ACHIEVING SECONDARY WASTEWATER TREATMENT STANDARDS USING ZERO-ENERGY COMBINED TREATMENT AND DISPERSAL TECHNOLOGY

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ABSTRACT

Combined treatment and dispersal technology (CTD) is a reliable, sustainable, non-electric, low-impact means of treating domestic wastewater to secondary standards and dispersing the treated water to the native soil within the CTD system footprint. CTD technology uses naturally occurring microflora and chemical processes to degrade wastewater organic matter, achieving NSF/ANSI 40 Class 1 standards for 5-day carbonaceous biological oxygen demand (25 mg/l) and total suspended solids (30 mg/l). Extensive third-party testing has shown CTD technology to meet NSF/ANSI 40 standards immediately upon system start up. CTD technologies typically include a manufactured wastewater distribution device surrounded by system sand conforming with ASTM C33 particle gradation specifications. Septic tank effluent enters the manufactured CTD device, where distribution and filtering occur, followed by additional passive microbial and chemical treatment in the surrounding system sand, resulting in a treated effluent. Rather than discharging primary-treated wastewater to native soil like a traditional gravel and pipe drainfield, CTD systems disperse secondary-treated effluent to native soil through an open-bottom design, providing an environmental benefit required by regulatory agencies for certain property development projects. CTD technology serves both single-family home and large-flow onsite wastewater treatment and dispersal challenges. The technology can also be specified as part of larger system where CTD technology is used to nitrify effluent before it is recirculated for denitrification, or for treatment as part of a water reclamation system. This paper describes the basic elements of CTD technology; including what it is, how CTD systems function, and why the systems are increasingly becoming an important solution for wastewater management professionals. Results of a long-term field hydraulic performance study conducted on CTD systems installed on single-family residences in Missouri are presented. Three case studies demonstrating the versatility of CTD technology in differing design applications are described.

INTRODUCTION

Overview

Onsite wastewater treatment system industry stakeholders are continuously developing and deploying new technologies intended to improve the overall performance and management of decentralized wastewater treatment systems, particularly for private onsite wastewater treatment system applications. Over the past quarter century, these efforts have yielded a technology known as combined treatment and dispersal or CTD. This technology consists of a sewage treatment system where wastewater is clarified in a septic tank, then treated to achieve United States Environmental Protection Agency (USEPA) secondary wastewater treatment standards within the CTD system, where it is dispersed from the bottom of the CTD bed system to the underlying native

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soil, thereby being treated and dispersed within a single, space-saving footprint. These treatment and dispersal processes take place using indigenous microflora and without the need for electricity or chemical additives.

American Decentralized Wastewater Treatment Infrastructure

Decentralized wastewater treatment, also referred to as onsite wastewater treatment, is an important but frequently overlooked part of the nation's wastewater infrastructure, serving more than one-quarter of the United States population (approximately 30 million homes). About one-third of all new single-family home development is served by a septic or other decentralized treatment system. The USEPA has identified onsite septic as a critical component of America's wastewater infrastructure (USEPA, 1997). CTD represents one of many technologies utilized in decentralized wastewater treatment and dispersal systems.

The United States Census Bureau reports that the distribution and density of septic systems vary widely by region and state, from a high of about 55 percent in Vermont to a low of about 10 percent in California. New England states have the highest proportion of homes served by septic systems; New Hampshire and Maine both report that about one-half of all homes are served by individual systems. More than one-third of the homes in the southeastern states depend on these systems, including approximately 48 percent in North Carolina and about 40 percent in both Kentucky and South Carolina. These numbers demonstrate that having effective and reliable technologies to meet new-home construction and septic repair needs in areas served by onsite wastewater treatment systems is a critical aspect of the nation's onsite wastewater infrastructure.

CTD System Design and Function

The onsite wastewater industry needs to provide space-saving and energy-efficient technologies for new-home construction and existing onsite system repair. CTD products in the marketplace today incorporate recycled plastics and other innovations, with the products used to replace traditional crushed rock, which is a non-renewable natural resource that must be blasted, crushed, screened, and washed before being transported and installed in an onsite wastewater treatment system. Passive CTD provides a reliable method of sustainable treatment, effluent dispersal, and energy conservation to meet the nation's onsite wastewater treatment system needs.

