CALCIUM EFFECT ON THE SOIL SEDIMENTATION – MEASUREMENT METHODE

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Abstract

Nutrients such as phosphate and soil particles are much more susceptible to loss with sediments in eroding soil and run-off water, and this loss due to the erosion has a negative influence on agricultural output. To prevent it, various approaches have been taken, including the idea that particle driven coagulation may speed up sedimentation and minimize the quantity of material lost. The specific purpose of this study was to examine the efficiency of bivalent salt-based coagulants in enhancing the sedimentation process in the laboratory in a flow-through sedimentation tank. The effect of Ca^{2+} cations was studied by adding a 100 mg/L solution of the chemicals in a flow-through tank. A soil solution of 0.10 g/L concentration was flowing in the tank at a flow rate of 40 mL/min. The pictures were analyzed by using ImageJ program (analyze and collect data), Origin 6.0 program (plot a graph with multi Y axis) and Surfer 12 program (make 3D model) to assess sedimentation progress. We verified that the addition of a certain amount of divalent cations, calcium, to the tank improved settling of the sediments.
Keywords: *sedimentation, erosion, calcium, recovery, coagulation*

KALCIUM HATÁSA A TALAJ ÜLEDÉKKÉPZŐDÉSÉRE - MÉRÉSI MÓDSZER

Összefoglalás

Az olyan tápanyagok, mint a foszfát, sokkal érzékenyebbek a veszteségre az erodálódó talajban és a lefolyó vízben történő elsodródással. Az erózió miatti veszteség negatív hatással van a mezőgazdasági termelésre. Ennek megakadályozására különböző megközelítések születtek, többek között az az elképzelés, hogy a hozzáadott anyagok által vezérelt koaguláció felgyorsíthatja az üledékképződést, és így minimálisra csökkentheti az elvesztett anyag mennyiségét. E tanulmány konkrét célja az volt, hogy megvizsgálja a kétértékű sóalapú koagulánsok hatékonyságát az ülepedési folyamat fokozásában laboratóriumi környezetben, átfolyós ülepítőmedencében. A Ca^{2+} kationok hatását a vegyszerek 100 mg/L koncentrációjú oldatának egy átfolyásos tartályban történő hozzáadásával vizsgáltuk. A folyadékban 0,10 g/L koncentrációjú talajoldat áramlott, az áramlás 40 mL/perc volt. A képeket az ImageJ program (adatok elemzése és gyűjtése), az Origin 6.0 program (grafikon készítése több Y tengellyel) és a Surfer 12 program (3D modell készítése) segítségével elemeztük az ülepedés értékelésére. Igazoltuk, hogy bizonyos mennyiségű kétértékű kation, kalcium hozzáadása a tartályhoz javította a lebegőanyag ülepedését.
Kulcsszavak: *ülepedés, erózió, kalcium, visszanyerés, koaguláció*
JEL kód: *Q53*

Introduction

Water erosion has been identified as the most significant cause of land degradation worldwide, especially in arid and semi-arid areas. These areas make up around 41% of the Earth's land surface (VAEZI et al., 2017). The loss of considerable volumes of soil particles and essential nutrients from land-based agriculture is a global problem as a result of these erosion processes (LUNDEKVAM – SKOIEN, 1998). Furthermore, if sediment and nutrients that are not caught close to their source would eventually wind up in huge surface water bodies and finally in the sea, and recovering any of it for active land-based use will be prohibitively expensive.

Because of their larger relative surface area and thus better adsorption capacity, nutrients prefer to bind in larger relative amounts to tiny particles (ZHANG et al., 2015). Simultaneously, it is particularly difficult to sediment the smaller, silt or clay-sized particles when their suspension travels across a pond (-system). The particle size in the clay fraction is near to or already within the colloid size range, which has little settling ability (few cm/day) (ULÉN, 2004). The combination of being nutrient-rich and being difficult to sediment necessitates a specific attention on the clay and silt fractions in attempts to improve surface water quality.

Much study has been conducted to better understand the mechanics of flocculation and the solid/liquid separation process. Separation is caused by the aggregation of materials into floc particles, which can subsequently be separated in part by sedimentation, with further water removal performed by gravity thickening and mechanical techniques. For example, according to (BRASKERUD et al., 2013), increased aggregation of suspended particles may result in more effective settling and a reduction in the movement of sediment and nutrients downstream.

The negative surface charge of suspended solids prevents them from aggregating into larger particles. The suggested strategy is based on the idea that by adding cations to the solution, this double layer may be reduced. This is a well-known phenomenon employed as part of wastewater treatment methods where coagulants are extensively used to settle the smaller (colloid size) particles (METCALF – EDDY, 2003).

Material

The experiment was conducted in a settling tank with a prepared solution and chemicals.

Solution: For the solution 4.50 g of soil was mixed in 1500 mL of distilled water in a laboratory glass cylinder. The sediment concentration was selected to approximate high quantities of total suspended solids encountered in runoff water in boreal regions. (PUUSTINEN et al., 2005). The solution was stirred for 20 mins using a magnetic stirrer then the solution was left to settle for 5 min. After this 5 mins, the big particles (diameter is bigger that 0.033 mm, all of the sand) settled easily in the bottom. To separate the smaller particles (used in the experiment, smaller diameter as 0.033mm), 1000 mL from the top of solution was removed by using a pump and keeping 500 mL form the bottom of solution not necessary for our experiment. From this solution we prepared the solution needed for experiment by mixing it with distilled water in 2-to-1 ratio. Each prepared solution were sufficient for two runs.

