Assessing Ultraviolet Optical Screening Tool Technology for Delineating an In-situ Contaminated Sediment Layer

Kirklyn B. Davidson
Dalhousie University, Halifax, Canada, Kirklyn.Davidson@dal.ca

Craig Lake
Dalhousie University, Halifax, Canada, Craig.Lake@dal.ca

Ian Spooner
Acadia University, Wolfville, Canada, Ian.Spooner@acadiau.ca

Ben Sweet
SCG Industries, St. John, Canada, jwbsweet@scgindustries.com

ABSTRACT: The Ultra Violet Optical Screening Tool (UVOST) is a direct-push tool which was designed to delineate petroleum non-Aqueous Phase Liquids at land-based contaminated sites. The UVOST is specially designed to measure the fluorescent wavelength return of a material through a sapphire window on the device's probe. The advantage of this method is that can rapidly delineate petroleum hydrocarbons during site investigations. The purpose of this research is to further investigate the capabilities of the UVOST system and its ability to rapidly delineate the spatial distribution of organic-rich, unconsolidated, water-covered sediment contaminated with dioxins and furans. The hypothesis is that the UVOST system will be able to produce a "signature" fluorescence pattern for the organic-rich sediment that can be used in the field to quickly delineate the presence or absence of this sediment by qualitative means. This innovative application of the UVOST system will produce more reliable volume calculations of water-covered contaminated sediment relative to conventional sampling protocols (i.e. gravity coring). To test this hypothesis, field work was carried out at Boat Harbor in Pictou County, NS, Canada. The contaminated site consists of a stabilization lagoon which has received industrial wastewater from a kraft pulp mill for the past 50 plus years. The site is slated for remediation and conventional sampling (i.e. gravity coring) has identified a pervasive layer of black organic rich sediment contaminated with dioxins and furans overlying uncontaminated marine sediment. In this study the results of 18 samples from two separate clusters within the stabilization lagoon are presented to demonstrate the UVOST systems effectiveness in delineating an in-situ contaminated sediment layer. These results are presented as a proof-of-concept for the device in this application. Results indicate that the UVOST system can vertically delineate the presence or absence of an organic-rich sediment which will assist in producing more accurate volume estimates for remediation projects which require the delineation of a water-covered sediment.

Keywords: sediment; remediation; delineation; UVOST; stabilization lagoon

1. INTRODUCTION

A stabilization lagoon (Boat Harbor) in Pictou County, NS, (Canada) has been receiving industrial effluent from a pulp and paper mill and other sources for the last 50+ years. Over this time, the site has changed from an estuary (prior to 1967) before its conversion, to a freshwater stabilization lagoon [1-3]. This conversion resulted in the deposition of organic-rich black sediment over the pre-existing estuarine silt. The black sediment is contaminated with both dioxins and furans, as well as elevated metals [1, 4, 5, 6]

In 2015 it was announced that the site will be remediated after closure in 2020. One of the primary objectives of this remediation is the complete removal of the contaminated black sediment to restore the stabilization lagoon. The remediation process at Boat Harbor [7] requires the development of techniques to determine the in-situ volume of the contaminated black sediment. This paper presents a method that can be used to rapidly determine the in-situ thickness of contaminated sediment, which can be combined with basin bathymetry to produce precise volume of the contaminant.

Previous estimates indicate that the volume of contaminated sediment within the stabilization lagoon is approximately 577,000 m^3 [8], based on data collected from gravity cores. However, the spatial resolution of the data is coarse as 200-400m exists between gravity core data points.

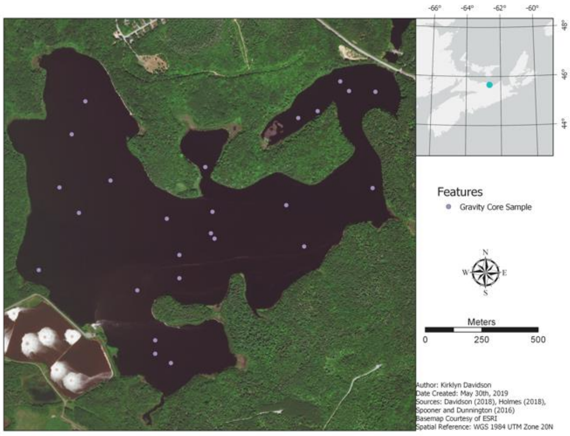

Figure 1. Gravity core sample locations taken in Boat Harbor for contaminated sediment volume estimation.

