IMAGE PROCESSING FOR QUANTITATIVE ANALYSIS OF FLUID FINE TAILING'S, DOSED WITH ANIONIC POLYAMIDE BASED FLOCCULANT

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ABSTRACT
Understanding long-term dewatering behaviour of oil sands tailings is significant to the success and optimization of tailings reclamation plans. Long term dewatering, of tailings is somewhat complex due to mechanical creep and or structuration driven by electrochemical forces, between clay particles. To modernize conceptual models of tailings dewatering, fabric evolution, of tailings over months has been studied using, Porosmetry, SEM, ESEM, as well as optical microscopy. Morphological, information is extracted from various images using a variety of image processing techniques. In this context, the main idea to this study was to use "Image processing" software, primarily "Fiji-Image J" for fabric investigation and quantitative analysis, of the amended fluid fine tailings (FFT). The long-term fabric evolution in an initially 0.10 m thick sample suggests growth in aggregate size, increase in average pore-size, although decrease in porosity.

RÉSUMÉ
Comprendre le comportement d'assèchement à long terme des résidus de sables bitumineux est important pour le succès et l'optimisation des plans de remise en état des résidus miniers. La déshydratation à long terme des résidus est quelque peu complexe en raison du fluage mécanique et / ou de la structuration entraînée par les forces électrochimiques, entre les particules d'argile. Afin de moderniser les modèles conceptuels de l'assèchement des résidus, l'évolution des tissus, des résidus au fil des mois a été étudiée à l'aide de la porosmétrie, du MEB, de l'ESEM et de la microscopie optique. Morphologique, l'information est extraite des diverses images en utilisant une variété de techniques de traitement d'image. Dans ce contexte, l'idée principale de cette étude était d'utiliser le logiciel "Image processing", principalement "Fiji-Image J" pour l'étude des tissus et l'analyse quantitative de la FFT modifiée. L'évolution à long terme du tissu dans un m échantillon épais suggère une croissance de la taille des agrégats, augmentation de la taille moyenne des pores, bien que la diminution de la porosité.

1 INTRODUCTION

Dewatering of oil sands tailings to facilitate reclamation and ecological restoration of tailings disposal areas remains quite challenging. Tailings disposal technologies and practices certainly are open to further optimization to increase effectiveness of dewatering and to reduce costs (COSIA 2015).

Oil sands tailings are initially composed of water, residual bitumen, sands, and fines (silts and clays). The coarser particles i.e. >44um, settle and segregate from the remaining tailings quickly after deposition. The fine particles remain suspended and termed FFT (fluid fine tailings). After few years of placement in the tailings ponds, FFT only settles to about 30% or 35%, and thereafter do not appreciably dewater (Beier et al. 2009**,** Chalaturnyk et al. 2002**).** Consequently, oil sands operators have developed several technologies to accelerate dewatering, such as centrifugation and in-line flocculation.

Polymer –induced flocculation of fines is incorporated in many of the new tailings technologies. Such technologies can increase the solid content to 50- 55% by mass, in hours to days. (Matthews et al., 2011, Wells, 2011)**.** However, dry land reclamation may require upwards of 70% solids content. Therefore, understanding the long-term dewatering, behavior of oil sands tailings is important to the success and optimization of tailings reclamation plans. The processes involved in the dewatering, of oil sands tailings over a longer time (months to years), not only incudes consolidation, but may be influenced by creep or thixotropy /structuration. Recent laboratory work (Salam et al. 2017) suggests that such time-dependent behavior may bear substantially on the dewatering behavior of polymer amended FFT deposits.

The work in this paper complements the investigations of Salam et al (2017) and others, by attempting to visualize physical changes in the fabric of tailings as they progress through different stags of dewatering, from scales of hours to months. To this end, Images are obtained using SEM/ ESEM and a high-power optical microscope. The images are analyzed using freeware "Image J" and digital image processing techniques, to quantify fabric evolution in polymer amended tailings. The long-term goal of the work is to improve conceptual models of tailings dewatering that could allow for further optimization of polymer does, type, and application.

