Annotated Bibliography of Literature Related to Compatibility of Water Softeners and Onsite Wastewater Treatment Systems

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The following is a review of selected sources that discuss anecdotal and scientific findings regarding the use of water softeners with onsite systems. Sources are listed chronologically according to date of publication. Experimental design and results are included with each reference. Where anecdotal evidence is recounted, quotation marks used with the headings are only indicative of the subjective nature of the study and not intended to be dismissive. In some cases, comments are included in the review of individual sources. These are not intended as firm conclusions, but are simply observations by the author. Summary thoughts are included at the end of the file. ***This is a work in progress and should not be construed as complete or authoritative.***

Note: the following abbreviations are used in this document:

NS: No softener
WSD: With softener discharge
WOSD: Without softener discharge

SLS: sodium lauryl sulfate
SLES: sodium lauryl ether sulfate (sodium laureth sulfate)

STE: septic tank effluent
RTE: recirculation/blend tank effluent

TSS: total suspended solids
BOD_5: five-day biochemical oxygen demand
CBOD: carbonaceous biochemical oxygen demand

Gross, M. and T. Bounds. 2007. The Effect of Water Softener Backwash Brine in Onsite Wastewater Treatment Systems. Eleventh Individual and Small Community Sewage Systems Conference Proceedings, 20-24 October 2007, Warwick, Rhode Island. American Society of Agricultural and Biological Engineers, St. Joseph, Michigan.

Experimental Design 1

- 18 systems studied in field
- No indication of numbers with and without softeners
- Samples collected from Recirculation / Blend tank and lysimeters installed to sample at 30 cm (12 in.) below the infiltrative surface of the soil treatment area

Results (no statistical significance indicated)

- Chloride (Recirc / blend tank effluent [RTE])
  - WSD: median 1050 mg/L; range 84 to 10,900 mg/L
  - WOSD: median 48 mg/L; range 32 to 112 mg/L
- CBOD (RTE)
  - WSD: median 4 mg/L; no range reported
    - Increased over time
  - WOSD: median 3 mg/L; no range reported
- TSS (RTE)
  - WSD: median 8 mg/L; no range reported
    - Increased over time
  - WOSD: median 5 mg/L; no range reported
- TN
  - WSD: mean 19.9 mg/L; median 14 mg/L; no range reported
    - Nitrification decreased over time as measured by increased NH_3-N
  - WOSD: mean 15.6 mg/L; median 12 mg/L; no range reported
- E. Coli: No results reported

Experimental Design 2 (no statistical significance indicated)

- Backwash discharge removed from one system (with advanced treatment component in recirc configuration) approximately 60 days after startup
- Samples collected from

Results

- CBOD, TSS and TN levels reduced after backwash removed

Experimental Design 3 (no statistical significance indicated)

- Model tank with volume 28.4 L (7.5 gal)
- Simulated sludge (identified as "identical to that used in NSF effluent screen testing protocol") was added
- One day's backwash volume based upon the "water softener representative's calculations" was added - no volumes given
- Red dye added to backwash for contrast

- tap water dosed at a volume scaled to 570 L/day (150 gal/day)

Results

- Visible stratification of brine and re-suspension of simulated sludge

Comments

- NSF effluent screen testing protocol calls for use of styrene beads instead of simulated effluent
- Scaling density in conjunction with other parameters is an issue

Bassett, E. 2005. An Installer's Observations of the Effects of Water Softeners on On-site Wastewater Systems. ***In*** **Proceedings of NOWRA & WQA Septic-Softener Symposium, Cleveland, OH, October 2005.**

'Experimental' Design

- Anecdotes of malfunctioning systems in NM

'*Results'*

- Valve on water softener stuck open resulting in "water from the conditioning unit" flooding the system and leading to "ineffectiveness, destruction of drain fields, and sometimes even the catastrophic destruction of the on-site system"
- Build-up of calcium carbonate on the air orifices of advanced treatment (type of units?) systems used by commercial owners, including restaurants and shopping centers
- Biomass clogging of pipes leading to onsite systems

