

## **APPENDIX A**

### **SUPPLIER RECOMMENDED FIELD APPLICATION RATES**

Supplier recommendations for stabilizer dilution and application rates, for typical field applications, are documented in this appendix. Appropriate dilution and application rates for sample preparation in this study were selected based on these reported values. Supplier recommendations were extracted from assorted literature on each product, which was collected by TxDOT personnel and the research team. Information is given only on the three products evaluated in this study, which are not identified by name (see Chapter 2). Specific citations to the sources of this information are not given in order to avoid identifying the specific products evaluated.

The dilution and application rates discussed here were not tailored to the specific soils tested in this study. Rather, an attempt was made to identify the usual dilution and application rates suggested by the suppliers for routine use of their products.

**IONIC STABILIZER**

***Dilution Rate:***

<i>Recommended Dilution Rate</i>	<i>Equivalent Volumetric Ratio</i>
1 gallon concentrate per 200 gallons of water up to 1 gallon concentrate per 400–500 gallons of water	1:200 to 1:500
Mix 300:1 solution (water to product concentrate)	1:300
1 gallon should be mixed with 350 gallons of water	1:350
Diluted at a ratio of 360 parts water to 1 part product	1:360
product at 1:500 (concentrate to water)	1:500
product at 1:220 (concentrate to water)	1:220

All dilution rates fall in the range of 1 gallon of concentrate per 200 to 500 gallons of water. The laboratory procedure provided by the manufacturer suggests a dilution ratio of 1:300. This value is similar to two other dilutions suggested.

Conclude: **Volumetric dilution of 1 to 300 is typical.**

***Application Rate:***

<i>Recommended Application Rate</i>	<i>Equivalent Rate (gal:yd<sup>3</sup>)</i>
1 gallon of product, when diluted, treats 30 yd <sup>3</sup> of soil	1:30
1 gallon product to 33 cubic yards of base material	1:33

The 1:33 application rate is given in a letter not originating from the product's manufacturer and in an untitled set of specifications. The 1:30 rate is noted in the manufacturer's application guidelines, as well as two other sets of installation instructions contained in the manufacturer's literature.

Conclude: **Application rate of 1 gallon product to 30 cubic yards of soil is typical.**

## ENZYME STABILIZER

### *Dilution Rate:*

<i>Recommended Dilution Rate</i>	<i>Equivalent Volumetric Ratio</i>
1 fluid ounce concentrate per gallon water	1:128
1 gallon concentrate per 1,000 gallons of water	1:1,000
1 gallon concentrate per 10,000 gallons of water	1:10,000
1 gallon concentrate per 4,000 gallons of water	1:4,000
1 gallon concentrate per 500 gallons of water (minimum dilution)	1:500
1 cm <sup>3</sup> concentrate per 5 L of water	1:5,000

A ratio of 1:500 is listed as the minimum dilution rate by volume required to ensure penetration of the stabilizer through the soil. The 1:128 value therefore seems unreasonable. The extreme value of 1:10,000 is mentioned repeatedly in terms of dust suppression and as a means of adding water to soil that is too dry. The manufacturer's literature stated that, as a general rule, a dilution of 1:1,000 should be used for dry soil. No definition of dry soil was given.

Conclude: **Volumetric dilution of 1 to 1,000 is typical.**

### *Application Rate:*

<i>Recommended Application Rate</i>	<i>Equivalent Rate (gal:yd<sup>3</sup>)</i>
1 gallon of product diluted with the required amount of water needed to bring 165 yd <sup>3</sup> of material up to optimum moisture (1L per 33 cubic meters)	1:165
0.004 fluid ounce concentrate per gallon of aggregate mix (assume $\gamma_d = 100$ pcf)	1.04:165
8 gallon concentrate per surface acre (70L/hectare or 1 gallon for every 6000 ft <sup>2</sup> ) (assume 6 in. deep)	1:100.85

For the last entry the application described in the reference is for sealing the bottom of a pond as opposed to a roadbed application. The remaining two recommendations are in agreement with an application of 1 gallon of stabilizer to 165 cubic yards of soil.

Conclude: **Application rate of 1 gallon product to 165 cubic yards of soil is typical.**

## POLYMER STABILIZER

### *Dilution Rate:*

<i>Recommended Dilution Rate</i>	<i>Equivalent Volumetric Ratio</i>
1 gallon concentrate per 30 gallons of water	1:30
1 gallon concentrate per 24 gallons of water	1:24
1 gallon per 34 gallons of water	1:34

The range of dilution rates appears to be 1 gallon of concentrate diluted by 24 to 34 gallons of water. A dilution ratio of 1:30 falls within the middle of this range.

Conclude: **Volumetric dilution of 1 to 30 is typical.**

### *Application Rate:*

<i>Recommended Application Rate</i>	<i>Equivalent Rate (fluid oz:yd<sup>3</sup>)</i>
2 gallons of 1:30 volumetric dilution per square yard	56.7
1 gallon of 1:24 volumetric dilution per square yard (assume 6 in. deep)	30.7
1.0 to 1.75 fluid ounces per cubic foot of soil to be treated, mixed with the water necessary to achieve 3% over optimum moisture content	27 to 47.25
Product mixed with water can range from 0.05 to 0.075 gal/yd <sup>2</sup> . (assume 6 in. deep with a dilution of 1:30 by volume)	1.3 to 1.9
0.0023 gallon product solution diluted at 30:1 per cubic yard	0.3
25 cm <sup>3</sup> per 100 lbs dry soil (about 0.04 gallon/8 inches depth/yd <sup>2</sup> )	23.0

The rate of 1.0 to 1.75 fluid oz per ft<sup>3</sup> of soil came from a well-outlined procedure for application of this product. The range of 27 to 47.25 fluid oz of stabilizer per yd<sup>3</sup> also suggests that 23.0, 30.7, and 56.7 may be reasonable application rates per cubic yard. The two low values appear questionable; one is from a testing lab unconnected to the manufacturer, while the other required assumptions concerning the dilution ratio and the depth of stabilization. A mid-range value of 1.4 fluid oz per ft<sup>3</sup> seems justified. This is equivalent to 37.8 fluid oz per yd<sup>3</sup> or 1 gallon of concentrate per 3.39 yd<sup>3</sup>.

Conclude: **Application rate of 1 gallon product to 3.39 cubic yards of soil is typical.**

## APPENDIX B

### RESULTS FROM TESTS TO CHARACTERIZE CHEMICAL COMPOSITION OF STABILIZER PRODUCTS

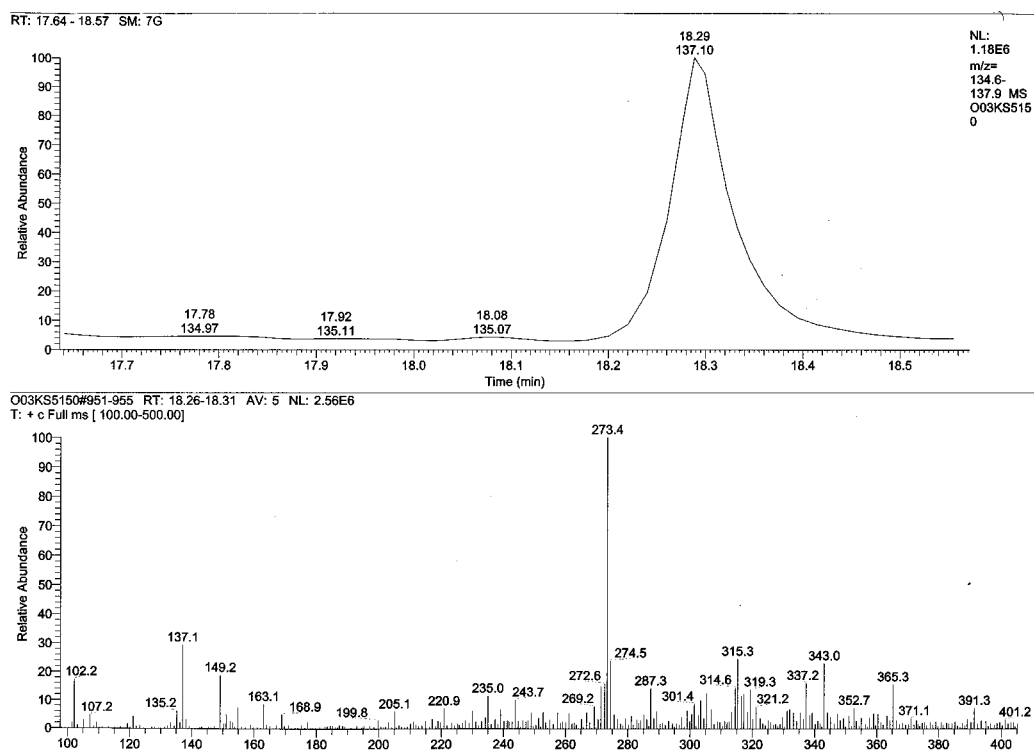


Figure B-1. HPLC/MS results for limonene

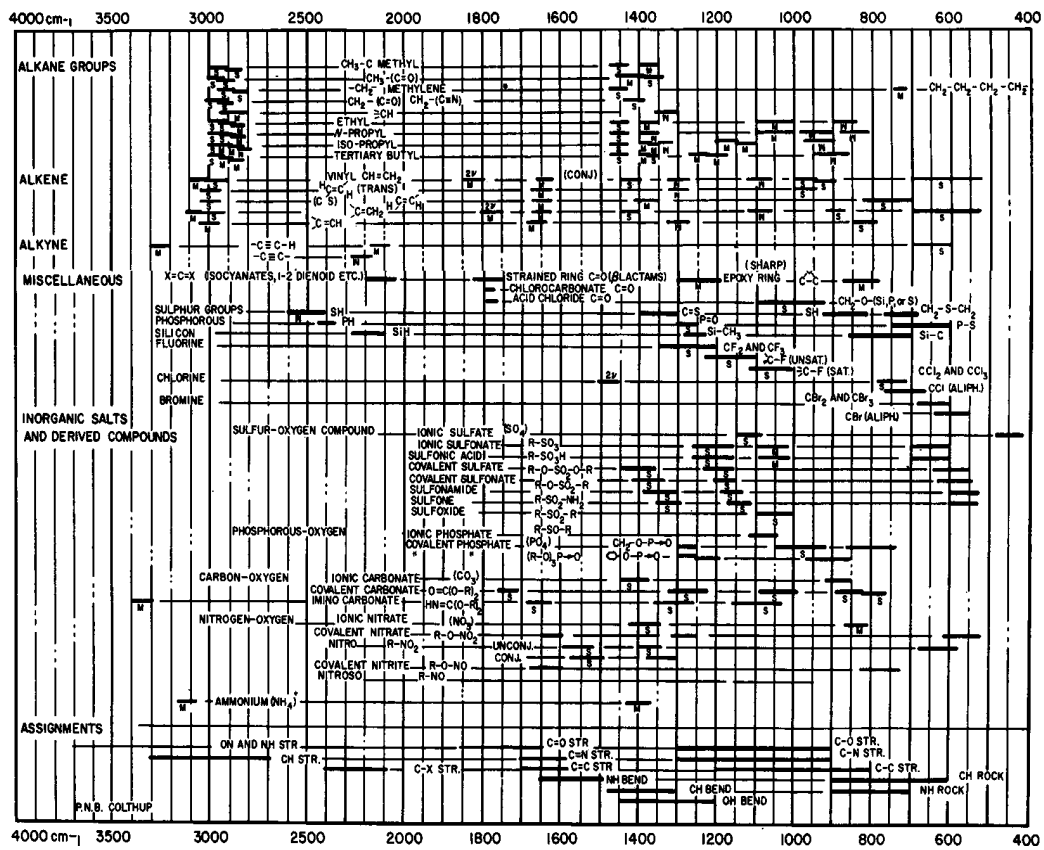
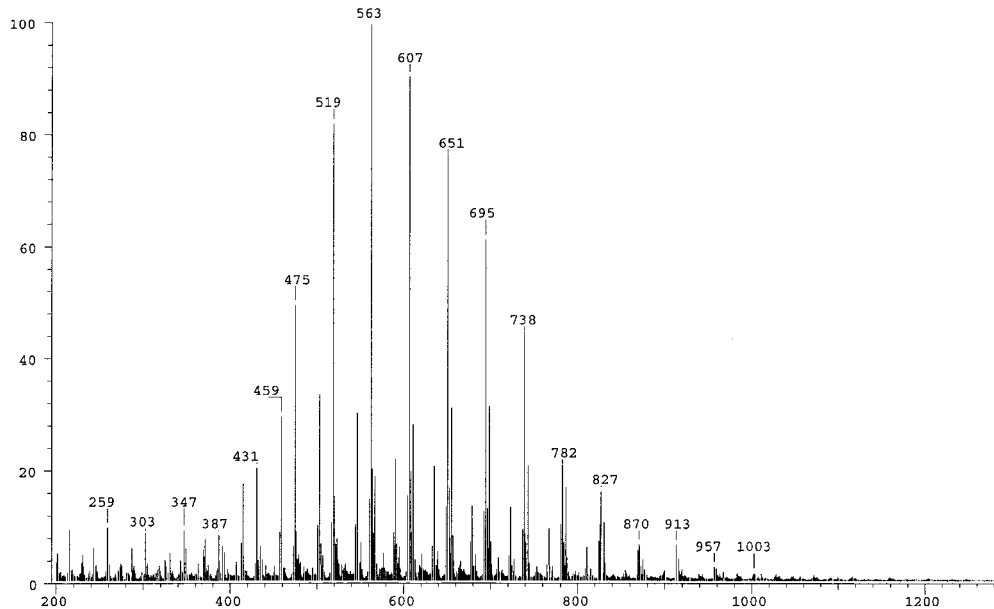


Figure B-2. Infrared absorbance for organic functional groups (from Klute 1986)

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 Samp: KSHAW/P22  
 Comm: Mass Spec Facility, Chem. & Biochem, UT Austin  
 Oper: rr Study: FAB/NBA Client:  
 Base: 562.87 Masses: 200.00 > 1999.98 #Peaks: 1837  
 Peak: 1000.0 mmu Intensity: 15567028 RIC : 384937976  
 REG #9 @ 0.26 min (FAB +Q3MS HMR UP LR) (/10>20) 1.6E+07



Date: Wed Dec 20 14:31:08 2000 ICIS: 8.3.0 SP1 for OSF1 (V4.0) build 97-324 from 20-Nov-97

