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ELECTROCOAGULATION: IMPROVING THE EFFICIENCY AND REDUCING THE FOOTPRINT FOR WATER RECOVERY TREATMENT CENTERS

Prepared by:

Ron Snyder
Frank Berry
Hydrotech, Inc.
and
Roger Lehman, P.E.
Weston Solutions, Inc. (WESTON®)

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Electrocoagulation: Improving the Efficiency and Reducing the Footprint for Water Recovery Treatment Centers

Ron Snyder[1], Frank Berry[1], and Roger Lehman, P.E.[2*]

[1] Hydrotech, Inc.
[2] Weston Solutions, Inc.
*Correspondence should be directed to Roger.Lehman@WestonSolutions.com

ABSTRACT

One solution to address overloaded collection and treatment systems is to develop satellite units for wastewater treatment. The challenge is to implement a treatment system of such efficacy that these satellite units can exist throughout an area without a large footprint. Membrane bioreactors are one option; electrocoagulation is another.

Ecolotech systems are designed to meet effluent criteria that allow the non-potable reuse of the effluent, while solids are transmitted to the centralized wastewater treatment plant. The system can create an unobtrusive water recovery facility by replacing tradition treatment equipment. A small footprint can be used to effect a 95% reduction in wastewater effluent to the collection system, an odor-free system, rapid implementation, and a source of emergency non-potable water. This paper describes the electrocoagulation process, Ecolotech system components, and case study results providing proof of concept for use in small wastewater treatment and water recovery facilities.

KEYWORDS

Electrocoagulation, water recovery, wastewater reuse.

INTRODUCTION

The Clean Water Act of 1972 ushered in a new era in treatment of domestic wastewater. The accompanying federal construction grant program allowed municipalities to offer wastewater treatment to large portions of their communities at relatively low cost. Rapid increases in our population in the three subsequent decades have placed inordinate demands on our infrastructure, including the treatment of wastewater. Most municipal wastewater treatment plants are decades old and yet even as they deteriorate, there is need for expansion. Key sections of the wastewater collection systems in many communities will reach the century mark in the next couple of decades. Across the U.S., the space, time, and capital budget needed to expand these critical pieces of infrastructure are often not available. Add to this mix the fact that regulators have imposed increasingly strict discharge limits for wastewater treatment plants, and we now have a recipe for a crisis.

One proposed solution to this infrastructure crisis is the use of water recovery treatment centers (WRTCs). WRTCs, also known as “satellite,” “scalping,” or “mining” treatment systems, are small treatment units located close to the source of the wastewater and are designed to meet specific effluent criteria based upon the disposal of the effluent (i.e. agricultural irrigation, residential irrigation, industrial reuse, etc). The effluent from the WRTC can be reused in an industrial process, used as make-up water at a generating station, or for both agricultural and urban/suburban irrigation. Membrane bioreactors (MBRs) are common for these types of systems, but the cost can be prohibitive.

METHODOLOGY

Electrocoagulation: An Overview

Electrocoagulation systems have been in existence for over 100 years (Dieterich, patented 1906), using a variety of objects to impart the electrical charge into water, including plates, balls, fluidized bed spheres, wire mesh, rods, and tubes. Coagulation is the process of aggregating smaller particles into larger particles known as floc. Coagulation can be induced either chemically or electrically. Chemical coagulation is used in many water and wastewater treatment processes around the world; however, the cost of chemicals and resulting sludge volumes as well as byproducts are causing many facility operators to reconsider the use of chemical coagulation in their treatment process.

Schulze demonstrated in 1882 (Benefield et al., 1982) that contaminants in water such as heavy metals, organics, and inorganics are held in solution primarily by electrical charges and that by disrupting these charges, contaminants will begin to aggregate into larger flocs that can be removed by filtering or settling. Woytowich (1993) showed that 98% of oil emulsions and heavy metals can be removed from bilgewater using electrocoagulation. Additionally, previous studies have also shown electrocoagulation to be effective at killing bacteria in wastewater.

Several studies (Renk, 1989; Franco, 1974; Duffey, 1983) have shown that heavy metals treated with sufficient activation energy will precipitate into acid-resistant oxide sludges like $NiFe_2O_4$ that pass the Toxicity Characteristic Leaching Procedure (TCLP), allowing the sludge to be reclassified as non-hazardous.