A rapid, reliable method for the accurate determination of contaminated sediment volume is required to reduce remediation costs. The Ultraviolet Optical Screening Tool (UVOST) can produce real-time, multivariable analysis of multiple layers (both sediment and water) by deploying a probe system, equipped with both a light detection apparatus and conductivity dipole. The UVOST is most commonly used to identify and delineate sites impacted by hydrocarbon contamination. In the Boat Harbour study, the ability of the UVOST to accurately determine the thickness of the organic-rich contaminated sediment layer will be determined. As the device records both conductivity and fluorescent waveforms, the significant potential exists for delineating variable sediment layers with different organic matter compositions (i.e. contaminated sediment and estuarine sediment). This represents a new application for the UVOST, beyond traditional hydrocarbon impacted site applications.

2. METHODS

2.1. Data collection

Gravity coring and core extrusion were selected as comparators to UVOST probe results as these two methods were applied in the initial investigation of contaminated sediment at Boat Harbour and were used to verify thicknesses and inform remedial decisions [1, 2, 7, 8, 9, 10].

2.1.1. Gravity coring

Sediment cores were collected from within Boat Harbor to provide a direct comparison of thicknesses to UVOST probe results. Sediment cores were collected using a Glew gravity coring device (Figure 2) [11]. 100 sediment gravity cores with an additional 13 duplicate samples were collected. In this study, only 18 sediment cores from two cluster sample locations (Figure 5) are presented for a direct comparison of sampling methods. Gravity coring was conducted from a barge on-site. The gravity coring device was lowered through the water column and into the contaminated sediment and underlying grey estuarine sediment. Upon refusal into the grey sediment, a brass weight was released from the surface to trigger the sealing mechanism on the gravity coring device which is required for sediment retrieval. The gravity core was removed from the water and a rubber stopper was placed in the bottom of the core to contain the sediment in the core barrel prior to extrusion.

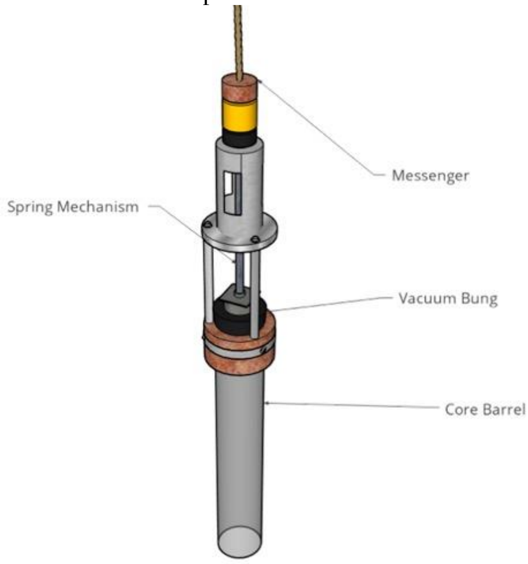

Figure 2. Glew gravity coring device.

2.1.2. Gravity core extrusion

Sediment gravity cores were extruded with a Glew portable extruding device (Figure 3) using previously developed protocols [1, 2, 3]. Immediately after core collection, the rubber stopper was removed from the core barrel, and an extrusion "bung" was inserted in its place. An extrusion platform was then affixed to the top of the core barrel, and the core barrel was placed within the Glew portable extruding device's "core holder" (Figure 3). Gravity cores were extruded to the water-black sediment interface initially, and again until the black-grey sediment interface was seen at the center of the extrusion platform; establishing the thickness of the black sediment.

