Applying Freeze Technology for Characterisation of Liquids, Sludge and Sediment – 16371

Jens Eriksson *, Howard Stevens **, Adam Foster **
* Studsvik Nuclear AB
** Studsvik, Inc.

ABSTRACT
Planning of decommissioning activities for objects containing contaminated or potentially contaminated solids below a water table or solids in a water saturated environment requires proper characterisation. One technique for sampling of water saturated objects is the freeze technology. This technology is proven and frequently used for environmental characterization and remediation applications. The design of the sampling tools intended to be used for radiological characterization allows for samples to be taken at specific depths and at specific locations within the contaminated area without disturbing the contaminated material around the sampling location. Using a modified sampling probe, also available, sample cores can be taken which provide a frozen cross-section sample such that an accurate profile of the location and concentration of the contaminants as a function of the depth into the contaminated sludge or sediment is obtained. The same technology can also be scaled up and used to accurately remove contaminated fractions with essentially no cross-contamination with surrounding material.

INTRODUCTION
Planning of decommissioning activities for objects containing contaminated solids in a water saturated environment such as sediments or sludges require proper characterization. The need for accurate characterization requires accurate sampling of the contaminated area. Sampling of contaminated areas should be conducted in such a way that accurate samples can be obtained at the desired location and depth without cross contamination occurring with surrounding material while the sample is being collected.

Using traditional sampling techniques, it is difficult to provide highly accurate measurements for contaminants in the desired sampling area. Traditional sampling techniques provide confirmation that a contaminant is present in the collected sample. However; the exact location, depth and concentration of the contaminant cannot be accurately determined. This is due to both disturbance of the sample itself, as well as disturbance of the materials around the desired sampling area as the sample is being collected. This can create challenges in determining the exact location and amount of soil or sludge that needs to be remediated to fully recover the contaminated material. As such, remediation projects in such water saturated environments tend to involve the removal and disposal of excess amounts of material.

Through the use of the techniques and sampling devices that have been developed with the freeze technology, many of these concerns can be alleviated. Two main sampling techniques have been developed using the freeze technology. The freeze sample probe can be implemented to perform sampling in a wide range of loose and compacted sediments and sludges at a specific depth to retrieve a desired sample volume. Alternatively, the reverse core freeze sampler is implemented to obtain core samples that provide a vertical profile of the sludge or sediment. Thus, the reverse core freeze sample provides accurate data on the location of the contamination and the concentration of the contaminant as a function of depth. Ultimately, through the use of these sampling techniques, a 3D model of the entire contaminated area can be created that contains the radiological, physical and chemical properties of each layer of the sediment or sludge.

BACKGROUND

Water exists in four different forms in a water-particle matrix as shown in Figure 1.

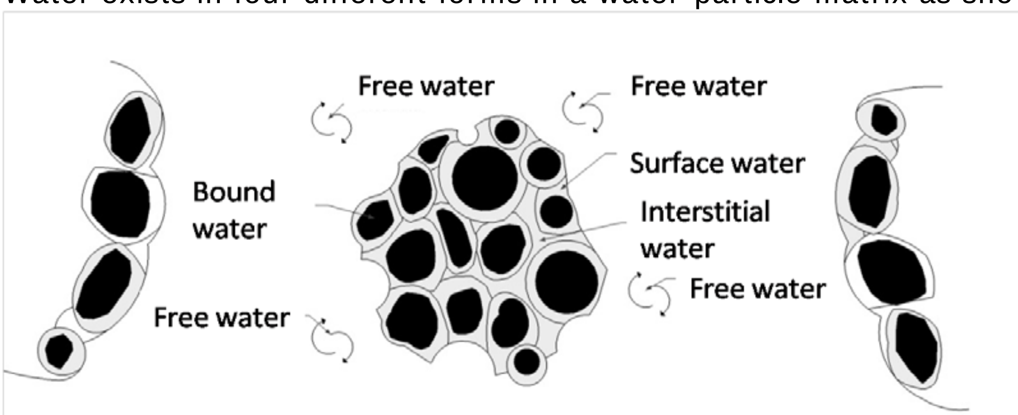

Figure 1. Four different forms of water in water-particle matrix. [1]

