

Applications of Subsurface Drip Dispersal Technology in Engineered Ecological Systems

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ABSTRACT

Subsurface drip technology is being applied to wetlands in a resourceful manner in order to solve several treatment situations. These situations include aeration of an 11,000 m³/d (3×10^6 gpd) remedial treatment wetland at a petroleum polluted site; flow distribution across a vertical flow wetland at temperatures below -25°C; flow distribution into a horizontal flow wetland of septic tank effluent from a single-family home; and, aeration of a subsurface flow wetland treating cheese-processing wastewater in Minnesota, USA.

KEYWORDS

Subsurface, drip, wetland, aeration, effluent, disposal, dispersal, treatment.

INTRODUCTION

This paper summarizes current advances in the use of subsurface drip dispersal (SSDD) technology in engineered ecological systems. The application of SSDD for dispersal and reuse of both primary and secondary treated effluent in soil is a well-established technology, and has been adequately reported elsewhere (U.S. Environmental Protection Agency, 2003).

The concept of subsurface irrigation goes back to the pharaohs who buried porous pots in the desert to irrigate trees. In 1874 Nehemiah Clark was issued a patent for an irrigation pipe coupling with a leaking connector (Clark N, 1874). Drip irrigation technology became a practical tool with the development of the plastics industry. The first use was in greenhouses in England and France. Early experiments with subsurface drip failed due to root intrusion and unreliable drippers. Advances in subsurface drip irrigation have made this technology appropriate for wastewater dispersal. The initial use of SSDD systems was strictly for soil application of both primary and secondary treated effluent. Due to the successful operation of large-scale SSDD projects, such as the Hawaii Kai golf course, Kukuiula Development (Gushiken E.C., 1995) and the City of Ocala (Harris, D.G. et. al., 2000), SSDD is finding both novel and diverse uses in the environmental engineering community.

The primary benefit of SSDD is that it allows precise, uniform application of small quantities of fluids (water or air) over large areas. Because engineered ecological systems such as constructed wetlands, have increased in size and scope, SSDD has been employed, often in novel ways, to drive treatment processes within the ecosystem.

Constructed wetland reed-bed technology was developed in Germany in the 1950's by Dr. Kathe Seidel and others (Seidel K., 1973, Börner T. *et al.*, 1998). Constructed wetlands comprise self-contained, artificially engineered wetland ecosystems. They utilize particular combinations of plants, soils, bacteria, substrates and hydraulic flow systems to optimize the physical, chemical and microbiological processes naturally present within root zones of the plants. Since the early 1990's, wetlands research in Europe has focused on both horizontal and vertical flow systems, as well as combined horizontal and vertical flow systems (Platzer C., 1996, ÖNORM B 2505, 1997, Gesellschaft zur Förderung der Abwassertechnik d.V (GFA), 1998, Cooper P.F., 2003).

This paper will discuss case studies of four innovative and different applications of SSDD technology to wetlands. These cases demonstrate 21st century technology:

- Aeration of an 11,000 cu m per day (3×10^6 gpd) BTEX (benzene, toluene, ethylbenzene, and xylene) treatment wetland in Casper, Wyoming, USA
- Flow distribution across a vertical flow wetland serving a population of 6,000 people and operating at sub-zero temperatures in Shenyang, Hunnan New District, China
- Flow distribution into a horizontal flow wetland of septic tank effluent for a single-family home in Burnett, Washington State, USA.
- Aeration of a subsurface flow wetland which treats cheese-processing wastewater in Minnesota, USA.

CASE STUDIES

Case Study 1: Wetland Aeration:

The Problem: Constructed wetland systems, including free water surface (FWS) and vegetated submerged bed (VSB) wetlands, are oxygen-transfer limited systems (Sartoris J. *et al.*, 2000, United States Environmental Protection Agency, 2000). While organic matter can be degraded and cycled through these wetland systems anaerobically, oxidation of nitrogenous compounds will require mechanical addition of oxygen (Austin D. and Wallace S.; 2003) through either airlift pumps (Hanson A. *et al.*, 2001), fluctuating water levels (Behrends L. *et al.*, 1996), or forced bed aeration (Wallace S., 2001b). Of these three methods, the uniform distribution of small quantities of air throughout the wetland (forced bed aeration) has been found to be the most effective; hence, has been used in widespread commercial application (Wallace S., 2002). In conventional treatment processes such as activated sludge tanks or aerated lagoons, the mixing action of the air bubbles is significant and can be counted upon to disperse dissolved oxygen throughout the basin. The side roll aeration pattern is a classic example of this. By contrast, in constructed wetlands the flow velocity is very low, the water depths are shallow (<0.6 m) and the wetland contains granular media or plant detritus within the water column. These factors combine to drastically reduce the effective zone of influence of each aeration orifice.