2 MATERIALS PREPEARTION AND SAMPLING

This FFT had a sand to fine ratio of 0.25, an MBI estimate clay content of 28 % to 32%. An anionic polyamide-based flocculant was prepared in a 0.4 % stock solution and applied to the tailings at a dosage of 600 ppm. The tailings were mixed with the polymer for 10s using a mixer speed of 250 (Salam et al, 2017). This is found to generate CSTs and stress growth, yield stresses in the same range as in-line polymer injection done at the full scale, at a least one field trial (Mizani) 2016.

Polymer amended FFT dosed with 600 ppm of an anionic polymer, hereafter "the tailings" were deposited in multiple replicates (10) of 15 cm diameter transparent acrylic columns to a material height of 10 cm, shown in Figure 1. A tensiometer was also inserted into two of the columns to measure pore-water pressure. The acrylic columns had no drainage. For testing and sampling, five different days labelled, covered from underneath duplicate columns were designed. Samples taken out from those columns, were used for production of scanning electron microscopy images, for different days, i.e. (7,14,28,56,72 days). Moreover, for analysis of hourly basis structuration behaviour, optical microscope images were generated for samples obtained from the same batch tailings, i.e. (1,2,4,8,24 and 48 hours), using a thin needle from the top 1 cm.

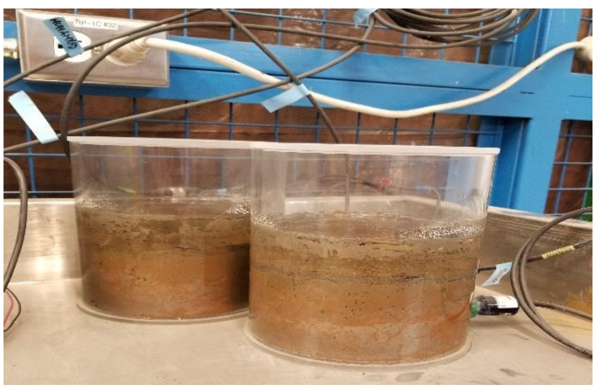

Figure 1: 10 cm column experiment for quantification of consolidation (Salam et, al. 2017)

3 OBTAINING IMAGES

3.1 Scanning Electron Microscopy

A Tescan Vega-II XMU VPSEM, which has adjustable pressure, and rapidly freeze samples immediately before scanning, was used for the SEM imaging. The applied voltage was 20 kv, 148 us/pixel, was the scanning speed, and the working distance was 10 mm. The view field was kept at 750 microns, magnification of 200x.

Samples were taken out from each duplicate dated, labelled columns. Due to wet nature of tailings, the samples were flash frozen to temperatures less then 173k after placement in the SEM device. Examples, of SEM sample Images obtained at 28 days and 72 days are shown in Figure 2.

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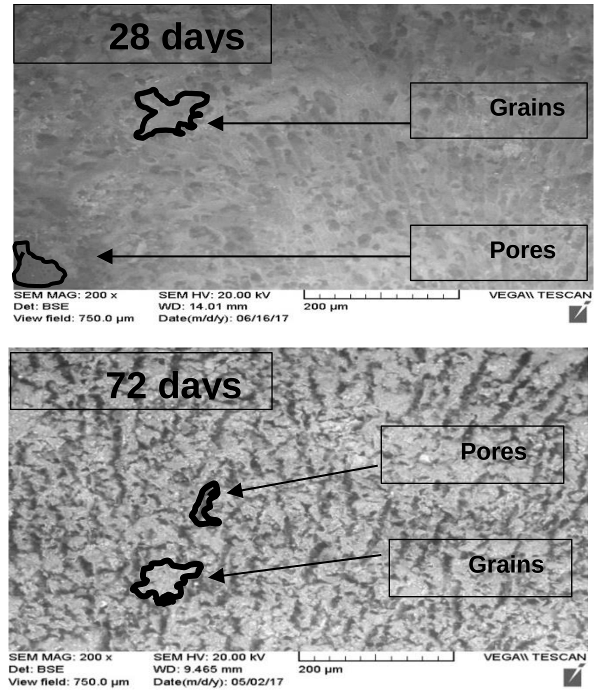


Figure 2: SEM Images for 28 ,72 days tailings samples, dozed with Anionic Polymer "600 ppm" (Salam et, al. 2017)

3.2 Optical Microscopy

Images were generated using a high powered optical microscope, the "Nikon model eclipse ti: NIS Elements AR3.2. A magnification of 200x was used. Images were recorded at 1, 2, 4, 8, 24, and 48 hours. Examples Of optical microscopy images are shown in Figure 3.a and 3.b.

