WQRF | Water Quality Research Foundation

An Independent Research Foundation of WQA

Executive Summary

Environmental Impact Study:

- **Water Softener Effects on Septic System Performance**

www.wqa.org

www.wqa.org/MarketTheResearch/

Water Softener Effects on Septic System Performance

This study was undertaken to investigate the effect home ion-exchange water softeners may have on the performance of onsite septic tanks. A laboratory study was set up with columns that contained solids collected from operating septic tanks. Wastewater was added with varying levels of sodium, as well as calcium and magnesium, modeling the periodic addition of regenerant from softeners operating at different salt dosing ranging from high efficiency to very poor efficiency. To reinforce the column experiments, data were obtained from private septic tanks to determine the effluent quality from septic tanks which did or did not receive the regenerant from softeners.

The data indicate that the use of efficiently operated water softeners (at or above ~3000 gr/lb salt efficiency) improves septic tank performance, while the use of very inefficient home softeners (at or below ~1000 gr/lb salt efficiency) may have a negative effect on solids discharge to the drain field. The level of impact will depend on the level of hardness in the water, whether the regeneration waste is discharged to the septic tank, and the amount of excess sodium present in regeneration wastes.

The study of Water Softener Effects on Septic System Performance was conducted through the Virginia Polytechnic Institute and State University, funded by the Water Quality Research Foundation, and reported in 2013.

Executive Summary

Softeners and Septic Tanks

Home water softeners are often used in homes that use wells or other water sources with high hardness because of either aesthetic concerns or potential detrimental effects of the hardness on water heaters and appliances. Onsite wastewater treatment is also frequently used in rural locations. Thus, they often coexist in many locations.

Softeners

While many types and configurations of ion exchange water softeners exist, they most commonly consist of a control valve, a softener tank containing cation exchange resin, and a brine/salt storage tank (Figure 1). When water containing calcium and magnesium cations is passed through the ion exchange resin, the calcium and magnesium will replace the sodium ions on the resin because they have a greater affinity for the active sites in the resin media. After continued use of a water softener, the resin eventually runs out of available exchange sites and must be regenerated. To accomplish this, a brine solution is passed through the resin. An abundance of sodium ions displaces the calcium and magnesium hardness ions that have accumulated on the resin over several days or weeks, causing them to release from the resin while the sodium in the brine solution takes their place on the exchange sites. The waste brine solution, or “regenerant” contains the calcium and magnesium hardness ions that have been removed from the resin, as well as the excess sodium that was needed to drive the hardness removal process. The salt concentration of the waste is typically diluted 6-fold by rinsing steps conducted during regeneration, but then it is further reduced to a total dilution of 160- to 400-fold with other household liquid waste; however, since the waste from the regeneration process alone can contain a fairly high salt concentration, its disposal into onsite wastewater treatment systems has been a topic of debate and the focus of this study.

There are different types of water softening units, and the distinction between them has to do with the unit’s approach to the regeneration cycle. A historical water softener, with limited use in recent times, called a “time clock” softener, operates with a timer that triggers regeneration when the resin is estimated to be saturated with hardness based on water hardness levels and water usage calculations. The timer settings can be ascertained through simple calculations, but changes in water quality, as well as water usage levels, can lead to problems including overuse of salt and water. The most common type of water softener now in use is called a “demand-initiated regeneration” (DIR) unit. These units keep track of the water usage and then trigger regeneration based on various factors, including amount of water used, electrical conductivity of the resin, or by monitoring the hardness of the effluent. Once one of these parameters reaches a set level, the regeneration process is initiated. These DIR water softeners are very reliable in sensing the need for regeneration and reduce the occurrence of problems associated with time clock units described earlier. These DIR systems can be very efficient in both the amount of salt or water used compared to the amount of hardness removed. This is significant in terms of the amount of discharges into the septic tank.

