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Subsurface Drip Wastewater Systems — North Carolina's Regulation and Experience

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INTRODUCTION

Interest in subsurface drip wastewater systems in North Carolina was a natural evolution from our experience with the use of low pressure pipe (LPP) technology, as we have become acutely aware of many inherent problems with LPP systems. Some progressive public school districts were the first to delve into this exciting new concept in wastewater management which had its origination in Israel. School system personnel visited operating systems in Georgia, and had their consultants present proposals to apply this technology to their local situations in North Carolina. Here, the concern was not the same as in Israel — and perhaps in many sites in the more arid regions of the United States — that is to efficiently utilize reclaimed wastewater for irrigation in agricultural production. In the relatively water-rich southeastern states, interest in drip is based primarily upon its ability to efficiently distribute, treat and dispose of wastewater effluent, often on sites with severe soil limitations.

We did our best to rise to the occasion, to both learn as much as we could, as quickly as we could, about this technology, and to devise appropriate mechanisms to allow for its use in North Carolina. We were fortunate to be faced with an aggressive but highly conscientious industry advocate, a Governor who supported our gaining in-depth knowledge of this technology, and a newly effective rule which provided a framework for the development and implementation of Innovative and Experimental technologies. We fortunately had and took advantage of an opportunity to travel to Israel in the Spring of 1993, between various terrorist incursions, with a small group of regulators, researchers, consultants and product developers, to visit where various system components are made, and glean as much as we could from the multiple years of product research and development experience in its place of origin. This was truly an enlightening experience. I proceeded to develop and perfect a computer program to evaluate the hydraulic design of simple to complex drip distribution networks, to enable us to properly evaluate the designs we were receiving from school systems and other prospective applicants. My work was presented at the Seventh International Symposium on Individual and Small Community Sewage Systems in December, 1994, in Atlanta [Berkowitz and Harman (1)]. Wastewater Systems, Inc., subsequently was issued an Innovative Approval of their "Perc-Rite®" System, allowing for the first series of system designs to be approved and installed. Our initial Innovative Approval issued in 1993 was for aerobically treated effluent only. We concurrently issued an Experimental Approval to Wastewater Systems, Inc., for use of their anaerobic system, which requires only a septic tank for effluent pretreatment.

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INITIAL EXPERIENCE WITH AEROBIC SYSTEM

The first installation -- at the E.O. Best School in Franklin County-- was quite a learning experience. This system served as the replacement for a sand filter-dry ditch discharge. The sand filter was renovated and proposed to remain online. The available drainfield area available was relatively large, but had extremely marginal soils, with just a thin veneer of permeable sandy clay loam overlying a tight clayey subsoil. The micro-variations in soil conditions were not adequately assessed during the initial siting of the over seven miles of drip tubing required for this system. The pressure-compensating emitters in the drip lines do an excellent job of uniformly delivering effluent to good and bad soils indiscriminately, and significant surfacing occurred in approximately 15-percent of the drip field area. This problem was for the most part solved by relocating this portion of field into the designated repair area, and by effectively utilizing Perc Rite's control capabilities, to adjust the dose volume to each zone to account for variable soil loading rate capabilities.

Another significant performance problem was quickly brought to light by the system's self-monitoring features. Excessive infiltration/inflow into the school's collection sewers and the main septic tank became apparent during wet-weather periods, leading to surface failures. The majority of the sources of infiltration/inflow have since been eliminated, such as by installing a new, 10,000-gallon septic tank. Wastewater flows now remain below system design rates, and system performance has improved greatly.