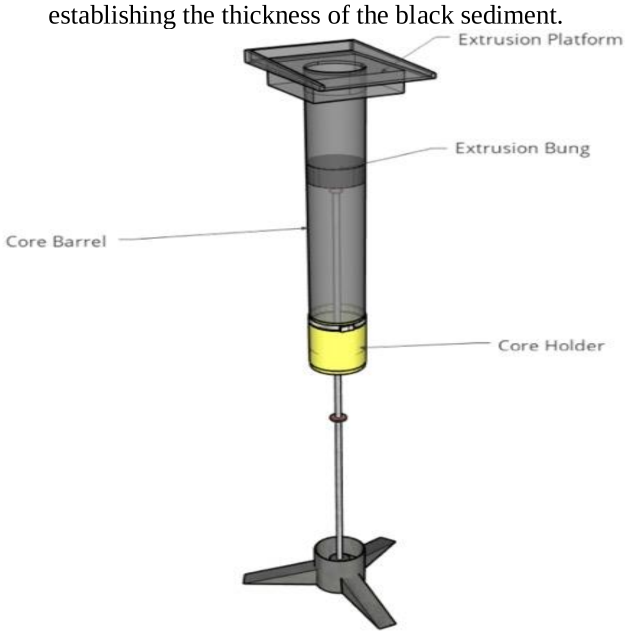

Figure 3. Glew portable extruding device.

2.1.3. UVOST Probe

Prior to the collection of UVOST probe data, both quality control and quality assurance measures were conducted. These measures included the calibration of background fluorescence levels (< 5mV) using the reference emitter (RE), which is a standard for the UVOST device, as well as the adjustment of RE intensity (10,000 $\pm$ 1000 pVs) [12]. During deployment, an integrated winch and pulley system resulted in a controlled penetration rate of less than 1 cm/s, producing high resolution data retrieval. A potentiometer was attached to the UVOST probe head to measure the depth of the probe during deployment. Extension rods (1m in length) were attached to the probe head to permit the sampling of all layers of interest (Figure 4). Data collection commenced above the air-water interface, which allowed for the collection of multiple mediums; air; water; black contaminated sediment; and grey estuarine sediment at each sample site. In total, 100 UVOST logs were collected; the results from 18 are the subject of this paper.

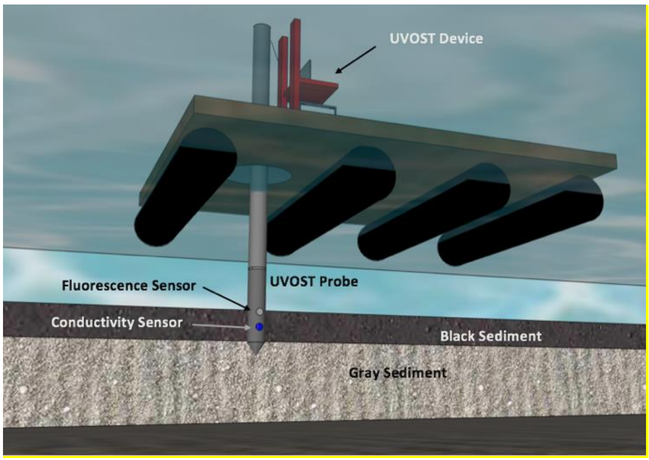

Figure 4. UVOST probe sampling schematic.

3. RESULTS AND DISCUSSION

3.1. Sample locations

18 UVOST logs were acquired during the first portion of field trials along with sediment gravity cores at the same site. Sample locations can be seen in Figure 5. Samples were collected in two clusters within 2m of each other so that local variation between collection methods could be examined. As sample locations were close together, they have been grouped into two clusters which are represented by a single black dot within the map and are labelled with their respective paired sample numbers.

Figure 1: Gravity core and UVOST probe sample locations in this study.

3.2. Site specific sample data

A comparison of the thickness of the black contaminated sediment obtained using the gravity core and the thickness obtained using the UVOST for the two sample sites (i.e. cluster samples 1-8 and 9-18 in Figure 5) are presented below in Tables 1 and 2. Small variations in thickness on a local scale are expected as the morphometry of the sediment surface shows variation in the bathymetric models of the basin [1-3]. Samples 1-8 were collected in the western section of Boat Harbor (Figure 5). This area has very consistent bathymetry likely leading to reduced variability in the thickness of the contaminated sediment between samples [1-3].

