Cost Effective Upgrade to Meet 503 Sludge Regulations

John R. Currie

In 1991 Lebanon TN, a rural community with a population of about 16,000 and a major industrial wastewater generator in the form of a candy factory, was faced with upgrading its wastewater facility to increase plant capacity. Originally built in 1960, the facility consisted of primary rectangular clarifiers with trickling filters. As consistent with the industry standard at that time, the primary sludge was then anaerobically digested

The facility had an upgrade in 1975 in which it was converted to extended air activated sludge with secondary clarification. Due to the long sludge age, the anaerobic digesters became nothing more than storage vessels, especially since the mixing and the heating system were inoperable.

In 1991 upgrade the city and its consultant, Water Management Services, were considering a revision to the facility operation by utilizing the trickling filters as roughing filters. The activated sludge portion of the facility would no longer store sludge for extended periods and the existing digesters would be used for anaerobic digestion. The result would be an increase in the plant capacity to 6.0 MGD without expanding equipment and tankage.

During this same period, EPA was proposing new sludge regulations, the final draft of which was signed in November 1992, with promulgation in February 1993. The proposed regulation introduced the definition for high quality sludge or biosolids which included pollutant limits, Class A pathogen and vector attraction reduction. Tennessee was also developing high quality biosolids definition at the time under the direction of Bob Odette.

In 1991 the city and Water Management Services began reviewing technologies available to meet the Class A requirements for pathogen reduction. Part of the initial review was to look at the alternatives defined under paragraph 503.32 of the proposed new regulations which includes six alternatives for meeting a Class A classification. Alternative 5 defines certain processes, which under the old EPA regulation 257 were designated as a Process to Further Reduce Pathogens (PFRP): composting, heat drying, heat treatment, thermophilic aerobic digestion, beta ray irradiation, gamma ray irradiation, and pasteurization.

Since the promulgation of the 1979 Regulation, other technologies have been developed which provide similar results with respect to pathogen reduction. The EPA Pathogen Equivalency Committee has reviewed some of these processes, including the AeroTherm process, to verify their ability to achieve Class A results.

Process Evaluation

In reviewing the available technologies for the Lebanon facility, the consultant did not consider beta or gamma ray irradiation as viable options because of the overall plant size and the complexity of these systems. Heat drying and pasteurization were also eliminated from further consideration.

The processes meriting further consideration included composting, lime stabilization, and the AeroTherm two-stage digestion process. Composting, however, presented concerns about odor, space, and capital costs and was dropped.

Lime/alkaline stabilization has a long history as a relatively simple process with low capital costs. This has been one of the primary advantages to the process. Lime/alkaline stabilization could also achieve the pathogen reduction and vector attraction reduction requirements as noted by the 503 sludge regulations.

One of the major disadvantages of lime/alkaline stabilization treatment process is that it does not reduce organic matter.

Other sludge stabilizing methods involve the destruction of the volatile contents of wastewater sludge and, therefore, reduction of the amount of sludge required for disposal. In fact, the mass of dry sludge solids is increased in the lime/alkaline stabilization process because of the addition of lime. Problems have resulted with regards to odor, due to the release of ammonia and other compounds from the dewatered sludge. Considering the sensitivity of odors in the operation of Lebanon WWTP, odor control would have to be considered in any further evaluation. Regardless, the engineer's evaluation noted that lime stabilization provides an acceptable process and merit for further consideration.

The AeroTherm two stage digestion process is an aerobic thermophilic process which is utilized as a pretreatment step in conjunction with anaerobic digestion. As a thermophilic process, the AeroTherm system reduces the number of disease causing organisms (pathogens) in wastewater sludge. The AeroTherm system also conditions the raw sludge to enhance the digestibility prior to the anaerobic digester. This preconditioning is accomplished through aerobic thermophilic means for an 18-24 hour period.

Upon completion of the initial aerobic thermophilic stage, the sludge is then processed in an anaerobic digester for a detention time varying from 15 to 20 days. Actual detention may vary dependent upon the location and/or type of sludge. Typically the digester is operated in the mesophilic temperature range. Therefore heat recovery is provided with the AeroTherm system to ensure operation of the digester in the mesophilic range.

Developed in 1981 as a result of Swiss Regulations for beneficial use, the major disadvantage of the process is the lack of U.S. experience. To offset this disadvantage, CBI Walker submitted information to Water Management Services regarding the pathogen reduction. The data included both pilot work and a lab demonstration. The data presented by CBI Walker verified the process capability with respect to pathogen reduction and vector traction reduction.

One of the prime advantages of the two-stage digestion process for Lebanon would be the continued utilization of the existing anaerobic digesters. A minimal amount of changes and modifications would be required to incorporate the AeroTherm system with the existing digester complex. Some of these changes were due to inoperable existing equipment.

The engineer's report noted that the availability of the digester complex and the ability to produce liquid Class A Biosolids favored the use of a thermophilic pretreatment process. Therefore, use of the AeroTherm system with existing anaerobic digester complex was a viable solution meriting further consideration for the Lebanon WWTP. The final evaluation of the AeroTherm and any other process would have to consider the reduction of solids and reuse of the existing facility.

Life Cycle Evaluation

Water Management Services determined that lime/alkaline stabilization and the AeroTherm system with a retrofit of the existing anaerobic digester complex offered the two most feasible solutions to Lebanon's situation. Use of the AeroTherm system provided several advantages which made it very attractive despite the initial belief that lime/alkaline stabilization would be less capital cost. These advantages included the following:

- Retrofit with the existing facility
- Liquid or dry Class A Biosolids
- Small footprint for the system
- Low operating costs
- Reduced hauling costs

In considering the two systems, an evaluation of each system was done considering the process design, capital costs and the operation and maintenance expenses. Capital cost would definitely favor the lime stabilization process. However, the life cycle costs for each process were also considered in the final analysis. These costs include electrical power, chemical usage, maintenance and labor, disposal and amortization of debt. The accompanying tables reflect a summary of each system's annual cost with respect to operation and the annual amortization of the project capital cost. These costs were an estimate as projected by Water Management as part of its 1991 report and have not been revised to reflect current costs.