Ecolotech System

The challenge for electrocoagulation has long been to process wastewater at a sufficient rate to make it economical (one million gallons per day or larger). This paper presents a point-of-use water recycling system, Ecolotech, that is attainable at a reasonable cost, does not contribute to environmental problems through the addition of chemicals, and does not require significant space. The concept of the system is shown in Figure 1. The key feature of the Ecolotech WRTC, which enables the unobtrusive integration of a water recovery facility within a planned community, is the replacement of traditional, bulky flocculation/coagulation and biological treatment equipment and materials with a small state-of-the-art electrocoagulation unit, shown in Figure 2. This size facility enables the unobtrusive integration of a water recovery facility within a planned community. It is the unique application of this proven technology that enables the small facility footprint and offers the following advantages over the alternative of constructing additional trunk sewer capacity:

- 95% reduction in wastewater effluent from the development, resulting in:
  - Savings in wastewater transportation costs
  - Elimination of expensive and time-consuming sewer expansion projects
- Water reuse
- Odor-free operation
- Rapid construction to support the development needs
- Provides an emergency water supply for firefighting
- No local biosolids management needed since they are passed to centralized treatment plant for disposal
- Potential housing of other services, such as telephone, Internet, cable, etc

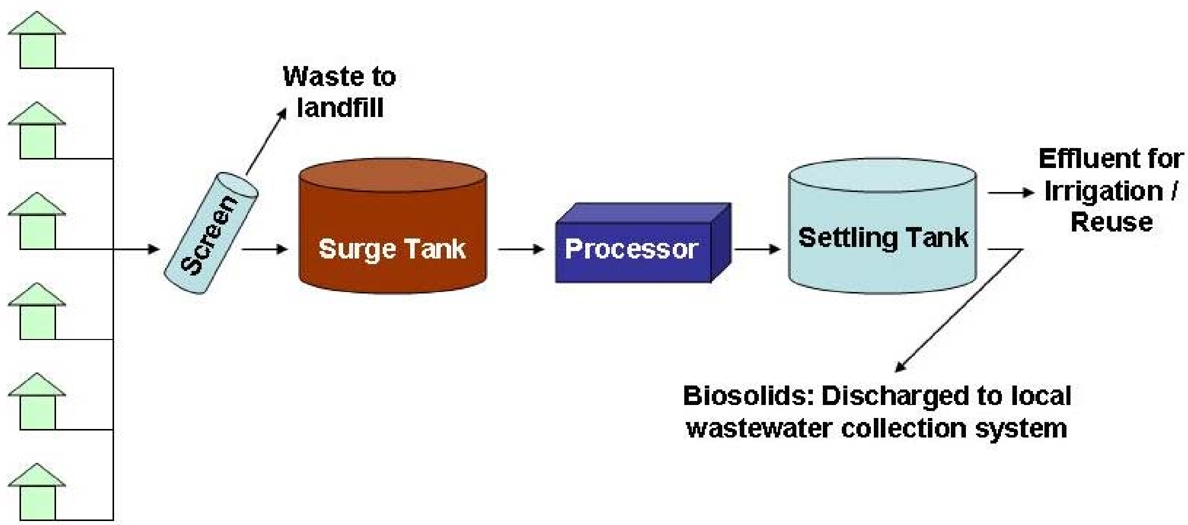

Figure 1. Ecolotech system concept.

Process Description

The typical Ecolotech WRTC consists of screening equipment, an electronic precipitation and solids settling unit, and settling tanks. California DHS Title 22 requires the effluent to pass through an approved filter and sterilization system to satisfy regulations permitting the unrestricted reuse of recovered water. A conceptual process flow diagram, showing a fully redundant system, is provided as Figure 3. The system depicted is California DHS Title 22 compliant with approved filters and disinfection components. The following sections provide more detail about the components in the WRTC.

