# WQRF Environmental Impact Study-Changes in septic tank effluence due to water softener use

*Excerpted and edited for clarity*

This study was undertaken to investigate the effect home ion-exchange water softeners may have on septic tank performance. A column study was set up, and varying levels of sodium were added to wastewater influent and these were added to columns that contained solids collected from operating septic tanks. In addition, effect of slug influent solutions, which mimic regeneration flow, with varying amounts of sodium along with calcium and magnesium were investigated. To reinforce the lab column experiments, data were obtained from private septic tanks [in Naples, New York] to determine the effluent quality from septic tanks which respectively diverted and received the regeneration flow.

## INTRODUCTION

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 on water heaters and appliances. Onsite wastewater treatment is also frequently used in rural locations. The softening process uses ion exchange technology to remove calcium and magnesium from water and replace them with an equivalent concentration of sodium. The exchange resin in the water softener has a limited capacity and it eventually becomes saturated with calcium and magnesium. The resin must then be regenerated using enough sodium to break the cationic bonds the hardness elements formed The sodium is introduced at varying quantities depending on initial hardness and softener efficiency. This waste regenerating solution (regenerant waste) consists of sodium as well as the calcium and magnesium removed from the saturated resin. The regenerant waste must be disposed of periodically, and the simplest disposal method is to discharge it to the sewer system or to the septic tank of the onsite waste water treatment system, as applicable.

The combined use of home ion exchange softeners and septic tanks raises several issues. First, because sodium has been exchanged for calcium and magnesium, wastewater generated in the home and discharged to the septic tank will have elevated sodium levels which may affect physical and chemical reactions. In addition, when regenerant is periodically discharged to the septic tank, additional sodium ions along with the exchanged calcium and magnesium are added to the contents. Higgins and Novak (1997 a) have shown that high concentrations of sodium can lead to deflocculation in activated sludge systems, but that calcium and magnesium can help in the settling of the solids. Higgins and Novak (1997 b) also proposed that when the monovalent to divalent cation ratio exceeds two, effluent characteristics in activated sludge systems can deteriorate. Therefore, if the ratio of monovalent to divalent ions exceeds a desirable level for such operation in anaerobic conditions in septic tanks, it is reasonable to theorize that combining septic tanks with ion exchange softening may result in poor quality discharges from septic tanks to the drain field or subsequent treatment components.

Some onsite industry leaders believe that the brine produced by regeneration of the exchange resin within the water softener has a negative effect on the ability of the septic tank to settle solids and treat wastewater. There has been limited research to suggest that addition of the brine solution can actually improve onsite wastewater treatment system performance (Water Quality Association, 1978). These concerns have led to a few states passing laws or providing guidance to divert regenerant away from the septic tank. Options include discharge to a dedicated drain or to a separate tank for collection and offsite disposal (Harrison and Michaud, 2005). Diverting regenerant leads to substantial extra costs of installation and maintenance for an extra tank or associated piping and drainage systems.

The water softener regenerant includes an abundance of sodium, but also a large amount of calcium and magnesium that accumulated on the resin over several days. Increased levels of sodium have been shown to inhibit settling and increase deflocculation of settled solids especially in industrial wastewater plants (Murthy et al., 1998).

# WQRF Environmental Impact Study—Changes in septic tank effluence due to water softener use

*continued from page 9*

Magnesium and calcium, however, have been shown to have the opposite effect on settling (Murthy et al., 1998), which might improve operation of a septic tank. While the research cited above did not specifically consider septic tanks, it does suggest that addition of regenerant to a septic tank could improve overall performance provided the benefit gained from calcium and magnesium is not offset by the detrimental effects of excess sodium ions.

The concentrations of these constituents are affected by the time between regeneration cycles. Some softeners provide regeneration on a planned schedule, “time clock softeners”, while others operate based on the household water usage, “demand initiated regeneration (DIR) softeners”. Time clock softeners may be improperly set or regenerate too early in some situations (e.g. when a household is away on vacation and the system is not by-passed), which would discharge an abundance of sodium to the septic tank without the corresponding calcium and magnesium. However, a DIR system takes these schedule variances into account and regenerates when the resin has been calculated to be saturated, based on water usage and average water hardness. These differences in operation present another variable in the effect water softeners may have on septic tanks.

