Water Treatment Lime Residuals and Cement Kilns: Lower Disposal Costs and Beneficial Reuse

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The City of Gainesville, through its utility, Gainesville Regional Utilities (GRU), owns and operates the Murphree Water Treatment Plant (WTP), which has a service population of over 175,000. The plant has a rated capacity of 54 mgd, with an annual average production of 25 mgd. The raw water total calcium carbonate hardness (from the 16 Floridan Aquifer wells) typically ranges between 260 and 310 mg/L. The plant was constructed in 1975 to be one of the most modern conventional lime-softening water treatment plants in the state.

The plant process utilizes calcium quicklime (CaO) to facilitate the softening reaction:

$$CaO + Ca(HCO_3)_2 = 2\ CaCO_3 + H_2O$$

The hardness precipitates out of solution in the form of calcium carbonate. No soda ash or polymer is added. The residual is approximately 98 percent calcium carbonate. Common terms for the residual include lime sludge or lime residuals. Approximately 30 dry tons of lime residuals are produced daily in the process of meeting water demand.

Until the early 1990s, GRU disposed of lime residuals through land application at the neighboring Alachua county farms. Due to the clay-like nature of the lime residuals, spreading required specialized equipment, making land application a labor intensive practice that was discontinued when the option of lime slurry hauling became available.

Lime slurry recycling is done by transporting the liquid residual through contract haulers to electric generating facilities in the central part of the state. There, the slurry is used in wet scrubbers to help decrease sulfur dioxide emissions. Although this is a fairly workable means of disposing of the lime residuals, the cost per dry ton is high ($54/ton) since the load is only 30 percent solids, and no lime slurry is removed when the power plants are in outage or shut down for annual maintenance. In addition, the lime slurry market is disappearing as power plants have converted to dry scrubbers, which completely eliminates their need for lime slurry. Some power plants installed their own lime slurry feed system, effectively halving their demand for lime slurry from water treatment plants. During these periods of low demand, the water plant must de-water with an older-style rotary drum vacuum filter to dry the material, which then must be stored in the lime residual stockyard. The dried product from the vacuum filter is approximately 60 percent total solids, and after six months of storage the residuals become 70 percent total solids.

The diminishing use of lime slurry at power plants resulted in a decade of intermittent solids production. As a result, GRU became pressed to find options for solid lime residual disposal and began an extensive review of potential reuse options, as well as costs for landfill disposal. Guidance documents included an analysis of multiple Floridan lime residuals that consistently met applicable standards (Townsend et al., 2001), as well as a Florida Department of Environmental Protection (FDEP) document for land application (FDEP, 2006). An American Water Works Association (AWWA) study in 2009 of 46 water treatment plants identified that only 35 percent of them practice reuse primarily through agricultural application or topsoil manufacturing, with the remaining systems disposing through landfilling or sewer discharge (AWWA, 2009). However, one technical report for the Iowa Department of Transportation reported the use of 20 tons of water treatment plant lime residuals in cement production (Baker et al., 2004). The constraints for GRU's disposal of lime residuals included a timely solution before hurricane season, budget considerations, and choosing an environmentally responsible method.

Methodology

A lime residual sample was collected and analyzed for metals, semi-volatiles, volatiles, mercury, pesticides, and herbicides. After the analysis, an initial request for proposals for solid lime residual disposal yielded no responders. However, given the high purity and clean appearance of the residual, a paint manufacturer was interested. Unfortunately, the material was later determined to be unsuitable. The GRU then explored options to offer the lime residual as fill dirt in a remediation site, but the lime residual was unsuitable for that process as well. Other options were also discarded when the material was determined to be unworkable for roadbase material due to its low plasticity and for batch cement plants due to its clay-like properties. More options were eliminated due to the lack of local industrial partners. These included the use of the calcium carbonate in extender and filler materials, asphalt roofing products, glass manufacturing, floor coverings, animal feed, beet sugar refining, drywall compounds, and cultured marble. Additionally, the potential for use in irrigation canal lining was discarded in the screening process due to the low quantity of material required and the lack of local applications.

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The GRU is also an electric utility, so using the lime residual in its power generating process was explored. However, direct use for emissions control was not possible, in that GRU's 235 MW coal-fired Unit 2 at its Deerhaven Generating Station employed a dry scrubber, which has no use for lime residual. Using the lime residuals on the coal piles for dust control at Deerhaven was considered. The utility also contacted Seminole Electric Cooperative, but the GRU lime residuals lacked the necessary chemistry for the Seminole process.