Table 1: Cluster samples 1-8 thickness comparison

Core Sample	Sediment Thickness (cm)	UVOST Sample	Sediment Thickness (cm)
BHUV19-0001	44	**19LIF01**	46
BHUV19-0002	37	**19LIF02**	36
BHUV19-0003	33	**19LIF03**	31
BHUV19-0004	36	**19LIF04**	38
BHUV19-0005	35	**19LIF05**	35
BHUV19-0006	37	**19LIF06**	42
BHUV19-0007	35	**19LIF07**	36
BHUV19-0008	33	**19LIF08**	33

Samples 9-18 were collected in the eastern portion of Boat Harbor. At this site, there is increased local variability as samples were taken near a natural channel. This increase in local variability is likely the cause for variation seen between sites in samples 9-18 (Table 2).

Table 2: Cluster samples 9-18 thickness comparison

Core Sample	Sediment Thickness (cm)	UVOST Sample	Sediment Thickness (cm)
BHUV19-0009	24	**19LIF09**	24
BHUV19-0010	21	**19LIF10**	22
BHUV19-0011	16	**19LIF11**	18
BHUV19-0012	17	**19LIF12**	21
BHUV19-0013	15	**19LIF13**	17
BHUV19-0014	30	**19LIF14**	26
BHUV19-0015	28	**19LIF15**	22
BHUV19-0016	18.5	**19LIF16**	20
BHUV19-0017	16.5	**19LIF17**	16
BHUV19-0018	15.5	**19LIF18**	21

3.3. Gravity core and UVOST probe direct comparison

3.3.1. Linear regression

A comparison between contaminated sediment thickness measurements derived from the UVOST probe and those derived by extrusion of gravity cores was accomplished using linear regression for each sample location (Figure 6). These data indicate strong correlation (R^2 = 0.90).

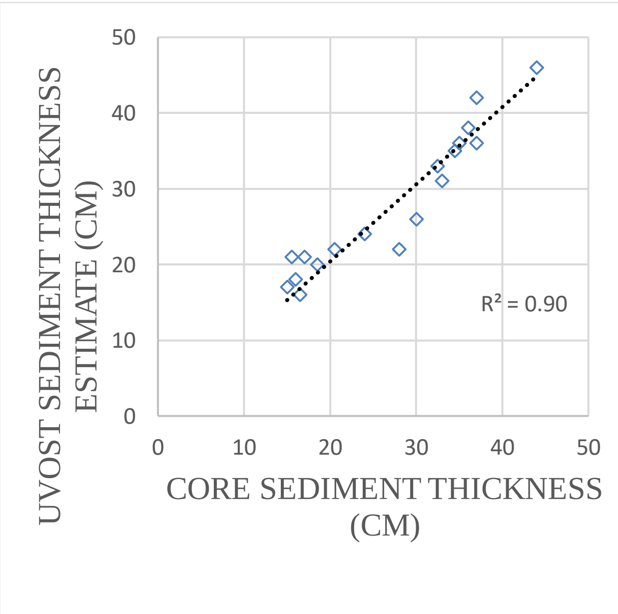

Figure 2: Comparison of gravity core sediment thickness to thickness estimation from UVOST. The solid dashed line represents a linear regression and subsequent R^2 value for the comparison.

Some of the variability between the two techniques is likely related to small scale variations in sediment thickness in the cluster locations as might be expected in natural environments. Alternatively, the variation in black sediment thickness may be related to the sensitivity of the UVOST to the transition layer between the water column and the surface of the black sediment. The transition layer was noted to be an area above the sediment in which the sediment had a density similar to that of water. This transition zone is not necessarily captured accurately during the extrusion process of sediment gravity coring.

4. Conclusions

The UVOST appears to be an effective device for delineating low density organic-rich contaminated sediment in shallow aquatic freshwater environments. The results obtained from the UVOST compare well to estimates obtained by gravity coring and extrusion. Small differences in sediment thickness determined by the two techniques can be attributed to natural variability in sediment thickness over short distances as well as sensitivity in detection of the sediment water interface. The ability of the UVOST to simultaneously record water depths, the water/sediment interface and also produce an accurate estimate of black sediment thickness depth, suggest that the UVOST is effective for projects requiring rapid and accurate assessment of contaminant volume in aquatic environments. The potential for reliable estimation and reduced cost is significant. Future assessment of the utility of UVOST will involve the analyses of the complete data set comprising over 100 sample sites.

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