The capital costs associated with this project considered modifications to the existing digester complex, new equipment, the site and other miscellaneous items covered under construction contingencies, etc. While odors were of particular concern with respect to the lime stabilization process, it was not considered in the capital cost for the system.

The initial evaluation did not consider the capital costs associated with odor control for the lime stabilization process. Chemical costs associated with lime addition were based on 0.6 pounds of lime per pound of sludge. The report suggested that actual design of the lime stabilization system may require as much as a 1:1 ratio of lime to sludge. The utilization of gas generated by the anaerobic digester was not considered to offset energy use within the AeroTherm two stage digestion process. Regardless, the initial evaluation concluded that the AeroTherm system with rehabilitation of the existing digester complex was the most cost effective approach for Lebanon.

Engineering Design and Construction

Upon completion of Water Management Services' report, Lebanon proceeded with the design of the facility. While an advantage of the AeroTherm system was reutilization of the anaerobic digester complex, implementing it was a challenge. To develop the most effective system, a cooperative effort between Water Management Services, the city of Lebanon, and CBI Walker was necessary. A decision was made to locate the AeroTherm system within the existing building affixed to the digesters. Use of the existing building provided a central location for the complete sludge treatment process, simplified loading of vehicles for sludge disposal, minimal overall construction costs, and maximal use of the existing facility.

CBI Walker provided engineering assistance to develop the system layout. Water Management Services provided the necessary information to finalize the AeroTherm process design.

Comparison of Annual Costs, First Year

	Lime/Alkaline	Aerotherm/Anaerobic
Annual Operating Cost	$131,200	$70,600
Amortization of Debt	$49,600	$91,468
TOTAL	$180,800	$162,068

Comparison of Annual Costs, Year 2010

	Lime/Alkaline	Aerotherm/Anaerobic
Annual Operating Cost	$189,200	$102,100
Amortization of Debt	$49,600	$91,468
TOTAL	$238,800	$193,568

The joint efforts of both companies resulted in a completed set of plans and specifications submitted for review by the State of Tennessee in the spring of 1993.

In July 1993 a contract was awarded by Lebanon for the construction of the new facility. CBI Walker received a contract from the general contractor to provide an AeroTherm system sized to treat 20,000 gpd of raw sludge. Actual construction was completed in the fall of 1994. The AeroTherm system and anaerobic digester complex was started in late 1994 with full operation on raw sludge in the spring of 1995.

Facility Operation

The facility was placed into operation in February 1994. The anaerobic digester was started without the benefit of a seed sludge from a nearby digester facility. During the construction of the facility waste sludge was stored on site resulting in sludge with a very long sludge age. Upon start up small portions of the stored sludge was fed with fresh sludge to the two stage digestion process. It was later decided to proceed with the fresh sludge being produced and to dispose of the remainder of the sludge which was stored during construction.

The facility is still in the process of retrofitting the primary clarifiers. Therefore the AeroTherm two stage digestion process has been treating 100% secondary sludge. After one year of operation, the operating data is as follows:

- Class A pathogen reduction
- Raw sludge concentration of 4 - 4.5%
- Digester temperature maintained with AeroTherm
- 50% TSS destruction
- 50-55% VSS destruction
- 21-23% dewaterability

It is intended to liquid land apply as the primary method of biosolids disposal. Therefore dewatering is done intermittently at this time.

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Landfill Leachate Management: Combining Biophysical Treatment With Ultrafiltration/Reverse Osmosis

Josef F. Grusauskas, David L. Mathews, and David M. Laliberte

With the passing of Subtitle D in 1993, landfill owners and operators have had to focus on a new issue: leachate management. Leachate is the liquid produced when moisture, such as rainfall, enters the landfill and stays in contact with the solid waste long enough to leach out and dissolve some of the materials' constituents. A common method of leachate management for Florida landfills has been to collect the leachate in storage facilities and truck the material to domestic wastewater treatment plants.

The Palm City II Landfill Expansion designed by Hazen and Sawyer for Martin County consists of two 12-acre double HDPE lined cells and a state-of-the-art leachate treatment system to meet the new Subtitle D requirements. The leachate treatment system was required because the landfill leachate generation (ranging from 15,000 to 30,000 gpd) could not be properly handled by municipal domestic wastewater treatment plants within the county, and the leachate evaporation pond previously permitted was inadequate. The landfill expansion was designed to extend the current facility's life by 10 years at the current 400 ton/day rate and bring the facility into closure.

Martin County owns and operates the solid waste facility for its residents. The population of 125,000 are mainly cluster developments along the coast of the approximately 549 square mile rural county. The facility also serves the four cities within its border, which include Stuart, Jupiter Island, Sewalls Point, and Ocean Breeze Park.

The 400-acre Palm City II Landfill facility was permitted for operation in 1985 and is planned to close in 2006. As with most solid waste facilities in rural communities, it is located outside the urban service area making public services limited. Therefore, the landfill was previously designed with eight lined evaporation ponds with a total capacity of 10 million gallons.

The system pond controlled leachate volume by evapotranspiration using three volume fountain pumps based on an average of 56 inches of rainfall a year. This method of leachate removal has proven to be inadequate for the landfill.

The permitted leachate pond system appeared to maintain leachate levels under normal weather conditions with the exception of abnormally high rainfall periods, such as, tropical storms experienced during the summer months. The limitation of the ponds were also demonstrated over the past four year period (1992-1996) when the facility experienced over 80 inches of rainfall per year. The county hauled 36 million gallons of leachate to six different WWTPs, some located over 70 miles away, to maintain permit compliance. It is also important to note that over half of the hauled leachate during this period was stormwater falling directly into the ponds.

