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Study of the link between erosion of cohesive sediment and biological activity

Cranfield University

College Road

MK43 0AL

UK

Tuteur entreprise :

Robert Grabowski

Tuteur académique :

Stephane Rodrigues

Solène Jahan

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Abstract

Composed of small particles like silt and clay, cohesive sediment constitutes a specific riverbed structure because of the particular link between particles. This type of sediment is also a natural habitat for bacteria, algae or invertebrate. If cohesive sediment can have effects on this biological activity, several studies have shown that the inverse is also true. This reports aims to synthetize technical considerations made during a 4th-year engineering school internship from 23rd April to 12th July 2019 based on the study of the link between the erosion of cohesive sediment and biological activity in Cranfield University (UK).

Acknowledgements

First, I would like to thank my Polytech supervisor Stephane Rodrigues for bringing knowledge about sediment erosion mechanisms during all scholar year. Those theoretical and practical foundations have guided me a lot during this internship.

I thank my Cranfield University supervisor Robert Grabowski as well for making me interested and invested in this project and for providing precious support, advices and knowledge necessary to the experiment progress.

I would like to thank particularly Cranfield PhD student Cameron Ray for helping me in the setup of the method, above all for the flume experiments.

Thanks a lot to Paul Barton for showing me how to use specific laboratory material, for advising me in the setup of the EPS extraction protocol and for helping me solving a lot of experimental issues all the internship long. Thank you for your patience and your availability.

Thanks to lab technicians Rodrigo Leitao, Richard Andrews and Ceri Dawson for providing me lab inductions, allowing me to progress in my lab work according to safety and security rules.

Thanks to workshop manager Graham Hartwell for cutting 30 acrylic tubes for my experiment.

Finally, thanks to Cranfield University for providing such a great opportunity for international student to complete internships with quality laboratory material and highly qualified staff.

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Note: Pictures presented without the name of the author were taken by myself.

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1. Introduction

Essentially composed of very fine particles (less than 63µm), cohesive sediments are involved in process like nutrients transport, carbon flux modifications or turbidity at the time of erosion. Thus, cohesive sediments must be taken into account when managing with environmental aquatic issues.

The aim of this internship is to test and choose a means of characterizing erosion of natural cohesive sediment with a Sediment Erosion Channel (figure1). The goal is to study the link between erosion and biological activity in this type of sediment. Consequently, the internship also aims to find a way of characterising Extracellular Polymeric Substances in cohesive sediment. Indeed, previous studies have shown that Extracellular Polymeric Substance produced by living organisms has a significate influence on the erosion of cohesive sediment (Grabowski, Droppo, & Wharton, 2011). At the end of the internship the method was applied to a program of experiments aiming to highlight the role of biological activity in the erosion of cohesive sediment. Biological activity was related to bacteria and algae activity only. An experiment with Chironomids was supposed to be done in order to report the effects of burrows on cohesive sediment, but there was not enough time to do it before the end of the internship.

This internship took place in Cranfield Water Science Institute, in England. Part of Cranfield University, this department is specialized in teaching and research in the areas of waste water treatment, drinking water, agriculture and catchment management. Several PhD students are currently working on sediment in Cranfield Water Science Institute. One of them, Cameron, was working on the link between the clay concentration in the sediments and the amount of Xanthum, a gum that imitates EPS. As a result, the experiment also aims to compare the results of the experiments with Xanthan gum and an artificial kaolin and sand mixture to the results of the same measurements obtained with naturally produced EPS.

The principle of the experiment is to prepare 60mm diameter sediment core tubes and to run them into the Sediment Erosion Channel called flume. Same core tubes were used to prepare sediment for laboratory analysis like bulk density, water and organic contents and EPS content at 1, 2 and 3cm depth. The experiment consisting of letting sediment in the core tube incubating for 1 week in 12h light/12h darkness conditions aims to highlight the role of consolidation and development of biological activity in natural sediment. The experiment in darkness aims to highlight the role of non-chlorophyllian organisms in the EPS production, while the one with antibiotics in the water aims to highlight the role of algae inhibiting the activity of bacteria.

Erosion should possibly be less important with a more important biological activity because of the production of EPS, which can act like a protective layer on cohesive sediment. Biological activity could also change sediment stability and increase the erosion.

What are the effects of algae and bacteria on the erosion of cohesive sediment? What are the limits of the method and its areas of improvement?

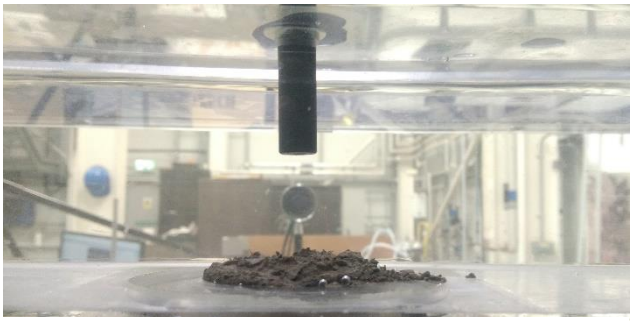


Figure 1: Erosion of a cohesive sediment core in the flume

2. Material and method

2.1 Tests for the determination of the protocol

The protocol has to be tested and prepared in advance in order to be able to put in place a precise and replicable method for the study of erosion of cohesive sediment and the link with biological activity. To achieve that, each part of the experiment was tested before putting in place the study.

2.1.1 *Preparation of the material and lab authorisations*

The first step was to start ordering material. The Water Science Institute already owned 9 core tubes (figure 2). In April, 20 others core tubes were ordered for Cameron's experiments, the PhD student working on artificial cohesive sediment. They were also used for the experiments of this internship with natural sediment. 50ml centrifuge tubes, acrylic tubes and cork stoppers were also ordered in May and June.

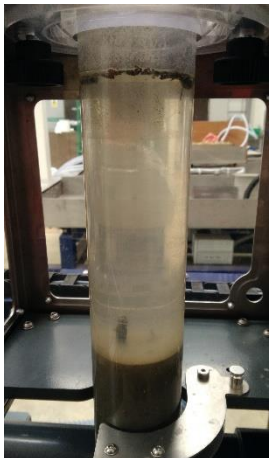


Figure 2: Core tube filled with sediment

In order to be authorised to work in the three different laboratories were experiments should take place, lab inductions were organised to teach safety rules in those specific places. Lab users could also ask small trainings to lab technicians in order to learn how to use specific material (i.e. centrifuge, autoclave, Mastersizer…).

Antibiotics were also needed. As they are toxic, they requires a COSHH assessment, that is to say a precise description of the handling and the products (concentration, maximal exposure time, etc.) that had to be approved and authorised by laboratory managers. Then, the COSHH assessment is put online on Intelex, a risk and COSHH assessment platform where all hazardous activities are recorded.

2.1.2 *Sediment collection and characterisation*

A first an amount of cohesive sediment was collected in order to test several ways of preparing core tubes. Those test cores were used to test flume settings depending on the way cohesive sediment are eroded in the flume, as well as water and organic contents determination method. Those sediments were also used for learning how to use the Mastersizer, a device allowing particles size analysis.

Sediments were collected from a brook in Copple (figure 3) on 14th May 2019. The grab (figure 4a) was not very efficient because of a large amount of organic matter above the sediment, for example

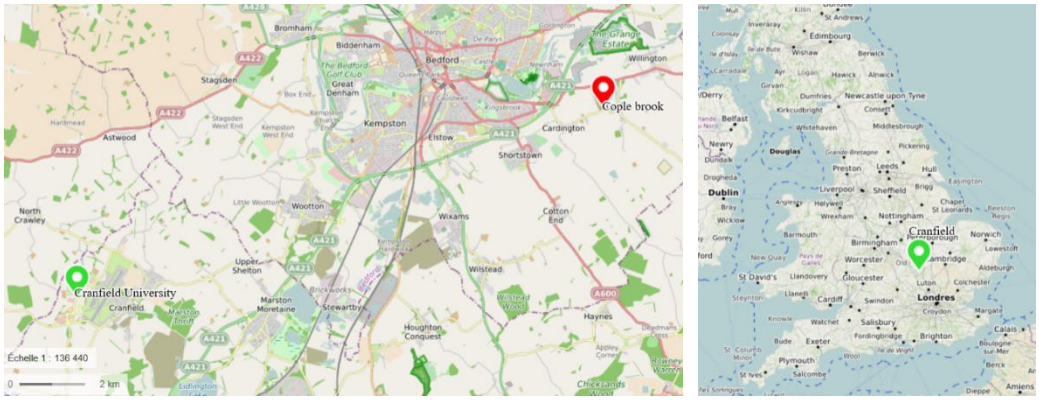


Figure 3: Localisation of Copple brook (in red) besides Cranfield University (in green) (left) and localisation of Cranfield in the UK (right). Source: Open Street Map

dead leaves and wood. Sediment collection with the core (figure 4b) was difficult because sediments were very cohesive from 15 cm depth: it was consequently difficult to extract it from the core. Only 10 cm thick have been collected with the core. The majority of sediments was collected with a bucket and a shovel directly from the riverbed (figure 4c) and stored in four closed buckets in an icebox during the drive to the lab. In the lab, sediment were mixed in one big container and stored in a 4° C fridge.

Figure 4a: Grab. 4b: Core. 4c: Cohesive sediment collected with bucket and shovel

A Mastersizer was used to determine particle size of the collected sediment (figure 5). The sediment sample is diluted in a stirred beaker. This liquid sample passes into small pipes into the device. Thanks to the volume of the particles analysed, the Mastersizer achieves 5 measurements of the sample and gives an average of the particle size distribution (figure 6) at the end. For this experiment on cohesive sediment, the interest of the Mastersizer was to know the percentage of particles under 63µm. This threshold value was chosen in the Mastersizer settings, and it gave a percentage of 81.25% mud (12.73% clay and 68.53% silt) and 18.75% sand.

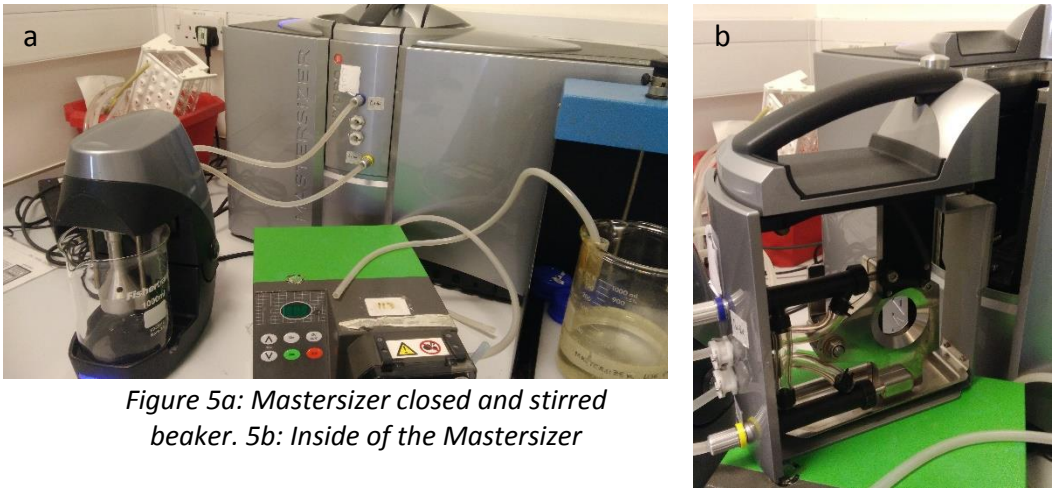


Figure 5a: Mastersizer closed and stirred beaker. 5b: Inside of the Mastersizer

Figure 6: Chart representing particles size distribution in Copple brook

2.1.3 *Filling core tubes*

Core tubes must be prepared in a way imitating at maximum natural consolidation. The aim is to avoid resuspended sediment in the water column, sedimentation in two distinct different layers (one with pure sand and the other one with finer particles like clay or silt) and air bubbles in the sediment. Moreover, the adopted method has to be easily replicable in order to avoid bias between experiments.