Multiple CTD products are certified to meet the NSF/ANSI 40 Class 1 wastewater treatment criteria. These products typically incorporate a manufactured device surrounded by a coarse-grained sand, or "system sand", most often sand conforming with ASTM C33 particle size gradation requirements, with some state department of transportation sand gradation specifications also being suitable. Upon entering the manufactured CTD device, effluent is typically distributed and filtered, with additional treatment in the surrounding system sand, resulting in secondary treated effluent. Effluent distribution can be achieved using either gravity or pressurized flow, but most often occurs via gravity flow. Figure 1 illustrates an exploded view of a typical CTD system, showing the manufactured product with system sand around and below the manufactured device. Once the installation is complete, system sand will be around and under the manufactured product, in addition to being in contact with native soil. The system sand thickness may vary between 6 and 24 inches, with the most common basal system sand thickness being 6 inches. Vegetated backfill covers the system. Figure 2 shows a common CTD product mid-installation, prior to backfilling with system sand, final grading, and being vegetated at the ground surface. Secondary wastewater treatment and treated effluent dispersal occur within and around the manufactured CTD product and system sand, with treated water passing directly from the system sand into the underlying native soil without the need for a lined collection system or transfer to a separate drainfield.

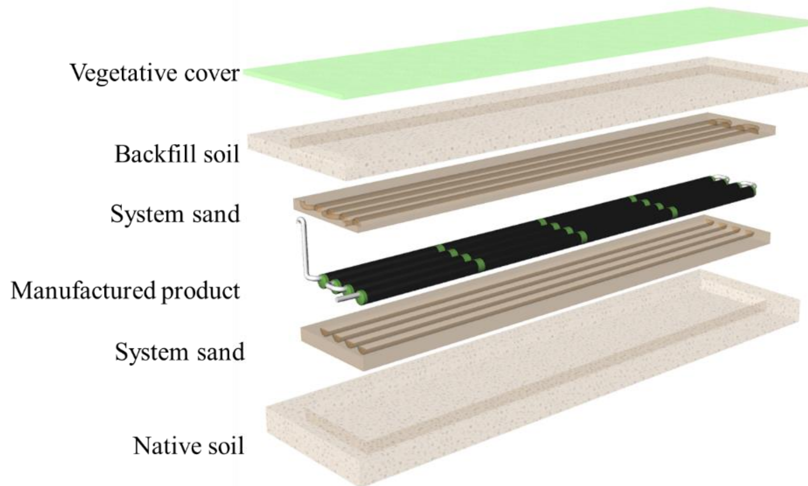

Fig. 1 – Exploded view of typical CTD components

The manufactured device in a typical CTD system may include combinations of pipe, cuspated plastic, synthetic aggregate, or filter fabric and other geosynthetics. Core components may be surrounded with filamentous plastics, synthetic aggregate, and layered geosynthetics, each of which provides surfaces capable of supporting fixed-film aerobic bacterial growth. It is the growth and proliferation of aerobic bacteria within both the manufactured system and surrounding and underlying system sand that allows for the biological consumption and breakdown of organic compounds in septic tank effluent, resulting in the attainment of secondary wastewater treatment standards. The consumption of organics and lowering of wastewater strength by aerobic bacteria is supported in part by the permeable coarse-grained system sand, which allows oxygen to naturally recharge from the atmosphere above the CTD system and migrate into the CTD components and system sand, thereby supporting microbially mediated aerobic treatment processes. System sand is also a liquid-transfer media, facilitating


Fig. 2 Typical CTD system prior to backfilling with system sand and final grading

vertical and horizontal infiltration of treated effluent for release to the native soil around the CTD system.

CTD System Performance

Extensive third-party testing has demonstrated non-mechanical, zero-energy CTD systems to consistently meet USEPA secondary wastewater treatment standards. Secondary wastewater treatment standards include three parameters: 5-day carbonaceous biochemical oxygen demand ($cBOD_5$) of less than 25 milligrams per liter (mg/l); total suspended solids of less than 30 mg/l; and a pH ranging between 6 and 9 (40 CFR 133). Third-party testing has shown that CTD systems are capable of lowering the organic matter in influent domestic wastewater, where the typical BOD_5 concentration ranges from 100 mg/L and 300 mg/L (NSF/ANSI 40, 2020), down to a $cBOD_5$ concentration of 10 mg/l or less. The influent TSS concentration reduction commonly ranges from a typical 100 mg/L and 350 mg/L (NSF/ANSI 40, 2020) to 10 mg/l or less. Wastewater treated using CTD technology typically has a pH toward the lower end of the 6-to-9 allowable range.