Table 1. Martin County Palm City 11 Landfill Leachate Characteristics

Parameter	Concentration (mg/l)
pH, (SU)	6.5 - 7.5
Alkalinity (CaCO3)	1,800
Arsenic	0.017
Cadmium	0.005
Chromium	0.04
Iron	6
Lead	0.0059
Manganese	0.27
Sulfate	100
Sodium	1,150
BOD	220
COD	2,200
TOC	650
Chloride	1,400
TDS	5,600
TSS	30
Phosphorus	0.37
Ammonia Nitrogen	480
Nitrate Nitrogen	0.05

Regulatory Requirements

DEP issued a construction permit for the leachate treatment system on August 10, 1994. The permit requires that primary and secondary drinking water quality standards must be met prior to discharge of the permeate into the on-site stormwater pond.

Leachate Treatment System

The treatment process selected for the Martin County Palm City II Landfill consists of a combination of biophysical treatment with ultrafiltration/reverse osmosis (UF/RO). Figure 1 depicts the treatment system process schematic. The treatment system is designed to handle a maximum of 30,000 gpd of leachate. The treatment system is also capable of treating a wide range of biological and chemical constituents. Leachate characteristics of grab samples collected at the landfill leachate pump station are shown in Table 1. The following subsections describe the leachate treatment system.

Leachate Storage Tanks

Two 300,000 gallon double wall glass-fused-to-steel tanks were designed to store the landfill leachate prior to treatment. The above ground tanks were designed with secondary containment capable of storing 110 percent of the volume of the liquid within the primary tank as required by DEP. The dimensions of each tank are: 53 foot diameter primary tank with 19 foot sidewall; and 64 foot diameter secondary tank with 19 foot sidewall. The tanks are equipped with a free-span aluminum roof. The glass-to-fused-to-steel tanks were selected based on the long-term corrosion and abrasion protection provided by the coating process. This type of coating process also eliminates the coating maintenance costs.

Biophysical Treatment

The first part of the process consists of a powdered activated carbon/activated sludge treatment system, also referred to as the PACT system. The PACT system combines biological treatment (i.e., activated sludge) with adsorption on powdered activated carbon enabling physical and biological treatment to occur simultaneously. The two-stage batch PACT system is designed for flexibility of operation and the ability for nitrification (first stage) and denitrification (second stage). Figure 2 shows the typical operational stages of the two-stage batch PACT system.

The influent leachate feed pumps will deliver approximately 15,000 gallons to the first stage SBR No. 1. The unit will react and settle during a 24 hour period. Approximately 12 hours after SBR No. 1 has been filled, the influent leachate feed pumps will deliver approximately 15,000 gallons to the first stage SBR No. 2. This unit will also react and settle during a 24 hour period. In this first stage process, the aeration tank (SBR) enables the system to carry high mixed liquor suspended solids concentrations (biological solids and powdered activated carbon) and remove most of the gross pollutants. Approximately 12 hours after SBR No. 2 has been filled, SBR No. 1 will decant into the second stage anoxic tank where denitrification will occur for approximately 7 hours. When the anoxic interval has elapsed, powdered activated carbon is added and an aerobic interval will occur for approximately 5 hours. The treated leachate is then decanted to the equalization tank which serves as a reservoir for the downstream treatment process. Settled carbon is countercurrently recycled from the second stage to the first stage to maintain a high level of suspended solids in the mixed liquor. This two-stage system not only

exposes leachate to two treatment zones, it also uses the carbon's adsorptive properties. As the carbon is withdrawn from the second stage and transferred to the first, a form of "big-regeneration" takes place. Adsorbed organics are biologically oxidized and the adoptive properties of the carbon particles are partially renewed.

This type of operation will continue to cycle, until the leachate has received full process treatment. The biophysically treated effluent then passes through a shallow bed rapid rate sand filter for polishing prior to the UF/RO system. The projected characteristics of the PACT and rapid rate sand filter effluent is presented in Table 2.

The second part of the process consists of a UF/RO system for final treatment of the mineralized constituents. The projected blended, mean and peak leachate characteristics prior to treatment by the UF/RO system are presented in Table 3.

Ultrafiltration/Reverse Osmosis Treatment

Based on the projected leachate characteristics quality presented in Table 3, a UF/RO treatment system was designed to produce a high quality effluent that will meet primary and secondary drinking water quality parameters. The leachate is fed to the UF/ RO system by transfer pumps located at the rapid rate sand filter. The UF/RO system includes iron filters, ultrafiltration, pretreatment cartridge filters, pretreatment chemical conditioning, reverse osmosis skid, post treatment degasification and chemical addition prior to discharge to the on-site stormwater pond.

The two manganese greensand iron filters are rated for 98% removal of the influent iron for a feed flow of 21 gpm. The leachate will be pretreated with potassium permanganate prior to the iron filters to reactivate the manganese greensand media.

The UF system will consist of three pressure vessels, each housing three Hydranautic Model 8040-FFF-2120 ultrafiltration membranes operating at an overall recovery of 70 percent. The spiral-wound membranes, constructed of hydrophilic polyolefin, will operate at a feed pressure of 90 psig. The cartridge filter housing will be equipped with five micron cartridge filter elements to remove suspended materials prior to the RO system.

The RO system will consist of a 3:2:2:1 array of pressure vessels, each housing three Hydranautic Model 4040-LHA-CPA2 RO membranes operating at an overall recovery of 75 percent. The 4-inch, spiral-wound, thin-film, composite membranes will operate at a feed pressure of 266 psig. The RO system will operate at an average flux rate of 11 GFD. The projected permeate characteristics are shown in Table 4.

The permeate water from the RO unit is fed directly to the degasifier and chlorine contact tank. The degasifier will remove carbon dioxide that is present in the permeate stream prior to the chlorine contact chamber. The chlorine contact chamber is located directly underneath the degasifier and will collect the degasified product water. As the product water is collected in the chlorine contact chamber, post treatment chemicals, chlorine and sodium hydroxide will be added to the water. The chlorine will provide the required disinfection, while caustic addition will adjust the pH prior to discharge to the on-site stormwater pond.