Three different filling method were tested. The advantages and drawbacks are synthetized in the table 1. Before each method test, coarse components like stones and big dead leaves of branches were removed from the sediment as it could affect erosion at the small scale of the core tube.

Preparation of the core tubes for the experiment with antibiotics includes to choose the right antibiotics. A similar study (Lundkvist, Grue, Friend, & Flindt, 2007) used a Kanamycin and Neomycin mix at a 150mg/L concentration. Those antibiotics can be purchased from the scientific supplier website Sigma Aldrich. However, as explained above, the purchase and the use of those toxic antibiotics within the university needs your COSHH assessment to be authorised before (appendix 1). As this operation can take time, is it necessary to anticipate it.

Table 1: Synthesis of advantages and drawbacks of each filling core tubes method

Method name	Protocol	Results	Simplicity / replicability	Avoiding air bubbles	Avoiding suspended sediment	Homogenous sand/mud repartition	Natural consolidation
Shovel	A shovel was used to collect some sediment from the mixture. Sediment was put directly into the core tube. No water added above sediment.	Uneven surface. Sediment surface was eroded whereas the measurement hasn't begun.					
Dilution	A known amount of sediment was diluted with a known volume of water in a bucket and well mixed. The liquid was poured into the core tube and let settle for 24h.	Sand settled well before mud. Sometimes finest clay particles did not settle					
Bucket	A mixture of sediment was poured in a bucket with water gently poured over it. After letting consolidating overnight, core tubes were planted into sediment and sediment were aspirated thanks to a vacuum created with a core extruder.	The aspiration of sediment did not worked; it fell again into the bucket.					
Plastic bag	Sediment was put into a pierced plastic bag which was used like a piping bag to fill the core. 170ml of water was then gently poured on the sediment. The core was let consolidate overnight.	The hole in the plastic bag became bigger and bigger. Necessity to change it after a few cores.					

Not suitable Moderately suitable Well suitable

2.1.4 *Flume use and settings*

Measurement of erosion threshold was made with a Sediment Erosion Channel called flume (figure 7). The concept of the erosion measurement with the flume is based on a piston that pushes up a sediment core into the channel to make these sediments eroded. The flume allows to measure the amount of sediment that has been eroded by measuring the difference between the initial position of the piston and its final position. As you can see on the figure 8, flow rate decreases as the piston raises, that is to say when a 5mm layer of sediment is fully eroded.

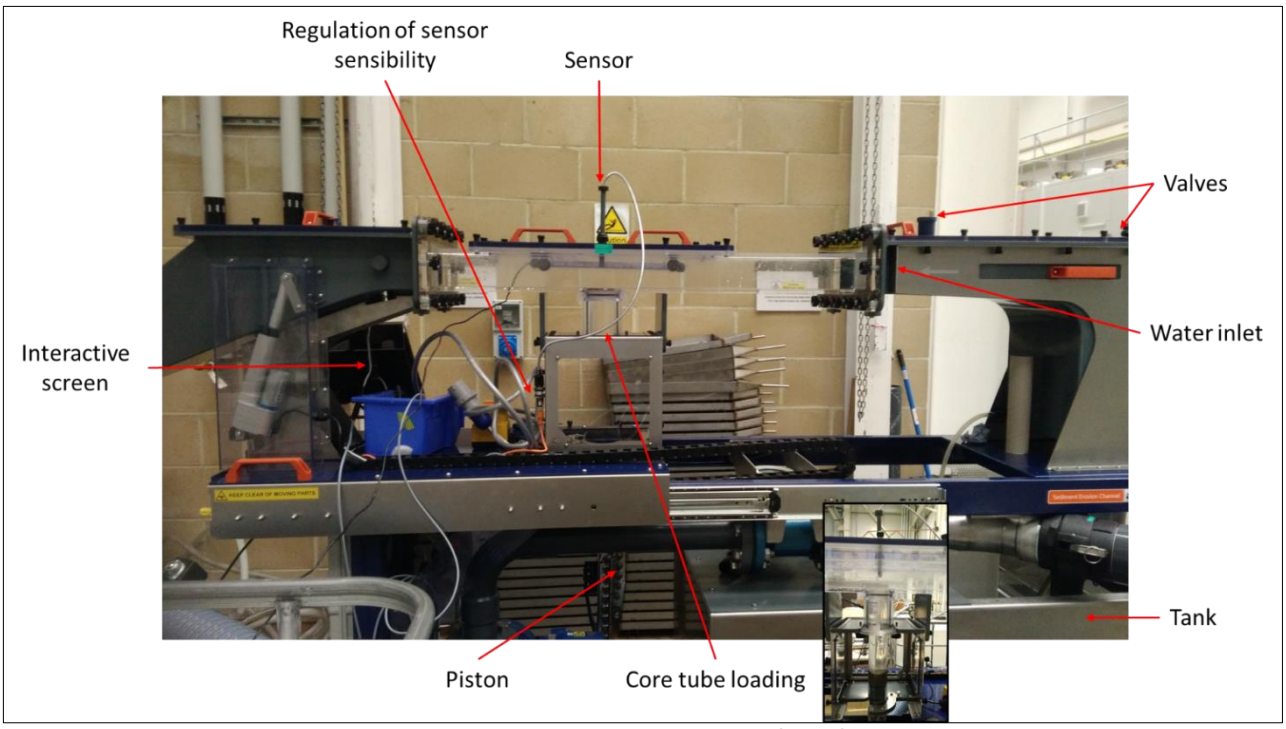


Figure 8: Principal components of the flume

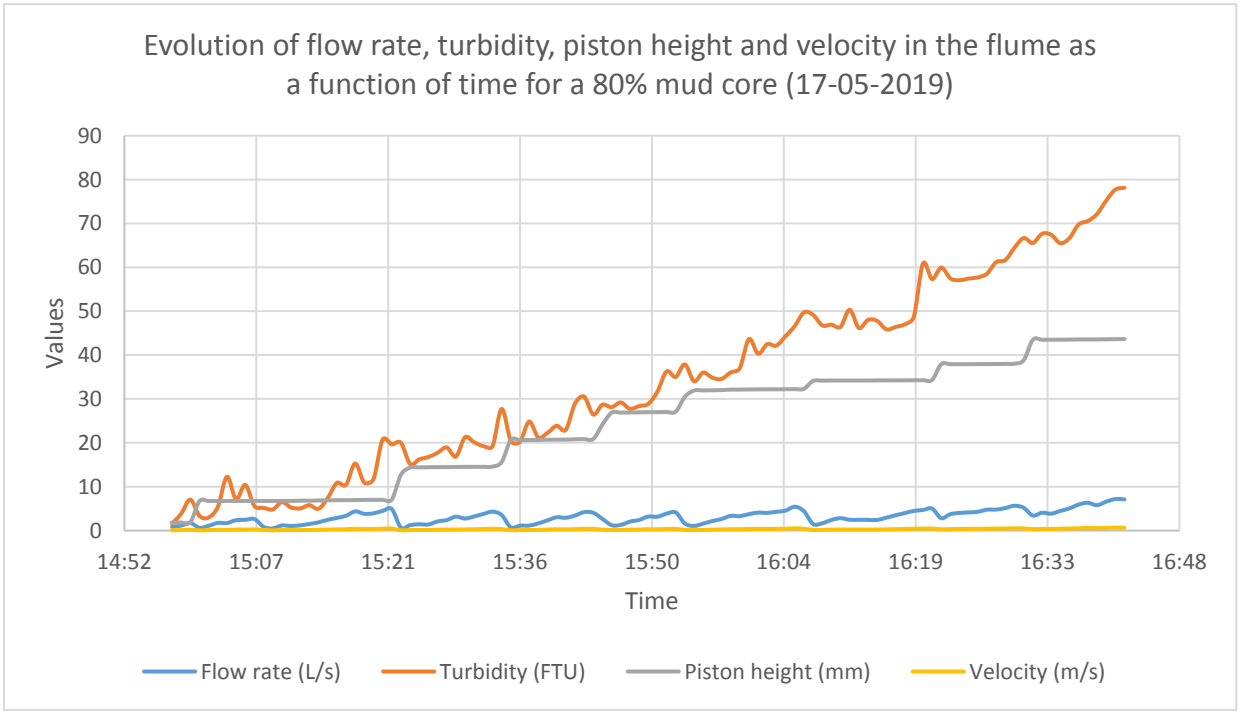


Figure 7: Chart representing evolution of different parameters during a flume experiment

Water speed, flow rate, height of the piston, turbidity and others settings are recorded all along the experiment and are represented by curves as a function of time on a screen connected to the system. The operator can easily record the data connecting a memory stick to the system. He is able to change the start flow, the incrementation and the value of the water speed during the experiment and can also raise or lower the piston manually (figures 9 and 10).

Before running any experiment with cores made of different mud concentrations, it was necessary to compare the impacts of the different flume settings.

- *Position of the pipe bringing water into the flume*

Water inlet into the flume can be low or high depending on the position the pipe is installed. The aim of changing the position of the pipe for a lower position was, among others, to reduce the apparition of secondary flows in the flume. Finally, the pipe was put in the lower connection in order to obtain reduced flow inertia. Moreover, less secondary flows were observed in this lower position. In contrast, the upper connection is preferably recommended for sediment transport study because it allows unrestricted water flow into the tank (Armfield, 2019).

- *Flow settings*

The flume is equipped with a Channel Mode and a Core Mode (figures 9 and 10). With the Channel Mode, the flow rate is constant and there is no piston movement. With the Core Mode, the operator can change different settings and the piston can be switched on. After each erosion (that is to say when the sensor cannot detect the sediment anymore), the pump returns to a resting flow. The **resting flow** corresponds to the maximal flow without erosion and was fixed at 0.3 L/s according to the flume supplier. In the case of cohesive sediment and after a few tests with cohesive sediment cores, it appeared that in general no erosion happens under 0.5 L/s, so the **start flow** was fixed at this value. The operator can choose the value of the **incrementation**, that is to say the value of flow rate in L/s that will be added to the previous value in a given time. He also has to choose the holding time, that is to say the time taken to reach the speed incremented as parameterized just before. It seemed that sediments were more evenly eroded with a incrementation value of 0.2L/s than with a higher value. Still with the aim of eroding evenly the sediment surface, **holding time** was set to 20sec. Indeed, lower values showed a less even erosion of sediment, and consequently a less natural erosion. Moreover, a higher value would make the experiments too long.

