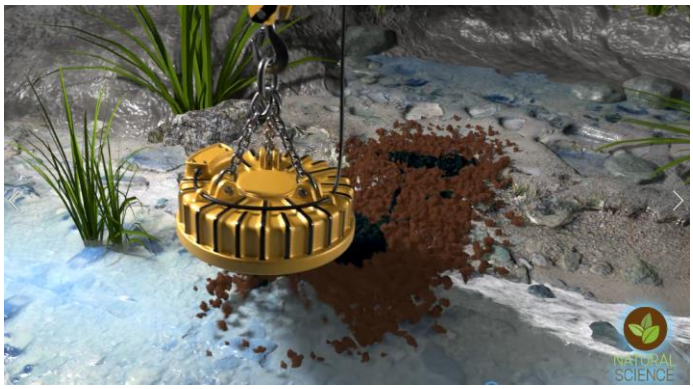
MAGNETIZABLE ABSORBENT TECHNOLOGY (MAT™)

2019 R&D100 Award Entry



Visualization of Applying Magnetic Absorbent Technology to a shoreline spill.

BRIEF DESCRIPTION

Natural Science's Magnetizable Absorbent Technology provides a magnetizable, hydrophobic fibrous organic product that can be manipulated magnetically to trap and remove environmental spills, including oils, fuels, chemicals and PCBs. Effective on land, water and other surfaces, this technology efficiently addresses environmental accidents, water treatment, and filtering needs across many industries.

SUMMARY

Oil and chemical spills continue to be environmental threats on both small and large scales worldwide. In many cases these spills occur in areas and regions that do not lend themselves to easy access or to standard methods of remediation. In some locations like the Niger Delta, where one of the most devastating spills on the planet is located, access to clean water and the mangroves on which the entire ecology depends were horrifically impacted. New techniques are needed to remediate these damaging spills without further harm to the limited fresh water supply and to remove and lock away the chemicals while leaving water behind. Simple methods to retrieve and dispense of the material used in the clean-up process are also necessary.

Magnetizable, hydrophobic, organic and non-leaching absorbents were not available on the world market until now. The magnetizability of these absorbents is a significant and novel approach. It enhances the clean-up technology and improves the manipulation and handling of absorbents in toxic environments.

Oil and magnetizable absorbent in water

Magnetic retrieval of oil and magnetizable absorbent

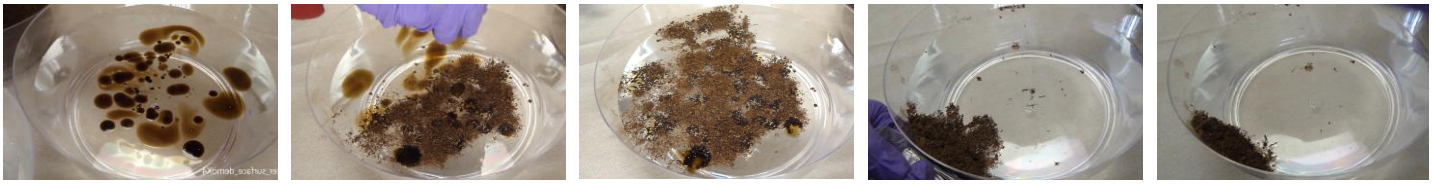
PRODUCT DESCRIPTION

What does the product do?

Natural Science's Magnetizable Absorbent Technology ("**MAT™")** absorbs spilled hydrocarbons and its by-products (oils and fuels) along with a wide range of chemicals. The list includes polychlorinated biphenyls (PCBs) and even blood, and it can absorb 5 to 10 times its weight in spills. Once absorbed, the captured spilled materials degrade within the walls (cellular structure) of the MAT absorbent (absorption agent) without leaching back into the environment even under increased external pressure. In addition, MAT absorption agents are magnetizable, hydrophobic organic materials that float on water. The absorbent's magnetizability enables unique means of retrieval, confinement, and manipulation with magnets not otherwise available. See demonstrations: https://www.naturalscienceusa.com/emop-demos2