Cation: The cation that was used as coagulant in this study is the calcium (Ca^{2+}) since it has low impact and its harmless to the environment and these were salts that were easily available (SEBOK et al., 2020). The calcium was added as laboratory grade, chloride salt. We mixed 1100 mg of calcium chloride ($CaCl_2$) with 1000 mL of distilled water in a baker so it resulted 300 mg/L concentrations of Ca^{2+} ion solution.

Both the solution and cation were in a different container and pumped to the tank (Figure 1.) which this case much closer to the reality than being in the same container. In this study the pumps utilized are peristaltic dosing pumps, which are employed to inject small yet precise volumes of the solution and chemicals to the tank. We used two pumps the first deliver 26 mL/min from the solution and the second deliver 14 mL/min from the calcium solution (which, together with the soil solution, resulted as 100 mg/L Ca^{2+} ions in the tank). In total the pumps add about 40 mL/min to the tank full of distilled water. We tested in a dark chamber with light sources on the top of the tank and black background to deliver consistent and reliable indirect backlighting to the tank.

Two cases were tested, a control one with no salts injected to it just distilled water simulates the added solution and one with 100 mg/L concentrations of cations. Each case was repeated three times to illustrate the consistency of our experimental results. The duration of every run is 13 minutes. The JPEG pictures were taken by a Fujifilm FinePix S8600 camera in manual mode, with settings of 4608 x 2592 pixels (16:9, L, fine quality), shutter speed 60 and aperture F2.9. At the beginning of each run, pictures were taken every minute. The camera and cylinders were changed to designated places and orientation for every run.

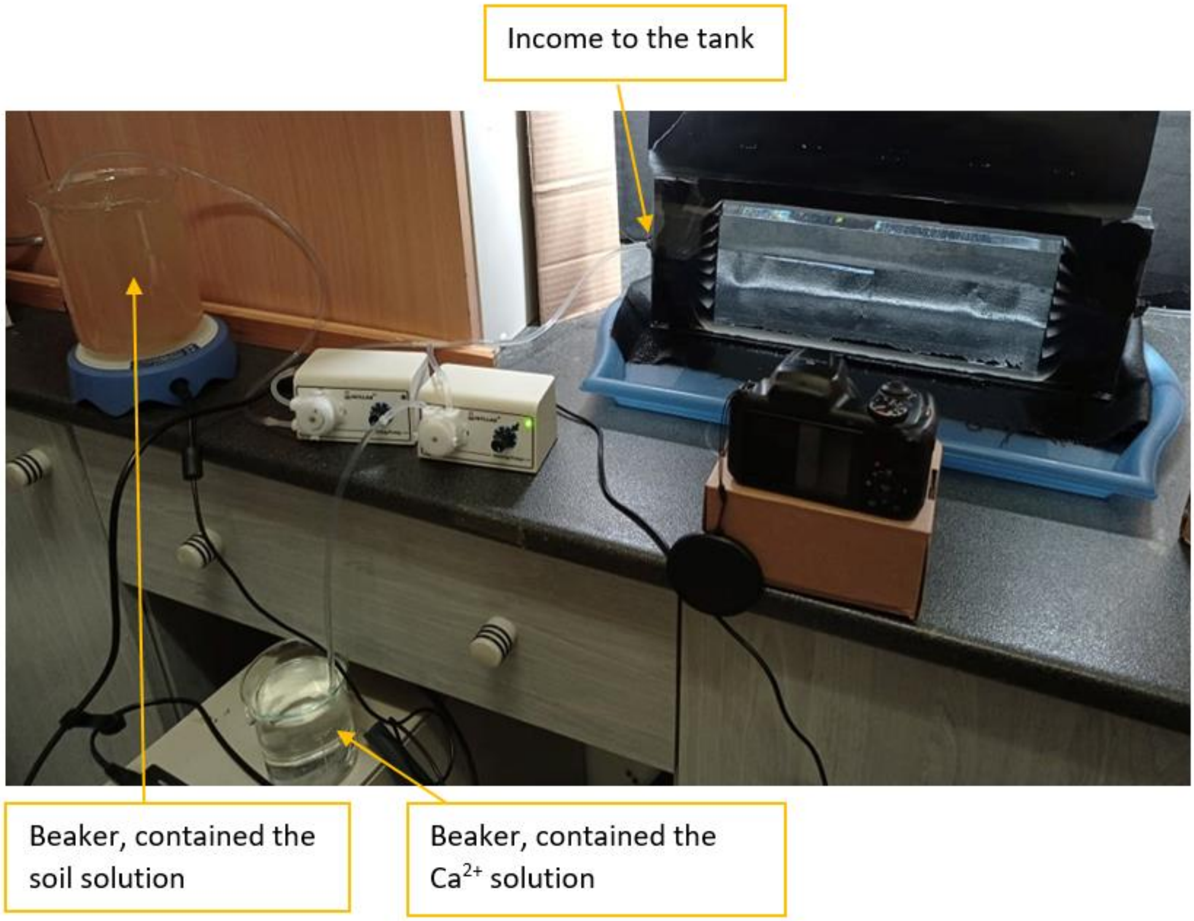

Figure 1. Setup of the experiment (Photo by Razane Akil)

Methods

The soil concentration was 100 mg/L in final stream and the stream was 40 mL/min. By using the IrfranView program, version 4.51, a software used as an image viewer, editor, organizer, and converter for Microsoft Windows, as well as picture creation and painting features, we edited and adjusted the original photo (Figure 2.) by cropping and removing the middle section of the settling tank, and converting it to grayscale (Figure 3.).