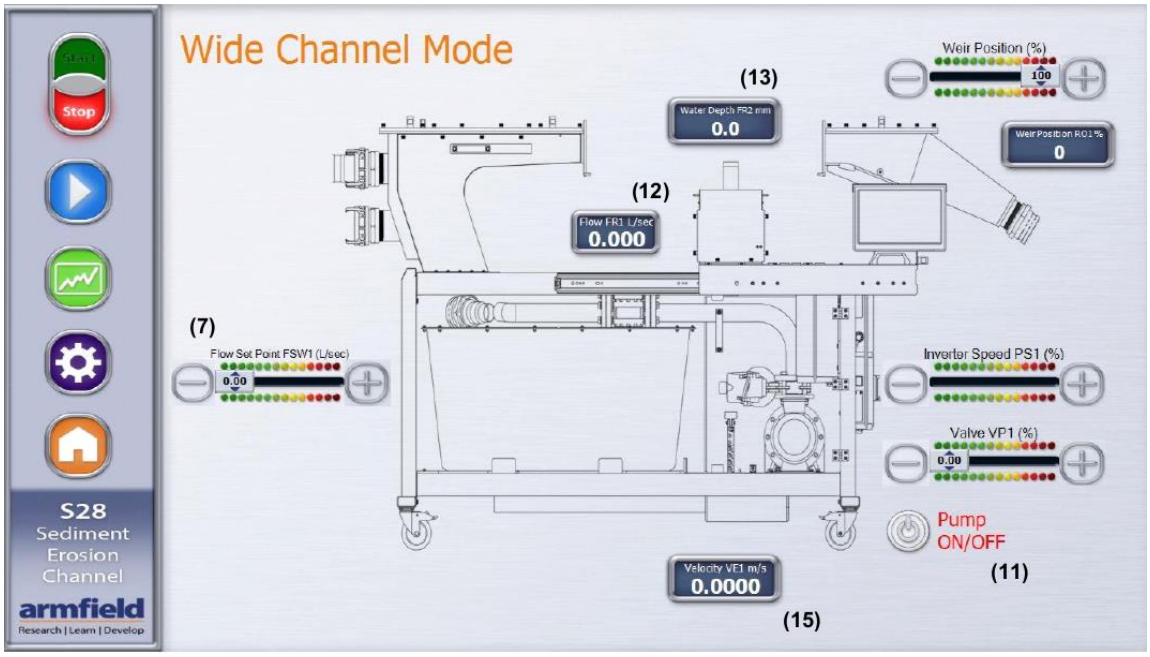


Figure 9: Interactive screen when Channel Mode is on. Source: Armfield, 2019

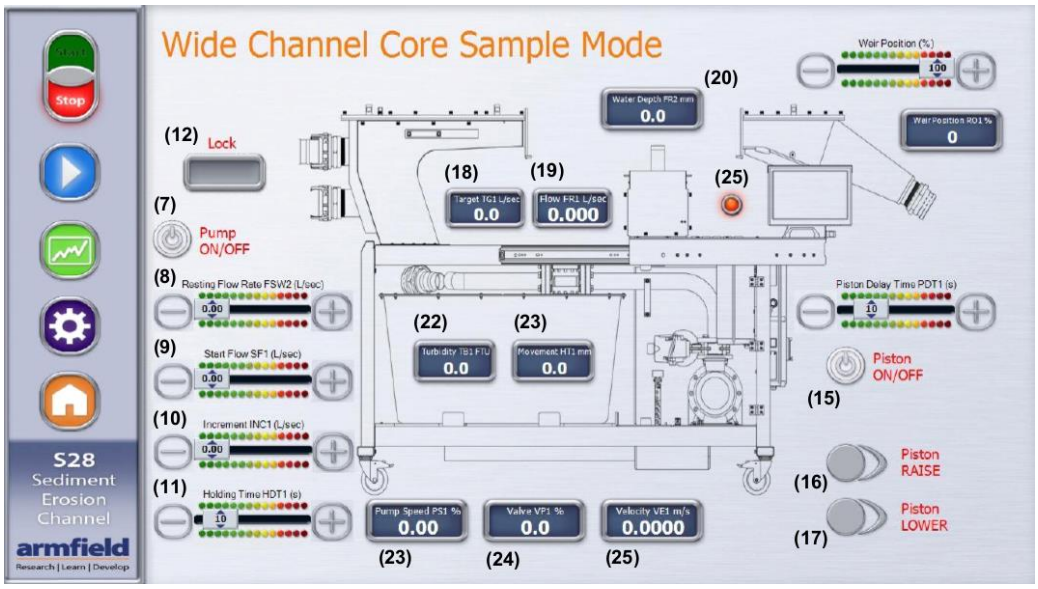


Figure 10: Interactive screen when the Core Mode is on. Source: Armfield, 2019

- *Turbidity threshold*

As an ultrasonic sensor detects the sediment surface in the core, the piston under the core does not rise. When the sensor cannot detect the sediment anymore, the piston raises until the sensor is able to detect the sediment surface. Above a turbidity of approximately 110 FTU in the flume, it appeared that the sensor was not able to detect the sediment anymore. Before that, when turbididty exceed approximately 60 FTU, the visual determination of erosion threshold becomes very difficult (figure 11). The issue is that this value comes very quickly with the erosion of cohesive sediment: these particles are so small that they stay suspended in the water, contrary to the sand that settles and does not affect turbidity that much. It was observed during the tests that turbidity stays constant when water speed decreases: these small particles need much more time to settle, allowing turbidity to decrease. This turbidity issue oblige to empty and clean the flume very regularly. To rectify this, an IVC tank of $1m^3$ will be connected to the flume in order to increase the volume of water and allow to dilute suspended particles. It can also help to let those particles settle and recover clean water on the top of the IVC. It was not connected to the flume for the period of this internship but will be for the next PhD students' experiments.

Figure 11: Turbid water after eroding two cohesive sediment cores

- *The sensor*

The sensor detects the sediment at one point in the middle of the sediment surface. The latter is never totally homogeneous, so the piston can raise whereas there is still sediment to erode. This issue was solved turning the button determining the sensitivity of the sensor with a screwdriver (figure 12). On the interactive screen, a light is turning red if the sensor cannot detect the sediment and green if it can detect it. When this light turns red whereas the sediment surface is not fully eroded, it means that the sensor is not sensitive enough. The operator has to turn the button with the screwdriver to the right until the yellow light is consistent. This yellow light is consistent when the sensor detects the sediment well and is off when it cannot detect the sediment. Opposite, if the light is still green whereas the sediment surface is fully eroded, it means that the sensor is too sensitive. The operator has to gently turn the button to the left until the yellow flashing light is off. The flow rate will go back to the resting flow rate (0.5L/s), and after 5 seconds (as it is the piston delay chosen by the operator), the piston will raise to 5mm more. Immediately, the operator has to turn the button to the right until the yellow light is consistent again: it means that the sensor detects

the sediment surface and that the flow rate can increase again to erode the new 5mm sediment layer.

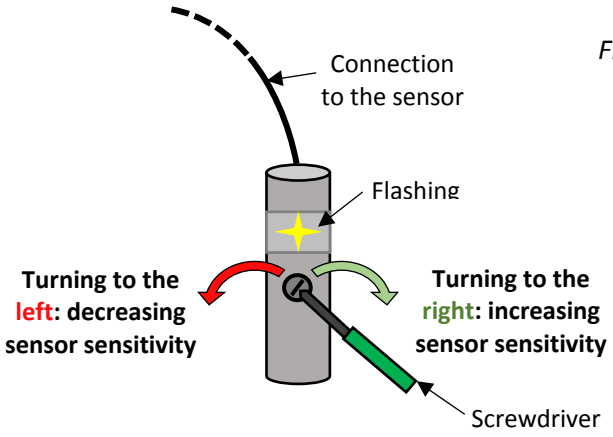


Figure 12 : Sensitivity of the sensor

- *PIV system*

A laser-equipped system will be coupled to the flume shortly. The system is already in the lab and I could see the setup of the system at the beginning of June. This system allows to characterise very precisely the flow in the flume thanks to the analysis of the particles movement in the water. It can provide very precise vector charts and should help to understand the water movement into the flume and consequently its influence on the erosion of the sediment.

2.1.5 *Bulk density, water content and organic content*

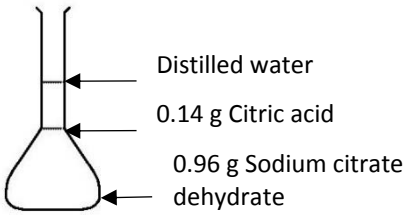
Bulk density, water content and organic content have to be measured for each replicate for three different depths: 1, 2 and 3cm. The main difficulty here was managing to collect sediment for those analysis at different depths of the core tube.

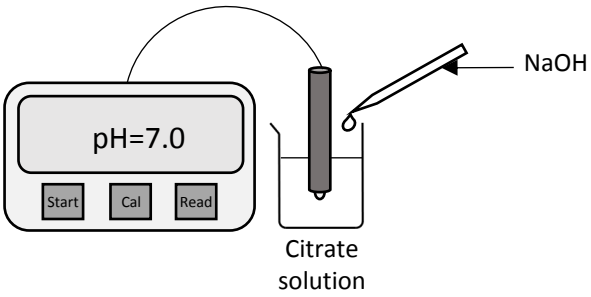
The first approach was to use three cut syringes (normal syringes holes are too small to let sediment being aspirated in the syringe), one for bulk density, one for water and organic content and one for EPS measurement. The three syringes were supposed to be pushed over 1cm in the sediment column, and then the operator had to aspire this first centimetre layer of sediment with the syringes. This method did not work because of air inlet due to the shape of the cut of the syringe. Finally, sediment column was extruded with a core extruder centimetre by centimetre and the layer was cut with a plastic square. Then, a simple oven drying method is generally used to determine water content. None particular issue was detected while testing this method, apart the fact that the operator has to think about weighing the empty cups before filling it with wet sediment. In the same way, loss on ignition was used to determine organic content, putting the sediment in a 450ºC furnace. The issue was more important with bulk density because it was necessary to collect a known volume of sediment. As the syringe aspiration method did not worked, the operator has to put sediment directly into the cut syringe with a spatula.

2.1.6 *EPS extraction and measurement methods*

EPS extraction was probably the most uncertain step of the experiment. At the beginning, the method research started with papers readings. One study (Brookes, Evershed, Goulding, & Hirsch, 2014) was particularly interesting because authors managed to extract and measure EPS from soil biofilms with a relatively simple method using citrate. After a few discussions with laboratory technicians, it appeared that this method could be put in place in the laboratory. However, the total carbohydrate measurement method (Dubois & Gilles, 1956) they used was quite dangerous because of phenol use. Reading papers, it appeared that others authors have tested less harmful methods for the health and the environment, using UV spectrophotometer and no phenol. This method was selected for EPS measurement, assuming that EPS amount equals carbohydrate amount. The method below (figure 13) was applied to cohesive sediment samples:

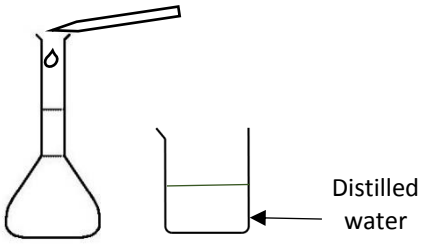
- *First extraction with citrate on wet sediment*

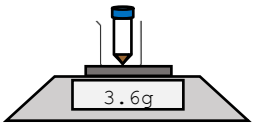




1 Vortex citric acid, sodium citrate and a bit of distilled water in a 200ml calibrated flask

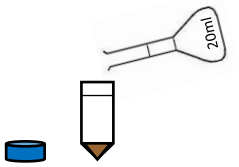
2 Adjust to pH 7

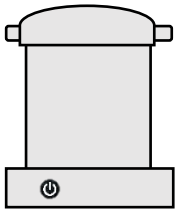




3 Complete to 200ml with distilled water. Vortex

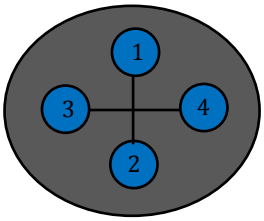
4 Weigh 3.6g of wet sediment in a 50ml centrifuge tube



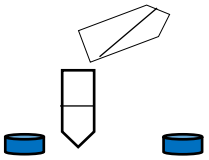


5 Pour 20ml of citrate buffer in each centrifuge tube with sediment sample

6 Put in the autoclave for 30min at 121ºC



Equilibrate 1 and 2 masses and 3 and 4 masses in the centrifuge



7 Centrifuge the tubes at 3200xg for 10min at 4ºC

8 Pour the supernatant in a new 50ml centrifuge tube

Figure 13: EPS extraction protocol

Then, the supernatant was snap frozen with liquid nitrogen (figure 14) and stored at -80ºC waiting for the measurement of carbohydrate content.