Harrison, J., and C. Michaud. 2005. Home Water Treatment System Discharge to On-site Wastewater Systems. ***In*** **Proceedings of NOWRA & WQA Septic-Softener Symposium, Cleveland, OH, October 2005.**

Experimental Design

- Description of typical workings of softeners; advantages of using softeners; an assessment of impact on septic systems according to measurements and observations; account of current regulatory trends

Results (selected results presented here; much more is discussed in this paper)

- Advantages of using softeners
  - reduces energy consumption, improves water heating efficiency and creates savings in soaps, detergents and cleansers
- Typical hardness removal, TDS addition and associated discharge volume
  - Low level of hardness: Treating source water with 5 grains per gallon (gpg) hardness adds 179 mg/L TDS with 25 gallons discharge per week
  - Severe level of hardness: Treating source water with 30 gpg adds 1,074 mg/L TDS with 150 gallons discharge per week
- Regulatory trends

- WI, TX and MT include BMPs to address specific issues for onsite systems
- TX, MT and NM regulations include specific language restricting use of softeners in conjunction with advanced treatment technologies

Husain, S. and C.D. Litchfield. 2005. A Quantitative Analysis of the Impact of Salt on the Microorganisms in an Aerobic Wastewater Treatment System, *In* Proceedings of NOWRA & WQA Septic-Softener Symposium, Cleveland, OH, October 2005.

Experimental Design

- Bottle studies using aerobic wastewater collected from unnamed source
- 3 mL of inoculum and varying concentrations of brine from 0 to 50,000 mg/L
- Each supplemented with 1% (w/v) Nutrient Broth (Difco J - complex organic compounds of beef extract and peptone)
- Incubated under stationary conditions at room temperature

Results

- No inhibition at salt concentrations from 0 to 10,000 mg/L
- Inhibition at 50,000 mg/L as indicated by a 30 hour lag period before CO_2 production recovered; magnified by additions of sodium lauryl sulfate

Experimental Design 2

- Aerobic inoculums exposed to 50,000 mg/L brine for two hours prior to addition to flasks
- Incubated under stationary conditions at room temperature

Results

- Lag at 50,000 mg/L but no significant difference

Kinsley, C., A. Crolla, & D. Joy. 2005. Impact of water softeners on septic tanks – field evaluation study. Final report to the Canadian Mortgage and Housing Corporation. Ontario Rural Wastewater Centre, Collège d' Alfred, University of Guelph.

Experimental Design

- 39 operating tanks – 17 WSD, 22 NS (no indication of number of compartments or presence of effluent screen)
- Survey: water softener type and amount of salt used, tank age, date of last pump-out, number of residents and bedrooms, type of septic system, soil type, and any history of bed failure or water quality problems

Results

- Na and Cl levels significantly different

- Na levels
  - WSD
    - 644 mg/L (STE)
    - 586 mg/L (sludge)
  - WOSD
    - 160 mg/L (STE)
    - 233 mg/L (sludge)
- Cl levels
  - WSD
    - 1537 mg/L (STE)
    - 1609 mg/L (sludge)
  - WOSD
    - 125 mg/L (STE)
    - 146 mg/L (sludge)

- No significant differences in CBOD, VSS, TSS and sludge accumulation when comparing tanks with and without softener discharge
  - $CBOD_5$ (STE):
    - 320 mg/L WSD
    - 304 mg/L WOSD
  - VSS (Sludge):
    - 31.8 mg/L WSD
    - 31.5 mg/L WOSD
  - TSS (STE):
    - 1048 mg/L WSD
    - 751 mg/L WOSD
  - Solids accumulation:
    - 107 L/capita-yr WSD
    - 118 L/capita-yr WOSD
- No significant difference in median sodium adsorption ratio (SAR) values (SAR is the mathematical relationship of sodium to the combination of calcium and magnesium calculated as follows:

$$SAR = \frac{(Na^{+}\{mmol/L\})}{\sqrt{1/2[(Ca^{2+}\{mmol/L\}) + (Mg^{2+}\{mmol/L\})]}}$$

