BACTERIAL ASSESSMENT OF APPLIED TREATED EFFLUENT FROM WASTEWATER SYSTEMS

By

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BACTERIAL ASSESSMENT OF APPLIED TREATED

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Abstract: Aerobic Treatment Systems (ATS) are a form of water reuse, practiced by citizens in the United States and in Oklahoma. ATS collect water, including wastewater, leaving home(s) and discharge the treated wastewater on the soil surface. ATS treat wastewater effluent through processes of aeration; some ATS use methods of nitrogen reduction and chlorination disinfection. In Oklahoma, ATS are regulated for two years, post installation by a certified technician. Concerns for human health and the safety of the environment are associated with land-applied effluent from ATS relative to possible *Escherichia coli* (*E. coli*) and fecal coliform bacteria concentrations; treatment processes in Oklahoma need to be investigated to quantify bacteria concentrations in effluent. Phase one of this study quantified bacteria concentrations from the holding (pump) tanks of ATS relative to the environmental condition under which they were stored. *E. coli* populations did not completely die off until week four of the study indicating survival of the bacteria for long-periods in holding tanks. Phase one also showed fecal coliform testing results contained levels of fecal coliforms exceeding 200 MPN/100 mL sample; fecal coliform concentrations thrived under certain environmental conditions, increasing concerns about the presence of bacterium. Phase two of this study quantitated bacteria concentrations in the soil after applying the effluent from the pre-treatment tanks of ATS. *E. coli* concentrations dropped to less than 200 MPN/g (under all stored conditions) at 48 hours. Exceeding levels of fecal coliforms were detected throughout the study (phase two); under certain environmental conditions fecal coliforms thrived in the soil and did not die off. The overall findings from phase one and phase two of this research lead to an ATS assessment of rules and regulations in Oklahoma pertaining to *E. coli* and fecal coliform bacterium concentrations. Enforcement standards in Oklahoma are lacking in regulating ATS, especially in regards to established bacteria standards. Enhanced levels of regulations were recommended and a fact sheet was created to inform the public of associated concerns. ATS discharge exceeding levels of bacteria under variable conditions.

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CHAPTER I

AEROBIC TREATMENT SYSTEMS: DETERMINING BACTERIA CONCENTRATIONS RELATIVE TO STORAGE CONDITIONS

Abstract

Aerobic Treatment Systems (ATS) in Oklahoma are regulated by the Oklahoma Department of Environmental Quality (ODEQ). ATS treat water leaving homes and discharge the water on residential areas. The systems do not require a National Pollutant Discharge Elimination System (NPDES) permit. The objective of this research was to quantify bacteria concentrations from the holding (pump) tanks of ATS stored under different environmental conditions. The bacterium *Escherichia coli* (*E. coli*) and fecal coliforms were tested in samples collected from three separate ATS holding tanks. The IDEXX Colilert methods were used to assess bacteria concentrations in the samples. The electrical conductivity (EC) and pH of each sample were also measured. The samples were stored under three different environmental conditions (indoors not exposed to direct light, outdoors exposed to direct light, and outdoors but not exposed to direct light) to evaluate microbial growth and/or die-off over time. *E. coli* concentrations declined to less than 1 MPN/100 mL during the fourth week of the study. Fecal coliforms thrived under certain environmental conditions, exceeding 200 MPN/100 mL for the entire eight week study period. Detecting bacteria in ATS holding tanks suggests bacteria will be applied to the soil when the effluent is land applied.

Introduction

As population increases, conservation methods and water use management are becoming a vital aspect for citizens; water availability for future generations is threatened by population increases and increasingly dry weather patterns (USEPA, 2012a). Currently in Oklahoma, private, residential wastewater treatment systems are commonly installed in rural communities (ODEQ, 2011a). The treatment systems treat wastewater leaving homes and reuse the water for outdoor irrigation purposes (ODEQ, 2011b). Reusing treated wastewater for outdoor irrigation purposes conserves clean water for future generations, especially in times of drought. Recycling wastewater for outdoor irrigation, through treatment systems, allows Oklahomans to practice water conservation. In order to protect the safety of the environment, rules and regulations pertaining to effluent discharge must be reviewed, along with *Escherichia coli* (*E. coli*) and fecal coliform health concerns.

Waste Water Treatment Facilities (WWTF) collect wastewater from surrounding communities within a municipality and treat the water prior to disposal. In certain locations, WWTF are not in operation (rural communities); this requires residents, instead of municipalities, to control the treatment processes and disposal methods of treated wastewater (USEPA, 2012b). Small towns in Oklahoma do not have WWTF in or near the area. Residents of theses rural communities treat their personal wastewater on their private property and dispose of the treated effluent in accordance with state and federal regulations. Technological advances in the United States allow for residents of these rural communities to properly dispose of their waste safely, without potentially causing harm to the environment; however, human health and environmental risks associated with *E. coli* and fecal coliforms raise concern with these systems (Sheikh, 2010).

Aerobic Treatment Systems (ATS) are being used by citizens across the United States. Only in use in the United States for a decade or two, ATS have grown as a popular replacement for septic systems (USEPA, 2000). As ATS wastewater treatment has escalated over the years, numerous versions and/or manufacturers of the treatment systems have increased; all ATS makes and models include the same processes for treatment disinfection methods (ODEQ, 2011b). As defined by the United States Environmental Protection Agency (USEPA) aeration is: “A process which promotes biological degradation of organic matter in water. The process may be passive (as when waste is exposed to air), or active (as when a mixing or bubbling device introduces the air)” (USEPA, 2014). In association with defining aeration (an ATS process), USEPA (2014) defines the aerobic treatment process: “Process by which microbes decompose complex organic compounds in the presence of oxygen and use the liberated energy for reproduction and growth. (Such processes include extended aeration, trickling filtration, and rotating biological contractors).” Treatment procedures of ATS are similar amongst various design models produced by manufacturer(s), all including an aerobic treatment process.

The ATS associated with this report (Figure 1) are equipped with three tanks: a pre-treatment tank (collects all water, directly from the home), a treatment tank (aerobic treatment process, treating the effluent for disinfection prior to discharge), and the pump tank or holding tank (water transferred from the treatment tank, and treated effluent is pumped for irrigation).

Figure 1. One of the three Aerobic Treatment Systems (ATS) where sample water was collected and tested for bacteria concentrations. The top of the tanks should be a minimum of 2 inches above the grounds surface; please note these tanks do not comply with that regulation (ODEQ, 2012).

The systems are located on the home/land owners' properties and maintained by a certified technician for two years, post installation (ODEQ, 2011b). ATS in Oklahoma are regulated by the Oklahoma Department of Environmental Quality (ODEQ) with standards in compliance under the EPA. According to ODEQ, an aerobic treatment unit is defined as follows: "…a treatment unit provides digestion of organic matter through oxidation and has been tested and certified by an ANSI accredited certifier as meeting the most current ANSI/NSF Standard 40, whether or not it includes nitrogen reduction" (ODEQ, 2012). The maximum contaminant level for *E.* coli, produced by ATS, are not included in the state's standards. The maximum contaminant level for fecal coliforms, in association with ATS, are not to exceed 200 colonies per 100 mL sample; however, fecal coliform testing is not required under state regulations (ODEQ, 2012).

This research quantifies bacteria concentrations in samples collected from the holding (pump) tanks from three separate ATS. Treated effluent discharge (ATS) may pose a threat to human health and the safety of the environment when bacteria survives in the water, post treatment. Bacteria contamination may also occur when discharging treated effluent, over a period of time, to the same exact location. In order to assess bacterial concerns associated with treated effluent and human health, potential risks associated with the bacteria *E. coli* and fecal coliforms and human contact, were reviewed.

Literature Review: Bacteria

Escherichia coli (*E. coli*) are bacterium having the potential to cause harm to human health (CDC, 2013). Living in human and animal intestines, these bacteria are easily transmitted to humans through contact with contaminated water (CDC, 2012). Transmission of *E. coli* to humans occurs through the human ingestion of contaminated water and/or the ingestion of crops irrigated with contaminated water (Pennington, 2010).

Irrigating crops with ATS treated water in Oklahoma is not viewed as a violation of regulations (ODEQ, 2012) where the source of contaminant (treated effluent) has the potential to cause human illness (Pennington, 2010). It has been suggested that treated wastewater effluent has the highest level of bacterial contamination, in regards to recycled water, raising health concerns (Toze, 2006).

Increased levels of treatment (tertiary treatment) have been suggested to further reduce levels of bacterium in wastewater; however, it has been shown that some bacterium and/or pathogens will resist tertiary treatment (Toze, 2006). Tertiary treatment is an additional treatment process, beyond the second treatment process (World Bank, 2014). Additions of chlorine for increased disinfection is one example of tertiary treatment (World Bank, 2014). Some pathogens are resistant to the tertiary treatment chlorine, dependent upon initial bacterium contamination levels (Toze, 2006). It has been shown that the survival rates of *E. coli* are dependent upon weather conditions (Blaustein et al. 2013). It was suggested that further research of bacterial associations with treated effluent must be reviewed in order to fully assess the health risks associated with organisms surviving in the water or applied to soil (Toze, 2006).

In addition to *E. coli*, the presence of fecal coliforms in soil and/or water pose potential threats to human health (USEPA, 2012c). Research shows that fecal coliforms exist even after the tertiary treatment of chlorine disinfection (Shuval et al. 1973). Shuval et al. (1973) reported initial mean averages of coliforms existed in a reservoir before and after chlorine disinfection. While coliforms decreased after chlorine disinfection, populations did not die-off (Shuval et al. 1973). It has also been stated due to aeration bacteria populations increase more so than what would occur naturally (Guy and Catanzaro, 2002).

It has been suggested that ATS work efficiently due to the lack of maintenance required to ensure discharge of treated effluent (Guy and Catanzaro, 2002). ATS are required to be maintained by a certified installer a total of four times, throughout a lifetime, all within the first two years of installation (Guy and Catanzaro, 2002). Bacteria (*E. coli* and fecal coliforms) assessments are not included in the four time inspection processes (Guy and Catanzaro, 2002).

Concerns about *E. coli* and fecal coliforms in water and/or soil have been previously stated; however, not in direct association with ATS. The future of water reuse is greatly increasing; rules, regulations, and research have not had a chance to catch up with ATS installation technology. Do potential threats to human health and the safety of the environment occur when ATS discharges bacterium contaminated water over time to the same location?

Materials and Methods

An ATS certified installer was contacted and samples were collected from the holding (pump) tanks of three home/land owners' properties. The samples were stored under three different environmental conditions to determine the bacteria concentrations over time. Under each environmental condition, two 100 mL sampling bottles stored the samples (treated effluent). The environmental conditions were indoors not exposed to direct light, outdoors exposed to direct light (UV), and outdoors not exposed to direct light (shade). Samples were tested weekly (over an eight week period) to determine the bacteria concentrations over time.

Samples were tested by using the IDEXX Colilert sampling equipment and procedures. IDEXX is an approved testing procedure for testing water, certified by the EPA (IDEXX, 2014). IDEXX Colilert sampling detects *E. coli* and fecal coliform concentrations based upon the Most Probable Number (MPN) technique (IDEXX, 2014). Appropriate dilution factors were determined for each sample duplicate and replicate in order to guarantee that samples were within the maximum detection limit of 2419.6 MPN/100 mL.

After determining the dilution factors, sample bottles were shaken (6 turns) before extracting a subsample from each container. The sample water was added to deionized water (DI) for a total of 100 mL of solution. IDEXX reagent capsules were poured into each sample and shaken until dissolved. Samples were then poured into a seal tight packet and sealed using the IDEXX sealing machine. Each packet was labeled and placed in the oven at 35°C for 24 hours. After the incubation time of 24 hours, the samples were removed from the oven and yellow/fluorescent wells were quantified to determine the MPN/100 mL of the sample: positive fluorescent wells indicated the presence of *E. coli* and positive yellow wells indicated the presence of fecal coliforms (IDEXX, 2014).

Additional parameters were tested for each sample. The electrical conductivity (EC), pH, and temperature of each stored solution were monitored. The EC (µs/cm) and pH were tested using an EC/pH probe. The probe was calibrated as directed by the manufacturer. According to the USEPA, "Conductivity is a measure of the ability of water to pass an electrical current. … affected by the presence of inorganic dissolved solids… Conductivity is also affected by temperature: the warmer the water, the higher the conductivity. …failing sewage systems would raise the conductivity" (USEPA, 2012d). Acceptable EC readings of 150 to 500 µs/cm is a range known safe for fish in streams, readings not within this range may negatively impact plants or animals (USEPA, 2012d). Due to exceeding maximum EC levels (on the probe), dilution factors were applied. The pH measures the acidity and basic concentrations of water (USEPA, 2012e). The standard for pH (in the United States) for water ranges from 6.5 to 9.0 (USEPA, 2012f). The outdoor and indoor temperatures were recorded to analyze the influence of temperature on bacteria concentrations over time.

Results and Discussion

E. coli concentrations were initially greater than 10^2 to 10^4 MPN/100 mL sample. Samples stored outdoors (not exposed to direct light) had lower initial concentrations (concentrations detected prior to storing samples under different environmental conditions) of approximately 650 MPN/100 mL of *E. coli* compared to initial concentrations for samples stored outdoors (exposed to direct light) at 68,000 MPN/100 mL and samples stored indoors (not exposed to direct light) at approximately 9,200 MPN/100 mL. These results suggest that the maintenance performed by the certified installer (up to two years post ATS installation) was inconsistent and/or lacking, based upon the quantity of *E. coli* quantified as the initial concentrations (Figure 2).

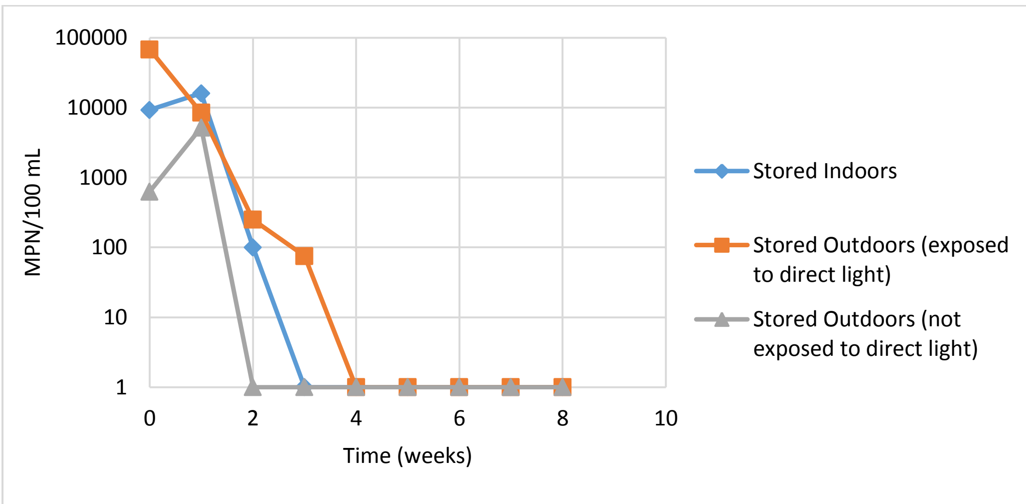

Figure 2. Results of *E. coli* concentrations (MPN/100 mL) for samples stored under different environmental conditions over time.