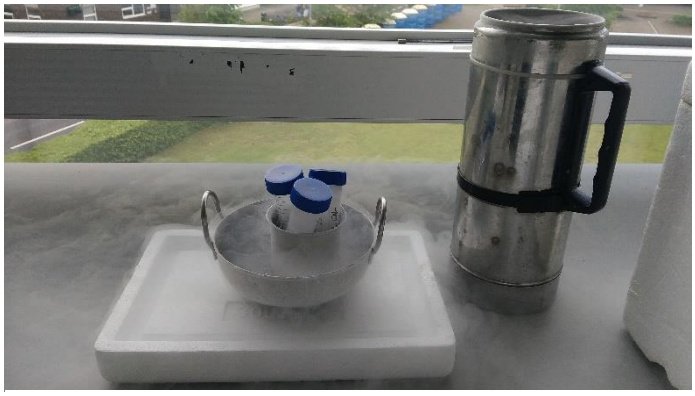


Figure 14: Supernatants snap freezing with liquid nitrogen

Carbohydrate content was measured with an UV spectrophotometer. In order to create a glucose calibration curve, 5 glucose concentrations from 0 to 40µg/ml were prepared according to the table below. Three replicates were done for each concentration, excepted for 0 µg/ml standard, which was the reference. As the minimal mass for the balances in the lab was 10mg, it was necessary to make a dilution (table 2).

Table 2: Dilution method, glucose standards concentrations and corresponding absorbance

Standard name	Mass of powder glucose in 100ml (mother solution) (mg)	Volume of mother solution withdrawn to be diluted (ml)	Final concentration in the intermediate 10ml solution (µg/ml)	Absorbance
0	0	1	0	0.000
10A	9.7	1	9.7	0.002
10B	9.9	1	9.9	0.103
10C	9.7	1	9.7	0.008
20A	19.6	1	19.6	0.124
20B	19.7	1	19.7	0.226
20C	20.2	1	20.2	0.118
30A	29.4	1	29.4	0.291
30B	29.8	1	29.8	0.275
30C	30.4	1	30.4	0.415
40A	40.2	1	40.2	0.400
40B	40.3	1	40.3	0.415
40C	41.7	1	41.7	0.526

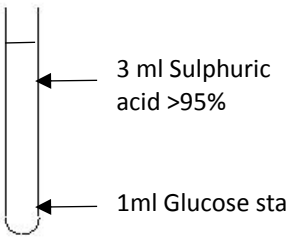


Figure 15: Test tubes vortexed and cooled in ice

After filling test tubes as explained in the figure 15, test tubes were vortexed and cooled in ice. Indeed, sulphuric acid increases quickly the temperature of the solution. Then, tubes were transferred into spectrophotometer cuvettes (figure 18) and their absorbance was measured in the UV spectrophotometer. The calibration curve obtained (figure 16) should be able to give glucose concentration of a sample knowing its absorbance.

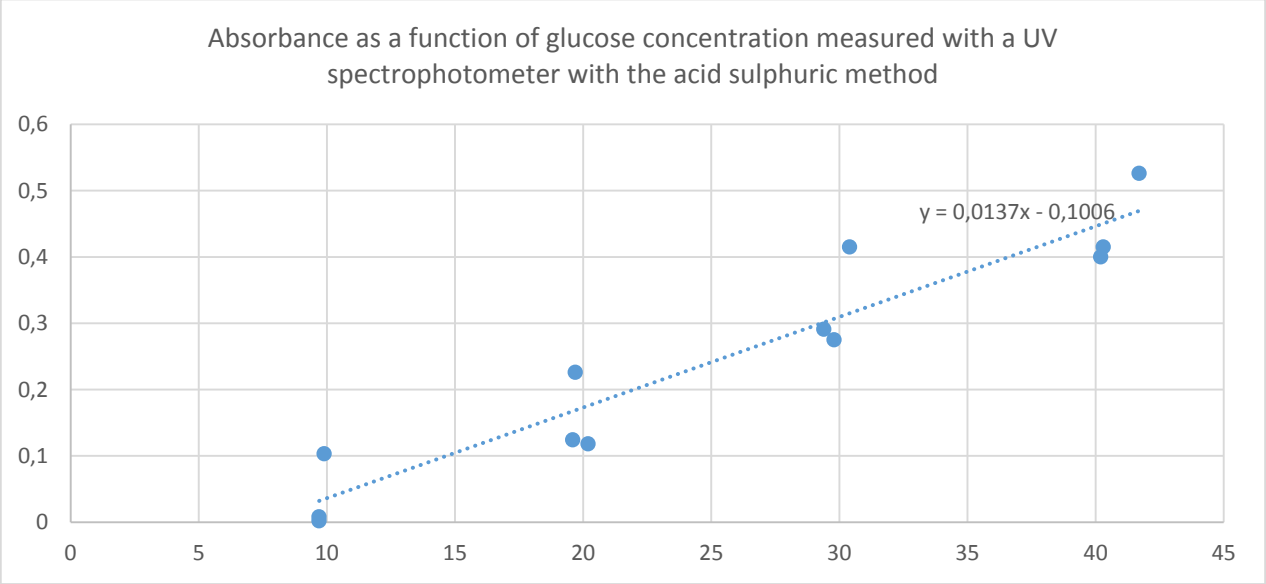


Figure 16: Glucose calibration curve with three replicates per concentration

Supernatants were frozen, so it was necessary to put them in a 38°C water bath (figure 19) before being able to prepare spectrophotometer cuvettes. Once the supernatant is completely liquid, the protocol is the same as the glucose standards preparation. 1ml of supernatant is put in a test tube with 3ml of sulphuric acid, vortexed and cooled in ice for 2min before being transferred into spectrophotometer cuvettes.

At this step of the experiment, it seemed that the EPS extraction did not worked. Indeed, whereas an homogenous slightly pink solution was expected, an heterogeneous solution with brown flocs floating in sulphuric acid was obtained (figure 17).

Those brown flocs seemed to be suspended particles from the sediment sample. A second try was completed with dry sediment, and the result was the same: the supernatant wasn't separated enough from the solid phase. That is why filters syringes were tested to extract the supernatant.

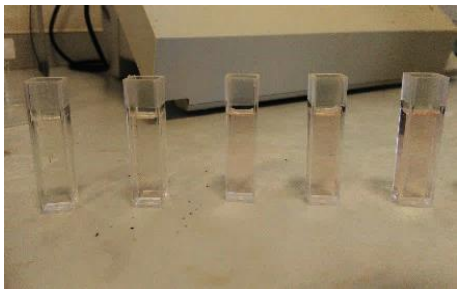


Figure 18: Glucose standards

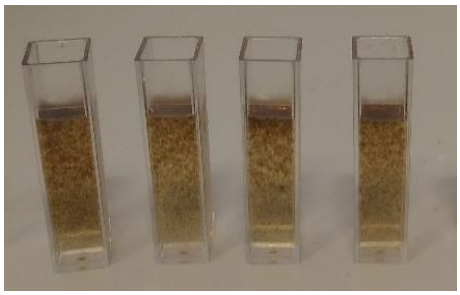


Figure 17: 1ml supernatant + 3ml sulphuric acid mix

Figure 19: Water bath to warm frozen supernatants

2.2 Method adopted for the study of the link between erosion and biological activity

2.2.1 *Sediment collection and characterisation*

Sediment was collected exactly at the same place as the first sediment collection. On this 23rd May. 16kg of wet sediment were collected in four buckets, and then mixed in one big container in the lab. Coarse components were removed manually: sediment was too cohesive to be sieved.

For the particle size analysis, twelve samples of approximately 100g each were run in the Mastersizer, in order to obtain a representative average of the sediment particle size. Mastersizer settings were changed in order to get the exact percentage of the inferior to 63µm particles without having to do a linear interpolation. A volume percentage of each size was obtained, however the mass percentage was more useful in order to calculate the mass of sand that must be added to the mixture. This mass percentage was calculated from the volume percentage using sand, silt and clay bulk densities in table 3.

Water content in the table below was determined with oven drying method, putting the sediment 17h at 105°C.

Table 3: Percentages of mud, sand and water in gross sediment collected on 23rd May

	Mud content (<63µm)	Sand content (>63µm)	Water content	Total
Volume percentage (dry)	83.5%	16.5%		100%
Mass percentage (dry)	84.8%	15.2%		100%
Mass percentage (wet)	50.5%	9.1%	40.4%	100%

In order to be able to compare the results of this experiment done with natural sediment with a similar thesis experiment done with artificial kaolin and sand, the mud contents must be equal in the two experiments. Mud contents, so the mass of particles with a size inferior to 63µm, was 50%, 25% and 10% (for the dry part of the mixture). For convenience let's call C_1 the mixture with 50% of mud, C_2 the mixture with 25% of mud and C_3 the mixture with 10% of mud. Approximately 7kg of each mixture was needed to prepare the core tubes of all the experiments, so 72 core tubes. Considering that the mud content of dry gross sediments is superior to 80%, it was necessary to add sand to the three different mixtures to get 50%, 25% and 10% of mud. To calculate the mass of gross sediment and the mass of sand it was necessary to add to each mixture, let's call **x** the mass of **mud**, **y** the total mass of **sand**, **z** the mass of **water**, **w** the mass of **gross sediment** and **s** the mass of **pure sand** to add. In the equations below, 0.505 and 0.404 are respectively the frequency of mud and the frequency of water in the gross sediment. "7" corresponds to the 7kg needed for the final weight of sand, mud and water. The first equation in each equation system represents the relation between the amount of sand and the amount of mud, different for each mixture. Solving those equations systems allows knowing the mass of gross sediment (w) and the mass of pure sand (s) needed for each mixture, knowing that there is already 9.1% of sand in the gross sediment.

$$For\ C_1 : \begin{cases} y = x \\ x = 0.505w \\ z = 0.404w \\ x + y + z = 7 \end{cases} \Rightarrow \begin{cases} x_{C1} = 2.5kg \\ y_{C1} = 2.5kg \\ z_{C1} = 2kg \\ w_{C1} = 4.95kg \end{cases} \Rightarrow s_{C1} = 2.05kg$$

$$For\ C_2: \begin{cases} y = 3x \\ x = 0.505w \\ z = 0.404w \\ x + y + z = 7 \end{cases} \Rightarrow \begin{cases} x_{C2} = 1.45kg \\ y_{C2} = 4.38kg \\ z_{C2} = 1.17kg \\ w_{C2} = 2.89kg \end{cases} \Rightarrow s_{C2} = 4.11kg$$

$$For\ C_3: \begin{cases} y = 9x \\ x = 0.505w \\ z = 0.404w \\ x + y + z = 7 \end{cases} \Rightarrow \begin{cases} x_{C3} = 0.65kg \\ y_{C3} = 5.83kg \\ z_{C3} = 0.52kg \\ w_{C3} = 1.28kg \end{cases} \Rightarrow s_{C3} = 5.72kg$$

The exact weights of gross sediment and mud were measured with a balance before being mixed together in buckets equipped with lids with the help of a shovel. The three mixtures C_1, C_2 and C_3 were stored in the fridge at 4°C during all the experiment time.

2.2.2 *Filling core tubes*

According to the z values (mass of water in the final mixture) in the equations results, the amount of water is much higher in C_1 than in C_2 and C_3 because of the lower amount of pure sand added. However, the water content affects the biological activity as well as the creation of air bubbles in the core tube while filling it. That is why the amount of water was balanced adding water in C_2 and C_3.

Like shown in figure 21, core tubes intended to be eroded in the flume were blocked with rubber stoppers at the far end of the tube in order to be able to attach the piston to it with screw and nut. Core tubes intended to be analysed in the laboratory were blocked with rubber stoppers at approximately 20cm of the top of the core. Indeed, those core tubes was intended to be extruded and extrusion was easier when the stoppers were already high in the tube.

