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FROM THE EDITOR'S DESK

Now that the storm has passed, we'll learn how much damage was caused by Hurricane Florence and the cost of cleanup. It is always tragic to witness loss of life and property damages from storms. It was especially disconcerting to see how much flooding occurred in communities along North Carolina rivers from the second so-called "500-year flood" in two years (Hurricane Matthews in 2016). We'll wait and see what effect this will have on government plans for the future, especially in North Carolina whose legislature voted to ignore science and climate change predictions in coastal planning back in 2012. Many of those flooded probably don't have flood insurance given their location above the 100-year floodplain. Yet for those covered by such insurance, how many times does one need to be flooded out to see that the solution is to relocate to higher ground? A November 4, 2017 article in the New York Times reported that "a house in Spring, Tex., has been repaired 19 times, for a total of $912,732 — even though it is worth only $42,024." Although federal flood insurance doesn't work for everyone inflicted with flood damages for a host of reasons, the frequency of this repair would not be done if it weren't for federal flood insurance. Floodplains are so named for an obvious reason yet people found them desirable places to build homes and commercial properties after levees and dams were built to reduce natural flooding. Now seemingly more frequent, extreme events overtop levees and cause millions of dollars of damage (https://www.climate.gov/news-features/blogs/beyond-data/2017-us-billion-dollar-weather-and-climate-disasters-historic-year). It will be interesting to see the response of various levels of government for minimizing flood damages in the future.

Ralph Tiner
WSP Editor

I hope you've noticed that we changed the publication schedule for *Wetland Science & Practice*. We decided to publish quarterly issues in January, April, July, and October (one month later than before). This allows us to devote the July issue to publishing abstracts from our annual meeting and focus on other meeting-related matters. We will also be publishing student research project reports funded by SWS research grants – the first of which is provided herein by Marisa Szubryt, Southern Illinois University Carbondale. All this plus other contributions will provide more information about ongoing wetland research, restoration projects, and other initiatives to readers. We continue to seek articles on your wetland activities or creative writing on the natural history of wetlands in your locale. Meanwhile thanks to all who have contributed to this issue: Royal Gardner and Erin Okuno for their indepth analysis of current U.S. wetland regulations, Evan Park and Martin Rabenhorst for introducing us to new technology for documenting reduction in anaerobic soils, Marisa Szubryt for her research project report, Max Finlayson for submitting the article he and SWS colleagues published in *The Conversation*, Mary Johnston for information on wetland activities in the Big Thicket, and Doug Wilcox for his *From the Bog* cartoon.

Happy Swamping! ■

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COVER PHOTO:

Spotted Turtle (*Clemmys guttata*)
Photo courtesy of Mal Gilbert

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22 N Carroll St., Ste 300, Madison, WI 53703
608-310-7855
www.sws.org

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Assessing New Developments in IRIS Technology

C. Evan Park and Martin C. Rabenhorst[1], Department of Environmental Science and Technology, University of Maryland

ABSTRACT

Reducing soil conditions may impact more static properties like soil morphology, as well as more dynamic soil chemical properties and microbial ecology. Identifying reducing conditions is especially important when evaluating wetland soil systems. Indicator of Reduction in Soils (IRIS) tubes have been approved by the National Technical Committee for Hydric Soils (NTCHS) as a method to identify reducing soil conditions. Recently, a new development in IRIS technology utilizing flexible films has emerged. IRIS films are strips of vinyl sheeting painted with iron- or manganese-oxide paint. The films are intended to simplify field work and facilitate acquisition and computer analysis of IRIS images. This mesocosm study demonstrates that IRIS films perform comparably to IRIS tubes and accurately document reducing soil conditions.