Screening

A screener/compactor is used to remove large debris from the influent. The removed debris is pressure washed to an extent that virtually eliminates fecal matter and odor. (Treated effluent is used for the wash water to minimize the use of potable water.) The remaining debris is then compacted. The end product is a dry solid that can be discarded as solid waste. The screened water flows into an underground storage tank for subsequent treatment. The selection of the screen unit is important to the process. Experience during pilot testing found that some screening

Figure 2. An electrocoagulation unit.

units permitted unacceptable levels of particulate material to pass through. Hair and certain other material, if not properly removed, can cause operational problems with pumps and valves. The key feature of the Ecolotech unit is that the screener has small pore size (2mm) and uses shearing maceration. Figure 4 shows a typical setup for a screen unit and Figure 5 shows an example of the end product from a properly operating screener/compactor unit that washed the debris.

Electrocoagulation

The electronic precipitation and solids settling processor is the heart of the system (see Figure 2). The processor treats the wastewater through electrocoagulation. The unit consists of a large enclosed chamber that contains a series of metallic plates that serve as anodes and cathodes. The plates are electrically charged with DC current. The screened wastewater is pumped into the processor and is bombarded with electrons as it passes through the plates. Parasites in the water are destroyed instantly during this phase, with a greater than 4 log kill rate and with virtually no regrowth. Suspended particulates in the wastewater are electrically charged, causing particle aggregation. Dissolved solids precipitate out of solution and combine with the suspended solids, forming a floc that facilitates subsequent settling.