The study of Water Softener Effects on Septic System Performance was conducted through the Virginia Polytechnic Institute and State University, funded by the Water Quality Research Foundation, and reported in 2013.
Water Quality Research Foundation

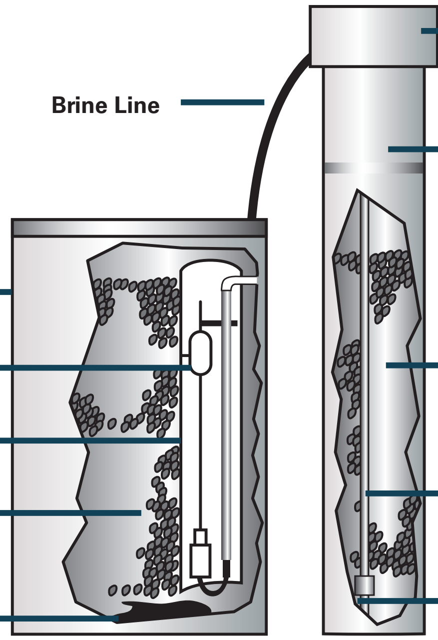


Figure 1. Typical residential water softener with automatic control valve. (McGowan, 2000)

Septic Tanks

Many rural homes are served by septic systems. While many types and configurations of these systems exist, they typically consist of a septic tank, where all household wastewater is first collected, and a drain field, where the final effluent is dispersed into the soil (Figure 2). There are four defined functions of a commonly used septic system: to receive wastewater, separate solid materials from the wastewater, provide partial treatment of wastes, and disperse treated effluent into drain fields. The tank allows solids to settle or float and provides an environment for partial degradation of organic constituents by microbes (Figure 3). The solids separation that occurs in the tank results in a 'clear zone' of clarified effluent. The clarified effluent may pass through an effluent filter prior to dispersal into the drain field where it is subjected to further natural treatment in the soil prior to recharging groundwater. Partially digested solids are retained in the tank until they are removed during regular maintenance. Altogether, these systems provide a simple and effective solution to rural wastewater management as long as they are properly designed, sited, installed, used, and maintained.

The study of Water Softener Effects on Septic System Performance was conducted through the Virginia Polytechnic Institute and State University, funded by the Water Quality Research Foundation, and reported in 2013.

WQRF | Water Quality Research Foundation

The quality of treated water from septic systems is typically characterized and judged or evaluated by the five-day biochemical oxygen demand (BOD5), total suspended solids (TSS), volatile suspended solids (VSS), chemical oxygen demand (COD), and analysis of other constituent concentrations (e.g. fecal coliforms or nitrogen when advanced treatment schemes are used downstream from the septic tanks). If the septic tank does not provide sufficient primary treatment (solids separation and some anaerobic digestion), effluent strength may exceed the soil treatment capacity. This can result in surface discharge of effluent or release of poorly treated effluent into groundwater. The effect that large concentrations of brine water constituents (particularly sodium) in the regenerant discharges from softeners may have on septic system treatment capacity is a main reason for the debate regarding how waste regenerant from water softeners should be handled.

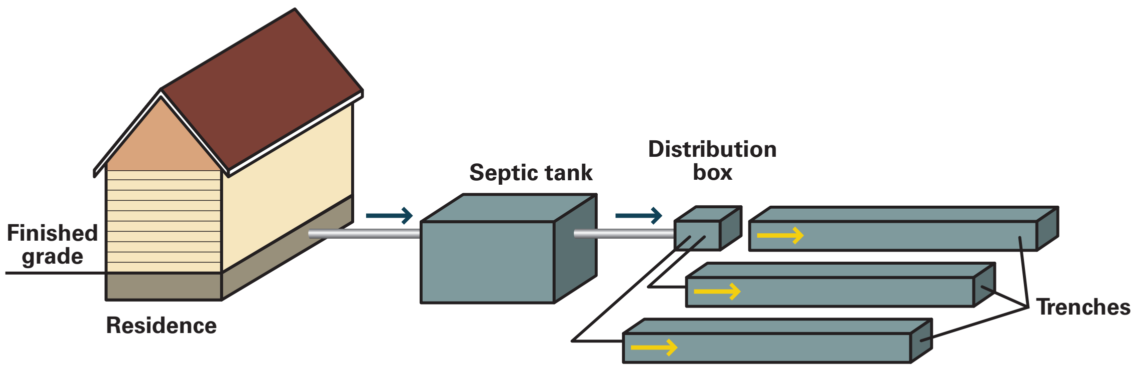


Figure 2. Typical conventional septic system configuration. Many variations are possible. (CIDWT 2009)