The treatment efficacy for two CTD systems achieved during NSF/ANSI 40 certification testing at the Massachusetts Alternative Septic System Testing Center (MASSTC) in Buzzards Bay, Massachusetts is provided to demonstrate the ability of CTD technology to passively reduce the organic-matter content in domestic wastewater. The results are taken from the NSF International wastewater technology reports published following the third-party testing process at MASSTC. Both systems are 1-ft-diameter cylindrical systems that include a combination of a pipe with layered geosynthetics. Both systems were underlain by 6 inches of system sand meeting ASTM C33 specifications, with sand also placed to at least the uppermost elevation of the product. Both systems were tested using a daily flow of 450 gallons under the NSF/ANSI 40 hydraulic loading protocol, which calls for daily cyclical increases in flow to simulate typical household water usage.

Table 1 provides a summary of results for BOD, TSS, and dissolved oxygen (NSF International, 2014 and 2015) for the two CTD system designs, referred to as System 1 and System 2. The length of System 1 was 210 feet, while the length of System 2 was 150 feet. Therefore, at a daily flow of 450 gallons, the linear loading rate to the CTD product within the systems sand was 2.14 gallons per day per foot for System 1 and 3.00 gallons per foot per day for System 2. Both systems received an average BOD load of 180 mg/l, or 0.67 pounds of BOD per day at a flow of 450 gallons over the 26-week certification testing cycle. System 1 reduced the organic load by 95%, while System 2 reduced the organic load by 94%. The passive BOD consumption capacity was 0.003 and 0.004 pounds per day per foot of CTD product for Systems 1 and 2, respectively.

The presence of dissolved oxygen is key to the passive biological treatment process taking place within a CTD system. Dissolved oxygen data are provided in Table 1 to demonstrate the effect and necessity of having permeable system sand surrounding the CTD manufactured product, which is critical to proper function. The pore space within the coarse system sand allows atmospheric oxygen to passively migrate from the ground surface to the CTD system components, thereby facilitating aerobic biological degradation of the wastewater. The influent dissolved oxygen from the septic tank was measured to be 0.3 to 0.4 mg/l. While passing through the CTD system during the treatment process, the dissolved oxygen concentration increased to 2.4 to 3.5 mg/l, corresponding to a sixfold increase for System 1 and a sevenfold increase for System 2. The dissolved oxygen concentration increased substantially from the point where effluent entered the CTD system, even while the wastewater exerted the demand necessary to reduce the incoming organic load by up to 95%. The presence of post-treatment residual dissolved oxygen in the effluent shows that the system would be capable of digesting an organic load that exceeds the 180 mg/l average influent BOD concentration.

Table 1. NSF/ANSI 40 certification testing results (expressed in mg/l)

Parameter	CTD System 1	CTD System 2
Biochemical oxygen demand		
Influent (BOD_5)	180	180
Effluent ($cBOD_5$)	9	11
Total suspended solids		
Influent	200	210
Effluent	11	7
Dissolved oxygen		
Influent	0.3	0.4
Effluent	2.4	3.5

Fig. 3 - CTD NSF/ANSI 40 certification testing oxygen demand trends for System 1 (left) and System 2 (right)