Figure B-3. FAB results for the enzyme stabilizer

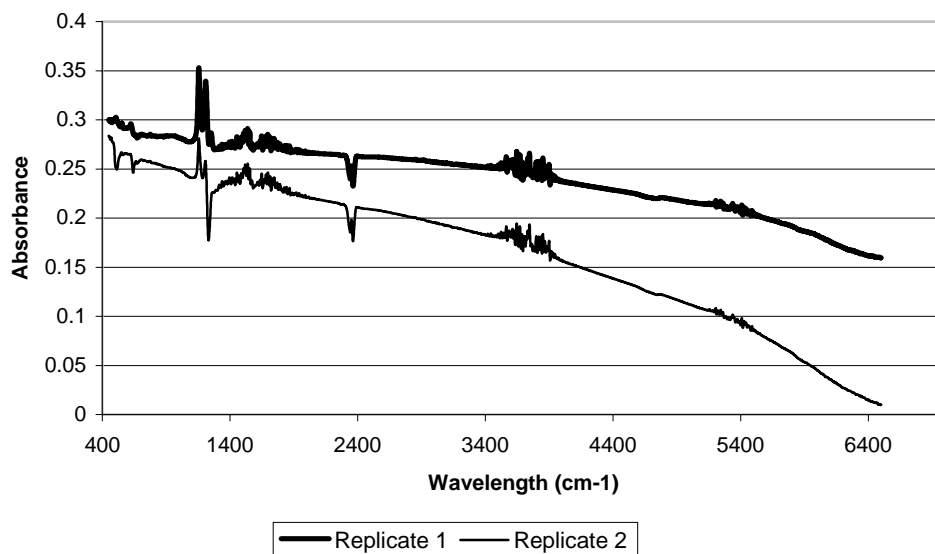


Figure B-4. FTIR results for polymer stabilizer

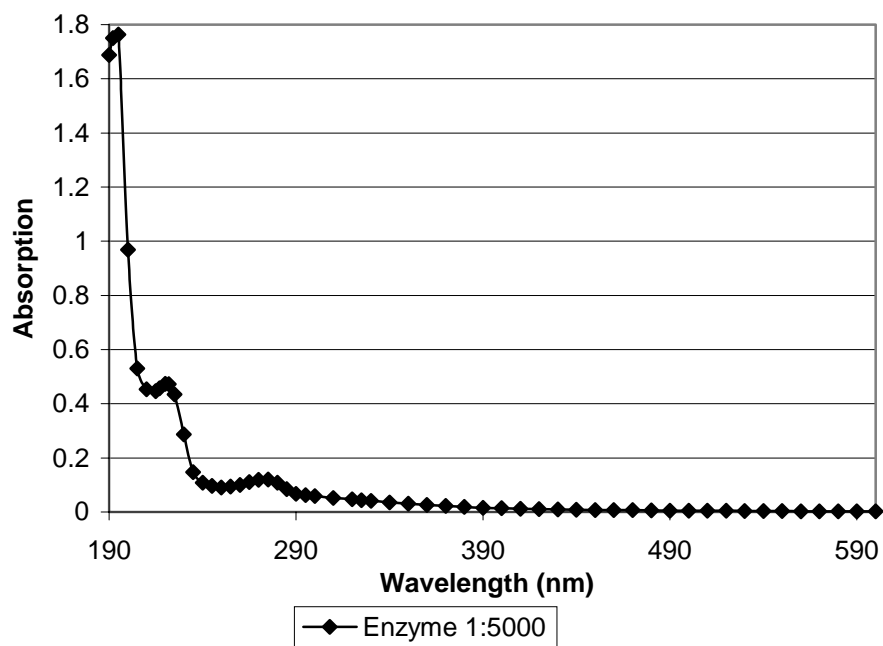


Figure B-5. UV/Vis spectroscopy results for enzyme stabilizer at 1:5000 dilution

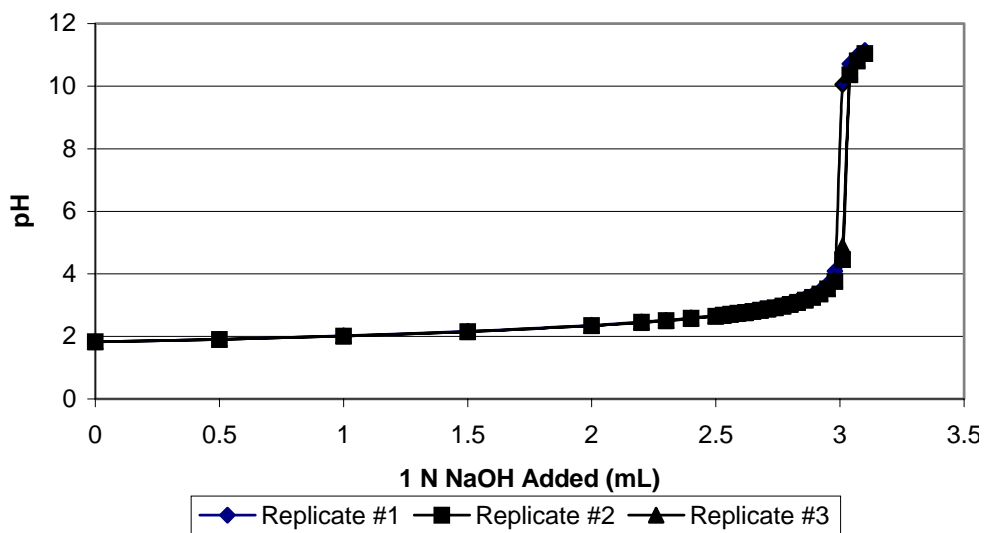


Figure B-6. Titration replicates for ionic stabilizer



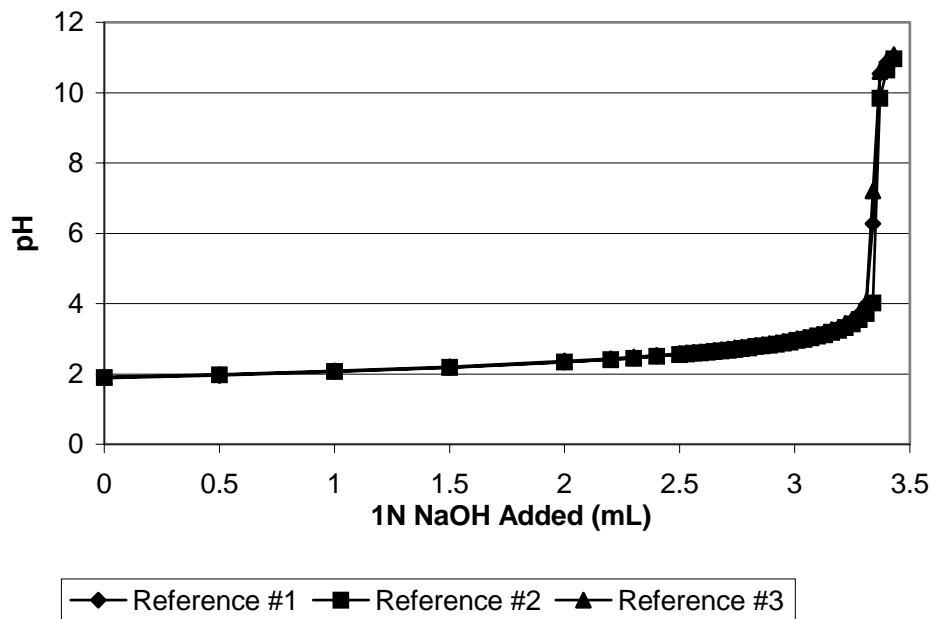


Figure B-7. Titration replicates for sulfuric acid

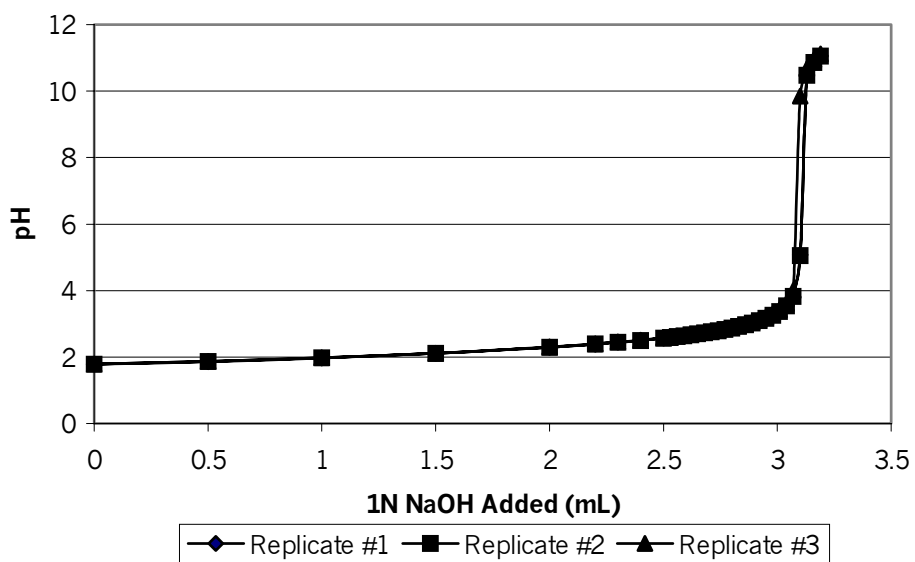


Figure B-8. Titration replicates for sulfonated limonene

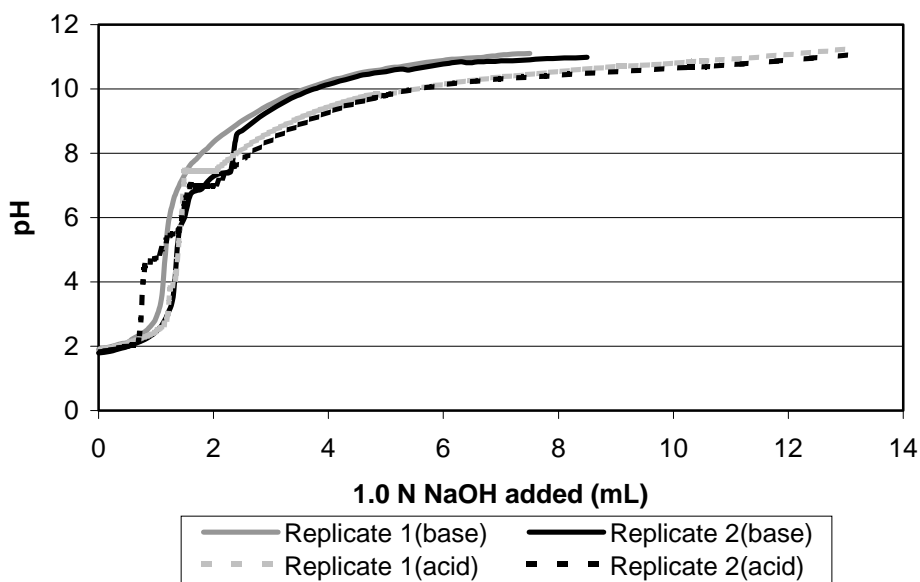


Figure B-9. Titration replicates for polymer stabilizer

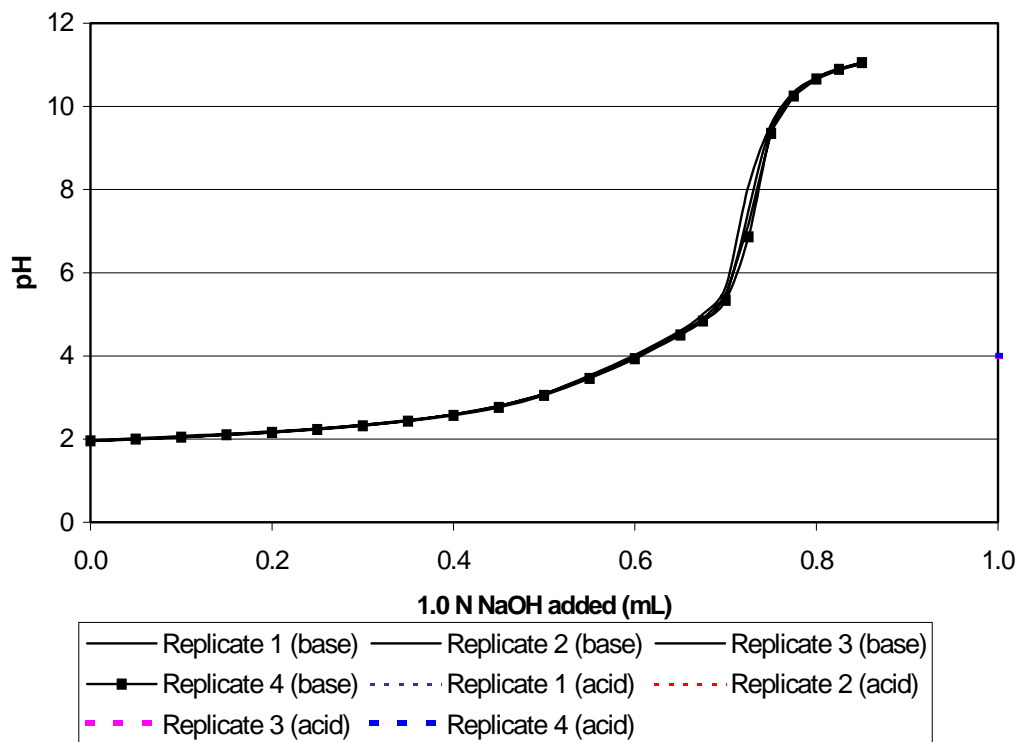


Figure B-10. Titration replicates for enzyme stabilizer

## APPENDIX C

### BET PORE SIZE DISTRIBUTION COMPARISONS

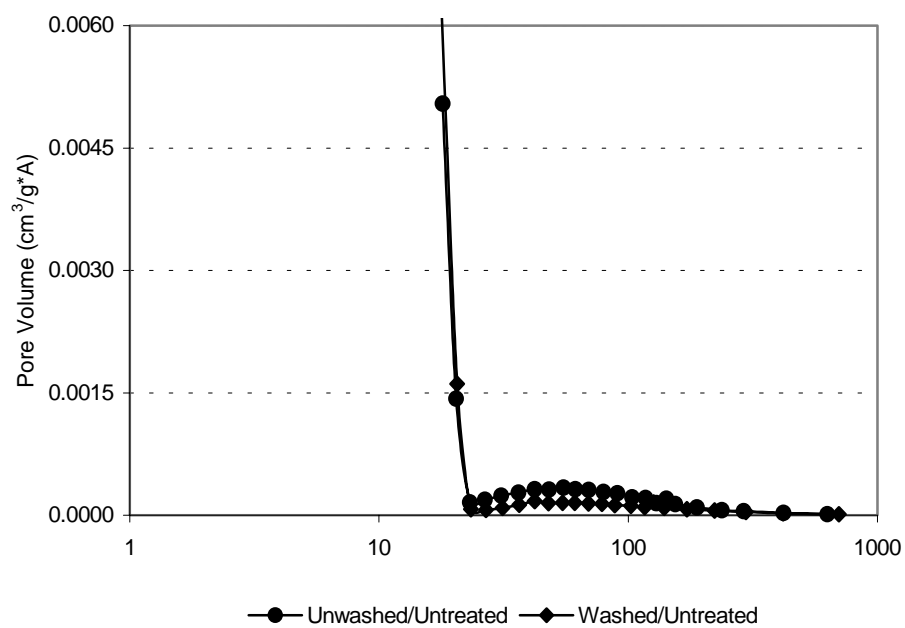


Figure C-1. Pore size distribution comparison for washed/untreated and unwashed/untreated samples of sodium montmorillonite

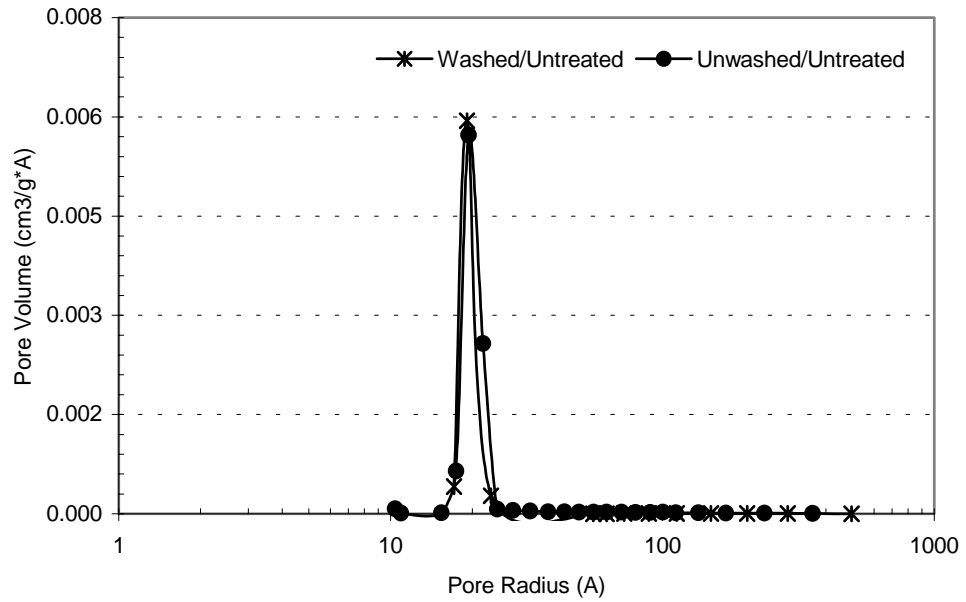


Figure C-2. Pore size distribution comparison for washed/untreated and unwashed/untreated samples of Bryan soil

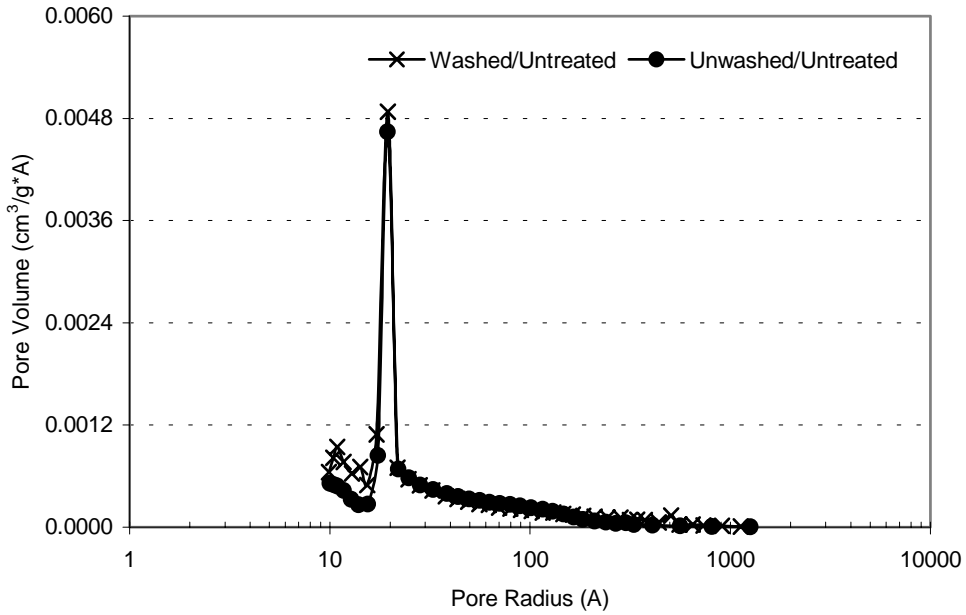


Figure C-3. Pore size distribution comparison for washed/untreated and unwashed/untreated samples of Mesquite soil

## **APPENDIX D**

### **ESEM IMAGES**

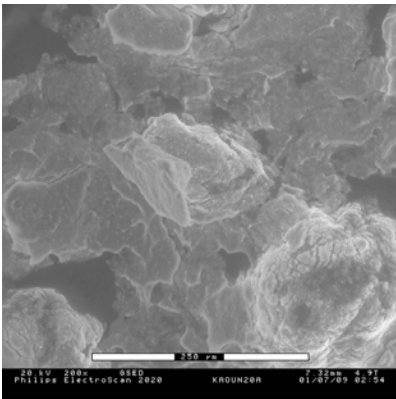
This appendix presents ESEM images of untreated and treated samples obtained at 200×, 7,000×, and 14,500× magnifications. The appendix is subdivided according to the soil type:

- Appendix D.1. ESEM images of kaolinite
- Appendix D.2. ESEM images of illite
- Appendix D.3. ESEM images of sodium montmorillonite
- Appendix D.4. ESEM images of Bryan soil
- Appendix D.5. ESEM images of Mesquite soil

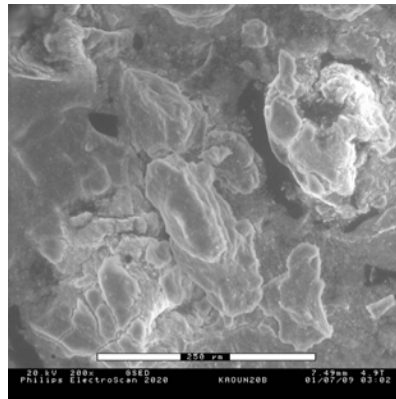
Furthermore, the ESEM images are organized by magnification. Images are presented at the specified magnification for the untreated samples, then for the samples treated with the ionic stabilizer, polymer stabilizer, enzyme stabilizer, and sulfuric acid. Triplicate results, designated A, B, and C, are reported for each soil and treatment combination.



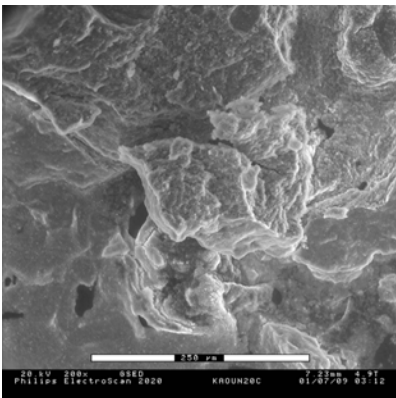
Appendix D.1. ESEM images of kaolinite



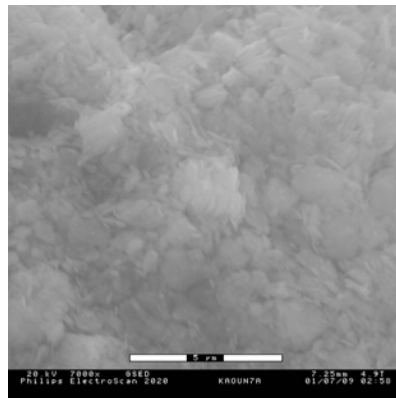
Untreated  
Kaolinite at 200x-A



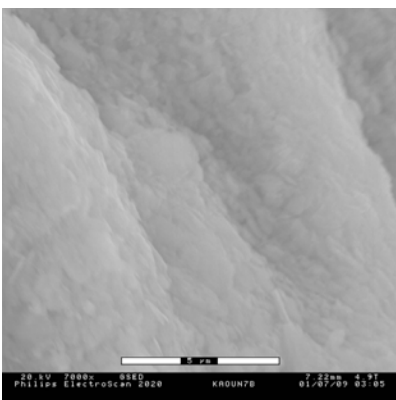
Untreated  
Kaolinite at 200x-B



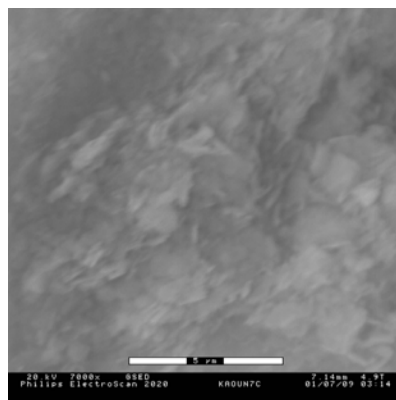
Untreated  
Kaolinite at 200x-C



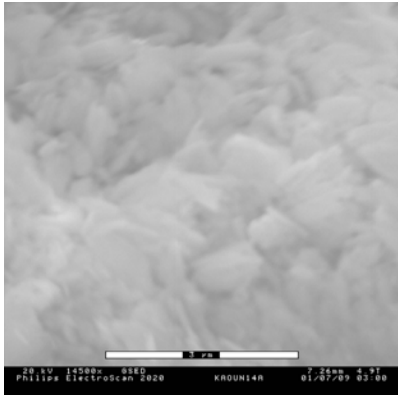
Untreated  
Kaolinite at 7000x-A



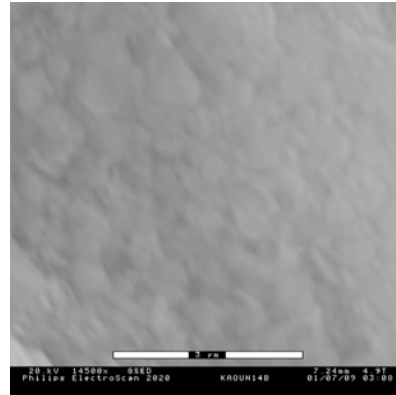
Untreated  
Kaolinite at 7000x-B



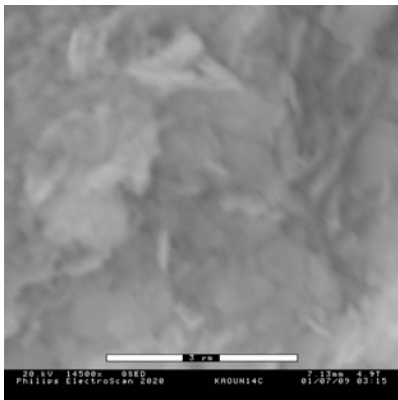
Untreated  
Kaolinite at 7000x-C



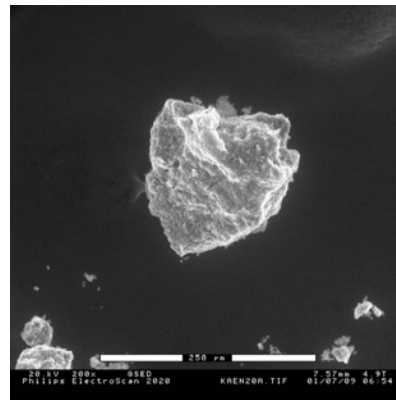
Untreated  
Kaolinite at 14500x-A



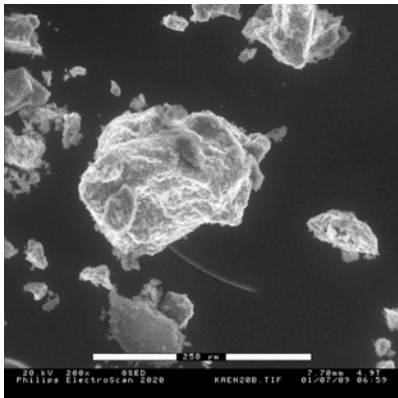
Untreated  
Kaolinite at 14500x-B



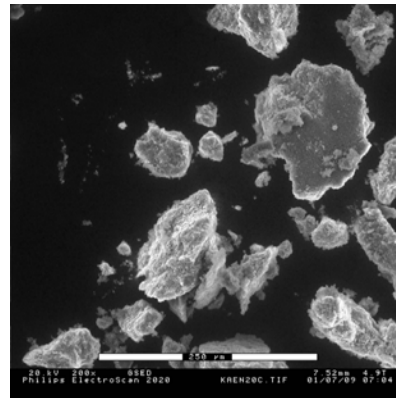
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Ionic Stabilizer Treated  
Kaolinite at 200x-A

