APPLIED MINERALS INC.

Leading Global Producer of Halloysite Clay

Halloysite Clay for Oil Spill Remediation

APPLIED MINERALS INC.

Summary

- Applied Minerals Inc. has the ability to supply large scale quantities of Halloysite Clay from its Dragon Mine Halloysite Deposit in Juab County Utah to assist in the cleanup of oil spills globally. The Company is fully permitted and is currently mining and producing products.

- The Company has an abundant measured resource of Halloysite Clay. There is over 4.5mm total gross tons of this material that has already been mined and sits on on the surface of the property, immediately available to be deployed. The Company's resource is "measured" by an independent JORC accredited geologist recognized as a world expert on clays.

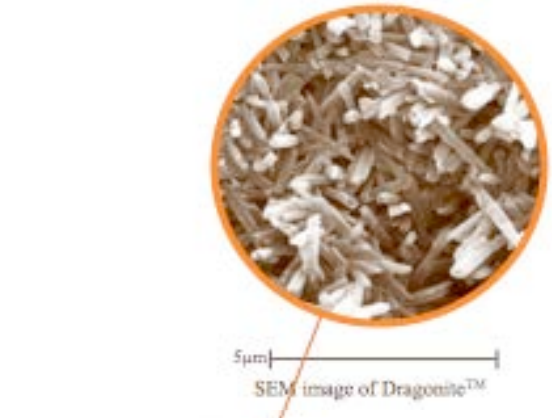
- Applied Minerals' initial study (data is contained within) demonstrates that its non chemically modified Halloysite Clay product, due to its high surface area, non water swelling nature, small particle size and unique porous tubular morphology, is able to:
  - *Adsorb between 85%-245% of its weight in oil in a seawater environment*
  - *After the oil is adsorbed, Halloysite de-emulsifies it from the surface via formation of marble sized spheres/micelles, which will then float in a dispersed manner* ***(Halloysite Clay is not a sinking agent)***
  - *Due to the surface chemistry of the product, these dispersed spheres rapidly enhance the growth of bacteria necessary for hydrocarbon degradation. Data indicates that 98% of the hydrocarbon is naturally degraded within 7 days of the colonization of bacteria.*

- This study is ongoing, however, in light of the Company's recent developments, it feels that it is at a stage to strongly recommend considering its solution as an additional method for remediating spills immediately.

Applied Minerals Inc: Dragonite™ brand of Halloysite Clay

Who is Applied Minerals?

- Global producer of the *Dragonite*™ brand of Halloysite Clay from its wholly-owned Dragon Mine in Utah
- The Dragon Mine is one of only two known resources of halloysite globally
- **4.5M tons** of surface piles – previously mined and **ready to ship**
- 1.4M ton easily accessible underground resource
- Resource is quanitified by an independent JORC accredited geologist
- Fully permitted and currently in production



What is Halloysite Clay?

- Halloysite is an inert natural clay exhibiting a hollow tubular morphology
- Chemical formulation is identical to commonly used Kaolin clay
- Halloysite is EPA 4A listed, biocompatible, and designated as GRAS by the FDA

Dragonite™ in powder form

How does the *Dragonite*™ brand of Halloysite Clay remediate oil?

Physical Remediation:

- The Dragonite™ brand of Halloysite Clay, due to its high surface area, non water swelling nature, small particle size and unique porous tubular morphology, is able to adsorb between 85%-245% of its weight in oil in a seawater environment. After the oil is adsorbed, Dragonite™ de-emulsifies it from the surface via formation of marble sized spheres/micelles, which will then float in a dispersed manner (Dragonite™ Halloysite Clay is not a sinking agent).

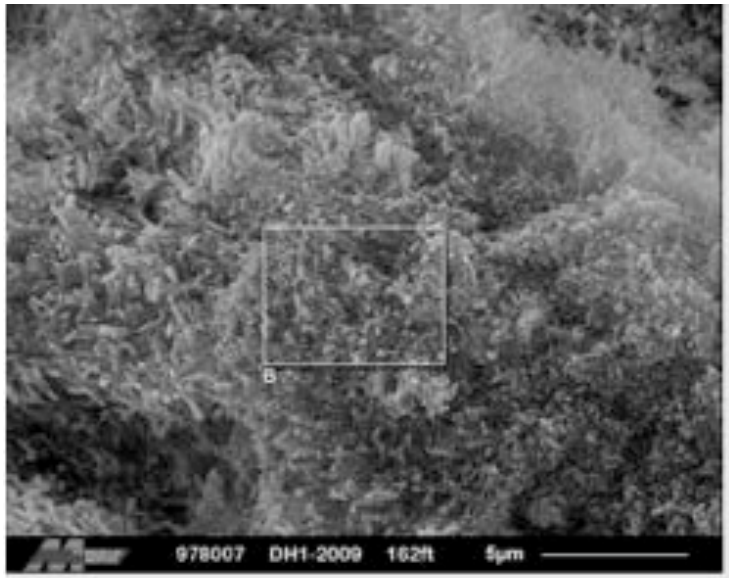
Bioremediation:

- Due to Dragonite's™ surface chemistry, the dispersed spheres described above rapidly enhance the growth of bacteria necessary for hydrocarbon degradation. Data indicates that 98% of the hydrocarbon is naturally degraded within 7 days of the colonization of bacteria.