The Solution: SSDD tubing, when used for aeration, is an ideal method of delivering small quantities of air uniformly across the wetland, allowing for effective aeration of the entire reactor volume (Dufay J.A., 2000). This uniform application of aeration has been employed to develop engineered wetland systems for treatment of petroleum hydrocarbons (Wallace S., 2001a). Since petroleum hydrocarbons are most effectively degraded under aerobic conditions, wetlands with

aeration are more effective than non-aerated systems (Moore B.J. et al., 2000). Degradation rate constants for aerated wetlands have been demonstrated to be over 50% higher than non-aerated systems (Kadlec R.H., 2002). The full-scale wetland system was started up in May, 2003. Since startup, the system has been hydraulically loaded at approximately 2,700 m³/d (45% of design). System performance to date for benzene, BTEX, and gasoline-range organics (GRO) is summarized below:

Table 1. Mean influent and effluent concentrations for the BP Casper wetland treatment system, May 2003 – March 2004 (Wallace S.D. and Kadlec R.H.; 2004):

Compound	Wetland Influent	Wetland Effluent
Benzene, mg/L	0.17	Non-detect (0.01)
BTEX, mg/L	0.47	Non-detect (0.01)
GRO, mg/L	2.02	Non-detect (0.05)

Case Study 2: Reed-bed treatment system at Shenyang, China:

The Problem: The constraints given by the client were that a surface area of only 6.500 m² were available for wastewater treatment of 6.000 person equivalents (p.e.); that is, about 1 m² / p.e. This is far lower than European standards of at least 2,5 m² / p.e. for a vertical flow constructed wetland. Furthermore, the artificial wetland must operate under frost conditions of between -25° to -30°C during February and March.

The Solution: The SSDD distribution system will avoid freezing of the distribution network and will intensify the biological activity in the root/soil filter system. The uniform application over the entire area by drip application will achieve a dramatically increased usage of the filter volume, in comparison to a conventional distribution system.

The system consists of four stages:

- 1) Pre-treatment: Screen and operating building, sedimentation tank, sludge silo, pump-station, and mechanical filter
- 2) Sewage sludge treatment: Sludge de-watering in reed-planted sludge drying basins
- 3) Biological treatment: Three reed-planted artificial wetlands (vertical flow) with SSDD application.
- 4) Outlet: Into stormwater treatment wetlands

The sand was still frozen in March, 2004 and in April the reeds were planted. The system did not operate until April 2004. At the moment the system is operating at about half capacity and as designed, however the test of this innovative solution will only take place in the winter of 2005.

Case Study 3: The use of SSDD in applying primary treated effluent into a wetland for a single-family home:

The Problem: Burnett is a rural community in Pierce County, Washington. In the late 1800s Burnett was built as the home for hundreds of coal miners and their families. The location was poorly chosen (by today's standards) because of its marginal soils, a high water table and straight

pipe discharge into local streams. Burnett closed its mine in 1921. The present town is built over the mines, shafts, tunnels, cave-ins and old sewer and water lines of the abandoned coal-mine. These features are conduits for partially treated or untreated wastewater to flow into nearby South Prairie Creek, an important salmon spawning habitat.

The demographics have changed since Burnett was a thriving coal-mining town. In 1998 the town was home to many elderly couples, widows, and low to middle income workers. The average income was less than \$30,000 a year. The residents occupy the same cottages that were built in the late 1800s. Some of the cottages have been remodeled, but many remain in their original form, and all of them were serviced by straight pipes or failing septic systems.

Small Flows Quarterly of Fall 2000 Vol. 1 No. 4 reported as follows:

Burnett Begins Its Journey of Change:

In 1996, Burnett formed the Burnett Wastewater Disposal Task Force (BWDTF), which comprised community members from both Upper and Lower Burnett. Its purpose was to find solutions to Burnett's onsite wastewater problems. The task force applied for and received a \$25,000 Physical Improvement Project grant from the Pierce County Department of Community Services. The grant was earmarked for assessing site conditions and exploring repair options. Shortly after, Burnett received a \$95,000 grant from the U. S. Environmental Protection Agency through the National Onsite Demonstration Program (NODP) Phase II, which is administered by the National Small Flows Clearinghouse in Morgantown, West Virginia.