INTRODUCTION

The Technical Standard for Hydric Soils (TSHS) was developed by the NTCHS to identify soils that satisfy the definition of a hydric soil, either where hydric soil field indicators are lacking, or in the development or evaluation of field indicators. The TSHS can be applied to numerous areas of study, including wetland delineation, wetland construction, and restoration projects. The TSHS requires proof that a soil is saturated and anaerobic. To this end, numerous methods have been developed to identify reducing conditions - the quantifiable evidence of anaerobic conditions. These include two basic methods: 1) the use of platinum electrodes (joined with a reference electrode) to directly measure the oxidation-reduction potential of a soil, which in conjunction with pH measurements can be used to confirm reducing conditions; 2) the application of alpha-alpha-dipyridyl dye to the soil - if the soil is reducing, the dye will react with Fe^{+2} and exhibit a bright pink color (National Technical Committee for Hydric Soils 2015). These methods have limitations because they require specialized equipment or expensive chemicals and they only provide data for the conditions at the moment of observation so the measurements must be made repeatedly for recording duration. In the early 2000s, a new method of identifying reducing conditions was introduced which addressed these limitations - Indicators of Reduction in Soils (IRIS) tubes. These were designed to be a simple, inexpensive field instrument (Castenson & Rabenhorst 2006; Jenkinson and Franzmeier 2006; Rabenhorst and Burch 2006; Rabenhorst 2008; Rabenhorst et al. 2008). The tubes are 60-cm long pieces of half inch schedule 40 PVC plastic (0.84” OD) painted with iron-oxide paint that are inserted into the soil. Under reducing conditions, the oxides in the paint become reduced and soluble and are removed from the tube, resulting in a pattern that can be quantified to identify reducing conditions. The TSHS requires a majority (3 out of 5) IRIS tubes to have at least 30% paint removal from any contiguous 15-cm zone in the upper 30 cm of the tube (National Technical Committee for Hydric Soils 2015). Estimation of paint removal by sight has proved unreliable (Rabenhorst 2010), so more trustworthy methods of quantifying paint removal have been developed. The simplest approach is to use 15x6.7-cm Mylar grids that can be wrapped around the zone of greatest paint removal on the IRIS tube which can be quantified after marking squares where substantial paint has been removed. Some image analysis approaches have also been applied to quantify paint removal, but the difficulty is in obtaining a 2-dimensional image from the 3-dimensional cylindrical tube in order to conduct the analysis.

TABLE 1. Properties of soils used in the study.

Property	Soil 1	Soil 2
Soil Series	Elkton	Downer
Sampling Location (coordinates)	39.007851, -76.847337	39.007929, -76.850181
Depth	0-15 cm	0-20 cm
Horizons sampled	A	A and AE
Texture	Silt Loam	Loamy Sand
% OC	8.4	1.4

1 Correspondence author for contact: mrabenho@umd.edu

Recently, a manganese oxide paint has also been developed for use on IRIS tubes (Rabenhorst and Persing 2016). Although IRIS devices painted with Mn oxide paint have not yet been approved for use by the NTCHS, they do appear promising with regard to their performance in helping to recognize reducing soil conditions (Persing and Rabenhorst 2016).

While IRIS tubes are attractive due to their conceptual simplicity, they do have some limitations. In addition to the previously mentioned problem of obtaining data from the 3-dimensional structure, the manufacturing of the tubes is time consuming because they must be painted one at a time on a special device that rotates the tube. There is also the issue of abrasion during insertion into the soil causing paint removal and thereby introducing error to the data collection. With these limitations in mind, the use of IRIS films is being explored in order to improve data collection and ease of use (Rabenhorst 2018). During the manufacture of films, large vinyl sheets can be painted and then cut into 3-inch wide strips, which reduces manufacturing effort. When films are inserted into the ground, they are enclosed in a protective polycarbonate sheath which mitigates abrasion. Then, when they are removed from the soil, they can be laid flat, simplifying image acquisition.

RESEARCH OBJECTIVES

The research objectives of this project were: 1) to assess the ability of IRIS films to document reducing conditions; 2) to compare paint removal from IRIS tubes and IRIS films under the same conditions; and 3) to generate preliminary laboratory data as background for projects assessing the efficacy of IRIS films in the field.

METHODS

This was a laboratory-based mesocosm study utilizing three replicate 20-L mesocosms of each of two contrasting soils that were saturated, and for which redox potential was documented using Pt electrodes and alpha-alpha-dipyridyl dye. Samples were collected from A-horizons of soils in the Elkton series and the Downer series. Approximately 80 L of each soil material was sieved moist through a ½” sieve and homogenized, and then stored refrigerated (6°C) to minimize changes in organic carbon prior to initiation of the experiment. Mesocosms were made from 5-gallon (20 L) buckets that were perforated around the bottom.