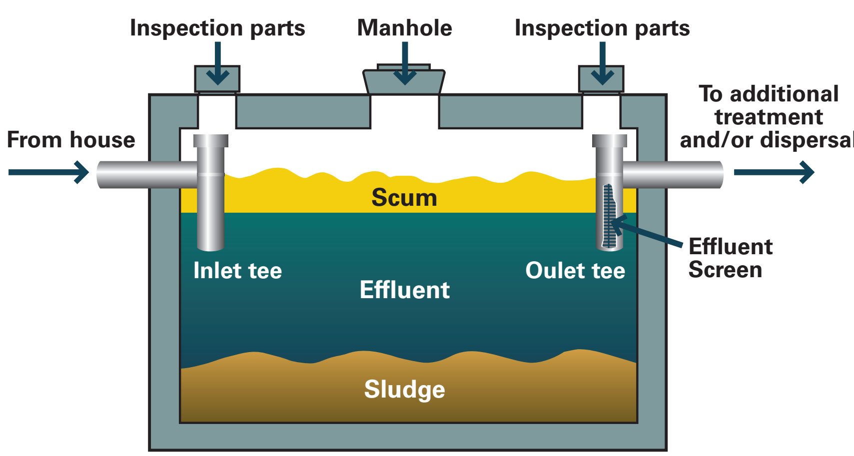


Figure 3. Typical one compartment septic tank illustrating solids separation and development of clear zone. The outlet tee (on right) is designed to draw clarified effluent from the clear zone, through an effluent screen, and then out of the tank, and convey it to the next component (NFSC 2000).

Monovalent and Divalent Cations

The dominant inorganic cations in water and wastewater systems are monovalent (single charge) and divalent (charge of two). Sodium is a common monovalent cation and calcium and magnesium are common divalent cations. The ratio of monovalent to divalent cations (on an equivalent basis), or the "M/D" of a wastewater, has been shown to affect the efficiency of certain treatment processes (e.g. settling time) which can, in turn, have an effect on the quality of the effluent stream.

Studies have shown that the addition of calcium and magnesium to industrial wastewater treatment systems decreased the time it took to settle out, and as more divalent cations were intentionally added, the chemical oxygen demand (COD) in the effluent decreased even further. However, the research also shows that excess sodium can lead to deteriorating effluent characteristics due to poor settling.

Even though the original research considered only industrial activated sludge treatment (as opposed to residential anaerobically operated septic tanks), it is important in this present study because the same ions are involved in residential water softening and onsite septic systems. Furthermore, these data serve as reason to consider the addition of regeneration waste from a softener to a septic tank as possibly beneficial to the waste treatment process in onsite wastewater systems. Depending on the actual M/D ratio of the waste (e.g. how much sodium was concentrated in the waste, as well as, how much calcium and magnesium was washed off the resin), the regenerant could potentially serve as a settling aid through reintroduction of divalent cations in the same manner as in the industrial wastewater treatment plants. The similarity between systems and the potential benefits leads to this investigation for a parallel effect on the quality of the effluent stream from septic tanks.

Materials and Methods

Column Study

To allow for control and comparison of the input of various levels of cations, five identical columns were constructed to simulate five septic tanks in a laboratory setting operated in parallel. Standard PVC pipe, five feet in length and six inches in diameter, were used to serve as the lab-scale septic tanks. Holes were drilled every six inches from the top of the pipe and tapped for sampling spigots. After the first two experimental runs, investigators decided to add influent below the top of the water surface to better simulate a septic tank operation. To do this, another hole was drilled and tapped in between the third and fourth spigots from the top of the column with an elbow, tube, and a funnel attached to allow for influent addition.

Septic tank solids (settled liquid sludge from the bottom) were pumped from a septic tank in Blacksburg, VA, placed in plastic containers, and transported to the laboratory for use in each run. The solids were then mixed to ensure uniform consistency and then distributed among the five columns. Water was then added to a depth of four feet and ten inches. In later runs, salt additions were also initially distributed to each column based on the experimental scenario being modeled and the expected steady-state values of the ions of primary concern (e.g. sodium, calcium, and magnesium). Tin foil caps were placed on top of each column to limit any effect light may have on the septic tanks. After waste distribution and salt amendments, the columns were allowed to settle for several days before testing commenced.

The columns were operated in each run in a way that simulated septic tank use. Raw wastewater was collected from the Blacksburg Wastewater Treatment Plant and used as influent for the columns. A volume of 3.8 L of influent was added to the column each day to allow the columns to have a seven-day detention time. The influent received salt additions that were calculated based on the specific experimental scenario being modeled. To make room for the daily influent addition, 3.8 L was also removed from the clear zone of the columns every day.

A total of five runs were conducted over a one-year period. The column runs were initially operated for three weeks. Runs were subsequently extended to eight weeks. Data from the first few runs indicated that more useful results were just starting to appear towards the end of the first three weeks, and it was determined to be beneficial to extend the run time.