The Washington Department of Health awarded \$75,000 to Burnett. The town used money from this third funding source for constructing, evaluating, and reporting findings for emerging or under-utilized onsite wastewater technologies.

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In addition, the Washington On-Site Sewage Association (WOSSA) donated time for site evaluations and system design and installation. The association also requested donations from companies interested in installing septic systems for the Burnett project, explaining to these companies that they would get local and national recognition in numerous reports documenting the outcome of the project. Through these requests, Burnett was able to pool another \$52,200.

Management Setup:

WOSSA was the NODP grant recipient, and WOSSA's executive secretary was the contact person for the project. Project coordinators are Jerry Stonebridge, past president of WOSSA and current president of Stonebridge Construction Company, Inc., and Bill Stuth Jr., WOSSA board member and resource person. The Tacoma-Pierce County Health Department is the permitting agency, and the BWDTF provides field support with property owners.

The Solution: Fifteen innovative treatment and disposal systems were installed and monitored. One of these is a horizontal flow reed-bed wetland of approximately 10 sq. m. area. The effluent is from a septic tank. The wetland is designed in two sections, each 5 sq. m.. Even though only one section of 5 sq. m. (0.57m. x 8.80m.) was activated (fig 2), over the last five years excellent results have been consistently obtained. As happens with projects of this type, Mr. Jerry Stonebridge (representing WOSSA) reported that the funds were exhausted, and there was no money left for monitoring. While we have no data, the author personally inspected the site and can report that the effluent from the wetland is clear and odorless, and that the homeowner was very proud of his system.

Figure 2: Five sq. m. wetland treating septic tank effluent from a single family home.



Case Study 4: The use of SSDD to aerate subsurface flow wetlands treating cheese-processing wastewater in Minnesota:

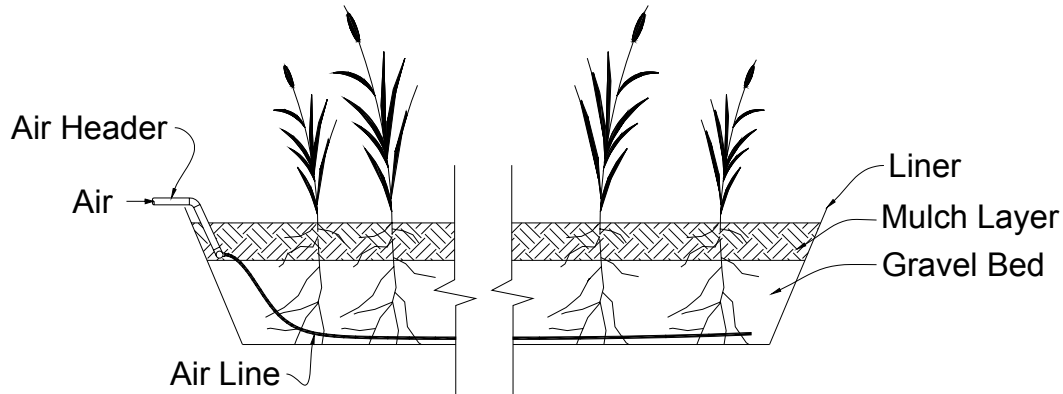
The Problem: The owners of a small family-run cheese plant replaced their on-site septic system in 1997 with a new septic tank, subsurface flow constructed wetland and an infiltration bed. Due to the cold climate, the wetland and infiltration bed were insulated with mulch. Quarterly sampling was initiated under a County operating permit. The initial round of sampling showed influent concentrations far higher than expected for CBOD₅ (2,820 mg/L vs. 174 mg/L design value). Further investigation revealed that antiquated facility piping resulted in most of the cheese processing waste being diverted to the septic system. Core sampling of the septic tank revealed large accumulations of cheese solids. Organic overloading of the subsurface flow wetland was obvious, with anaerobic protein degradation within the subsurface flow wetland causing a net production of ammonia. This organic loading, if left unabated, would have caused rapid biomat plugging and hydraulic failure of the infiltration bed.

The Solution: In April 1999, an aeration system using SSDD tubing was retrofitted to the wetland cell to increase the oxygen transfer rate.