Figure 20: Filling core tube with a pipping bag

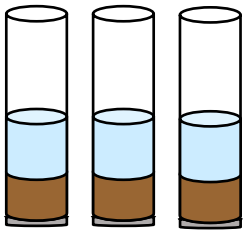
According to table 1, the "plastic bag method" was the most advantageous and was consequently chosen to fill the cores. One inferior corner of a square plastic bag was pierced with a one-centimetre diameter hole. The hole must not be too small: water tends to exit the pipping bag before sediment otherwise, what would affect homogeneity. The sediment was remixed and put into the plastic bag with a shovel. Sediment was pressed toward the hole, removing air from it (figure 20). This piping bag was set above the core in order to fill it with approximately 6 centimetres of sediment. The experiment only needs 3 centimetres, but the height of sediment tends to decrease with consolidation overnight.

For one-week incubation experiment, core tubes were left one week in a lab, next to a window. For one-week incubation in darkness, core tubes was put in the same place as for the others incubations but with a bin bag around the tube. An air entry was left, with the opening downward in order to avoid light penetration. For one-week with antibiotics incubation, core tubes should be left next to the window like the simple one-week experiment, with antibiotics diluted in the 170ml water.

The following diagram summarizes all the measurements for one concentration (50, 25 or 10% mud) of one experiment (T_0, one-week, one week in the dark or one week with antibiotics). Details of each measurement are explained later.

For one mud concentration

Flume work

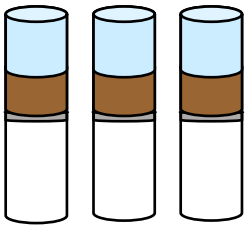


Waiting:

- Overnight for control experiment (T_0)
- 1 week 12h light/12h darkness for one week incubation experiment (1W)
- 1 week in darkness for the experiment in the dark (DARK)
- 1 week with antibiotics 12h light/12h darkness for the antibiotics experiment (AB)

Eroding the cores into the flume

Laboratory work



Waiting:

- Overnight for control experiment (T_0)
- 1 week 12h light/12h darkness for one week incubation experiment (1W)
- 1 week in darkness for the experiment in the dark (DARK)
- 1 week with antibiotics 12h light/12h darkness for the antibiotics experiment (AB)

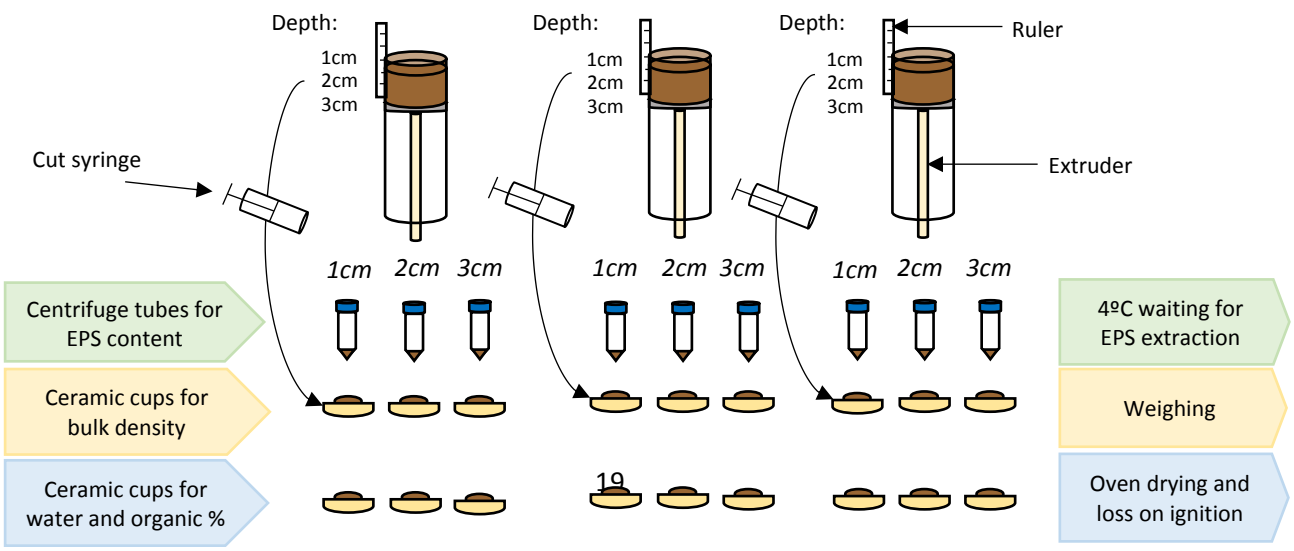


Figure 21: Synthesis of the experiments to complete for one mud concentration

2.2.3 *Flume use and settings*

- *Starting the flume*

The first thing to do when working with the flume is checking that the water in the tank is clean enough to be able to detect visually the erosion threshold. Otherwise, it is necessary to drain the tank and to fill it with clean water. It is also necessary to check that the date and the time are correct in order to be able to recognize files corresponding to the correct run while recovering data from the flume at the end of the day.

Firstly, the core previously filled with sediment (C_1, C_2 or C_3) was screwed into the flume. The grey stopper at the bottom of the core tube was attached to another bigger stopper allowing to fix the piston on the core tube with a screw and a nut. Once the piston fixed to the core tube, the piston was raised using the interactive screen in order to align the water level with the opening on the bottom of the flume

Using the Wide Channel Mode, the Flow Start Point was firstly set to 0.3L/s to gently fill a few centimetres of the channel and avoid particle resuspension in the core. Then, the flow rate can be raised to 1.2L/s to fill the rest of the channel. During this step, the pump must be turned on and the valve located at the top of the flume opened in order to avoid a too high air pressure in the flume: it could block the filling of the flume. The valve must be closed as soon as the flume is filled up, otherwise water can escape from it.

Once the flume is filled up, the operator can use the Core Mode to enter the following settings in table 4:

Table 4: Synthesis of the values to enter in the flume before starting to run it

Settings	Value
Resting flow rate	0.3 L/s
Start flow	0.5 L/s
Increment	0.2 L/s
Holding time	20 sec
Piston delay	5 sec

The operator can lock those settings and turn the pump on. Then, he has to raise manually the piston until the sediment surface is aligned with the opening on the bottom of the flume and set the meter showing the height of the piston to zero. The operator has to raise the sensor until it does not detect the sediment surface anymore. After turning the piston on, the piston will raise automatically until the sediment surface is close enough to the sensor to be detected. This raising corresponds approximately to 5mm. The meter shows now 5mm for the piston height. In total, 30mm will be raised and eroded in the flume in order to study the three first centimetres of the sediment surface.

- *Recording data*

The flume software records automatically the evolution of flow rate, velocity, turbidity and piston height (figure). The detection of the erosion threshold is visual and corresponds to the flow rate when the departure of several particles with a size superior or equal to 1mm is observed. The departure of the first tiny particles and bigger flocs (with a size superior or equal to 1cm) were also recorded visually (appendix 2). In order to help the operator to detect more precisely erosion threshold in spite of turbidity, a lamp enlightening the sediment surface was attached to the top of the flume. For each segment of 5mm height, the operator records visually the threshold for small particles, for 1mm particles and for bigger flocs. Once he knows the value for bigger flocs, he can increase the increment value to 0.4 L/s until the 5mm are fully eroded. When those 5mm are eroded, the operator has to turn the button for the sensitivity of the sensor to the left (decreasing the sensibility). The light turns red: it means that the sensor cannot detect the sediment surface, and the

piston automatically rises. If it rises more or less than 5mm, it is possible to adjust manually the height of the piston, before pushing again the button “Piston on”. Otherwise, the piston will not rise automatically next time sediments are eroded. The increment value is changed again for 0.2 L/s, and the operator can start again to record the departure of particles.

- *Ending and cleaning of the flume*

When the 30mm are eroded and the values recorded, the operator can turn the pump off and open the two valves on the top of the flume in order to allow draining. The piston is lowered in order to remove the core from the piston. The core tube is unscrewed, and a quick clean can be done opening the lids of the flume and vacuuming the sediment.

Sometimes the flume was entirely cleaned flushing clean water through the flume, the pipes and the tank at a high flow rate (up to 10L/s). Weir position was changed with the interactive screen to clean it. After that, lids and pipes were left opened overnight or during the week-end in order to let the flume aerate.

2.2.4 *Laboratory work: separation of sediment at different depths*

As the flume provides erosion threshold values for different depths, it was interesting to measure characteristics like bulk density, water content, organic content and EPS for three different depths also.

After filling the core tubes with sediment and water as explained above and letting incubate for one week for some experiments, water was gently removed from the core tube and the sediment was raised in the tube with the help of a core extruder. A ruler was attached to the tube with adhesive and helped to indicate the thickness of the sediment layer that was pushed out of the core with the extruder. Once a one-centimetre layer of sediment was pushed out of the core tube, a plastic square was used to “cut” the sediment column in order to recover the first centimetre of sediment on this plastic square. This amount of sediment was then separated into two ceramic cups and a 50 ml centrifuge tube for further analysis as explained below. Then, the plastic square was rinsed with tap water and the sediment column was pushed up one centimetre more to recover the second and the third centimetres following the same method.

2.2.5 *Bulk density, water content and organic content*

As for the flume experiment, in order to estimate the error due to handling, three replicates of the measure of the bulk density, water content and organic content were done for each depth of each concentration of each experiment (control sample, after one week, after one week in the dark and after one week with antibiotics).

Wet **bulk density** was determined by weighing a known volume of sediment. An empty laboratory ceramic cup was weighed. Then, a known volume of sediment was taken from the amount of sediment on the plastic square using a cut syringe. This volume of sediment was put into the ceramic cup and weighed. Bulk density value was obtained using the following formula:

$$\rho = \frac{m_{cup+sediment} - m_{empty\ cup}}{V_{sediment}}$$

Water content was determined by measuring the weight of sediment (figure 21a) before and after drying in the oven. An empty laboratory ceramic cup was weighed. Some of the sediment was taken from the amount of sediment on the plastic square, was put into the ceramic cup, weighed and put into the oven at 105°C. After at least 17 hours in the oven, the cup was weighed again. Water content value was obtained using the following formula:

$$WC = \frac{m_{cup+wet\ sediment} - m_{cup+dry\ sediment}}{m_{cup+wet\ sediment} - m_{empty\ cup}}$$

The cup with dry sediment was then put into the furnace at 450°C (figure21b) for 4 hours and then cooled in a desiccator (figure 21c) in order to measure **organic content**, obtained using the following formula:

$$OC = \frac{m_{cup+dry\ sediment} - m_{cup+sediment\ after\ 450°C}}{m_{cup+dry\ sediment} - m_{empty\ cup}}$$

Figure 22a: Weighing of samples after ignition. 21b: Samples in the furnace at 450ºC. 21c: Samples to cool in desiccators.

2.2.6 *EPS extraction and measurement method*

Some of the sediment was taken from the amount of sediment on the plastic square, put in a 50ml centrifuge tube and put in a 4°C fridge for further analysis. The adopted method was the one explained in the first sub chapter: EPS was extracted from wet sediment and the supernatant was filtered with 0.22µm syringe filters before measurement with sulphuric acid in order to remove suspended organic matter.

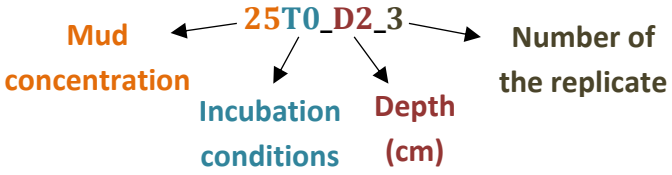
3. Results

On the day of the report deadline, only control experiment measurements and erosion threshold for the one-week incubation samples were recorded. Depending on the core tubes delivery that will allow to incubate several samples at the same time, the continuation of the results will be presented at the oral presentation on Monday 15th July.