  - WSD median 8.0; range 0.5 to 17.8
  - WOSD: median 2.3; range 0.9 to 15.4
  - No visible malfunction in soil treatment areas installed in clay soils when SAR values exceeded 10
- Conditions in soil treatment area
  - 7 of 39 systems exhibited hydraulic malfunction defined as 1. Surfacing effluent or 2. Elevated operating level in tank.
  - None of systems with malfunction had softener backwash
  - 6 of 7 malfunctioning systems installed in clay soils
  - Mean age of failed systems was 31 with range of 20 to 40 years

- Subjective evaluation of corrosion: 59% of tanks with softeners exhibited obvious corrosion of the outlet baffle while only 29% of tanks without softeners showed these signs

Comment

- Survey includes a section to document conductivity at three depths in first chamber but no results reported.

Pickney, R 2005. Effect of Water Softeners on Septic Systems . *In* **Proceedings of NOWRA & WQA Septic-Softener Symposium, Cleveland, OH, October 2005.**

'Experimental Design'

- Anecdotes of service calls to 20 systems out of 1500 under contract for maintenance;   presumably, all received softener backwash discharge

'Results'

- Septic tank has little or no scum layer
- Effluent screen has usually clogged in less than three years after water softener was installed
- Septic tank has little odor (much different from "normal healthy tank")
- BOD_5, and TSS are generally similar to lower than "normal" tank
  - No numbers reported
- Fecal Coliform numbers are far less than normal septic tanks.
  - No numbers reported
- Solids accumulate faster in the bottom of the tank (and into effluent filter causing it to clog)
  - No numbers reported
- Flow control orifice (usually Orenco Effluent filter) has often been blocked due to crystals forming around 3/8" holes
- Conductivity was usually over 1000 times higher than "normal" septic tanks.
  - No indication of where conductivity was measured; no numbers reported

Spratt, M. and G. Grimestad. 2005. Water Quality Changes in Conventional Onsite Wastewater Treatment Systems Associated with Use of Sodium Based Water Softeners. ***In*** **Proceedings of NOWRA & WQA Septic-Softener Symposium, Cleveland, OH, October 2006.**

Experimental Design 1

- 3 septic systems each sampled on a single day

Results

- Improved cation balance with re-introduction of Ca and Mg in softener backwash: $Na\%_{wosd}$ = 91% and $Na\%_{wsd}$ = 75.8%;
  - Comment: no concurrent reporting of TSS in these tanks

Experimental Design 2

- TSS measured in two 'conventional' systems
  - 1 WSD
  - 1 NS

Results

- TSS levels: WSD = 21 mg/L and NS = 48 mg/L
  - Comment: no concurrent reporting of any other parameters
  - Comment: both levels much lower than average reported in C and T of 80 mg/L

Experimental Design 3

- TDS and density measured at 3 sites/sources

Results

- A water softener using seven pounds of salt per week would account for less than a 0.1% increase in wastewater density, which is 'unlikely to measurably change the sedimentation rate'.
  - Comment: single measurements do not shed additional light on density stratification/solids re-suspension issue within tanks

Experimental Design 4

- Calculated SAR values for source water, wastewater WOSD and wastewater WSD

Results

- SAR WOSD = 16.79
- SAR WSD = 14.39
- Adding discharge reduces SAR values of water reaching drainfields

Experimental Design 5

- SAR values calculated based on operating systems (presumably 2 systems, one of which was sampled twice – not clear)

Results

- Average SAR WOSD = 25.78 (n=3)
- Average SAR WSD = 11.61 (n=3)
  - No specific information provided, but presumably no malfunction
  - Few indications of problems according to survey of MT sanitarians.
  - Montana soils are high in Ca with only 2 of 54 soils 'vulnerable to dispersion due to addition of SAR 12 water'.

Konsler, T. 2003. Neighborhood Surveys in Orange County: Two Case Studies. *Presented at* 19th Annual NC Onsite Wastewater Treatment Conference. October 21-23, 2003.