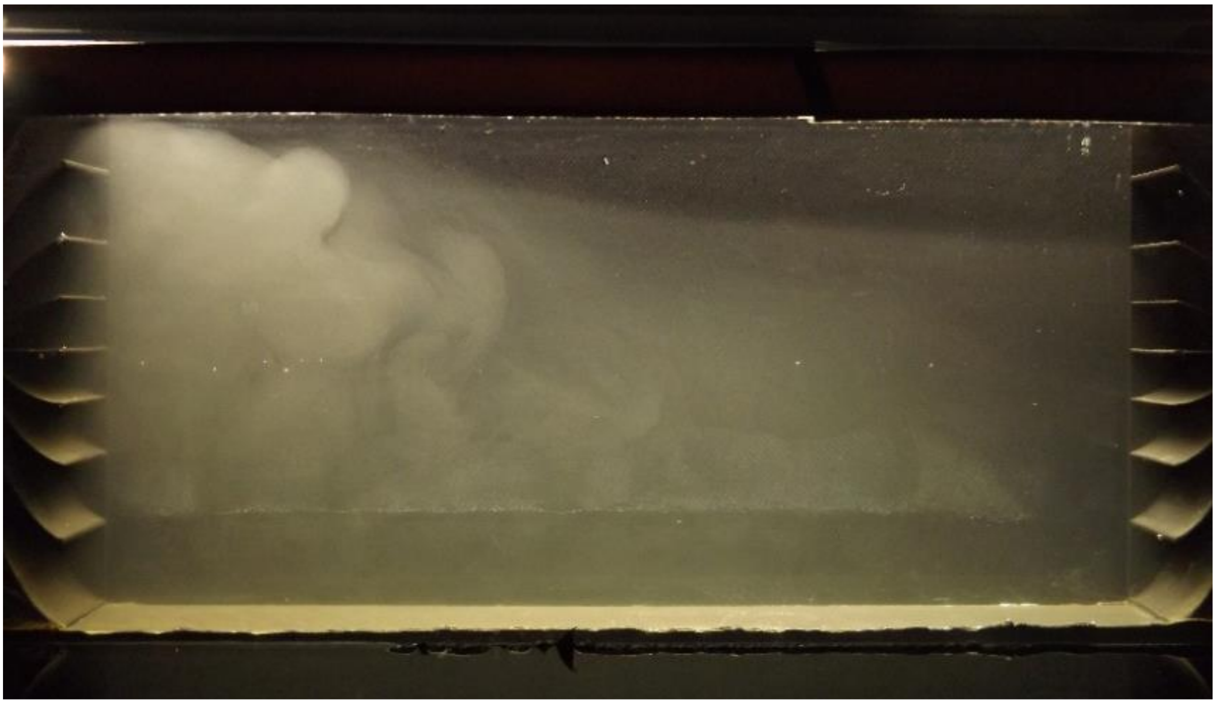

Figure 2. Original picture, taken by the camera (Photo by Razane Akil)

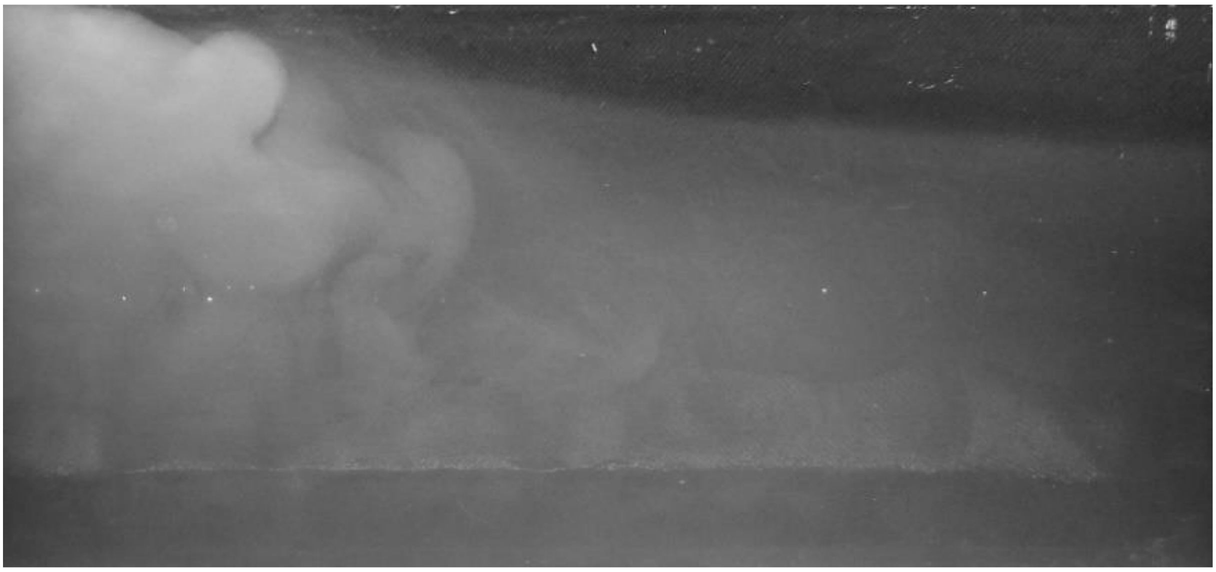

Figure 3. Picture, cropping the middle section and converted into grayscale (Photo by Razane Akil)

From the measurements of each case we took 13 photos and the time between every two photos is 1 min (Figure 4 and 5).