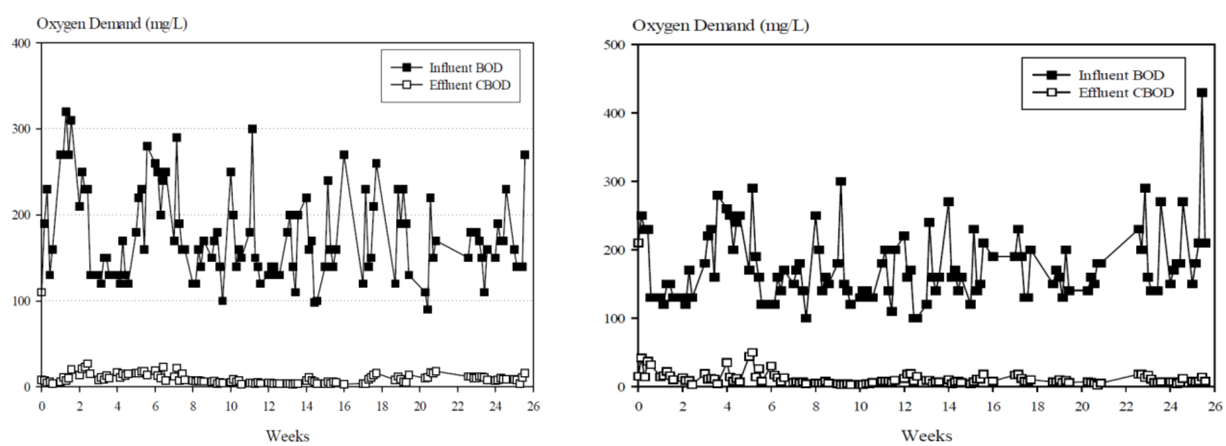

Figure 3 provides influent BOD and effluent $cBOD_5$ concentration data from NSF/ANSI 40 certification testing at MASSTC for CTD System 1 and System 2, as described previously (NSF International, 2014 and 2015). For influent BOD_5 concentrations fluctuating between approximately 100 and 300 mg/l, from a qualitative perspective, the effluent $cBOD_5$ concentration is consistently and substantial reduced throughout the 26-week NSF/ANSI 40 test period. The oxygen demand data profiles shown for Systems 1 and 2 are typical of CTD technology, which is marked by consistency and reliability, with a high degree of resilience to influent concentration fluctuation, temperature, and flow volume. While electro-mechanical wastewater treatment systems characteristically require a start-up period to achieve compliance in order to allow a microflora population capable of meeting treatment requirements to develop, CTD systems typically meet secondary treatment standards at or shortly after start-up. This capability of providing immediate performance shows that, beyond continuous-use applications, CTD systems are ideal for intermittent and inconsistent flow usage conditions, such as with seasonal dwellings and vacation/second homes.

Sizing

As discussed previously, CTD systems meet secondary wastewater treatment standards at the interface between the system sand and native soil. The transition from septic tank effluent to secondary treated effluent involves a lowering of the organic content of the effluent, as measured by $cBOD_5$ and TSS concentrations. By decreasing the organic content of the effluent, the potential for native soil pore clogging at the interface of the system sand and native soil is reduced. In the absence of native soil pore clogging, or in the presence of weakly developed clogging, as is likely when applying wastewaters of reduced organic strength compared to septic tank effluent, infiltration rates are higher than for clogged soil (Tyler, 2001). An example of the principle of differing infiltration rates as a function of effluent organic content was published by Tyler, where loading rates for effluent having a BOD_5 of less than 30 mg/l are 1.3 to 3.0 times greater than effluent having a BOD_5 greater than 30 mg/l. Siegrist (2017) published a strategy for establishing hydraulic loading rates based upon level of effluent treatment and soil texture. Under Siegrist's framework, the difference in hydraulic loading rate for highly treated effluent ($cBOD_5$ of 5 mg/l and TSS of 5 mg/l) and septic tank effluent ($cBOD_5$ of 150 mg/l and TSS of 75 mg/l) is a factor of five for sand/loamy sand, a factor of four for sandy loam/silt loam, and a factor of two for silty clay loam/clay loam.

The dispersal component of a CTD system is represented by the contact area between the system sand and native soil. Treated effluent exiting the system sand would customarily be expected to have $cBOD_5$ and TSS concentrations of 10 mg/l or less, allowing for the use of a higher hydraulic loading rate to the native soil than would be used for septic tank effluent having comparatively higher $cBOD_5$ and TSS concentrations (Siegrist, 2017). Increasing the hydraulic loading rate results in a smaller dispersal area footprint, and correspondingly a more compact dispersal area, than would be required for a conventional gravel and pipe dispersal area. The use of increased effluent loading rates for highly treated effluent may follow established state guidelines for treated effluent or could be determined by the CTD product manufacturer. With the system sand footprint determined as the quotient of the daily design flow and soil load rate, the use of increased soil loading rates results in a more compact system footprint than a comparable gravel and pipe drainfield.

An added beneficial aspect of CTD system sizing is that it is possible to test and certify CTD products in a bed configuration, representing another space-saving aspect of CTD design. While CTD systems are capable of being constructed in a trench configuration, they are most often configured in a bed arrangement, eliminating the space between trenches and increasing the compactness of the treated effluent dispersal area. Combining the use of higher effluent loading rates and a bed geometry, the land area utilized by a CTD system could be on the order of 60% smaller than the land area occupied by a conventional gravel and pipe system, translating to a CTD footprint that saves space on the building lot. The compact footprint of CTD technology is often of particular importance in existing wastewater treatment system repair applications, where constraints on developed property limit available space and repair system siting options.

Operational Considerations

The benefits of a zero-energy, non-mechanical system that provides NSF/ANSI 40-level secondary treated effluent are significant from an operations and maintenance perspective. Without the need for an external power source, there are no concerns about aerators or recirculating pumps shutting down as would occur for an electro-mechanical system, resulting in the "treatment" tank becoming a septic tank, as effluent is no longer being treated. In contrast, natural, biological treatment processes in a CTD system continue to function even during a power outage.

Maintaining the electro-mechanical components in mechanical treatment systems is essential to proper function and achieving secondary wastewater treatment. For non-mechanical CTDs, there are no moving parts, so replacement parts are not required. Therefore, the need for operation and maintenance beyond that required for a traditional gravel and pipe system is eliminated.