Despite variable initial concentrations, all samples (stored under each environmental condition) had *E. coli* concentrations of 10^5 MPN/100 mL per sample during the first week (Figure 2). *E. coli* concentrations in the samples stored indoors and outdoors not exposed to direct light actually increased from their initial concentrations. Samples stored outdoors exposed to direct light had *E. coli* concentrations that remained above the detection limit the longest time (i.e., surviving the longest) until the fourth week. Once *E. coli* concentrations decreased to less than 1 MPN/100 mL, all samples stored under each environmental condition remained less than the detection limit of 1 MPN/100 mL (Figure 2).

Fecal coliform concentrations increased from initial concentrations of approximately 10^4 to 10^5 MPN/100 mL, under each stored environmental condition. Under all three storage conditions, the fecal coliform concentrations increased in week 1 compared to their initial concentrations; all samples under each stored condition had fecal coliform concentrations of approximately 10^5 MPN/100 mL during week one (Figure 3) post ATS treatment.

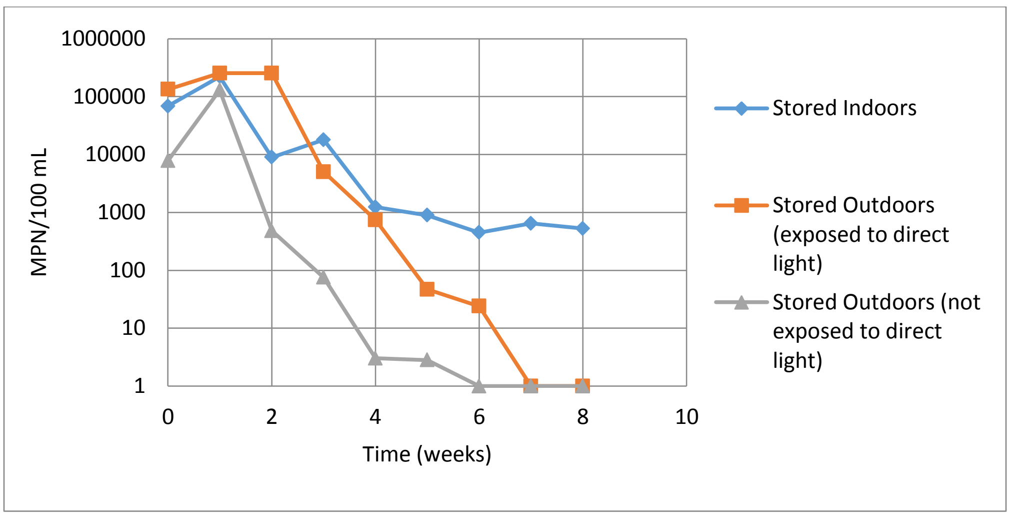

Figure 3. Results of fecal coliform concentrations (MPN/100 mL) for samples stored under different environmental conditions over time.

Concentrations in samples stored outdoors exposed to direct light continued to increase from the initial concentration (approximately 133,000 MPN/100 mL) to concentrations during week two (approximately 255,000 MPN/100 mL) until week three (approximately 5,000 MPN/100 mL); samples stored outdoors exposed to direct light had fecal coliform concentrations decrease by approximately 2 log cycles from the second to third week (Figure 3).

Fecal coliform concentrations for samples stored outdoors not exposed to direct light decreased faster compared to the other environmental conditions and reached the detection limit of 1 MPN/100 mL at the sixth week. Samples stored outdoors exposed to direct light reached the detection limit during the seventh week (Figure 3). Samples stored outdoors exposed to direct light and not exposed to direct light had fecal coliform concentrations decrease by 5 log cycles through the 8 week period (Figure 3).

Fecal coliform concentrations remained elevated in samples stored under more constant temperature conditions (70°F to 80°F) of the laboratory. Samples stored indoors had final fecal coliform concentrations of approximately 500 MPN/100 mL. The consistent temperature environment allowed fecal coliforms to survive (Figure 4). These results suggest that fecal coliforms, dependent upon non-variable weather conditions, can survive in the ATS holding (pump) tanks for at least eight weeks post ATS treatment (Figure 3).

The controlled indoor air temperatures (samples stored indoors) and the outdoor fluctuating air temperatures (samples stored outdoors) were documented throughout the study (Figure 4). Consistent controlled indoor air temperature reflects the fecal coliform steady concentrations from week four through the final week of testing for samples stored indoors.

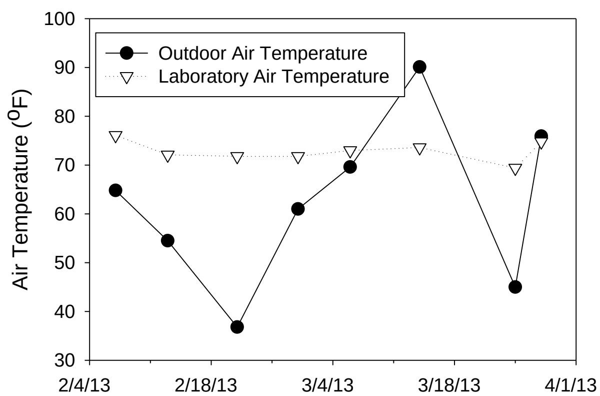

Figure 4. Air temperature variation for samples stored inside and outside the laboratory.

The EC (µs/cm) was tested under each stored condition and the results show samples stored outside (not exposed to direct light) started at lower EC levels (Figure 5). The EC levels for samples stored outside in the shade exceeded 5,000 µs/cm only one time (week two), throughout the study (Figure 5). All samples stored indoors and outdoors (exposed and not exposed to direct light) increased in EC during the second week of testing due to sampling error (Figure 5). DI water has an EC level of 0.5 µs/cm and industrial water has been valued at EC levels up to 10,000 µs/cm (USEPA, 2012d). Of the three stored conditions tested, two storage conditions (samples stored indoors not exposed to direct light and samples stored outdoors exposed to direct light) never fell below EC levels of 10,000 µs/cm (Figure 5). EC levels exceeding 10,000 µs/cm suggest that some species may not tolerate EC levels at that range in streams (greater than 500 µs/cm) (USEPA, 2012d).

Initial pH values ranged from 7 to 8 for all samples under each stored condition (indoors and outdoors). The pH values decreased slightly for all samples in the first week; however, pH increased throughout time during the study period for all samples from the sealed stored containers and consumption of oxygen (Figure 6). Samples stored outdoors exposed to direct light and samples stored outdoors not exposed to direct light exceeded pH values of 9 during the final week of testing; whereas samples stored indoors remained under a pH value of 8 throughout the study (Figure 6). Again, the pH could be an indicator of more favorable environmental conditions for bacteria survival for the samples stored inside the laboratory.

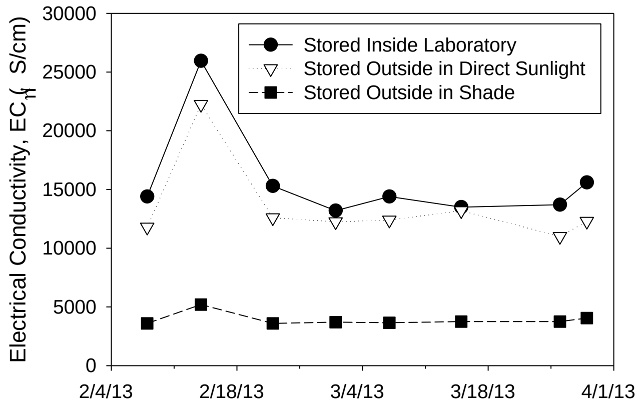

Figure 5. Electrical conductivity (EC) of sample water stored under different environmental conditions.

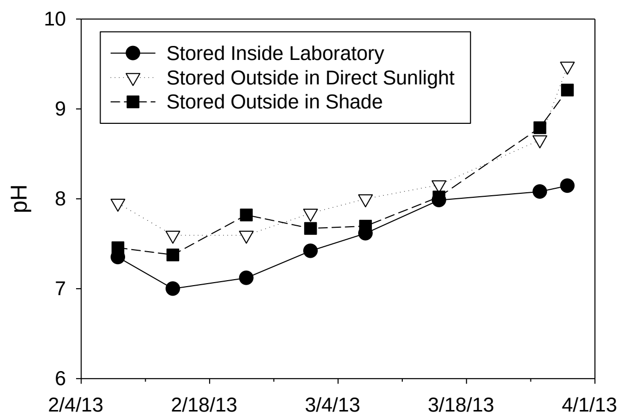

Figure 6. pH values of sample water stored under different environmental conditions.

Conclusions

Significant *E. coli* (1,000 to 100,000 MPN/100 mL) and fecal coliform (10,000 to 200,000 MPN/100 mL) concentrations were measured from the holding tanks of ATS treatment systems. A potential exists for these high concentrations in effluent to be land applied. This study also suggests that storage conditions are an important factor for *E. coli* and fecal coliform concentrations of discharged ATS effluent. This study shows despite initial concentrations, *E. coli* survived under different environmental conditions for two to four weeks post ATS treatment. Fecal coliforms died-off to less than 500 MPN/100 mL for samples stored indoors not exposed to direct light post ATS treatment, suggesting that dependent upon stored conditions, ATS holding (pump) tanks contain fecal coliforms that thrive in storage and are then discharged to the soil.

CHAPTER II

AEROBIC TREATMENT SYSTEMS: DETERMINING SOIL BACTERIA CONCENTRATIONS AFTER APPLYING EFFLUENT

Abstract

The bacterial impact of the application of effluent from Aerobic Treatment Systems (ATS) in regard to soil bacteria levels is currently unknown. The objective of this research was to determine soil concentrations (MPN/g) of the bacteria *Escherichia coli* (*E. coli*) and fecal coliforms after the application of pre-treatment (tanks) sample water to soil. Initial concentrations were quantified prior to application of sample water (25.0 mL) to the soil rings. A sandy loam soil was packed in the soil rings to a bulk density of 1.5 g/cm^3. Duplicate rings were stored under different environmental conditions: indoors not exposed to direct light, outdoors exposed to direct light, and outdoors not exposed to direct light. Soil samples (2 g) were then acquired from the soil surface of each soil ring. The initial moisture content was maintained (40 percent) at initial levels by adding (25.0 mL) deionized (DI) water to one of the duplicate samples; the moisture content was allowed to decrease in the other sample. Initial *E. coli* concentrations were approximately 500 MPN/g; whereas, initial fecal coliform concentrations were approximately 36,000 MPN/g. *E. coli* concentrations decreased after sample water (ATS pre-treatment tanks) was applied to soil; after 48 hours, all samples under each stored condition decreased to less than the detection limit of 1 MPN/g for *E. coli*. Fecal coliform concentrations in samples stored outdoors exposed and not exposed to direct light never died-off. Electrical conductivity (EC) and pH were tested and

recorded for samples under each stored condition. Greater than 10^2 to 10^3 MPN/g concentrations of fecal coliforms have the potential to survive in soil after applying ATS pre-treatment water to the soil surface.

Introduction

Aerobic Treatment Systems (ATS) discharge treated effluent from human waste through irrigation on residential areas. ATS are water reuse systems regulated in Oklahoma by the Oklahoma Department of Environmental Quality (ODEQ) under section 252, chapter 641 (ODEQ, 2012). ATS typically include three tanks (the pre-treatment tank, treatment tank, and the holding (pump) tank). The pre-treatment tank collects all water and wastewater leaving a home and contains non-treated wastewater effluent. The pre-treatment tank transfers water to the treatment tank where the water is treated through aeration, and transferred to the holding or pump tank; the holding (pump) tank contains the treated effluent available for irrigation (Figure 1). Soils have the potential to become contaminated by excessive applications of effluent containing bacteria. There is a need to test soils receiving ATS applied effluent to fully document potential threats to human health and the environment. Transport to rivers or streams can then occur through runoff or soil leaching.

The EPA does not regulate ATS; local and state agencies regulate ATS (USEPA, 2013a). In Oklahoma, municipalities operating a Waste Water Treatment Facility (WWTF) are required to obtain a National Pollutant Discharge Elimination System (NPDES) permit prior to discharging treated wastewater effluent; ATS system owners and operators are not required to obtain a NPDES permit (OPDES permit) in Oklahoma (ODEQ, 2011c).

E. coli and fecal coliforms have the potential to adversely affect human health, if contacted. Current rules and regulations include fecal coliform concentrations at less than 200 cfu/100 mL but fail to specify limits for *E. coli* concentrations in effluent associated with ATS and standards do not require *E. coli* and fecal coliform sampling or testing (ODEQ, 2012). The ODEQ does include that methods of disinfection (excluding spray irrigation and chlorination disinfection) should decrease fecal coliforms to less than 200 colonies per 100 mL; however, testing and sampling requirements were revoked in 2012 (ODEQ, 2012). Concerns for human health exists when ATS irrigate crops and/or when ATS are used on residential areas, increasing the risk for human contact that may result in gastrointestinal illness.

Literature Review

According to the Center for Disease Control and Prevention (CDC): "Most *E. coli* are harmless and actually are an important part of a healthy human intestinal tract. However, some *E. coli* are pathogenic, meaning they cause illness, either diarrhea or illness outside of the intestinal tract" (CDC, 2012). Apart from human intestines, pathogenic bacterium are present in all warm blooded mammals and spread thorough fecal matter (Gallagher et al. 2012). *E. coli* is an indicator for fecal coliform contamination in water (Gallagher et al. 2021). While *E. coli* exists currently in regulations as an indicator of the presence of fecal coliform contamination in water, *E. coli* existence also serves as a suggested indicator for crops and Best Management Practices (BMPs) for food and safety (UC, 2014).

The presence of *E. coli* in soil over time is highly dependent upon soil properties; certain soils are capable of harboring thriving concentrations of *E. coli* (Liang et al. 2011). The fate of *E. coli* also show trends of survival rates in temperate weather conditions (Gallagher et al. 2012). Aside from temperature, the most prevalent determining factor of *E. coil* presence in soil is reported to be soil moisture content (Gallagher et al. 2012). Research shows *E. coli* existing at higher concentrations in more saturated soil conditions when compared to dry soil conditions (Gallagher et al. 2012). However, *E. coli* (0157:H7) was detected in small pores of dry soils, throughout the length of one study (Ibekew et al. 2006). Exposure to solar radiation is also a factor in *E. coli* presence in soil (Ibekew et al. 2006). Studies show *E. coli*, non-dependent upon harsh weather conditions, can survive in soil for periods exceeding three months (Ibekew et al. 2006).

Crops, specifically lettuce, are linked to having the ability of harboring *E. coli* (0157:H7) in their leaves (Ibekew et al. 2006). Lettuce leaves act as a host and *E. coli* populations can survive in the plant; this process would be the source of contamination from the plant to human (Ibekew et al. 2006). Crops contaminated with *E. coli* (0157:H7) potentially require methods of disinfection (Ibekew et al. 2006). In Oklahoma standards do not inform ATS owners/operators to not use treated effluent on home gardens and/or consumable crops (ODEQ, 2012).

Enterobacteriaceae populations in soil with and without chemical fertilizers have been researched; studies showed that the bacterium existed under both environmental conditions (Estrada et al. 2003). The bacteria levels for samples stored in soil (without chemical fertilizer) decreased below 1 MPN/g (detection level) after 80 days (Estrada et al. 2003). The bacteria for samples stored in soil with chemical fertilizers (calcium ammonium nitrate) failed to decrease to non-detectible levels (never dying-off) (Estrada et al. 2003). This study suggests that chemical fertilization (calcium ammonium nitrate) applied to the soil will increase the survival rates of bacteria (Estrada et al. 2003).