Dragonite™ Halloysite Clay: Advantages

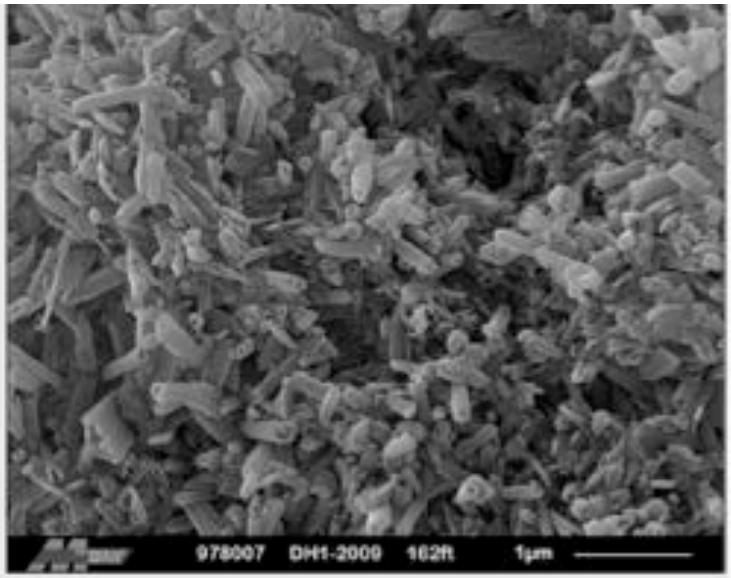
- Naturally occurring tubular morphology with high surface area (65-120 m^2g^{-1}) and porosity
- Treatable with an eco-friendly fatty acid to ensure flotation of sequestered oil
- Non-swelling clay
- Effective in both deep sea (mixing via wave action) and marshland environment (adsorption via capillary "wicking" action)
- Ability to adsorb between 85%-245% of its weight in oil in a seawater environment
- 98% of the adsorbed oil is naturally degraded within 7 days of the colonization of bacteria
- Ability to load the clay's tubes with an EPA approved bioremediation agent to further enhance bioremediation
- Cation exchange capacity improves from 11 in powder form to 47 when submersed in seawater (surface becomes activated by the sodium in seawater)
- Capacity utilization of 22.0% (the lowest amongst clays) provides greatest amount of surface area available for the attachment of positive ions to promote bacteria growth
- US FDA designated GRAS material (Generally Recognized as Safe) as a food item
- Toxicity tests (48 hr, EC_{50}) with marine larval organisms indicate that the clay is nontoxic to marine life
- Halloysite has an identical chemistry to commonly used kaolinite clay