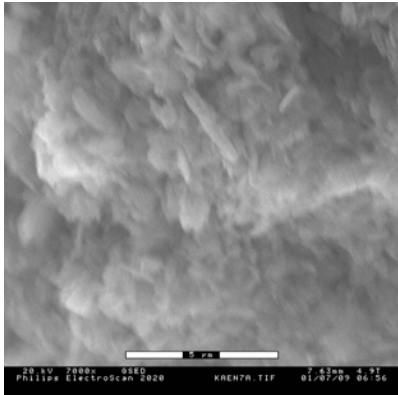


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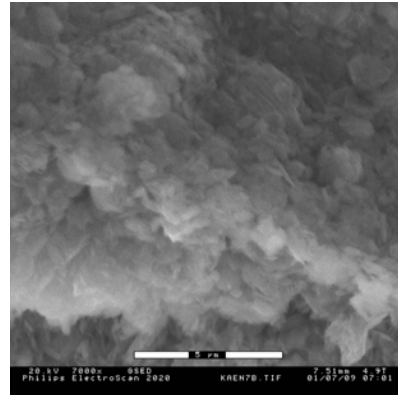


Ionic Stabilizer Treated  
Kaolinite at 200x-C

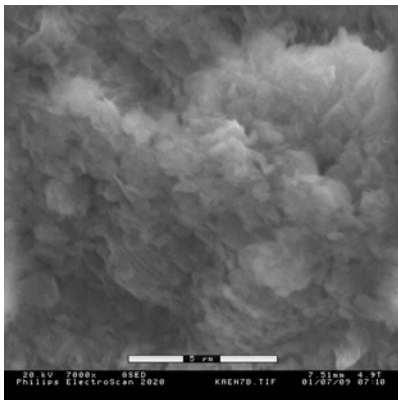




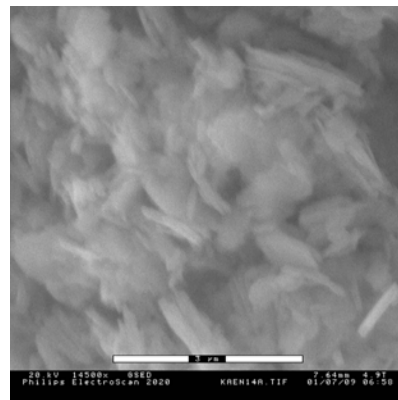
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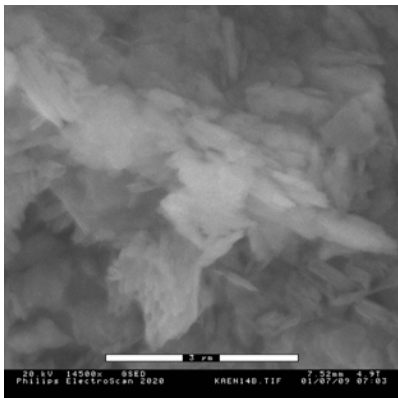
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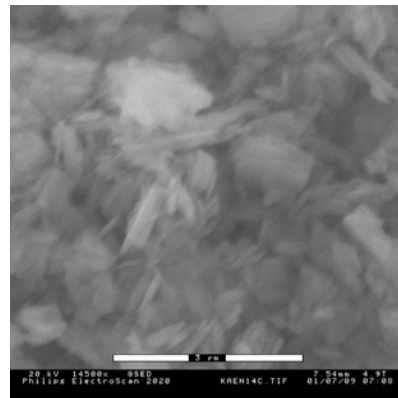
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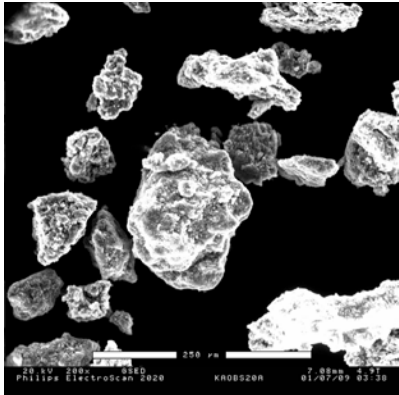
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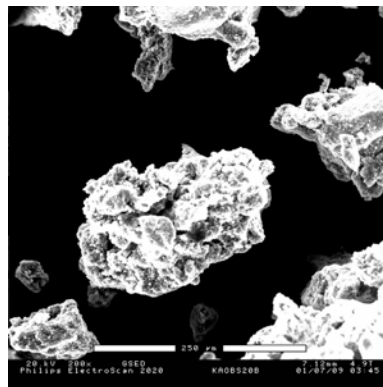
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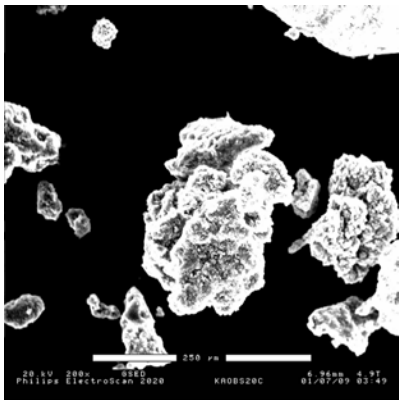
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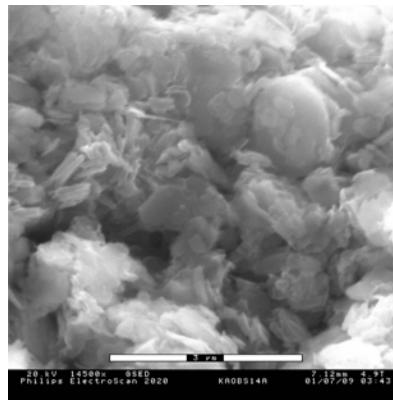
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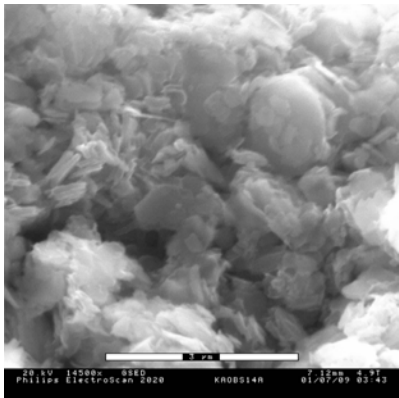
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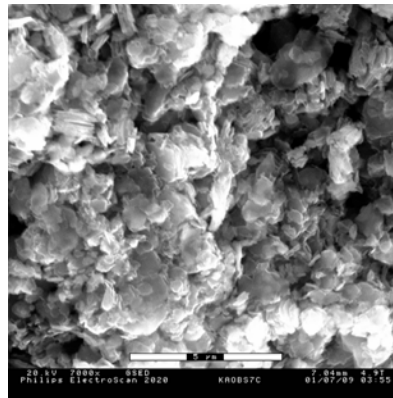
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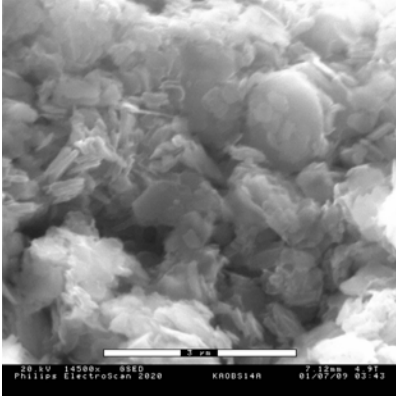
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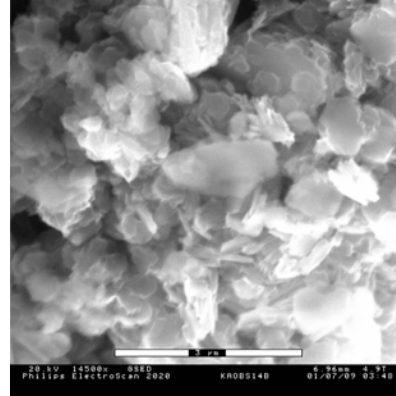
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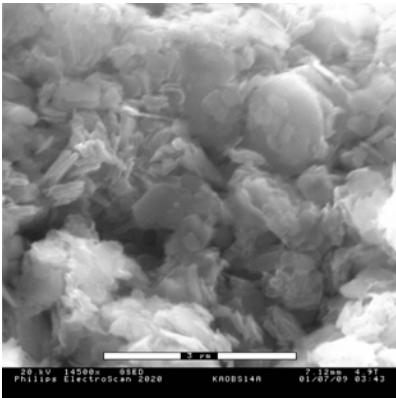
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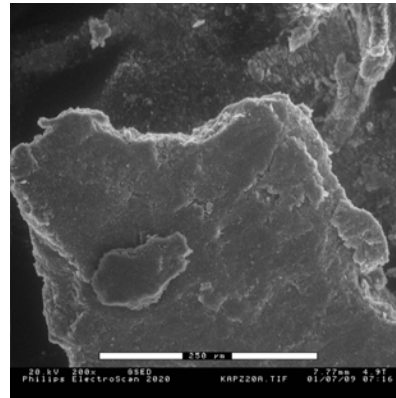
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Kaolinite at 14500x-A



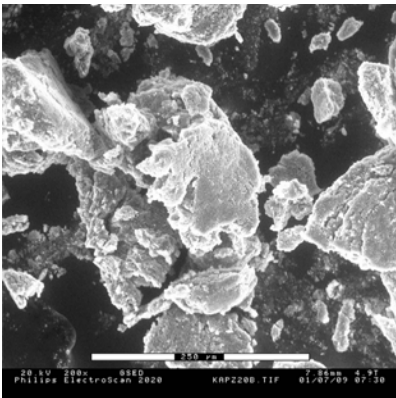
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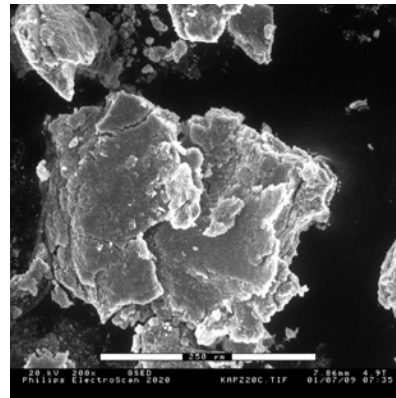
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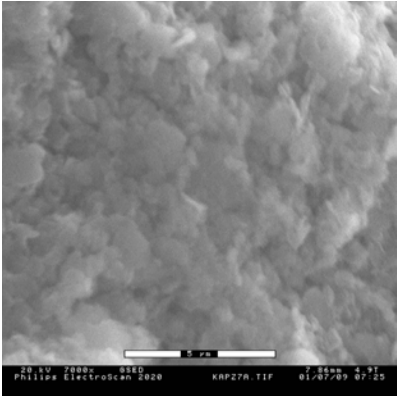
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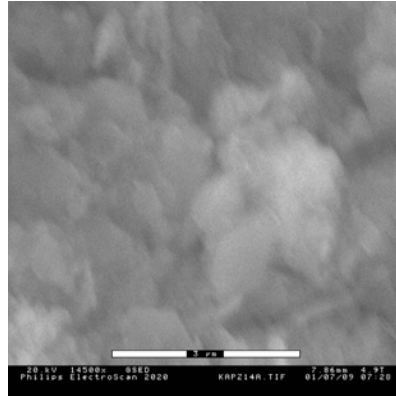
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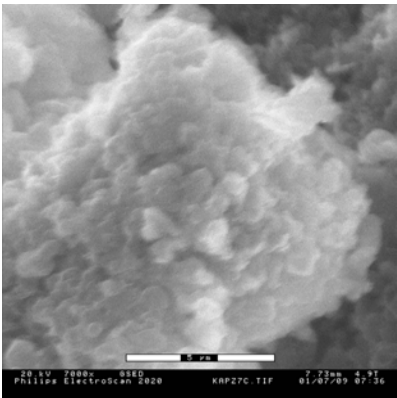
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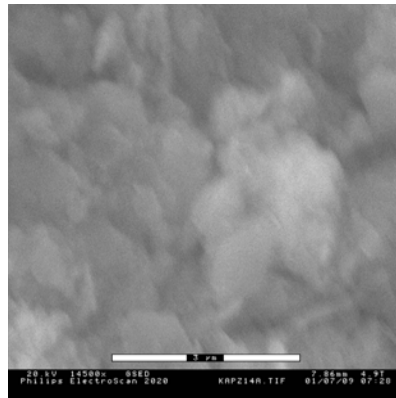
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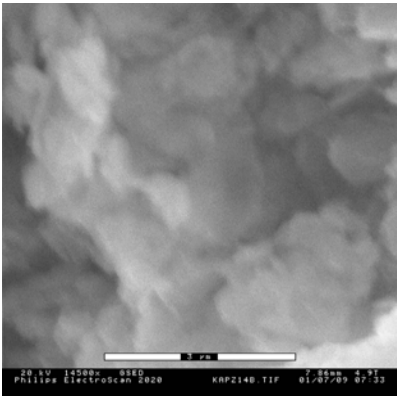
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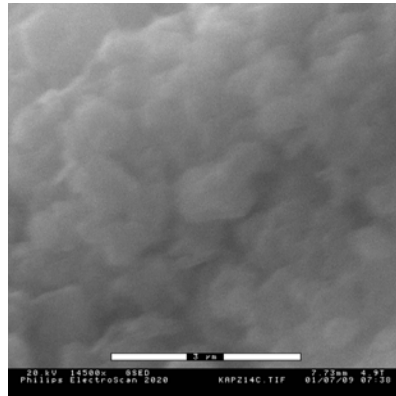
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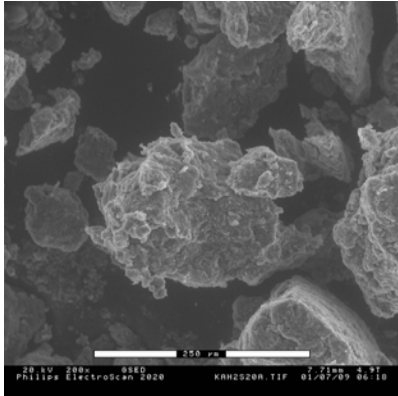
Enzyme Stabilizer Treated  
Kaolinite at 14500x-A



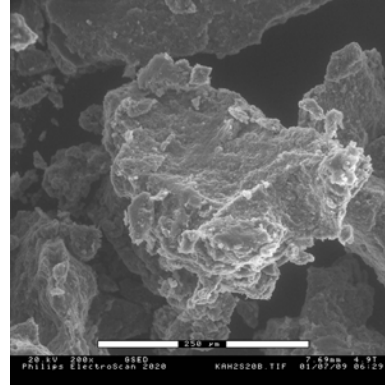
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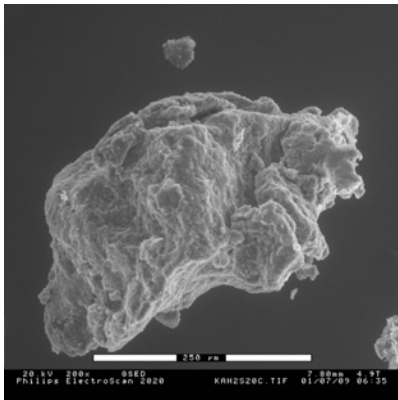
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Kaolinite at 14500x-C



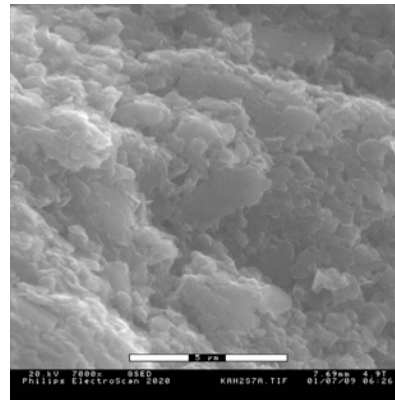
Sulfuric Acid Treated  
Kaolinite at 200x-A



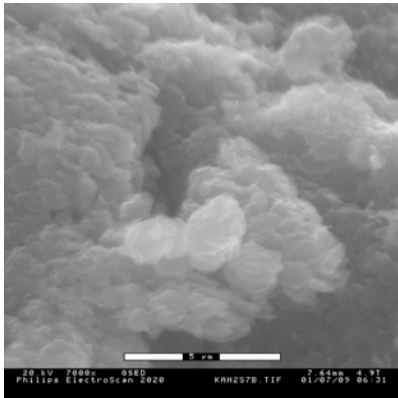
Sulfuric Acid Treated  
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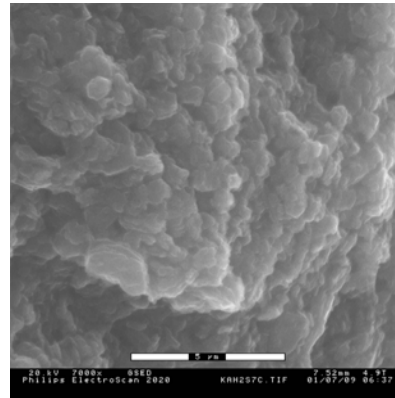
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Kaolinite at 200x-C



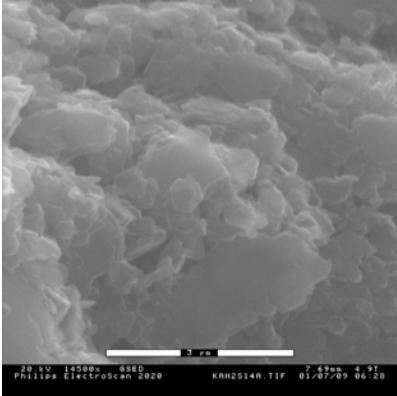
Sulfuric Acid Treated  
Kaolinite at 7000x-A



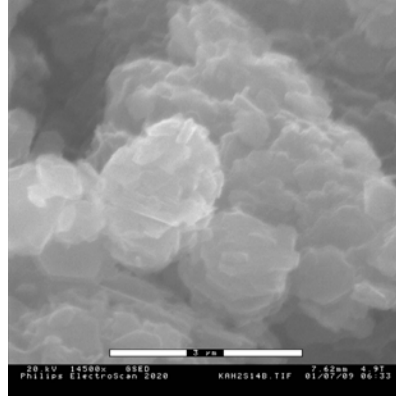
Sulfuric Acid Treated  
Kaolinite at 7000x-B



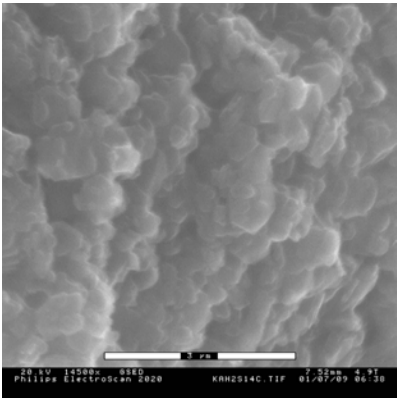
Sulfuric Acid Treated  
Kaolinite at 7000x-C