MISSOURI FIELD PERFORMANCE STUDY

Overview

A third-party field performance study was conducted on 30 CTD Presby Environmental, Inc. Advanced Enviro-Septic systems installed principally on single-family homes in Missouri. The field performance study was undertaken in response to a Missouri Code of State Regulations requirement for an experimental use approval of innovative systems used for on-site sewage dispersal applications. The objective of the field performance study was to assess the hydraulic function of 3- to 8-year-old installations located within three geographical areas of the state. The field performance study was led by Dr. Randall J. Miles, Associate Professor Emeritus at the University of Missouri College of Agriculture, Food & Natural Resources. With advanced degrees in agronomy and soil science, Dr. Miles lectured on soils at the University of Missouri for over 30 years. A representative from the Missouri Department of Health and Senior Services (DHSS) was also in attendance and participated in the field inspection work to verify Dr. Miles' findings.

The system being studied was approved at experimental level by the DHSS twice, with differing pipe and system sand sizing criteria for each approval, as follows:

- 2012 approval – Under the initial 2012 approval, the system was approved for use at a variable 50 to 70 feet proprietary product length per bedroom, with the size of the system sand footprint based upon variable soil loading rates, and 6 inches of sand below the system piping.

- 2015 approval – The initial 2012 approval was revised in 2015, where the system was sized at a fixed length of 50 feet per bedroom and the system sand footprint was calculated based on 90% of the area required for the applicable soil loading rate assigned to the site, with 6 inches of sand below the system piping.

As a result of the product approval history, surveyed field installations could range from a minimum of 50 feet of pipe per bedroom up to 70 feet of pipe per bedroom. Of note is that the present-day manufacturer's installation recommendations of this product utilize the more conservative values from the two approvals, with 70 feet of system pipe required per bedroom and the required system area being 90% of what would be required for the soil loading rate assigned rate to the site. Because current-day system sizing employs the maximum surveyed pipe length and lower-bound of the surveyed soil loading rates, the field performance study did not differentiate between sites based on either pipe length or soil loading rate. Systems installed under the 2012 approval may have less pipe than 70 feet per bedroom or employ a smaller system sand footprint than would be specified under current-day day design requirements. This aspect of the investigation represents an element of conservatism relative to system sizing under a potential future general use approval that would result from successful field performance study implementation.

Field Evaluation Protocol

All installation sites in the study were visited a single time for an assessment of hydraulic function. The field evaluation was comprised of a non-intrusive, walkover visual assessment of the entire site with a focus on the area where the system was installed. The field evaluator assessed the presence of surfacing effluent as well as the presence of shallow saturated soil in and around the system installation location, in addition to the presence of malfunction indicators such as odors associated with wastewater and staining associated with past effluent breakout events. The assessment included a topographical evaluation for potential overland flow toward the system installation site that could potentially interfere with proper operation. Where the occupant of the structure was present and available, the field evaluator conducted an interview about the functionality of the system and whether it had exhibited signs of malfunction, including surfacing effluent or effluent backing into the home. Collected information was recorded on a standardized form approved for use by the DHSS. The field evaluator documented findings in a report that was submitted to DHSS in support of a general use approval of the product. The systems were not installed with effluent sample collection equipment or flow meters, so effluent quality and hydraulic loading capacity were not assessed.

Determination of system performance was based on the number of documented system failures reported to DHSS. In the context of the field performance study, the term “failure” was defined to mean the following: any failure of the system to function properly so as to cause the discharge of untreated or partially treated wastewater onto the ground surface, or back up of effluent into the residence, solely and proximately as a result of design defect. The overall rate of failure for the study was determined as the number of documented failures attributed to failure of the system divided by the number of installed systems surveyed and expressed as a percentage. Under the terms of the DHSS experimental approval, in the event that certain qualifying conditions were found to be present, a system could be excluded from the study if any of the following were found to apply: improper or non-code-compliant installation; excessive or improper use, including hydraulic overload; inaccurate site evaluation and system sizing; or installation of the system by an unauthorized installer.

Product Approval Criterion

If less than 10% of systems evaluated were determined to be found to be in a condition of failure, the system would be deemed to have passed the field performance evaluation. Therefore, no more than three subject systems could be determined to be in a failure condition for a 30-system sample size.

Results

The overall results of 30 individual systems showed 29 systems to be functioning properly, while one system was in a state of failure, as discussed further below. The study included sites located within three major geographical areas of Missouri: the Kansas City area, Southwest Missouri with an emphasis in the Branson, Table Rock Lake area, and the St. Louis area, primarily north and south of the metro area. Findings for each geographical area are summarized below, followed by results based on soil loading rate.