Iron and manganese coated tubes and films were made using paint prepared following the procedures specified by Rabenhorst and Burch (2006) and Rabenhorst and Persing (2017). Into each mesocosm were installed 12 IRIS tubes (6 Fe and 6 Mn) and 12 films (6 Fe and 6 Mn). Also, into each mesocosm were installed 5 replicate Pt electrodes each, at depths of 5 cm and 15 cm from the surface, and a calomel reference was installed in each mesocosm using a salt bridge (Veneman and Pickering 1983). The mesocosms were placed within 10-gallon (38 L) containers and then were saturated from the bottom up to prevent air pockets by adding water to the outer container. The water table was equilibrated at the soil surface. Temperatures in the lab were monitored continuously at 1 hr intervals. One week, two weeks and four weeks after saturation, two replicates

FIGURE 1. Eh-pH stability diagram showing development of reducing conditions (means of 5-7 electrodes recorded daily over 28-day experiment). During the experiment the pH rose slightly (0.4 to 0.8 units). Redox potential (Eh) in both soils dropped below the ferrihydrite stability line and the NTCHS TS line within three days of saturation.

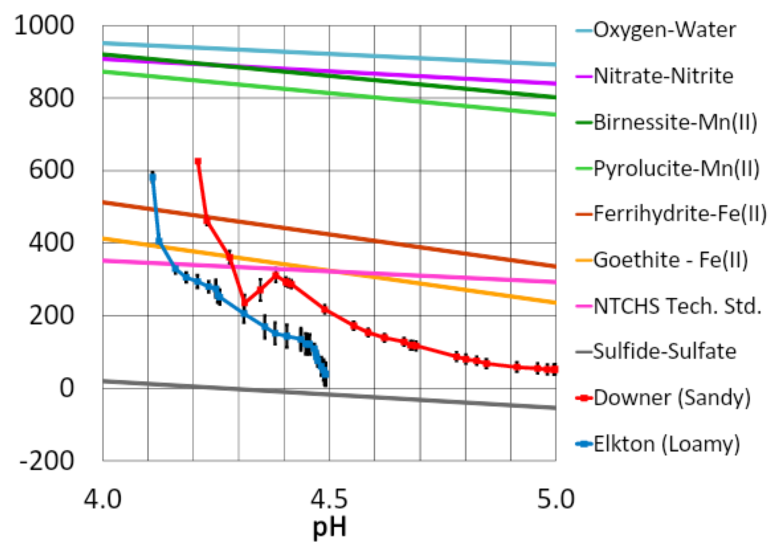
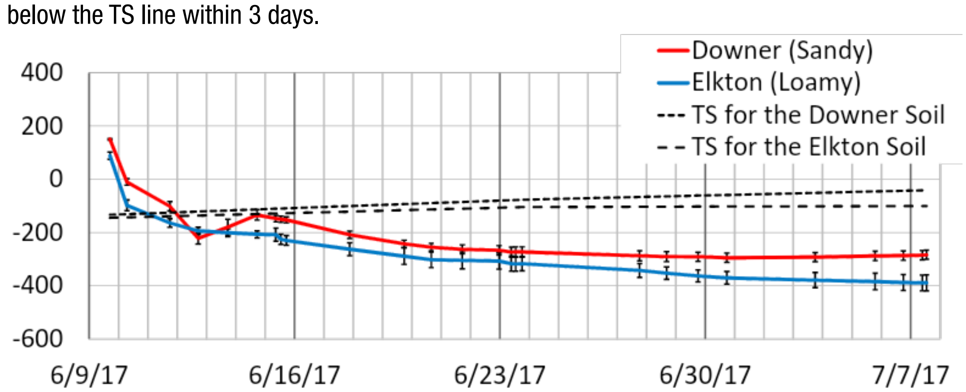


FIGURE 2. Mean Eh values (error bars show SEM) for the two sets of mesocosms relative to the ferrihydrite (Fh) stability line (0 on Y axis) and to the technical standard (TS) lines (based upon measured pH values). Both soils dropped below the Fh line within one day and they dropped below the TS line within 3 days.



of each IRIS device were removed from each mesocosm. After rinsing and drying, films were scanned using a flatbed scanner. Tubes were scanned using a specially modified flatbed scanner configured to roll the tubes keeping them directly above the scanning head as the image was collected. Tubes were scanned in two segments that were later recombined into a single image of the tube using Photoshop software. Digital scans of the devices were converted to binary images (painted areas white and stripped areas black). Paint removal from tubes and films was quantified using ImageJ software. Comparisons were made and the effects of device type, coating type and soil type were assessed by analysis of variance using JMP software (SAS Institute 2014).

