to what they say on they would do on paper, i.e., lying on their application forms. Ultimate goal of field checks is to discourage and eliminate unprofessional behaviors of licensed professionals. As a starting point, a 10% value may be used for selecting permit applications for random field checks

Step-5: Issuing permits online

Step 5 is the final step a regulatory agency can take to complete the process of implementing an online permitting system. Step 4 allows authorized users to submit permit applications online along with the fees necessary for processing the application. The process of issuing the permit does not happen online and regulators would still be in charge of conducting final reviews of the applications and issuing permits in paper form for applications that are approved. At Step 5, the computer program will have all the information necessary for reviewing the application and making the decision for approval or denial of an application and will actually issue an electronic permit (e-permit) for those applications that are approved, and issue denial letters with the reasons for denial and the information on how to appeal the denial for those applications that are not approved.

Thus, a regulatory program that moves to step 5 can offer to citizens a cost-effective and efficient permitting process on a 24/7 basis and implement a random but consistent program to audit the accuracy of the information submitted by authorized users of such a system. Citizens as well as the service providers will benefit from this type of online permitting system and the permitting agency can benefit as well because implementation of such a system will free-up resources, both personal and financial, that can be used for conducting programs that can truly protect public health and environmental quality with the use of permitted wastewater systems.

Designing a rule-based computer program that can implement the rules and regulations that are approved following public input process in a consistent manner on a 24/7 basis will require regulatory agencies to seriously analyze their permitting processes before implementing and enforcing rules. When designed correctly, a computer program should be able to guide the applicant (authorized user) through the application process and offer online technical assistance with respect to the type of onsite treatment and effluent dispersal system that will be necessary for meeting the wastewater and site conditions present for the applicant's case.

Today, under the paper permitting process, the industry relies on regulators to do such consulting work because the first contact the applicant has is typically with the local regulator. In places where a private sector person is allowed to prepare the permit application for an applicant, the applicant typically has to rely on that person's expertise about all possible wastewater system options that may be available for the applicant's needs. A rule-based permit issuance program can offer all the possible options for meeting the applicant's needs and let the applicant select appropriate the system. Such a program can help the industry to reduce or eliminate personnel and regulatory bias about onsite wastewater technologies and puts the applicant in charge of the decision-making process for selecting an appropriate onsite wastewater system from the list of all possible systems that can be approved.

A list of companies who can help you move your current regulatory programs online is available on our web site.

The future is bright

As we see it, the future of advanced onsite wastewater systems is bright. Such systems are needed today for replacing old septic tank drain fields that are failing or are inadequate to meet the current water quality standards and such systems will be needed for the new growth that is occurring in areas not served by centralized systems. In the future, all professionals involved with the application of onsite systems will have to work with advanced technologies and will have to be held accountable for their activities to the public that depend on use of these technologies for their wastewater management.

Many professional organizations have been formed to represent interests of all types of professionals working with onsite systems, and these organizations will have to develop and implement procedures that will allow the general public to constantly give feedback on their services. A routine evaluation and assessment of onsite wastewater products and services by the public when used by the professionals within onsite industry can really help the industry to grow in a mature and responsible fashion in the future. Timely improvements in onsite wastewater treatment and onsite effluent dispersal technologies along with professional and responsible management of these technologies are the two key elements that can ensure a bright future for all professionals working with onsite systems.

Finally, we hope that from now on the answer to the age-old question “What do you do when the land does not perc and the sewer is not coming?” will be “Use advanced onsite wastewater systems technologies with a service contract from a responsible management entity.” We also hope that in the future, regulators, planners, and all other wastewater service providers will grow out of “septic mentality” and embrace the use of advanced onsite wastewater systems technologies with management. On our web site, you can find a list of companies that offer products and services for solving your current onsite wastewater problems as well as for meeting your future wastewater management needs, along with numerous tools to assist all the professionals, site evaluators, designers, engineers, and service providers in their work with the advanced onsite wastewater systems technologies.

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