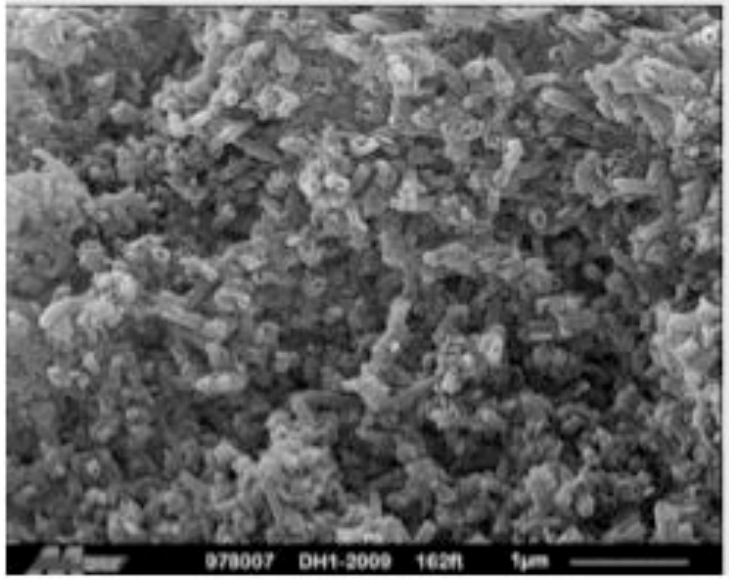
SEM Image of Dragonite™ Halloysite Clay

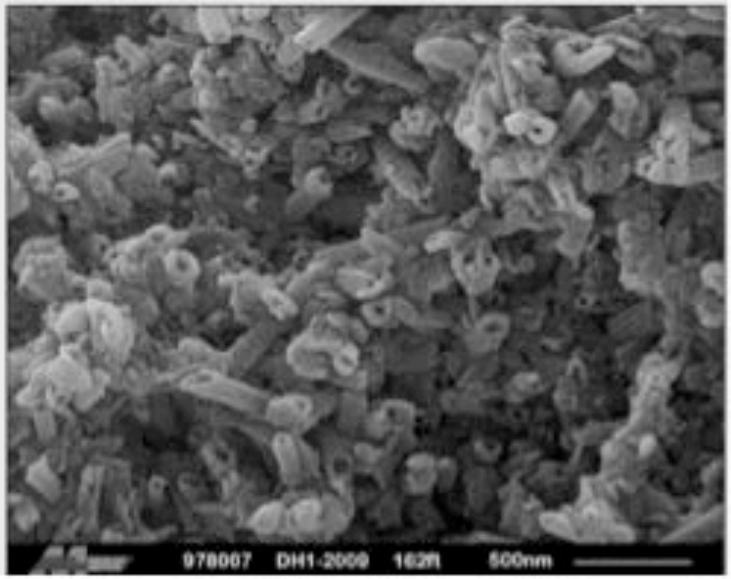


XRD Results

Kaolinite:	Not Detected
Halloysite:	99.5%
Alunites:	Not Detected





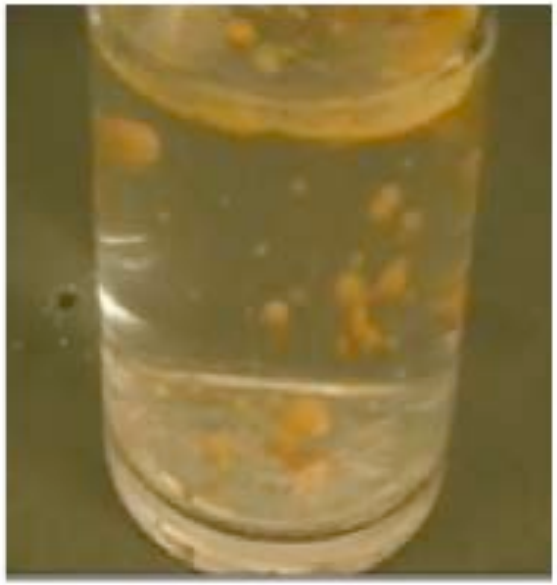


Dragonite™ Halloysite Clay Typical Analysis

True Specific Gravity	2.52
Refractive index at room temperature	1.534, dried at 100°C 1.548
Density	2.70 ± 0.03 gcm^{-3}
% Total Shrinkage	21.40
pH in water	6.4
Oil Absorption (Linseed Oil) Powder	**40 lbs/ 100 lbs Dragonite™**
Oil Absorption (Linseed Oil) In Seawater	**85 – 245 lbs/ 100 lbs Dragonite™**
BHT Surface Area	65-120 m^2g^{-1}
BHT Pore Volume	1.2 – 1.34 ml/gm
Cation Exchange Capacity	11.0 meq/ 100g
Cation Exchange Capacity in Seawater:	47 meq/100g due to activation
Hunter Brightness	77.0 – 98.4
Particle Size Distribution:	
<5 μm	100%
Avg PSD	1.5 μm
Aspect Ratio (L/D)	20

Dragonite™ Halloysite Clay in Oil Remediation: Physical Remediation

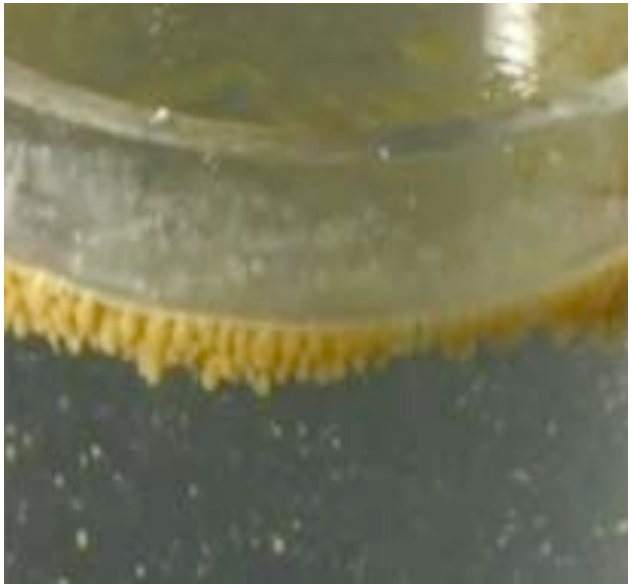
- **Solution for Marshland Environment**



- Dragonite™ Halloysite Clay is a natural and untreated sorbent for a marshland environment. (**Left)** Dragonite™ is added on top of assimilated oil polluted salt water. (**Middle & Right)** Images after clay has adsorbed, de-emulsified & dispersed oil. On oil polluted marshland, the clay will adsorb oil via capillary "wicking" and prevent penetration to the subsurface. Dragonite™, when used as a wicking sorbent material, is superior to Bagasse because it does not need to be recovered once it adsorbs oil, which avoids disruption of the marsh wildlife.