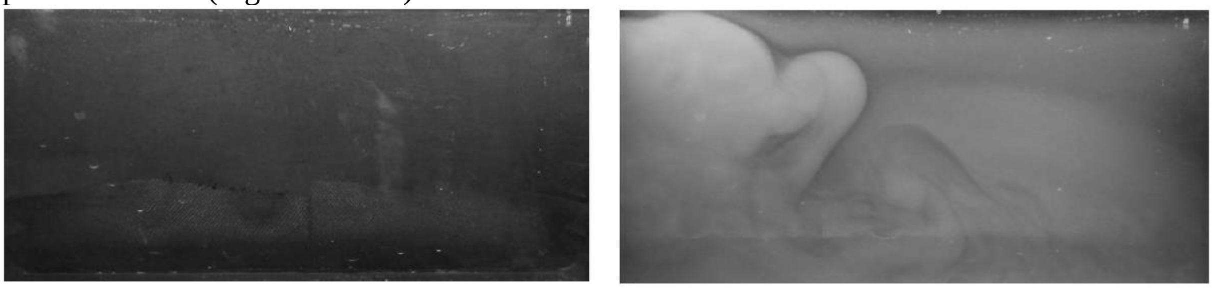

Figure 4. Photo at 1 and 13 min in the original case (Photo by Razane Akil)

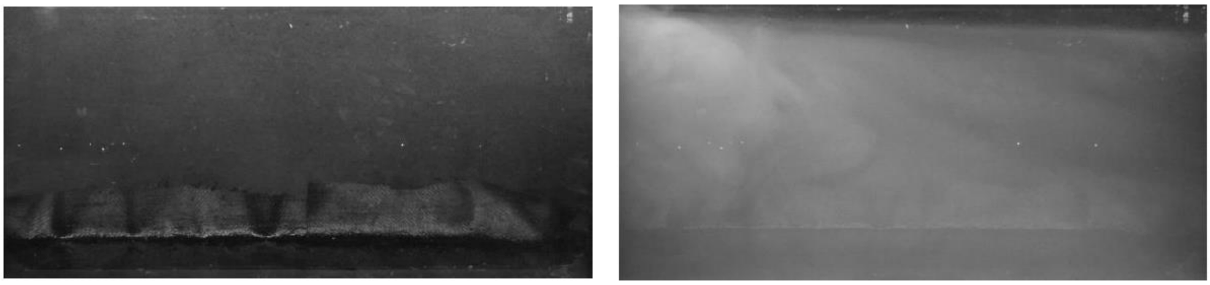

Figure 5. Photo at 1 and 13 min in the cation treated case (Photo by Razane Akil)

After converting all the photos in the same way, we used the ImageJ program (version 1.53k) to analyze them. ImageJ is a raster (row and column) image data display, annotate, modify, calibrate, measure, analyze, process, print, and save program. It can read the majority of common raster image formats as well as raw data files in text format, such as those found in spreadsheets. We used two type of analysis on each picture, first one is the Histogram and second one is the Plot Profile.

The histogram shows in the Figure 6. with all the information needed about the diagram such as the minimum and maximum number of pixels and from this diagram we made a table of data on Excel and we have also done the same work for 13 control photos and 13 cation treated photos.

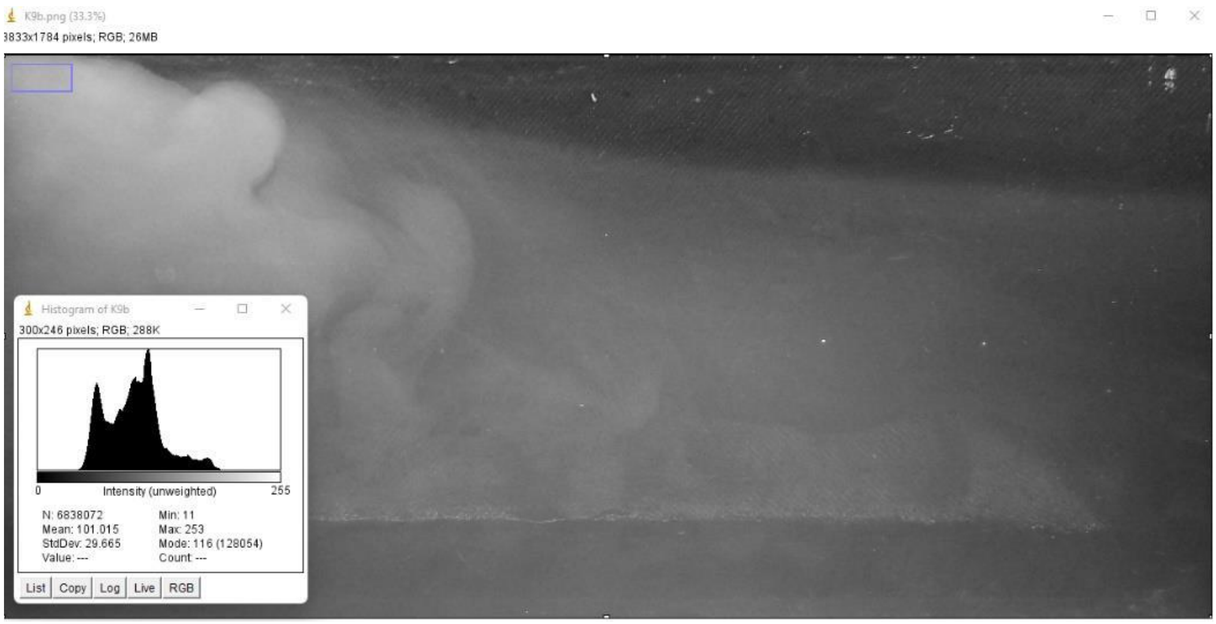

Figure 6. The Histogram analysis type

The histogram analysis type gives us just the percentage of darkness. It takes into account all of the pixels in the picture (raw and column) and for these photos, the program accounts for 256 pixels classes. And because it's grayscale, the darkness point has a value of zero pixels while the lighter point has a higher value, equal to 255, so the pixels' range is between 0 and 255 from black to white point.