Table 5: Results for control experiment and one-week incubation experiments (erosion threshold values only)

Name of the sample	Sand content (%)	Mud content (%)	Incubation time (days)	Depth (cm)	Bulk density (kg/m³)	Water content (%)	Organic content (%)	Erosion threshold (L/s)	EPS content (µg/ml)
50T0_D1_1	50	50	1	1	1659.20	29.05	3.74	2.6	
50T0_D1_2	50	50	1	1	1859.91	31.34	4.05	4.8	
50T0_D1_3	50	50	1	1	1729.70	30.88	3.91	3.7	
50T0_D2_1	50	50	1	2	1700.08	29.04	3.98	3.4	
50T0_D2_2	50	50	1	2	1756.86	28.78	3.83	5.2	
50T0_D2_3	50	50	1	2	2020.60	29.65	4.13	3.5	
50T0_D3_1	50	50	1	3	1848.53	28.00	3.50	4.4	
50T0_D3_2	50	50	1	3	1719.65	29.48	3.77	5.9	
50T0_D3_3	50	50	1	3	1894.94	28.93	3.92		
25T0_D1_1	75	25	1	1	1882.94	22.56	1.35	3.3	29.31
25T0_D1_2	75	25	1	1	1905.84	23.06	1.31	3.0	29.31
25T0_D1_3	75	25	1	1	2008.21	23.46	1.36	2.7	8.44
25T0_D2_1	75	25	1	2	1955.46	21.99	1.28	3.3	23.33
25T0_D2_2	75	25	1	2	1993.34	22.06	1.28	3.5	29.31
25T0_D2_3	75	25	1	2	2017.10	22.33	1.24	3.4	27.34
25T0_D3_1	75	25	1	3	1997.60	19.75	1.13	4.1	8.36
25T0_D3_2	75	25	1	3	1985.49	21.50	1.41	3.4	18.36
25T0_D3_3	75	25	1	3	2027.16	22.28	1.45	3.1	29.31
10T0_D1_1	90	10	1	1	1927.10	20.38	0.86	1.1	160.12
10T0_D1_2	90	10	1	1	1842.39	20.26	0.80	1.7	168.66
10T0_D1_3	90	10	1	1	1927.58	20.92	0.89	1.6	136.18
10T0_D2_1	90	10	1	2	1920.70	19.38	0.94		141.65
10T0_D2_2	90	10	1	2	1899.60	19.30	0.80	2.4	140.63
10T0_D2_3	90	10	1	2	1943.69	19.10	0.76	1.9	133.26
10T0_D3_1	90	10	1	3	1845.41	18.79	1.03		212.96
10T0_D3_2	90	10	1	3	2680.00	19.79	0.86	1.9	140.63
10T0_D3_3	90	10	1	3	2010.94	19.03	0.82	2.9	
501W_D1_1	50	50	7	1				2.5	
501W_D1_2	50	50	7	1				3.3	
501W_D1_3	50	50	7	1				3.3	
501W_D2_1	50	50	7	2				3.2	
501W_D2_2	50	50	7	2				4.2	
501W_D2_3	50	50	7	2				5.4	
501W_D3_1	50	50	7	3				3.5	
501W_D3_2	50	50	7	3				5.1	
501W_D3_3	50	50	7	3				4.5	

The name of the samples gives the following indications:



Blank cells in erosion thresholds column correspond to samples where an air entry destroyed the sediment column or when turbidity was too high so see the threshold.

In order to interpret those results, the three replicates were averaged for one depth of one mud concentration. As we would expect, organic contents decrease with mud concentration but does not change with depth. Water content decreases with depth and mud concentration. Erosion threshold increases with depth and mud concentration (figure 23).

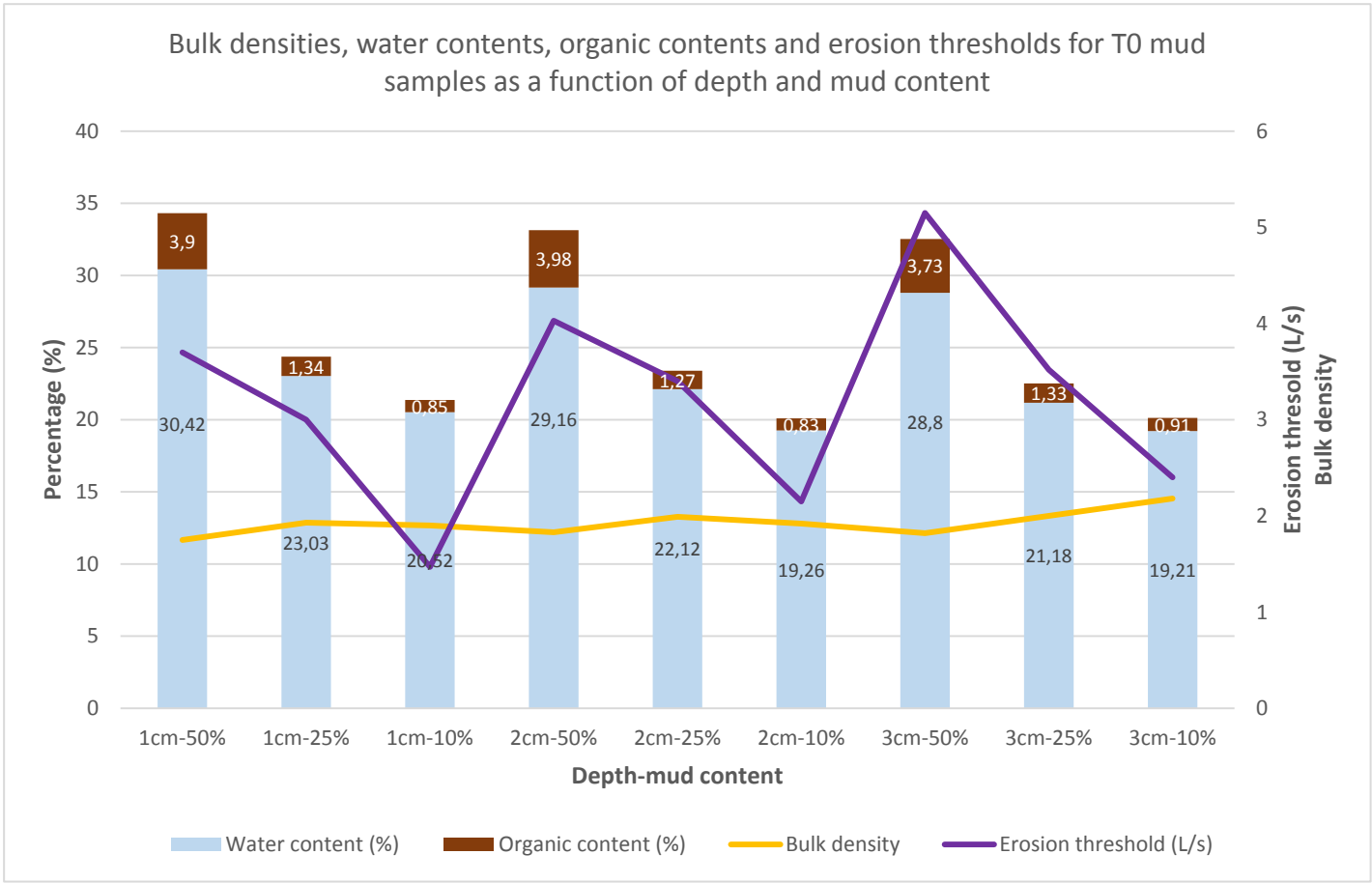


Figure 23: Synthesis of the results with control experiment T_0

Bulk density increases slightly with depth (figure 24) and seems to be much lower for C_1. At 3cm depth, bulk density seems to increase clearly with the sand content. Looking more precisely at the results table, it appears that two replicates over three of 10T0_D3 sample present a much higher value than for the others depths.

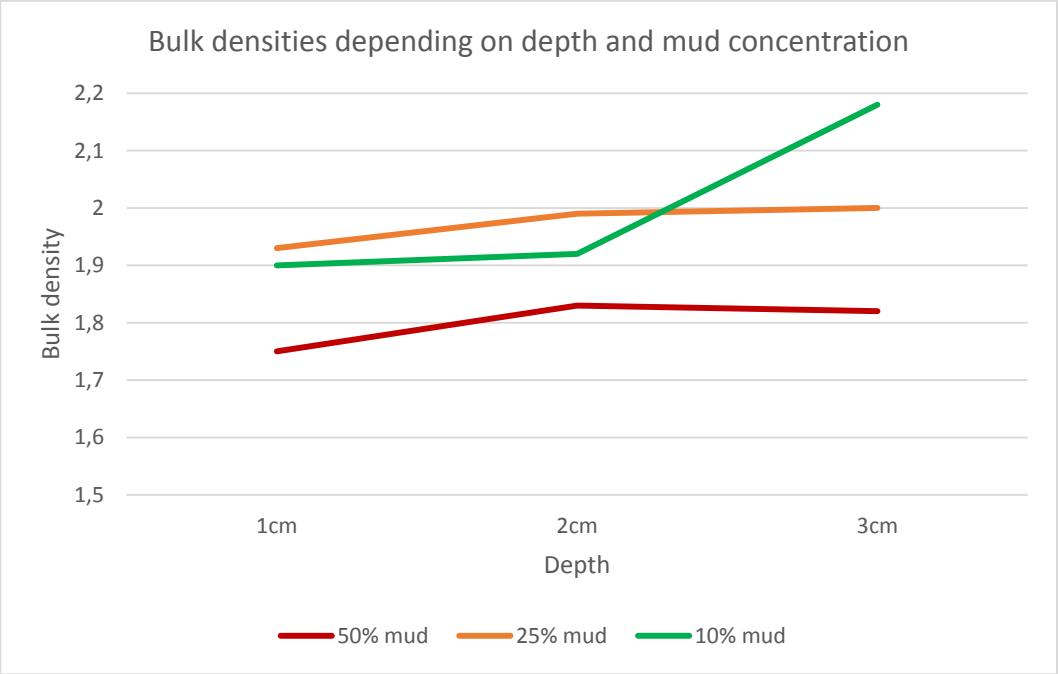


Figure 24: Evolution of bulk density as a function of depth and depending on mud concentrations

Very small difference is observed between control experiment and one-week incubation experiment (figure 25).

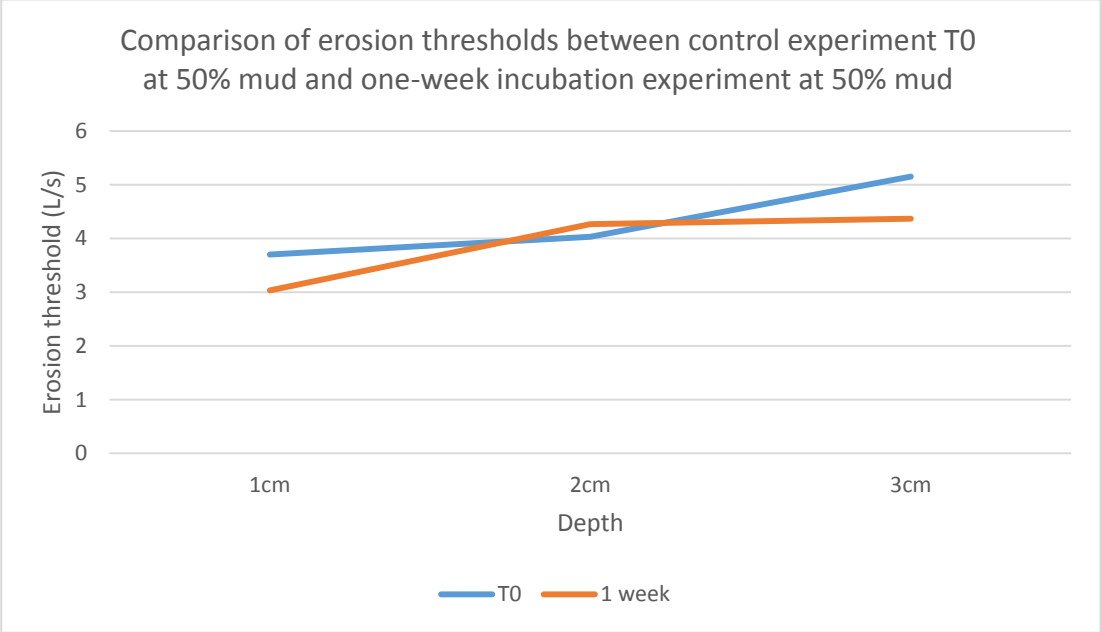


Figure 25: Evolution of erosion threshold as a function of depth depending on the incubation time

Concerning EPS results, only available for C_2 and C_3 for the moment for control experiment, absorbance values for the 10% mud samples were much higher than for the 25% sample (figure 26). Moreover, the variability is quite high down the core tubes but this variability is not the same for each replicate.