The UF/RO cleaning and flushing system consists of a cleaning and flushing solution tank, 5-micron cartridge filter and cleaning pump. The cleaning pump, constructed of corrosion resistant materials to handle high and low pH cleaning chemicals, is designed to clean the UF system in a single pass and the RO system in several passes. The cleaning tank is equipped with an immersion heater for biological cleaning at higher temperatures.

The concentrate from the UF/RO system will be sent to a 60,000 gallon double wall glass-fused-to-steel tank. The tank dimensions are: 25 foot diameter primary tank with a 17 foot sidewall; and 28 foot diameter secondary tank with a 17 foot sidewall. The tank is also equipped with a free-span aluminum roof. The concentrate will then be recirculated to the active lined cells at the landfill or trucked to a county approved industrial deep injection well.

Table 2. Pact Effluent Characteristics

Parameter	Leachate Characteristics (mg/L)
BOD (5 Day - 20-C)	<20
Suspended Solids (before filtration)	25
Suspended Solids (after filtration)	<5
Nitrate Nitrogen	<10
Ammonia Nitrogen	<5

Table 3. Leachate Characteristics Prior to UF/RO

Parameter	Blend (mg/L)	Mean (mg/L)	Peak (mg/L)
TDS	5,100	5,600	7,600
Calcium	250	170	170
Magnesium	90	60	60
Sodium	900	1,150	1,800
Potassium	500	520	540
Barium	0.2	0.2	0.2
Strontium	0.8	0.8	0.8
Alkalinity	1,510	1,800	2,500
Chloride	1,450	1,400	1,900
Sulfate	40	50	100
Silica	15	15	15
Iron	4.0	6.0	9.0
pH	7.2	7.2	7.2
Temperature ℃	25	25	25

Procurement

The project was successfully bid on June 15, 1995. A total of six bids were received. Envirocon of Florida, Inc. was the lowest, qualified, responsive bidder. The total bid price was $3.52 million. The notice to proceed for the project was issued by Martin County on August 14, 1995.

Table 4. Projected Permeate Characteristics

Parameter	Permeate Characteristics (mg/L) as CaCO3
Total Dissolved Solids	334.6
Calcium	4.3
Magnesium	2.5
Sodium	60
Potassium	41.5
Barium	ND
Strontium	ND
Alkalinity	76.8
Chloride	137.1
Sulfate	22.8
Silica	ND
Iron	0.3
pH	4.96
Temperature ℃	25

Construction Schedule

The construction schedule, which includes start-up services, is anticipated to take approximately 12 months. The leachate treatment system is scheduled to be fully operational in August 1996. The contract documents for the PACT and UF/RO processes was based on guaranteed performance specifications for a one-year period.

Conclusion

The combination of the PACT and UF/RO processes will provide Martin County with a long-term solution to landfill leachate management at the Palm City II Landfill.

References

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Vermiculture as a Domestic Wastewater Class A Stabilization Methodology

Bruce R. Eastman

Orange County Environmental Protection Department in partnership with the city of Ocoee, American Earthworm Company and Mid Florida Mining have completed a pilot study to determine the feasibility of using vermiculture (earthworms) for pathogen stabilization of domestic wastewater residuals to a Class A, which is the highest degree of stabilization as defined by EPA.

This project was the concept of Barnell Logue, owner of American Earthworm Company, and me. Mr. Logue had been working with earthworms *(E. Fotida)*, for a number of years, in the solid waste industry and had performed some vermicomposting with wastewater residuals. New and more stringent rules dictated the need for permitting of all reuse and disposal practices related to residuals. In addition, there was no background research into the effectiveness of pathogen stabilization using vermiculture. Some research done by Professor Clive Edwards, of Ohio State University, indicated the possibilities of this methodology.

Public perception of the agricultural reuse of wastewater residuals is negatively accepted to date and, with ever increasing populations, suitable reuse areas are shrinking and costs for transport and application climbing. With the publication of 40 CFR, Part 503, EPA required additional pathogen stabilization, known as the “Process to Further Reduce Pathogens (PFRP).” Orange County, also, passed its own residuals disposal ordinance to cope with ever increasing citizen complaints.

It was the intention to eventually require the highest class of stabilization from residuals generators in order to alleviate public displeasure and eliminate the possibility of any public health concern. This would require residuals to be stabilized to a Class A pathogen standard as defined by the EPA. Most stabilization methodologies require high capital expenditures and use large amounts of energy. This made it incumbent upon the regulatory agencies to investigate new low cost, low tech alternatives to stabilization. Therefore, a partnership was formed with Orange County EPD, Ocoee, American Earthworm Company, and Mid Florida Mining to perform a pilot study to indicate vermiculture’s possible use.

Vince Miller, with the Atlanta office of EPA, was given a proposal of the project and a subsequent permit was issued. DEP’s Dr. Philip Kane oversaw the project and provided technical assistance.

On March 8, 1996, the project began at the Ocoee’s wastewater treatment facilities on Mims Road. Approximately eight tons of dewatered residuals were laid out into two rows, five feet wide by thirty feet long and one and one-half feet deep. Ocoee’s sludge had to be spiked with sludge from Kissimmee to obtain one of the pathogen indicators required for the study. In addition, the sludge was then inoculated with enteric virus.