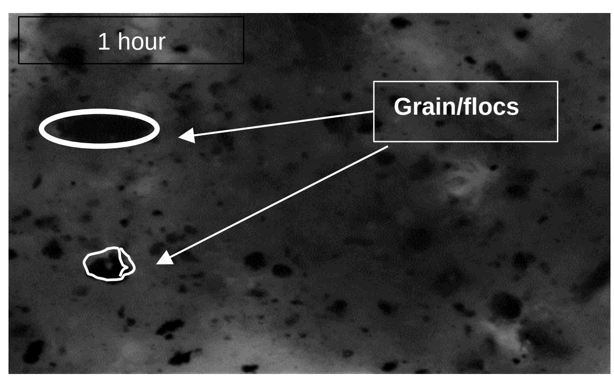


Figure 3.a: Optical microscopic images for 1-hour sample dozed with anionic polymer 600ppm

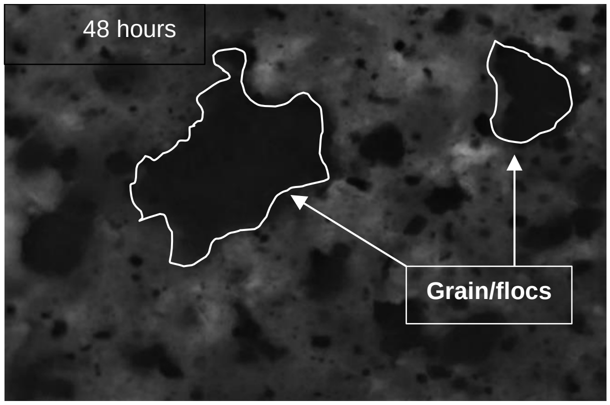


Figure 3.b: Optical Microscopic Image for, 48-hour Sample dozed with Anionic polymer "600ppm."

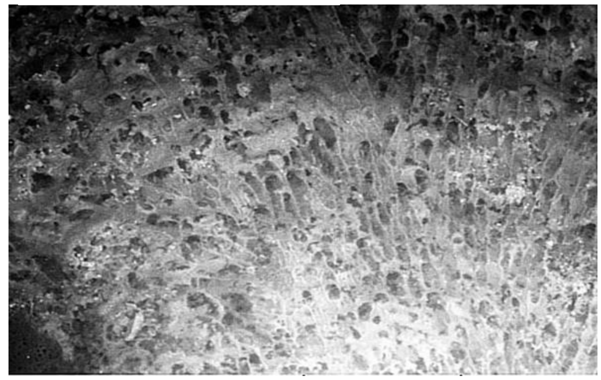
4 IMAGE TREATMENT

All images were treated in the adobe photoshop 2016, as well as in Fiji Image J, (Ferreira and Rasband, 2012). Images were treated as follows

1. Setting the scale. Images produced from both SEM and optical microscopy were pixel based, these pixels were converted from 64 bits to 8 bits to create photorealistic images, which would be easy for analysis and scaled into 1.0202 pixels/ µm. The conversion of pixels into "µm" was to tell the software, what pixel represent in real world terms of size or distance (spatial calibration).
2. Filters were applied to remove high and low spatial frequencies. After considerable trial and error, it was decided to apply consistent filters to all images. Results of images after filtering are shown in Figure 4, (A-B) and Figure 5 (C-D) for optical microscopy.
3. Application of Weka Segmentation. Weka segmentation is a Fiji plugin, where collection of machine learning algorithms is combined with the group of chosen features of images, to produce, pixel-based segmentations, in our case, to separate grains and pores on several images, the boundaries of grains are manually outlined. This information was then used to train the segmentation tool by machine learning, (Ferreira and Rasband, 2012), which is then subsequently applied to all images.
4. Blurry portions in the segmented images were removed using thresholding. As thresholding can affect the image properties, it was attuned properly to remove only unwanted frequencies. Following the procedure developed in Mizani (2016), thresholding can be guided in an unbiased way by analyzing the rate of change of particle mass capture versus threshold. Mizani (2016) found that identifying a minimum in the rate of mass change function could be used to threshold in an unbiased way. After thresholding in each pixel, the images were converted to either black or white, where black, corresponds to 0, and 255 for white to generate a binary image.