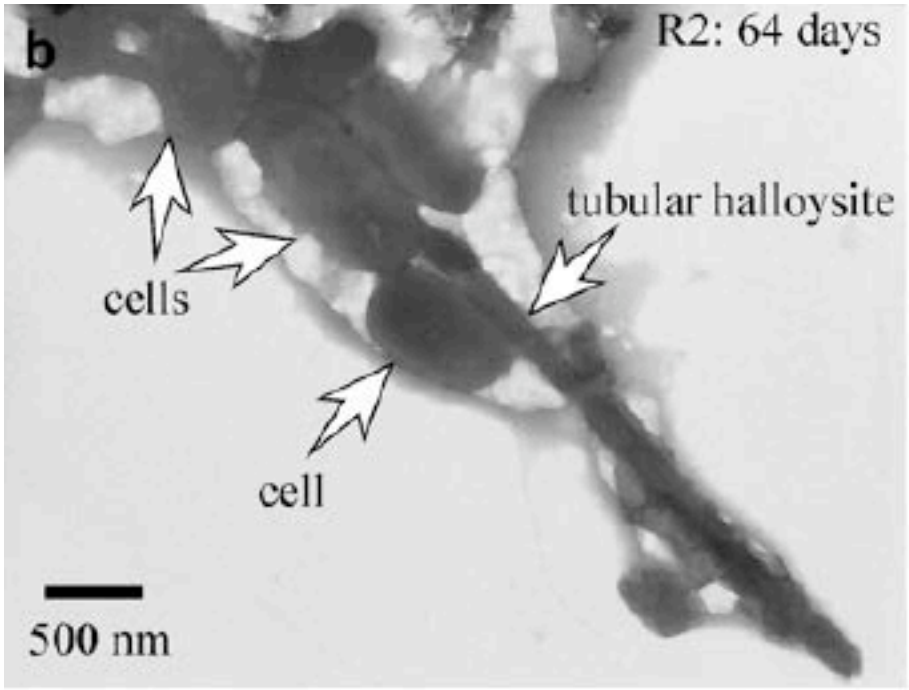
Dragonite™ Halloysite Clay in Oil Remediation: Physical Remediation

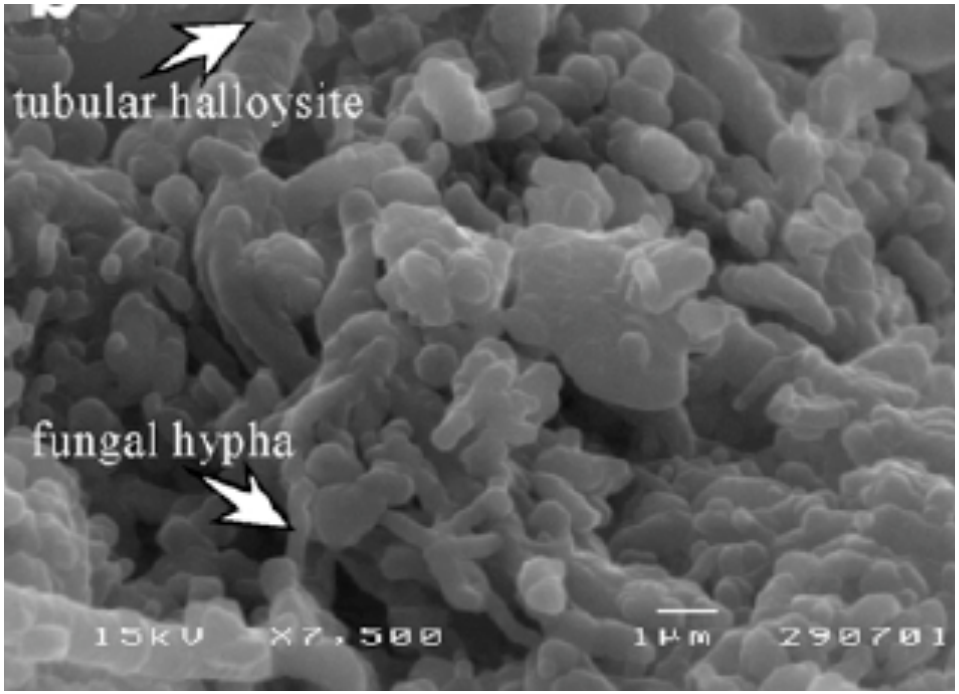
- **Solution for Deep Sea Environment**



- Dragonite™ Halloysite Clay is hydrophobically treated to enhance micro-droplet dispersion and ensure floatation in a deep sea environment. (Left) Dragonite™ is added on top of oil-polluted saltwater. (Middle & Right) Images of floating clay/oil micro-droplets after clay has adsorbed, de-emulsified & dispersed oil. Micro-droplets will float on the surface until hydrocarbon is rapidly biodegraded.