The first type of water that freezes is the free water and interstitial water. As ice crystals begin to form, surrounding water molecules migrate to the frozen ice crystals. If the water flow is good, single particles are excluded from the freezing matrix and pushed in front of freeze front. The boundary between frozen and unfrozen material is called the freezing point. The difference between the advancing speed of the ice front and the speed of the particles is the main factor that determines whether the small particles are entrapped in the ice or pushed ahead of the ice front. [1, 2] Figure 2 provides a visual representation of the typical freezing process that occurs naturally.

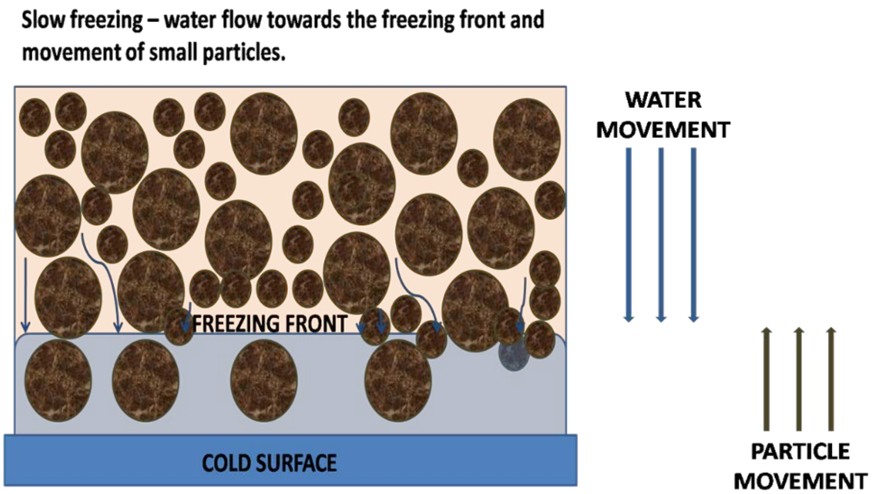

Figure 2. Influence of natural freezing process on particle and water movement within sludges and sediments. [3]

A “fast freezing” rate, that does not exclude small particles, can be defined as the rate at which the crystallization of the water molecules around the particles is faster than the net flow of water molecules into the structured ice layer. At this rate, the particles become entrapped in the ice, and the particles remain intact following freezing and subsequent thawing. [1, 2]

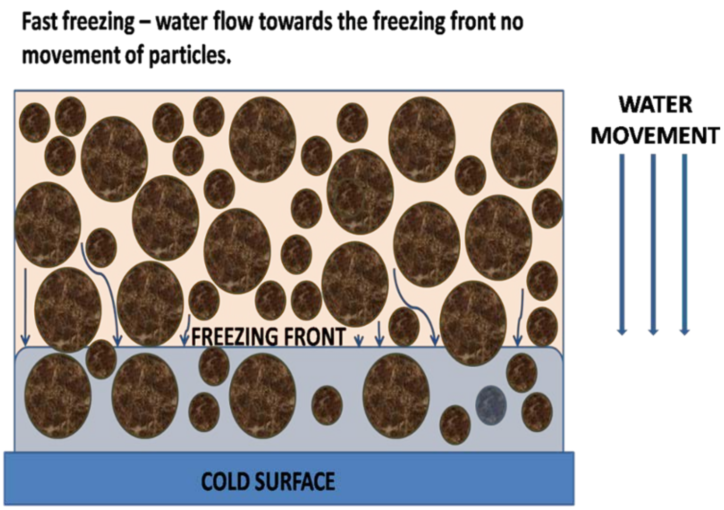

Figure 3. Influence of fast freezing rate on particle and water movement within sludges and sediments. [3]

DISCUSSION

To avoid changes in the material properties, freeze sampling should be conducted at low temperatures to guarantee fast freezing is achieved where the solid particles are trapped within the ice matrix. Additionally, at lower temperatures, the bound water and surface water will freeze thereby ensuring that the particles remain intact in the frozen sample. [3] Through extensive testing and evaluation of the freezing process, advanced freeze sampling techniques and devices have been developed. These include a freeze sampling probe and a reverse core freeze sampling method.