The white fraction indicates the detection of high turbidity which means floating of soil particles and that's because the particles are reflecting the light. In case of numbers, with a higher propotion of white pixel numbers (related to soil particles) the turbidity is increasing. However the higher darker pixel fraction menas that less particles reflecting the light in the system. As we can see, this technique is not ideal for analysis, but it does provide us with some valuable data to compare the whole process.

The other type of analysis is the plot profile shows in Figure 7. It is also came from the ImageJ program. We also created a data table in Excel and repeated the process for 13 photographs as the control soil was investigate and 13 photos about the cation treated soil.

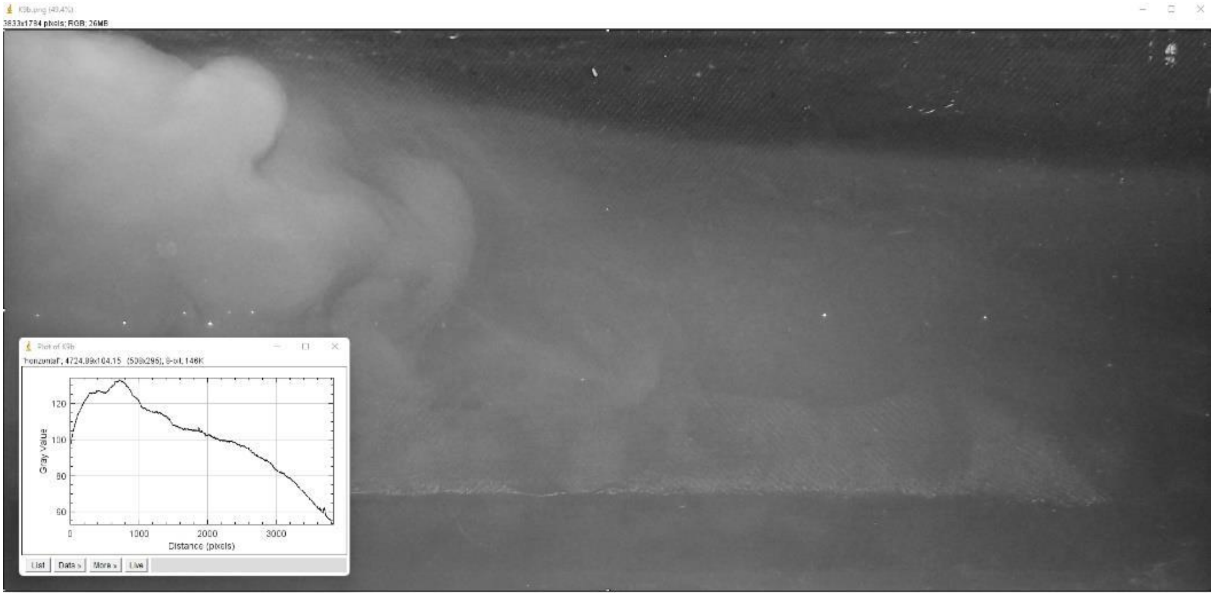

Figure 7. Plot analysis type

As we can see, on the plot the x axis, there are the distance from the left side (in pixels). And the y axis, we can find the gray value. From the plot we can distinguish that if the value is higher, the column is lighter than the others. This sort of graphic provides information regarding the distribution of the tank's contents.

