Protocol for Using and Interpreting IRIS Tubes

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more field investigation. As we finish our renovations on the Nolo and Germania series, we can begin planning the next projects. We believe our modeling techniques will be transportable for use with other soil series in Potter County and elsewhere in MLRA 127. They will also help guide field work and correlation decisions. The Sweden series could use a new coat of paint.

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Protocol for Using and Interpreting IRIS Tubes

Martin C. Rabenhorst

Scientists may be interested in documenting reducing conditions in soils for a variety of reasons. Those working in the arena of wetland delineation may wish to demonstrate that a soil meets the Technical Standard for Hydric Soils (National Technical Committee for Hydric Soils, 2000). The Technical Standard can be used to evaluate or test new Field Indicators (FI) for Hydric soils, or it can also be used to confirm that a soil is hydric in the absence of a Field Indicator, such as in a disturbed site. Others working in the area of wetland remediation may wish to demonstrate that the soil of a recently created or restored wetland is actually reducing and, therefore, functioning like a hydric soil.

The standard and approved approaches for documenting reducing conditions have been the use of Pt and reference electrodes to measure Eh (Patrick et al., 1996) or the use of colorimetric dyes that indicate the presence of reduced chemical species, such as the use of alpha-alpha-dipyridyl to demonstrate the presence of reduced Fe(II) in the soil solution (Childs, 1981). While researchers may be comfortable using electrodes to measure Eh, many practitioners find the complications associated with measuring and interpreting Eh data to be overly complex. A drawback of using alpha-alpha-dipyridyl is that it may carry some health risks. Safety information indicates that alpha-alpha-dipyridyl can be harmful if inhaled or absorbed through contact with skin. It can be irritating to the eyes, respiratory system, and skin and is toxic if swallowed. Therefore, it should be used with caution.

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In the last few years, IRIS technology has been introduced as an alternative method for documenting reducing soil conditions. The original idea was developed by Jenkinson (2002), and has since been further developed and tested (Rabenhorst and Castenson, 2005; Jenkinson and Franzmeier, 2006; Castenson and Rabenhorst, 2006). IRIS tubes have been approved by the National Technical Committee as an alternative way to document reducing soil conditions required by the Technical Standard (NTCHS, 2005).

Theory

IRIS tubes are sections of 1/2-inch schedule 40 PVC tubing (outside diameter 0.84 inches, 21 mm), usually approximately 24 inches (60 cm) long, that have been coated with an Fe oxide paint. To evaluate whether a soil is reducing, the tubes are inserted into a soil, usually during a period when the soils are anticipated to be saturated. Under saturated conditions, heterotrophic soil microbes begin to deplete dissolved oxygen as they oxidize soil organic matter. Once the oxygen has been depleted, which may take a couple of days or several weeks depending on the soil temperature, the microbes begin to use alternative electron acceptors such as oxidized Fe. As the saturated soils become progressively reduced, soil microbes that oxidize soil organic matter will cause solid phase Fe(III) (iron oxides) to be reduced to the soluble Fe(II) form. Under such conditions, the reddish iron oxide paint applied to IRIS tubes becomes dissolved and removed, revealing the white PVC underneath. The removal of a certain portion of the paint within a defined zone constitutes evidence that the soil is reducing.

IRIS Tube Fabrication

Jenkinson (2002) experimented with a variety of materials and concluded that lightly sanded PVC tubing was the best substrate for receiving application of the Fe oxide paint. He suggested that the Fe(III) oxyhydroxide mineral ferrihydrite be used to coat IRIS tubes because it is a poorly crystalline mineral that commonly forms in wetland systems. As we began to manufacture and use IRIS tubes, however, we noticed that paint that was dominantly ferrihydrite rubbed off easily under normal handling conditions. Further work demonstrated that when Fe oxides were synthesized to enhance the transformation of ferrihydrite to goethite such that the synthesized mixture contained approximately 30 to 40% goethite (with the remained being ferrihydrite), the suspension could be effectively used as a durable coating on the IRIS tubes (Rabenhorst and Burch, 2006).