The sludge was layered on a bed of filter sand with a layer of impermeable clay under it. This was for leachate recapture, if needed, which would be collected in a plastic trash can at one corner of the sand pad. A canopy shed was constructed over the rows to keep weather out and for better moisture control. Also, a chicken wire fence was installed to keep out animals. The test row was then seeded with fifty pounds of *E. Fotida*. The second row would serve

Total and Fecal Coliform (MPN) Results

Sample Identification	Log MPN/g Total Coliform	Log MPN/g Fecal Coliform
1. Test Row (NE)	0.099	0.093
2. Test Row (C)	1.07	1.05
3. Test Row (SE)	1.07	1.05
4. Control Row (NE)	1.07	1.05
5. Control Row (C)	1.07	1.05
6. Control Row (SE)	1.07	1.06
7. Worms (Gray Tub)	0.58 (MNP/ml)	0.48 (MNP/ml)
8. Worms (Blue Tub)	0.58 (MNP/ml)	0.48 (MNP/ml)

Total and Fecal Coliform (MPN) Results

Sample Identification	Log MPN/g Total Coliform	Log MPN/g Fecal Coliform
1. Control Row (NE)	0.065	0.047
2. Control Row (C)	0.043	0.058
3. Control Row (SE)	0.064	0.049
4. Test Row (NE)	-0.28	-0.16
5. Test Row (C)	-0.21	-0.00
6. Test Row (SE)	-0.32	-0.00
7. Worms (Composite)	-0.00 (MNP/ml)	-0.00(MNP/ml)

Indicator Organisms Baseline Data: Plate Count Results

Sample Identification		Log CFLU/g Plate Count
1. Test Row (NE)	A. TL	376
	B. FC	301
2. Test Row (C)	A. TL	423
	B. FC	314
3. Test Row (SE)	A. TL	427
	B. FC	313
4. Control Row (NE)	A. TL	399
	B. FC	313
5. Control Row (C)	A. TL	453
	B. FC	326
6. Control Row (SE)	A. TL	451
	B. FC	329
7. Worms (Gray Tub)	A. TL	5 (CFU/ml)
	B. FC	5 (CFU/ml)
8. Worms (Blue Tub)	A. TL	6 (CFU/ml)
	B. FC	5 (CFU/ml)

Indicator Organisms Baseline Data: Plate Count Results

Sample Identification		Log CFLU/g Plate Count
1. Control Row (NE)	A. TL	113
	B. FC	70
2. Control Row (C)	A. TL	123
	B. FC	99
3. Control Row (SE)	A. TL	116
	B. FC	76
4. Test Row (NE)	A. TL	1.14
	B. FC	2.8
5. Test Row (C)	A. TL	2.3
	B. FC	-0.0
6. Test Row (SE)	A. TL	1.14
	B. FC	-0.0
7. Worms (Composite)	A. TL	-0.00 (CFU/ml)
	B. FC	-0.00 (CFU/ml)

as the control for the project which was scheduled to last for ninety days. Worm density was determined by amount of food that could be consumed in a day as well as reproductive rates. Samples of worms and residuals, for baseline data, were taken by Tri-Tech Laboratories and analyzed for the four pathogen indicators listed in Part 503, (Fecal Coliform, Salmonella, Helminth Ova and Enteric Virus). Each row had one sample collected from the northeast end, center of row and the southeast end. Results were positive for all samples except one negative Helminth Ova in the control row and two negatives, one in the control and one in the test row, for Enteric Virus. Worms were analyzed for the same pathogen indicators and were negative for all.

Worm densities were calculated at consumption rates of one times body weight per day. However, it appeared the worms were eating upward of two times their body weight. Therefore, the project was cut short at sixty-two days as opposed to the original ninety days. During that time each row was watered equally and turned with a pitchfork as needed for inspection of the worms. No leachate was generated from the project and there were no unusual occurrences.

Final data samples were taken at the end of the sixty-two days. Analysis indicated a significant reduction of total coliform and fecal coliform. All samples from the test row were negative for E. Coli and negative for Salmonella, Helminth Ova and Enteric Virus. The control row indicated reduced pathogen indicators except Helminth Ova, which was negative. The worms again tested negative for all parameters.

It is obvious that vermiculture is effective as a stabilization method for wastewater residuals. The next question is how practical will this method be in a full scale operation? Currently, a two year study is being developed by Orange County EPD, Ocoee, American Earthworm Company, and Mid Florida Mining.. A full scale operation will stabilize all residuals produced by Ocoee and distribute the products, worms and castings, with a follow-up sampling program to assure stabilization and product quality.

Vermiculture may very well be an answer to the problems of residuals disposal and reuse, at the least it will be an additional tool giving generators another option.

Helminth Ova Result

Sample IdentificationREACTION	GROWTH	UNITS
1. Control Row (NE)	<1	OVA/4g
2. Control Row (C)	<1	OVA/4g
3. Control Row (SE)	<1	OVA/4g
4. Test Row (NE)	<1	OVA/4g
5. Test Row (C)	<1	OVA/4g
6. Test Row (SE)	<1	OVA/4g
7. Worms (Composite)	<1	OVA/4ml

Enteric Virus Results

Sample Identification	CPE REACTION	Units
1. Test Row (NE)	-	PFU/1g
2. Test Row (C)	+	PFU/1g
3. Test Row (SE)	+	PFU/1g
4. Control Row (NE)	+	PFU/1g
5. Control Row (C)	-	PFU/1g
6. Control Row (SE)	+	PFU/1g
7. Worms (Gray Tub)	-	PFU/1ml
8. Worms (Blue Tub)	-	PFU/1ml

Enteric Virus Results

Sample Identification	CPE REACTION	Units
1. Control Row (NE)	-	PFU/1g
2. Control Row (C)	-	PFU/1g
3. Control Row (SE)	-	PFU/1g
4. Test Row (NE)	-	PFU/1g
5. Test Row (C)	-	PFU/1g
6. Test Row (SE)	-	PFU/1g
9. Worms (Composite)	-	PFU/1ml

Enterotoxigenic E. Coli Results

Sample Identification	ETEC Results	Log MPN/g Fecal Coliform
1. Test Row (NE)	+	0.093
2. Test Row (C)	+	1.05
3. Test Row (SE)	+	1.05
4. Control Row (NE)	+	1.05
5. Control Row (C)	+	1.05
6. Control Row (SE)	+	1.05
7. Control (15-5065A)	+	NA
8. Control (15-4921)	-	NA
9. Worms (Gray Tub)	-	0.48 (MNP/ml)
10. Worms (Blue Tub)	-	0.48 (MNP/ml)