Sulfuric Acid Treated  
Kaolinite at 14500x-A

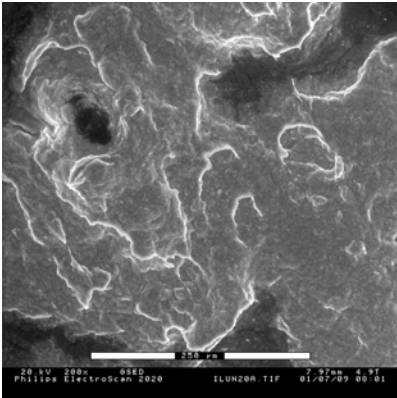


Sulfuric Acid Treated  
Kaolinite at 14500x-B

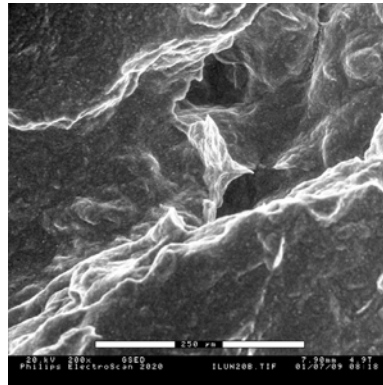


Sulfuric Acid Treated  
Kaolinite at 14500x-C

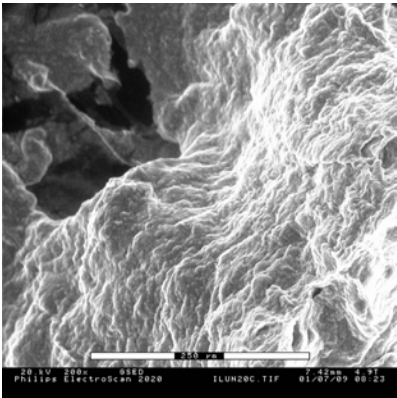
Appendix D.2. ESEM images of illite



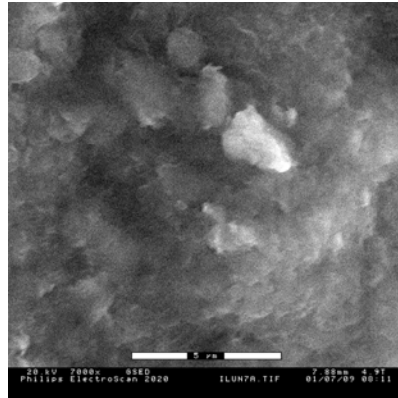
Untreated  
Illite at 200x-A



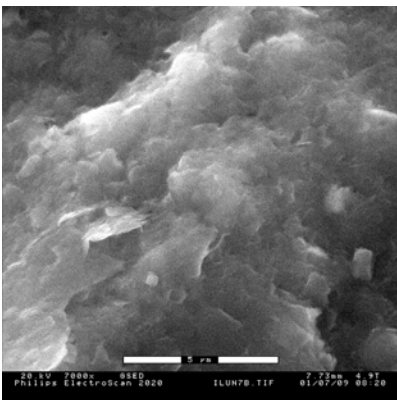
Untreated  
Illite at 200x-B



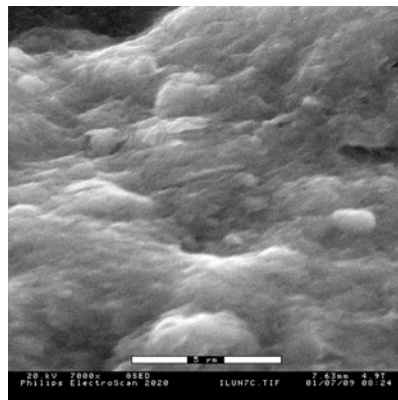
Untreated  
Illite at 200x-C



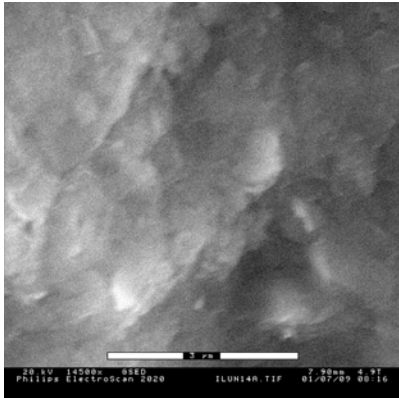
Untreated  
Illite at 7000x-A



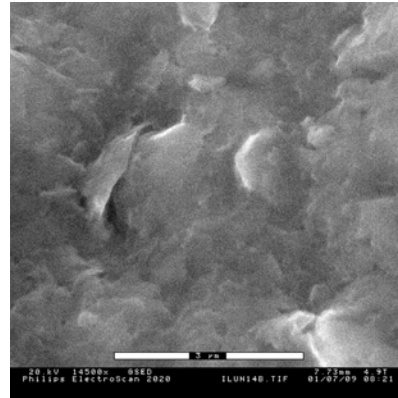
Untreated  
Illite at 7000x-B



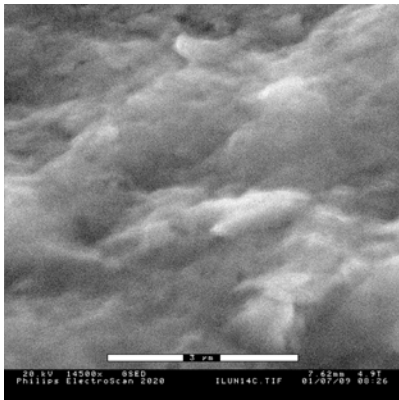
Untreated  
Illite at 7000x-C



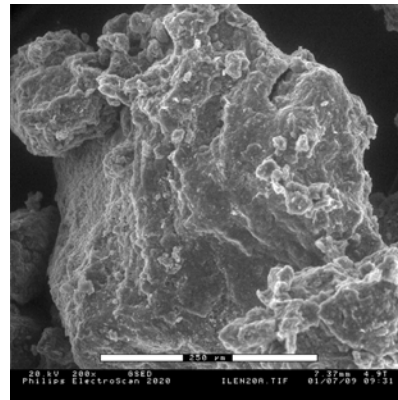
Untreated  
Illite at 14500x-A



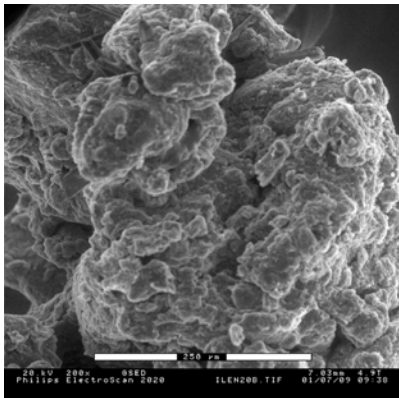
Untreated  
Illite at 14500x-B



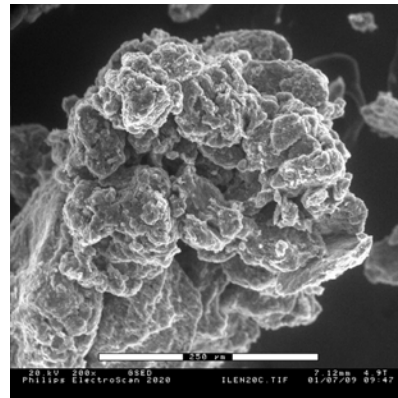
Untreated  
Illite at 14500x-C



Ionic Stabilizer Treated  
Illite at 200x-A

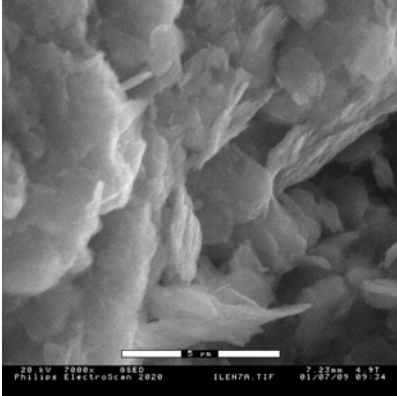


Ionic Stabilizer Treated  
Illite at 200x-B

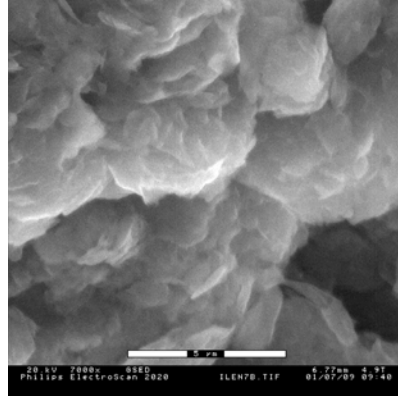


Ionic Stabilizer Treated  
Illite at 200x-C

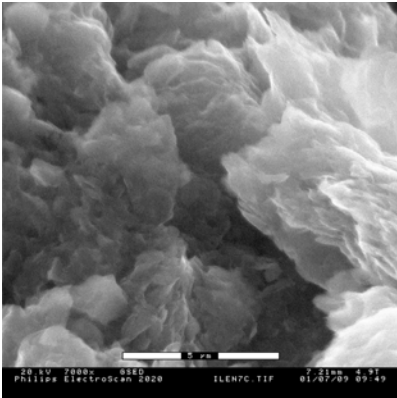




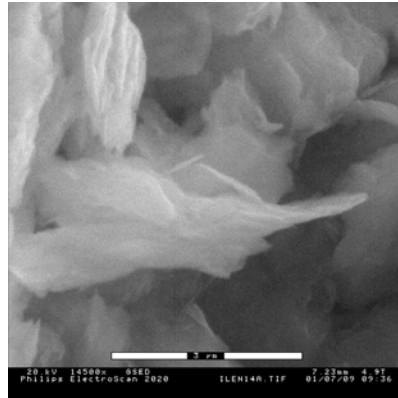
Ionic Stabilizer Treated  
Illite at 7000x-A



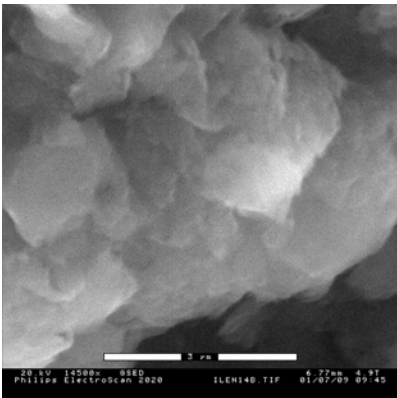
Ionic Stabilizer Treated  
Illite at 7000x-B



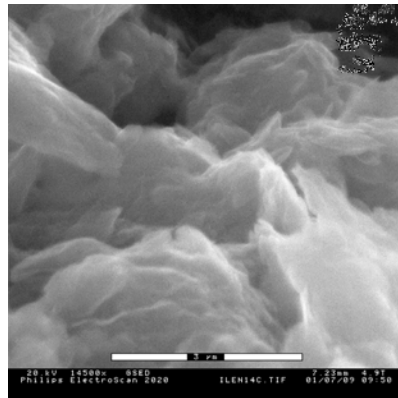
Ionic Stabilizer Treated  
Illite at 7000x-C



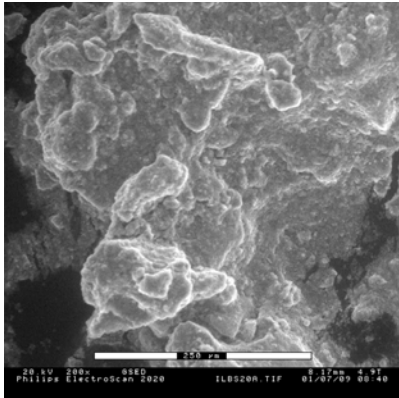
Ionic Stabilizer Treated  
Illite at 14500x-A



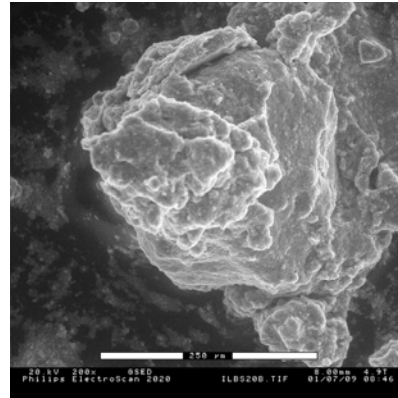
Ionic Stabilizer Treated  
Illite at 14500x-B



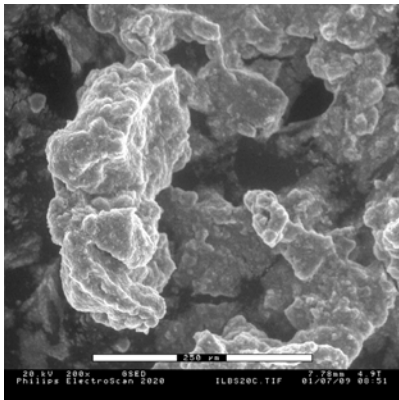
Ionic Stabilizer Treated  
Illite at 14500x-C



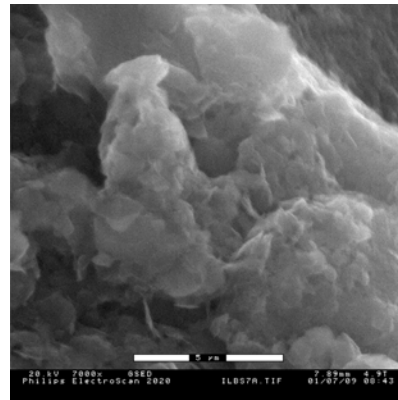
Polymer Stabilizer Treated  
Illite at 200x-A



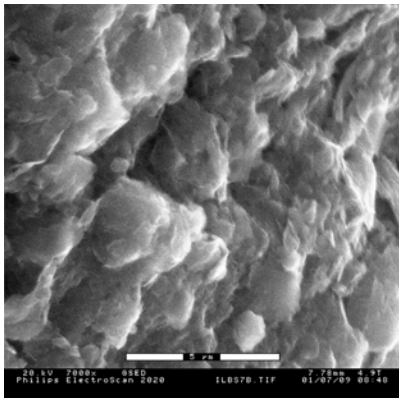
Polymer Stabilizer Treated  
Illite at 200x-B



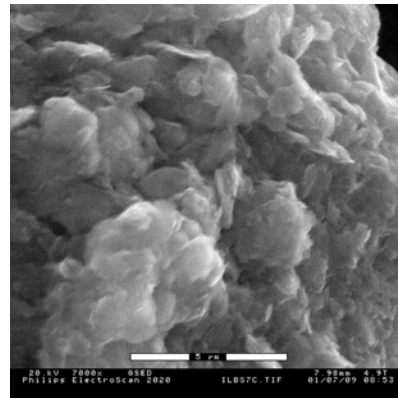
Polymer Stabilizer Treated  
Illite at 200x-C



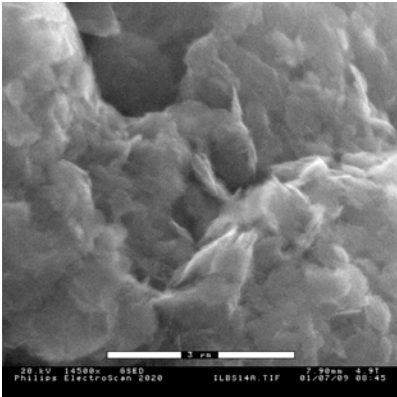
Polymer Stabilizer Treated  
Illite at 7000x-A



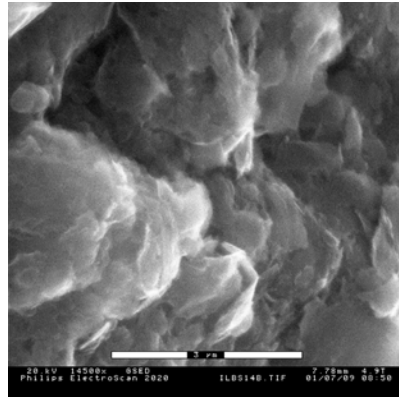
Polymer Stabilizer Treated  
Illite at 7000x-B



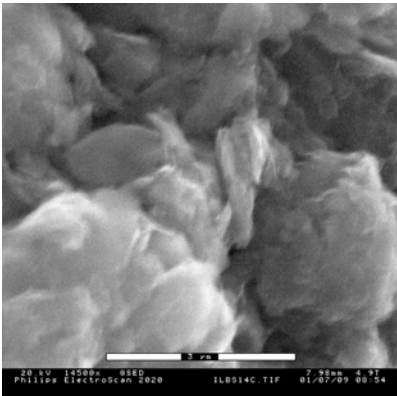
Polymer Stabilizer Treated  
Illite at 7000x-C



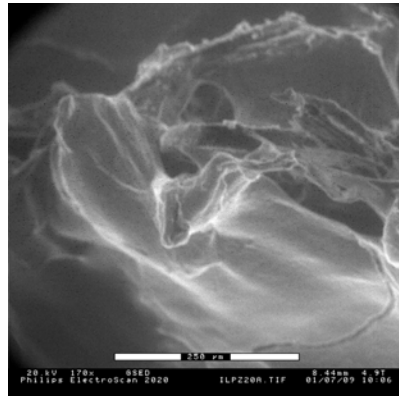
Polymer Stabilizer Treated Illite at 14500x-A



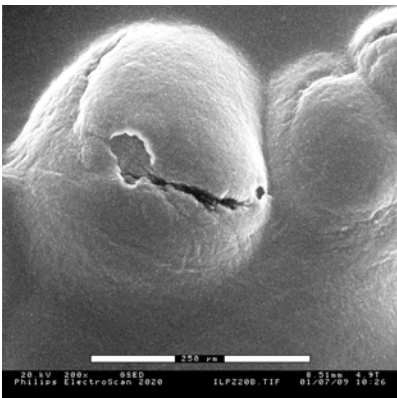
Polymer Stabilizer Treated Illite at 14500x-B



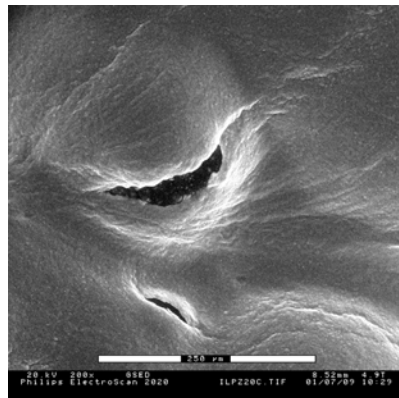
Polymer Stabilizer Treated Illite at 14500x-C



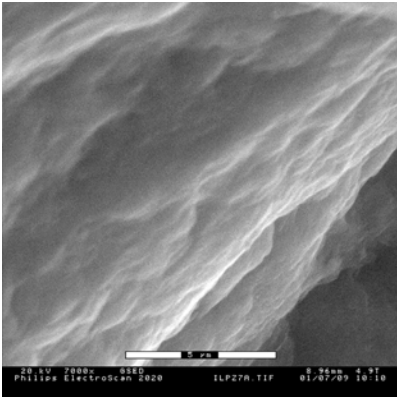
Enzyme Stabilizer Treated Illite at 200x-A



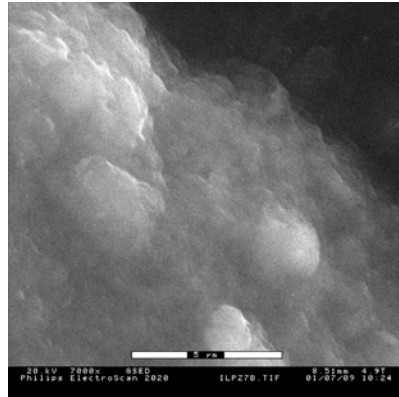
Enzyme Stabilizer Treated Illite at 200x-B



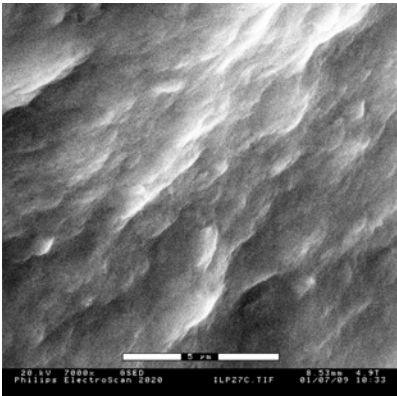
Enzyme Stabilizer Treated Illite at 200x-C



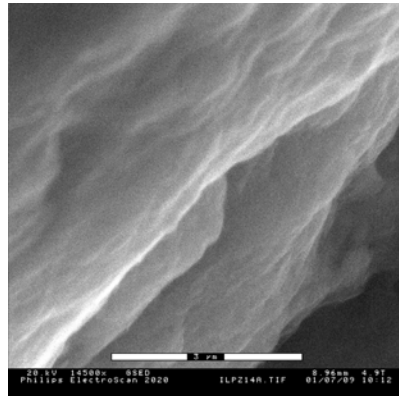
Enzyme Stabilizer Treated  
Illite at 7000x-A



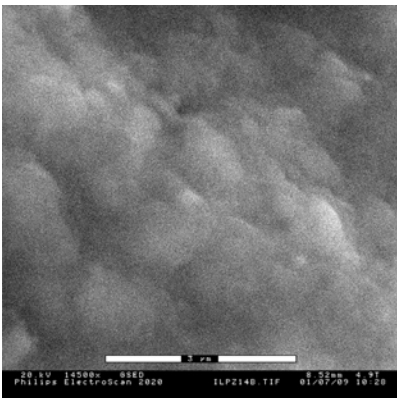
Enzyme Stabilizer Treated  
Illite at 7000x-B



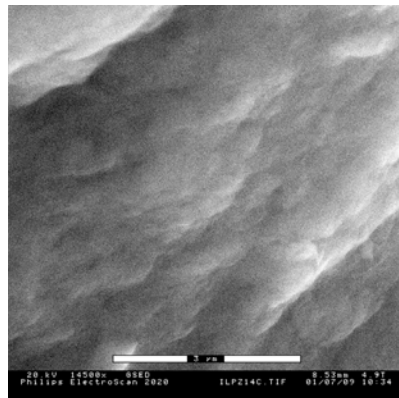
Enzyme Stabilizer Treated  
Illite at 7000x-C



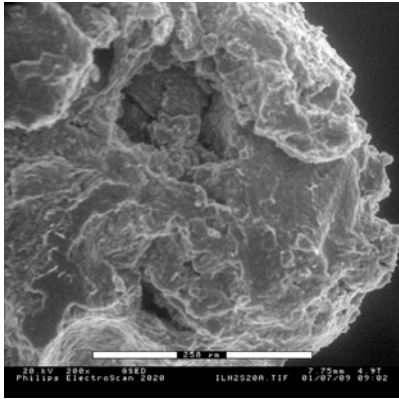
Enzyme Stabilizer Treated  
Illite at 14500x-A



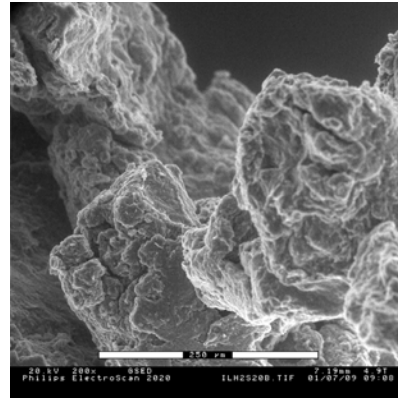
Enzyme Stabilizer Treated  
Illite at 14500x-B



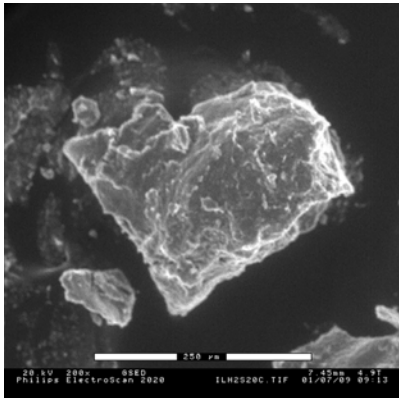
Enzyme Stabilizer Treated  
Illite at 14500x-C



