HEALTH RISKS OF USING GRAY SOIL COLORS TO DETERMINE ONSITE SUITABILITY

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ABSTRACT

Historically, in Virginia, gray soil colors of chroma 2 or less (Munsell Color Charts, 2000) have been used to identify the seasonal water table (SWT) when determining suitability for an onsite wastewater disposal system (OWDS). Research in the upper Coastal Plain in central Virginia, using an automated data logger, monitored the depth and duration of SWT in a well drained soil with gray soil colors below 40 inches. The results indicated SWT was closely related to the depth of redoximorphic concentrations in the soil in the absence of gray redoximorphic depletions. Soil horizons (located above the depth to gray depletions) with only distinct strong brown concentrations were saturated 50-64% of the wet season (Dec-May); horizons with 3 and 4 chroma depletions were saturated 89-100%. An adjacent peat moss OWDS was design using gray colors to indicate SWT. This research indicated the SWT intruded into the stand-off zone beneath the OWTS, into the gravel pad, and into the peat moss units for extended periods. As a result, the use of only gray redoximorphic depletions to indicate the SWT meant the OWDS directly discharged into the SWT, creating potential health and environmental risks. Therefore, using ALL redoximorphic features, instead of only gray redoximorphic depletions, to identify SWT is more scientifically accurate and would reduce the risk of failing OWDS and the risk to public health.

INTRODUCTION

Soils are an important consideration when evaluating a site for an onsite wastewater disposal system (OWDS). One of the most critical soil features is whether a seasonal water table (SWT) is present, and if it is, at what depth and for what duration. Typically, the OWDS is designed to discharge into soil above the SWT, allowing the aerobic soil to serve as a treatment media for removal of pathogens. In the past, in Virginia, the SWT has been identified by the presence of gray soil colors of a chroma 2 or less, (Munsell Color Charts, 2000). This resulted in installation of OWDS at shallower depths in the soil than if redoximorphic features had not been used at all. This separation distance to the SWT is often called the stand-off distance. Soil colors resulting from soil wetness are called redoximorphic (redox) features (Schoeneberger, 2012). Researchers have shown that gray soil colors are not the only, or even the best, indicator of the SWT (Vepraskas, 1992).

As part of a larger statewide project, research was undertaken to evaluate one of the most common, and problematic, soils of central Virginia. While this soil meets the requirements for an OWDS (Commonwealth of Virginia, 2012), installed OWDS’s often present premature hydraulic problems or hydraulic failure during the wetter portions of the year.

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MATERIALS AND METHODS

Devices that were programmable and would record the water table level automatically were purchased from Remote Data Sensing, Inc. (NOTE: mention of trade names, products or companies does not constitute an endorsement). A WL-40 well (recorded water levels up to approximately 40 inches below the surface) was purchased from Remote Data Sensing and installed at the site. The data logger was programmed to record the water table depth every 6 hours.

In addition to using an automated monitoring well, a manual observation well was installed to confirm automated well accuracy.

A large diameter (4 inches) hole was bored by hand in the soil to a depth of 48 inches. A small amount of clean pea gravel was poured into the bottom of the boring. Each data logger had a marking indicating the depth the monitoring well was to be set into the ground, so the amount of gravel used in the bottom of each hole was determined case-by-case. Once the well was established at the correct depth in the ground, approximately 30 inches of pea gravel was added around the outside of the well casing. Then 8-12 inches of bentonite grout was poured into the annular space and water added, to create a water-tight seal around the well casing. The final few inches of the annular space were backfilled with excavated soil from the borehole.

A large diameter (4 inches) hole was bored by hand in the soil to 48 inches to install a manual observation well. A small amount of clean pea gravel was poured into the bottom of the boring. Two-inch diameter PVC pipe was cut to the desired length and placed into the hole, with an open end resting on the pea gravel at the bottom of the hole. The pipe had numerous, small (3 mm) perforations drilled to allow for easy movement of groundwater. A threaded cap was screwed onto the top of the pipe to seal it. Approximately 30 inches of pea gravel was added around the outside of the well casing up. Then 8-12 inches of bentonite grout was poured into the annular space and water added, to create a water-tight seal around the casing. The final few inches of the annular space were backfilled with excavated soil from the borehole.

Once installed, the data logger was programmed following procedures outlined by Remote Data Sensing.