Experimental Design

- Over the course of a 9-month period, LHD received accounts of sewage backing up out of tanks at three homes with tanks receiving water softener discharge
- These accounts were investigated according to LHD protocol

Results

- Similarities among residences:
  - Age at malfunction: 6 months, 7 months, 9 months
  - All 3 were pump systems
  - All 3 had the same brand effluent screen in the septic tank
  - Average house value was $540,000
- Conditions noted:
  - Effluent coming out of risers
  - Premature plugging of effluent screens
  - No stratification of septic tank contents.

Metcalf and Eddy, 2003 – Na concentrations above 3500 mg/L inhibit anaerobic digestion

- Cl concentrations over 180 mg/L inhibit autotrophic microorganisms

Bashir, B., Matin, A. 2001. "Combined Effect of Calcium and Magnesium on Sodium Toxicity in Anaerobic Treatment Processes". Electronic Journal of Environmental, Agricultural and Food Chemistry.

Experimental design

- Bench studies of a completely-mixed 5 L anaerobic digester seeded with digesting sludge from local wastewater treatment plant
- 100-150 ml mixed liquor removed daily and part of this analyzed for pH, VSS and NH_3-N remainder centrifuged and made up to volume with synthetic feed and returned to reactor.
- Organic loading rate at the start of the experiment was 0.5 g/l/day, gradually increased to 1.8 g/l/day and maintained at this level for the duration of the project
- Calcium and magnesium added to reactors when inhibition due to cation toxicity was at its peak
- Optimum Ca and Mg concentration (at which the inhibition is minimum) recorded according to percent COD reduction, percent methane production and volatile fatty acids concentration

Results

- Slow reduction in COD removal efficiency up to Na concentration of 6000 mg/L (attributed to acclimatization)
- Rapid reduction in COD removal efficiency from 6000-9000 mg/L
- Re-introduction of Ca and Mg with softener backwash antagonized (decreased) the inhibition
  - COD removal efficiency increased from 66% to 90%
  - Methane production increased from 40% to 62 %

    - VFA concentration decreased from 2350 mg/L to 325 mg/L
- Optimum concentrations of 200 mg/L and 325 mg/L are required for the effect to be seen

Crites, R. and G. Tchobanoglous. 1998. Small and Decentralized Wastewater Management Systems. McGraw-Hill. Boston, MA.

Experimental Design

- Referenced Ayers, R. S. 1977. Quality of Water for Irrigation. *Journal Irrigation Division ASCE*
- Cited Ayers conclusion that "SAR <10 should be acceptable for soils with a significant clay content (15 percent clay or more). Soils with little clay or non-swelling clays can tolerate an SAR up to 20, particularly if the TDS is 800 mg/L or more.

Patterson, R. A., 1997 "Domestic Wastewater and the Sodium Factor", Site Characterization and Design of On-site Septic Systems, ASTM STP 1324, M.S. Bedinger, A.I. Johnson, and J.S. Fleming, Eds., American Society for Testing and Materials.

Experimental Design 1

- Effluent samples from 50 septic tanks collected and analyzed to determine 'typical' effluent
- Collected information on crust depth, sludge depth, persons using facility, period since last pump-out
- Included survey questionnaire to determine typical management and loading of the wastewater systems, particularly the use of washing machines and laundry detergents.

Results

- Significant additions of sodium with use of certain products

Experimental Design 2

- Simulated effluents made to replicate SAR 1, 3, 8 and 15 conditions and of low EC similar to septic tank effluent were used to infiltrate through soils.
- Tests included standard percolation test, disc permeameter on *in-situ* soils and a laboratory method developed for treating undisturbed cores.

Results

- STE SAR>3 resulted in reduced K_{sat} values in Australian soils (many of which are inherently high in Na) particularly when accompanied by low EC

National Sanitation Foundation. 1978. *The Effect of Home Water Softener Waste Regeneration Brines on Individual Aerobic Wastewater Treatment Plants*. National Sanitation Foundation, Ann Arbor, MI, USA.