Enterotoxigenic E. Coli Results

Sample Identification	ETEC Results	Log MPN/g Fecal Coliform
1. Control Row (NE)	+	0.047
2. Control Row (C)	+	0.058
3. Control Row (SE)	+	0.049
4. Test Row (NE)	+	-0.16
5. Test Row (C)	+	-0.00
6. Test Row (SE)	+	-0.00
7. Control (15-5065A)	+	NA
8. Control (15-4921)	-	NA
9. Worms (Composite)	-	-0.00 (MNP/ml)

Salmonella Results

Sample Identification	GROWTH REACTION	Units
1. Test Row (NE)	+	7 cell/g
2. Test Row (C)	+	3 cell/g
3. Test Row (SE)	+	4 cell/g
4. Control Row (NE)	+	9 cell/g
5. Control Row (C)	+	2 cell/g
6. Control Row (SE)	+	6 cell/g
7. Control (15-5350A)	+	15 cell/g
8. Control (15-5255)	+	NA
9. Worms (Gray Tub)	-	NA
10. Worms (Blue Tub)	-	NA

Salmonella Results

Sample Identification	GROWTH REACTION	Units
1. Control Row (NE)	+	1 cell/g
2. Control Row (C)	-	<1 cell/g
3. Control Row (SE)	-	<1 cell/g
4. Test Row (NE)	-	<1 cell/g
5. Test Row (C)	-	<1 cell/g
6. Test Row (SE)	-	<1 cell/g
7. Control (15-5350A)	+	12 cell/g
8. Control (15-5255)	-	NA
9. Worms (Composite)	-	NA

Helminth Ova Results

Sample Identification	#OVA/CYST	Units
1. Test Row (NE)	4	OVA/4g
2. Test Row (C)	1	OVA/4g
3. Test Row (SE)	4	OVA/4g
4. Control Row (NE)	<1	OVA/4g
5. Control Row (C)	2	OVA/4g
6. Control Row (SE)	1	OVA/4g
7. Worms (Gray Tub)	<1	OVA/4ml
8. Worms (Blue Tub)	<1	OVA/4ml

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Deep Well Injection in Florida

William A. J. Pitt

The first recorded instance of deep well injection in Florida was in 1943. Brine produced as a by-product of oil extraction from the Sunniland oil field in southwest Florida was disposed of by pumping it back into the lower zones of the Floridan aquifer, specifically into an early Eocene age formation called the Oldsmar Limestone. The geologic interval within the Oldsmar Limestone into which the brine was being injected was referred to as the "Boulder Zone." This name was given to that injection zone by the oil well drillers themselves as a testimony to the difficulty they encountered when drilling through it. The zone is very cavernous, and when the drillers penetrated the top of the caverns, unsupported portions of the cavern roofs would drop to the floor of the caverns. Drilling through those fallen rocks would give the impression of drilling through loose boulders. It made drilling difficult, causing not only loss of drilling fluid circulation but also presenting an unsteady surface on top of which the drill bit would wobble and shake before gaining a good grip on the solid cavern floor.

In the late 1950s the first injection of municipal effluent began with a single injection well in Broward County just west of Lighthouse Point. Effluent was discharged into the upper parts of the Floridan aquifer, but that was soon abandoned in favor of the more transmissive "Boulder Zone" which allowed greater injection volumes at lower injection pressures. It was also at about this time that concern for potential contamination of overlying aquifers was starting to be considered.

The decade of the 1970's domestic injection wells were developed all along the east coast of Florida, from Dade County in the south to Brevard County in the north, and on the west coast in Pinellas County. Also during this period, several industrial injection wells were developed in the Florida panhandle, and in Polk, Indian River, and Palm Beach counties. Regulations lagged behind and permitting was handled on a case by case basis using unspecific federal and state rules to maximize the protection of the overlying aquifers.

The 1980's witnessed an increasing awareness of the problems associated with wastewater disposal and its effect on the quality of groundwater. This awareness translated into numerous pollution control regulations at federal, state, and local levels. In 1981 Chapter 17-6 (now 62-610 Wastewater Facilities Regulation) was enacted to control the discharge of wastewater through spray irrigation, percolation pond, wetland disposal, and overland flow. As a result of these and other regulations, the cost of wastewater disposal escalated, and smaller utilities began to consider deep well injection and its attractive economic benefits. Its inherent problem of high construction cost is offset by its economical operation, low maintenance cost, and the fact that it requires the least amount of land of any other disposal alternative. It can be constructed on site, eliminating the need for long pipelines or outfalls. When properly designed and constructed. it is also environmentally sound.

The enactment in 1982 of the Florida Underground Injection Control Rule (Chapter 17-28 and now 62-528), formalized the permitting process for deep well injection and made it more understandable and easier to implement. The following year Florida received enforcement primacy for deep well injection from the federal government. This reduced permitting difficulties and raised the appeal of deep well injection for smaller utilities.

Also in the 1980s the municipal/industrial deep injection well made its first appearance in Florida. The first was installed in Sarasota County for disposal of reject water from a desalination plant. It was also the first injection well of any type to become operational in Sarasota County. Within a year two similar wells were under construction in that county, and soon the use of deep well injection for desalination plant reject water became the standard throughout south Florida.

Unlike spray irrigation, overland flow, or rapid infiltration basins, deep well injection avoids potential contact by placing the treated waste stream thousands of feet below the ground (although that same level of treatment would have allowed spraying it on the surface of the land). In addition, it reduces the contamination of the surficial aquifers and of groundwaters. In southeast Florida it is a superior disposal alternative to ocean outfalls because it avoids contamination of near shore waters and the damage to the fragile reefs. In Southwest Florida, deep well injection is used to avoid discharging waters with low level radioactive wastes via ocean outfalls.