The data logger was visited on a variable frequency, depending on such variables as the number of water table readings taken daily, weather conditions, and the need to replace the well’s battery.

A detailed soil profile description was made at the research site during well excavation from the auger boring. Standard nomenclature and procedures were used in soil profile descriptions (Schoeneberger, 2012).
When data collection was underway, downloaded water table readings were processed using Microsoft Excel. Data were analyzed to determine the number of days the seasonal water table was in various depth ranges (horizons) in the ground, and the cumulative number of days each soil depth was saturated.

Precipitation data from the Richmond International Airport, where official NOAA weather data are collected, were used to evaluate rainfall during the study period. Monthly rainfall totals during this study were compared to the monthly 29-year averages for the Richmond area.

This site was located in the northern portion of Henrico County, near Richmond, VA. An automated WL-40 data logger and two manual observation wells were installed on the residential property at #11097 Ryall Road. Monitoring wells were located approximately 15 feet away from the OWDS, off to the side (at the same contour elevation) and away from the wastewater flow. While the soil was suitable for a conventional OWDS, insufficient area was present, so a Puraflo (peat moss) Biofilter (NOTE: mention of trade names, products or companies does not constitute an endorsement) OWDS was permitted due to its reduced area requirements. The soil at the OWDS site was excavated to a depth of 24 inches, 6 inches of clean gravel (3/4 – 1 inch diameter) was installed, the Puraflo modules were set on the gravel pad and pipes connected. Soil was used to backfill and landscape the site. The OWDS was installed and began operation in August 1998. Water table monitoring began mid-November 1999.

The site was located at the bottom of a long (approximately 700 feet) linear-linear slope (Schoeneberger, 2012) of 3-4%, on a toeslope landscape position. There was a small creek nearby. The wells were in a small, wooded area while the majority of the upslope area was in fescue-type grasses or mulched landscaped beds, and a few single-story residential homes.

The type of soil at the site, Emporia (Fine-loamy, siliceous, subactive, thermic Typic Hapludult), formed in moderately fine textured, stratified, unconsolidated fluvio-marine sediments of the upper Coastal Plain. When compared to the official soil series description for the Emporia series, the soil at this site fell within the Range In Characteristics, meaning the soil studied was typical or representative of Emporia soils. Following is the detailed soil profile description from the site:

**Emporia sandy loam**

A 0-1 inch; very dark graying brown (10YR 3/2) sandy loam; moderate fine & coarse granular structure; friable, deformable, slightly sticky, slightly plastic; moist

E 1-11 inches; light yellowish brown (10YR 6/4) sandy loam; few fine round quartz pebbles (4-5 mm); moderate fine & medium subangular blocky structure; friable, deformable, slightly sticky, slightly plastic; moist

Bt1 11-16 inches; yellowish brown (10YR 5/6) sandy clay loam; moderate fine, medium & coarse subangular blocky structure; friable, deformable, slightly sticky, slightly plastic; moist
Bt2  16-29 inches; yellowish brown (10YR 5/6) clay loam; few fine round quartz pebbles (3-4 mm); common medium distinct strong brown (7.5YR 5/8) redoximorphic concentrations; friable to firm, semideformable, moderately sticky, moderately plastic; moist

Bt3  29-43 inches; yellowish brown (10YR 5/8) sandy clay loam; common medium distinct strong brown (7.5YR 5/8) redox concentrations; common medium & coarse prominent very pale brown (10YR 7/3) and few fine prominent light yellowish brown (10YR 6/4) redox depletions; firm to very firm, semideformable, moderately to very sticky, moderately to very plastic; damp; soil becoming denser & harder to dig with increasing depth

Bt4  43-60 inches; strong brown (7.5YR 5/8) sandy clay; few fine rounded quartz pebbles; common medium prominent light gray (10YR 7/2) and few fine prominent light yellowish brown (10YR 6/4) redox depletions; common medium prominent red (2.5YR 4/8) redox concentrations; firm, deformable, moderately to very sticky, moderately to very plastic; damp

RESULTS

A key component of any water table monitoring study is the amount of precipitation received at the site, and its distribution pattern during and prior to the study period. While the summer and fall of 1999 were very dry (only 42% or normal, long-term average precipitation), the winter and spring of 1999-2000 received the long-term (29-year) average precipitation.