This study was designed to investigate the effect of water softener discharges on septic tank performance. This was achieved through the use of column studies (simulated lab-scale septic tanks), oil flocculation tests, anaerobic digestion studies, and case studies of operating septic tanks. The objective of this research was to determine the relative performance of a septic tank under the different conditions that can develop with water softener use. Simulated septic tank operations were considered both with and without the discharge of regenerant into the septic tanks

## OVERVIEW OF SEPTIC SYSTEMS

Many rural homes are served by septic systems. There are four defined functions of a septic system: to receive wastewater, separate solid materials from wastewater, provide treatment of wastes, and disperse treated effluent (Toor, et al., 2012). While many types and configurations of these systems exist, they most commonly consist of a septic tank, where all household wastewater is collected, a distribution device, and a drain field where effluent is dispersed into the soil as shown in Figure 2-2 (Toor, et al., 2012). The tank allows solids to settle or float and provides an environment for partial degradation of organic constituents by microbes. The solids separation that occurs in the tank results in a ‘clear zone’ of clarified effluent (Figure 2-3). The clarified effluent is dispersed into the drain field where it is subjected to further treatment prior to recharging groundwater (Toor, et al., 2012). Partially digested solids are retained in the tank until they are removed during regular maintenance. Altogether, these systems provide a very simple and effective solution to rural wastewater management as long as they are properly designed, sited, installed, used, and maintained.

The quality of treated water from septic systems is typically characterized by the biochemical oxygen demand (BOD), total suspended solids (TSS), chemical oxygen demand (COD), and analysis of other constituent concentrations (e.g. fecal coliforms or nitrogen) (Toor, et al., 2012). 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) may have on septic system treatment capacity are a main reason for the debate regarding how waste regenerant from water softeners should be handled. Concerns include resuspension of settled solids and inhibition of microbiological activity.

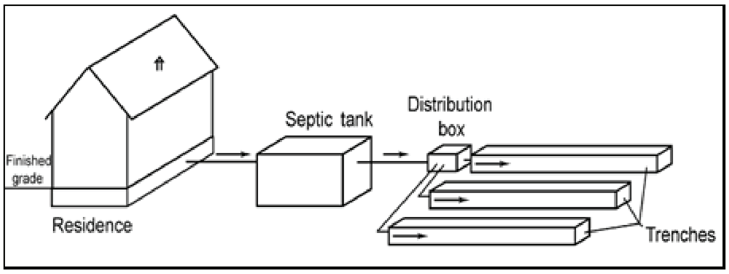


**Figure 2-2**. Typical conventional septic system configuration. Many variations are possible. (CIDWT 2009)

# WQRF Environmental Impact Study—Changes in septic tank effluence due to water softener use

*continued from page 10*

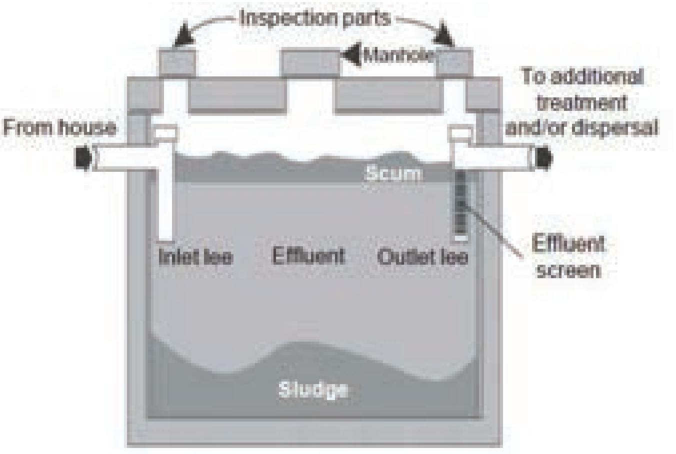


**Figure 2-3.** Typical one compartment septic tank illustrating solids separation and development of clear zone. The outlet tee (on right) is designed to draw clarified effluent from the clear zone, through an effluent screen, to then out of the tank and convey it to the next component (NFSC 2000).

## OVERVIEW OF MONOVALENT AND DIVALENT CATIONS

Inorganic ions can be positively charged (cations) or negatively charged (anions). The dominant inorganic ions 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 "M/D" is useful when dealing with the effect of cations on flocculation. The M/D ratio 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 from activated sludge treatment plants (Higgins and Novak, 1997c).

## EFFECT OF M/D RATIO ON TREATMENT PROCESSES AND EFFLUENT QUALITY

Changes in the cation concentration of wastewaters has been directly associated with the treatment properties of that wastewater. Lab studies by Murthy et al. (1998) have shown that the addition of calcium and magnesium to activated sludge decreased the time it took to settle out when compared to a control where little calcium and magnesium was present in the influent wastewater. Further lab studies by Murthy et al. (1998) concluded that the effluent quality from activated sludge reactors was positively influenced by the presence of the divalent cations, calcium, and magnesium as indicated by the chemical oxygen demand (COD) of the effluent. As more of these divalent cations were added, the COD in the effluent decreased, which would support the earlier finding that these constituents aided in settling times. Furthermore, a higher M/D ratio resulted in higher effluent COD concentration in full-scale activated sludge treatment plants. These data serve as reason to consider the addition of regeneration waste 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. depending on how much sodium was concentrated in the waste as well as how much calcium and magnesium was washed off the resin), there is a possibility that regenerant could serve as a settling aid in the same manner as in the experiments by Murthy et al. (1998).