Dragonite™ in Oil Remediation: Bioremediation



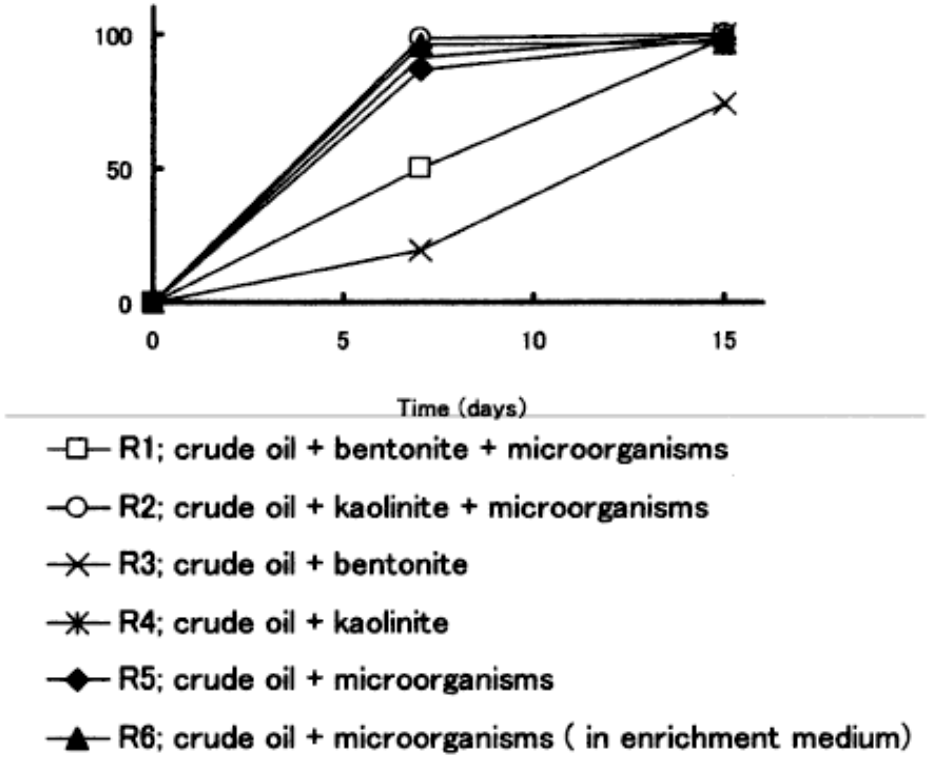


- Halloysite rapidly enhances the growth of bacteria necessary for hydrocarbon degradation. SEM image (left) and TEM image (right) of a bacterial cell network formation after 64 days consisting of short and long rod-shaped bacteria and spherical bacteria attached to the edges of Halloysite. Data sourced from 1997 Sea of Japan Russian tanker spill.[1]

1 - Siti Khodijah Chaerun, Kazue Tazaki, Ryuji Asada And Kazuhiro Kogure (2005). 'The Interaction Between Clay Minerals And Hydrocarbon-Utilizing Indigenous Microorganisms In High Concentrations Of Heavy Oil: Implications For Bioremediation', Clay Minerals 40, 105 - 114