<u>*Results by Geography*</u>

Twelve systems were assessed in the Kansas City area. This area had a wide array of sites that possessed soil loading rates ranging from 0.20 to 0.55 gallons per day per square foot (gpd/sf). One was a business (Dollar General Store), with the others being residential. All systems were functioning as designed with no negative objective site assessment components noted in any of the assessed systems. When home occupants were interviewed, their responses were positive about the performance and satisfaction with the system. Overall, all of the systems in the Kansas City area performed satisfactorily.

The southwest Missouri/Branson area assessment component consisted of 11 systems. This area had a wide array of sites that possessed soil loading rates ranging from 0.20 to 0.40 gpd/sf. This area possessed many systems that were on smaller lots as a result of the Table Rock Lake environment as well as sites with steeper slopes. All systems were functioning as designed with no negative objective site assessment components noted in any of the assessed systems. When home occupants were interviewed, their responses were positive about the performance and satisfaction with the system. Overall, all of the systems in the southwest Missouri/Branson area performed satisfactorily.

The St. Louis area assessment component consisted of 7 systems. This area had a wide array of sites that possessed soil loading rates ranging from 0.20 to 0.65 gpd/sf. With one exception, the systems were functioning as designed with no negative present-day objective site assessment components noted in any of the assessed systems. When home occupants were interviewed, their responses were mostly positive about the performance and satisfaction with the system. Those that expressed dissatisfaction centered on system installers that did not return calls immediately after reporting pump problems or breakout observations. Two of the St. Louis-area systems were installed improperly and repaired more than two years prior to the field performance assessment. In both cases, the repaired systems required placement of fill over the system sand; once the repairs were completed and the system installations were brought into compliance with manufacturer's requirements, the systems functioned properly. One system in the St. Louis area exhibited a wastewater odor, but was not found to have evidence of surfacing effluent or saturated surficial soil. The odor source could have been from the system's venting apparatus, which includes pipes above the ground surface.

The one St. Louis-area system that had less-than-expected performance was designed using a soil loading rate of 0.65 gpd/sf. This soil loading rate was regarded by the site evaluator as much greater than expected for the soils of this geographical and geological area of Missouri, likely resulting in a smaller system sand footprint than would be required for a comparatively lower soil loading rate. Additionally, the site evaluator considered the parking of vehicles on the upslope side of this system as a potential contributor to diminished system performance as a result of soil compaction that caused the collapse of soil pore space, thereby reducing native soil permeability. Vehicle traffic was also found to potentially result in increased surface water flow from upslope onto the system dispersal/treatment area. In summary, multiple factors likely negatively influenced the poor performance of this system.

Results by Soil Loading Rate

Soil loading was a strong consideration in setting the design of this study to assist in assessing the long-term sustainability of the CTD technology being evaluated. There were 10 systems that had soil loading rates of less than 0.25 gpd/sf; 2 sites in the Kansas City area; 4 in the southwest Missouri/Branson area with 4 in the St. Louis area. The systems for this lesser loading category in both the Kansas City and southwest Missouri/Branson areas were observed to perform satisfactorily. The three systems in the St. Louis area had some variability based upon improper installation or the detection of a wastewater odor that were resolved, and no problems were identified in the field assessment.

A total of 20 sites in the study had soil loading rates greater than 0.25 gpd/sf; 10 sites in the Kansas City area; 7 sites in the southwest Missouri/Branson area; and 3 sites in the St. Louis area. The systems in this greater loading rate category in the Kansas City and southwest Missouri/Branson areas all were assessed to be performing as designed. The three greater than 0.25 gpd/sf loading rate sites in the St. Louis area had inconsistencies, but only one was in a state of failure, as discussed previously. The one in a state of failure appeared to have been undersized relative to the soil loading rate of the site native soil, based upon the 0.65 gpd/sf soil loading rate.

Discussion

Construction and Operational Discussion

Some of the field evaluator’s general observations on the long-term sustainability of the systems include ensuring that surface water controls are present to divert stormwater run-off originating from upslope areas away from the system to limit water intrusion and the possibility of erosion. Controlling excessive vegetative growth by mowing would promote effluent dispersal through evapotranspiration. Avoiding vehicle traffic on and around the installation site protects against soil compaction that can reduce soil permeability within, around, and beneath the site that would reduce receiving soil permeability. The use of trained and certified installers who follow the manufacturer’s installation procedures increases the likelihood of successful long-term system operation. Two systems were installed without all of the system sand being covered with soil backfill, resulting in surfacing effluent over two years prior to the field survey. Upon completion of the installations with the addition of backfill, the systems functioned properly.