Subsurface drip irrigation is commonly reviewed as a safe discharge method for dispersing treated wastewater for irrigation (Franti et al. 2002). Subsurface drip irrigation, or drip tubing, discharges treated wastewater to the soil at least 15 cm below ground surface (Franti et al. 2002). Surface saturation may occur through drip tubing causing concern for human health and the safety of the environment (Franti et al. 2002). Increasing the depth of drip tubing decreases the possibility for surface saturation to occur, declining potential human health risks (Franti et al. 2002). Installing drip tubing at 30 cm greatly reduces the soil saturation rates when compared to installations at 15 cm (Franti et al. 2002). Initial application of disposal should be concentrated dependent upon the soil infiltration rate (Franti et al. 2002). Bacteria concentrations are dependent upon initial application loads of treated effluent, in association with soil infiltration rates, and depth of piped tubing installations (Franti et al. 2002).

Associations with wastewater and high levels of selenium were reported near the San Joaquin Valley in California (USDA, 2013). Application of wastewater to a reservoir resulted in increased levels of selenium, causing harm for plants and animals (USDA, 2013). Experts suggested applying the wastewater to a centralized area and establishing salt-tolerant plants within the root zone of the soil (USDA, 2013). This application essentially increased properties of pasts damaged soils (USDA, 2013). The bacteria (*E. coli* and fecal coliforms) concentrations associated with the wastewater and soil were not reported in this study (USDA, 2013).

Reports show application of wastewater to soil has the potential to increase soil degradation over time (USDA, 2013). Wastewater application through irrigation to the soil increases clean water supplies for future water scarcity concerns (USDA, 2013); however, high levels of *E. coli* have been associated with applied treated wastewater effluent to soil from irrigation (Liang et al. 2011; Gallagher et al. 2012; Ibekew et al. 2006; Estrada et al. 2003 and Franti et al. 2002). Based upon limited available data, more research is needed on bacteria (*E. coli* and fecal coliform) concentrations in soil post ATS application.

Materials and Methods

Samples were collected from the pre-treatment tanks of three separate ATS (located on residential properties) and tested for this study. Initial *E. coli* and fecal coliform concentrations were quantitated (MPN/100 mL) prior to soil application. The soil used for this study had low organic matter (OM) content and was classified as a sandy loam soil. The soil was packed into six (7 cm diameter and 4 cm deep) circular soil rings at a bulk density of 1.5 g/cm^3. Soil rings (and duplicates) were stored under three separate environmental conditions: indoors not exposed to direct light, outdoors exposed to direct light, outdoors not exposed to direct light. Samples were weighed over time to determine changes in the soil moisture content throughout the study period. The initial moisture content (40%) after application of ATS sample (25.0 mL) was maintained for one of the duplicate soil rings under each stored condition by application of deionized (DI) water. The samples were tested for bacteria concentrations of *E. coli* and fecal coliforms post soil application.

Samples were tested using IDEXX Colilert testing methods and procedures. Samples were quantitated based upon the Most Probable Number (MPN) (MPN/g). Testing the soil for *E. coli* and fecal coliforms involved extracting 1.0 g of soil from each ring and adding 99.0 mL of deionized water (DI) to the soil sample (1 g). The IDEXX Colilert reagent was added to the solution, shaken until dissolved, sealed, and placed in the oven at 35°C for a 24 hour incubation time. Photographs were taken before and after extraction under each stored condition throughout the length of the study (Figure 7).

Figure 7. Samples KS1 and KS2 stored indoors (not exposed to direct light) on the left represents Day 1 (one hour) of soil extraction prior to testing, and on the right is the final day (96 hours) of extraction, prior to testing.

A total of 2 g (soil) were extracted from each soil ring on each testing day. The *E. coli* and fecal coliform concentrations were quantified by using 1 g of the extracted soil and the pH and EC were measured by consolidating 1 g of the extracted soil; pH and EC were measured by using the same testing probe. The probe was calibrated for pH by using pH standard solutions (4, 7, and 10) and the probe was calibrated for EC at 1413 µs/cm.

The pH was measured at a 1:2.5 ratio of soil/water. The solution was shaken for 30 minutes and pH values (under each stored condition) were recorded. pH values (6 to 7) are preferred by bacteria (Estrada et al. 2003). The EC was measured at a 1:20 ratio of soil/water. The solution was shaken for approximately two hours and results were recorded for each stored condition. Many factors influence the EC of soil (USEPA, 2011). According to the USEPA, "Electrical conductivity of earth materials is influenced by the metal content (sulfides) in the rock, porosity, day content, permeability, and degree of pore saturation" (USEPA, 2011). The indoor and outdoor air temperature was recorded for each environmental stored condition.

Results and Discussion

Initial *E. coli* concentrations were below detection limits (less than 1 MPN/g) for all soil rings (under each stored condition) prior to application of ATS effluent. Sample ATS effluent (25.0 mL) was applied to each soil ring under each stored condition. Concentrations for *E. coli* were approximately 520 MPN/g for all samples one-hour post application of ATS sample effluent to soil rings (Figure 8). *E. coli* concentrations in the soils were less than the detection limit after 48 hours (Figure 8). Samples stored outdoors (not exposed to direct light) showed *E. coli* concentrations increase from non-detectible levels to 175 MPN/g.

At 72 hours (3 days), samples stored outdoors not exposed to direct light had a spike in concentrations of *E. coli*. Past studies suggest that *E. coli* can survive for longer periods under moist soil conditions when compared to dry soil conditions (Gallagher et. al, 2012). Samples stored outdoors not exposed to direct light experienced a spike in *E. coli* based upon the moist to dry soil conditions; the spike was not observed for samples stored outdoors exposed to direct light experiencing dry soil conditions (Figure 8).

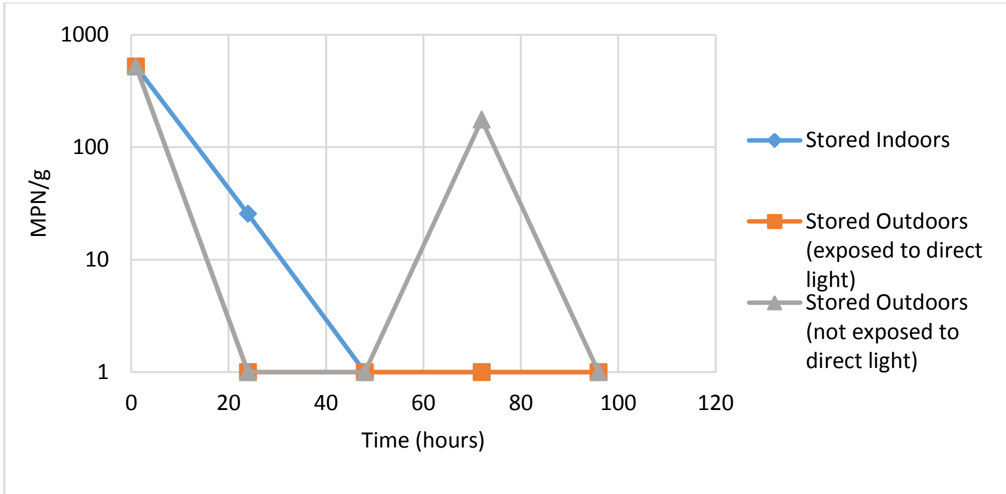

Figure 8. Results of *E. coli* concentrations (MPN/g) for samples stored under different environmental conditions over time.

Sample ATS effluent was quantitated for initial fecal coliform concentrations prior to applying the sample water (ATS pre-treatment tank effluent) to the soil. The ATS effluent had an average initial concentration of approximately 4,000 MPN/100 mL. Directly after application of ATS effluent to soil rings (25.0 mL), concentrations were tested. Fecal coliform concentrations increased one-hour post application to soil averaging approximately 36,000 MPN/g (Figure 9) for all samples under each stored condition. At 24 hours all samples under each stored condition dropped by two to three log cycles. At 72 hours samples stored indoors had fecal coliform concentrations of approximately 100 MPN/g (Figure 9) and declined to below detection limits (less than 1 MPN/g) for the final testing (96 hours). Samples stored outdoors exposed and not exposed to direct light never showed fecal coliforms dying-off after the first 24 hour sample, with final concentrations of approximately 900 MPN/g for samples stored outdoors exposed to direct light and approximately 350 MPN/g for samples stored outdoors not exposed to direct light (Figure 9). Samples tested over time were not always tested from the surface and an influence of sampling and testing results would occur by application of ATS effluent over time to the same location.

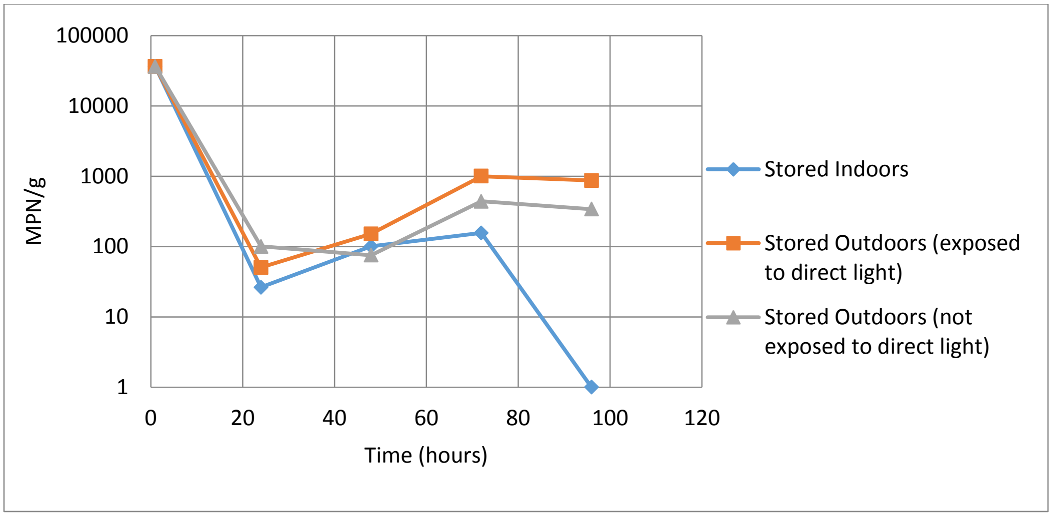

Figure 9. Results of fecal coliform concentrations (MPN/g) for samples stored under different environmental conditions over time.

Non-parametric statistic tests were used to statistically analyze the influence of variables on fecal coliform concentrations since the data was not normally distributed. The Mann-Whitney Rank Sum Tests (MWRST) is defined as "…a distribution free method used as an alternative to the Student's t-test for assessing whether two populations have the same locations. Given a sample of observations from each population, all the observations are ranked as if they were from a single sample, and the test statistic is the sum of the ranks in the smaller group" (Everitt, 2002). The MWRST compares two groups where the smallest number is classified as "rank 1" and larger number is classified as "rank of *n*;" rank *n* is simply the values of the two groups being compared (GS, Inc., 2013). The null hypothesis was that no differences existed in the two populations, and information gathered is represented by the P-value (GS, Inc., 2013). The median values were used to determine significant statistical differences at $\propto = 0.05$.

Table 1 represents the comparison of samples with added DI water to maintain moisture content versus samples where only sample ATS sample effluent was applied; results show no statistically significant difference (P-value = 0.704). Table 2 shows a statistically significant difference compared with the median values between samples stored indoors (Group A) verses samples stored outdoors (Group B) (P-value = 0.013). As shown (Table 2) the median values are different between the two groups more so than would be expected by chance. The final MWRST reviewed was a comparison between samples stored outdoors exposed to direct light and samples stored outdoors not exposed to direct light. This comparison (Table 3) showed no statically significant difference (P-value = 0.721). Statistical analyses suggested that significant differences only occurred for those samples stored outdoors (exposed and not exposed to direct light) compared to the samples stored indoors (Table 2).

Table 1. MWRST comparison between samples with DI water applied to duplicates (B) versus samples were only ATS effluent was applied (A).

Group	**N**	**Missing**	**Median**	**25%**	**75%**
A	12	0	75.000	12.508	345.000
B	12	0	177.500	50.000	351.250
					Mann-Whitney U Statistic = 65.000
					T = 143.000
					n (small) = 12 and n (big) = 12
					(P = 0.704)

Table 2. MWRST comparison between samples stored indoors (A) versus samples stored outdoors (B).

Group	**N**	**Missing**	**Median**	**25%**	**75%**
A	8	0	25.005	0.01000	125.000
B	16	0	252.500	50.000	492.500
					Mann-Whitney U Statistic = 23.500
					T = 59.500
					n (small) = 8 and n (big) = 16
					(P = 0.013)

Table 3. MWRST comparison between samples stored outdoors (exposed to direct light) (A) verses samples stored outdoors (not exposed to direct light) (B).

Group	N	Missing	Median	25%	75%
A	8	0	327.500	50.000	1172.500
B	8	0	177.500	62.500	352.500
					Mann-Whitney U Statistic = 28.000
					T = 72.000
					n (small) = 8 and n (big) = 8
					(P = 0.721)

The average soil pH under all stored conditions ranged between 6.6 and 7.5 (Figure 10). This is an acceptable range for bacteria to survive in soil (Estrada et al. 2003). Soil pH ranging from 6.0 to 7.0 are preferred for bacteria growth (Estrada et al. 2003). The pH values increased slightly after ATS sample effluent was applied to the soil. Overall, pH values decreased over time (Figure 10).

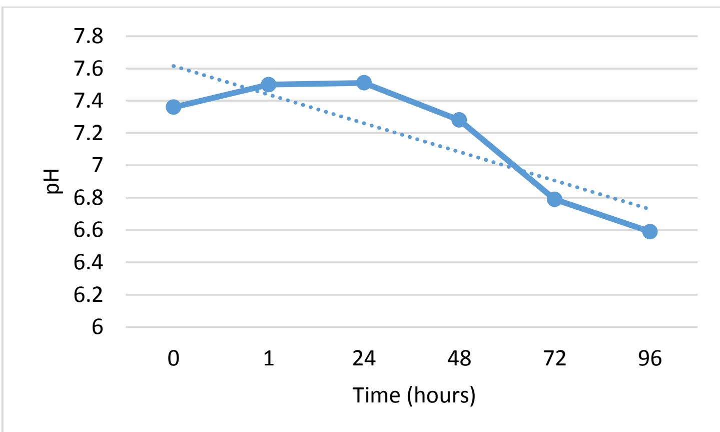

Figure 10. The average pH values under all stored conditions in soil samples before and after application of ATS effluent. The dotted line is a best fit linear trendline to show a slight decrease in pH over time.

The EC was initially 6100 µs/cm (Day 0) prior to application of ATS sample effluent to the soil. After application of ATS sample effluent to the soil, the EC increased immediately and continued to increase (slightly) over time until the final day of testing where EC levels greatly increased to approximately 40,000 µs/cm (Figure 11). Application of ATS sample water applied to the soil increased the EC.

The samples stored over time under different environmental conditions collected from ATS pre-treatment tanks and applied to soil were tested during a summer month (Figure 12). The temperature ranged between approximately 30° C and 25° C under outdoor stored conditions throughout the sampling period (Figure 12). Samples stored under indoor environmental conditions experienced temperature conditions ranging between approximately 25° C and above 20° C during the sampling period and over time (Figure 12).