Figure 6 A to D, SEM and Figure 7 Optical microscope images a.1 to e.1 illustrates detail and step wise results attained through image processing using Image J for the 28-day SEM images, and the 48 hours optical microscope images.

28-days SEM image "A"



72-days SEM image "B"

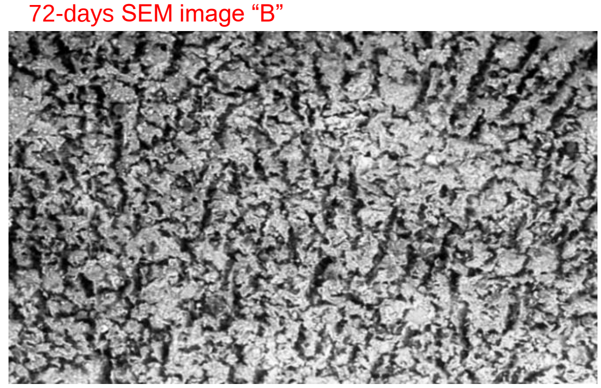
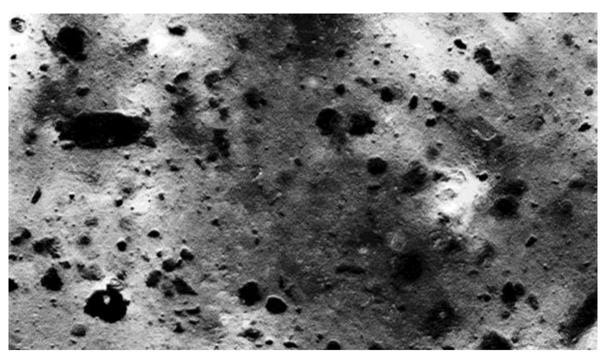


Figure 4: A to B treated image results for SEM images 28 days and 72 days using Image processing tools

1-hour O.M image "C"



48- hours O.M image “D”

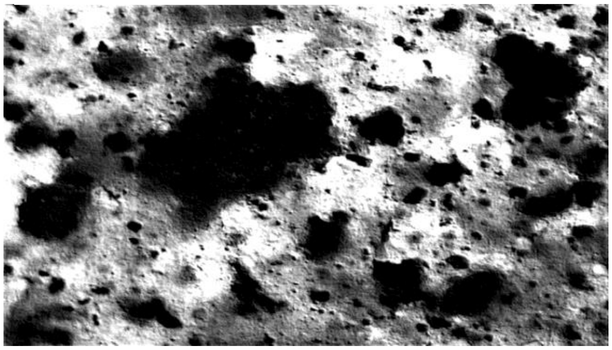
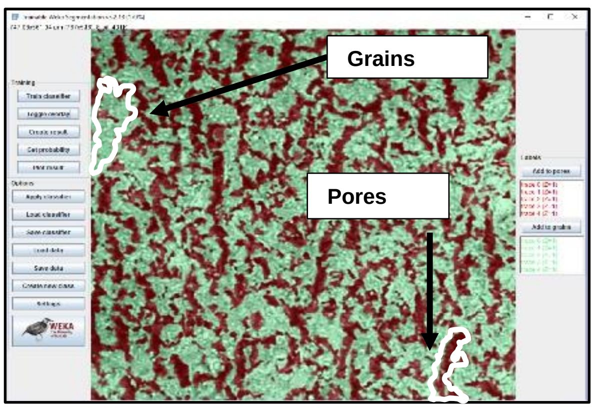
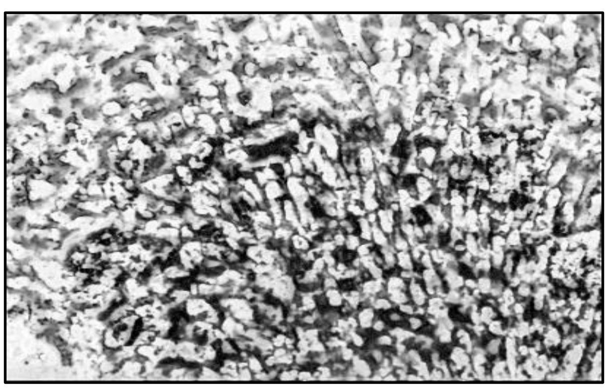