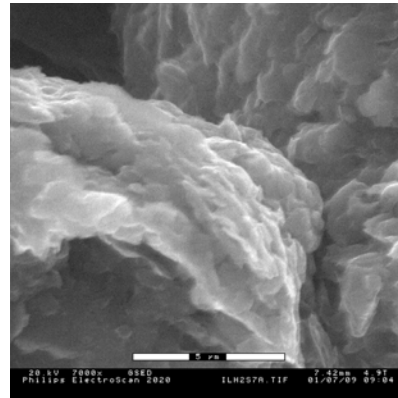
Sulfuric Acid Treated  
Illite at 200x-A



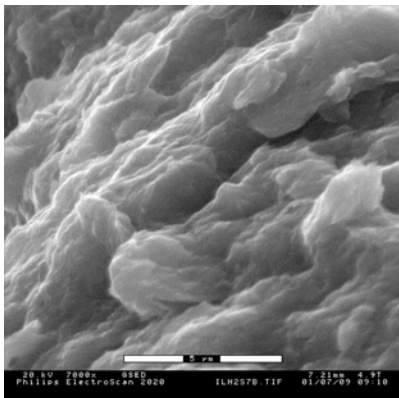
Sulfuric Acid Treated  
Illite at 200x-B



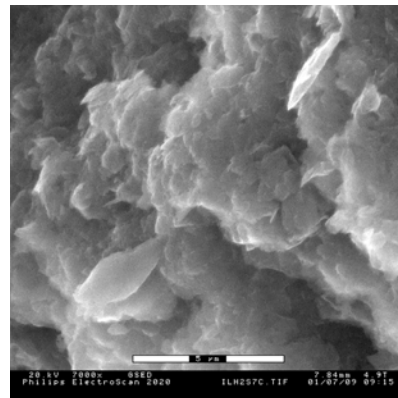
Sulfuric Acid Treated  
Illite at 200x-C



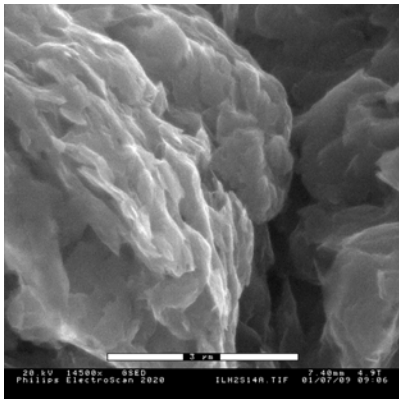
Sulfuric Acid Treated  
Illite at 7000x-A



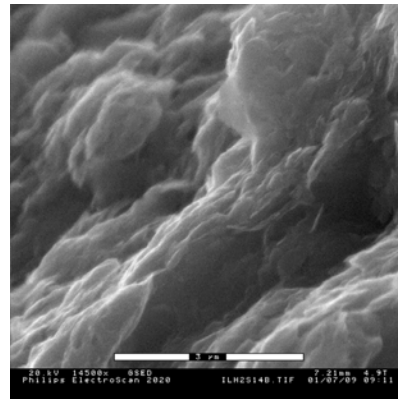
Sulfuric Acid Treated  
Illite at 7000x-B



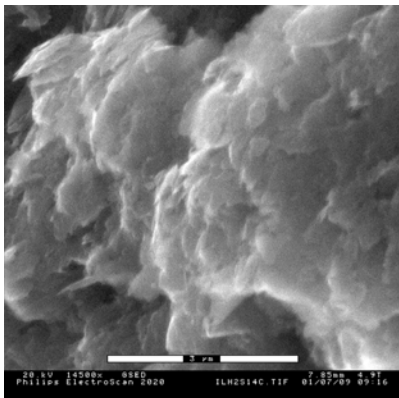
Sulfuric Acid Treated  
Illite at 7000x-C



Sulfuric Acid Treated  
Illite at 14500x-A

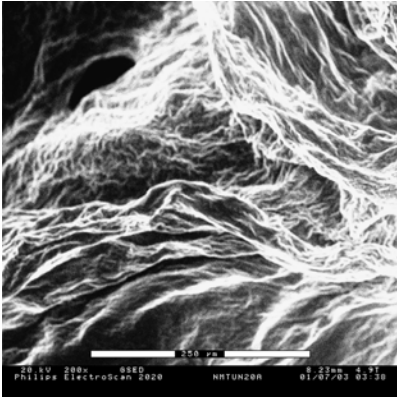


Sulfuric Acid Treated  
Illite at 14500x-B

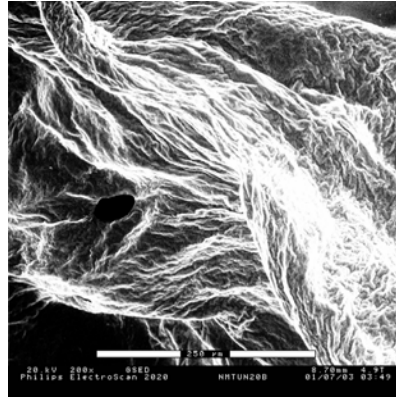


Sulfuric Acid Treated  
Illite at 14500x-C

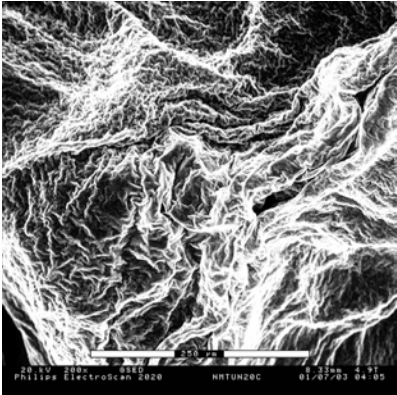
Appendix D.3. ESEM images of sodium montmorillonite



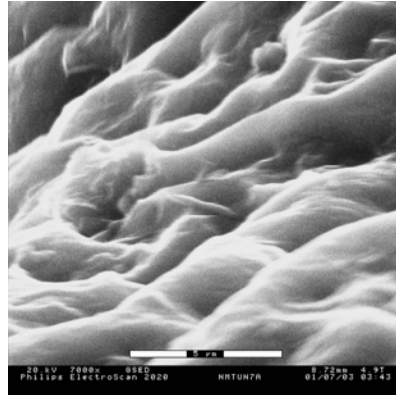
Untreated  
Sodium Montmorillonite at 200x-A



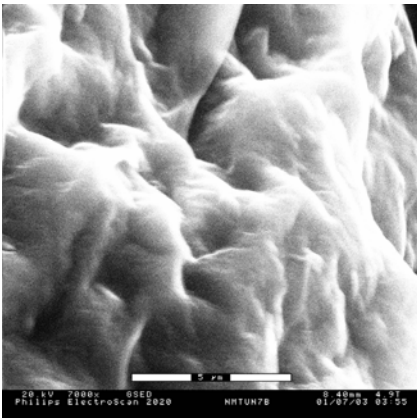
Untreated  
Sodium Montmorillonite at 200x-B



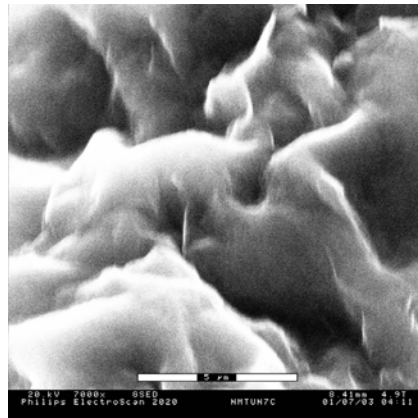
Untreated  
Sodium Montmorillonite at 200x-C



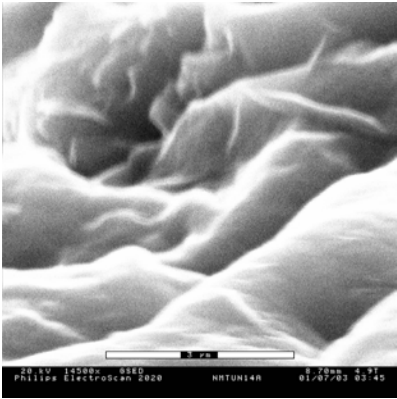
Untreated  
Sodium Montmorillonite at 7000x-A



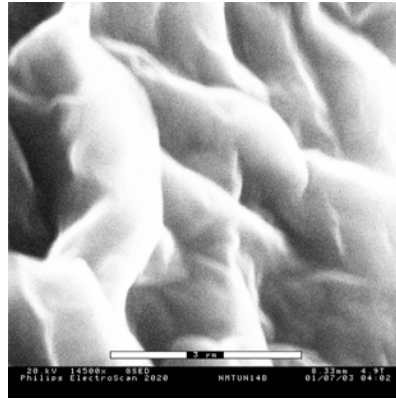
Untreated  
Sodium Montmorillonite at 7000x-B



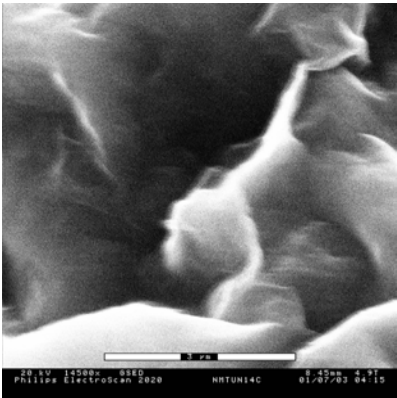
Untreated  
Sodium Montmorillonite at 7000x-C



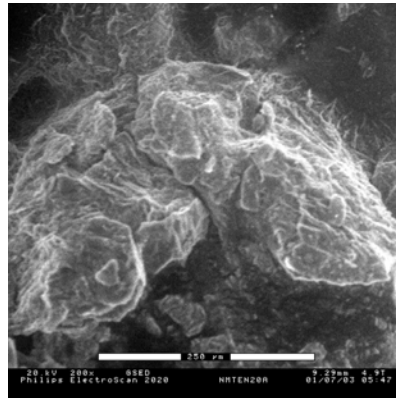
Untreated  
Sodium Montmorillonite at 14500x-A



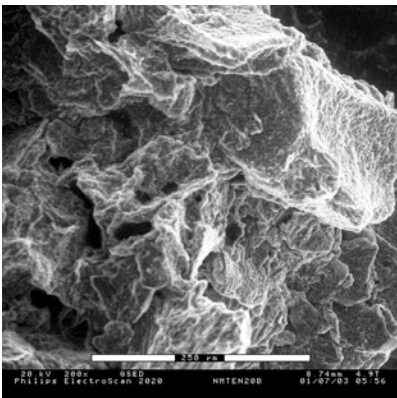
Untreated  
Sodium Montmorillonite at 14500x-B



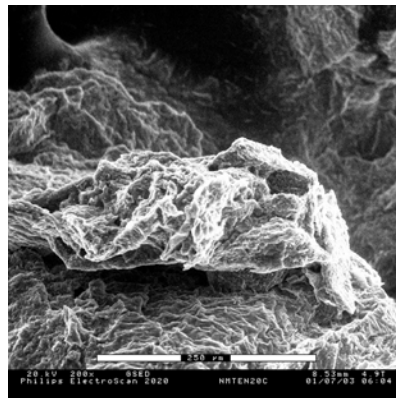
Untreated  
Sodium Montmorillonite at 14500x-C



Ionic Stabilizer Treated  
Sodium Montmorillonite at 200x-A

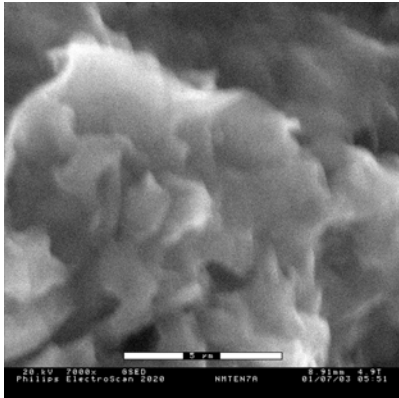


Ionic Stabilizer Treated  
Sodium Montmorillonite at 200x-B

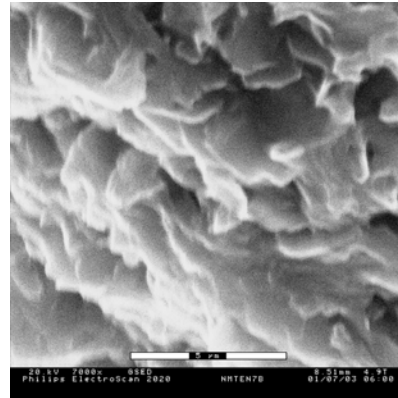


Ionic Stabilizer Treated  
Sodium Montmorillonite at 200x-C

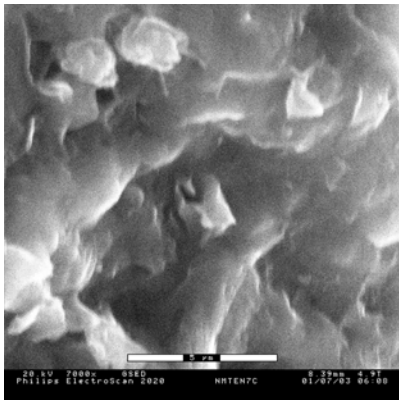




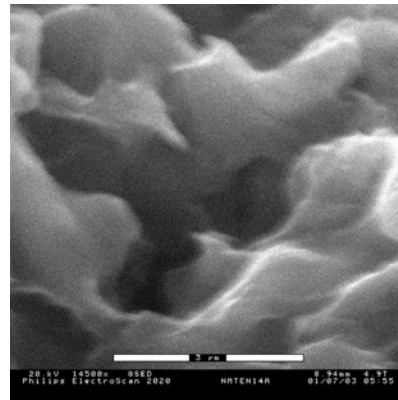
Ionic Stabilizer Treated  
Sodium Montmorillonite at 7000x-A



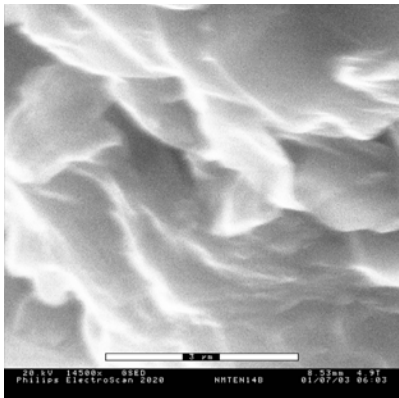
Ionic Stabilizer Treated  
Sodium Montmorillonite at 7000x-B



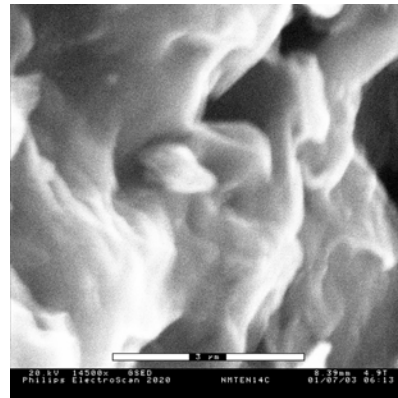
Ionic Stabilizer Treated  
Sodium Montmorillonite at 7000x-C



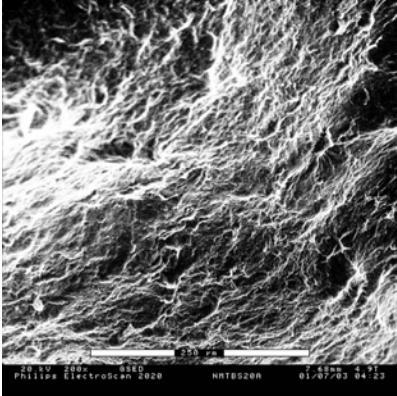
Ionic Stabilizer Treated  
Sodium Montmorillonite at 14500x-A



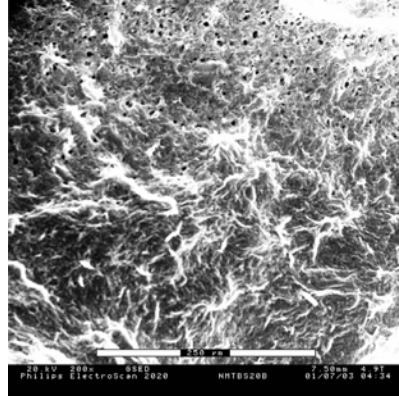
Ionic Stabilizer Treated  
Sodium Montmorillonite at 14500x-B



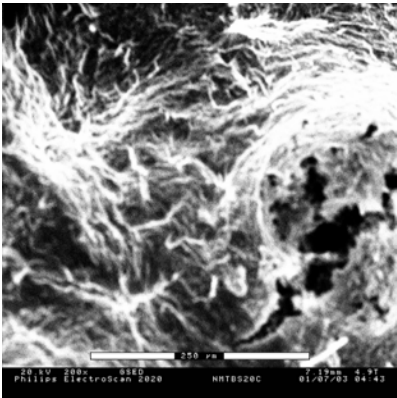
Ionic Stabilizer Treated  
Sodium Montmorillonite at 14500x-C



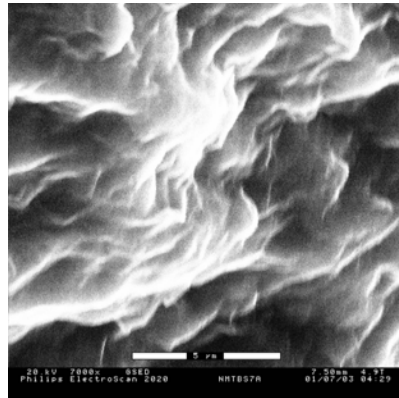
Polymer Stabilizer Treated  
Sodium Montmorillonite at 200x-A



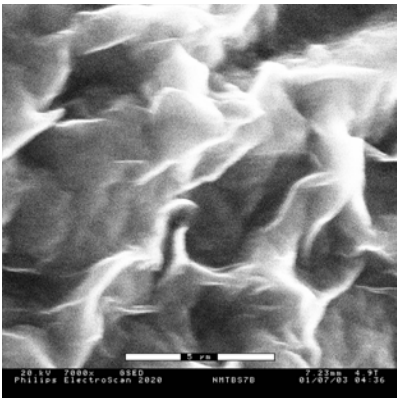
Polymer Stabilizer Treated  
Sodium Montmorillonite at 200x-B



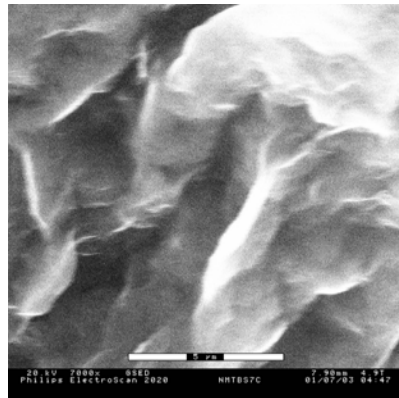
Polymer Stabilizer Treated  
Sodium Montmorillonite at 200x-C



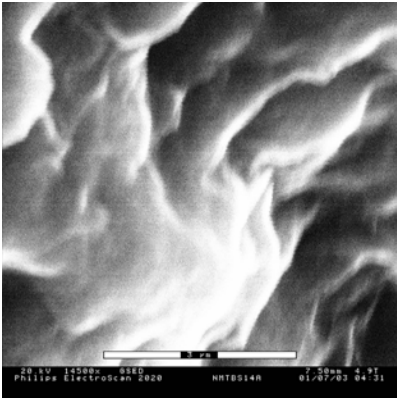
Polymer Stabilizer Treated  
Sodium Montmorillonite at 7000x-A



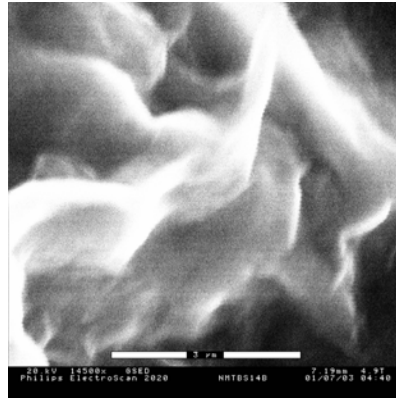
Polymer Stabilizer Treated  
Sodium Montmorillonite at 7000x-B



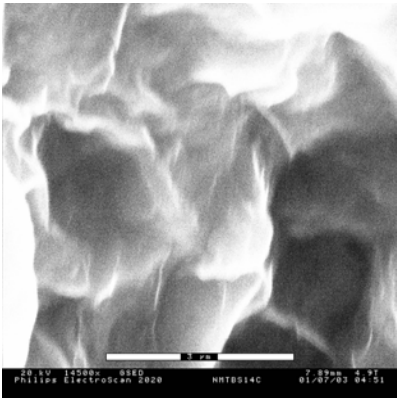
Polymer Stabilizer Treated  
Sodium Montmorillonite at 7000x-C



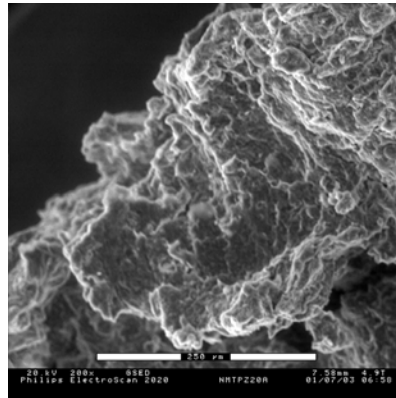
Polymer Stabilizer Treated  
Sodium Montmorillonite at 14500x-A