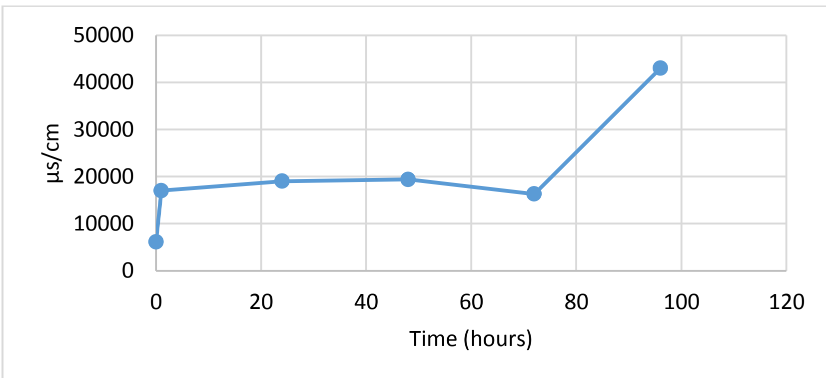

Figure 11. Electrical conductivity (EC) in soil samples before and after application of ATS effluent.

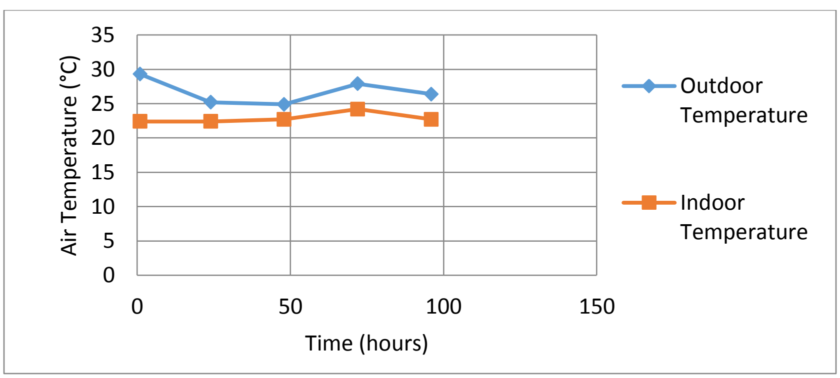

Figure 12. Indoor and outdoor air temperature before and after storing samples under different environmental conditions.

Conclusions

This study documented fecal coliform concentrations of greater than 300 MPN/g post application of ATS (pre-treatment) effluent to soil for samples stored outside, but *E. coli* concentrations decreased below detection limits. Applying ATS effluent to the soil also decreased the pH of the soil and increased the EC. In terms of fecal coliform concentrations, the only statistically significant variable investigated in the study was whether the sample was stored indoors or outdoors. It should be noted that this study was conducted on a soil with low organic matter content; extended application of ATS will also increase organic matter content in soil, providing more favorable survival and growth conditions for bacteria. ATS regulations should increase standards pertaining to *E. coli* and fecal coliforms; tertiary forms of disinfection, along with increased regulation standards extending certified maintenance requirements beyond two years post installation should be included in the requirements.

CHAPTER III

AEROBIC TREATMENT SYSTEMS: REVIEW OF RULES AND REGULATIONS

Abstract

Standards in Oklahoma fail to regulate *Escherichia coli* (*E. coli*) and fecal coliform concentrations associated with Aerobic Treatment Systems (ATS) in a residential setting. Exceeding levels (greater than 200 MPN/100 mL) of *E. coli* and fecal coliforms were quantified from the holding (pump) tanks from three separate ATS in Oklahoma (Stambaugh, 2014). Samples were stored under variable environmental conditions; however, fecal coliform bacteria did not die-off after eight weeks for samples stored indoors (Stambaugh, 2014). Exceeding levels (greater than 200 MPN/g) of fecal coliforms were quantitated from ATS pre-treatment tanks when the effluent was applied to soil (Stambaugh, 2014). Samples were stored under different environmental conditions and results showed the bacteria surviving under certain conditions (samples stored outdoors exposed and not exposed to direct light) (Stambaugh, 2014). This research suggests the potential for ATS tanks to contain and discharge *E. coli* and fecal coliforms to soil (Stambaugh, 2014). Reoccurring applications of ATS discharge to the soil has the potential to cause harm to human health through contact and the environment through soil leaching and/or runoff. Rules and regulations (pertaining to ATS) from states under the jurisdiction of United States Environmental Protection Agency (USEPA) Region 6 were reviewed and a fact sheet was created to inform current owners/operators of potential risks associated with ATS relative to bacteria (*E. coli* and fecal coliform).

Introduction

The Oklahoma Comprehensive Water Plan (OCWP) was established (2012) and recommendations for water recycling and water reuse systems were priority conservation methods for the *Oklahoma's Water for 2060 Act* that was passed in 2012 (OWRB, 2014). Current drought conditions (abnormally dry to exceptional drought) and future drought concerns suggest citizens need to practice water conservation to conserve water for future generations in Oklahoma (USDM, 2014). Aerobic Treatment Systems (ATS) reuse wastewater from homes for outdoor irrigation purposes.

ATS installations are occurring in the United States. In Oklahoma ATS are regulated by the Oklahoma Department of Environmental Quality (ODEQ) (ODEQ, 2012). ATS collect all water leaving home(s) in a pre-treatment tank; the pre-treatment tank transfers the wastewater effluent to the treatment tank (water is disinfected by aerobic treatment, nitrogen reductions, or chlorine disinfection); treated wastewater effluent is then transported to the holding (pump) tank where it is then discharged on lawns of residential areas. Concerns with *Escherichia coli* (*E. coli*) and fecal coliforms are associated with ATS. *E. coli* and fecal coliforms can be transmitted to humans through water contamination or through crops irrigated with contaminated water (CDC, 2012). Current rules, regulations, and standards fail to provide safe testing and sampling frequency regulatory criteria standards associated with ATS (ODEQ, 2012). An overall study of the rules and regulations pertaining to ATS bacterium levels for states under EPA (Region 6) is needed.

Due to recent technological advances of ATS installations, bacteria research associated with ATS is limited. According to the ODEQ, methods of disinfection associated with ATS are required to decrease fecal coliform bacterial levels to less than 200 colonies per 100 mL sample (Effective Date, 7-1-2012) (ODEQ, 2012); however, fecal coliform testing and sampling requirements were revoked in 2012 along with a subset of soil testing, assurance of proper operation testing, average daily release field testing, turbidity testing, and treatment disinfection testing (ODEQ, 2012). A National Pollutant Discharge Elimination Permit (NPDES), regulating waste discharge into bodies of our nation's water, are not required for ATS owners/operators (in Oklahoma) and NPDES (OPDES) permits have not been issued for ATS discharge (ODEQ, 2012).

Recently, in Oklahoma, a lawsuit occurred between neighbors pertaining to high concentrations (approximately 3,800 and 1,500 cfu/100 mL) of fecal coliform bacteria in a nearby stream (Aspinwall, 2013). It was believed that the bacteria concentrations collecting in the stream where directly related to a point source, an ATS (Aspinwall, 2013). The ATS was discharging water to the surface through spray irrigation; the investigation report stated, "according to DEQ spokeswoman …the sprinkled water is chlorinated but not considered safe for human contact" (Aspinwall, 2013). The court ended up not deeming the ATS owner/operator accountable despite exceeding concentrations of bacteria found up and downstream from the ATS (Aspinwall, 2013).

A study in Virginia showed that all ATS owners need a Virginia Pollution Discharge Elimination Systems (VPDES) permit, and that 10,000 VPDES permits have been issued for individual ATS owners (prior to and the year of 1991) (Hanna et al. 1995). According to Hanna et al. (1995), Virginia's regulations are lenient compared to Delaware and South Carolina which do not allow ATS to discharge treated effluent to their waters (Hanna et al. 1995). A total fecal coliform bacterium count must be no greater than 200 colonies per 100 mL for ATS in Virginia (Hanna et al. 1995). It was reported that out of 45 samples collected from ATS, 16 of the samples failed to be in compliance with the Virginia State regulations (less than 200 colonies per 100 mL) (Hanna et al. 1995). Studies showed fecal coliform population existence is an indication of failing disinfection processes (Hanna et al. 1995).

Studies in Australia also suggested concerns with ATS and the process of applying treated effluent to soil (irrigation) (Ivery, 1996). The Health Department of Western Australia set regulations pertaining to ATS with requirements of bacteria (fecal coliforms) maintained in compliance under 10 colonies per 100 mL (Ivery, 1996). In order to regulate the standard, field audits are conducted; out of 32 audits (over a 30 month time span) reports showed that not one sample exceeded the bacterial concentration limit; however, the systems tested included five tanks (anaerobic, aeration, clarification, disinfection, and pump tank) prior to soil application (Ivery, 1996). This study reported harmful outcomes are associated with ATS and spray irrigation (Ivery, 1996). It was also suggested that ATS irrigation (spray irrigation) poses a threat to human health and the safety of the environment when irrigating consumable crops (Ivery, 1996). In Oklahoma, the rules and regulations associated with ATS do not restrict spray irrigation and/or the use of ATS effluent discharge for irrigating consumable crops (ODEQ, 2012).

The Texas Commission on Environmental Quality (TCEQ) regulates standards associated with ATS (TCEQ, 2012). ATS in Texas are defined as secondary treatment with standards under Title 30, Chapter 285 (TCEQ, 2012). No regulations associated with *E. coli* and fecal coliform limits were discovered; however, a requirement of 100 acres or more of land is a qualification of owning/operating an ATS (TCEQ, 2008). In Arkansas, the Arkansas State Board of Health (ASBH) regulates ATS (ASBH, 2012). ATS are required to obtain a NPDES permit in Arkansas (ASBH, 2012); however, no *E. coli* and fecal coliform bacterial standards were found (ASBH, 2012). New Mexico has a fecal coliform standard stating non-exceeding limits of 200 colonies per 100 mL for disinfection and treatment standards are required not directly pertaining to ATS; monitoring fecal coliform concentrations is required annually post two year installation (NMEIB, 2005). Louisiana does not specify standards for *E. coli* and fecal coliform concentrations pertaining to ATS; however, ATS are listed as secondary treatment processes (LAC, Title 51 Part XIII).

Oklahoma regulates that exceeding levels (greater than 200 colonies per 100 mL) of fecal coliform constitutes a violation in association with ATS in Oklahoma (ODEQ, 2012). Bacteria concentrations discovered in association with ATS in Oklahoma suggests rules and regulations in Oklahoma fail to regulate *E. coli* and fecal coliform bacteria discharge (Stambaugh, 2014).

Most all states recognize the National Sanitation Foundation (NSF) and the American National Standards Institute (ANSI). The NSF/ANSI Standard 40 (residential on-site systems), allows manufactures of ATS to become certified under NSP/ANSI standards (40) (NSF, 2014). The NSF/ANSI standards and testing for certification criteria are an accredited form of recognition; however, the standards fail to include ATS bacterial data associated with *E. coli* and fecal coliforms (NSF, 2014).

Methodology

ATS in Oklahoma are regulated under Title 252, Chapter 641 (ODEQ, 2012). ATS cannot be used when systems are discharging treated effluent less than 100 gallons/day or greater than 1,500 gallons/day (ODEQ, 2012). Disinfection methods state that bacteria (fecal coliform) are to be less than 200 colonies per every 100 mL tested (OEDQ, 2012). ATS in Oklahoma are regulated two years post installation by a certified installer (ODEQ, 2012). Maintenance requirements, fecal coliform counts, and other standards are not monitored, regulated, nor tested by a certified technician after the systems have been installed for two years (ODEQ, 2012).

Owners of septic systems do not need a NPDES permit because water does not surface (USEPA, 2013c); however, ATS are designed to irrigate on the surface and do not require a NPDES permit in Oklahoma (ODEQ, 2012). The Oklahoma Pollutant Discharge Elimination Systems (OPDES) permit states bacteria (coliform) limits may be set for permit operators discharging to a lake (ODEQ, 2011d). OPDES permit holders (Class A) are advised that bacteria (fecal coliform) tests are required for sludge twice a month (dependent upon permit); however, land application of "biosolids" has been revoked as of July 1 of 2013 (ODEQ, 2011d).

ATS are not regulated under water reuse standards (Title 252, Chapter 627) (ODEQ, 2012). The water reuse standard (Appendix A) separates water reuse (users) into five categories (ODEQ, 2011e). Category 1 is "reserved" (ODEQ, 2011e). Category 2 states bacteria (fecal coliform) should be tested daily and no bacteria (fecal coliforms) can be found except in four samples of test performed weekly (four of seven samples) (ODEQ, 2011e). Category 3 states that bacteria (fecal coliforms) should be tested three times per week and have no greater than 400 cfu/100 mL per sample and less than 200 cfu/100 mL monthly average (ODEQ, 2011e). Category 4 requires users to test fecal coliform concentrations once a week with results less than 800 cfu/100 mL per sample and a monthly average less than 200 cfu/100 mL (ODEQ, 2011e). Category 5 is not classified (ODEQ, 2011e). Category 2 and Category 4 water reuse suppliers are required to submit monthly reports to the ODEQ; whereas Category 3 water reuse suppliers are required to maintain monthly reports (ODEQ, 2011e).

Results and Discussion

The sampled ATS in Oklahoma contained greater than 200 MPN/mL of *E. coli* and fecal coliforms in the holding tanks (2013) (Stambaugh, 2014). ATS sample effluent (pre-treatment tanks) has the potential to discharge *E. coli* and fecal coliform to soil (Stambaugh, 2014). Standards in Oklahoma regulate water reuse (Chapter 627) with higher fecal coliform and bacteria standards compared to ATS effluent regulatory standards (Chapter 252) (Table 4). Water reuse (Chapter 627) users are required to perform fecal coliform bacteria testing; (ODEQ, 2011e) whereas, ATS (Chapter 252) owners/operators and certified installers have been excluded from performing fecal coliform testing based upon fecal coliform concentrations (Stambaugh, 2014). Sampling and testing requirements for ATS were revoked in 2012 (ODEQ, 2012).

Under Chapter 627 water reuse standards in Oklahoma the uses and restrictions for water reuse are stricter than the regulations for small ATS at the residential level. Under Chapter 627 water reuse standards, Category 3 users are allowed to only use recycled water for specific designated purposes: below surface irrigation, irrigation for landscape in areas restricted for human contact, irrigation for pastures,

> "…concrete mixing, dust control, aggregate washing/sieving, new restricted access golf course irrigation systems, industrial cooling towers and one-through cooling systems, restricted access irrigation of sod farms, soil compaction, and existing restricted golf course irrigation systems utilizing water that has received primary treatment in lagoon systems" (ODEQ, 2011e). Under Chapter 252 ATS standards in Oklahoma, ATS owners/operators and certified installers (two years post installation) do not have designated disposal requirements for the treated wastewater and are only required to "…ensure that the system is maintained and operated properly so that: sewage or effluent from the system is properly treated and does not surface, pool, flow across the ground or discharge to surface waters;" (ODEQ, 2012)

however, the revoked sampling and testing requirements (ODEQ, 2012) in association with bacteria concentrations collected from ATS and stored over time (Stambaugh, 2014) suggest the operation and maintenance requirements are lacking in enforcement and quality assurance operations in association with ATS treated wastewater disposal.

Rules and regulations associated with ATS do not regulate *E. coli* and fecal coliform concentrations associated with ATS (Stambaugh, 2014). Standards under EPA (Region 6) areas fail to regulate *E. coli* and fecal coliform concentrations associated with ATS (Table 5). Based upon the given results and *E. coli* and fecal coliform concentrations discovered from pre-treatment and holding tanks from three separate ATS in Oklahoma (Stambaugh, 2014), a fact sheet was created to inform current and future ATS owners/operators of the suggested maintenance protocols and the potential health and environmental risk associated with *E. coli* and fecal coliforms that may result from undermanaged ATS (Figure 13).

Table 4. Regulating ATS versus water reuse regulatory standards in Oklahoma.