The prepared PVC tubes are placed in a lathe-type device where they can be rotated at approximately 50 to 100 rpm, and the Fe oxide paint is then applied to the tube using a foam brush so that a uniform coating is attained. Once the paint dries, the Fe oxides are stable and tubes can be stored indefinitely. A line is usually drawn on the tubes at some fixed distance (often 20 inches or 50 cm) from the bottom (Fig. 1; see section of color photos on next page). This line is used as a reference point when the tubes are being inserted into the soil. Tubes can be obtained commercially from InMass Technologies at www.iristube.com.

Tube Installation

Experience over the years has demonstrated that soils are heterogeneous systems, and this is also true when trying to assess redox status. To achieve confidence in measured values, one must typically make replicate measurements. When measuring Eh, the NTCHS has suggested that five replicate Pt electrodes be used, and they also suggest that five replicate IRIS tubes be used to obtain reliable results.

When installing an IRIS tube, a pilot hole is first made using a 7/8-inch-diameter push probe, and the tube is then inserted into the hole. If the soil is dry at the time of insertion, water may be poured down the pilot hole to help minimize abrasion when the tube is set in place. The IRIS tube is gently inserted into the pilot hole until the mark on the tube is at the soil surface (20 inches or 50 cm). If tubes are to be installed to a shallower depth (if stones or some other barrier is encountered at a shallower depth), the depth of the soil surface should be marked on the tube with a permanent marker (Fig. 2). Five replicate IRIS tubes should be installed within a uniform “plot” or study area. Generally, these five tubes will be placed within a 1- to 2-m^2 area. Tubes should be evenly distributed through the plot in any convenient layout and can be up to a meter apart from each other (Fig. 3.)

Monitoring Strategies

For basic monitoring, tubes can be left in place for approximately 4 wk. Because the removal of Fe from the tubes is a function of microbial activity, this process is temperature dependent. Rabenhorst and Castenson (2005) demonstrated that there was a positive relationship between increased soil temperature and IRIS paint removal in the temperature range below approximately 9 or 10°C. At temperatures greater than 9 or 10°C, the relationship was less clear. Therefore, because soils may be saturated during cold periods before or early in the growing season, it may be necessary to install IRIS tubes for multiple periods. One approach is to install replacement tubes subsequent to the initial 4-wk period. This can be repeated throughout the duration of the wet season (Fig. 4a). If better temporal resolution is desired, the tubes can be installed more frequently (at 2-wk intervals), so that the periods of installation overlap (Fig. 4b). IRIS tubes can also be used in the manner of reconnaissance in more remote or inaccessible locations by installing them for a longer period (3–6 mo or throughout the entire wet season) when water tables are expected to be high. In such cases, the removal of paint might be more difficult to interpret quantitatively, but it can still be useful to indicate whether reducing conditions develop within those soils. When it is time for tubes to be retrieved, they can be nudged or pushed slightly side to side to break the soil–tube contact before they are extracted vertically from the soil.

Interpretation of Paint Removal

Once retrieved, tubes should be gently rinsed under a stream of water to wash away any adhering soil, and this can be facilitated by using a soft bristle brush with the water. Care should be taken to avoid any abrasion that might remove Fe oxide paint from the tube. The proportion of paint that was removed from a particular area is usually estimated visually by making comparisons with prepared standard charts, such as those used for estimating redoximorphic features in soil profiles. (In conducting research, we usually make more accurate measures of paint removal by scanning and image analysis). Estimates should be made while the entire tube is examined by rotating the tube (Fig. 5.) To improve the accuracy of the visual estimations, it may be helpful to have two persons make independent assessments, and then average the two sets of data.