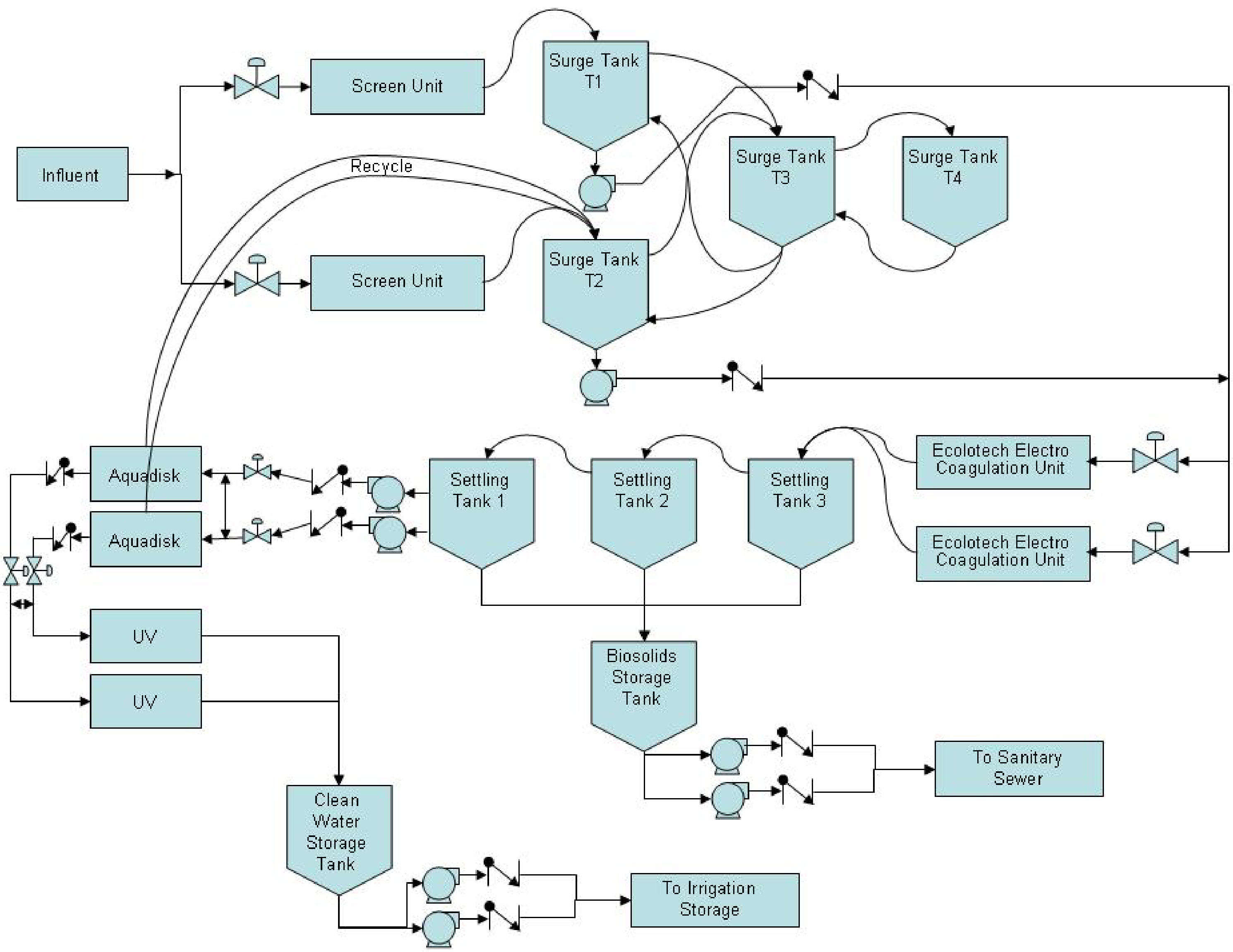

Figure 3. Conceptual process flow diagram.

Figure 4. Typical screen unit.

Figure 5. Washed material from screen.

Settling and Solids Handling
After electrocoagulation, the water is delivered to a settling tank. The floating floc is vacuumed off of the top and mixed with the settled solids for transmission to the municipal plant. The processed water is decanted off of the settled solids and pumped to a storage area. The partially treated solids from the settling tank are combined with the removed floating floc and routed to the municipal sewage treatment plant for further processing. However, the sewage load to the municipal plant is now only about 5% of the original volume.

Title 22 Components
To meet the requirements of unlimited reuse in California, the WRTC effluent would need to be pumped through an approved California DHS Title 22 filter and then sterilized using ultraviolet light before placement in the storage area. As with the screening process, treated effluent is used to backwash the filters and the wash water is recycled through the WRTC.

Typical Layout
The compact size of the Ecolotech WRTC system allows for placement on a small lot (0.3 acres). Figure 6 depicts a typical in-ground tank system with the WRTC located in a building constructed atop the tanks. The tanks provide surge capacity to handle diurnal peaks as well as manage flows during the early stages of a power failure until back-up power can be brought online to resume treatment.

Control System
The WRTC is controlled by a Command, Service, and Maintenance Facility (the Command Center), which utilizes state-of-the-art electronics and software to control WRTC systems. This Command Center can be locally or remotely sited, and has the ability to control multiple WRTC systems. Typically, a Command Center is located within the treatment center. The Command Center detects any disruptions and automatically switches the flow to backup equipment. It should be supervised by an on-call operator as required who would be instantly notified by the system of any significant problem (operational costs are not considered part of the scope of this paper).

The main system electronics would be housed in a standard steel equipment rack located in the control room. The functionality would consist of all of the monitoring and parallel processing of the system inputs and outputs as well as user inputs as needed for operation of the WRTC. The control logic is scripted into each system and provides the interaction and process control as required. Analog inputs monitor level, temperatures, and flow rates. Digital inputs monitor switches, sensors, doors, and any other on/off input as needed for switching to back-up pumps or system components. Relay-driven digital outputs drive valves, indicator lamps, and contactors as needed.

On-screen graphics and status indicators provide an overall view of the system. Touching the screen brings up a detailed window of the selected function, with any errors, problems, and potential problems highlighted. Built-in e-mail and logging facilities will not only track these occurrences, but provide automatic escalation procedures. Multiple user interface windows will be created as needed. Actual JPEGs of the various areas can be overlaid with invisible buttons to make the system extremely intuitive.