Applications. MAT can be used on large- and small-scale spills on land or water. It has industrial applications at chemical plants, petroleum plants, water treatment facilities, and engineering/scientific facilities where many types of spills can occur. In addition, it has applications at harbors, businesses, and municipalities that must deal with occasional spills; some of which can be toxic. A growing need for MAT is within industries that produce water that contains oil and other contaminants. This water is not potable and does not meet standards for normal disposal without treatment. MAT provides the following additional advantages:

- Environmentally benign
- Improves the removal and handling efficiency of spent absorbent because of its magnetizability
- Absorbs harmful chemicals and prevents them from leaching back into the environment
- Limits the handling of toxic spills by human hands because of its magnetic properties
- Provides faster clean up and magnetic containment of spills
- Improves and increases the application value of sorbents to confined spaces or otherwise difficult retrieval locations
- Efficiently bonds the oxide particle with hydrocarbons which enhances the efficiency of the product
- Works with Electromagnetic Remediation Technology Systems such as electromagnetic ramps to retrieve spent sorbents from water. See video #4: https://www.naturalscienceusa.com/emop-demos2



Spilled oil is absorbed by MAT and pulled toward a magnet

Spilled oil is absorbed by MAT and lifted by a magnet

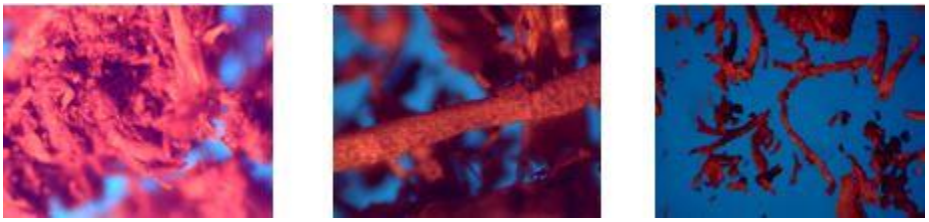
How does the product operate?

Fibrous Organic Absorbents. Many naturally hydrophobic organic materials, such as soil humus (peat) shown below, are fibrous and act as ionic exchangers. They exchange either positively charged ions (cations) or negatively charged ion (anions) in their interactions with some other substances. These fibrous materials also combine well with nano-sized (10^{-9} m) or micron-sized (10^{-6} m) iron oxides. This includes Iron III and Iron II oxides such as magnetite (Fe_3O_4) and electrolytic iron oxide particles. The oxide particles are held and attracted to the fibers by the electromagnetic properties (electrostatic forces) of the two materials. The resulting product is a magnetizable organic absorbent that is enhanced by the combined properties of the two substances.

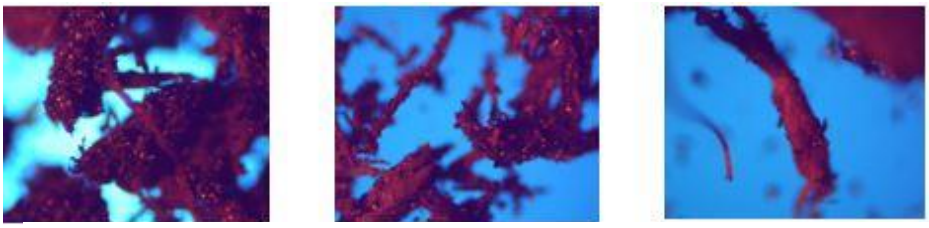
Magnetizable absorbent

Magnetizable absorbent attracted to a magnet

Microscopic images of the combined product are shown below. The absorbency of the humus is unaffected by adding the oxide particles. Moreover, the oxide particles form a weak bond with hydrocarbons that leads to an additional enhancement when cleaning such spills: the soil humus, which is already a natural hydrophobic absorbent, is now also magnetizable and efficient at collecting hydrocarbons spills, as well as chemicals and other substances. The product is buoyant on water, and magnetite particles do not oxidize to form rust in fresh or saltwater. Other iron oxides are sufficiently stable on the time scales useful in cleanups.