As cited in: Bruursema, T. Compatibility of Water Softeners and Residential Wastewater Treatment Systems. *In* Proceedings of NOWRA & WQA Septic-Softener Symposium, Cleveland, OH, October 2006.

Experimental Design 1

- 250 gallons of wastewater per day was diverted from a municipal supply and applied to systems with ATUs.
- One unit received additional waste stream from softener regenerated at the rate of 3.5 pounds of salt per regeneration with 3 regenerations per week (no backwash volume given)

Results

- No significant effect on BOD_5 or TSS levels (Need actual document to get numbers)
  - Comment: mixed effluent applied to aerobic units

Experimental Design 2 and Results: See Corey, et. al., 1977

Corey, R.B., E.J. Tyler, M.U. Olotu. 1977. Effects of water softener use on the permeability of septic tank seepage fields. *In* Proceedings of the Second National Home Sewage Treatment Symposium. ASAE Publication 5-77. ASAE, St. Joseph, MI.

As cited in Tyler, E. J. 2005. Soil Infiltration and Percolation of Wastewater as Affected by Water Softener Use. *In* Proceedings of NOWRA & WQA Septic-Softener Symposium, Cleveland, OH, October 2005.

Experimental Design

- 38 STE samples from 11 households sampled from one to five times for SAR, salt concentration and total water potential.
- 5 of 11 using water softeners
- Samples collected from STE and beneath mound soil treatment areas
- SAR and total soluble salts (m_0) values were applied to a model of K_{sat} related to swelling (McNeal, 1970) and used to construct a threshold value curve for soil with 10% montmorillonite

Results

- STE_{NS}
  - SAR = 4.8 (range 2.5 to 10.4)
  - m_o = 9.9 meq/L (range 7.0 - 14.2)
- STE_{WSD}
  - SAR = 8.1 (range 3.0 to 16.4)
  - m_o = 14.3 meq/L (range 7.4 – 29.5)
- SAR and m_o of all 38 septic tanks were in the stable range or below the threshold limit of 85% of maximum hydraulic conductivity
- Soil structure and hydraulic conductivity is maintained if m_o is high regardless of the SAR.

- At high SAR solutions and low m_o structure and soil hydraulic conductivity will decrease.
- "Other factors influence the swelling of clays in soil. The presence of oxides, low pH and organic matter at low SAR probably stabilize the soil while organic matter at high SAR and mechanical stress destabilize." *E. J. Tyler*

McCarty, P.L. 1964. "Anaerobic waste treatment fundamentals III." Public Works, 95, 91-94.

NOTE: this info as cited in Bashir and Matin, 2001(document not yet located)

Experimental Design

- Anaerobic bacteria – unknown experiments

Results

- Moderate inhibition at 3500 to 5000 mg/L Na
- High inhibition at 8000 mg/L Na
- Comment: much higher levels of Na than normally seen in septic tanks with backwash discharge

Weibel, S. R., T. W. Bendixen, and J.B. Coulter. 1954. Studies on household sewage disposal systems. Part III. U.S. Dept. of Health, Education and Welfare, Robert A. Taft Sanitary Engineering Center.

Experimental Design 1

- Bench studies using 455 gallon laboratory tank, raw sewage in 8 daily feeds and 47 gallons of salt feed at the rate of one gallon per minute (to simulate 41,000 grains of hardness)

Results

- Increasing Cl with tank depth
- Suspended solids removal efficiency of 60 to 70%
- Max Cl concentrations of 8000 mg/L

Experimental Design 2

- Bottle studies using sludge from both 'salt' tanks and 'normal' tanks

Results

- CO_2 gas production inhibited with 1.5% added salt but less inhibition in sludge from 'salt' tank indicating acclimatization of microbes to high salt conditions

Experimental Design 3

- Soil core studies using a silt loam with a known susceptibility to sodium damage; 'salt' effluent with Cl ranging from 7,000 mg/L and gradually decreasing to 500 mg/L and ‘normal’ effluent varying from 100 mg/L to 50 mg/L

Results

- Percolation rates maintained at a higher level with ‘salt’ effluent, but soil structure is more damaged, indicating potential long-term effects
- Comment: These results were refuted in Tyler, 2006.