Figure 1 is the hydrograph for the mid-November 1999 to June 2000 monitoring period. Based on the detailed soil profile description from the site, key morphologic features were highlighted on the hydrograph. Redox features (distinct strong brown concentrations) were first observed starting at 16 inches; very pale brown depletions and strong brown concentrations were observed below 29 inches; and light gray depletions and red concentrations were observed below 43 inches.
Figure 1. Hydrograph generated from an automated monitoring well, with key redoximorphic features highlighted. November 1999 to June 2000 period.

It is worth noting that while the site was significantly drier than normal prior to the start of monitoring in mid-November 1999, the depth to the SWT (or free water in the well) was much shallower than the depth to light gray (10YR 7/2) colors in the soil. That remained true during the entire winter-spring monitoring period. Table 1 is a summary of the data from Figure 1.

Table 1 looks at the amount of time the SWT was present in soil horizons with, or without, redox features. As would be expected when the upper 16 inches of the soil profile had no redox features, the SWT was seldom present (only 3% of the monitoring period). The Bt2 horizon (16-29 inch depth) had common distinct strong brown (7.5YR 5/8) redox concentrations and the SWT was present 64% of the monitoring period. The Bt3 horizon (29-43 inch depth) had common distinct strong brown (7.5YR 5/8) redox concentrations and common prominent very pale brown (10YR 7/3) depletions and the SWT was present 100% of the monitoring period. A rapid drop in the SWT started in late April, corresponding to shrubs and trees leafing-out and a rapid increase in evapotranspiration at the site. This continued until the well went dry (at a depth of 41 inches). Monitoring continued through the dry summer-fall period, and into the next wet season.

The Bt2 horizon with distinct strong brown (7.5YR 5/8) redox features was characterized by sharp rises and more gradual drops in the SWT. The Bt3 horizon with distinct strong brown (7.5YR 5/8) and prominent very pale brown (10YR 7/3) redox was characterized by continuous saturation. This was all occurring ABOVE the depth where gray redox depletions were observed.

**Ryall Road: Nov 18, 1999 - May 11, 2000**

During this 176 day period where there was water in the observation well:

<table>
<thead>
<tr>
<th>Depth ( in.)</th>
<th>Redox Feature</th>
<th># Days</th>
<th>% Cumulative Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 16</td>
<td>None</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>16.1-29</td>
<td>St Brown</td>
<td>112</td>
<td>64</td>
</tr>
<tr>
<td>29.1-41</td>
<td>St Brown &amp; Very Pl Brown</td>
<td>176</td>
<td>100</td>
</tr>
</tbody>
</table>
Table 1. Summary of the automated monitoring well data, separations based on key redoximorphic features. November 1999-May 2000.

Summer 2000 was drier than normal, and fall 2000 was especially dry (October 2000 was the driest October on record in Richmond, VA). Fall 2000 had only 41% of normal, long-term average precipitation, and winter-spring 2000-2001 had only 75% of long-term average precipitation. Because of this, the SWT was suppressed or delayed at the site.

Figure 2 is the hydrograph for the mid-December 2000 to May 2001 monitoring period. This figure shows how the SWT was not present in November, as was the case in fall 1999, due to drought conditions. Sporadic rains in December promoted the formation of a temporary SWT. Finally, after more consistent precipitation, the SWT was established and the familiar “saw-tooth” hydrograph began in mid-January.

Figure 2. Hydrograph generated from an automated monitoring well, with key redoximorphic features highlighted. December 2000 to May 2001 period.

Table 2 summarizes the amount of time the SWT was present in soil horizons during the winter-spring 2000-2001 monitoring period.
Ryall Road: Dec 17, 2000 - May 2, 2001

During this 137 day period where there was water in the observation well:

<table>
<thead>
<tr>
<th>Depth (in.)</th>
<th>Redox Feature</th>
<th># Days</th>
<th>% Cumulative Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 16</td>
<td>None</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>16.1- 29</td>
<td>St Brown</td>
<td>68</td>
<td>50</td>
</tr>
<tr>
<td>29.1- 40.3</td>
<td>St Brown &amp; Very PI Brown</td>
<td>122</td>
<td>89</td>
</tr>
<tr>
<td>40.4 -</td>
<td>Dry Hole</td>
<td>11</td>
<td>100</td>
</tr>
</tbody>
</table>


As was the case the prior winter-spring period, the SWT was seldom present in the upper 16 inches of the soil profile (only 6% of this monitoring period). The Bt2 (16-29 inches depth) had the SWT present for 50% of the monitoring period; the Bt3 (29-43 inches depth) had the SWT present for 89% of the monitoring period. Starting in late April, there was a rapid drop in the SWT due to the rapid increase in evapotranspiration. The well went dry in May (at a depth of 41 inches), but monitoring continued through June 2001.