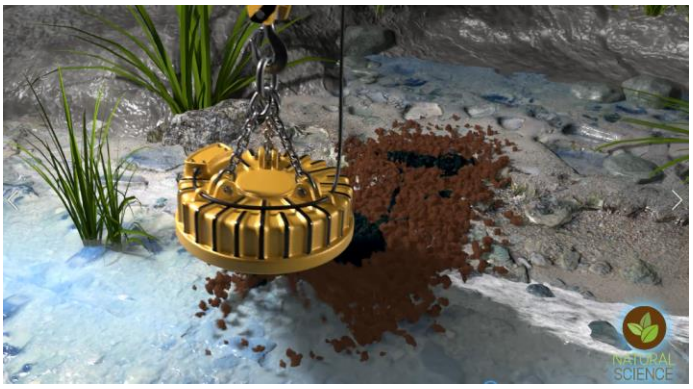
Three microscopic images of fibrous humus absorbent at 200 X magnification



Three microscopic images of the fibrous humus absorbent combined with magnetite. The oxide particles are strongly attracted to the fibers due to electrostatic forces.

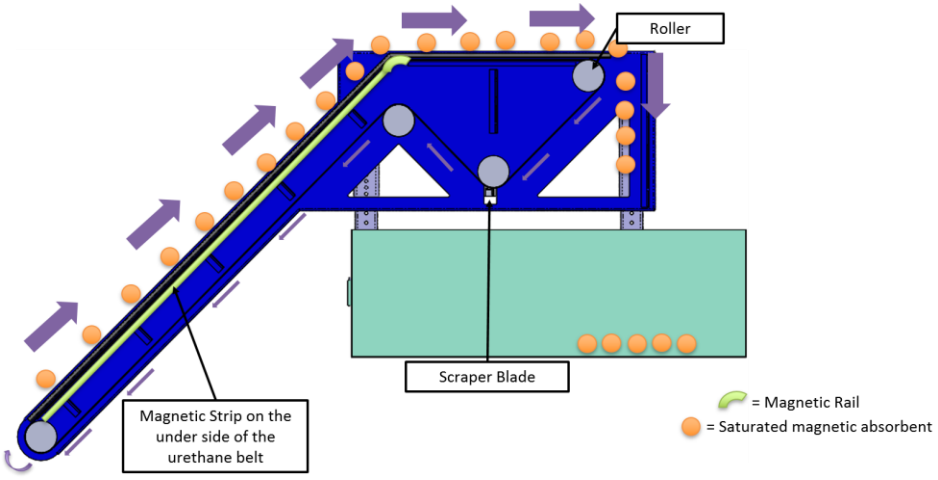
Non-leaching. The product repels water due to the polar nature of water molecules. At the same time, it absorbs and locks away other non-polar liquids (oil, chemicals, etc.) and soluble solids within its cell walls (cellulose membrane). Once spilled material is absorbed, the absorbent does not allow leaching back out into the environment even with increased external pressure. The interaction of the absorbent with external magnetic fields magnetizes the absorbent along with its absorbed spill. The tiny oxide (micron sized) particles temporarily act as small dipole magnets that attract each other. This in turn causes the fibers to which they are attached to be attracted to each other as well as to the poles of the external magnet. This allows the saturated absorbent to be magnetically attracted, placed over a containment vessel and released into the vessel when the magnetic field is powered off.

Product buoyancy and retrieval. The buoyancy of the combined magnetized product is an important property that has many advantages for spills that occur on water and shorelines around the world. For example, in many shallow water spill situations, heavy hardware is either not usable or is not the best approach to the problem. Cleaning shallow waterways and marshland with the simple application of the magnetizable absorbent and a hoist- or crane-type magnet is a versatile and unique option, particularly in places where access is difficult. The embedded video demonstrates the concept. See video #3: https://www.naturalscienceusa.com/emop-demos2.