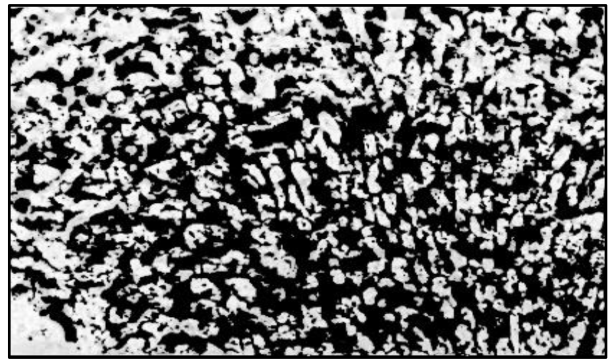
Figure 5: C TO D Treated Optical Microscopic Images for 1 hour and 48 hour using Image processing tools.



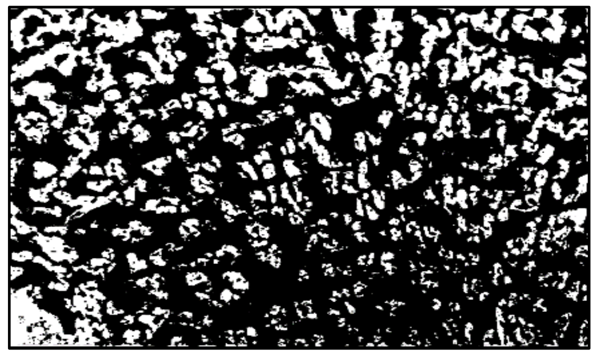
A (weka segmentation)



B

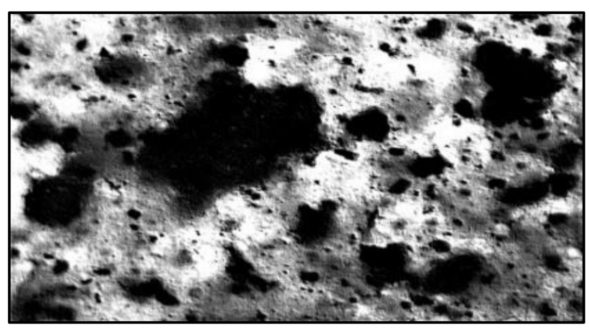


C

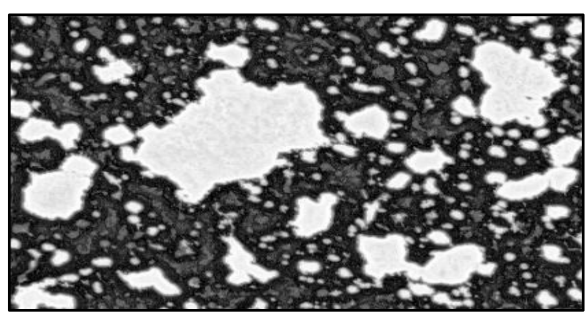


D

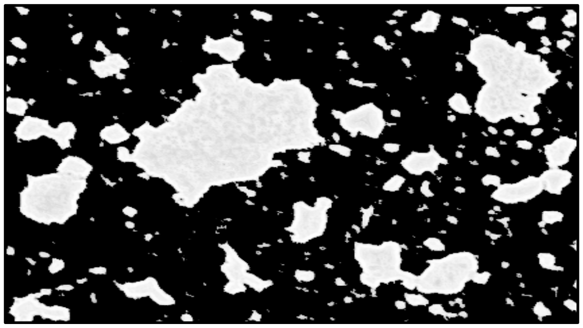
Figure 6: (A) Segmentation of Image using Trainable weka segmentation, white grains, black pores (B),Generation of Probility Image Pores specifically; (C),Threshold Image removed unwanted Frequencies; (D),Image converted into Binary Image after thershoulding