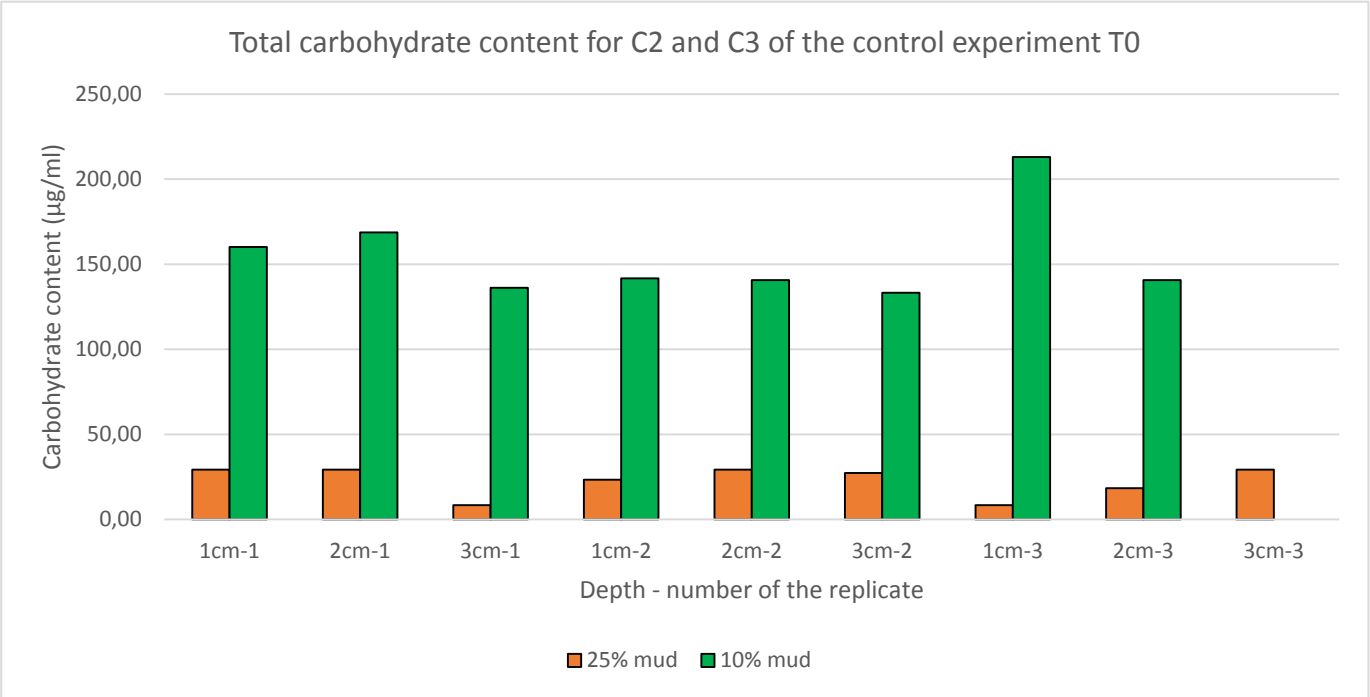


Figure 26: EPS values for C_2 and C_3

4. Discussion

The first part of the experiment with the control experiment aims partly to check if the adopted method is globally suitable comparing the expected results with those obtained. The sand that was added in the gross sediment was dry and pure (supposed without organic molecules), so we would expect organic content to decrease with mud concentration. That is what is clearly observed in the results. Loss on ignition should consequently be a suitable method for determination of organic content in cohesive sediment. Same, erosion threshold seems to increase with depth and mud concentration, which was expected and demonstrate that the flume is a quite performing device to measure erosion.

As explained in the method, water content was supposed to be the same in all the mud concentrations when core tubes were filled up. However, water content increases clearly with mud concentration. This could be explained by the ability of clay to absorb water because of its electronegativity. However, a higher water content seems to be related to a lower bulk density and a lower bulk density is related to a lower erosion threshold. Yet, higher water content related to higher mud concentration is also related to a stronger electrostatic force between particles, which decreases distance between particles, increases bulk density and consequently increases erosion threshold. Regarding the results, effect of water content seems to be less important than electrostatic forces in affecting bulk density and by extension erosion threshold.

Regardless of the mud concentration, depth seems to have a high impact over erosion of cohesive sediment. The weight of the superior layers increases compaction phenomenon, decreasing the amount of water in the sediment and by extension increasing bulk density and erosion threshold.

Nevertheless, the erosion measurement method as well as bulk density, water content, organic content and EPS content method present limits. First, filling the core with the piping bag is not a perfect solution: even if the air is removed from the sediment in the bag, other air bubbles are formed when sediment fall into the core tube. Bubbles that remain in the sediment core can then affect erosion. Nearly each core tube that was run into the flume presented small bubbles that were escaping from one side of the core tube during the experiment, weakening a small part of the sediment column. However, when a side of the column was affected by bubbles, erosion threshold was determined looking at the other side of the column. Moreover, pushing up the core can affect the stability of the sediment: we could see natural burrows disappearing from the sediment column when we were raising the piston because they were mashed. Stones, leaves and wood can also affect the stability of sediment, forming a protective layer or bringing sediment to erosion. Furthermore, the core sediment surface is not perfectly flushed when the piston raises. For that, the sediment surface is often uneven, that is probably the reason why it can be high variability in erosion thresholds values.

Thus, in addition to make detection of erosion threshold difficult, suspended particles recirculating in the flume can affect the water erosion capacity. Despite the choice of the lowest connection for the water inlet pipe, the flow was not fully laminar and we could see secondary flows forming at the beginning of the channel.

Concerning bulk density measurement, compaction in the syringe affects air and water content in the sediment, and consequently bulk density. That is why bulk density is still the same no matter the depth and the mud concentration. Nevertheless the comparison is still possible because the same method was applied to all the samples.

Few values were measured for one-week incubation experiment at this day. However, there is nearly no difference between erosion threshold values for control experiment and one-week incubation.

One week is maybe not enough to observe significant effects on erosion, from consolidation or biological development.

Considering EPS results, values seems to be unusual. Indeed, EPS content should be lower in 10% mud because there is no EPS in pure industrial sand added to the gross sediment. The method adopted was used by Redmile-Gordon on a sieved soil to obtain particles inferior to 2mm. The particle size distribution of the soil is not known, but if the method was made for sandy soil and not for cohesive it could explain why the method seems to extract more EPS on 90% sand sediment than on 75% sand sediment. But the absorbance values could also correspond to additional organic matter not filtered by 0.22µm syringe filters and not to glucose molecules revealed by sulphuric acid. Even there, absorbance values were unusually much higher for C_3 than for C_2 whereas the method and the filter were the exactly the same.

In conclusion, the method is not perfect and could be improved with further tests and material, but it still gives a global idea and allows to compare different samples as soon as the method is repeatable and rigorously the same between the samples. Moreover, it is not possible to answer to the first part of the problematic for the moment as long as values for the incubation one week, in the dark and with antibiotics are not known yet. Hopefully, all those experiment will be run for the next two weeks (appendix 3) and results will be presented at the oral presentation on Monday 15th July. Finally, statistical analysis would be necessary in order to interpret properly the results in the end.

Conclusion

The topic of this internship was inspiring and should be studied in more details over a longer period. Indeed, I have learned a lot of methods and ways of using specific material. However I did not have the time to study the topic in depth. For example, taking into account flow characterisation with the PIV system should be really interesting in the study of the erosion of cohesive sediments. Indeed, the channel walls and the way water is flushed into the flume can create perturbations on the flow and it should be useful to know those effects in order to interpret erosion threshold results. An experiment with Chironomids burrows would have been very interesting too, but for that we need to know if the piston raise during flume experiment does affect burrows or not.

First, this internship taught me how to use in autonomy various scientific devices like the Mastersizer, the flume, the autoclave or the centrifuge. I was also initiated to snap freezing with liquid nitrogen. Furthermore, this internship allowed me to learn a lot about lab work planning and material preparation. None method is certain until it has not be tested in real conditions and it is necessary to allow time in the experiment planning for when an issue appears. It was also a good practical approach of erosion, well completing theoretical lessons in school.

I also got an overview of the British working approach, between flexibility and rigour. This management method is really appreciable because it allows to get autonomous and independent in a project, and by extension to get involved and motivated in it. It was very pleasant to improve my English level in those conditions.

Concerning the rest of the experiments, running them with antibiotics is not certain because of the antibiotics delivery time. Moreover, incubations last seven days and it is not possible to run more than six cores in the flume per day, considering the flume lab opening times and the fact that one core takes one hour to be eroded in the flume. Looking at the results, the EPS extraction method needs to be reviewed for the last two weeks. If the rest of the experiments are going well, results could be used as a comparison point for Cameron's thesis in order to contrast results with natural sediment and artificial sediment made with kaolin sand and Xanthum gum as a biological link.

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Appendix 1

COSHH-1418-0619

Workflow Stage: Authorised **Workflow Status:** Current **Person Responsible:** Solène Jahan **Due Date:** Sunday, June 20, 2021

Complete COSHH > Review (Unclaimed) > Review (Claimed) > Authorisation > RAMP > **Authorised** > Archived

COSHH Information

Hint: Once the fields in this section have been completed, click Save above to progress.

Hint: Any comments made during the review / authorisation section can be reviewed by opening up the Workflow Tracking section further down this page.

Hint: Where a data entry box has two diagonal lines in the lower right hand corner, this indicates that it can be expanded by clicking and dragging.