FIGURE 3. Representative images of IRIS tubes and films from one of the Elkton and one of the Downer mesocosms.

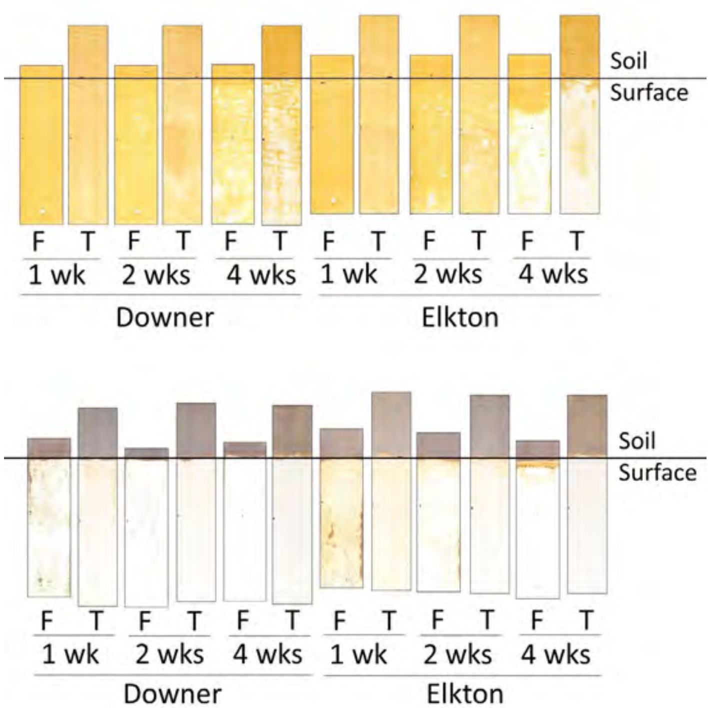
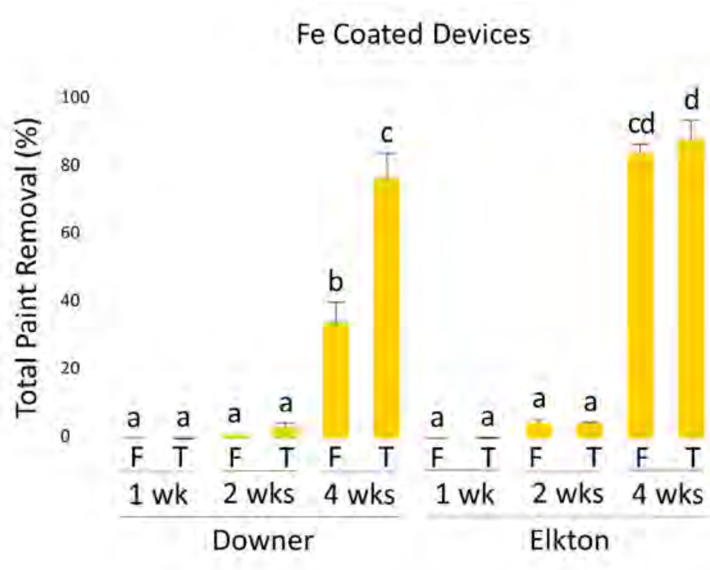


FIGURE 4. Portion of Fe oxide paint removed from IRIS devices after 1, 2 and 4 weeks from the two sets of mesocosms. Bars with the same letters are not significantly different at the 0.05 level.



RESULTS AND DISCUSSION

The redox potentials (Eh) and pH data are plotted on a stability diagram in Figure 1. The redox potentials of all mesocosms started out below the birnessite stability line and quickly dropped below the ferrihydrite stability line within one day and dropped below the technical standard line within three days (Figures 1 and 2). The speed with which the soils became reducing following saturation was probably related to both the relatively high organic carbon (OC) content of the soils (1.4 and 8.4% for the Downer and Elkton soils, respectively) and to the warm conditions of the laboratory which mostly ranged from 21.5°C to 23°C, averaging 22°C (data not shown). These temperatures were quite high relative to springtime soil temperatures and would have facilitated microbial activity.