Moving in another direction, GRU contacted dairy farms, but it was determined that the land application of bovine waste created alkaline soil conditions. Further searches eventually identified two peanut farmers who could use approximately one third of the stored residuals; however, the delivery had to be timed to coincide with planting season in the fall and the application method was uncertain.

Also along agricultural lines, GRU was contacted by a rancher interested in converting

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silvicultural uplands into pasture and needed large quantities of lime to add alkalinity to the soil. Since the soil in the surrounding pine timberlands is acidic, the rancher needed to adjust the soil pH in order to convert the timberlands into pasturelands that could support grasses. The rancher proposed applying approximately 2 tons/acre, an application rate below the 9 tons/acre listed in the FDEP guidance document. It was determined that no water bodies would be impacted after both an aerial map review and a site inspection. Approximately 132 tons were transported to the silvicultural property, but application efforts were hindered by frequent clogging of the spreading equipment. Unfortunately, the Knight Slinger manure spreader used in the 1990s was no longer operational and a suitable method for land application was not identified after extensive interviews with multiple manufacturers, vendors, and farmers. Although the fertilizer spreader had been used successfully with another utility's lime residuals, it clogged repeatedly with the lime residuals from GRU.

The GRU was also contacted by an enterprising farmer who owned an abandoned borrow pit. The farmer's proposal included transportation and disposal costs. However, GRU had to decline the use of a nonregulated landfill, even though the distance to the farmer's property was significantly less than either of the two lined landfills in the area.

Success was finally achieved with the cement manufacturing industry. Following up on a 2004 Iowa study that used 20 tons of lime residual at a cement kiln, GRU contacted a local Portland cement production facility and provided them with liquid and solid samples for analysis. All results were satisfactory. The cement plant obtained a Title V air permit modification to add the new material in the quarry with the raw materials. Due to stormwater regulations, the cement plant was required to incorporate all GRU lime residuals the day of delivery. Given concerns about clogging the hopper, the initial transfer was limited to 220 tons. It was determined that the best point of residual addition was in the quarry with the sand and gravel materials. The cement plant instrumentation required adjustment and monitoring as the lime residuals were a higher concentration of calcium carbonate than the native limerock mined from the on-site quarry. Once FDEP approval was obtained, the cement plant ceased production for six weeks to facilitate the new procedures. During that time, GRU contacted a second cement plant with similar operations, and deliveries were coordinated to both cement facilities to optimize GRU's loading of the material. GRU then contracted a commercial hauling company and the dump trucks were loaded by utility operators.

Table 1. Screening, Pilot, and Full-Scale Options Investigated for Lime Residual Disposal

Market	Purpose	Issues	Decision
Paint Production	Base pigment in paint	Small variations in color made residuals unsuitable	No
Fill Material	Fill dirt for remediation site	Use not approved by FDEP	No
Crop Liming	Alkalinity for crop production	Could not be spread using available equipment, planting schedules, 1 ton/acre meant coordinating with many farms	No
Pineland Conversion	Alkalinity for grasses	Could not be spread using available equipment	No
Roadbase Material	Bearing surface for pavement	Material not suitable for construction	No
Chemical Production	Neutralize acidic waste streams	No use for solid, only liquid byproduct. Small quantity desired.	No
Concentrated Animal Feeding Operations (CAFO)	Vector control, alkalinity for soils	CAFOs are not required to apply lime to biosolids, alkalinity provided through biosolids	No
Power Plants	Dust control on coal storage piles	Facilities not interested	No
Borrow Pit	Stockpile residuals in borrow pit for agricultural use in the future	Not a regulated facility, no stormwater control, no available means for spreading	No
Extender and Filler Material	Raw material	No local application	No
Dry Wall Compounds	Raw material	No local application	No
Cultured Marble	Raw material	No local application	No
Irrigation Canal Lining	Prevents water loss through seepage	No local application	No

Pilot and Full-Scale Application Option	Purpose	Issues	Decision
Timberland conversion	Change acidic soils to neutral pH for pasture soil conditions	Clogging of spreading equipment	No
Cement Plant	Added to raw materials	Silica, daily load limit, weather	Yes

Results and Discussion

Analytical results of the lime residuals consisted primarily of nondetections for metals, volatiles, semivolatiles, mercury, herbicides, and pesticides (Table 2). These results are consistent with previously published results of drinking water treatment lime residuals (Townsend et al, 2001).