FIRST EXPERIMENTAL ANAEROBIC SYSTEM

Our experience with the first large drip system utilizing septic tank effluent only was also a success from the standpoint of what we have been able to learn from it, although its ultimate performance has been less than desirable. The permitting of this system was through our Experimental and Innovative (E & I) program, with Wastewater Systems commissioning Dr. Bob Rubin, North Carolina State University, to extensively monitor and evaluate this system in accordance with a pre-approved research protocol. North Carolina's Wastewater Laws and Rules set forth the mechanism by which new and often proprietary products can be approved for installation (2). E & I systems are systems, components or devices not specifically described in the State Rules or for which reductions in minimum horizontal or vertical separation requirements or increases in maximum long-term acceptance rates are proposed. An E & I system is granted Innovative status when third-party documentation supports a finding that the system shall perform equal to or better than a previously approved system, through controlled pilot-scale research or statistically valid monitoring of full-scale operational systems. Innovative systems can be used at any site where product-specific approval conditions can be met. Other unproven E &I systems can be permitted if they will be included as a part of an approved third-party research or testing program, where a non-experimental backup system could be used if the experimental system fails, or if the experimental system serves as a repair to an existing malfunctioning system. The experimental aspect of this first large anaerobic drip system was considered to be use of the subsurface drip system with only septic tank pretreated effluent. In conjunction with Dr Rubin's research/monitoring of this system, Wastewater Systems, Inc., commissioned Ayres and Associates to perform a third party evaluation of hydraulic loading criteria for its subsurface drip systems, based upon a review of systems which had been in operation in Georgia for a number of years.

This first large North Carolina anaerobic drip system installation was designed to serve as the replacement/repair wastewater system for the 67 lot Lake Wheeler Mobile Home Park. Available drainfield area was somewhat limited, but contained an excellent deep, well-structured Piedmont clayey soil. The approved design called for the installation of over eight miles of drip line, based upon a 13000 gallons per day design flow rate and a long-term acceptance rate of 0.15 gallons per day per square foot. Four large separately dosed field zones were utilized, each containing nearly 11000 feet of drip tubing.

Many problems were encountered with the Lake Wheeler system:

- severe infiltration/inflow problems occurred initially, despite most of the collection sewer lines having been reconstructed (it turned out the service connection points were the main sources of significant inflow).
- micro soil permeability variations, attributed primarily to site disturbance during the removal of trees and tree root balls during site preparation, contributing to localized surface failures.
- excessive solids wash-through into the effluent dosing tank, which was exacerbated by hydraulic surges during wet weather periods, which caused frequent blinding of the drip system filters. This problem was largely solved by the installation of additional baffles in the initial septic tank compartment, and the installation of a high-capacity effluent filter.

But the most extensive problems encountered were associated with what has proven to be the scourge of pressure distribution systems on sloping lots — drainback, both within individual lines not installed perfectly on contour, and most significantly drainback into the lower laterals in each field at the end of each scheduled dosing event. Drainback is the redistribution of the effluent remaining in a pressurized pipe network from the upper to lower portion of the network at the end of each dosing event. The severity of this problem at Lake Wheeler forced us to examine this issue in considerable detail. We realized there are significant competing interests involved. On one hand, it is desirable to dose the drainfields with multiple small doses. For example, Mississippi's drip standards call for dosing each field zone at least six times per day. At Lake Wheeler, this would mean six, 542-gallon doses to each of the four field zones per day (based upon the 13000 GPD design daily flow rate). But in order to deliver 80 percent of a dose to the field when the pipe delivery network is fully pressurized, the minimum dose volume needs to be at least six times the volume in the laterals plus the volume of the portions of supply line and supply manifold which drain between doses. Even if this dose volume criteria is met, up to 20 percent of the dose volume will be distributed under gravity flow conditions, not while the system is fully pressurized. If smaller dose volumes are utilized, the percent of the dose delivered under non-uniform conditions proportionally increases. The particulars of this conflict for Lake Wheeler is illustrated in Table 1.