Dragonite™ in Oil Remediation: Bioremediation

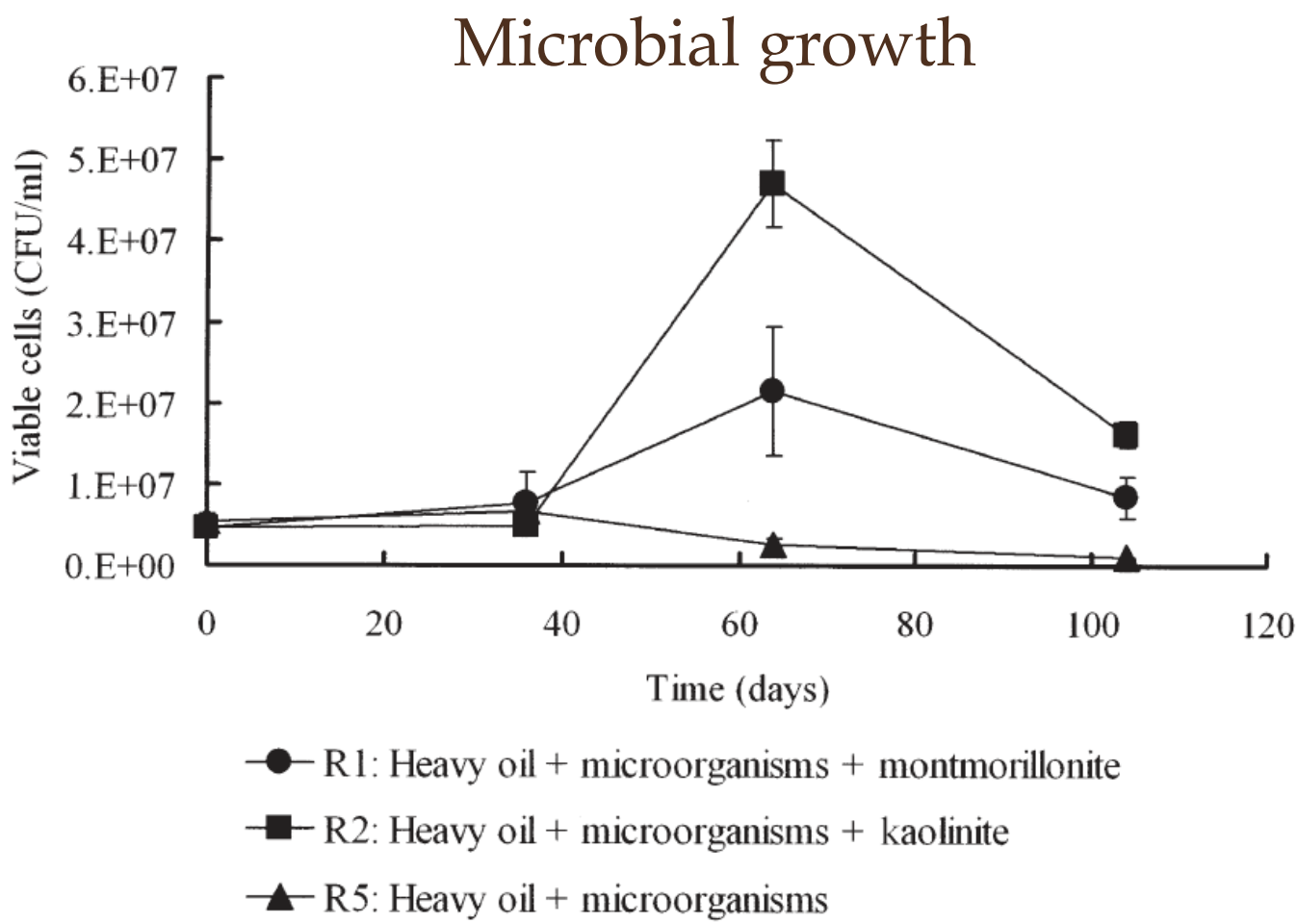
Removal Efficiency of Hydrocarbons



- Data indicates that upon colonization of bacteria on a Halloysite-oil microsphere, 98% of the hydrocarbon is naturally degraded within 7 days- eliminating the need to retrieve the sequestered oil. Data is sourced from 1997 Sea of Japan Russian tanker spill.[2]

2 - Chaerun, S. Khodijah, Tazaki, Kazue, Asada, Ryuji (2003). 'Double Function of Bentonite and Kaolinite as Adsorbents and "Microbial Growth-Support Media" for Degradation of Crude Oil', Kanazawa University Repository for Academic Resources

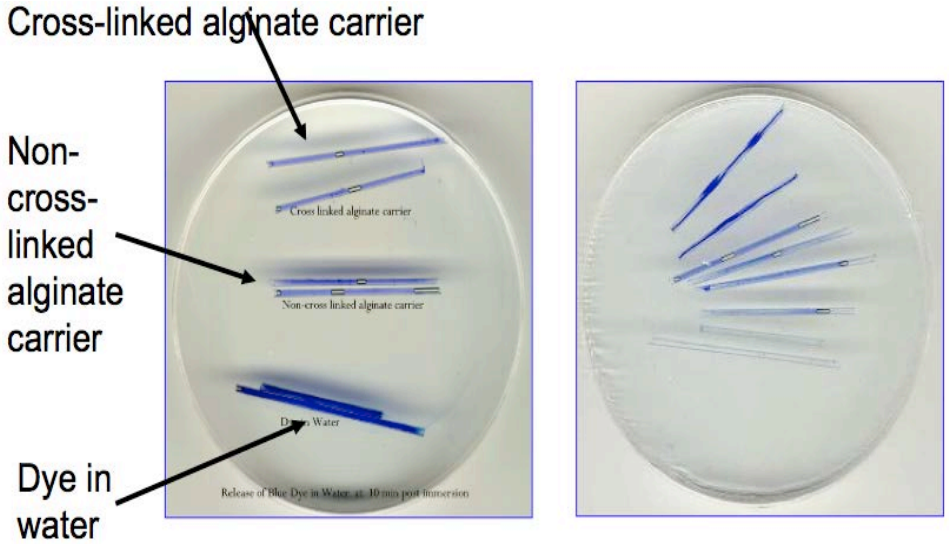
Dragonite™ in Oil Remediation: Bioremediation



- Microbial growth (bacterial and fungi) as viable cells in colony-forming unites per ml over the course of the experiment. Error bars represent standard deviations[1]

1- Siti Khodijah Chaerun, Kazue Tazaki, Ryuji Asada And Kazuhiro Kogure (2005). 'The Interaction Between Clay Minerals And Hydrocarbon-Utilizing Indigenous Microorganisms In High Concentrations Of Heavy Oil: Implications For Bioremediation', Clay Minerals 40, 105 - 114