To begin the process of lime residual disposal with the cement plants, GRU hauled approximately 40 percent of the stockpiled material to the cement plants over a period of 12 days. Hauling activities were during the main operating hours at the quarry and the water treatment plant. While the lime residuals create storage, stormwater, and application issues with agricultural users, there were few issues with the cement manufacturers. The first cement plant has produced cement with a 10 to 15 percent recycled lime content. The one concern with the second cement plant was deviations in silica content in the transported material compared with the samples provided by GRU, which is still working with the second cement plant to determine the cause for the silica variations. Meanwhile, the first plant adds silica to the raw materials, so minor variations in lime residuals have limited impact on production.

Table 2. Analytical Results

Analyses	Result	Minimum Detection Level	Units
Mercury, TCLP	ND	0.0010	mg/L
Metals, TCLP			
Arsenic	ND	0.024	mg/L
Barium	ND	0.014	mg/L
Cadmium	ND	0.0021	mg/L
Chromium	ND	0.015	mg/L
Lead	ND	0.029	mg/L
Selenium	ND	0.041	mg/L
Silver	ND	0.016	mg/L
Pesticides, TCLP			
Chlordane	ND	0.0008	mg/L
Endrin	ND	0.00016	mg/L
gamma-BHC	ND	0.000060	mg/L
Heptachlor	ND	0.000060	mg/L
Heptachlor epoxide	ND	0.000060	mg/L
Methoxychlor	ND	0.000080	mg/L
Toxaphene	ND	0.0037	mg/L
Herbicides, TCLP	ND	0.00030	mg/L
2,4,5-TP (Silvex)	ND	0.0015	mg/L
2,4-D			

Analyses	Result	Minimum Detection Level	Units
Semivolatiles, TCLP			
1,4-Dichlorobenzene	ND	0.0010	mg/L
2,4,5-Trichlorophenol	ND	0.0017	mg/L
2,4,6-Trichlorophenol	ND	0.00069	mg/L
2,4-Dinitrotoluene	ND	0.00053	mg/L
Hexachlorobenzene	ND	0.00080	mg/L
Hexachlorobutadiene	ND	0.0011	mg/L
Hexachloroethane	ND	0.0007	mg/L
m&p-Cresol	ND	0.00071	mg/L
Nitrobenzene	ND	0.0011	mg/L
o-Cresol	ND	0.0015	mg/L
Pentachlorophenol	ND	0.00066	mg/L
Pyridine	ND	0.0015	mg/L
Volatiles, TCLP			
1,1-Dichloroethene	ND	0.085	mg/L
1,2-Dichloroethane	ND	0.032	mg/L
1,4-Dichlorobenzene	ND	0.030	mg/L
2Butanone	ND	0.070	mg/L
Benzene	ND	0.030	mg/L
Carbon tetrachloride	ND	0.068	mg/L
Chlorobenzene	ND	0.025	mg/L
Chloroform	0.054	0.050	mg/L
Tetrachloroethene	ND	0.048	mg/L
Trichloroethene	ND	0.025	mg/L
Vinyl chloride	ND	0.048	mg/L

ND = Not Detected NELAC Certified Laboratory

The cement disposal process for lime residuals is relatively new and lacks much in the way of comparisons. The 2009 AWWA survey of full-scale plant practices for lime residual disposal did not present recycling at cement kilns. The study using 20 tons of lime residuals eliminated cement plants from further consideration due to transportation costs. However, the cement plant in the study (Baker et al., 2004) was over 90 miles from the water treatment plant, while the greatest distance to a cement plant from the Murphree WTP was only 40 miles, greatly reducing transportation costs.

This new disposal process is a good fit for both industries. The quantity of limerock needed for cement production is greater than the quantity that can be supplied by water treatment plants, which makes for an ideal partnership. Should transportation or weather issues delay residuals delivery, the normal operations of the cement plant are unaffected because the cement plant quarry is an industrial setting capable of efficiently transferring large quantities of materials. The utility benefits from partnering with a company that has site safety and stormwater protection plans. The disposal cost of cement production, as compared with landfill disposal, is 2 percent, versus 18 percent of the Murphree WTP's annual operation and maintenance budget. The cost of liquid versus solid disposal potentially favors cement production solid disposal. However, GRU would have to invest in new rotary drum vacuum filters, storage area upgrades, and excavation equipment to convert the entire disposal process to a dewatered solid product.