On the final day of testing for each run, samples were collected and analyzed from the third, fifth, seventh, and eighth ports (numbered from the top of the column). This was done to determine if there were any differences with depth, and also provided assurance that the salt additions were similar throughout the column.

Each column was assigned a specific experimental scenario pertaining to hardness level treated, and/or whether the water softener regenerant was diverted. For example, in the study that began on September 19, 2011, the five columns simulated septic tanks receiving waste from houses with source water hardness of 0, 100, 200, 300, and 450 mg/L as $CaCO_3$ and with all regenerant diverted away. Another example of experimental variance would be the fourth run that began on March 29, 2012, where all five column scenarios simulated septic tanks serving houses with a source water hardness of 450 mg/L as $CaCO_3$. One remained unsoftened, one received softened water but no regenerant, and the other three received softened water with regeneration waste containing varying levels of sodium to simulate use of water softeners of varying efficiency (4000 gr/lb to 1000 gr/lb). This scenario was repeated in the fifth run beginning on June 27, 2012, with the same conditions for each column as in the fourth run. The run was conducted for eight weeks with the goal of verifying the results and showing the reproducibility of the data obtained in the fourth run.

The samples were periodically analyzed for each of the following characteristics:

- **Total solids (TS) and total volatile solids (VS)**
- **Total suspended solids (TSS) and volatile suspended solids (VSS)**
- **Chemical oxygen demand (COD)**
- **Five-day biochemical oxygen demand (BOD5)**
- **Protein content**
- **Polysaccharide content**
- **Analysis for ion concentration via ion chromatography (IC)**

All TS, VS, TSS, VSS, COD, and BOD5 testing were carried out in accordance with Standard Methods for the Examination of Water and Wastewater. Testing for solids was conducted three times per week (Mondays, Wednesdays, and Fridays). Likewise, samples for COD were collected and preserved on these days and run once per week. Samples for ion chromatography (IC) were collected once a week from the filtrate that passed through the filter paper used for measuring TSS and VSS. Testing for BOD5 concentration took place twice per week. Analysis for protein and polysaccharide content took place once a week during the first few runs.

Case Studies

Case studies were also organized, and samples were provided from New York and North Carolina.

The New York case study was carried out at an apartment complex in Naples, NY. There are two apartment buildings of same size, each at maximum occupancy. Each building has its own septic tank, but both buildings are served by the same water softener. The regeneration waste from this softener can be diverted to either of the two septic tanks. The regeneration waste was sent to one tank while the other tank received only the effluent from one apartment building. Sampling procedures were communicated to the Aquasource team managing the complex, and regular samples from both tanks were sent to the VA Tech lab twice a month. These samples were then analyzed for the same parameters as the other case study samples. BOD5 analyses were carried out by a local laboratory in NY certified for the analyses.

In North Carolina, onsite septic system industry professionals took samples from the "quiescent zone" of septic tanks and shipped them overnight to the lab at Virginia Tech. These samples were then analyzed for COD, TS, VS, TSS, BOD5, and VSS using the aforementioned methods. Samples were also analyzed to determine the concentrations of calcium, magnesium, and sodium in the septic tank discharge. These data were then compared to other case study samples and the comparisons were then related back to the column study data to see how well the lab study mimicked real world data.

The study of Water Softener Effects on Septic System Performance was conducted through the Virginia Polytechnic Institute and State University, funded by the Water Quality Research Foundation, and reported in 2013.