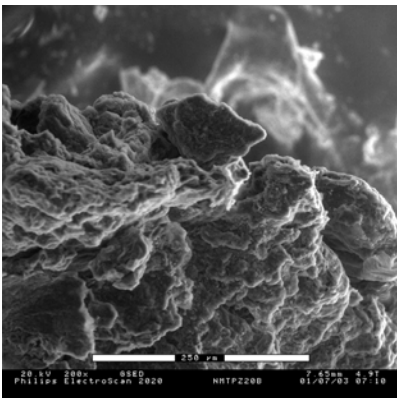
Polymer Stabilizer Treated  
Sodium Montmorillonite at 14500x-B



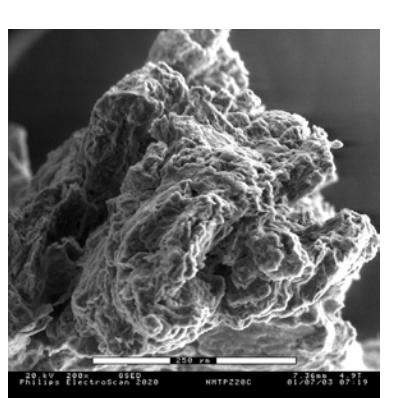
Polymer Stabilizer Treated  
Sodium Montmorillonite at 14500x-C



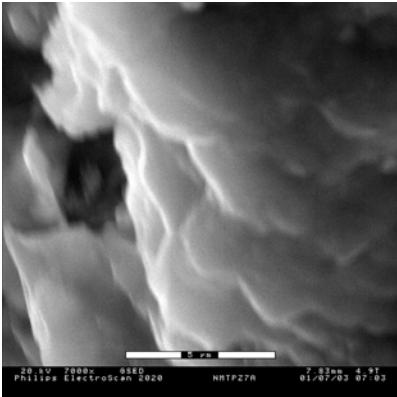
Enzyme Stabilizer Treated  
Sodium Montmorillonite at 200x-A



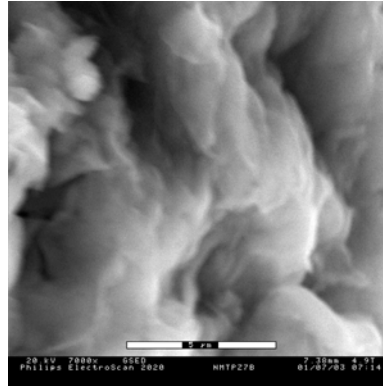
Enzyme Stabilizer Treated  
Sodium Montmorillonite at 200x-B



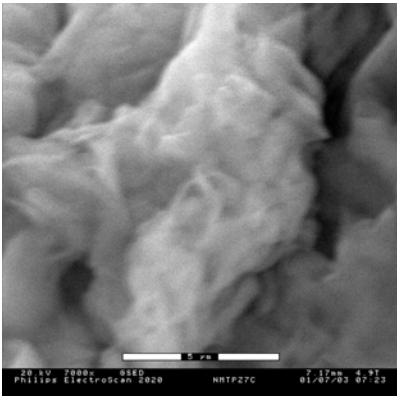
Enzyme Stabilizer Treated  
Sodium Montmorillonite at 200x-C



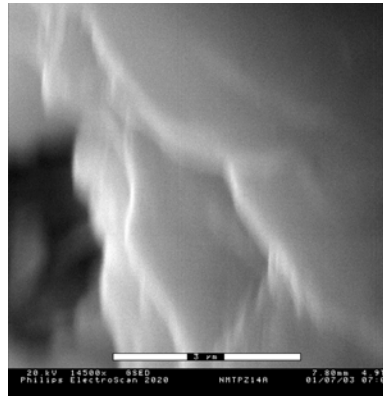
Enzyme Stabilizer Treated  
Sodium Montmorillonite at 7000x-A



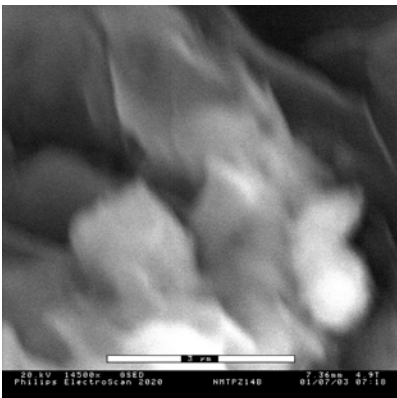
Enzyme Stabilizer Treated  
Sodium Montmorillonite at 7000x-B



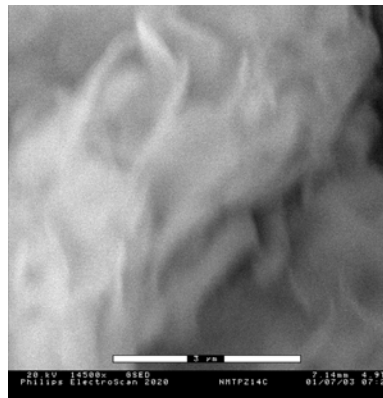
Enzyme Stabilizer Treated  
Sodium Montmorillonite at 7000x-C



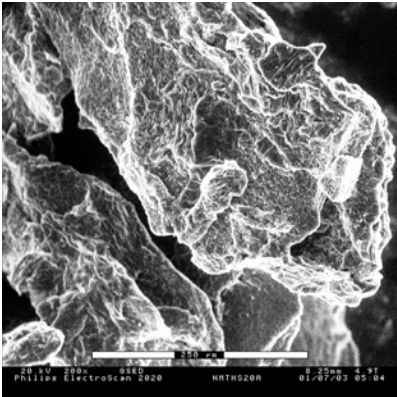
Enzyme Stabilizer Treated  
Sodium Montmorillonite at 14500x-A



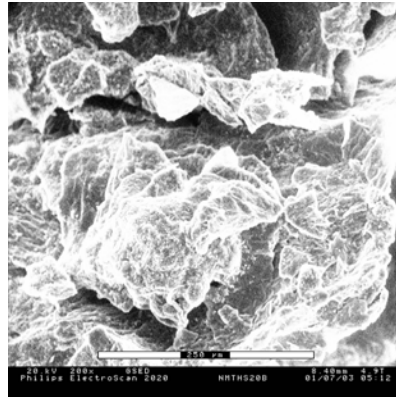
Enzyme Stabilizer Treated  
Sodium Montmorillonite at 14500x-B



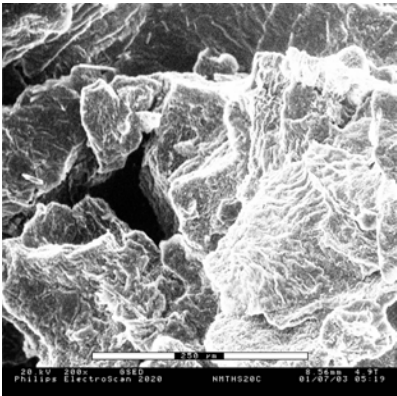
Enzyme Stabilizer Treated  
Sodium Montmorillonite at 14500x-C



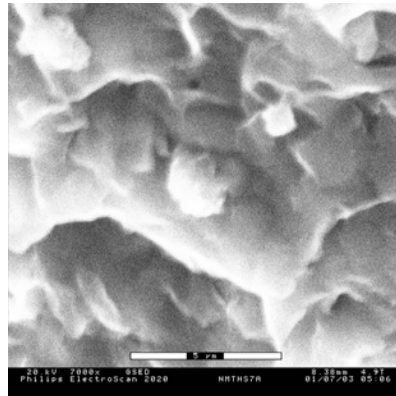
Sulfuric Acid Treated  
Sodium Montmorillonite at 200x-A



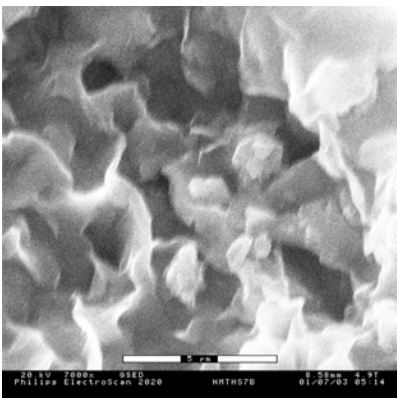
Sulfuric Acid Treated  
Sodium Montmorillonite at 200x-B



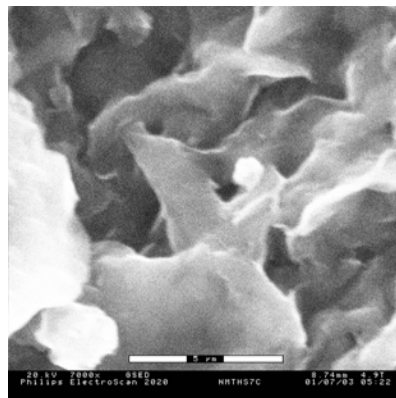
Sulfuric Acid Treated  
Sodium Montmorillonite at 200x-C



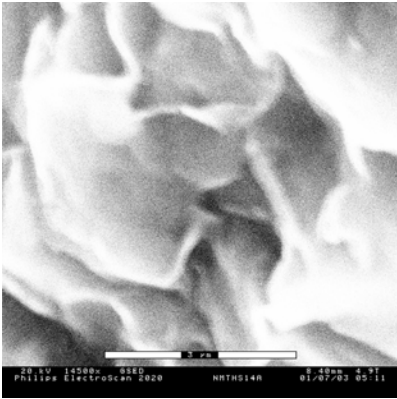
Sulfuric Acid Treated  
Sodium Montmorillonite at 7000x-A



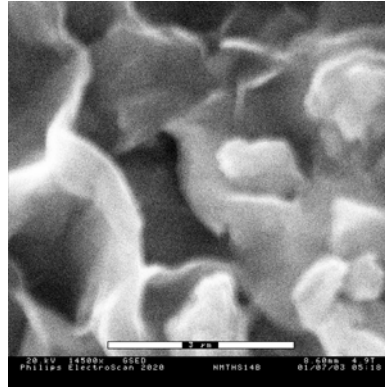
Sulfuric Acid Treated  
Sodium Montmorillonite at 7000x-B



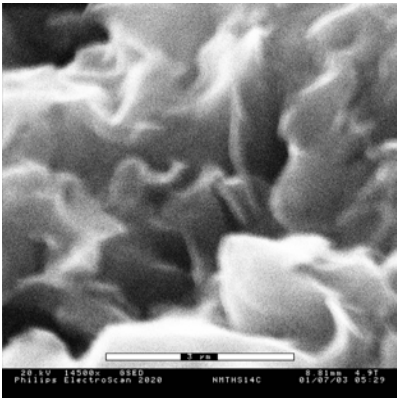
Sulfuric Acid Treated  
Sodium Montmorillonite at 7000x-C



Sulfuric Acid Treated  
Sodium Montmorillonite at 14500x-A

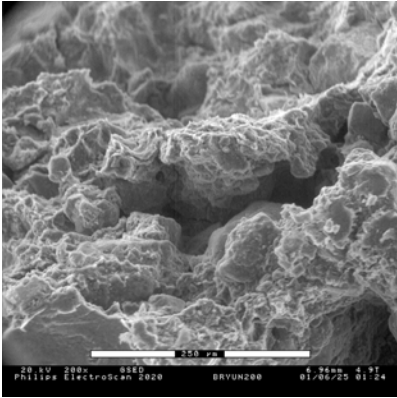


Sulfuric Acid Treated  
Sodium Montmorillonite at 14500x-B

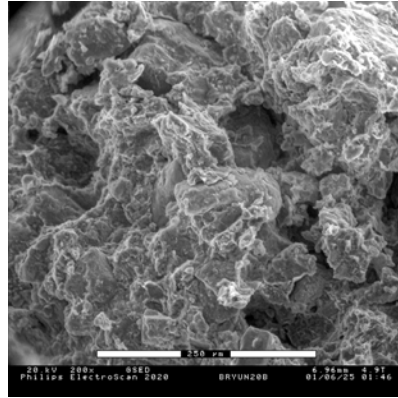


Sulfuric Acid Treated  
Sodium Montmorillonite at 14500x-C

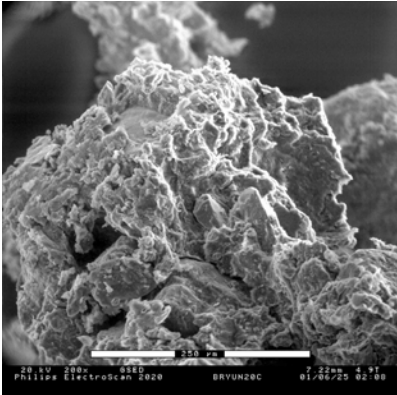
Appendix D.4. ESEM images of Bryan soil



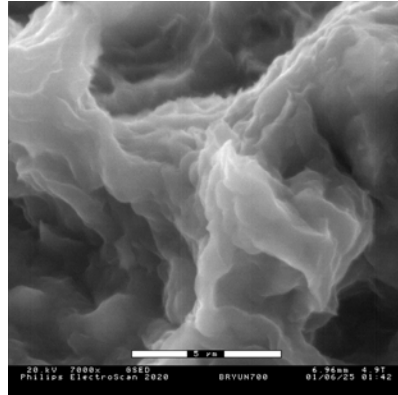
Untreated  
Bryan soil at 200x-A



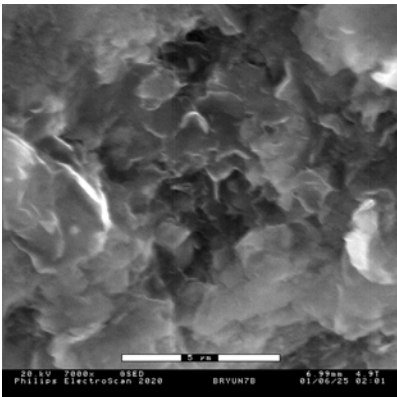
Untreated  
Bryan soil at 200x-B



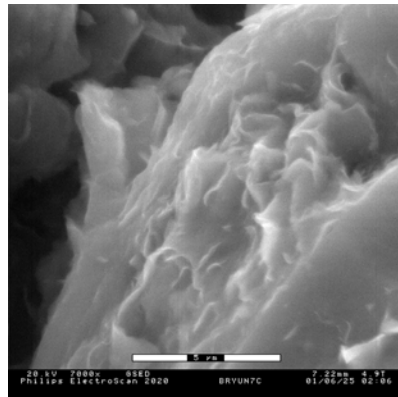
Untreated  
Bryan soil at 200x-C



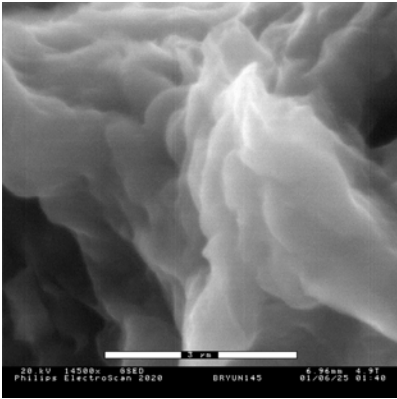
Untreated  
Bryan soil at 7000x-A



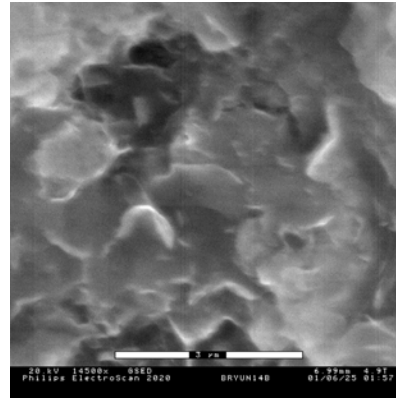
Untreated  
Bryan soil at 7000x-B



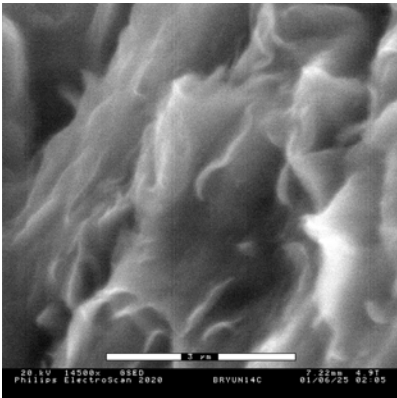
Untreated  
Bryan soil at 7000x-C



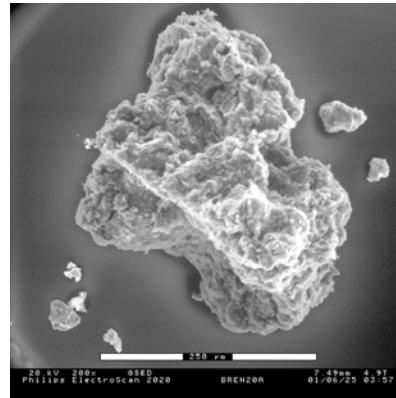
Untreated  
Bryan soil at 14500x-A



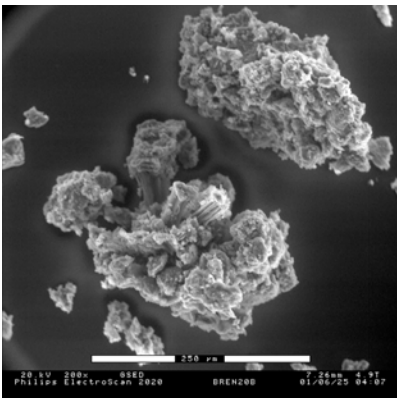
Untreated  
Bryan soil at 14500x-B



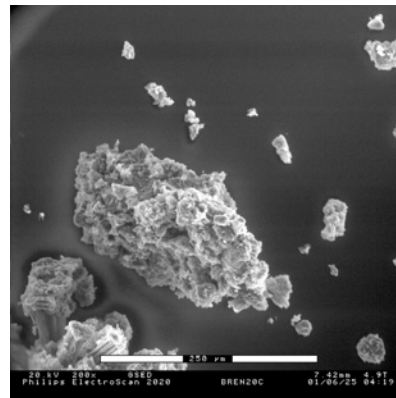
Untreated  
Bryan soil at 14500x-C



Ionic Stabilizer Treated  
Bryan soil at 200x-A

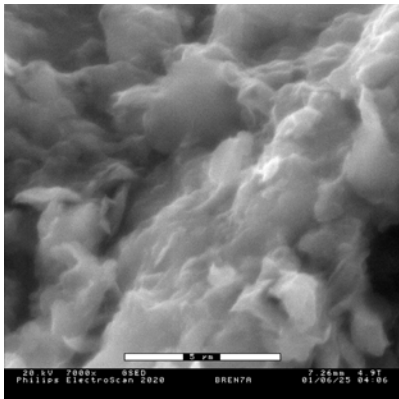


Ionic Stabilizer Treated  
Bryan soil at 200x-B

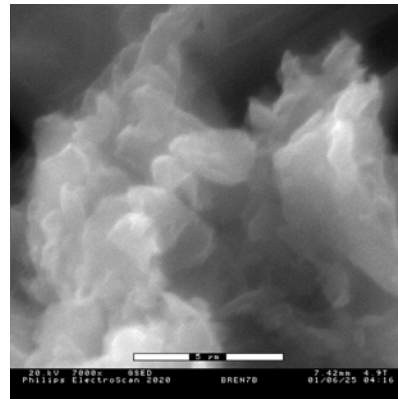


Ionic Stabilizer Treated  
Bryan soil at 200x-C

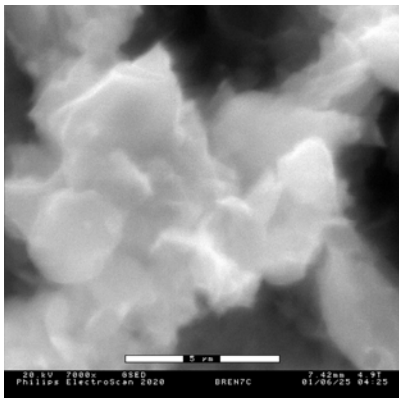




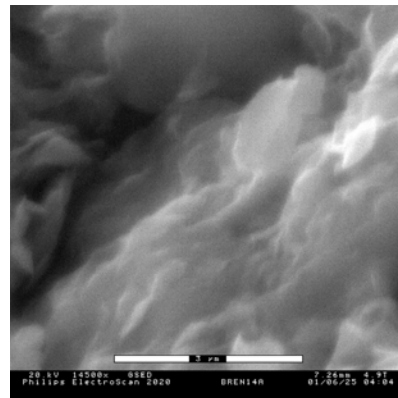
Ionic Stabilizer Treated  
Bryan soil at 7000x-A



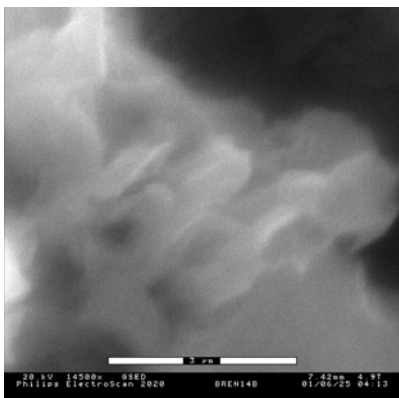
Ionic Stabilizer Treated  
Bryan soil at 7000x-B