Castenson and Rabenhorst (2006) compared Eh and pH measurements with the amount of paint removed in 10-cm (4-inch) increments from IRIS tubes in several flood plain seep wetlands in the Maryland Piedmont. The conclusions from that work are summarized in Fig. 6. Where 10% of the paint was removed within a 10-cm (4-inch) zone of the soil, 81% of the time the Eh and pH of the soil indicated that it was below the Technical Standard (TS) line defined by the equation AUTHOR CORRECT? $Eh = 175–60 \times pH$ (indicating that it was reducing). Where 20% of the paint was removed within a 10-cm (4-inch) zone of the soil, the Eh and pH of the soil indicated that it was reducing 90% of the time. Where 25% of the paint was removed within a 10-cm (4-inch) zone, the Eh and pH of the soil indicated that it was reducing 100% of the time. Figure 7 illustrates how this can be applied by identifying the 10-cm (4-inch) zone along the upper 30-cm (12-inch) of an IRIS tube where the maximum paint removal has occurred. Based on the data in Fig. 6, an interpretational summary is presented in Table 1.

The National Technical Committee on Hydric Soils specifies slightly different requirements to meet their definition of reducing soil conditions (NTCHS, 2005). The criteria for meeting the Technical Standard for reducing soil conditions as currently specified by the NTCHS requires

Table 1. Interpretation of soil redox status as a function of IRIS paint removal, as based on Castenson and Rabenhorst (2006).

Paint removed from a 10-cm section	Interpretation
%	
0	not reducing
1–5	probably not reducing
5–10	possibly reducing
10–25	probably reducing
>25	definitely reducing

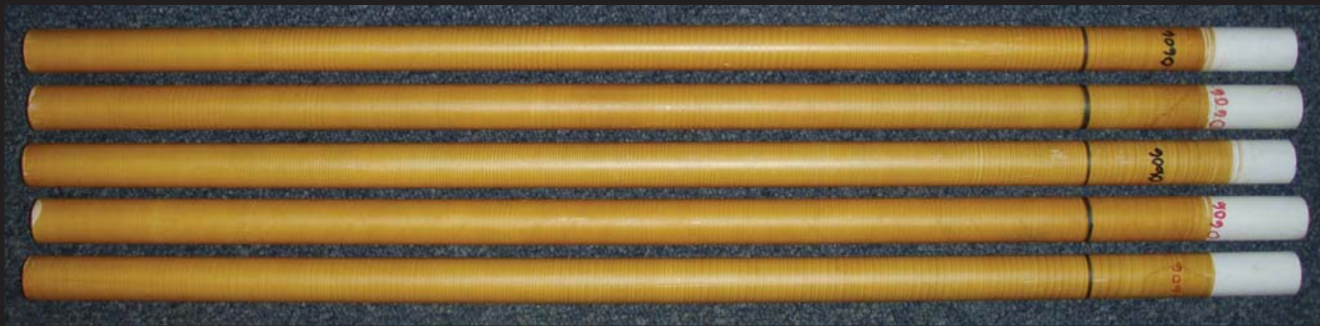

Fig. 1. Set of five IRIS tubes with line marking 50 cm (20 inches) from the bottom of the tube. The notation on the tube identifies the particular batch of paint used in making these tubes (0606).

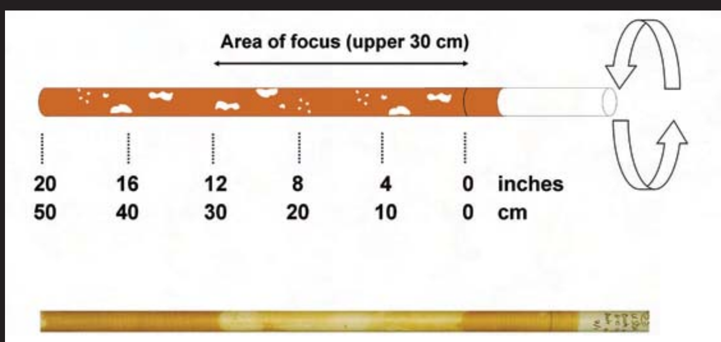

Fig. 5. Estimates of the proportion of the tube area where paint has been removed should be made while rotating the tube. When focusing on issues of hydric soils, the area of interest is the upper 30 cm (12 inches) of the soil.