The l990's has seen a continued growth of injection wells. A new development has been municipal/industrial deep injection wells for the disposal of treated landfill leachate. The first such in Florida was drilled in Charlotte county in 1992. It consists of fiberglass reinforced tubing, removable rubber packers, and a fluid-filled pressurized annulus that is continuously monitored. It disposes of leachate treated to drinking water quality levels in an activated carbon batch plant. The second of these type of leachate disposal deep injection wells is currently undergoing permitting. It was designed by CDM for the department of solid waste management in Dade County.

Deep injection wells are also used for water supply purposes. A recent development has been the re-emergence of deep injection wells for the storage of excess water for use at a later critical time. These Aquifer Storage and Recovery (ASR) wells are being used to store raw water as in the past, but are now also being used to store treated water. The stored treated water can be recovered and piped directly to the distribution system of a municipality without additional need of treatment, other than chlorination.

The latest development associated with aquifer storage and recovery wells involves injection of treated wastewater. This new development is different from previous ASR projects in that it is considered a reuse of reclaimed water. ASR with treated effluent is now undergoing the permitting process in Charlotte County. The wastewater effluent injected down these wells is to be treated to a higher degree than secondary treatment,but, to maintain treatment costs at affordable levels ,water quality parameter exemptions and aquifer exemptions may also be requested in order to meet state and federal regulations. Proposed wastewater reuse rules now being developed are expected to exert regulatory pressures that will ease permitting and help make widespread use of the alternative.

The Future Of Deep Well Injection In Florida

There are currently nearly 100 Class I injection well systems planned or in operation in Florida. Seven of them are municipal/industrial injection wells discharging desalination plant concentrate. Ten are industrial wells. The remaining, a large majority, are municipal wastewater discharge wells. Of the desalination reject injection wells, none has ever shown any indication of leakage or of upward travel of the injected fluids or of the overlaying fresh water. These wells inject water that is nothing more than the same water originally withdrawn except that its salts have been concentrated. This concentrate is then injected into an even more salt concentrated water, which if anything is benefited from the fresher mix.

Some of the municipal wells have been determined to have leaked effluent into zones above the injection zone and, although they are a very small number and located in border areas of the hydrogeologic regions suitable for deep well injection, they have been used as the barometer by which all injection wells are judged. What is almost always ignored is that the leakages have been detected in monitor wells designed specifically for that purpose before the leakage can affect our drinking water aquifer. To date, none of our drinking water supplies have been affected by a leaking deep injection well.

Deep injection well disposal remains one of the most attractive (both economically and environmentally) methods of treated effluent disposal and even with a strong emphasis on reuse deep well injection will still be needed for standby disposal. When a suitable injection zone and confining zone above it is present, there are no impacts from deep injection wells. This level of environmental protection can only be said of deep well injection; all other alternatives pose a much greater threat to the drinking water supplies and to the environment.

- Ocean outfalls not only affect the salinity of estuaries and the nutrient levels of the water, but their construction damages grass banks, coral heads, and other nearshore habitats.
- Reuse by spray irrigation of parks and green areas allows the placement of secondary treated effluent on the land surface in contrast with deep wells that place it thousands of feet below. Reuse brings the effluent in contact with people, and effluent tagged for reuse usually only receives filtration and chlorination beyond secondary treatment before it is sprayed. Most injection well systems also add filtration and chlorination beyond secondary treatment to avoid clogging of the geologic strata. Additionally, spray irrigation systems enrich the shallow water table drinking water aquifers with percolating nutrient rich effluent, while deep injection systems keep the effluent well below the water table aquifers. Finally, because many viruses and bacteria are known to survive even end point chlorination, and since end point chlorination is not required for spray irrigation, the issue of health safety with spray irrigation is still being debated.
- Percolation ponds carry similar problems and risk factors to the shallow aquifers as does spray irrigation, but the health concerns are not as serious because most percolation ponds are fenced-in from public contact.
- Slow rate infiltration via irrigation or via overland flow in access controlled sites generates little or no health concerns, but it poses environmental degradation of the surficial aquifer below the infiltration fields. This is probably the most expensive method, because of the large land requirement and the highly permeable land that is required. Good permeable soils are required, and the area of land required is in the range of 120 acres per million gallons of daily flow.
- Surface water discharges or direct reuse after advance treatment are probably the best environmental alternatives, but the costs are prohibitive at this time unless the water can be resold as drinking water, and the idea has no public appeal.

Deep well injection provides the opportunity for an orderly development of reuse practices by matching reuse expansion to injection reductions. This takes place in stages as the demand for wastewater for reuse increases. It is expected that deep well injection will continue to be the emergency release system for all the other alternatives.

Regulatory Chronology

Prior to the 1974 Safe Drinking Water Act, the implementation of Federal Underground Injection Control (UIC) rules in Florida followed a Federal Water Quality Administration order dated October 15, 1970. This document in fact had little effect on injection well construction unless federal funds were involved. The state criteria at the time was that deep injection wells could inject into the lower Floridan aquifer only. The Floridan aquifer in south Florida had been divided into three parts, upper, middle and lower. The state policy was that the upper Floridan was to remain untouched, and was being preserved for future use as a source of water for desalination purposes.

The middle Floridan was to be used to monitor the effect of withdrawals from the upper Floridan for desalination and to monitor the effect of injection into the lower Floridan. The lower Floridan was the only portion of the aquifer that could be used for injection. The effect of this state policy was critical to southwest Florida (including some areas of Sarasota, Charlotte, and other counties) because under that criteria it was hard to find a sufficiently permeable zone for large volume injection in the lower Floridan. Although there are very suitable permeable zones in the middle Floridan, the policy banned the possibility of injecting into those zones. A few years later, after the criteria had changed, it would be possible to develop injection wells into zones above the lower Floridan.

Starting in early 1973, UIC rules implementation in Florida followed a Decision Statement (Decision Statement No. 5) from the EPA administrator. Up to that time each injection system was evaluated individually and under different criteria. The EPA and the State of Florida relied heavily on the advise provided by the USGS which at the time possessed most of the scientific knowledge on the subject of deep well injection in Florida. The Decision Statement began the consolidation of a wide array of ideas into a single format, and was the precursor to the first write up of federal rules for deep well injection. In 1980 the UIC rules were consolidated in the Code of Federal Regulations (40-CFR Parts 144 and 146)and the general program requirements were presented in 40-CFR 122.