Benefits to the cement plant include a reliable source of clean material. The products of drinking water treatment are the combination of NSF Standard 60 certified material and high quality water from the Floridan Aquifer. As a value-added benefit, the potential exists to market the final product for Leadership in Energy and Environmental Design (LEED) credits. Using lime residuals could qualify for Credit MR 4.1 and MR 4.2 Recycled Content, as well as MR 5.1 and MR 5.2 Regional Material. The two cement plants could receive the lime residuals from multiple lime softening plants and the practice could easily be transferred to other cement plants.

The benefits to water utilities are numerous. Given the number of cement plants located in Florida, disposal through lime recycling could be a cost-effective solution for other lime softening water treatment plants. Another benefit for water utilities is that the life span of lime softening facilities can be extended through this process, as the cost of residual disposal has been cited as a reason for constructing costly new membrane filtration treatment facilities. For water systems where hardness is the main treatment concern, lime softening remains a cost-effective treatment option.

In researching disposal options, residual disposal costs for other systems were noted and compared with treatment capacity. The costs associated with hauling to the cement plants was competitive compared with similarly-sized systems that use agricultural application as their disposal method. For the Murphree WTP, the distance to the cement plants was comparable to any potential agricultural application if a reliable means of spreading could have been identified.

If land application of lime residuals becomes regulated to the extent of requiring land application plans, recycling through cement plants would be an attractive alternative. Utilities can coordinate with fewer parties and transfer residuals regardless of planting and harvest schedules, and the utilities are not involved with the application of the material.

Industrial ecology, whereby the byproducts from one industry become inputs

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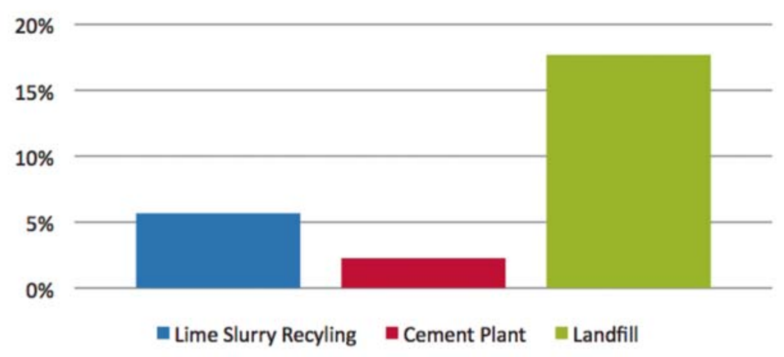

Figure 1. Disposal as a Percentage of O&M Budget

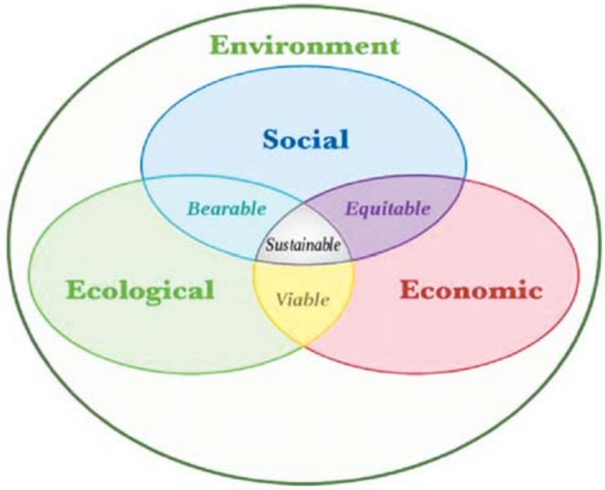

Figure 2. Factors Involved With the Selection of Best Alternatives for Lime Residual Disposals

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for another, is the most efficient, cost-effective, and environmentally sustainable practice for lime residual disposal. As shown in Figure 2, recycling lime through cement production is a practice that provides ecological, social, and economic benefit.

Ecologically, landfill capacity can be preserved and a natural resource can be extended through recycling drinking water treatment residuals. Transporting solids versus liquids means fewer trips to dispose of the same material and shorter hauling distances, which lowers carbon dioxide emissions. Economically, recycling lime residuals offered a lower cost alternative to landfilling and provided a valuable material to cement manufacturers. Socially, recycling drinking water treatment residuals is a mutually beneficial relationship for all involved parties—the utility, the cement manufacturer, the environment, regulators, and the consumer.

While the availability and practice of recycling lime residuals is still growing, the results from GRU's experience support continued research and practice for utility/cement manufacturing partnerships. As R. Buckminster Fuller said: "Pollution is nothing but the resources we are not harvesting. We allow them to disperse because we've been ignorant of their value."

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