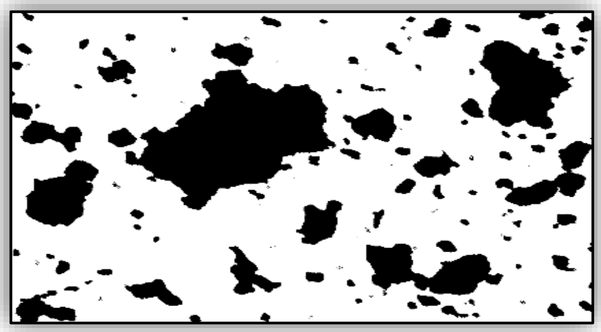
a.1



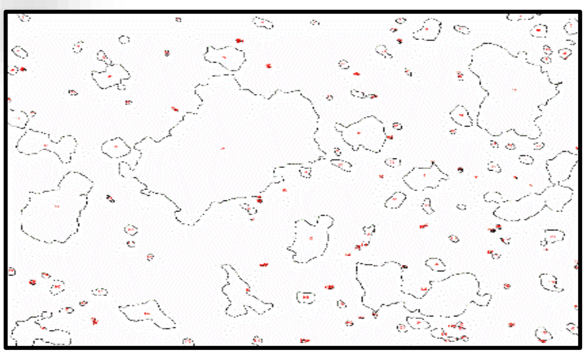
b.1



c.1



d.1



e.1

Figure 7: (a.1) 48 hour treated optical microscope image; (b.1) Production of Probility Image; (c.1) Thershoulded image removed unwanted Frequencies; (d.1) Thershoulded image converted into binary; (e.1) Flocs count of the 48 hour image

5 DIGITAL IMAGE ANALYSIS

Areas, perimeter, pore and grain number, circularity of pores and grains, and image porosity were calculated using built in algorithms in the “FIJI Image J” software, the following analysis are presented in this paper: (1) Total number of pores/grains with time for each day’s sample. (2) Total image porosity with time. (3) Pore diameter histogram with time. (4) Change in the cumulative average grain diameter.

6 RESULTS AND DISCUSSION

6.1 SEM Images, Pore and Grains analysis.

As shown in Figure 8, the total number of pores and grains decreases with time. This decline in pores number can be attributed to the growth of flocs during flocculation and/ or -squishing of the flocs together. As in Figures 9 and 10, more detailed analysis of pore sizes distribution shows that most changes are dominated by changes in the lowest of sizes (<10 microns). Figure 11 shows examples of SEM images at 7 and 28 days that seem to reflect the observed trend of decreasing the frequency of the smallest pores and grains suggested by the quantitative analysis.

The calculated image porosity is shown in Figure 12 with replicate images at each time. The image porosity shows a declining trend from about 28-34% to 22-23%. The real porosity of the samples changed from 83 to 67% over the same time frame. Note: that the porosity of any image of granular media is always substantially reduced compared to the 3D porosity (Marcelano. v et al 2007). These all results show a decreasing number but increasing size of pores and grains with time. This might be due to an ongoing process of floc growth.

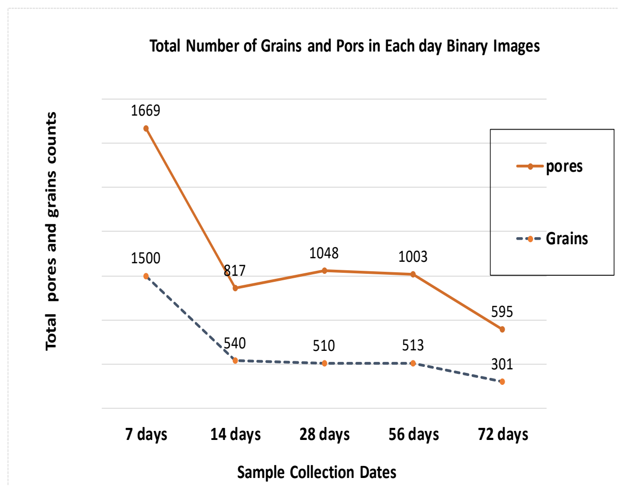


Figure 8: Total counts of grains and pores from single image for different days sample