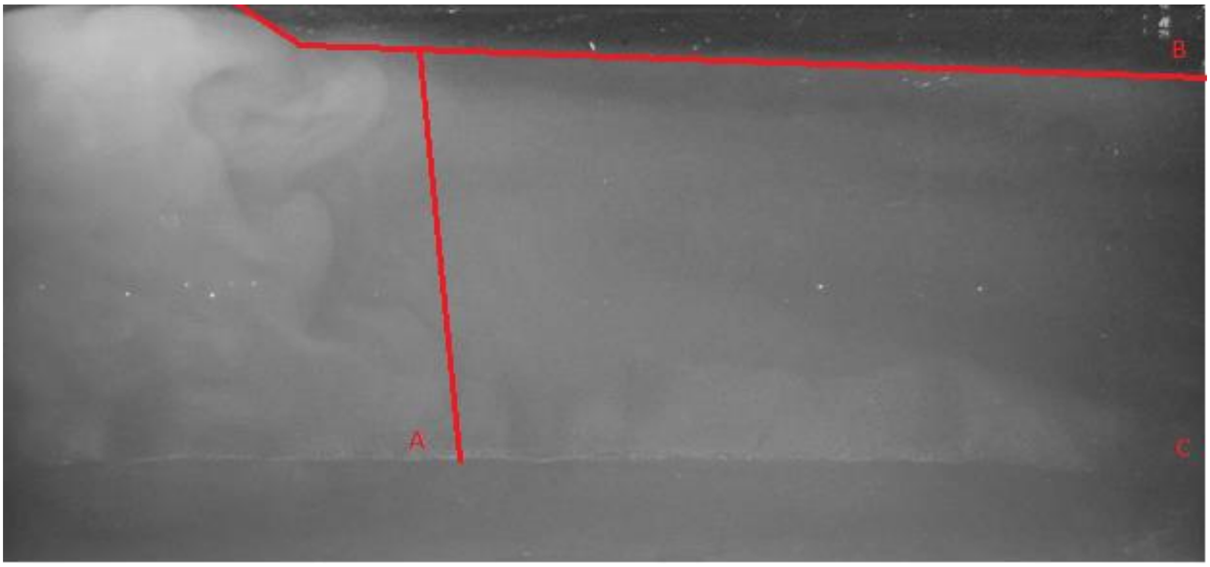

Figure 8. Photo at 12 min in the cation treated case describing the parts

As we can see, part A is approximately similar in both pictures, but in part B we can clearly recognize that the cation treated picture is very dark while the control picture is light, which means that in this part of the cation treated picture, we don’t have soil particles. This means that in the darker part, the turbidity is low due to the fewer soil particles. This implies that we have more settling in this part of the sedimentation tank. It is very hard to measure the turbidity at every point in the flow tank because the turbidity measurement is good for the experiment of the current situation but not for a continuous flow measurement. That's why we used photos and other methods to see the turbidity.

Results

After collecting all the data in Excel and save them in tables, Origin 6.0 program was used for visualize. All the data collected for the 13 control photos for the plot profile analysis type was converted to a graph (Figure 9.) and the same for the data collected from cation treated photos (Figure 10.).

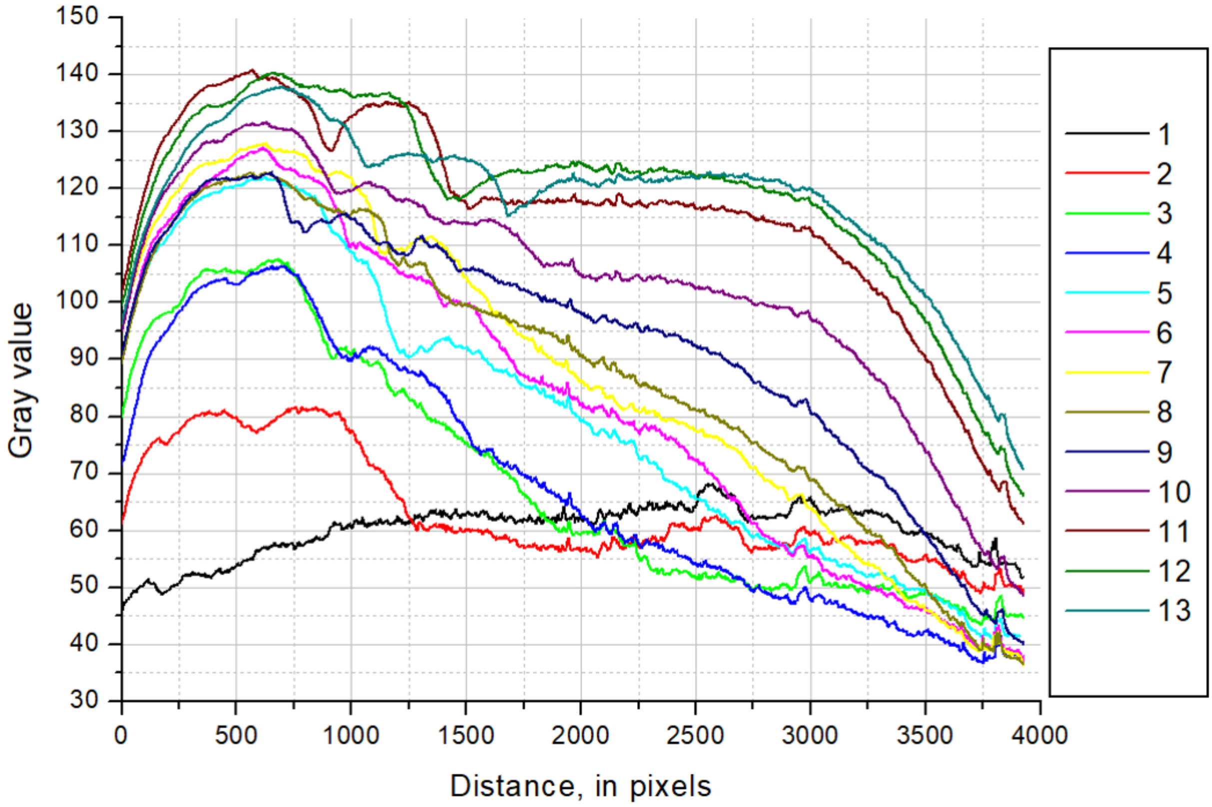

Figure 9. The gray values of the control case

This is all of the 13-plot profile from the first dataset, where were no chemicals applied (Figure 10). From this graph, we can identify, that the first section from 0 to 1000 pixels, the gray value is rising drastically under few minutes until the 4^{th} min, but after the 5^{th} min and between 1000 and 3000 pixels, there is a slow increasing. After the 11th minute, we can recognize that all of this stagnate where the last three line (11-13 mins) basically running together. It indicates that an equilibrium has been established, and the flow is self-stabilizing. The only change happens after the 3000 pixels, where the outflow has some turbulent effect, as it sucks out the water from the tank.