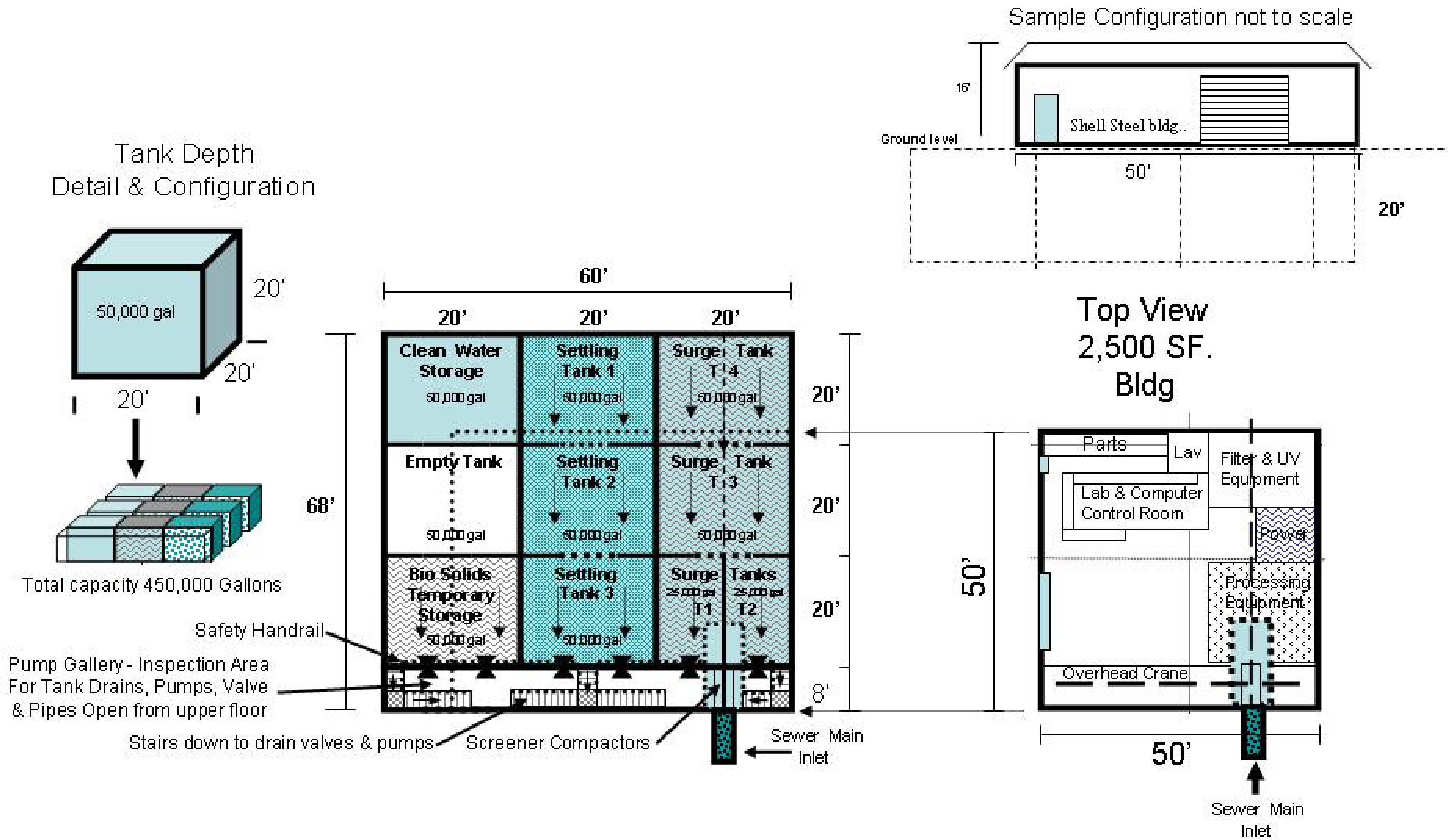

Figure 6. Water recovery treatment center typical vault tank plan.

Facility security is always an issue. The WRTC have two access keypads for facility entry and access can only be gained by entering a valid access code. The first level of access is for external personnel, such as garbage collectors and service engineers for cable, telephone, or other utility services. Access to the main treatment plant requires a second code for authorized personnel only.

To mitigate the unlikely event of a complete electrical failure, sufficient local storage is incorporated into the design in to allow for the collection of wastewater. Depending upon regulatory requirements, this storage volume can vary. Typically 12-24 hours is adequate for electrical service to be resumed, but as an additional fail safe, a stand-by generator is housed in the WRTC. An “empty” 50,000-gallon tank may also be included within the system for use on a temporary basis to replace any of the other tanks should repairs or maintenance be required.