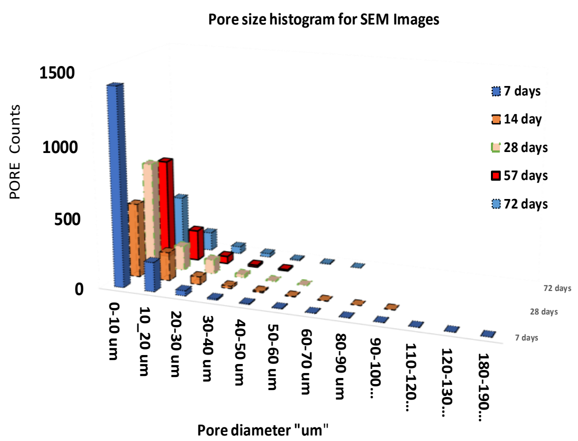


Figure 9: Pore diameter histogram for different date SEM images.

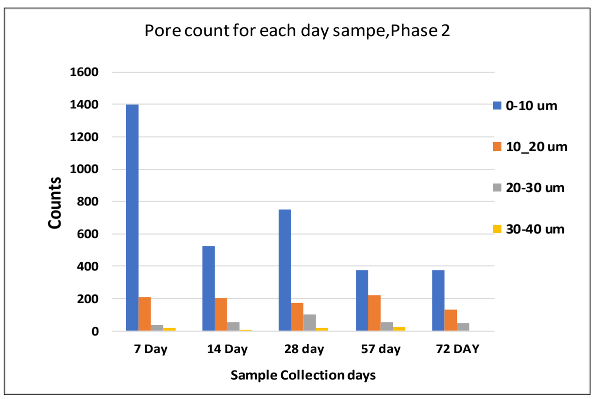
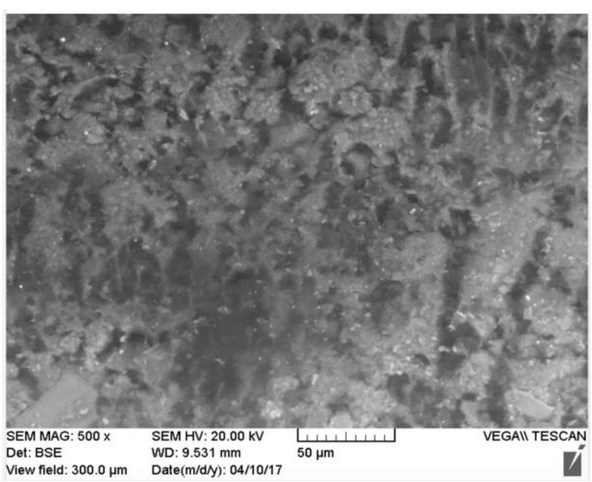