Table 1. Volume in Drip Laterals and Supply Manifolds, Lake Wheeler Mobile Home Park, North Carolina

Field Zone	Volume in Laterals (gallons)	Volume in Supply Manifold (gallons)	Total Network Pipe Volume (gallons)
1	143	67	210
2	144	138	282
3	144	237	381
4	144	117	260
Minimum Equalized Dose Volume to Meet 80% Delivery Criteria to Each Zone: 1100			
Average Doses per Zone Per Day, at Design Daily Flow Rate: 3			

The effect of this problem at Lake Wheeler, even when the 80% delivery criteria was met, was still a severe case of wet feet around the lowest few laterals in most of the field zones (especially Zone 3), where most of the effluent remaining in the large lateral/manifold pipe networks could be relieved.

On a micro scale, the drainback problem also occurred within individual laterals at Lake Wheeler, where some of the lateral lines were installed on a slight grade, instead of level, and the effluent remaining in the line could migrate and be released preferentially into the lower portion of the lateral after each dose cycle. These findings were similar to those reported by Amoozegar, et al (3), who quantitatively evaluated the extent of redistribution with both drip and LPP distribution networks, utilizing pilot systems set up in a laboratory setting.

To solve this problem at Lake Wheeler, additional valving and pipes were installed in an attempt to capture the majority of the drainback effluent at the end of each pumping cycle in a pump tank located below all field zones and pump this effluent back to the main distribution system pump tank. This was moderately successful, but created its own set of problems --the drainback water was returned into the field flush line, which goes back into the septic tank, and the addition of this drainback effluent worsened the hydraulic surge problem with the septic tank performance. The drainback system also served as a huge dewatering system during heavy rainfall events, whereby the drip network intercepted substantial quantities of percolating rainfall, further adding to infiltration/inflow entering the collection sewer system. And there also remained pockets of low areas in the fields which couldn't be captured by the drainback recycling system, which still serve as accumulation points for some of the drainback effluent.

Largely based upon this experience, some significant system design modifications have been instituted as summarized in Table 2.

Table 2. Drainback Reduction Techniques, Subsurface Drip Wastewater Systems
• Assure each lateral is installed level (on contour)
• Manifold-to-lateral connections must be over "dam" to prevent drainback from any lateral back into the supply manifold
• Reduce size of field zones and reduce size of supply manifolds, while still taking account of other critical hydraulic constraints, such as the effect of manifold size on head losses during field flushing
• Utilize top-feed manifold technique, whereby supply and return manifolds are reduced greatly in size and are both located above all field lines, preventing field lines or significant lengths of manifold segments from draining to lower laterals

Other than in the areas where overloading is attributed to drainback, the majority of the Lake Wheeler system drainfields have performed satisfactorily, with no evidence of effluent surfacing over its five-year period of operation. Rubin(4) also obtained a substantial amount of beneficial information on system performance hydraulically and chemically. One hypothesis investigated was whether the use of anaerobic effluent would increase the potential for denitrification to take place within the drainfield, and perhaps to a level greater than could be expected with aerobic effluent with reduced organic constituents (e.g.: recirculating sand filter or aerobic treatment unit effluent). Results seemed to support this hypothesis, with nitrate nitrogen concentrations being elevated in the soils immediately below the dripper lines, but markedly reduced within a short distance of the lines (See Table 3). The potential for elevated levels of nitrate still was observed, so other means of reducing Nitrogen may need to be employed in highly sensitive areas.

Table 3. Nitrate Nitrogen Distribution With Depth In Soil Samples Collected Adjacent To and Between Laterals of Drip Disposal System Emitters at Three Different Landscape Positions, Lake Wheeler Mobile Home Park*

	Upper		**Mid Slope**		**Toe Slope**	
Depth	**Adjacent**	**Mid-way Between**	**Adjacent**	**Mid-way Between**	**Adjacent**	**Mid-way Between**
0"-6"	1	1	2	2	2	1
6"-12"	2	1	2	1	4	1
12"-24"	3	2	10	2	8	5

24"-36"	5	3	8	2	12	4
36"-48"	7	5	12	3	10	6
* Data collected and presented by Dr. Bob Rubin (4)						