To summarize, wastewater is rapidly screened, treated, filtered, and disinfected to recover approximately 95% of the total volume for subsequent reuse. All equipment is duplicated to provide complete redundancy while error detection and switching to the stand-by back-up unit is achieved by the Command Center. The Command Center also initiates an error control and escalation procedure to ensure that faults are promptly rectified to enable the faulty element to be returned to stand-by status.

RESULTS

Process Case Study

The City of Taft, CA, is a community of approximately 6,000 people, located approximately 20 miles west of Bakersfield, CA. The City is predominantly residential, with some agriculture, oil exploration, and one large food processor contributing to the waste stream. The publicly owned treatment works (POTW) serves areas beyond the city limits and processes approximately 1.2 million gallons per day (mgd) of sewage. Peak loads at the POTW can exceed 1.4 mgd.

The food processor in the area creates large quantities of biochemical oxygen demand (BOD) and suspended solids, which are discharged into the City sewer for treatment. While the EPA has required and implemented stricter discharge requirements on the processing industry, the levels of contaminants still received by the municipal treatment facility now require additional treatment to allow usage of the effluent for irrigation. The City has requested the POTW to provide for an expanded volume of operations and to meet the Regional Water guidelines for BOD and total suspended solids (TSS), which are stricter than those required by National Pollutant Discharge Elimination System (NPDES) permit.

The POTW is a very basic aeration system that consists of two aeration ponds (10,000,000-gallon each) and one settling pond (7,000,000 gallons). The aeration ponds contain seven aerators that are powered by four 10-hp and three 20-hp motors. Treated water from the settling pond is conveyed to a processing holding area for final treatment. Total holding/treatment time from influent to effluent is currently 25 days. The cost, space, and time necessary for conventional expansion of the plant rendered this option unattractive, and so other means to achieve greater throughput and improved treatment were required. If the holding/treatment time could be reduced through an efficient pretreatment system, then a greater volume could be handled by the existing infrastructure.

The effluent is used for irrigation of an on-site vegetable field. If the holding/treatment time could be reduced through an efficient pretreatment system, then a greater volume could be handled by the existing infrastructure. Additionally, the City is having difficulty achieving Regional Water Board standards for BOD and TSS (below 30 mg/L and 40 mg/L, respectively).

The Ecolotech system was tested to measure BOD, assuming a comparable reduction in TSS. Pathogen reduction was also of key interest because the degree of initial reduction would also factor into the calculation of the ability to reduce treatment time and therefore increase throughput. Samples of water were taken from the influent and final finishing pond at the POTW and compared to influent treated using the Ecolotech system. The results of the sample test comparing Ecolotech treatment to "before and after" treatment results obtained by the POTW at Taft are summarized in the table below.

Table 1. Results of the Taft, CA, pilot test.

Contaminant	Source	Result	Units	% Reduction
BOD	Influent	675	mg/L	99.99+
	Effluent	225	mg/L	99.99+
	Ecolotech Treated	ND	mg/L	NA
Bacteria, Viruses, and Cysts	Influent	19,000,000	gm	95.7
	Effluent	2,500,000	gm	52.0
	Ecolotech Treated	1,200,000	gm	NA

On the basis of these results, it was projected that using the Ecolotech process as an adjunct to the current system would allow reduction in aerators from four 10-hp and three 20-hp motors to only three 10-hp units. Using the Ecolotech system for pretreatment would only require the holding/treatment capacity of one of the existing aeration ponds for the current volumes, allowing for a potential 50% increase in overall treatment capacity.

CONCLUSION

Pilot testing of the Ecolotech system has demonstrated that that electrocoagulation is a viable technology and that each unit can treat up to 250 gallons per minute (gpm) of wastewater. The Water Recovery Treatment Center is a viable option for communities that want to offer wastewater treatment to new development without having to invest heavily in new or upgraded infrastructure. Reusing treated wastewater will reduce the use of potable water for non-human consumption uses, therefore conserving a valuable resource for the community. Small-scale (<2 mgd) MBR systems typically cost about $10 million per mgd capacity. The Ecolotech system is estimated to be approximately 40% to 60% of the MBR cost, depending upon site conditions and other factors.

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