Dragonite™ Halloysite Tubes as a Carrier of Natural Microbes



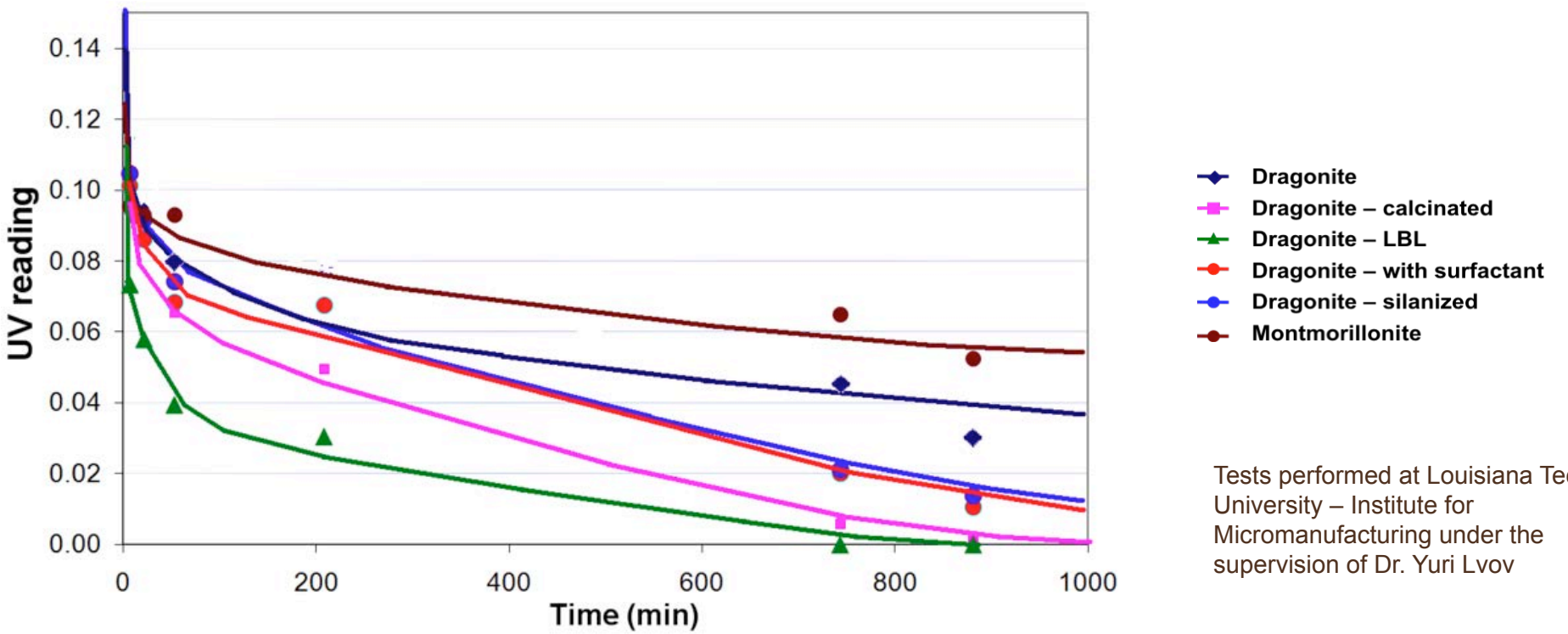
Release of blue dye in water at 10 min. post immersion

Release of blue dye in water at 48 hours post immersion

TEM of IBPC loaded into a Halloysite tube

- Due to its tubular nature, Dragonite Halloysite Clay's inner lumen can be loaded with an (an)aerobic bacteria in order to **expedite the biodegradation** of a hydrocarbon after it has been adsorbed by the clay. Release rates of the bacteria can be tuned based on the geometry of the Halloysite tube and methods of encapsulation such as layer-by-layer polyelectrolyte shell formation and placement of stoppers at the tube endings. The ability to load active agents within the tubes of the Halloysite was first discovered and patented by the US Naval Research Lab. Applied Minerals Inc maintains a license agreement on this patented technology.

Sorption of Toluene



Tests performed at Louisiana Tech University – Institute for Micromanufacturing under the supervision of Dr. Yuri Lvov

Dragonite can be modified through different methods to improve its sorption capability

Modification	Sorption %
Dragonite - with LBL polyelectrolyte shell formation	100.0%
Dragonite - Calcinated	99.6%
Dragonite - With Surfactant:	97.3%
Dragonite - Silanized	96.4%
Dragonite - Unmodified	91.8%
Comparison - Montmorillonite Clay	86.5%

Applied Minerals: Surface Piles of Halloysite

- Five Surface Piles of Halloysite at the Dragon Mine :

Waste Pile Number	Tons
1	957,280
2	734065
3	1,779,360
4	255,063
5	801,130
Total	**4,526,989**

- Five piles on the surface of the Dragon Mine hold 4.5M tons of material
- Piles are previously mined and ready to ship
- Extensive evaluation of mineralogy and chemistry content
- Piles tested by EPA and determined to be free of acid drainage with no material amount of heavy metals. http://www.pimausa.com/dragon.html

Applied Minerals: Surface Piles of Halloysite

Applied Minerals: Underground Halloysite Resource

Measured Resource:	596,700tons
+ Indicated Resource:	776,500tons
= Total:	1,373,200tons

- 1,373,200 ton readily-accessible underground resource with industry leading quality
- Extraction of material from this resource in progress

Processing and Logistics

KaMin LLC Plant

- **Agreement with KaMin LLC to toll process material**
  - Leading kaolin producer
  - Significant volume capacity
  - Capable of adding surface treatment and loading active ingredients on location
  - Utilize wet process technology

Dragon Dry Milling Plant

- Existing plant at Dragon Mine currently online
- Currently producing Dragonite-XR and HP
- Micronizing with 95-100% recovery
- Investing in a plant expansion to increase capacity and capabilities
  - Capable of wet and dry process
  - Also capable of producing pigments

