Appendix I. Soil and Greywater Constituents of Interest[1]

This section briefly discusses the constituents in greywater that could harm plants and soil. We list the recommended levels of the constituent, and the potential damages a plant can incur from the constituent. Readers generally familiar with soil and plants sciences may skip to the next section without loss of continuity.

Soil

pH: Soil pH measures the soil's acidity and affects the availability of plant nutrients, microbial processes, and plant growth. Most plants grow best in a soil pH of between 6 and 7, and the majority do best in the middle of this range.

Soluble salts: Excessively high salinity (measured in soil as soluble salts) can negatively affect plants in two ways. First, plants can be harmed by toxicity of a particular ion, like sodium. Second, the salts can cause water stress by interfering with a plant's ability to absorb water.

Horticultural plants have a range of tolerances to soluble salts. The level of salts in the soil considered "generally safe" for most plants is less than 2.0 millimhos per centimetre (mmhos/cm). Levels between 2.0 and 4.0 mmhos/cm are considered a "slight to moderate risk", depending on the salt tolerance levels of the plants. Anything above 4 mmhos/cm is a "severe" risk to most plants.

Boron: Boron is essential for plant growth at very low concentrations. However, it quickly becomes toxic if present in higher concentrations. Boron toxicity symptoms manifest first as stunted growth, and then necrosis on margins of older leaves. Generally safe levels of boron in soil are between 0.1 and 1 ppm, with between 1-5ppm in the "slight to moderate" risk range. Levels over 5ppm are considered a "severe" risk for most plants.

Greywater Irrigation

Acidity and alkalinity

pH: Recommendations for pH of irrigation water range from 5.5 to 8.4. The relationship between soil pH and irrigation water pH is important to consider. In alkaline soils, irrigation with alkaline (ph >7) water can cause plant health problems more quickly than in acidic (pH < 7) soil. The pH of greywater is affected by the pH of products used in the home; some are acidic, some basic, and others neutral.

Salinity

Too much salinity in irrigation water can negatively affect plants and soil health. Saline water makes it harder for the roots of plants to absorb water, inducing drought-like conditions even there is water available. The salts applied in irrigation water can also be left behind in the soil following

1 References for this section include Costello, L. et al. Abiotic Disorders of Landscape Plants: A Diagnostic Guide. University of California Agriculture and Natural Resources. Publication 3420. 2003, and Pettygrove and Asano (1985). Irrigation with reclaimed municipal wastewater-- A guidance manual. Water Quality for Agriculture. Agriculture and Consumer Protection 1994. http://www.fao.org/docrep/003/T0234E/T0234E05.htm

evapotranspiration, leading to soil degradation. We tested for salinity by testing for the constituents below.

Total dissolved solids (TDS) and Electric conductivity (EC): Total dissolved solids (TDS) and electrical conductivity (EC) are common measures of salinity. The dissolved solids in greywater are mainly salts (calcium, magnesium, sodium, chloride and bicarbonates). The dissolved salts form positively and negatively charged ions, which conduct electricity in relation to their concentration.

EC levels of 0.7 mmhos/cm or lower are generally safe for all plants. There is a "slight to moderate" risk for long term irrigation with water of 0.7-3.0 mmhos/cm, depending on the sensitivity of the plants, and a "severe" risk for irrigation water of 3.0 mmhos/cm or higher.

Water with less than 450 ppm of TDS is generally safe for use as irrigation water. TDS between 450 and 2,000 ppm is considered to be a "slight to moderate" risk, depending on the plant, while anything above 2,000 ppm is a "severe" risk to most plants.

The **sodium adsorption ratio (SAR)**, also called adjusted Rna, expresses the sodium hazard of water. The SAR is an indicator of the amount of sodium in the water relative to calcium and magnesium. Calcium and magnesium counter sodium's effect on soil. Sodium in irrigation water can accumulate in soil and result in undesirable physical soil characteristics. When wet, soil with high sodium levels doesn't drain as well and when dry the soil becomes very hard. Sodium can also accumulate in soil to sufficiently large amounts such that plant's uptake of sodium becomes toxic to the plant.

Generally safe SAR levels are less than 3. Levels between 3 and 9 are "slight to moderately" risky, and anything above 9 is in the "severe" risk category. Current recommendations for assessing SAR risk is to use a slightly modified calculation called "adjusted Rna". Adjusted Rna results are used identically to SAR, though believed to demonstrate a more accurate assessment of sodium hazards. We used adjusted Rna results in this study.

Ion toxicity

Plants can suffer from toxicity if ions in the water accumulate in the plant. At high concentrations, reduced yields and plant can occur; the degree of damage depends on uptake rates and the plant's sensitivity. Perennial-type plants, like fruit trees, are more sensitive, whereas annual crops are typically unaffected by ion toxicity. We tested ions of boron, chloride, and sodium. Most of the plants grown with greywater we studied were perennial, predominantly trees, and would be susceptible to ion toxicity. It is usually first evidenced by marginal leaf burn and interveinal chlorosis.

Boron: Because boron can be toxic to plants at very low levels, and is often found in detergents and cleaning products, boron toxicity due to greywater use could easily occur depending on what detergent and cleaning products are used in the home. Boron is also non-toxic to humans so is used in many "eco" products that may be attractive to ecologically minded greywater users. The general safe limit for boron concentrations in irrigation water is less than 0.5 ppm. The "slight to moderate" risk range of boron is between 0.5 and 1 ppm, depending on the specific tolerance level of the plant species, and anything over 1 ppm is a "severe" risk for most plants.

Chloride: Although an essential nutrient to crop growth, toxic levels of it in water can restrict plant growth. Chloride contributes to salinity of irrigation water, and when concentrations are high enough, can be toxic to plants. Chloride moves readily with the soil water and is taken up by the roots. It is then transported to the stems and leaves.

Water chloride concentrations up to 140 ppm are generally safe for irrigation use. Between 140-300 ppm chloride there is a “slight to moderate” risk, and sensitive plants may incur some injury. Long term irrigation with water containing more than 350 ppm chloride pose a “severe” risk for most plants. Note that these levels are for surface irrigation. During spray irrigation, evaporation concentrates dissolved solids, so acceptable levels are lower. Woody and vine plants and stone fruits are susceptible to chloride toxicity. The most sensitive species, e.g. some berries and avocado cultivars, can tolerate only up to 120 ppm of chloride, while grapes can tolerate up to 700 ppm or more.

Sodium: Sodium exists in nearly all irrigation water and is not necessarily a cause for concern unless high concentrations are present. Sodium in irrigation water can be absorbed by roots and foliage, and foliar burning can occur if sufficient amounts accumulate in leaf tissue.

The ability of a tree to tolerate sodium varies considerably. Sodium injury on avocado, citrus, and stone-fruit trees has been reported at concentrations as low as 115 ppm. Initially, sodium is retained in the roots and lower trunk, but after 3 to 4 years the conversion of sapwood to heartwood apparently releases the accumulated sodium, which then moves to the leaves causing leaf burn.

In general, safe sodium levels are less than 70 ppm, and low-medium risk range is 70-200. Levels over 200ppm pose a high risk to horticultural plants.