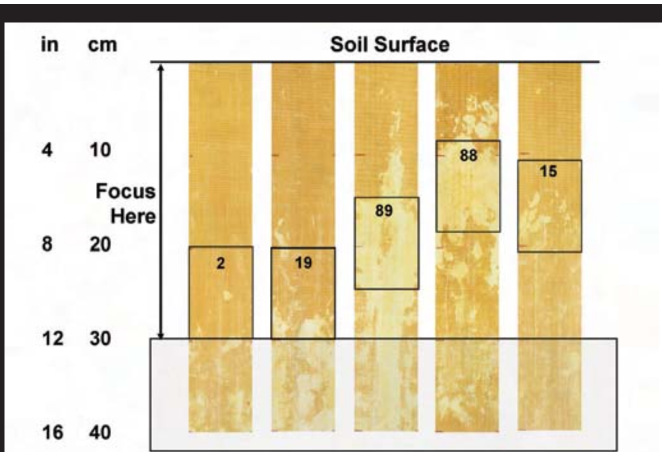

Fig. 7. Scanned images of five IRIS tubes are shown with a box surrounding the 10-cm (4-inch) zone where the maximum amount of Fe oxide paint was removed within the upper 30 cm (12 inches) of the soil (the main zone of interest when considering hydric soil issues). Numbers in the box represent the percentage of paint removed from this zone as measured by image analysis. Work by Castenson and Rabenhorst (2006) indicated that if 20% of the paint is removed within a 10-cm (4-inch) zone, there is a 90% likelihood that the soil is reducing according to the Eh specifications of the Technical Standard of the NTCHS.

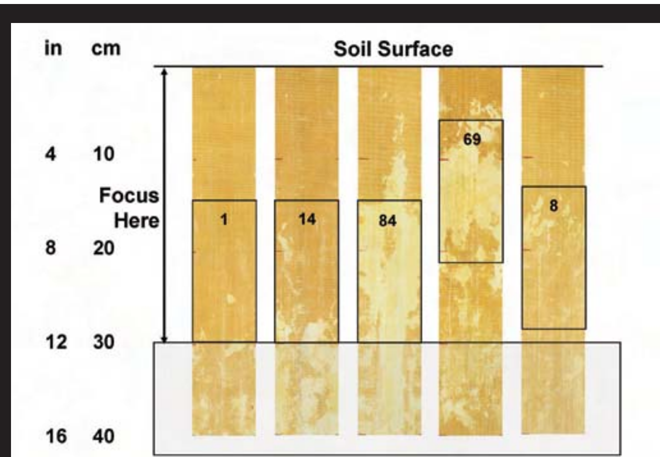

Fig. 8. Scanned images of five IRIS tubes are shown with a box surrounding the 15-cm (6-inch) zone where the maximum amount of Fe oxide paint was removed within the upper 30 cm (12 inches) of the soil (the main zone of interest when considering hydric soil issues). Numbers in the box represent the percentage of paint removed from this zone as measured by image analysis. The National Technical Committee on Hydric Soils has required that for a soil to meet the Technical Standard definition for reducing conditions, 30% of the paint must be removed from a 15-cm (6-inch) zone within the upper 30 cm (12 inches) of the soil, in at least three of five tubes.

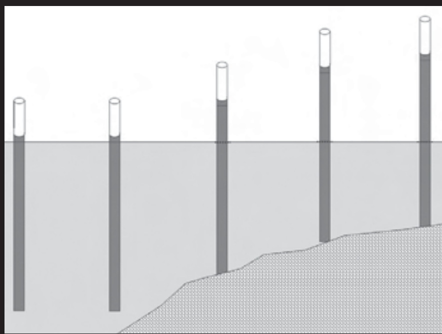

Fig. 2. IRIS tubes are typically inserted 50 cm (20 inches) into the soil unless rock, gravel, or some other impediment interferes. If the tubes cannot be inserted to 50 cm (20 inches), then a line should be drawn on the tube to indicate the location of the soil surface.