Authors notes:

1. Despite a preponderance of evidence that softeners should not pose a problem, reports continue to surface regarding malfunctions. The reports are not accompanied by hard data. It is critical to find out the reason behind the anecdotes since they are contradictory to most of the research that has been performed on this issue.
2. Basic issues must be ruled out for accurate comparisons:
    a. Negative user influence on septic system:
        i. Hydraulic overload (defined as average daily flows >70% of design)
        ii. Excessive use of cleaners, personal care products, etc.
        iii. Harmful additions to system (enzyme additives, garbage disposal use, FOGs, etc.)
        iv. Lack of maintenance
    b. Configuration of septic system
        i. Infiltration into components
        ii. Adequate capacity according to rules or guidelines
    c. Configuration of water treatment system
        i. e.g., commercial unit in residential use
        ii. Excessive salt settings
        iii. Improper calendar override settings on DIR units
        iv. Equipment malfunction
3. Assuming that ‘proper’ tank function is defined as effective solids removal, studies should focus on:
    a. Per capita solids accumulation rate
    b. Settleability of tank contents
    c. Rates of effluent screen clogging
        i. What is a reasonable rate?
        ii. Variation among the brands of screens installed is likely.
4. If removal of organic load is to be used in definition of ‘proper’ tank function, must sample influent.
5. Stratification has been documented relative to Na and Cl levels and appears to be reflected in density, TDS, conductivity, etc.
    a. Parameters must be measured at multiple elevations in tank to fully explain what is happening in the tanks.
    b. How quickly does this happen and how long does it persist?
    c. Once it occurs, does re-suspension of solids result? If so, how long does it take for this to happen and how long does it persist?

    d. Timing of sampling relative to discharge may be an important consideration. At the very least, time since regeneration must be documented if possible. Need to take samples over the course of 2 cycles.

6. Studies on microbial activity in both aerobic and anaerobic effluents generally indicate no inhibition at Na and Ca concentrations typically observed in the real world. Most studies were performed in the laboratory and not in operating systems. This does not account for the effect of real use by real people.
7. The addition of sodium lauryl sulfate magnification of inhibition in studies on aerobic effluent points to potential synergistic effect from user inputs. (Sodium lauryl sulfate is a detergent and surfactant often present in household cleaning and personal care products.) However, effect was only investigated by Husain and Litchfield at very high solar salt concentrations (50,000 mg/L).
8. The effect of SAR on soil permeability seems to be affected by many other factors (pH, organic matter, conductivity, CEC, clay mineralogy). Montana soils are rich in Ca and did not appear to be much affected by SAR>20. Australian soils are sodic and were affected by very low SAR (3). More research is needed here. There appear to be regional variations.
9. Both industries need to be involved in the investigation to make sure that proper expertise is brought to bear. Anecdotes of malfunctioning systems are reported, but not fully investigated by professionals from both industries to determine what other conditions might account for the malfunctions. This is hampering progress as it casts both industries in a bad light. Many times, the first service provider on the scene is the tank pumper. They must also be informed about the issue so that other professionals are consulted when problems are discovered.

Thus

10. A screening process should be implemented. When anecdotes are presented, the particular conditions should be investigated and documented to the fullest extent possible.
    a. If areas where high numbers of problems are identified, the full protocol should be implemented to gather a complete set of data on systems (say 12- 20 systems) in that area.
    b. Using this approach, we might be able to fund these ‘mini-investigations’ more readily. In-kind contributions of manpower from local business interests and regulatory professionals will be critical.
11. Proceed with screening systems using a modified version of the NOWRA/WQA Screening Tool that includes a significant homeowner survey.
    a. Identify hotspots
    b. Administer full survey to identify where to look more closely
12. Celluose
    a. What level of breakdown actually occurs in the tank?
    b. Degree of settling probably depends on the brand.
13. Compile data on amount of SLS in common household cleaning and personal care products