The freeze sample probe has been developed to provide the following capabilities:
1. Sample collection at desired depth and location without disturbing surrounding material when penetrating into the sediment.
2. Sample probe remains in a fixed position in the sediment during freezing to collect accurate samples.
3. Easy detachment of the frozen sediment sample from the sampler.
4. Production of a representative sample.
5. Provide desired sample volume/size to conduct the planned analyses.

Sampling Method

In order to collect a freeze sample, the sample probe is first lowered to the desired depth and at the desired location for sample collection. A vibration device is incorporated into the sample probe to assist in penetrating into dense or compact sludges with very little disturbance to the surrounding material. Once the sample probe is in the desired location within the sludge or sediment, the proprietary freezing process is initiated to create a frozen sample of the desired size/volume. Once frozen, the sample can be safely retrieved, attached to the freezing tip of the sample probe. The integrated vibrator assists in freeing the probe and sample from the surrounding material. After the sample has been retrieved, heat is then used to loosen and remove the frozen sample from the tip of the sampling probe. In order to ensure that material is collected only from the desired sampling location, the sample probe is designed such that freezing only occurs at the tip of the sampling probe.

Sampling Results

Figure 4 contains a photograph of a frozen sample that is being collected during a technology demonstration conducted on simulated sludge.

Figure 4. Freeze sample being collected from simulated sludge. [3]

During the technology demonstration, samples were collected in compact and non-compact sludge simulant, and samples were collected from depths of 20 cm and 40 cm into the simulated sludge material. It was found that the compacted sludge could not be penetrated by manual manipulation only. However, use of the integrated vibrator allowed the probe to easily penetrate to the specified depth to collect the desired freeze sample. The technology demonstration also showed that a sample size of 25 to 30 mL could be consistently achieved. Figure 5 contains a photograph of one of the samples collected during the technology demonstration after it has been removed from the tip of the sample probe.

Figure 5. Sludge sample collected using freeze sampling probe. [3]

In addition to the freeze sample probe, a modified sampling device has been developed to achieve reverse core freeze samples. The aim of the reverse core freeze sampler is to achieve a core sample that provides an accurate profile of the sludge as a function of depth. The device is very similar in design to the freeze sample probe; however, it is modified such that freezing occurs along the entire length of the shaft of the freeze sampler, as opposed to concentrated freezing at the tip of the sampler. Figure 6 contains a photograph of a reverse core freeze sample that was collected during the technology demonstration.

Figure 6. Reverse freeze core sample collected using freeze technology. [3]

The reverse core freeze sampling device shown above was used to collect core samples of 50 cm in length. As can be seen in the figure, the reverse core sampler is capable of producing a core sample that maintains the profile of the sludge and sediment without axial mixing of the sample during collection and retreival.

CONCLUSIONS

Characterisation is the first step in a decommissioning process. The importance of proper characterisation data should never be underestimated. Freeze sampling technology has been developed that allows accurate characterization of contaminated solids, sediments, and sluges in a saturated water environment. The freeze sampling technology allows for accurate sampling that cannot currently be achieved using traditional sampling techniques. Furthermore, the freeze sampling techniques that have been developed can be used to create an accurate 3D profile of the distribution of radiological, physical, and chemical characteristics of the entire contaminated area. This can be very beneficial for remediation projects where large amounts of contaminated material are likely to be disposed. With an accurate 3D model of the locations and depth of the contamination, the overall volume of material that must be remediate and ultimately disposed as radioactive or hazardous material can be minimized. Thus, decreasing the overall impact to the environment for such large scale remediation projects.

REFERENCES

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