REVISED INNOVATIVE APPROVAL FOR ANAEROBIC AND AEROBIC SYSTEMS

Information gathered during the experimental phase in addition to Rubin's work included the evaluation of hydraulic loading criteria by Ayres and Associates(5) and findings at other demonstration/research sites in North Carolina [Rubin, et al (6), Spooner et al (7)]. The information provided was deemed sufficient to allow for the issuance in 1996 of a revised Innovative Approval to Wastewater Systems, Inc., which allows for the use of both aerobic and anaerobically pretreated effluent (8). Elements addressed in this Innovative Approval are outlined in Table 4. The full text of this, other Innovative Approval documents, State Laws and Rules and a wealth of additional information on North Carolina's On-Site program are most readily accessible via our Homepage, at: **http://www.deh.enr.state.nc.us/oww/**

Table 4. Key Elements of Subsurface Drip Innovative Approval in North Carolina
• **Description of System Components** • **Pretreatment (varies for Anaerobic and Aerobic Systems)** • **Drip Field Dosing Tank/System Components** • **Subsurface Drip Field Components** • **Design Operating Criteria**
• **Siting Criteria**
• **Sizing Criteria**
• **Installation and Testing Procedures**
• **Description of System Components** • **Design** • **Installation** • **Certification** • **Operation**
• **Operation, Maintenance and Monitoring Requirements**

SUMMARY OF EXPERIENCE WITH SUBSURFACE DRIP IN NORTH CAROLINA

Subsurface drip systems, despite their approval for use and potential applicability, have received limited use thus far in North Carolina. The distribution of systems, and type of use are depicted in Table 5:

Table 5. Distribution of Subsurface Drip Systems in North Carolina*						
	Design Flow Range (GPD)					
Type of Facility	200-400	2000-3000	4000-6000	7000-8000	10000-15000	Total
Single Family Home	14					14
Public School			5			5
Commercial	2					2
Shopping Center			1	1		2
Subdivision				1		1
Mobile Home Park					1	1
Group Home			1			1
Highway Rest Area			1			1
County Park		1				1
TOTAL	16	1	8	2	1	28

*Information provided by Jack Harman, Wastewater Systems

The limitations which have kept use from being more extensive include system cost (especially for an individual home), the ability to use LPP systems on many sites where drip technology would also be feasible, relatively conservative siting and design parameters included in the Innovative Approval, and to the perceived cumbersome nature of the permitting process, in comparison with other technologies which may be applicable on sites where subsurface drip could also be considered. A currently popular alternative has been surface drip, both as a substitute for spray irrigation on residential building lots (requiring much less buffer requirements), and for large systems, as an alternative to either subsurface drip or to spray systems. It has been a quite natural technology to incorporate with wastewater reclamation systems utilizing highly pretreated effluent, which has received increasing interest as a wastewater management option in North Carolina. Design and siting constraints on surface drip have also been less rigorous, often further encouraging its preferential use.

The performance of our drip systems over the range of uses has generally been good, with some systems in continuous use for now over eight years. Summarized below are problematic issues which have arisen:

Design Issues

- Drainback must be carefully considered in every case, unless the drip drainfield zones can be installed dead level. Maximum drainback volume to be tolerated should not exceed five percent of the design dose volume into any lateral segment. New design methods (Table 2, above) appear to be capable of successfully addressing this issue.
- Soil/site limitations are less than for other subsurface systems, but still must be adequately addressed. In particular, micro-areas where natural soil variations or where disturbance caused by site preparation has significantly reduced soil permeability should preferably be identified up front, or they will certainly show up after the fact.
- High complexity of controls may be counter productive, especially for residential-scale systems. Lightning damage has often had to be reckoned with; warning devices have sometimes proven to be unnecessarily sensitive and often difficult to troubleshoot.
- Two feet per second scour velocity during flushing may not be sufficient to eliminate long-term build-up of slimes and possible clogging of emitters, especially when handling anaerobic effluent. This problem, where it occurs, could be expected to worsen with time, as increased lateral clogging leads to a further reduction in flushing scour velocity, which can in turn accelerate clogging. Systems monitored over a five-year period which were designed for flushing scour velocities in excess of three-feet per second have shown essentially no evidence of slime buildup (as reflected by no measurable reductions in irrigation and flushing flow rates or head loss increases within the field pipe network during flushing). Despite evidence of some lateral clogging at some sites, irrigation flow rates have not been found to have dropped by more than 15 percent in any system thus far monitored.