Further research has shown that excess sodium can lead to deteriorating effluent characteristics in activated sludge systems (Higgins and Novak, 1997c). This research examined M/D ratios in activated sludge and showed that sodium can be detrimental to settling when the M/D ratio exceeds two (Higgins and Novak, 1997c). This same research also showed that the effect of sodium could be reversed by the addition of calcium and magnesium, as long as the M/D ratio was reduced below two. Even though this research considered only activated sludge (as opposed to anaerobically operated septic tanks), this study is exceedingly important because it incorporates the same ions that are involved in residential water softening and also details the settling of solids, which is an important function of onsite septic systems. An extension of the Higgins and Novak study went further to show that an imbalance in cations in activated sludge systems can be a detriment to normal operation due to the effect the imbalance has on the solids (Higgins and Novak, 1997b). In this study, it was recommended that divalent cations be added to activated sludge systems that were having settling problems. For onsite systems, the addition of regeneration wastes with minimal excess sodium could serve as a divalent cation dose, which could improve settling and effluent quality. Another study on activated sludge found a correlation between an M/D threshold of two and decreased settling characteristics when this ratio was exceeded (Novak,

# WQRF Environmental Impact Study—Changes in septic tank effluence due to water softener use

*continued from page 11*

et.al., 1998). This study was also able to show that additions of sodium ions considerably weakened floc strength, which would be the reason for the decreased settling ability. This indicates the importance of divalent cations in an activated sludge system, which could correlate with their necessity in an onsite septic system. These findings are further expanded in additional studies by Higgins and Novak (1997a). Clearly, the role of calcium, magnesium, and sodium has been substantiated in activated sludge systems, so a similar role of these ions should be assessed in onsite wastewater treatment systems.

## DISCUSSION & CONCLUSIONS

The common way of measuring ion concentrations for comparison in this study was to obtain the monovalent to divalent cation ratio (M/D Ratio). This is the concentration of the sodium ions in solution divided by the concentrations of magnesium and calcium, on an equivalent weight basis (all other monovalent and divalent ions were negligible). Slug solutions with high levels of salts (Septic Tank Effluent M/D = 11; ~1000 gr/lb softener efficiency), mimicking regenerant wastes from water softeners with an inefficient regenerant cycle, increased the effluent solids, COD, and BOD5. However, if the regeneration wastes contained the same amount of calcium and magnesium, but a smaller amount of sodium (Septic Tank Effluent M/D = 5; ~2000 gr/lb softener efficiency), the negative effect on these effluent characteristics was greatly lessened. In an optimum case with a regeneration solution containing a minimal amount of excess sodium (Septic Tank Effluent M/D = 3; ~4000 gr/lb softener efficiency), mimicking the addition of regenerant discharges from water softeners with an efficient regeneration cycle such as from demand initiated regeneration - type(DIR) softeners, the effluent characteristics were improved compared to septic tank effluent where the regeneration wastes with varying levels of M/D ratio were diverted from the tank.

[Softener efficiency is calculated by dividing the exchange capacity in grains per gallon as $CaCO_3$ per cubic foot of resin by the salt dosage in pounds of salt per cubic foot of resin. For example, the efficiency of a softener capable of exchanging 20,000 gr as $CaCO_3/ft^3$ of hardness at a 5 lb/ft3 of dosage is calculated as follows:

$$\text{Efficiency} = \frac{20{,}000\ \text{gr/ft}^3}{5\ \text{lb/ft}^3}$$

Efficiency = 4000 gr/lb

The New York case study reinforced these data, showing that excessive levels of sodium concentrations correlated with an increased discharge of solids to the drain field while moderate levels showed lower solids being discharged. The NY data also indicated higher values for most of the analytical parameters in the tank not receiving regenerant, which points to potential problems if the divalent ions are removed but not returned to the tank. In North Carolina, there was no clear relationship between the M/D and the discharge characteristics for samples collected from septic tanks. The studies on grease flocculation and anaerobic digestion suggest that these processes are not affected by the sodium level since no differences were observed. Overall, the column studies and the New York case study indicate that the use of efficiently operated water softeners may improve septic tank performance, while the use of inefficient home softeners 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.

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