	OPDES Permit	**Fecal Coliform < 200 cfu/100 mL**	**Required *E. coli* Testing**	**Required Fecal Coliform Testing**	**Monitoring (2 years)**	**Monitoring and Testing (beyond 2 years)**
ATS		X			X	
Water Reuse		X		X	X	X

Table 5. ATS regulations for states under jurisdiction of EPA Region 6 areas.

	Fecal Coliform Testing	**Fecal Coliform < 200 cfu/100 mL**	***E. coli* Testing**	**NPDES Required Permit**	**Required Monitoring (2 years)**	**Required Monitoring (2 years post installation)**
Oklahoma	X	X			X	
Texas						
Louisiana						
Arkansas				X		X
New Mexico	X	X			X	X

Stambaugh, Bacterial Assessment of Applied Treated Effluent from Wastewater Systems, M.S. Thesis, Environmental Science, Oklahoma State University (2014).

Benefits and Concerns Associated with Aerobic Treatment Systems (ATS)

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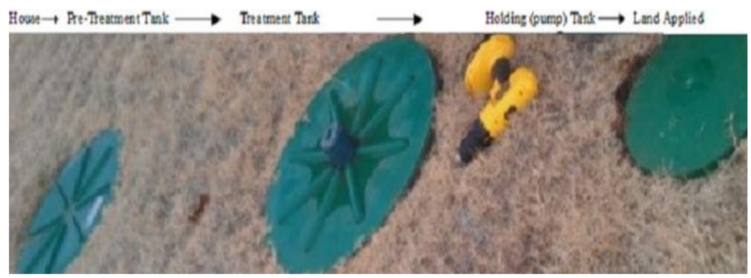

Aerobic Treatment Systems (ATS) collect residential grey water and wastewater leaving homes and discharge the treated effluent on lawns in residential settings. ATS installations are increasing in number throughout the United States (USEPA, 2000) and in Oklahoma. ATS are viewed as a beneficial, water conservation method because they recycle treated wastewater for outdoor irrigation. Proper operation methods and maintenance requirements are included to provide ATS owners/operators information to properly care for on-site septic systems (ATS). Concerns associated with ATS are also included to alert users to potential contamination to surface waters that may result from poorly maintained or improperly installed systems.

Benefits and Costs

ATS conserve our nation's natural resources by collecting and treating wastewater leaving homes and recycling the treated wastewater for outdoor irrigation. Currently, ATS are being installed as a replacement for failing septic systems in the United States (USEPA, 2000) and in newly constructed residences. Homebuilders find the idea of offsetting outdoor irrigation costs as an attractive benefit of ATS over septic systems. Homebuilders and Developers may prefer the installation of ATS compared to septic systems because they take up less lot space and allow for more closely spaced homes to be built in a residential development (OEDQ, ASTS).
ATS have a high initial cost for installation compared to septic systems; however, ATS cost decline over time (ODEQ, ASTS). ATS should be serviced and maintained by a certified installer (the individual installing the ATS) for two years by law (OEDQ, 2012). The certified installer covers all costs associated with maintenance performed for the first two years or amounts agreed upon in a signed contract with the homeowner.

After an ATS has been installed and maintained by a certified installer for two years, the maintenance and operation requirements must be performed by the homeowner (ATS owner/operator) or by a newly contracted certified maintenance company. Ongoing costs covered by the homeowner (owner/operator) may include sludge removal. The fee for hiring a certified technician to collect the sludge from the pre-treatment tank along with the charge for proper disposal methods will be paid by the homeowner. The sludge removal process should occur at regular intervals and be determined by the loading and size capacity of each system (ATS).

ATS Operations

ATS collect all water leaving a home in a pre-treatment tank. The solids collect near the bottom of the tank (sludge) and the liquid is transported to the treatment tank. The treatment tank is designed to treat the wastewater through a process of nitrogen reduction (ODEQ, 2012). Nitrogen reduction occurs in an aerobic system by microorganisms and bacteria present in the systems. These organisms feed on nitrogen, and this process results in a reduction of nitrogen.

Daily additions of chlorine should be used to treat the water and costs for chlorine disinfection (i.e., cost for chlorine) is the responsibility of the homeowner (owner/operator). The homeowner is also responsible for adding chlorine to the treatment tank every day. Chlorine must be deposited in the treatment tank by the homeowner (owner/operator) to treat the waste with chlorination disinfection prior to disposal and/or spray irrigation (ODEQ, 2012).

Once disinfection occurs, the treated wastewater is transported to the holding or pump tank where the water can then be used for outdoor irrigation purposes. Spray irrigation is not suggested. A drip tube irrigation piping system located at least 30 cm below the Earth's surface is the safest disposal method for treated wastewater (Franti et al. 2002).

Certified Installer and Homeowner Maintenance and Requirements

A certified installer must be licensed before installing an ATS (ODEQ, 2012). A certified installer will perform proper maintenance requirements associated with ATS for two years post installation (ODEQ, 2012). Once the certified installer's agreement expires (two years post installation) all duties performed by the certified installer initially are then transferred to the homeowner (owner/operator) as defined by the ATS regulatory standards in Oklahoma (ODEQ, 2012).

ATS maintenance duties include but are not limited to ensuring that "…sewage or effluent from the system is properly treated and does not surface, pool, flow across the ground or discharge to surface waters" (ODEQ, 2012). ATS may discharge treated effluent only when daily inputs are greater than 100 gallons or less than 1,500 gallons per day (ODEQ, 2012). ATS treated wastewater may only be discharged between 1-6 am with no exceptions (ODEQ, ASTS).

Water clarity may be measured by a secchi disk (an instrument used for measuring water clarity) and the bottom of the holding or pump tank must be visible at all times (ODEQ, 2012). If a homeowner chooses to discharge treated effluent through spray irrigation, "…a free chlorine residual of two tenths of a milligram per liter (0.2 mg/l) must be maintained in the pump tank" (ODEQ, 2012). Fecal coliform bacteria should not exceed 200 cfu/100 mL (ODEQ, 2012).

Bacteria

According to the United States Environmental Protection Agency (USEPA) "*Escherichia coli* (*E. coli*) is a type of fecal coliform bacteria… found in the intestines of animals and humans. …*E. coli* is a strong indication of recent sewage or animal contamination. …Sewage may contain many types of disease-causing organisms" (USEPA, 2013a).

The USEPA also states "Fecal coliforms are bacteria that are associated with human or animal wastes" (USEPA, 2013a). USEPA has set a Maximum Contaminant Level Goal (MCLG) for fecal coliforms at zero for drinking water (USEPA, 2013a).

Bacteria and *E. coli* have the potential to contaminate creeks and streams during rainfall events (USEPA, 2013a). Reports of human illness are associated with swimming, drinking, or ingesting contaminated water with *E. coli* and fecal coliform bacteria (USEPA, 2013a).

The young and elderly are more susceptible to illness caused by ingestion and/or consumption of *E. coli* and fecal coliform contaminated water (USEPA, 2013a). *E. coli* and fecal coliform may cause "…severe bloody diarrhea and abdominal cramps; and …acute kidney failure in children" (USEPA, 2013a).

Rules and Regulations Associated with ATS in Oklahoma

ATS are regulated by a certified installer two years post installation; further certified installer monitoring may occur upon a signed agreement between the ATS owner and the certified installer (ODEQ, 2012).

Standards include ATS fecal coliform bacteria concentration standards (ODEQ, 2012). Standards specify ATS should not exceed fecal coliform concentrations above 200 cfu/100 mL sample; however, fecal coliform sampling and testing requirements are not required (ODEQ, 2012).

ATS owners/operators do not need to obtain an Oklahoma Pollutant Discharge Elimination System (OPDES) permit prior to discharging treated effluent to the surface (ODEQ, 2011d). Specifications of ATS disposal are not limited (ODEQ, 2012).

Recent Research

(Stambaugh, 2014. Bacterial Assessment of Applied Treated Effluent from Wastewater Systems, M.S. Thesis, Environmental Science, Oklahoma State University).

In the discharge of ATS, fecal coliforms are mandated that they be less than 200 cfu/100 mL sample in Oklahoma (ODEQ, 2012). In a 2014 study of 3 typically installed ATS, approximately 10,000 to

200,000 MPN/100 mL fecal coliform concentrations were quantified from ATS holding (pump) tanks (Stambaugh, 2014). Approximately 36,000 to 900 MPN/g fecal coliform concentrations were quantified from ATS pre-treatment effluent applied to soil (Stambaugh, 2014).

Rules and regulations associated with ATS in Oklahoma do not include *E. coli* standards (ODEQ, 2012). Approximately 1,000 to 100,000 MPN/100 mL *E. coli* concentrations were quantified from ATS holding (pump) tanks (Stambaugh, 2014). Approximately 520 MPN/g *E. coli* was quantified one-hour after application of ATS pre-treatment effluent to soil (Stambaugh, 2014). However, the USEPA states that systems are "…required to disinfect to ensure that all bacterial contamination is inactivated, such as *E. coli*" (USEPA, 2013a).

Recommendations Based upon Recent Research

- Do not use ATS to irrigate crops or consumable plants.
- Bacteria contamination is transmitted to humans or animals through contaminated water or crops (CDC, 2012).
- Do not allow children to play near the surface of ATS discharge effluent where ponding or soil saturation may occur and potentially cause illness (CDC, 2012).
- Do not discharge treated effluent near a stream or creek potentially contaminating surface waters (ODEQ, 2012).
- Do not allow animals to consume ATS treated water.
- Human contact with ATS treated water should be avoided.
- Increase maintenance associated with ATS.
- Homeowners should hire a certified maintenance installer to perform ATS maintenance responsibilities and requirements if the homeowner is unable or unwilling to perform all the necessary steps.
- Large facilities generating greater than 1,500 gallons/day of water should not use ATS (ODEQ, 2012) and/or industrial facilities.
- Discharge ATS water through a drip irrigation piping system located at least 30 cm below the surface (Franti et al. 2002).
- Do not allow ponding or soil saturation to occur; runoff and soil leaching potentially lead to creeks, streams, or rivers (USEPA, 2013a).

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Figure 13. Fact Sheet

Conclusions

Additional research associated with streams located near ATS (discharged treated effluent) should be studied to determine effects ATS have on stream water quality, and determine if ATS owners/operators should obtain an OPDES permit. Future studies may be conducted through a survey response technique regarding homeowner and builder concerns. Suggested survey questions would be applicable for the owners/operators (of ATS) and include questions pertaining to maintenance performed. As the number of ATS installations are increasing in Oklahoma, the importance of considering human and environmental safety are more important; current rules and regulations (for ATS) are lacking in regulating *E. coli* and fecal coliform contaminations. Further recommendations are that ATS be regulated under Chapter 252, Chapter 627 (water reuse) based upon more stringent fecal coliform monitoring and reporting regulations; however, the rules and regulations pertaining to ATS should indicate users to not water crops and/or consumable produce from ATS treated effluent, preventing illness from possible ingestion of contaminants.

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APPENDICES A

ATS Owner's Manual

Retrieved from: http://www.npswastewater.com/clearstream.htm

NPS WASTEWATER SYSTEMS LIMITED

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Phone: 604-924-1085 Fax: 604-924-1785 e-mail: info@npswastewater.com
Toll Free 877-712-2233

NPS Wastewater Systems Limited

CLEARSTREAM SYSTEMS OWNERS MANUAL

MODEL 500H	416 IGPD
MODEL 600H	500 IGPD
MODEL 750H	624 IGPD
MODEL 1000H	832 IGPD
MODEL 1500H	1248 IGPD

CLEARSTREAM® WASTEWATER SYSTEMS, INC.

NSF® CLASS I

INTRODUCTION

The Clearstream System is one of the finest aerobic wastewater systems available today. Our system converts the sewage from your residence or business into a clear odorless liquid. This high degree of treatment is accomplished at a remarkable low operating cost per month. The system has been simplified over the years to make it as inexpensive to operate and as low in long term maintenance as possible. Homeowners who have lived with the nuisance of a septic odor lingering in their neighborhood will truly appreciate the pleasure of owning a Clearstream System

PROCESS DESCRIPTION

The Clearstream Wastewater Treatment System operates in the extended aeration mode of the activated sludge process.

Wastewater enters the aeration chamber of the system through a 4" Sch. 40 PVC inlet pipe. The wastewater is then mixed throughout the aeration chamber by releasing compressed air near the bottom of the chamber through a fine bubble diffuser. The rising air bubbles transfer oxygen to the wastewater which allows aerobic organisms to thrive and ultimately decompose the incoming waste matter

The turbulence caused by the rising air bubbles also creates a mixing pattern which keeps the sludge in suspension. As incoming wastewater enters the aeration chamber, existing "mixed liquor" from the aeration chamber is displaced into the bottom of the cone-shaped clarifier.

The clarifier chamber allows the water to still so that suspended solids in the "mixed liquor" can settle back into the aeration chamber for further biological breakdown.

The remaining clear water in the upper zone of the clarifier chamber is then discharged through the surge control weir and out the 4" Sch. 40 outlet pipe.

When properly loaded and maintained, the aforementioned process allows the Clearstream Wastewater Treatment System to provide years of satisfactory service for the consumer Clearstream Models meet the performance requirements of NSF Standard 40 Class I with a 30 day average of <25 mg/I CBOD and <30 mg/I TSS. Actual NSF test results used to determine if Clearstream met Standard 40 requirements averaged 6 mg/I BOD and 9 mg/I TSS

OPERATING MANUAL

In order for the Clearstream System to function at optimum performance levels the system will require periodic service. The normally expected service that is associated with the system includes:

1. Repair or replace aerator 2 to 10 years

2.Clean filters on aerator	6 mos. to 2 years
3.Break Lip scum in clarifier	6 mos. to 2 years
4.Pump sludge from aeration tank	2 to 5 years*
5.Pump sludge from pretreatment tank	2 to 5 years*
6.Check aeration diffusers	annually
7.Check surge control weir	6 mos.

* Any sludge removed from pretreatment tank or Clearstream Unit must be disposed of according to all provincial, local, and federal regulatory requirements.

To remove solids from pretreatment tank drop pump hose through access opening on top of tank all the way through to the bottom of the tank. Pump out the whole tank volume, then fill the tank back up immediately. To remove solids from aeration chamber, drop hose through access opening in tank all the way to the bottom of the tank. Pump only *1/2* of the total tank volume and fill tank back up with water immediately.

To determine if all system components are functioning properly, look and/or listen to see if the visual/audio alarm system is illuminated or making a buzzing sound. If the alarm is activated then either the aerator has thrown its breaker or the high level float inside the clarifier is indicating a high water level condition. Verification of either condition can be made by visually monitoring the push button breaker to see if it is in the out position indicating it has been thrown and opening the access opening to the treatment unit to see if the water level inside the clarifier is at alarm level. After inspection of the clarifier be sure to securely fasten the access cover back in place and tighten the tamper resistant bolt or bolts firmly.

To determine if the system has the desirable “mixed liquor” and effluent characteristics first remove the access cover. Monitor for odors coming from the tank. If the odor is a sweet or a musty smell the system is operating in a desirable aerobic condition. If the odor is foul or smells like a rotten egg, then the system is operating in an undesirable anaerobic condition. Visually monitor the “mixed liquor” for color. If the color is a brownish color, then it is operating in a desirable aerobic condition. If it is grey or black in color it is operating in an undesirable anaerobic condition. The system effluent should be clear with very few noticeable light brown solids suspended in the effluent. The effluent should not be dark or turbid in color or clear with great numbers of light brown suspended solids noticeable. After inspection of the system’s interior, be sure to securely fasten the access cover back in place and tighten the tamper resistant bolt or bolts firmly.