After the 1980 amendments to the 1974 Safe Drinking Water Act, EPA developed a mechanism for granting individual states primary enforcement responsibility or “primacy” on UIC and issued a guidance paper effective May 1981. Shortly thereafter, in August 1981 the Florida Regulatory Commission reviewed the first draft of the proposed UIC regulations that would result in the granting of primacy to the state. The regulations thus drafted became Chapter 17-28 (now 62-528) of the Florida Administrative Code. This Chapter 17-28 had been developed by the DEP in consultation with a group of advisors and representatives from industry, municipalities, consultants, environmentalists and others; of which this writer was a member representing the Engineering Societies (ASCE and FES). The Florida Regulatory Commission finally adopted the UIC Chapter 17-28 in April 1982 and in April 1983 EPA accepted Florida into primacy for this UIC program. As of this writing (January 1995) the 1983 regulations have not changed although the interpretation and application of the rules have been stiffened by the individual regulators and permit reviewers within the Technical Advisory Committees (TAC).

On-Going UIC Rulemaking

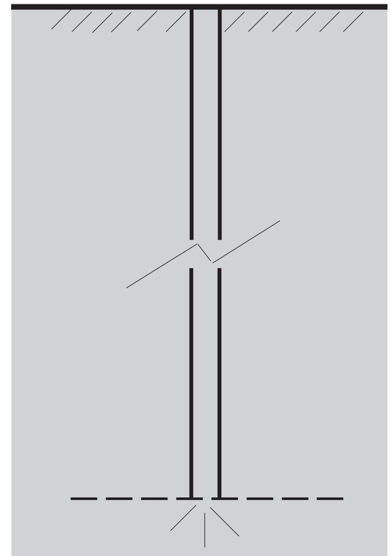
In 1989 a Chapter 17-28 rule revision attempt was begun and a new version, Chapter 62-52B, was approved in March. The new UIC rule is only slightly different from the existing one. The primary reason for changing the rule is to bring it in line with the federal rule and that way avoid challenges caused by differing interpretations between operators, regulators, and groups opposed to deep well injection. The new rule has now undergone three public hearings held in Tallahassee, Tampa, and West Palm Beach. Many of the public comments raised at the public hearings have been incorporated into the rule.

There are several elements in the new rule which will have the power to affect small utilities. Some effects will be restrictive but others will not be. For example, the new proposed rule carries language requiring that injection facilities located within a water resource caution area (a water shortage area such as the southwest Florida area), will have to conduct a reuse feasibility study and if the study shows that reuse is feasible then a permit renewal applicant will have to implement some reuse or an injection permit will not be issued. The reuse study will also need to be conducted exactly as dictated in Section 403.064 of the Florida statutes. Little leeway will be given to the engineers conducting the reuse studies. Another new change which will be very beneficial to every utility is that under the new rule any well that began operations after June 1, 1985 will be allowed to operate at injection velocities of 10 feet/second where before the maximum allowed velocities were 8 feet/second. This increases the actual capacity of the typical well by about 25 percent.

Many of the new changes are difficult to evaluate as to the beneficial or detrimental effect they may pose. There will now be more opportunity for public participation at the TAC meetings and better advertised public meetings, the mechanical integrity tests are being standardized for stricter control, the construction permit process for facilities that are planning expansion will be subject to review by other agencies not previously involved including Fish and Wildlife, Department of Agriculture, Soil Conservation Service, and even the Army Corps of Engineers. The Water Management Districts will also be more involved because of the reuse issue. In general however, the majority of the changes in the new rule address industrial wells and desalination reject wells that require tubing and packers and not domestic wastewater injection wells.

Other Recent Rules Affecting Injection Wells

In 1994 there were new legislative attempts at trying to limit the use of deep well injection. However, the effort was not aimed directly at the injection wells, as in the past, but indirectly at the wells' function. The 1994 legislature emphasized water reuse as the most desirable means of effluent disposal, and because deep injection wells are seen as counter to the reuse notion, injection wells were once again under attack. A position paper prepared by a coalition of utilities, lobbying efforts by the well drilling industry, and efforts of the engineering societies were successful in removing the more radical limitations on deep well injection from the newly enacted reuse rules, but there is still an erroneous understanding in the legislative community about deep injection wells. This misunderstanding has been fueled by uninformed newspaper articles and by allegations of certain individuals with little or no knowledge of the technical elements of deep well injection. According to a drilling industry lobbyist, simply pointing out that "the quality of the water injected thousands of feet underground is the same as that of reuse water irrigated on the land surface" is sometimes all that needs to be said to convince legislators that injection wells are unjustly criticized.



Two reuse rules passed the legislative process in 1995 and became law. The first rule (H-1743), known as the Apricot Act, encourages water reuse by allowing up to 30% of the reuse flow to be discharged to surface waters when reuse demands decrease. This discharge, however, must still meet all the discharge criteria for surface water discharges. The act also directs DEP to formulate standards by which reclaimed water can be stored in the Floridan aquifer for future reuse.

The second rule (H-1305) develops criteria for utilities to recover "prudent" costs of reuse implementation and requires utilities in water shortage areas to conduct reuse feasibility studies and to implement the results of the studies if feasible.

At the federal level there is pending regulation that would redesignate certain chemicals and materials as hazardous wastes, including certain levels of radioactive materials. This plays an indirect role in the injection well regulatory atmosphere of Florida because in Florida the UIC rule has always prohibited disposal of hazardous wastes, but this issue is becoming more and more the subject of debate since the determination of a waste as hazardous sometimes depends only on quantity, sometimes only on the material itself or on its synergistic effects, and sometimes even on who is concerned about the material. For example, chlorine at the treatment plant is just another water treatment chemical, but to the DOT it is extremely hazardous while in transportation.

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