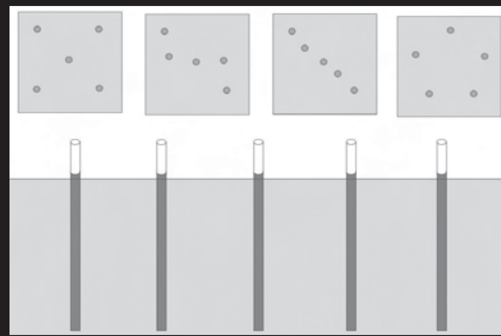

Fig. 3. Five replicate IRIS tubes should be inserted into a uniform area or “plot” that typically covers 1- to 2-m². The tubes can be placed in any convenient arrangement that ensures their even distribution over the area of interest.

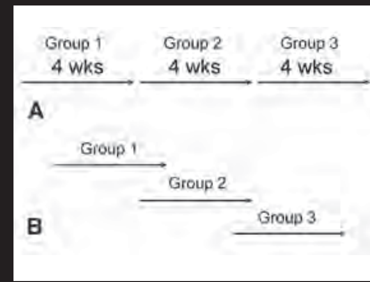

Fig. 4. (A) Groups of IRIS tubes are installed for approximately 4 wk, after which a replacement set can be reinstalled. (B) For better temporal resolution, groups of tubes can be installed at 2-wk intervals so that the periods of installation overlap.

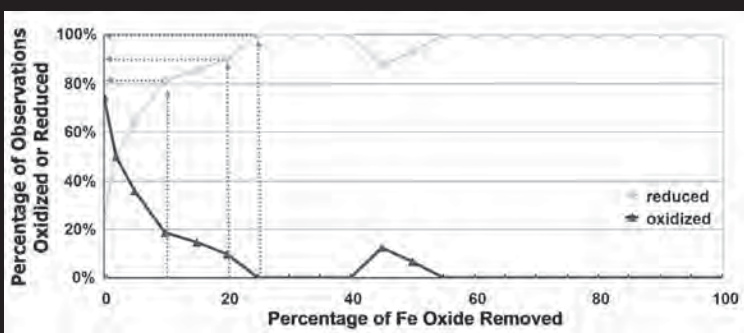

Fig. 6. The proportion of Fe oxide paint removed from a 10-cm (4-inch) section of IRIS tube related to the percentage of Eh pH observations where the soil was reduced or oxidized according the Technical Standard of the National Technical Committee on Hydric Soils. Note that when 20% of the Fe oxide paint is removed from a 10-cm (4-inch) zone, the soil was reduced in 90% of the observations. Modified from Castenson and Rabenhorst (2006).

that a zone on the IRIS tube 6 inches (15 cm) long, entirely within the upper 12 inches (30 cm) must have 30% or more of the paint substantially removed. This can be any contiguous zone 6 inches (15 cm) long within the upper 12 inches (30 cm), and at least three of five replicate IRIS tubes must show this level of paint removal. Application of the NTCHS criteria is illustrated in Fig. 8.

Conclusions

The use of IRIS tubes to assess the redox status of soils provides a reasonable alternative for soil practitioners who do not wish to make Eh and pH measurements or to use potentially hazardous dyes. Tubes should be inserted during the period when water tables are expected to be nearest the soil surface. Because of inherent soil variability, it is recommended that five replicate tubes be used. Published research has shown that when 20% of the paint is removed from a 10-cm (4-inch) zone, in 90% of the cases the soil is reducing according to the Eh requirement of the Technical Standard of the NTCHS. The specific criteria for IRIS tube use that have been approved by the NTCHS, however, are more conservative than those suggested by the work of Castenson and Rabenhorst (2006). This more conservative approach might be justified because most assessments of IRIS tubes will be done by visual estimation rather than by image analysis, and greater uncertainty will be introduced by the estimation process. Other uses and applications of IRIS tubes do not require such exacting requirements as meeting the Technical Standard of the NTCHS. For example, in wetland mitigation work, IRIS tubes can be used to demonstrate that soils are reducing and, therefore, functioning as hydric soils.

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