Conclusions and Performance Relative to Approval Criterion

In order to gain DHSS approval, the system must have been shown to have less than 10% of systems evaluated to be in a condition of failure. Based on the field survey results, 29 of the 30 surveyed system were found to be functioning properly and were deemed to have passed the field performance evaluation. The failing system was determined by the field evaluator to have been designed using a soil loading rate that was significantly greater than the prevailing native soil loading rates in that region of the state. The end result of such a soil loading rate incongruity is an undersized system sand footprint. In addition, the evaluator identified several other conditions at the site that could have negatively impacted the performance of the system. While the site could arguably have been eliminated from the evaluation as a result of these conditions, the evaluator determined that it was in the best interests of the survey to include it. The end result of the field performance study was system approval by DHSS.

CASE STUDIES

The case studies provided below showcase three applications that demonstrate the versatility of CTD technology for meeting different wastewater treatment system design needs. In the first case study, a traditional application of CTD technology is used to upgrade the onsite wastewater treatment system at a ski resort in Western Massachusetts, where wastewater is treated and dispersed within the footprint of the CTD system. In a Paradise, California case study, a portion of the system, which was located on bedrock, was lined with an impermeable membrane to allow for wastewater treatment within several cells, with dispersal via evapotranspiration ponds. In the last case study from Newbury, New Hampshire, CTD technology is used to nitrify effluent within a lined treatment cell, which is subsequently recirculated to the head of the system for denitrification, followed by onsite subsurface dispersal. Whether CTD technology is used in a classic application (combining treatment and dispersal in the same footprint) or as a component of a larger treatment or recirculating system constructed for water reclamation or nitrogen treatment, it is capable of serving a variety of needs, ranging from individual homes to large-flow applications.

Ski Resort in Charlemont, Massachusetts

The Berkshire East Mountain Resort is located in the Berkshire Mountains of Western Massachusetts. The resort offers skiing and snowboarding during the winter, as well as summer recreational activities that include downhill mountain biking, zip lines, a ropes course, and an alpine slide. The resort lodge includes on-site dining options with a full-service kitchen, as well as restroom facilities for patrons and employees. The resort was the first ski area in the world to produce 100% of its electricity from onsite renewable energy, specifically a wind turbine.

In 2022, the resort upgraded its existing wastewater management system with the construction of a new 9,900 gallon per day (gpd) onsite CTD system. The system is comprised of two beds constructed using pipe-based CTD technology, with each having a capacity of 5,000 gpd. Each bed consists of a pipe-based CTD technology installed within a system sand envelope (Figure 4). The system design includes discharge of the treated domestic wastewater through the bottom of the CTD system directly to the underlying native soil. Under the Massachusetts Department of Environmental Protection product approval, the system footprint could be 60% that of a comparable gravel and pipe dispersal system, saving space on the property for other resort operations. The distribution of wastewater to the pipes is via gravity flow from a distribution box, thus delivering a zero-energy wastewater treatment solution. The system was designed for installation entirely below the ground surface, allowing for full use of the system footprint area for traffic loads, given the capability of the CTD media to withstand an AASHTO H-20 load.

Fig. 4 – CTD system serving ski resort

FEMA Temporary Housing in Paradise, California

The 2018 “Camp Fire” in California devastated the community of Paradise, killing 85 people, destroying 11,000 homes, and displacing nearly 50,000 people. The Federal Emergency Management Agency (FEMA) needed to stabilize the situation and support rehabilitation of the community. FEMA’s plan required a 1,500-person workforce housing camp, which included 400 temporary housing units, laundromat, and food preparation and dining facilities. Complications for solving the housing camp’s onsite treatment needs included accelerated deadlines and extreme site limitations, including shallow lava formations, which impeded construction and precluded subsurface dispersal of treated wastewater, which needed to be dispersed via evapotranspiration.