Reference No.	COSHH-1418-0619
COSHH Owner	Solène Jahan
School/Service	Water
COSHH Assessment Type	Specific COSHH Assessment
Date of Assessment	20/06/2019 3:27:03 PM
Task/Process/Activity	Diluting antibiotics (Kanamycin and Neomycin) in water and pour it on sediments.
Types of individuals involved/affected	Staff and students

Specific COSHH Assessment

Details of Process/Activity

Frequency of Task/Process	Monthly
Duration of Task/Process	1.00 hr
Does this process pose any significant hazards to the following persons?	☑ Pregnant Workers ☐ Young Workers (<18 years) ☐ Disabled Workers ☐ Individuals susceptible to certain illnesses (e.g. Dermatitis, Asthma, etc.)
Operating Conditions	Routine

A. Substance Information

Attention: Include all hazardous substances, by-products, waste materials, and cleaning agents

Substance or ...	Physica...	Stock Q...	Quantity Dis...	SDS (if available)	Exposur...	...	Ref. ...	Hazard Classif...	Hazard Statements & R ...
Kanamycin sulfate	• Solid	1 g	0.23 g	SDS Kanamycin.pdf (42.33 KB)				• Serious Health Hazard	• H360
Neomycin trisulfate	• Solid	25 g	0.23 g	SDS Neomycin.pdf (37.35 KB)				• Serious Health Hazard	• H317 • H334

Order	Operation/Activity	Substance (s) Present	Approximate amount used at this step	Exposure Route	Frequency	Duration (min)	Controls used for this step	Severity	Likelihood
1	Weighing 12.75 mg of Kanamycin and 12.75 mg of Neomycin	• Kanamycin sulfate • Neomycin trisulfate	25.5 mg	• Eye Contact • Ingestion • Inhalation • Skin Contact	Monthly	10.00	Fume cupboard. Appropriate PPE (nitrile gloves, laboratory coat, safety glasses).	(3) Medium - An injury that requires first aid treatment and subsequent treatment by health care professional	(1) Very Unlikely
2	Dilute Kanamycin and Neomycin in 170 ml of tap water.	• Kanamycin sulfate • Neomycin trisulfate	25.5 mg	• Eye Contact • Ingestion • Inhalation • Skin Contact	Monthly	5.00	Fume cupboard. Appropriate PPE (nitrile gloves, laboratory coat, safety glasses).	(3) Medium - An injury that requires first aid treatment and subsequent treatment by health care professional	(1) Very Unlikely
3	Pouring water with antibiotics on the top of sediments in a core tube.	• Kanamycin sulfate • Neomycin trisulfate	25.5 mg	• Eye Contact • Ingestion • Inhalation • Skin Contact	Monthly	10.00	Fume cupboard. Appropriate PPE (nitrile gloves, laboratory coat, safety glasses).	(3) Medium - An injury that requires first aid treatment and subsequent treatment by health care professional	(1) Very Unlikely
4	Let incubate for 1 week (approximately 12h light/12h darkness) for further experiments.	• Kanamycin sulfate • Neomycin trisulfate	25.5 g diluted * the number of cores	• Eye Contact • Ingestion • Inhalation • Skin Contact	Monthly	10,080.00	Put the samples to incubate far from lab users crossing. Warning sign for other lab users.	(3) Medium - An injury that requires first aid treatment and subsequent treatment by health care professional	(1) Very Unlikely

Appendix 2

Depth beginning (mm)	Depth ending (mm)	Midpoint	Flow rate for erosion of tiny particles (<1mm) (L/s)	**[50T0_1] Flow rate for erosion threshold (particles 1mm) (L/s)**	Flow rate for erosion of bigger particles (few mm) (L/s)	Observations
0	5	2.50	1.7	**1.9**	2.9	Uneven surface
5	9.2	7.10	2.7	**3.3**	3.7	Less evenly eroded than the surface
9.2	14.8	12.00	3.5	**3.5**	3.7	
14.8	18	16.40	3.1	**3.3**	4.7	Stones, wood, leaves, bubbles
18	24	21.00	3.9	**4.1**	5.7	
24	30	27.00	4.3	**4.7**	5.5	
Depth beginning (mm)	Depth ending (mm)	Midpoint	Flow rate for erosion of tiny particles (<1mm) (L/s)	**[50T0_2] Flow rate for erosion threshold (particles 1mm) (L/s)**	Flow rate for erosion of bigger particles (few mm) (L/s)	Observations
0	5	2.50	2.4	**3.9**	4.6	
5	9.5	7.25	3.7	**5.7**	6.3	
9.5	15.2	12.35	3.9	**5.1**	5.7	Bubbles. Turbidity => more difficult to see erosion
15.2	20.3	17.75	4.3	**5.3**	6.3	Leaves, stones
20.3	26.4	23.35	4.5	**5.9**	6.7	
Depth beginning (mm)	Depth ending (mm)	Midpoint	Flow rate for erosion of tiny particles (<1mm) (L/s)	**[50T0_3] Flow rate for erosion threshold (particles 1mm) (L/s)**	Flow rate for erosion of bigger particles (few mm) (L/s)	Observations
0	4.25	2.13	1.9	**2.5**	3.5	Pointed/peaked surface
4.25	9.05	6.65	3.7	**4.9**	5.7	
9.05	15.5	12.28	3.1	**3.5**	4.1	

Depth beginning (mm)	Depth ending (mm)	Midpoint	Flow rate for erosion of tiny particles (<1mm) (L/s)	**[25T0_1] Flow rate for erosion threshold (particles 1mm) (L/s)**	Flow rate for erosion of bigger particles (few mm) (L/s)	Observations
0	5.5	2.75	2.3	**2.7**	3.3	Uneven surface (flocs)
5.5	10.5	8.00	2.5	**3.9**	4.3	
10.5	15.99	13.25	2.3	**3.5**	5.1	
15.99	21	18.50	2.5	**3.1**	4.7	
21	26.7	23.85	2.6	**3.8**	4.6	
26.7	32.7	29.70	2.7	**4.3**	4.9	
Depth beginning (mm)	Depth ending (mm)	Midpoint	Flow rate for erosion of tiny particles (<1mm) (L/s)	**[25T0_2] Flow rate for erosion threshold (particles 1mm) (L/s)**	Flow rate for erosion of bigger particles (few mm) (L/s)	Observations
0	4.82	2.41	1.9	**3.3**	4.3	Even surface, flat.
4.82	9.97	7.40	2.1	**2.7**	5.7	Bubbles
9.97	16.64	13.31	2.5	**3.5**	4.7	Bubbles, algae, stone
16.64	21.94	19.29	2.9	**3.5**	4.7	
21.94	25.74	23.84	3.1	**3.7**	4.5	Uneven surface (erosion on the front area)
25.74	30.45	28.10	2.5	**3.1**	4.5	
Depth beginning (mm)	Depth ending (mm)	Midpoint	Flow rate for erosion of tiny particles (<1mm) (L/s)	**[25T0_3] Flow rate for erosion threshold (particles 1mm) (L/s)**	Flow rate for erosion of bigger particles (few mm) (L/s)	Observations
0	5.45	2.73	2.1	**2.5**	4.5	Sand layer
5.45	10.9	8.18	1.9	**2.9**	5.3	
10.9	15.7	13.30	2.5	**3.3**	4.7	
15.7	21.7	18.70	2.3	**3.5**	4.3	
21.7	25	23.35	2.1	**2.9**	4.7	
25	29.85	27.43	2.1	**3.3**	5.5	

[10T0_1]

Depth beginning (mm)	Depth ending (mm)	Midpoint	Flow rate for erosion of tiny particles (<1mm) (L/s)	**Flow rate for erosion threshold (particles 1mm) (L/s)**	Flow rate for erosion of bigger particles (few mm) (L/s)	Observations
0	4.82	2.41	0.9	**1.1**	4.7	
						Core destroyed by bubbling water

[10T0_2]

Depth beginning (mm)	Depth ending (mm)	Midpoint	Flow rate for erosion of tiny particles (<1mm) (L/s)	**Flow rate for erosion threshold (particles 1mm) (L/s)**	Flow rate for erosion of bigger particles (few mm) (L/s)	Observations
0	5.43	2.715	0.9	**1.3**		
5.43	10.2	7.815	1.7	**2.1**		
10.2	15.45	12.825	1.5	**1.9**	2.7	Uneven erosion
15.45	20.25	17.85	2.3	**2.9**		
20.25	26.95	23.6	1.3	**1.9**	2.5	

[10T0_3]

Depth beginning (mm)	Depth ending (mm)	Midpoint	Flow rate for erosion of tiny particles (<1mm) (L/s)	**Flow rate for erosion threshold (particles 1mm) (L/s)**	Flow rate for erosion of bigger particles (few mm) (L/s)	Observations
0	5.47	2.735	1.1	**1.3**		
5.47	11.76	8.615	1.1	**1.9**	3.3	
11.76	15.64	13.7	1.3	**1.5**	3.7	
15.64	20.46	18.05	1.5	**2.3**		
20.46	25.81	23.135	2.1	**2.7**		
25.81	29.43	27.62	1.7	**3.1**	4.9	

[501W_1]

Depth beginning (mm)	Depth ending (mm)	Midpoint	Flow rate for erosion of tiny particles (<1mm) (L/s)	**Flow rate for erosion threshold (particles 1mm) (L/s)**	Flow rate for erosion of bigger particles (few mm) (L/s)	Observations
0	5.39	2.695	1.1	**1.9**	4.3	The sensor hurt a bit of sediment
5.39	11.1	8.245	2.1	**3.1**	4.9	Bubbles, wood, leaves
11.1	16.39	13.745	2.5	**3.3**	5.9	
16.39	22.5	19.445	2.9	**3.1**	4.9	
22.5	27	24.75	2.9	**3.1**	4.3	
27	32	29.5	2.9	**3.9**	5.1	Bubbles ++

[501W_2]

Depth beginning (mm)	Depth ending (mm)	Midpoint	Flow rate for erosion of tiny particles (<1mm) (L/s)	**Flow rate for erosion threshold (particles 1mm) (L/s)**	Flow rate for erosion of bigger particles (few mm) (L/s)	Observations
0	4.88	2.44	2.1	**2.7**	3.7	Uneven surface (slope)
4.88	9.17	7.025	3.1	**3.9**	4.7	
9.17	15.58	12.375	2.9	**3.9**	5.3	
15.58	20.21	17.895	2.9	**4.5**	5.1	Turbidity ++
20.21	25.64	22.925	3.5	**4.9**	5.3	
25.64	30.38	28.01	3.3	**5.3**	5.3	

[501W_3]

Depth beginning (mm)	Depth ending (mm)	Midpoint	Flow rate for erosion of tiny particles (<1mm) (L/s)	**Flow rate for erosion threshold (particles 1mm) (L/s)**	Flow rate for erosion of bigger particles (few mm) (L/s)	Observations
0	5.99	2.995	1.5	**2.1**	3.5	
5.99	10.06	8.025	3.9	**4.5**	5.3	
10.06	15.85	12.955	4.5	**5.7**	6.7	Bubbles
15.85	20.55	18.2	3.3	**5.1**	6.5	Big leaves ++
20.55	25.33	22.94	3.1	**3.1**	4.1	Plant residues ++
25.33	31.33	28.33	2.9	**5.9**	6.7	

Appendix 3

Provisional schedule for the last weeks considering that antibiotics will probably not be delivered before 4th July.

1W = one week incubation experiment; DARK = one-week incubation in the dark experiment; AB = one-week incubation with antibiotics experiment

50, 25, 10 = mud concentrations

24 Test EPS extraction on a dry sample [251W]: preparation of the incubation for the flume	25 Test EPS measurement with filter syringe	26 Test EPS measurement with filter syringe	27 [101W] and [10DARK]: preparation of the incubation for the flume	28 [10T0]: EPS measurement [25DARK} and [50DARK]: preparation of the incubation for the flume	29	30
1 [251W]: flume [1W]: preparation of the incubation for lab work	2 [DARK]; preparation of the incubation for lab work	3	4 [101W] and [10DARK]: flume [50AB] and [25AB]: preparation of the incubation for the flume [AB]: preparation of the incubation for lab work	5 [25DARK and [50DARK]: flume [10AB]: preparation of the incubation for the flume	6	7
8 [1W]: separation of the different depths Oven drying [1W]: EPS extraction and measurement	9 [1W]: Loss on ignition [DARK]: separation of the different depths Oven drying	10 [DARK]: Loss on ignition [DARK]: EPS extraction and measurement	11 [50AB] and [25AB]: flume [AB]: separation of the different depths Oven drying	12 [10AB]: flume [AB]: loss on ignition [AB]: EPS extraction and measurement	13	14

POLYTECH TOURS
35 ALLÉE FERDINAND DE LESSEPS
37200 TOURS

Solène Jahan

2018-2019

Résumé :

Composed of small particles like silt and clay, cohesive sediment constitutes a specific riverbed structure because of the particular link between particles. This type of sediment is also a natural habitat for bacteria, algae or invertebrate. If cohesive sediment can have effects on this biological activity, several studies have shown that the inverse is also true. This reports aims to synthetize technical considerations made during a 4th-year engineering school internship from 23rd April to 12th July 2019 based on the study of the link between the erosion of cohesive sediment and biological activity in Cranfield University (UK).

Mots Clés :

Erosion, cohesive sediment, mud, bacteria, algae, flume, bulk density, water content, organic content, EPS

Tuteur entreprise :

Robert Grabowski

Tuteur académique :

Stephane Rodrigues