To collect effluent samples from a system, a sample port must be added downstream of the effluent discharge. The sample port should be installed so that effluent cannot remain below the discharge water line and build up solids. A sample bottle should be capable of being lowered into the port on a string and laid on its side in the direct flow line of the discharge and removed when full of effluent.

The expected effluent from the system should be less than 25 mg/l CBOD and less than 300 mg/l TSS with a PH range of 6-9.

For the Clearstream Aerobic Wastewater Treatment Unit to function properly it must be used for the treatment of domestic wastewater from residences or other waste flows with similar loading characteristics. Typical domestic wastewater consists of the flow from toilets, lavatories sinks bathtubs/showers, and washing machines. To prevent malfunctions of your Clearstream Unit, the following guidelines should be followed:

1. Any sewage system, whether aerobic or septic, should not have inorganic materials (plastics, cigarette butts, throwaway diapers, feminine napkins, condoms etc.), that the bacteria cannot consume, discharged into the system.

2. Large amounts of harsh chemicals oil, grease, high sudsing detergents, discharge from water softeners, disinfectants or any other chemical or substance that kills bacteria should not be discharged into the system.

3. Excessive use of water over the design flow of the system, or organic overloading in excess of design parameters will cause the system not to perform to its fullest capabilities.

4. The proper operation of this or any other sewage treatment system depends upon the proper organic loading and the life of the micro-organisms inside the system. Clearstream is not responsible for the in-field operation of a system, other than the mechanical and structural workings of the system itself. Field abuse and overloading of the system can only be cured by the user of the system.

5. When wastewater discharge, into a Clearstream Unit is seasonal or intermittent to a point that the owner wishes to turn off the electricity (for more than three (3) months) to the aerator, the aerator inlet and outlet should be sealed to keep out moisture until the unit is ready to be restarted.

CLEARSTREAM INSTALLATION INSTRUCTIONS

Before installation of the Clearstream Treatment Tank, first install a trash trap (septic tank) with a volume of not less than 50% and not more than 100% of the gallon per day rating of the Clearstream unit.

CLEARSTREAM TANK INSTALLATION:

Note: To determine which is inlet and which is outlet. The inlet is a 7” stub of sch40 PVC pipe. The outlet is a much longer pipe connected to an internal filter. The difference can be easily observed from, the outside of The tank, before it is installed.

t Prepare an excavation having minimum dimensions of at least one (1) toot larger than the diameter of the tank- Make sure the depth of the excavation is deep enough to allow gravity flow to the inlet of the system and that the excavation bottom is level. Never install the Clearstream tank deeper than a depth that will require more than a maximum of 18 inches of riser depth, The access cover shall always be above final grade after tank installation- In applications where more than the maximum 18 inches of riser is required, install a lift pump upstream of the Clearstream tank in order to pump the trash tank effluent to the Clearstream tank at normal grade. In these special applications where a lift pump is required, contact NPS for more details as to pump size, maximum dosages and maximum flow rates.

2 Set the Clearstream tank in a prepared excavation that has a solid, level bottom that will eliminate tank settling. The excavation bottom should have no rocks or sharp objects present.

3 When lowering a fiberglass tart into the prepared excavation use the lifting eyes which are bolted into the tank top. When lowering a concrete tank into the prepared excavation use a spreader bar or nylon sling. Never lift fiberglass Clearstream tanks unless they are empty of all liquids,

4 Make sure the inlet 4” sch40 PVC pipe is aligned properly to the incoming sewage line and that the outlet 4” sch40 pipe is aligned to the downstream discharge line. Before setting the tank in the prepared excavation open the access cover and verify that the inlet and outlet pipes are aligned correctly,

5 For the Clearstream unit to function properly, the tank must be level- To properly level the tank, remove the access cover and lay a three (3) foot level across the access opening in several directions. Shift the tank in the hole as necessary to make the tank level in all directions. The tank may be slightly out of level, but it should not be out of level enough to cause tank malfunctions.

6. Fill the tank with water checking periodically making sure the tank remains level,

7 Connect the 4 sch40 PVC Clearstream inlet pipe to the outlet pipe from the trash tank. Make sure the trash tank outlet pipe is level with or higher than the inlet pipe to the Clearstream unit- The 4” sdh40 PVC outlet pipe from the Clearstream unit should now be connected to the discharge line. The Clearstream unit should only be connected to a plumbing system from a waste-water source which has been properly trapped and vented in compliance with provincial and Local plumbing codes

8. Back fill the excavation in layers with a back fill material that will settle properly around the tank. Tamp the back fill material as each layer is placed around the tank. If necessary, use water to help settle the soil around the tank. Special care should be taken to either tamp soil under where inlet and outlet pipes are bridging the excavation or use some other method of supporting pipes across the excavation. Do not back fill with heavy clay or large rocks.

9. Before completing the backfill, be sure the signal wire conduit from the alarm float to the Control Panel has been laid underground.

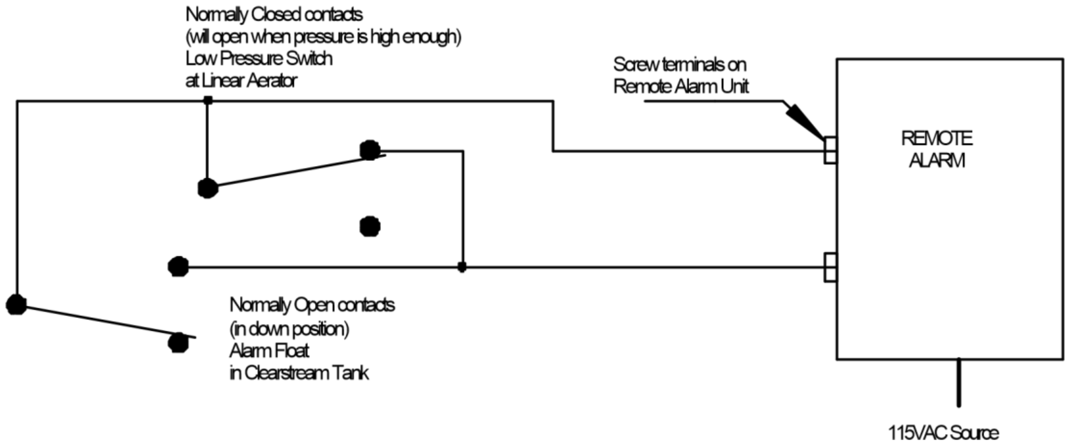
10. For below normal grade installations a Clearstream 20 inch diameter riser may be used on all models except the 1500 G.P.O. units. The 1500 G.P.O. units must use a 32 inch diameter riser. In no case shall more than 18 inches of total riser depth be used on a single Clearstream unit to bring the access cover above final grade. AU risers must be sealed with silicone to prevent ground water intrusion before back fill is completed.

11. Before leaving excavation site, be sure to securely fasten the Clearstream access cover in place with the tamper resistant bolt/bolts. Tighten bolts firmly to keep unauthorized personnel from gaining access to inside of tank.

CLEARSTREAM AERATOR AND ALARM PANEL INSTALLATION:

1. Mount the remote alarm unit in a location that can be easily noticed by the occupants.

2. Wire 115 Volt, 60Hz. power from an electrical disconnect to Clearstream Aerator. Wire from High Level Alarm Float to the Remote Alarm Panel. The Normally Closed contacts of the low pressure switch on the linear aerator (if present) should be wired in parallel at the alarm box with the Normally Open High Level Alarm Float in the Clearstream tank. When discharge pump is used wire power to pump tank and pump tank alarm float. All electrical wiring should be installed by a qualified person in compliance with applicable sections of the National Electrical Code or other more stringent local codes.



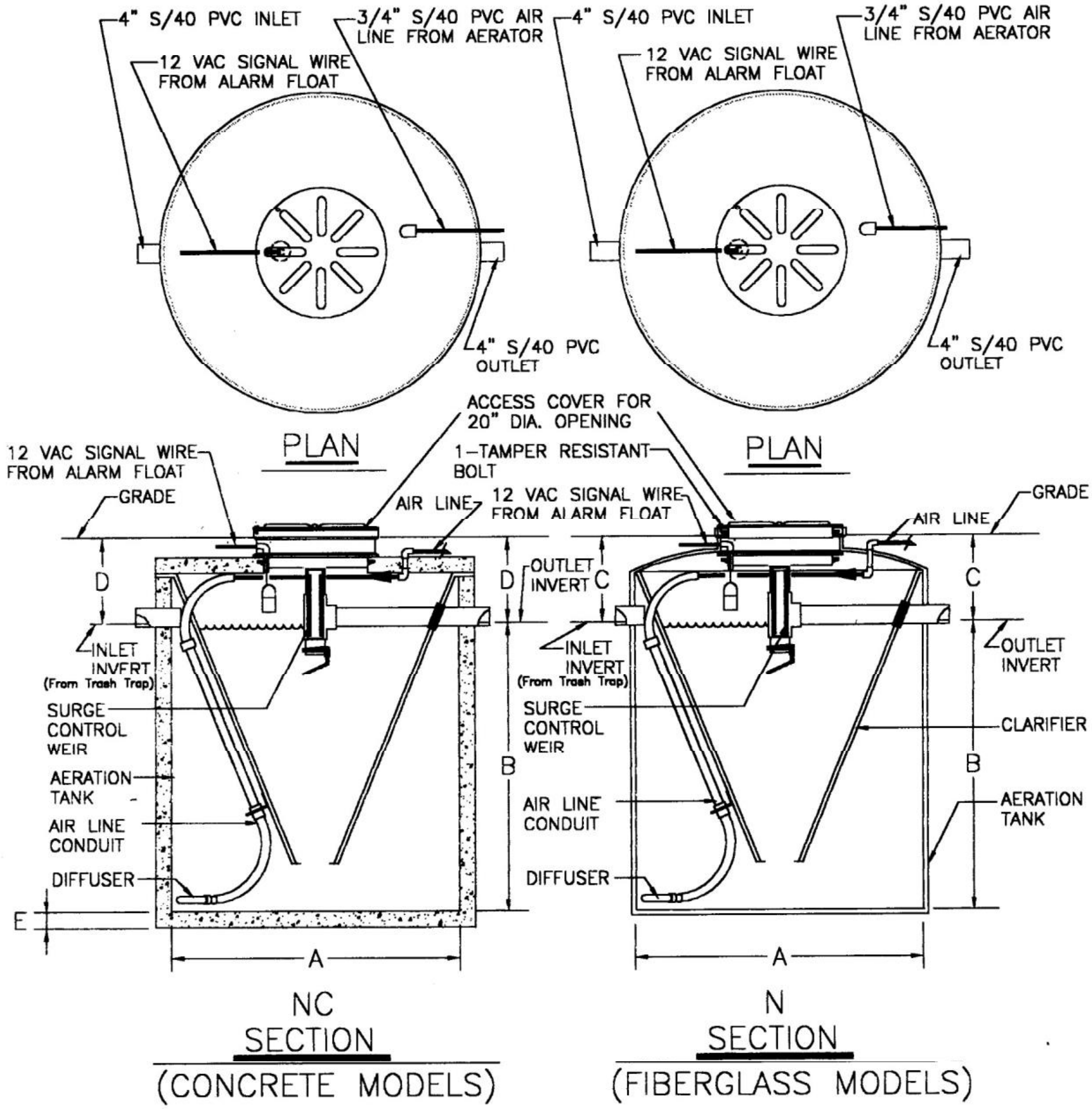
3. Install Aerator Model CS-103 as close as practical to tank, but in no case greater than one hundred (100) feet away (50'on 1500 G.P.D. units). Run 3/4' Sch.40 PVC air line from aerator connector to air line connection at Clearstream tank. Be careful to back fill underground air line in a manner which will not cause air line to leak. Aerator must be installed in a location that is dry, non-dusty and highly ventilated.

4. Turn power on at electrical disconnect and check for proper system operation.

COMPLIANCE WITH LAWS:

The Clearstream Unit must never be installed without first obtaining all permits and approvals from the local regulatory body. In areas that do not have local control over environmental activities, all applicable Provincial and Federal environmental codes must be adhered to. Only properly licensed and trained individuals should install Clearstream equipment.

DESIGN DRAWINGS



MODEL	A	B	C	D	E
500N/NC	5'-3"	5'-3"	1'-7½"	1'-4¾"	3"
600N/NC	6'-4"	4'-7"	1'-5½"	1'-5¾"	3"
750N/NC	6'-4"	5'-5"	1'-7½"	1'-5¾"	3"
1000N/NC	6'-4"	7'-3"	1'-5¾"	1'-5¾"	3"
1500N/NC	8'-0"	6'-10"	2'-0"	1'-7¾"	4"

U.S. Patent Numbers
5,221,470
5,770,081
5,785,854

SPECIFICATIONS

Clearstream Units

Model 500H

Treatment Capacity	416 IGPD
BOD Loading	125 lbs. BOD
Aerator (Model CS-103EL)	2.4 scfrn
Aerator (Model CS-103E)	2.4 sclm
Electrical	115v./60Hz/.75 amps/82 watts
*Electrical	115v./60Hz/3.8 amps/151 watts

Model 600H

Treatment Capacity	500 IGPD
BOD Loading	1.5 lbs. BOD
Aerator(Model CS-103EL)	2.8 scfm
*Aerator(Model CS-103E6)	2.8 scfm
Electrical	115v./60Hz/.75 arnps/82 watts
*Electrical	115v./60Hz/3.8 amps/157 watts

Model 750H

Treatment Capacity	524 IGPD
BOD Loading	1.85 lbs BOD
Aerator (Model CS-103FL)	3.6 scfm
*Aerator (Model CS-103F)	3.6 scfm
Electrical	115v./60Hz/1.05 amps/120 watts
*Electrical	115v./60Hz/4.7 arnps/195 watts

Model 1000H

Treatment Capacity	832 IGPD
BOD Loading	2.5 lbs. BOD
Aerator (Model CS-103G)	4.8 scfm
Electrical	115v./60Hz/4.7 arnps/220 watts

Model 1500H

Treatment Capacity	1248 IGPD
BOD Loading	3.75 lbs BOD
Aerator(Model CS-103H)	7..2scfrn
Electrical	115v./60Hz/6.58 amps/425 watts