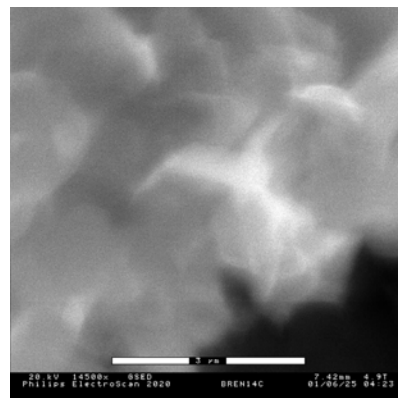
Ionic Stabilizer Treated  
Bryan soil at 7000x-C



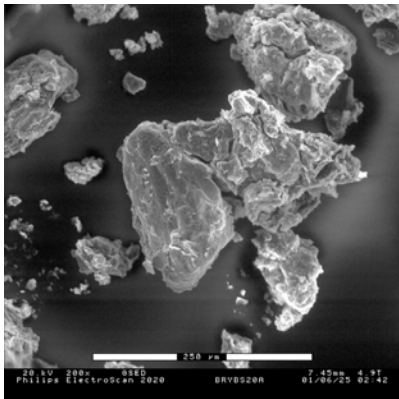
Ionic Stabilizer Treated  
Bryan soil at 14500x-A



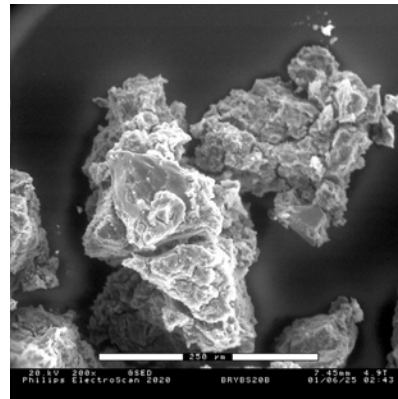
Ionic Stabilizer Treated  
Bryan soil at 14500x-B



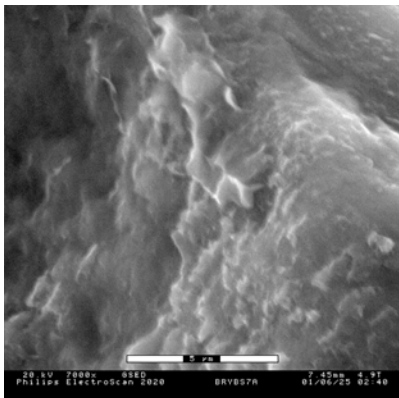
Ionic Stabilizer Treated  
Bryan soil at 14500x-C



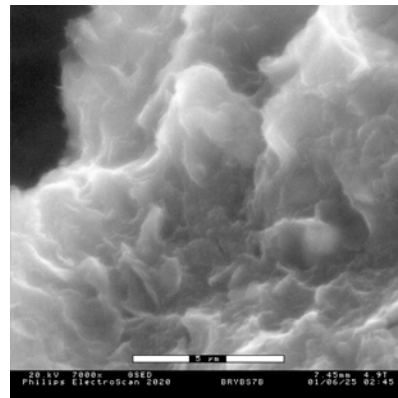
Polymer Stabilizer Treated  
Bryan soil at 200x-A



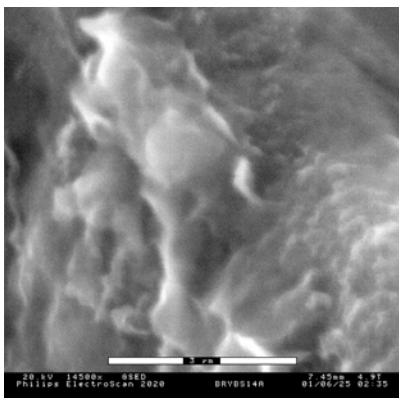
Polymer Stabilizer Treated  
Bryan soil at 200x-B



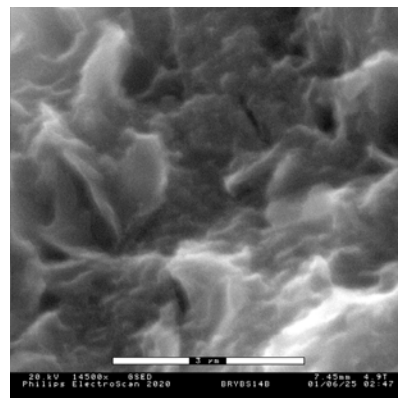
Polymer Stabilizer Treated  
Bryan soil at 7000x-A



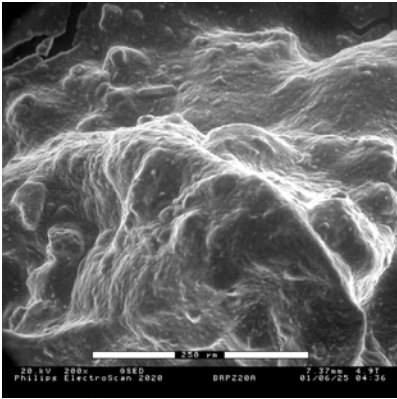
Polymer Stabilizer Treated  
Bryan soil at 7000x-B



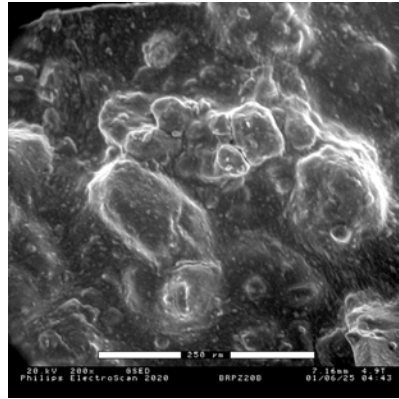
Polymer Stabilizer Treated  
Bryan soil at 14500x-A



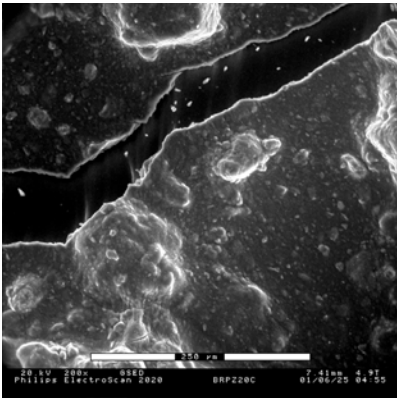
Polymer Stabilizer Treated  
Bryan soil at 14500x-B



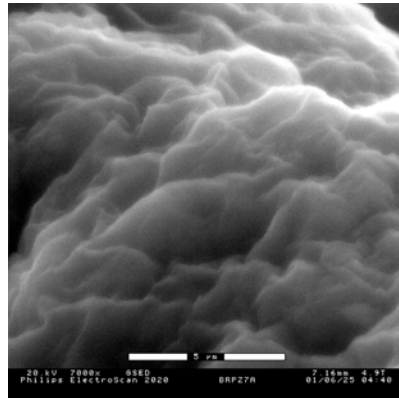
Enzyme Stabilizer Treated  
Bryan soil at 200x-A



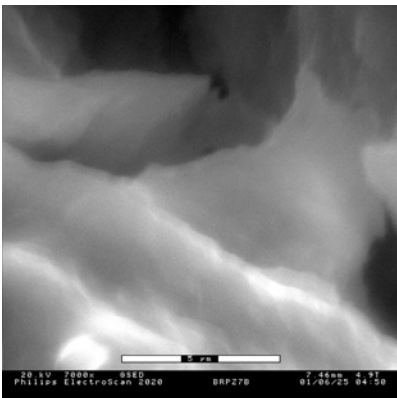
Enzyme Stabilizer Treated  
Bryan soil at 200x-B



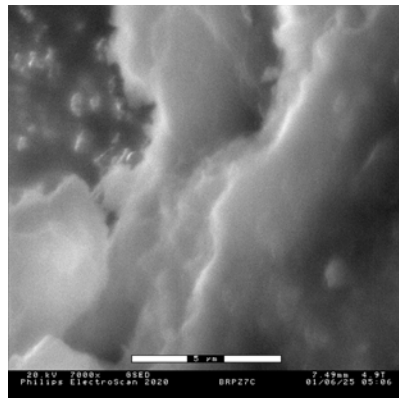
Enzyme Stabilizer Treated  
Bryan soil at 200x-C



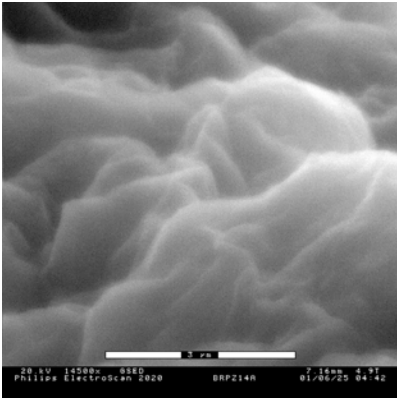
Enzyme Stabilizer Treated  
Bryan soil at 7000x-A



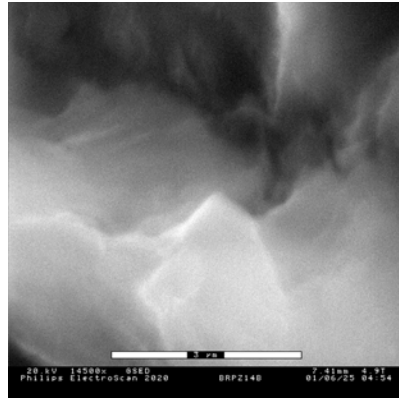
Enzyme Stabilizer Treated  
Bryan soil at 7000x-B



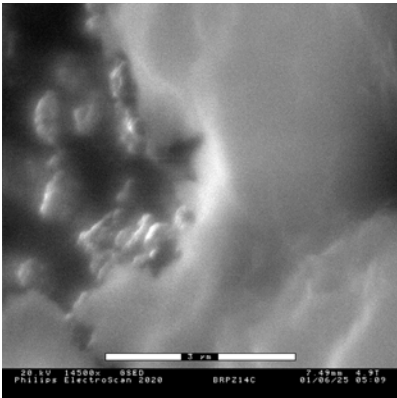
Enzyme Stabilizer Treated  
Bryan soil at 7000x-C



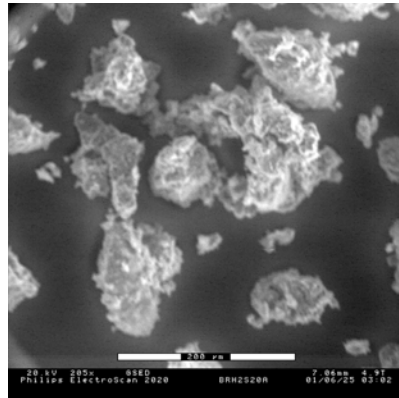
Enzyme Stabilizer Treated  
Bryan soil at 14500x-A



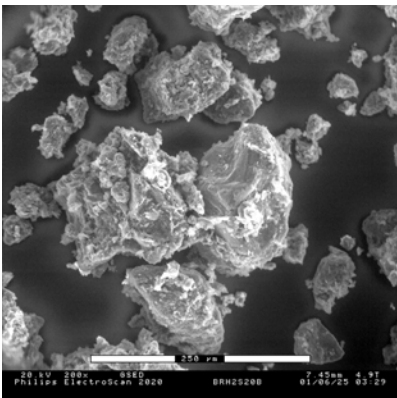
Enzyme Stabilizer Treated  
Bryan soil at 14500x-B



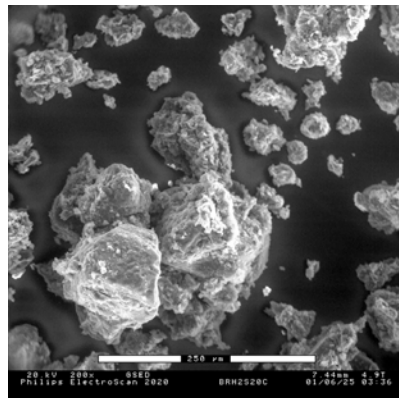
Enzyme Stabilizer Treated  
Bryan soil at 14500x-C



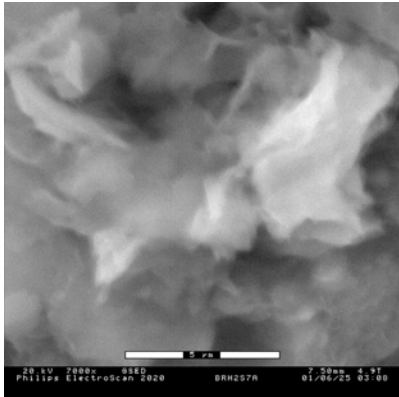
Sulfuric Acid Treated  
Bryan soil at 200x-A



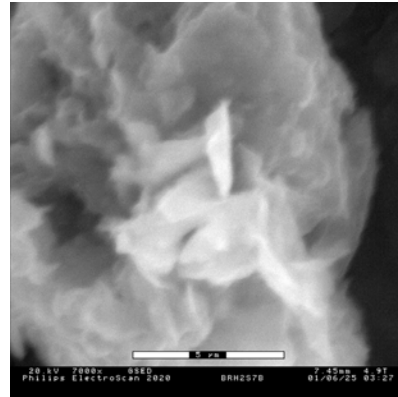
Sulfuric Acid Treated  
Bryan soil at 200x-B



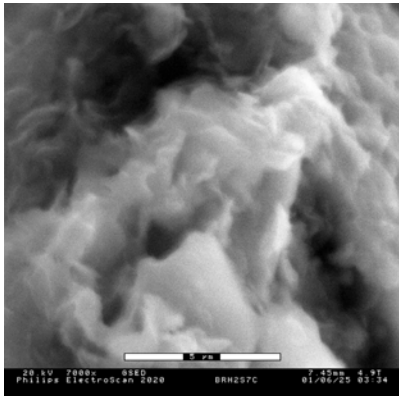
Sulfuric Acid Treated  
Bryan soil at 200x-C



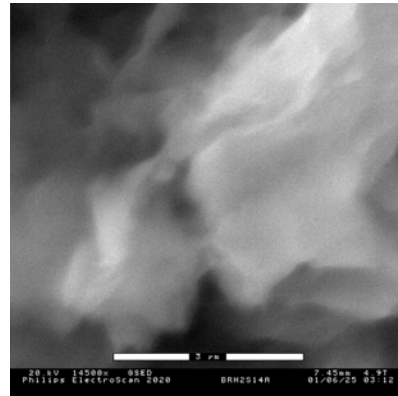
Sulfuric Acid Treated  
Bryan soil at 7000x-A



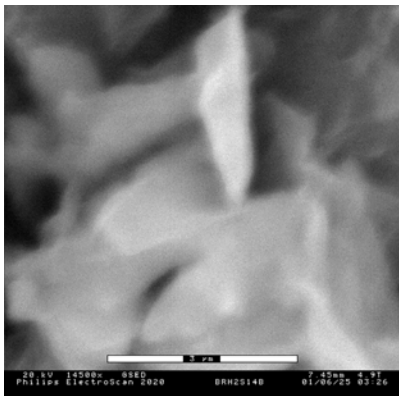
Sulfuric Acid Treated  
Bryan soil at 7000x-B



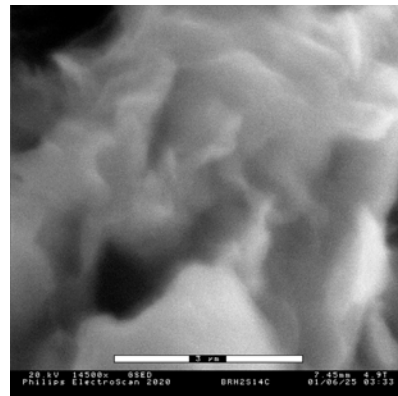
Sulfuric Acid Treated  
Bryan soil at 7000x-C



Sulfuric Acid Treated  
Bryan soil at 14500x-A

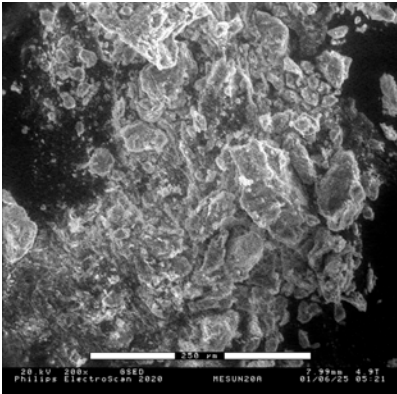


Sulfuric Acid Treated  
Bryan soil at 14500x-B

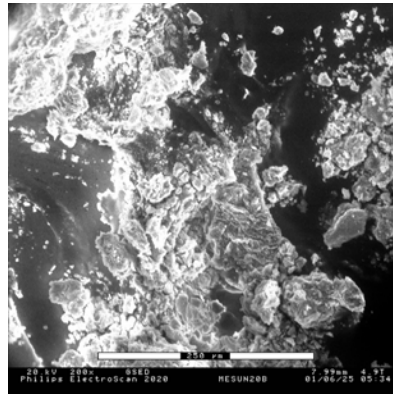


Sulfuric Acid Treated  
Bryan soil at 14500x-C

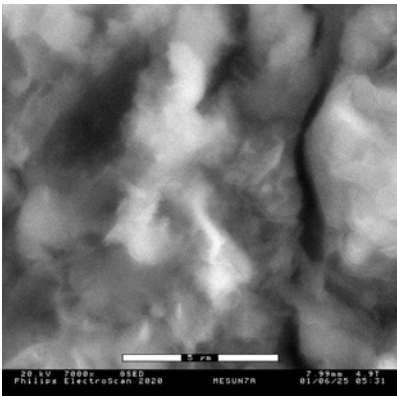
Appendix D.5. ESEM images of Mesquite soil



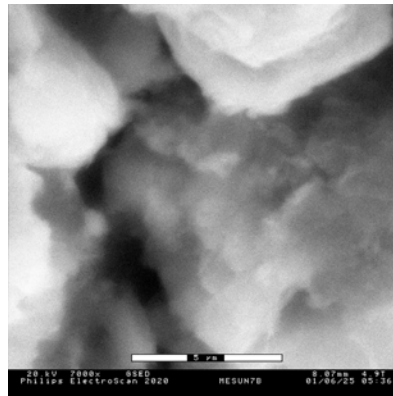
Untreated  
Mesquite soil at 200x-A



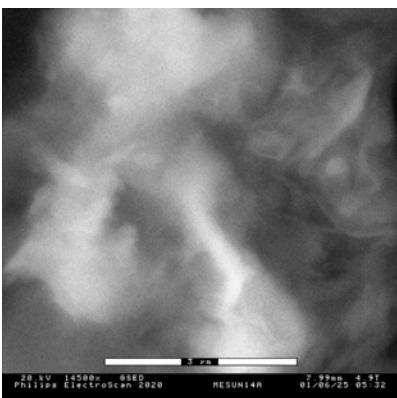
Untreated  
Mesquite soil at 200x-B



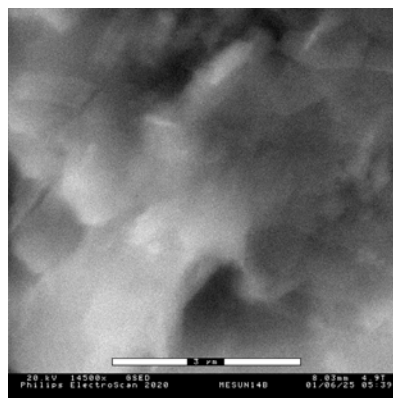
Untreated  
Mesquite soil at 7000x-A



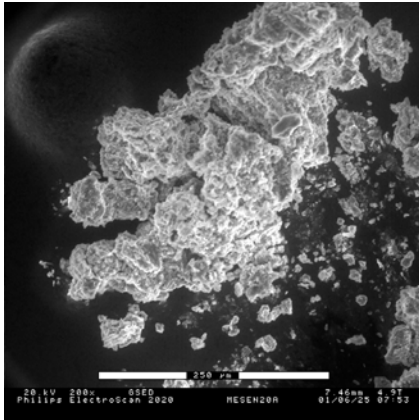
Untreated  
Mesquite soil at 7000x-B



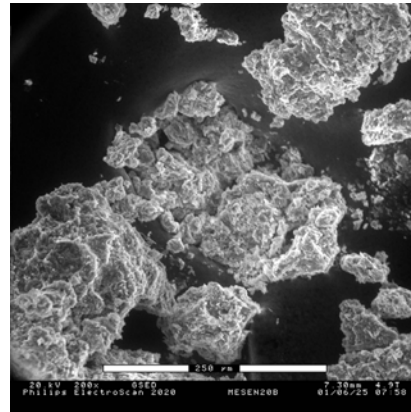
Untreated  
Mesquite soil at 14500x-A



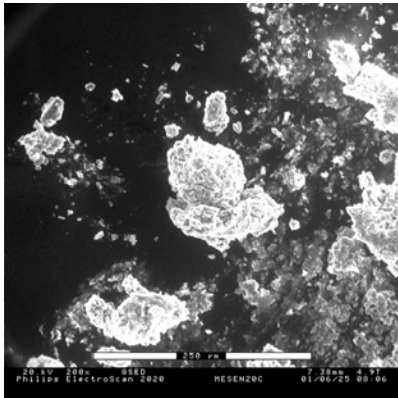
Untreated  
Mesquite soil at 14500x-B



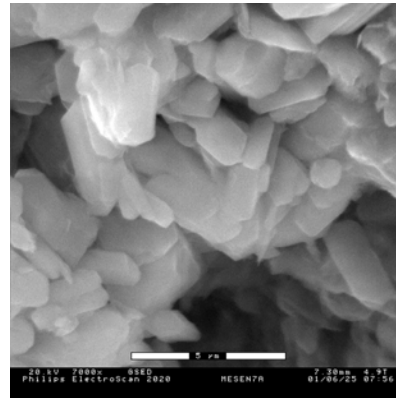
Ionic Stabilizer Treated  
Mesquite soil at 200x-A