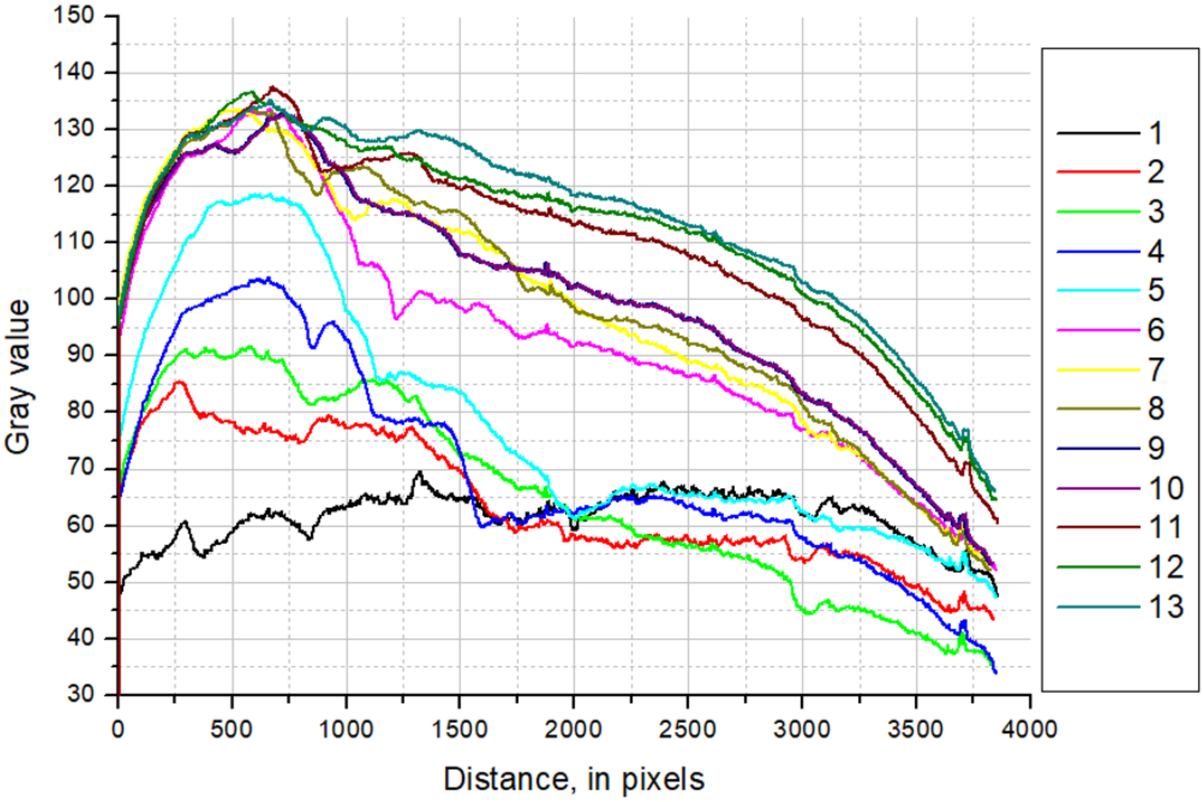

Figure 10. The gray values of the cation treated case

This is the same type of graph, but in that case, we add calcium ions (cation treated case). Here we can also see that there is high increasing in the first section from 0 to 1000 pixels for 5 minutes and after 5th min, it is stabilized. but we can recognize that after 1000 pixels there is sharply decreasing. After 3000 pixels not a big change could be defined in the graph. Probably, under a few minutes, the flow stabilized, and the settling continued.

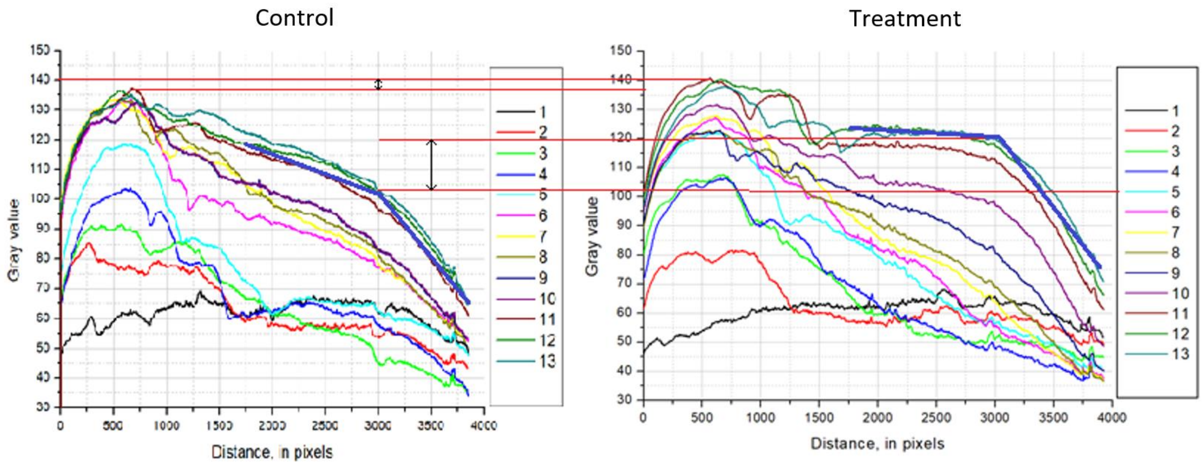

Figure 11. Comparison of the cation treated and control results

In Figure 11., the graph shows that the first and second minutes (red and black lines, labeled 1 and 2 in the graphs) are identical in both cation treated and control graph. It signifies that when the material reaches the tank, it acts the same, so the changes are not due to the material or the system, but to the calcium ion treatment and the time, which happened after 5 min.