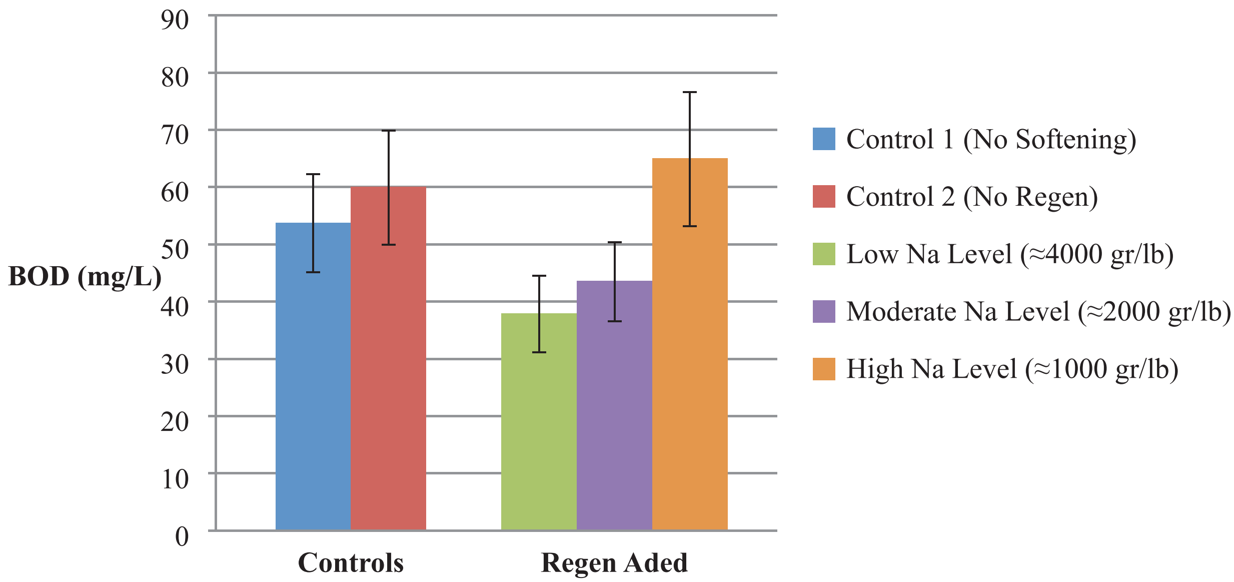
WQRF | Water Quality Research Foundation

Significant Findings of the Study

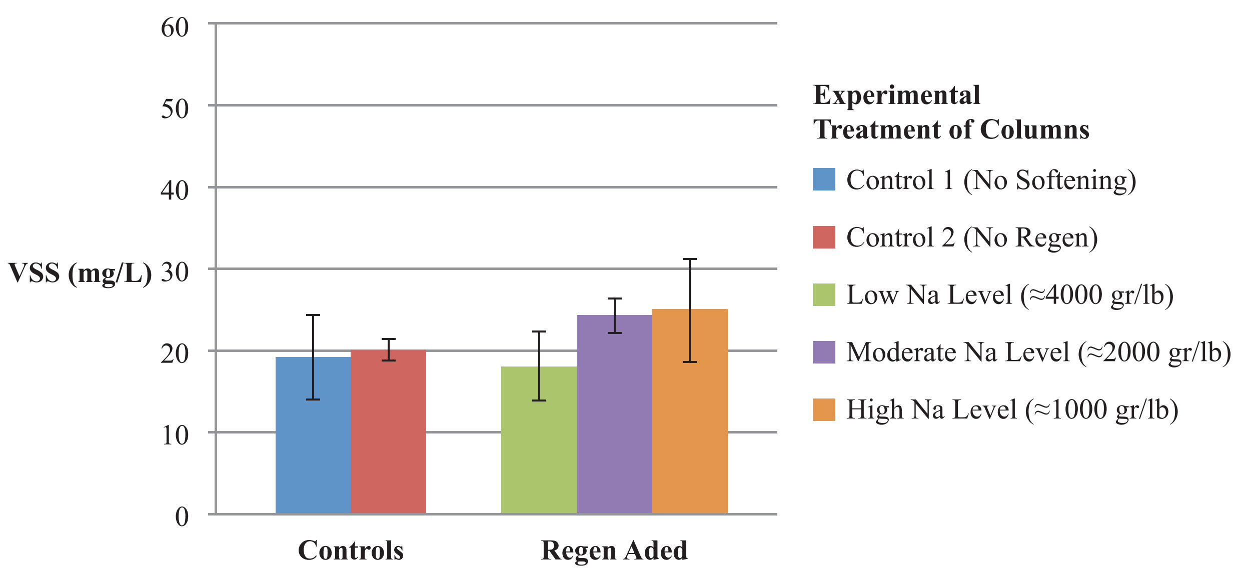
The first three runs were carried out mostly to gain practical experience and to further develop the plan for the last two runs. Furthermore, BOD and suspended solids are the main parameters utilized by residential onsite regulators. For these reasons, the data for these parameters gathered in the last two runs substantiated and confirmed the major findings of the study, which are described below.

The addition of regeneration wastes that contain calcium and magnesium with lower levels of excess sodium has been found to help in the settling of solids and, therefore, to produce a better quality effluent from an onsite operated septic tank. The amount of sodium, calcium, and magnesium is similar to the concentrations found in regenerant discharges from an efficiently operated water softener, such as a well operated DIR unit.