A 100,000 gpd modified combined treatment and dispersal system was selected to serve the housing camp (Figure 5). The system was designed to receive gravity-flow influent to four, 40,000-gallon septic tanks configured in series. The effluent is then segregated into four treatment paths to facilitate isolation during maintenance. The flow is split to four, geomembrane-lined, beds performing passive, secondary wastewater treatment. Each 25,000 gpd bed contains 8,400 feet of pipe-based CTD product surrounded by system sand for a total 33,600 feet of pipe. Treated effluent is

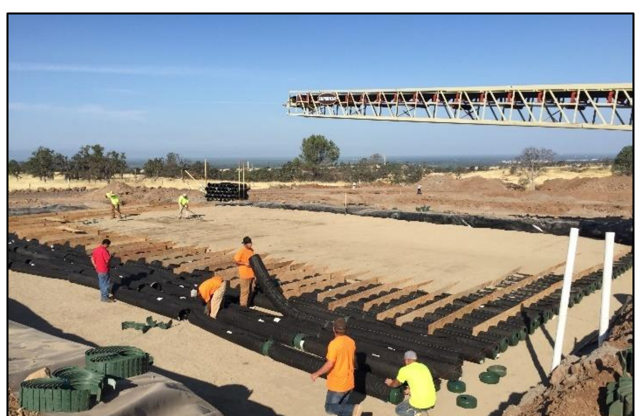

Fig. 5 – FEMA work camp wastewater treatment system

collected within the lined beds and gravity-distributed to four, ultra-violet disinfection units, each followed by a pump tank. Due to the site geology restricting the infiltration of treated effluent, two evapotranspiration ponds are used as the dispersal mechanism. The evapotranspiration ponds were also designed to allow for possible reuse as a golf course irrigation source.

The low maintenance, high flow system, including disinfection, allowed for full occupancy of the FEMA work housing camp. The system was functioning effectively, producing $cBOD_5$ and TSS concentrations to below 5 mg/l, with highly effective conversion of influent ammonia to nitrate.

Passive Community Treatment with De-Nitrification in Newbury, NH

The Blodgett Landing Community Wastewater Treatment Plant is a 50,000 gpd facility in Newbury, New Hampshire that uses advanced passive treatment, denitrification, and dispersal to purify the town's wastewater. As the town population grew, facility operators began detecting elevated levels of nitrogen in the groundwater and began pursuing an upgrade solution. The facility's limited budget required that any treatment plant upgrade solution be effective and affordable both in upfront cost and ongoing operation and maintenance expense.

The Blodgett Landing Community Wastewater Treatment Plant explored several options, including lining the original sand filters so that effluent could be recirculated into an Imhoff tank. However, this approach did not deliver consistent treatment results, especially during the winter months, due to uncontrolled freezing and insufficient denitrification whenever temperatures fell below a certain threshold.

The selected design was to replace an existing sand filter system with a system that would nitrify the effluent within a lined treatment cell. Influent wastewater is split between two Imhoff tanks that separate liquid and solids. Clarified effluent flows to a multi-level pipe-based CTD treatment cell, where organics are biologically consumed and influent ammonia is converted to nitrate without the need for electricity. The nitrified effluent is collected and subsequently recirculated to the two Imhoff tanks, where the partially treated effluent is blended with influent wastewater. The low-dissolved-oxygen, high-organic-carbon environment of the Imhoff tanks allows for conversion of nitrate in the partially treated effluent to nitrogen gas, thereby reducing the total nitrogen concentration. Treated effluent is dispersed within a drainfield adjacent to the treatment operations area.

System performance is excellent, consistently reducing $cBOD_5$ and TSS concentrations to below 10 mg/l. On average, the $cBOD_5$ concentration is 6.1 mg/l, while the average TSS concentration is 5.1 mg/l. The average total nitrogen reduction is 72.5%, achieving an average total nitrogen concentration of 7.9 mg/l. Passive disinfection is also provided by the system, reducing the fecal coliform level to an average of 2,100 colony forming units per 100 milliliters, for an average reduction of 99.98%.

Overall, the design was successful in providing a system capable of passively filtering and bacterially treating wastewater without the use of chemicals additions or exerting a large power demand for external oxygen addition. The system performs well in varying climactic conditions, including freezing New England temperatures and warm summer months. This project is an excellent example of how decentralized treatment systems can provide a passive, affordable, reliable and environmentally friendly solutions for residential, commercial and community use.

CONCLUSIONS

CTD has been in use across the North America for over 25 years, with installations expanding in the past 10 years as wastewater industry stakeholders seek reliable, sustainable, non-electric, low-impact means of treating and dispersing wastewater. CTD systems promote water reclamation by returning treated water to the underground environment where groundwater resources can be recharged, and are resilient relative to loss of power, changing climate, and natural events such as wildfires. The space-saving design allows for use on potentially design-challenged sites affected by space-constraints. CTD technology is a promising tool capable of providing future opportunities for innovative designs that overcome site-related design and construction needs, while delivering environmentally protective, dependable long-term service. As a result, CTD has transitioned to a key element of the wastewater treatment system framework in many regulatory jurisdictions.

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