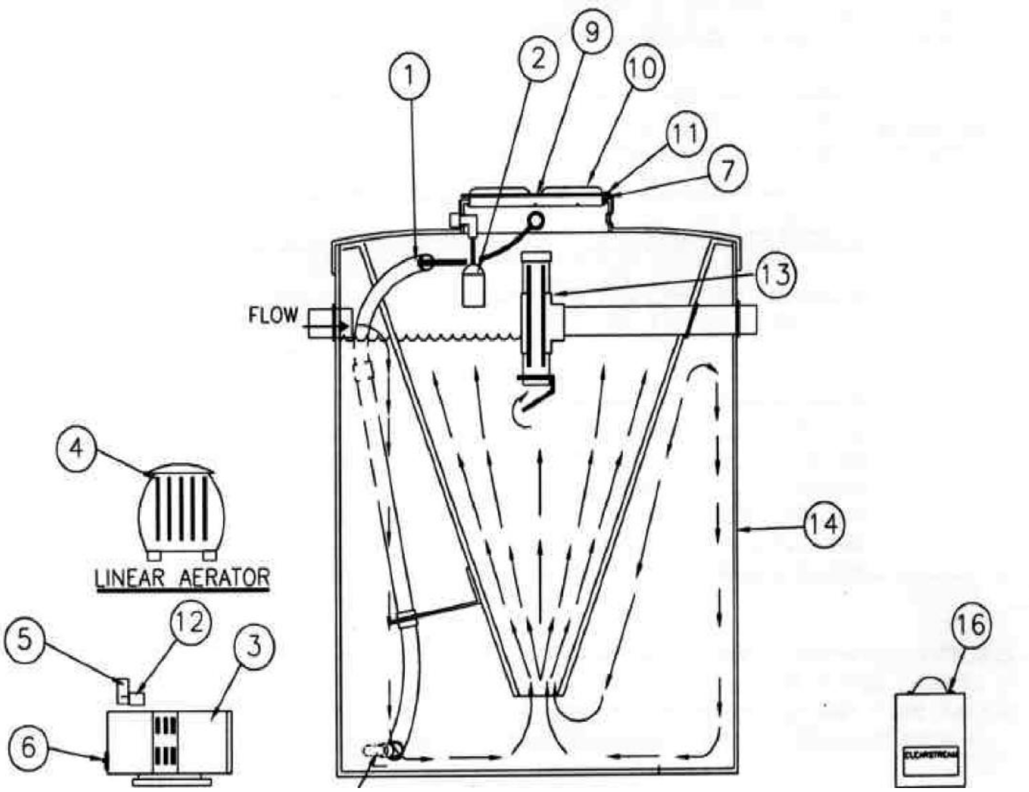
Pretreatment Tank

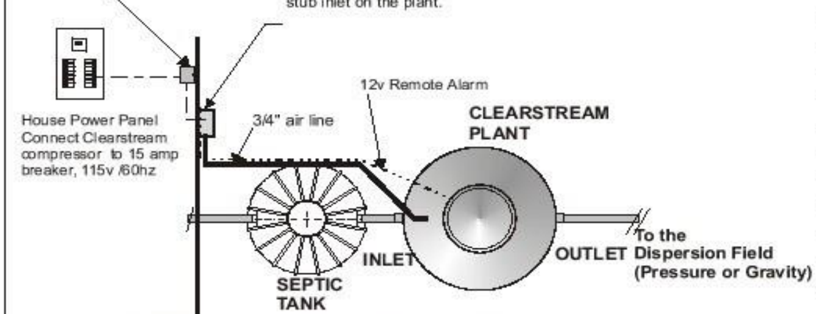
Minimum Capacity	1/2 Plant design flow
Minimum Liquid Depth	30 inches
Four Inch Inlet Tee Baffle Discharge	6 inches below liquid level
Four Inch Outlet Tee Baffle Intake	25% to 50% of liquid level

Inlet flow line must be a minimum of two (2) inches higher than the outlet flow line.

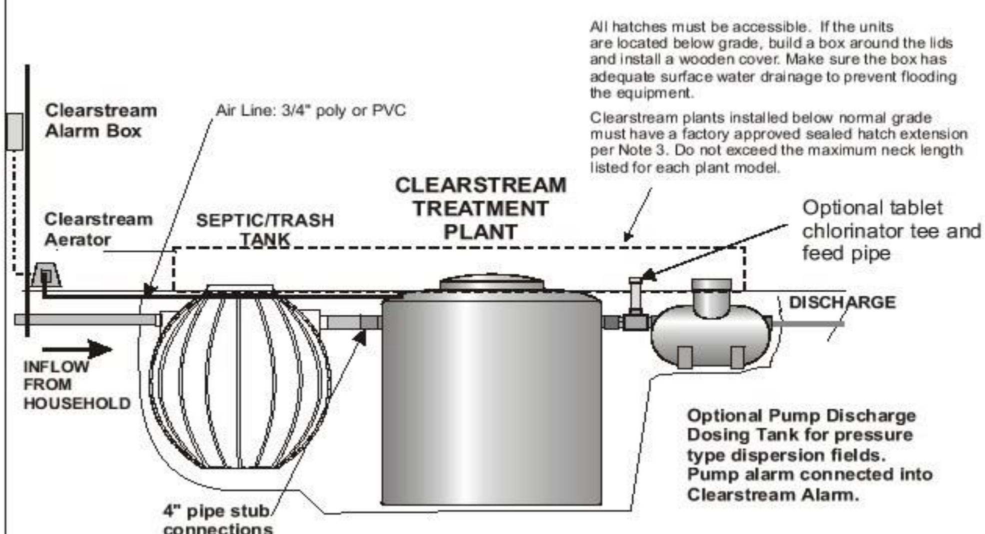
PARTS LIST AND FLOW DIAGRAM

PART NAME	PART NUMBER
1. AIR SUPPLY HOSE ASSEMBLY	CS-101
2. ALARM FLOAT	CS-102
3. ROTARY VANE AERATOR (OPTIONAL)	CS-103(E,E6,F,G,I
4. LINEAR AERATOR	CS-103(EL,FL)
5. EXTERNAL AIR FILTER	CS-104
6. INTERNAL AIR FILTER	CS-106
7. TINNERMAN FASTENER (1500N ONLY)	CS-110
8. FRP 32" DIA. EXTENSION (1500N ONLY)	CS-115
9. NAMEPLATE	CS-107
10. ACCESS COVER	CS-108
11. TAMPER RESISTANT BOLT	CS-109
12. CHECK VALVE	CS-105
13. FLOW CONTROL WEIR	CS-111(A,B,C,D,E
14. TANK	CS-112
15. DIFFUSER	CS-113
16. ALARM PANEL	CS-114(A,B,C,D,E
17. POLY 20" DIA. EXTENSION	CS-116(A,B,C)





TYPICAL INSTALLATION PLAN



MODEL	500H	600H	750H	1000H	1500H
Capacity impgal/day	416	500	624	832	1248
Septic Tank gals	600	600	600	750	1,000
Aerator Model	CS-103E	CS-103E6	CS-103F	CS-103G	CS-103H
Power (Amps Max.)	3.8	3.8	4.7	4.7	6.5
Power (Watts)	151	157	195	220	425
Dimensions					
Height	7'-0"	6'-3"	7'-1"	9'-0"	8'-6"
Diameter	5'-3"	6'-4"	6'-4"	6'-4"	8'-0"
Inlet/Outlet Invert	5'-3"	4'-7"	5'-5"	7'-3"	6'-10"
Pipe Connections	4"sch40	4"sch40	4"sch40	4"sch40	4"sch40
Weight					
Shipping Weight lbs	375	450	480	580	875
Flooded Weight lbs	7,500	9,500	11,000	15,000	22,000

POWER SUPPLY 115v/60hz 15 amp

NOTES

1. All Clearstream systems must have a septic tank ahead of the unit.
2. The outlet of the Septic tank must be at the same level as the inlet pipe to the Clearsteam.
3. For below normal grade installations, a Clearstream CS-115 6" extension riser must be used. In no case should the riser be more than 18" on model 500H and 600H, or 12" on models 750H, 1000H, or 1500H. Riser joints must be sealed watertight.
4. Make the excavation at least 1 foot larger than the unit and place 4" of sand or other fine-grained material on the bottom. Tamp the material smooth and level.
5. The tank must be level to function properly. During water filling, check the level periodically.

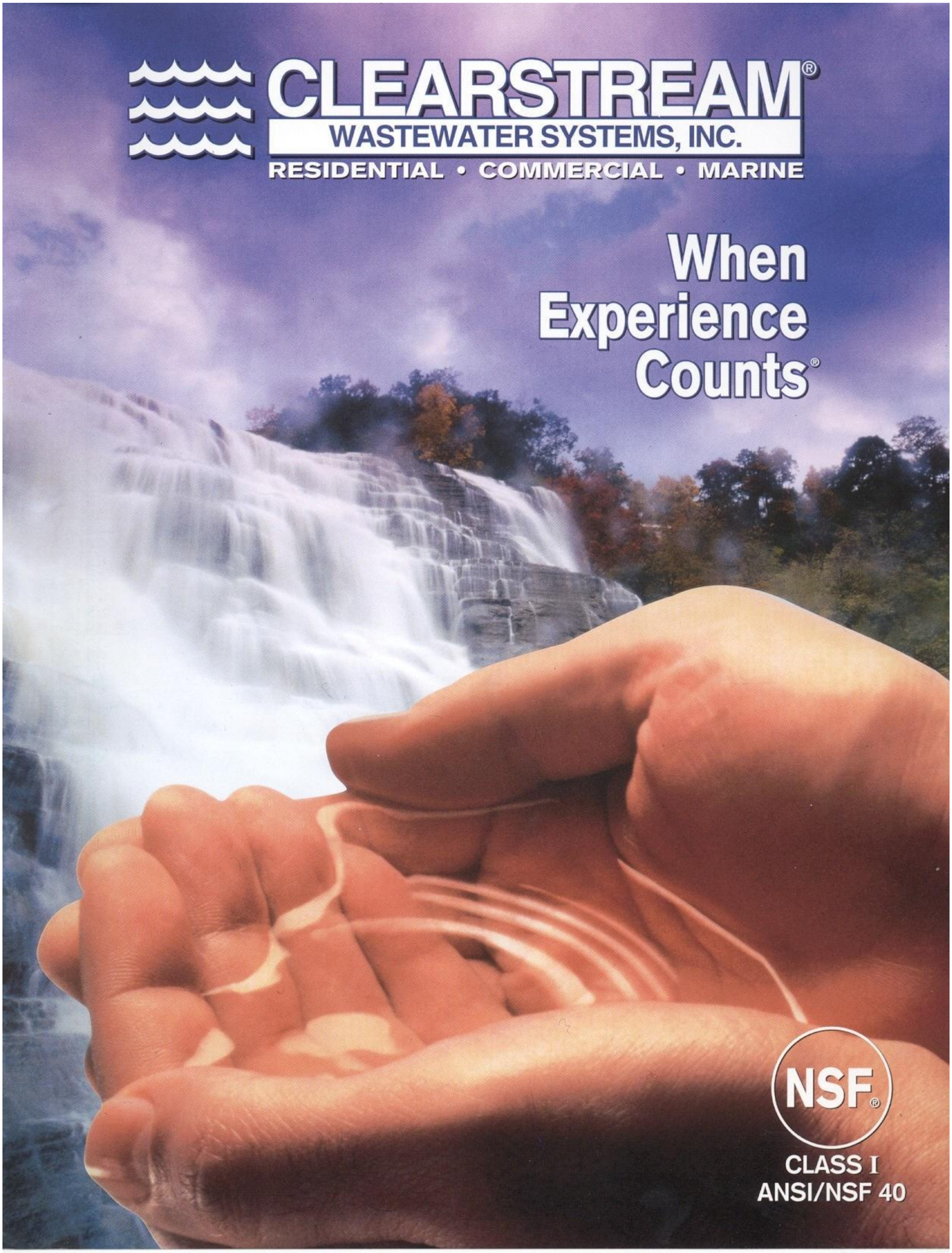
NOTICE
ALL LIDS AND COVERS MUST HAVE SECURITY LOCKS TO PREVENT UNAUTHORIZED ACCESS AND TAMPERING.

Authorized Dealer		
NPS WASTEWATER SYSTEMS LIMITED		
Date: 941015	Scale:	Rev: 980417
Unit 3, 1974 Spicer Rd., North Vancouver BC, V7H 1A2 Tel: (604) 924-1085 Fax: (604) 924-1785	CS-1	

APPENDICIES B

ATS Brochure

Retrieved from: http://www.npswastewater.com/clearstream.htm


CLEARSTREAM®
WASTEWATER SYSTEMS, INC.
RESIDENTIAL • COMMERCIAL • MARINE
When Experience Counts®
NSF®
CLASS I
ANSI/NSF 40

The Clearstream Wastewater Treatment System is a highly efficient "extended aeration" sewage treatment plant. This system, through aeration and clarification, provides a proper environment for aerobic bacteria and other micro-organisms that convert the incoming sewage into clear, odorless, and organically stable water. Test results taken from actual in-service applications of Clearstream Systems average consistently below the United States Environmental Protection Agency requirements for direct discharge of treated effluent.

Because of the high quality of effluent discharged from the Clearstream System, many alternative methods of disposal are made possible. Some regulatory agencies allow direct discharge of the effluent to streams, lakes, bays and other bodies of water. Where the regulatory agency does not allow direct discharge of treated effluent, many alternative on-site disposal methods may be used. Spray irrigation and drip irrigation of lawns, pastures, landscape beds, or even golf courses are common reuse methods. With additional accessories, the recycle of the effluent is made possible for many other non-potable water uses.

In areas with very slow percolating soils and/or high water tables, wastewater may surface even on new absorption systems. In areas with soils that percolate too fast, in rocky terrain, or in areas with high water tables, the effluent from a septic tank can move through the soil with little soil treatment, thus polluting underground water supplies or surface waters. In all the above cases, the discharge from the Clearstream System, when coupled with properly designed accessories, can prevent these type health hazards or pollution problems.

The simple compact design of the Clearstream System makes it easy to install and maintain. The 115V aerator is located remotely to prevent water damage or corrosion that can occur in tank mounted aerators. The aerator uses very little electricity and is easily replaced in less than five minutes. The durable, high quality aerator will last many years and is very inexpensive to repair or replace. A Clearstream audio visual alarm panel will notify the home owner immediately in the event of component or accessory malfunction.

The Clearstream Model 500N Wastewater Treatment System has been extensively tested by NSF, International under the lengthy and in-depth testing procedures of the NSF, International Standard 40. Clearstream test results averaged as low as 5 mg/l CBOD and 5 mg/l TSS. All Clearstream Standard 40 Models 500N, 600N, 750N, 1000N, and 1500N are classified as Class I systems with or without the optional Model 1100 Filter.

WHY CLEARSTREAM?

PERFORMANCE

Clearstream Wastewater Treatment Systems have been tested and certified by NSF, International to meet and exceed the requirements of the International Standard 40 evaluation developed by NSF and the Council of Public Health Consultants. In addition to the testing of our products by NSF, Clearstream has for many years successfully marketed its treatment systems nationally and internationally to meet a wide range of regulatory requirements. You can count on Clearstream products to work for you.

SIMPLICITY

Clearstream does not believe that the "State of the Art" in wastewater treatment systems is to see how complicated we can make a treatment system. We have based our business on the concept that "State of the Art" is to make the system as simple as possible while consistently providing a product that produces the highest degree of water quality. We strive for and have obtained simplicity and reliability of performance with our products. When special applications are encountered, Clearstream has all the necessary accessories to meet those needs. Some of these accessories include denitrification, tertiary filtration, chlorination, ozone or ultra violet disinfection, and remote electronic monitoring.

RELIABILITY

Although wastewater treatment systems are our life at Clearstream, we understand they are not and should not be constantly on your mind. Our mission is for the consumer not to be bothered by frequent malfunctions of their wastewater treatment system. The user friendly design of our equipment, along with the finest materials and components available, ensure long, trouble-free performance of our treatment systems.

CONSTRUCTION

Clearstream manufactures treatment systems constructed of "Fiberglass Reinforced Plastic" commonly called Fiberglass, and we also have Precast Reinforced Concrete tanks available. Our Fiberglass tanks are constructed of the finest chemical resistant isophthalic polyester resins and the best fiberglass reinforcement strands available. These tanks have been tested and certified by an approved IAPMO testing laboratory to meet and exceed the stringent construction requirements of the International Association of Plumbing and Mechanical Officials (IAPMO). In addition, Clearstream Fiberglass tanks have passed the test of time. Many thousands of our Fiberglass tanks have been in successful service for many years. Clearstream Precast Reinforced Concrete tanks are designed by structural engineers specializing in precast design. Our Precast Reinforced Concrete tanks meet the appropriate ASTM (American Society for Testing Materials) construction standards and have demonstrated excellent service in the field. Both the FRP and Concrete Clearstream tanks utilize only non-corrosive hardware. All hardware items are either PVC, Stainless Steel, Polyethylene or Neoprene. Corrosion is a major problem with buried tanks, particularly when they exist in a corrosive wastewater environment. Because Clearstream does not cut corners, we manufacture tanks that provide many years of service without structural failure or leakage.