Figure 10: Pore count from 0-40 um in each day SEM image



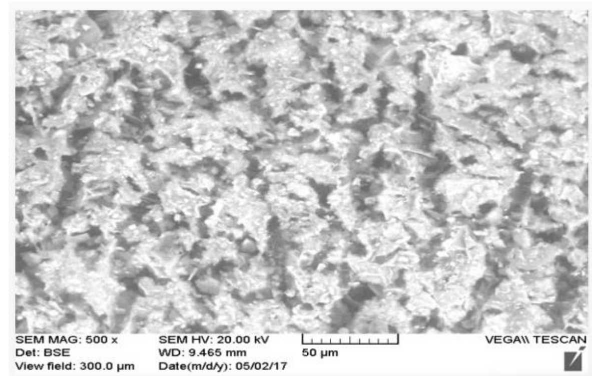


Figure 11: Day 7(top) and Day 28 (bottom) raw SEM images

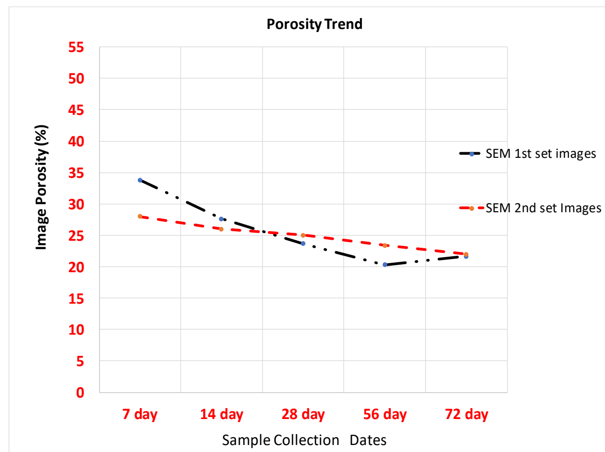


Figure 12: Trends in image porosity in SEM images

6.2 Optical microscopic images

The total number of flocs, and floc size distribution were analyzed over 48 hours in O.M images. After this time usable images could not be obtained due to the opaqueness of the samples.

The average floc diameter is shown Figure 13, showing data for two images captured at each time and shows a generally increasing trend with time. However, there are samples which show a decrease in average diameter between 8 to 24 hours. This may be due to settlement and segregation of the large flocs, but at this time this is only speculation. Interestingly in Figure 14, the size of flocs ranging between 0-10 µm initially increases up to 24 hours sample, after that a decreasing trend in 48 hours. This may be caused by ongoing flocculation, as previously invisible small particles combine to form an evident floc, some of which combines to become much larger flocs as in Figure 7 (d.1 thresholded image converted into binary image). A large change in the total area of solid material from 24 to 48 hours was also observed.

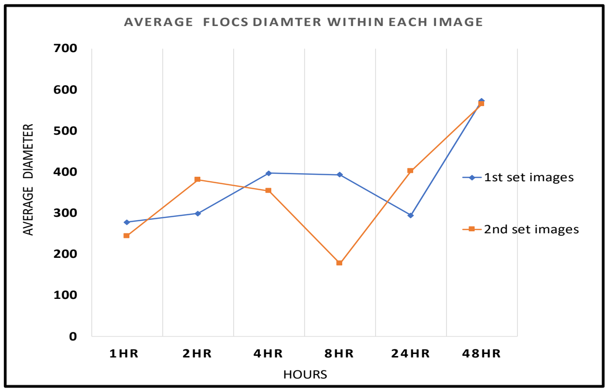


Figure 13 Average diameter of flocs mass in each day sample image

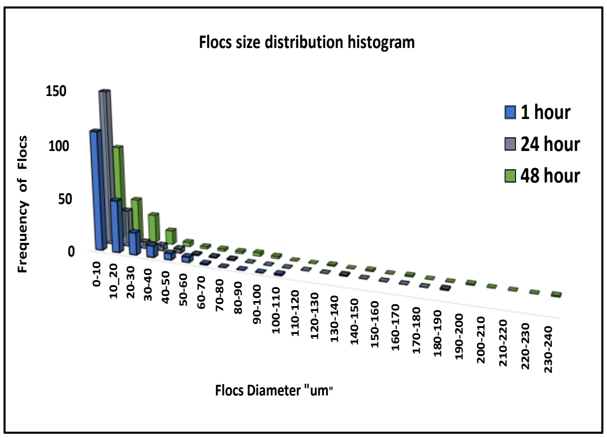


Figure 14: Flocs Count, Distribution Histogram for different date optical microscopic images

7 CONCLUSION

Analysis of both optical and SEM images suggest fabric changes over both short and long-time scales in the studied tailings. The optical microscopy shows quite clearly an increase in floc size in the 48 hours after sample preparation. The SEM images also suggest some ongoing fabric changes over days to weeks. These results are now being used to generate simple 3D visualizations of tailings geometry at microscopic scale, from which it is hoped that further insights on these tailings dewatering behavior can be found.

ACKNOWLEDGEMENTS.

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