Representative images of IRIS tubes and films from one of the Elkton and one of the Downer mesocosms are shown in Figure 3. A quick review shows that there was significantly more paint removed from Mn devices than from Fe devices at one, two, and four weeks. The percentage of Fe paint removal from the two soils is shown in Figure 4. Removal of the Fe paint from devices proceeded gradually. Over the first two weeks, there was negligible Fe paint removal (0- 5%) from devices in both the Elkton and Downer mesocosms. The amount of Fe paint removed from all devices and soils significantly increased between two and four weeks. At four weeks, more Fe paint was removed from devices in the Elkton mesocosms than from those in the Downer mesocosms (Figure 4), which may be the result of higher OC content and greater microbial activity.

Paint removal from the Mn devices was particularly rapid, where all devices (regardless of soil type) exhibited at least 80% removal after one week and approximately 99% after two weeks (Figures 3 and 5). After one week, slightly more Mn paint had been removed in the Elkton mesocosms than the Downer mesocosms, but this may not really be meaningful, and within two weeks there is no discernible effect of soil type (Figure 5).

When comparing performance of the two types of devices, mostly they performed the same but a few differences were observed. There were no effects observed with Fe coatings for the first two weeks. In week 4, there was significantly more Fe paint removed from tube than films in the Downer soil, but no significant differences were observed in the Elkton soil (Figure 4). In the case of the Mn coatings, however, the only significant differences were observed in week 1, where there was slightly more (significant, but perhaps not meaningful) Mn paint removal from tubes than from films (Figures 3 and 5).

CONCLUSION

In this study, the most dramatic differences in IRIS paint removal were related to the coating type, with greater proportions of Mn oxide paint being removed relative to Fe oxide paint which reinforces previous research indicating the relative ease with which Fe and Mn oxides may be solubilized under reducing conditions. This study also shows that the properties of the soil can affect paint removal and may be related to the quantity of organic carbon present. Furthermore, the amount of paint removed from the devices is a function of how long they are deployed. Overall, coated PVC films performed comparably to coated PVC tubes and accurately documented reducing conditions, and this suggests that films could reasonably be used in lieu of tubes. The effort involved in obtaining scanned images of films is much less than in obtaining scanned images of tubes. Future studies should examine additional soil types in mesocosms and especially in field settings. ■

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FIGURE 5. Portion of Mn oxide paint removed from IRIS devices after 1, 2 and 4 weeks from the two sets of mesocosms. Bars with the same letters are not significantly different at the 0.05 level.

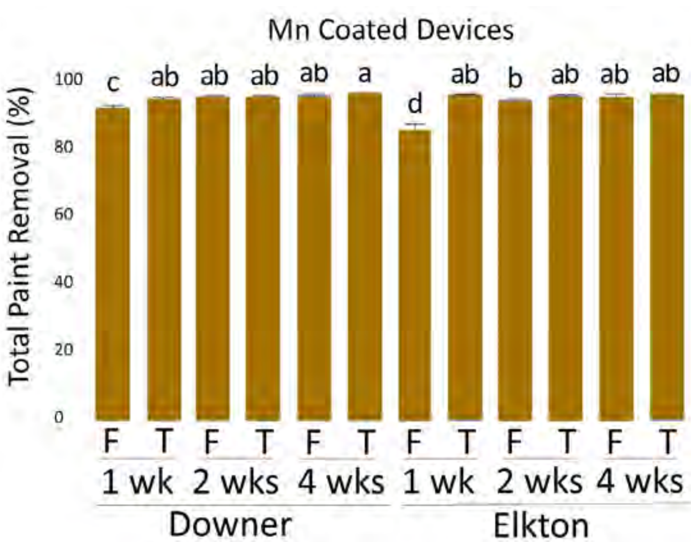

FIGURE 6. This graph reiterates the difference between Fe and Mn paint removal and the time effect for Fe devices. It also indicates that at four weeks, there is significantly more removal from Fe tubes than Fe films (statistical groups "b" and "c"). Note this figure groups devices from the two soils together.