COMPONENTS

Clearstream's aerators, control panels and accessory equipment are manufactured in the U.S.A. The aerator is housed in an attractive, protective enclosure that not only protects the aerator from the elements, but is also aesthetically pleasing. The Clearstream control panels utilize UL approved weather proof panel boxes designed for outdoor service. Clearstream has a long record of providing our customers with top quality materials and components at competitive prices.

WARRANTY

Clearstream warrants its equipment for two years, without hidden conditions. Our equipment, of course, lasts much longer than the warranty we provide, but we do not believe in offering prorated warranties that involve complicated warranty procedures, exceptions and exclusions. Our warranty is simple – if the equipment is defective, we will either give you a new one or repair the one you have. We choose not to use our warranty as a sales gimmick. The warranty replacement of defective components is a serious subject to us. We want to process our warranties without complications or controversy.

OPERATING COSTS

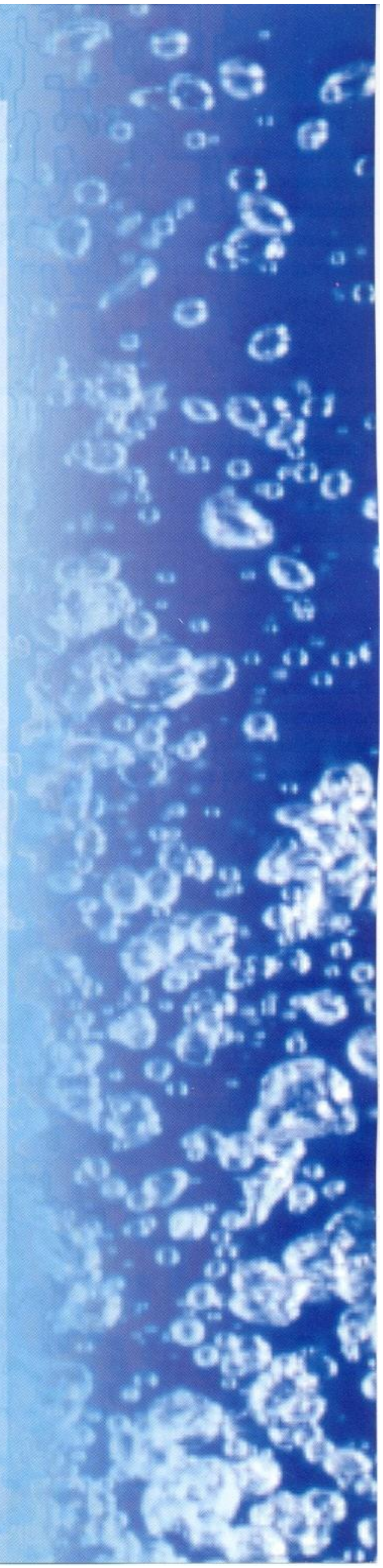
We believe Clearstream to be the most cost effective treatment system on the market. We believe this because we have made that one of our primary design considerations. The simple design and easy access to all Clearstream components and compartments allow service personnel to do their work with as little effort as possible. That translates into savings for you the consumer. With our many years of experience in the wastewater business, we designed the system so that when service is necessary, it can be accomplished without interrupting your schedule or requiring your yard to be dug up. The Clearstream 500GPD aerator uses only 131 watts of electricity which is less than a 150 watt light bulb. At 7 cents per kilowatt hour, that translates into only $6.60 monthly.

LOCAL INSTALLATION AND SERVICE

Clearstream only sells its products to professional on-site installers. Clearstream offers not only initial factory training for installation and service of our equipment, but we also provide on-going training and factory backup for problems encountered by our wholesale customers. Clearstream maintains one of the largest networks of wholesale customers in the industry because of our hands-on relationship with our customers. Clearstream's unparalleled experience allows us to help our customers solve potential problems that may occur. This backup assures you that not only do you have a local professional at your service, but you also have Clearstream's experience behind your local on-site professional.

REPUTATION

To be confident of who you are doing business with, we urge you to check out both Clearstream and the professional on-site installer with the Better Business Bureau and the local permitting authority over the on-site program in your area. We are proud of our reputation and business practices and encourage potential customers to check on our record.



Consider the advantages of
The Clearstream Home Wastewater System
above other comparable units:

TANK

Sturdy fiberglass or concrete construction

Easy to install design

Long-lasting non-corrosive components

Easy to service without digging in yard

Utilizes small pretreatment tank for grease and trash removal

AERATOR

Long life

Two-year warranty

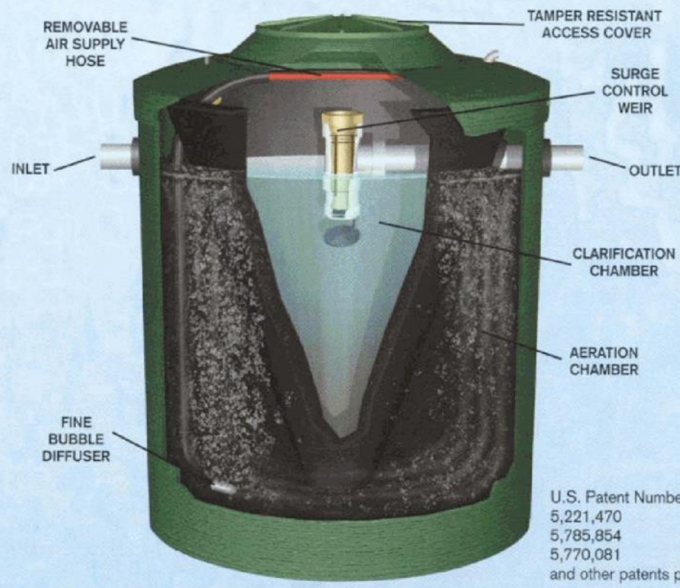
Quiet operation

Very low electrical usage

Installed outside tank to avoid flooding

500N costs approximately $6.60 per month to operate at 7cents per KWH

CLEARSTREAM TREATMENT UNIT



U.S. Patent Numbers
5,221,470
5,785,854
5,770,081
and other patents pending

Clearstream requires that a trash trap (septic tank) be utilized in front of the Clearstream tank to keep grease, toxic household cleaners and other undesirable substances from upsetting the aerobic bacteria in the treatment tank and to keep maintenance costs at a minimum.

Clearstream Wastewater Systems, Inc. has long enjoyed an excellent reputation among environmental engineers, regulatory agencies, and customers around the country. Clearstream's sewage treatment systems are available in sizes from 500 gallons per day to 1,000,000 gallons per day to serve residential, commercial and industrial applications.

For more information concerning the application, price and availability of a Clearstream Wastewater Treatment System, please contact:

or

Clearstream Wastewater Systems, Inc.
P.O. Box 7568
Beaumont, TX 77726
(409) 755-1500 • Fax (409) 755-6500
www.clearstreamsystems.com
(800) 586-3656

GUARANTEE

The Clearstream System has a two-year limited warranty against defects in material and workmanship from the date of purchase. The system and/or its components will be repaired or replaced with new or rebuilt equals to the original equipment, if all installation, operation and maintenance instructions of the manufacture have been adhered to.

SERVICE

In order for the Clearstream system to function at optimum performance levels, the system will require periodic service. The recommended service schedule includes:

SERVICE	FREQUENCY
Repair or replace aerator	2 to 10 years
Clean filters on aerator	6 months to 2 years
Break up scum in clarifier	6 months to 2 years
Pump sludge from aeration tank	2 to 5 years
Pump sludge from trash trap	2 to 5 years
Check aeration diffuser	annually
Check surge control weir	6 months

For the first two years from the date of purchase, your local installer, from whom you purchased your Clearstream System, will inspect your system on a routine basis for operational problems. Service on Clearstream electrical and mechanical components will be performed at no charge, if such components are found to be defective.

After the termination of the guaranteed service period, your local installer will make available a service policy for a nominal annual fee.

TO PREVENT MALFUNCTIONS OF YOUR SEWAGE SYSTEM, THE FOLLOWING GUIDELINES SHOULD BE FOLLOWED:

1. Any sewage treatment system, whether aerobic or septic, should not have inorganic materials (plastics, cigarette butts, condoms, throwaway diapers, etc.), which the bacteria cannot consume, discharged into the system.

2. Large amounts of harsh chemicals, oil, grease, high sudsing detergents, discharge from water softeners, disinfectants or any other chemical or substance that kills bacteria should not be discharged into the system. Garbage disposals are not recommended.

3. Excessive use of water, over the design flow of the system, will cause the system not to perform to its fullest capabilities.

4. The proper operation of this or any other home sewage system depends upon proper organic loading and the life of the micro-organisms inside the system. Clearstream is not responsible for the in-field operating of a system, other than the mechanical and structural workings of the plant itself. We cannot control the amount of harsh chemicals or other harmful substances that may be discharged into the system by the occupants of a household. We can only provide a comprehensive owners manual that outlines most substances that should be kept out of the system.

MODEL	SERVES UP TO	RATED
Model 500N	5 Residents @ 100 G.P.P.	500 G.P.D.
Model 600N	6 Residents @ 100 G.P.P.	600 G.P.D.
Model 750N	7.5 Residents @ 100 G.P.P.	750 G.P.D.
Model 1000N	10 Residents @ 100 G.P.P.	1000 G.P.D.
Model 1500N	15 Residents @ 100 G.P.P.	1500 G.P.D.

Clearstream Wastewater Systems, Inc.
P.O. Box 7568 • Beaumont, TX 77726 • (409) 755-1500 • Fax (409) 755-6500
www.clearstreamsystems.com
(800) 586-3656

APPENDICES C

Department of Environmental Quality: ATS

Retrieved from: http://www.deq.state.ok.us/factsheets/

Your New Home Has An Aerobic Treatment System

According to DEQ rules, the contractor that originally installed your system is required by law to maintain your system for the first two years at no additional charge to you, the homeowner.

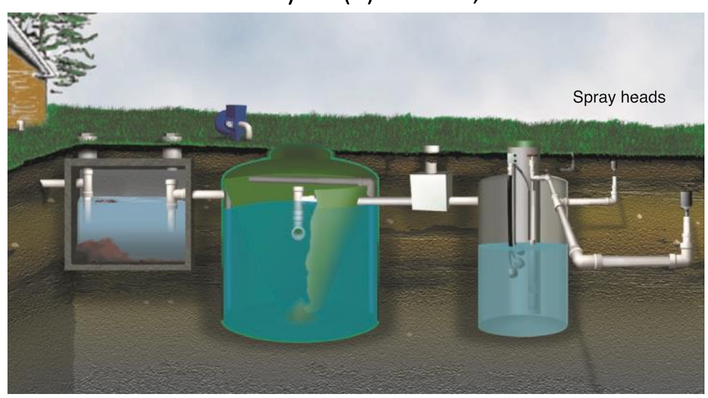
If there are any problems with the aerobic treatment system during the first two years, you should contact your system installer. If your installer fails to provide the required maintenance, please call DEQ at 1-800-522-0206.

After the initial two years, you must either perform the required maintenance yourself or contract with a maintenance provider. Below is the section of DEQ's rules that outline the maintenance requirements for aerobic systems.

252:641-10-3. Responsibility for Maintenance A. **Mandatory two year maintenance period.** The installer of any aerobic treatment system including those providing nitrogen reduction shall maintain the aerobic treatment system for a

period of two years following the date the system was installed at no additional cost to the owner. During the two-year mandatory maintenance period, the installer shall be responsible for the following:

1. Repairing, adjusting or replacing any broken or malfunctioning parts;
2. When spray dispersal is used, testing and recording the free chlorine residual of the effluent in the pump tank at least once every six (6) months;
3. Measuring and recording the depth of the sludge in the trash tank at least once every six (6) months;
4. Measuring and recording the volume of the sludge in forced-air aerobic treatment units at least once every six (6) months;



5. When pump tanks are used, conducting a clarity test and recording the results as passing or failing once every six (6) months. A passing clarity test is one where an eight-inch disk with alternating black and white quadrants is visible when placed on the bottom of the pump tank when the tank is at least one-third (1/3) full;
6. Notifying the owner of the system in writing of:
    a. The type and date of any repairs, adjustments or replacements performed on the system;

b. The results of the free chlorine residual test if required and, when applicable, the need to add chlorine and how to do it;

c. The depth of the accumulation of sludge in the trash tank and the need to have it pumped so that the depth of the sludge is never more than forty percent (40%) of the overall depth;

d. The volume of the sludge in the aerobic treatment unit and the need to have it pumped so that the volume of the sludge in the aerobic treatment unit is never more than forty percent (40%); and

e. The results of the clarity test and, if it fails the test, what the installer did or the homeowner has to do to correct it; and

7. Documenting all maintenance and testing performed on the system and maintaining those records at his/her business for a period of three (3) years following the date of service.

B. **Exclusions from maintenance.** The installer shall not be responsible for repairing aerobic treatment systems when the owner/operator is the sole cause of the damage to the system or the system's malfunction (e.g., sprinkler heads that properly retract into the ground but are nevertheless damaged by careless actions of the homeowner, excessive water usage, introduction of harmful items into septic system, etc.).

C. Owner responsible after two year period ends. After the expiration of the two-year mandatory maintenance period, the owner of the aerobic treatment system shall be solely responsible for maintaining or hiring someone to maintain the system so that it operates as designed.

For more information about aerobic treatment systems go to DEQ’s website at: http://www.deq.state.ok.us/eclsnew/Fact%20Sheets%20ECLS/System%20Fact%20Sheets/Aerobic.pdf

VITA

Kasie Dian Stambaugh

Candidate for the Degree of

Master of Science

Thesis: BACTERIAL ASSESSMENT OF APPLIED TREATED EFFLUENT FROM WASTEWATER SYSTEMS

Major Field: Environmental Science

Biographical:

Education:

Completed the requirements for the Master of Science in Environmental Science at Oklahoma State University, Stillwater, Oklahoma in May 2014.

Completed the requirements for the Bachelor of Science in Agriculture Science and Natural Resources: Environmental Science with option in Environmental Policy at Oklahoma State University, Stillwater, Oklahoma in 2011.

Experience:

- Environmental Internship, February 2014 – present, Oklahoma Water Resources Board (OWRB), Oklahoma City, OK
- Graduate Research Assistant (GRA), August 2012 – May 2014, Oklahoma State University, Stillwater, OK
- OSU Student Water Conference, April 2014 and April 2013, Oklahoma State University, Stillwater, OK
- Oklahoma Clean Lakes and Watershed Association (OCLWA) Conference, April 2014 and April 2013, Stillwater, OK
- Environmental Internship, May 2013 – August 2013, Oklahoma Water Resources Board (OWRB), Oklahoma City, OK

Professional Memberships:

- Golden Key International Honors Society, September 2013 – lifetime, Oklahoma State University, Stillwater, OK
- Society of Environmental Scientists (SES) President, August 2013 – May 2014, Oklahoma State University, Stillwater, OK
- Society of Environmental Scientists (SES) Member, August 2012 – May 2013, Oklahoma State University, Stillwater, OK
- Graduate and Professional Student Government Association (GPSGA) Representative/Liaison, August 2012 – December 2012, Oklahoma State University, Stillwater, OK