- **Current combined capacity of 30k+ tpa**





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Appendix:
Halloysite as Sorbent in Marshland Conditions: Wicking Study

October 18th, 2010

Preliminary testing performed under the direction of the EPA

Conducted at University of Cincinnati

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EXPERIMENTAL ANALYSIS OF SORBENT “DRAGONITE™”

The oil sorption behavior of this sorbent was evaluated under various conditions in microcosms. Each microcosm was composed of an underlying clean sand layer, an oiled-sand layer or oil layer (75% of oil saturation), and an overlying sorbent layer. The experiments were performed in sealed microcosms for 30 days. At day one and at the end of the period, each layer of the microcosm was separated and samples were taken. Samples were extracted with dichloromethane and quantified by UV espectro-photometer.

The results of the 5 experiments conducted for analysis of the sorbent are showed in table 1. Each experiment was set with a duplicate as follows:

Table

Experiment	Sorbent	Oiled-sand / oil layer	Sand layer	Water table level
A	1 cm	1 cm oiled-sand	5 cm	On top of the clean sand layer
B	1 cm	1 cm oiled-sand	5 cm	On top of the sorbent layer
C	1 cm	10 g oil	5 cm	On top of the clean sand layer
D	1 cm	10 g oil	5 cm	No water table level
E	1 cm	10 g oil	5 cm	Just 0.5 cm water layer on top of the sorbent layer

Note: Sand layer was separated into two layers. *Top sand* corresponds to the 1 cm upper portion of the sand layer. *Bottom sand* corresponds to the remaining 4 cm of sand layer.

The saturation concentration of oil in the oiled-sand was measured following same procedure as for the other samples. The result is showed at the end of table 1.

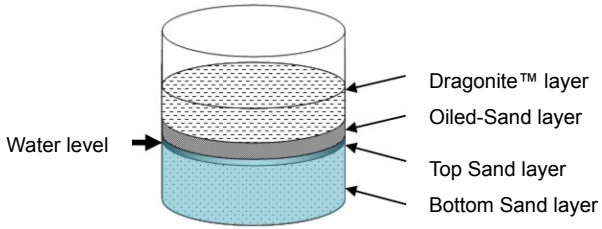
Conclusion:

Scenario A

Dragonite™ placed on top of sand-oil mixture which is on top of clean sand layer

Water Level: On top of the clean sand layer

	Results after day 1		Results after day 30	
	Run 1	Run 2	Run 1	Run 2
Percent of oil captured by Dragonite	62.0%	23.2%	50.3%	47.6%

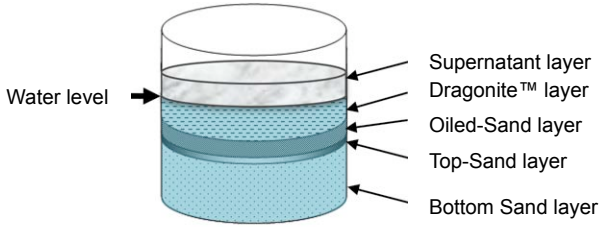


Scenario B

Dragonite™ placed on top of sand-oil mixture and below supernatant

Water Level: On top of the Dragonite layer

	Results after day 1		Results after day 30	
	Run 1	Run 2	Run 1	Run 2
Percent of oil captured by Dragonite	73.0%	52.4%	85.0%	49.0%

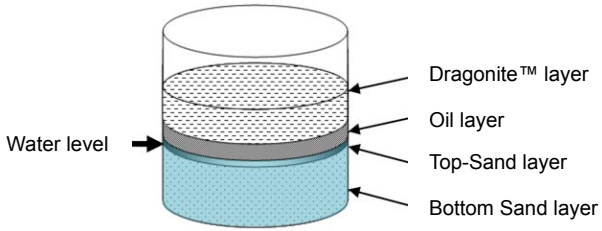


Scenario C

Dragonite™ placed on top of oil which is on top of clean sand

Water Level: On top of the clean sand layer

	Results after day 1		Results after day 30	
	Run 1	Run 2	Run 1	Run 2
Percent of oil captured by Dragonite	98.6%	97.8%	98.3%	97.0%

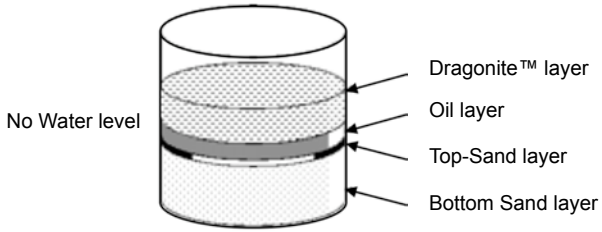


Scenario D

Dragonite™ placed on top of oil which is on top of clean sand

Water Level: No water present

	Results after day 1		Results after day 30	
	Run 1	Run 2	Run 1	Run 2
Percent of oil captured by Dragonite	60.1%	71.8%	80.2%	80.5%



Scenario E

Deemed to be non-applicable by researchers

Performed at an independent laboratory

Contact Information

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