As we can see, the first section (0-1000 pixels) is very similar: there is an increase in the first 5 mins and after the 5th minute it is stabilized at a maximum value (gray value 140). These increasing to the gray value 140 are equivalent, but the value in the cation treated graph is lower in general than the cation treated one, which means, already less material accumulated in the first section of the sedimentation tank. The real difference appears between 1000 and 3000 pixels and after 6 min which the lines are almost straight in the control graph while they are sharp oblique lines in the cation treated graph and the values are significantly lower than the control profiles. These lower values confirmed that the soil particles are more settled and the Ca^{2+} has a positive effect on sedimentation and helps the soil particles to settle better.

After 3000 pixels, there are not a big change between the cation treated and control graph. Both, they have a severe decreasing in the last section of gray value. So, we can deduce that it is not due to the chemicals, but to the influence of the system, which increases the speed of the solution owing to the flow out of the tank, and we may identify the source of this hard lowering.

Histogram results

The data resulted from 13 histograms is used with Surfer 12 program by calculating the average value for every column of pixel to make 3D wire map. Figure 12 shows the pixel number in case of control and cation treated settling change. It can be identified from the map that the higher value of gray scale which are the lighter points founded with the smallest number of pixels, in the first section while the lower value of grayscale, the darker points are founded with the higher number of pixels. But it is also clear that in the control map the grayscale value still more significant than the cation treated map. After approximately 5 minutes the cation treated map is darker than the control map which is demonstrate that at the darker part the of turbidity is lower and that’s mean less of materiel floated in the sedimentation tank so more settling of soil particles happen in general in case of cation treated.

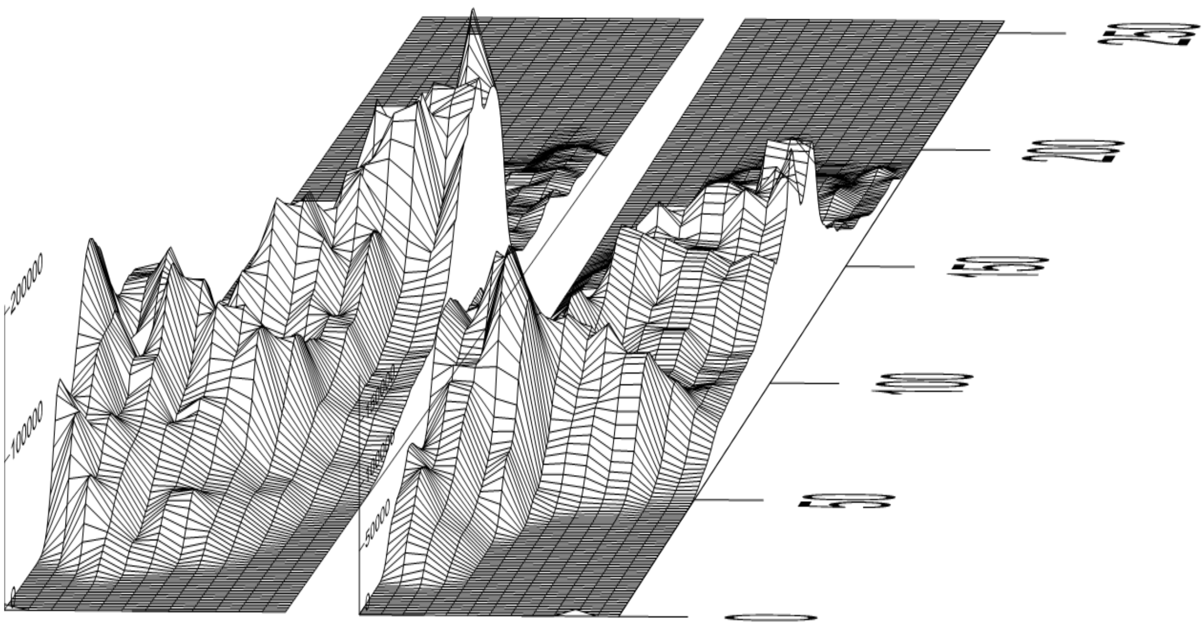

Figure 12: X axis: the time between 1-13 minutes; Y axis: the gray value, where 0 is the black, and 255 is the white; Z axis: pixel number at the current gray value

Conclusion

This study evaluated the significance of adding the divalent cation (Ca^{2+}) to the sedimentation process for improving the settling with low flow. The results of this study demonstrate that the cation content in a sedimentation tank plays a role in determining settling characteristics, which has a major impact on it.

During the experiment, we have to solve the problem of the proper measurement. Due to the small amount of the materials (after the pre-settling, we worked only with the smallest particles, which part has low ability to settling out), approximately 0.10 g/L, the conventional ways do not work. Even with sampling after time-to-time, the remaining materials, measured back after drying, not prove valuable and acceptable results. Based on it, and a previous study, we decided to analyze the color (turbidity) of the solution, with picture analyses.

When cations (Ca^{2+}) are present in the tank, they have an effect by decreasing the grayscale value and making the section much darker due to reducing the turbidity (and enable to see more of the black background) and improving the settling of soil particles. These results indicate that for utilities challenged by small particle disposal, their treatment processes could be optimized by adjusting chemical low-dosages. Moreover, the utilization of low amount, specific salt as a coagulant in the sedimentation process is non-hazardous and friendly to the environment, and keeping sediments has a beneficial environmental and economic benefit.

Now, after these analyses, we proved the increase in the sedimentation. In the future, we need to improve the measurement with other conditions such as increasing and determine the lowest effecting concentration of chemicals in the solution. The method could be used to analyse the effect of different ions to the sedimentation process, and provide a reliable alternative for measurement.

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