Installation Issues

- Keeping debris out of the drip laterals during installation has proven to be difficult. It can result in excessive head loss (and thus ineffective flushing), and emitter malfunction, as debris trapped in an emitter will cause its discharge rate to be excessive. Careful pressure measurement, flushing and field observation for hot spots and the elimination of defective emitters can usually rectify problems, but it can be quite time consuming to assure this has been done thoroughly.
- Like any subsurface system, infiltration/inflow into the collection system, including pretreatment tankage, must be eliminated for the system to be expected to perform properly. With controlled equalized flow distribution as an integral part of the drip system, any infiltration/inflow will quickly be identified.
- Site preparation steps must be carefully reviewed in order to minimize localized disturbance. Installation equipment must be selected specific to site conditions and limitations posed. Lines must be installed level, earthen backfill hand-compacted over the supply and return manifolds, and manifold-to lateral connections constructed over a compacted berm and carefully backfilled, to minimize drainback.

FUTURE ADVANCEMENT OF SUBSURFACE DRIP SYSTEMS IN NC

In order to further stimulate the implementation of subsurface drip technology in North Carolina, consideration is being given to modifying some system component and performance requirements. We will have failed, however, as has been proven with other technologies, if the constraints removed lead to chronic system failure. System use could come into disfavor whether or not this reaction is merited, regardless of any position taken by the regulatory community. Geoflow, American Manufacturing, Delta and Wastewater Systems have all expressed interest in us critically evaluating our requirements. Our Innovative Approval process provides for us to work with each individually. However, we are also now considering a generic approval for subsurface drip similar to what we have done for pressure dosed sand filters, and allowing each company to apply for product-specific coverage within the framework of this approval. We still firmly believe that each system should be under the auspices of a single manufacturer, since it is considered impractical to separate the drip tubing from the filters and controls necessary to properly dose and flush the system.

Areas being considered for modification in our approval include:

- Type of filtering required, and possible variations in backwashing capabilities. How number and type of filter can vary with level of pretreatment prior to the drip system shall also be reviewed.
- Under what circumstances is manual field flushing acceptable (if any)?
- Can flow-per-zone be adequately controlled by floats and timers, and not require sophisticated flow meters electronically monitored by the control processor?
- Can proper dose volume and dosing rate per zone and flow variance conditions by adequately monitored in any simpler fashion?
- Is an autodialer connection necessary for residential systems, or should audible/visible alarms suffice to warn users of system malfunction?

FUTURE AREAS OF RESEARCH

The place of anaerobic-vs-aerobic subsurface drip in the world of on-site wastewater management is still open to debate, which will hopefully be resolved by future research efforts. Questions to further investigate include:

- What long term acceptance rates are truly justified, based upon soil type and level of pretreatment?
- What are the advantages and disadvantages from a nutrient reduction standpoint of anaerobic-vs-aerobic pretreated effluent in conjunction with subsurface drip distribution?

  What techniques are available to maintain effective hydraulic performance of drip tubing and emitters? What chemical or physical treatments can be utilized, without harming the receiving soils or surrounding ground water?
- What other options are available or can be devised to deal with the drainback problem?
- What are the appropriate levels and methods of system monitoring, inspection, operation and maintenance needed to assure continuous effective long-term performance?

We believe subsurface drip is here to stay, and with the collaborative efforts of researchers, consultants, manufacturers, and yes, even regulators, it can be properly tweaked to be an increasingly important alternative on-site management technology.

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