The two graphs shown below are excerpted from the full report to show this key finding. The column labeled “low sodium level” has a lower BOD5 and lower level of VSS in the effluent compared to the other columns that is without any regenerant added to the column or higher levels of sodium added. The results from these columns show that a softener operated at a salt efficiency better than 2000 gr/lb leads to an efficiently operated septic tank, as well. A DIR unit efficiently set fits the need of the rural household providing softer water inside the house using lower levels of sodium chloride in recharging the unit and leading to an efficiently operated septic tank and discharge fields. Diversion of regeneration wastes from such units could be unfavorable to the effluent quality as noted by the increased BOD5 of the second column compared to columns 3 and 4 receiving low and moderate levels of sodium from softener regenerant.

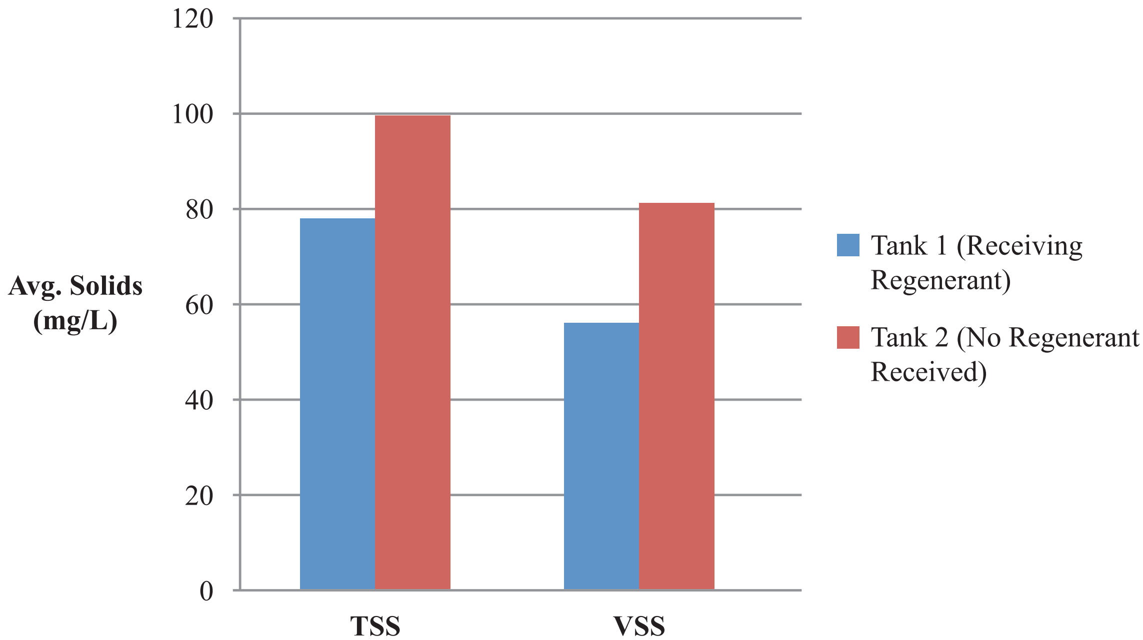


BOD (mg/L)
90
80
70
60
50
40
30
20
10
0
Controls
Regen Aded
Control 1 (No Softening)
Control 2 (No Regen)
Low Na Level (≈4000 gr/lb)
Moderate Na Level (≈2000 gr/lb)
High Na Level (≈1000 gr/lb)



VSS (mg/L)
60
50
40
30
20
10
0
Controls
Regen Aded
Experimental Treatment of Columns
Control 1 (No Softening)
Control 2 (No Regen)
Low Na Level (≈4000 gr/lb)
Moderate Na Level (≈2000 gr/lb)
High Na Level (≈1000 gr/lb)

The following graph, also excerpted from the full report, illustrates the results from two septic tanks operating side by side at an apartment complex in NY, one receiving the softener regenerant with the other not receiving it. The graph supports the conclusion that adding the regenerant to the septic tank yields lower TSS and VSS in the effluent. Furthermore, it indicates that diversion of regeneration wastes away from the septic tank may result in an effluent that is poorer in quality.



The addition of regeneration wastes that contain large concentrations of excess sodium can, however, be detrimental to solids settling and, therefore, produce a lower quality effluent. Such higher concentrations can be from the operation of a softener in an inefficient manner (</= 1000 gr/lb) in relation to the excessive use of salt for the removal of hardness.

WQRF | Water Quality Research Foundation

4151 Naperville Road
Lisle, Illinois 60532-3696 USA
Ph 630 505 0160
Fx 630 505 9637
www.wqa.org

An Independent Research Foundation of WQA