Due to startup problems, the aeration blower was operated only intermittently from April to July 1999, and began operating full-time thereafter. Since initiation of full-time aeration, CBOD₅

removal improved from 17% to 94%, while Total Nitrogen removal improved from 44% to 74%. This improvement in treatment efficiency allows the infiltration system to function effectively.

Figure 3: Wetland aeration system using SSDD components (Wallace S.D., 2001).



BENEFITS AND SIGNIFICANCE:

The cost benefits of wetland treatment technology can be summed up in a simple phrase:

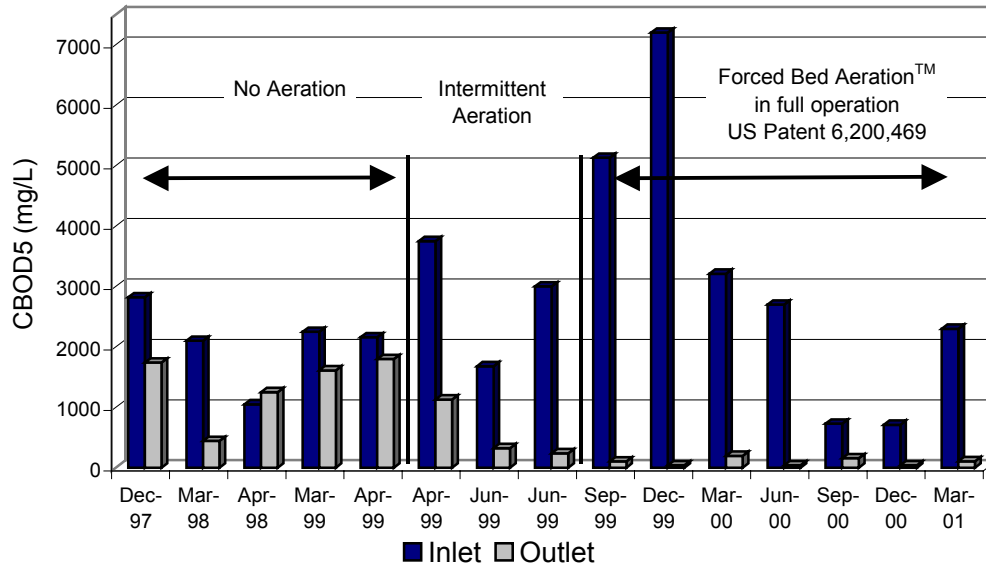
“Plants and bacteria work for free; people and machines don’t.”

The economics of wetland treatment are most favorable for site managers who can trade space for mechanical complexity, and who must operate a treatment system over long periods of time. Assuming that the space is available for wetland treatment and the economics are favorable, acceptance of wetland treatment by the general public and neighboring landowners is often quite high. Wetland treatment offers non-monetary benefits through the preservation of open space. With proper attention to hydrology and plant selection, they can be designed as visually attractive “amenities” that enhance the value of surrounding areas. Because of their low visual impact, wetland treatment systems are ideally suited for integration into parks, golf courses, prairies, and other open spaces.

Incorporating SSDD technology substantially increases the capabilities of engineered wetland treatment systems. The ability of SSDD to uniformly apply effluent across large areas minimizes the cross-section organic loading, and nutrients can be applied directly to the root zone where treatment is most effective. SSDD systems can be buried into the wetland under an insulating mulch layer, allowing effective performance under freezing conditions.

The use of SSDD in wetland aeration systems substantially increases oxygen transfer within the wetland reactor. Wetland basins are typically shallow (<0.6m) and filled with soil or gravel, which greatly limits aeration-induced mixing. SSDD is ideal in this regard since it can uniformly apply air throughout the wetland basin. Aeration has been shown to benefit wetlands treating high-strength waste. Aerobic conditions that develop as a result of SSDD aeration are effective in volatilizing and degrading petroleum hydrocarbons.

Figure 4: Comparison of aerated vs. non-aerated wetland performance (Wallace S.D., 2001):



The systems in all the case studies have been operating at levels well within the design specifications.

These demonstrate the advances in wetlands treatment for high strength waste such as from food processing, septic tank effluent etc.

SSDD also operates successfully under freezing conditions.

The ability to achieve high standards of effluent using smaller areas for treatment makes SSDD a valuable tool to achieve reduction of pollutants in the environment.

CONCLUSION:

Because of the widespread use of wetlands in the ecological engineering field, the multiple applications of SSDD technology in constructed wetlands is a leading indicator of what is possible in other engineered ecosystems.

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