Similar to the prior winter-spring period, the Bt2 horizon with only distinct strong brown (7.5YR 5/8) redox features was characterized by sharp rises and more gradual drops in the SWT. The Bt3 with distinct strong brown (7.5YR 5/8) and prominent very pale brown (10YR 7/3) redox features was characterized by continuous saturation. Again, the SWT was occurring ABOVE the depth where gray redox depletions were observed.

DISCUSSION

There was a clear relationship between redox features present and duration of saturation. Because of the fleeting, infrequent, short duration of the SWT in the upper 16 inches of the soil profile, conditions were not favorable for the formation of redox features.
In the Bt2 horizon (16-29 inches), the hydrographs indicate that while there was an irregular pattern to the presence of the SWT, it was present 50-64% of the time during the winter-spring period. And while there was a distinct “saw-tooth” pattern to the SWT in the Bt2, there were periods of continuous saturation for a week or more at times.

In the Bt3 horizon (29-43 inches), the hydrographs indicate nearly continuous saturation (89-100% of the time) during the winter-spring period. And this was occurring when precipitation was significantly below normal prior to, and during, portions of the monitoring periods.

Relating these hydrographs to the observed precipitation conditions, it would be expected that with more normal precipitation that the SWT would establish itself earlier in the fall and at a shallower depth in the soil than observed in Figure 1. Likewise, since the January-April 2000 period received the long-term (29-year) average precipitation, the hydrograph in Figure 1 for January-April is representative of the normal SWT present in the Emporia soil at the site. That is significant because the SWT, under normal or near normal precipitation conditions, is ALWAYS shallower in the soil than the depth to gray redox features.

The Puraflo OWDS utilized at this residential site was installed at 24 inches below the land surface, complying with regulatory requirements for stand-off distance from gray redox depletions, since gray colors were used to indicate the depth to SWT. However, based on continuous, automated monitoring at the site, it is evident that the SWT was present in the Puraflo modules and the gravel pad at least 1/3 to ½ of the time during the winter-spring period. The SWT was present in the 12 inch stand-off zone (beneath the pad) 100% of the time during the winter-spring period.

It is clear from this research that the soil was much wetter at shallow depths than had been anticipated when the gray redox features were used as the SWT indicator. Because of that, the OWDS was directly discharging into the SWT for extended periods. In addition, the stand-off zone beneath the OWDS was not an aerobic environment, but was in fact periodically or continuously saturated for the winter-spring period (3-5 months, based on this research). This allowed for the direct introduction of pollutants and pathogens into the SWT. As a result the OWDS could not function properly to safely treat and dispose of pollutants and pathogens.

The Emporia soil is classified as well drained, with the SWT below 36 inches (based on the depth to gray redox features). While the soil at the site met the physical and morphological criteria to be called an Emporia soil, the soil was much wetter for long periods of time than would be officially recognized. The soil at this site was continuously saturated below 29 inches; and it was periodically saturated below 16 inches for most of the winter-spring period. This soil would more correctly be classified as moderately well drained, with the SWT between 18-36 inches. Based on this research it is clear why OWDS’s in this supposedly well drained soil of central Virginia commonly have hydraulic problems, especially during the winter-spring period.

While gray redox features are one indicator of the SWT, they are not the only, or even the best, indicator of the maximum height of the SWT in the soil. This research clearly showed that using ALL redox features, instead of just grays, would be scientifically accurate and would help
prevent situations like this where OWDS’s are incorrectly designed, resulting in groundwater pollution and/or failing OWDS’s.

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REFERENCES

Commonwealth of Virginia, State Board of Health. 2012. 12 VAC 5-610-10 et seq. Sewage handling and disposal regulations. Richmond, VA.