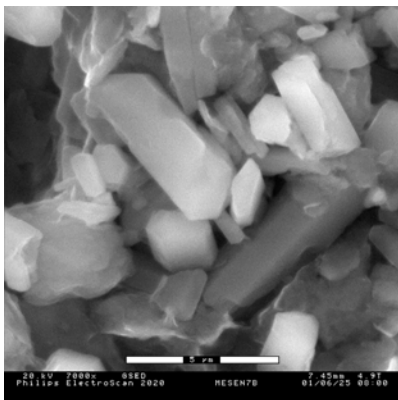
Ionic Stabilizer Treated  
Mesquite soil at 200x-B



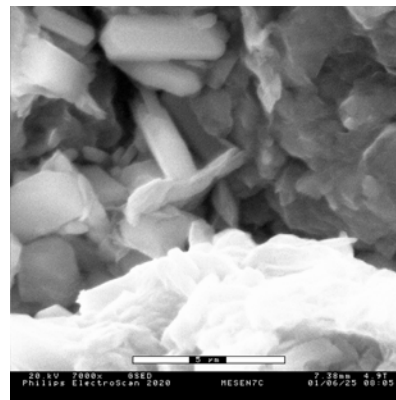
Ionic Stabilizer Treated  
Mesquite soil at 200x-C



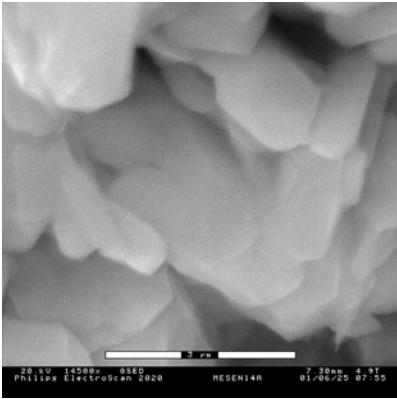
Ionic Stabilizer Treated  
Mesquite soil at 7000x-A



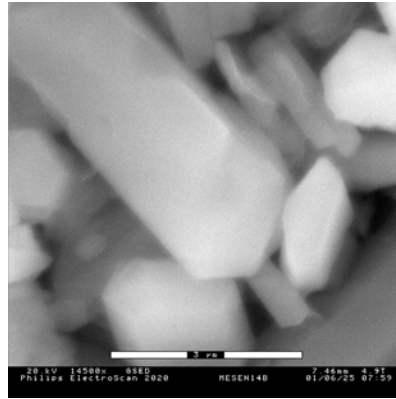
Ionic Stabilizer Treated  
Mesquite soil at 7000x-B



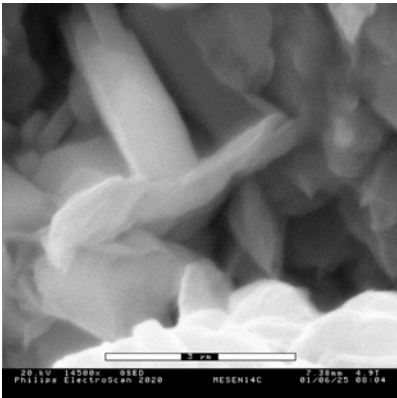
Ionic Stabilizer Treated  
Mesquite soil at 7000x-C



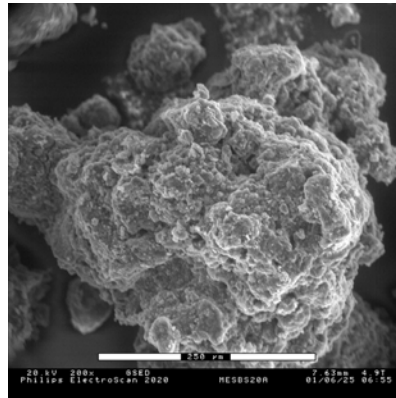
Ionic Stabilizer Treated  
Mesquite soil at 14500x-A



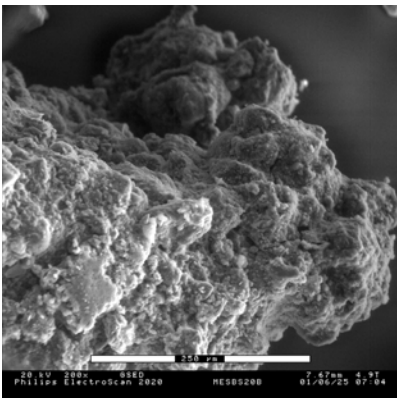
Ionic Stabilizer Treated  
Mesquite soil at 14500x-B



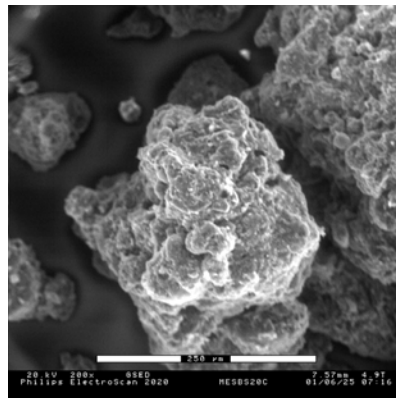
Ionic Stabilizer Treated  
Mesquite soil at 14500x-C



Polymer Stabilizer Treated  
Mesquite soil at 200x-A

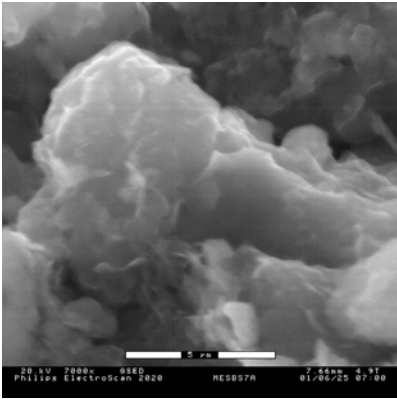


Polymer Stabilizer Treated  
Mesquite soil at 200x-B

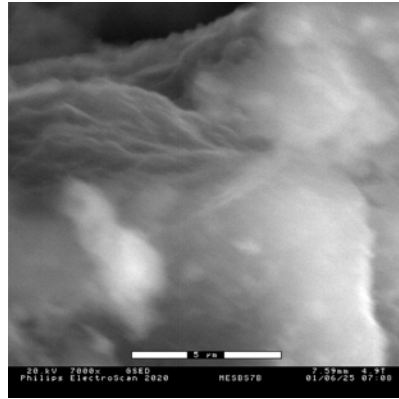


Polymer Stabilizer Treated  
Mesquite soil at 200x-C

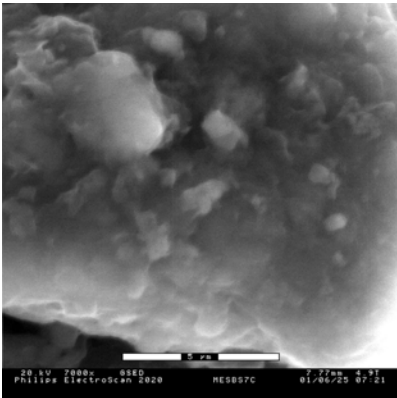




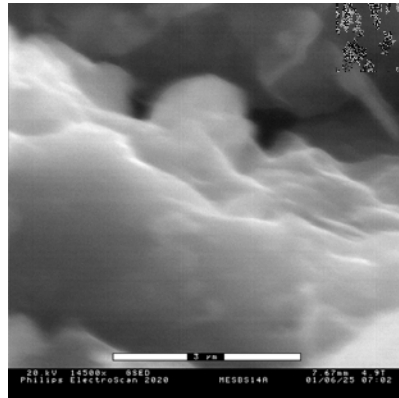
Polymer Stabilizer Treated  
Mesquite soil at 7000x-A



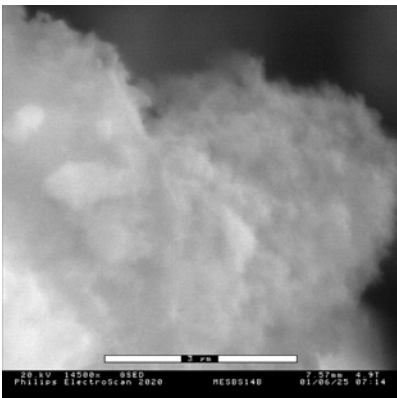
Polymer Stabilizer Treated  
Mesquite soil at 7000x-B



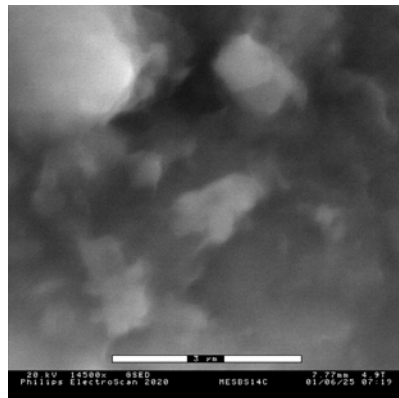
Polymer Stabilizer Treated  
Mesquite soil at 7000x-C



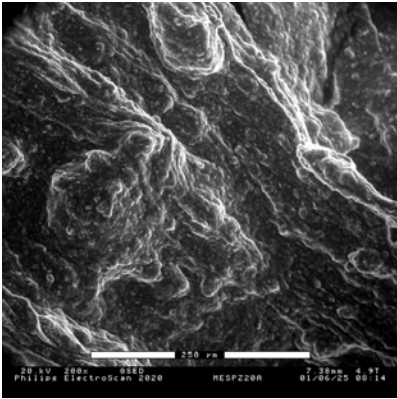
Polymer Stabilizer Treated  
Mesquite soil at 14500x-A



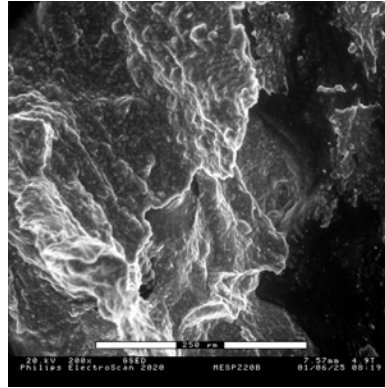
Polymer Stabilizer Treated  
Mesquite soil at 14500x-B



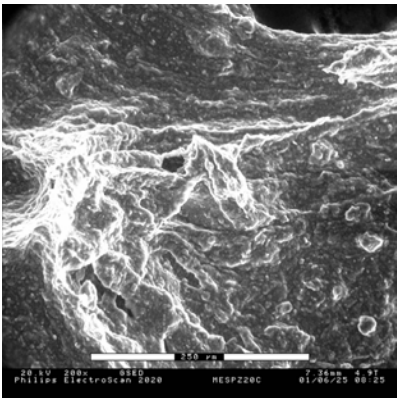
Polymer Stabilizer Treated  
Mesquite soil at 14500x-C



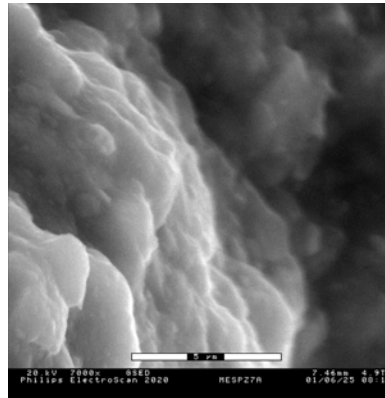
Enzyme Stabilizer Treated  
Mesquite soil at 200x-A



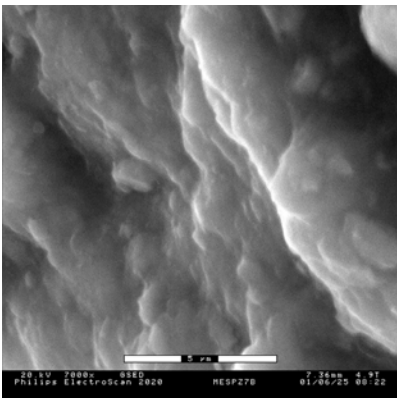
Enzyme Stabilizer Treated  
Mesquite soil at 200x-B



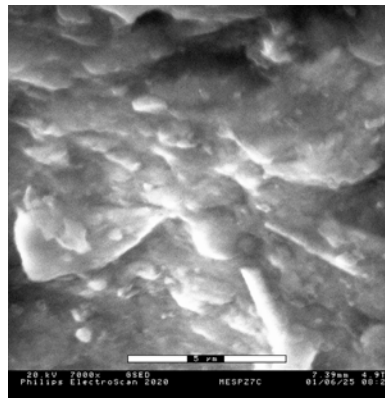
Enzyme Stabilizer Treated  
Mesquite soil at 200x-C



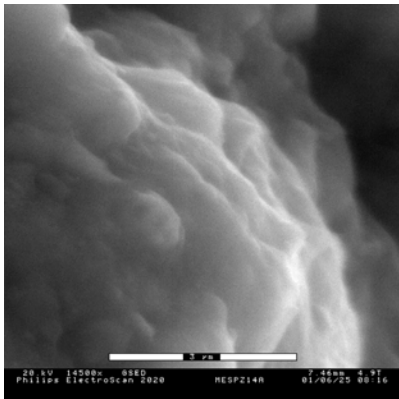
Enzyme Stabilizer Treated  
Mesquite soil at 7000x-A



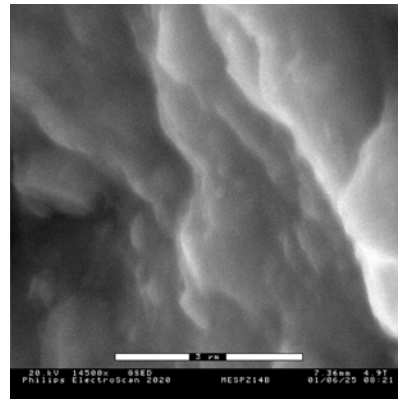
Enzyme Stabilizer Treated  
Mesquite soil at 7000x-B



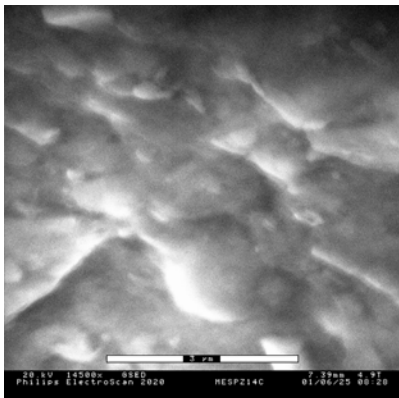
Enzyme Stabilizer Treated  
Mesquite soil at 7000x-C



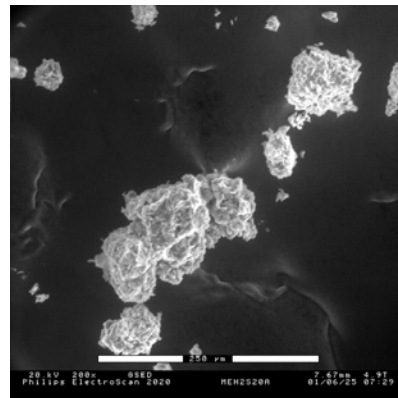
Enzyme Stabilizer Treated  
Mesquite soil at 14500x-A



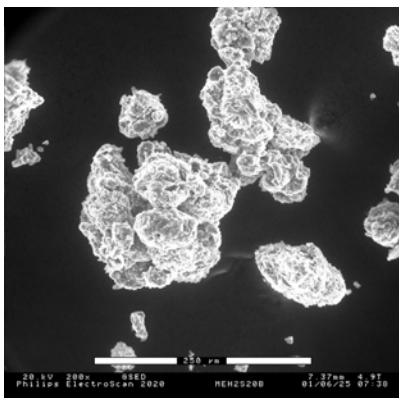
Enzyme Stabilizer Treated  
Mesquite soil at 14500x-B



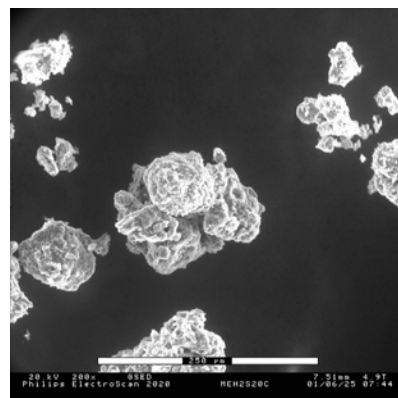
Enzyme Stabilizer Treated  
Mesquite soil at 14500x-C



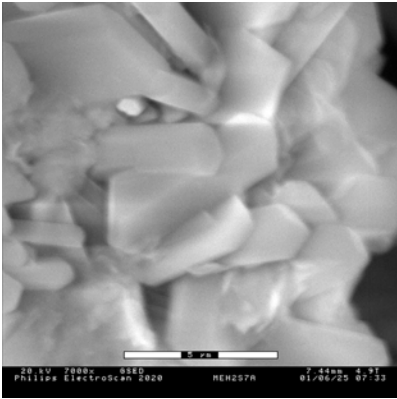
Sulfuric Acid Treated  
Mesquite soil at 200x-A



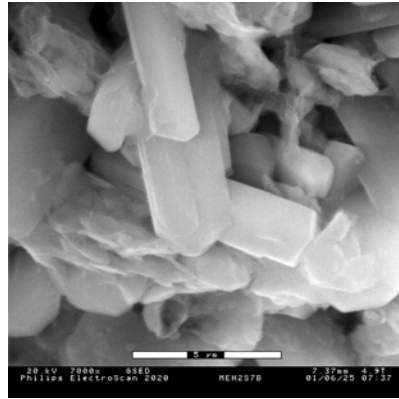
Sulfuric Acid Treated  
Mesquite soil at 200x-B



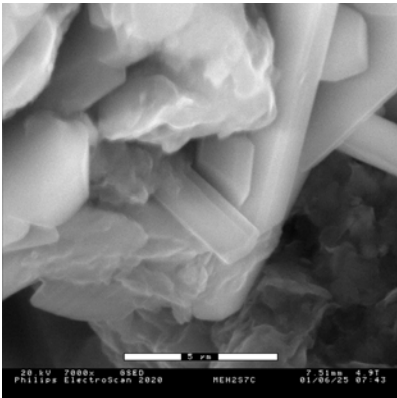
Sulfuric Acid Treated  
Mesquite soil at 200x-C



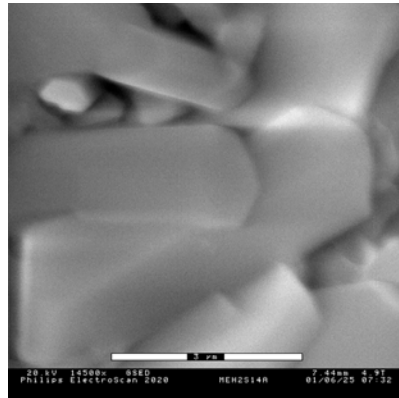
Sulfuric Acid Treated  
Mesquite soil at 7000x-A



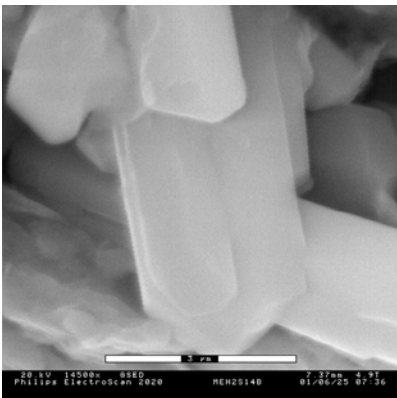
Sulfuric Acid Treated  
Mesquite soil at 7000x-B



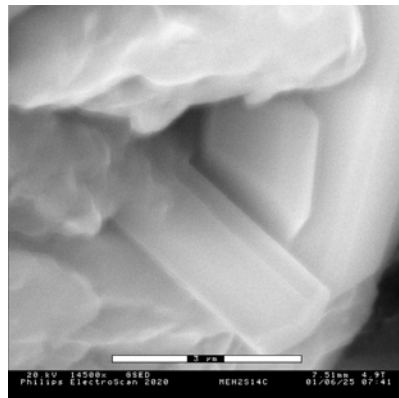
Sulfuric Acid Treated  
Mesquite soil at 7000x-C



Sulfuric Acid Treated  
Mesquite soil at 14500x-A



Sulfuric Acid Treated  
Mesquite soil at 14500x-B



Sulfuric Acid Treated  
Mesquite soil at 14500x-C