Rendering of shoreline cleanup

Continuous retrieval. Saturated absorbent can also be collected in a more continuous manner with electromagnetic ramps. On larger bodies of water and where large amounts of absorbents are used (large spill sites), electromagnetic ramps can continuously capture and collect the spent material. See video #4: https://www.naturalscienceusa.com/emop-demos2



Continuous retrieval with a magnetic ramp

Product disposal. Disposal of saturated magnetic absorbents can be done by burning in special incinerators for energy production. This depends on the nature of the spilled substance that was absorbed. In the case of waste collected from the cleanup of hydrocarbon byproducts and biofuels, burning can produce several thousand BTU's per kg of saturated product. When the absorbed waste is toxic or otherwise not environmentally safe to burn, it can be buried or placed in landfills. The

humus matter from which the product is made is already biodegraded, and it provides enough oxygen to support microbes in the soil which break down the oils that are captured by the absorbent. The absorbed oil will not leach from within the cellulose structure of the absorbent, but it will instead degrade within it. In some instances where disposal sites are not available the saturated absorbent can be safely left in place.

PRODUCT COMPARISON

How does this product improve upon competitive technologies? –Absorbent Technologies

Many organic, inorganic and synthetic absorbents are available on the market today. All absorbents become saturated and are either disposed of after use or mechanically manipulated for reuse with wringers, for example. Few absorbents meet the non-leaching environmental standards that would allow them to be left in place. Regardless of the type of absorbent used, large scale confinement, retrieval, collection and distribution in difficult locations is challenging. This is particularly evident in very toxic spill situations. MAT is transformative in its ability to magnetically confine, retrieve, collect and manipulate spills.

Organic absorbents. These absorbents include materials such as dry coconut shell fibers, peat moss, hay, sawdust, ground corncobs, feathers and other readily available carbon-based products. While these naturally hydrophobic absorbents can be used to clean oil on the surface of the water, widespread use of such materials results in a saturated waste product being left behind. These waste products must typically be managed by hand or with other mechanical methods but cannot be easily retrieved from the water.

Natural inorganic absorbents. Certain natural inorganic absorbents such as sand, clay and volcanic ash can absorb several times their weight in oil. These types of absorbents, however, are less likely to be hydrophobic and will absorb water as well as oil.

Synthetic absorbents. These are man-made products developed to absorb a high quantity of oil. These synthetic absorbents, such as polyethylene, nylon and other plastics, will generally float and are better suited for use in water environments. However, most synthetic absorbents cannot be cleaned after use and cause further environmental pollution if they are not completely removed and disposed of properly.

Comparisons

Broader applications. The ability to manipulate MAT with magnets provides for applications in confined spaces and difficult to reach areas where spills may reach. MAT can be deployed and retrieved in these locations with magnets without human intervention. This is necessary in toxic or oxygen deficient locations. that are otherwise not normally accessible. MAT provides a huge advantage in applications in deep wells that are used to access spills near beaches or close to water tables and aquafers.

In addition, magnetized absorbents can be used to clean up and remove a wide variety of other contaminants on many other nonporous surfaces with applications across many industries.

Easily retrieved and confined. A magnetic conveyor belt application on water allows for the continuous collection of saturated absorbent. This is particularly useful in very large- scale water spills where significant amounts of absorbent material may be dispersed and retrieved. The magnetic confinement afforded by MAT's iron oxide affinity to oil reduces the spread rate of oil on water spills. This is in the presence of an external magnetic field.

Labor-efficient. Because of easy magnetic recovery, MAT is much more labor-efficient and results in much greater recovery rates. The mixture can then easily be moved by traditional magnets and deposited into a containment vessel.

Safer. The ability to remotely handle MAT or to handle it at a distance with magnets provides safe interaction with toxic spills. Material handling in industries that deal with the disposal of the waste product also becomes safer and automation with magnets is already commonplace in industry.

Lightweight. MAT remains a very lightweight absorbent technology despite the addition of oxides. The bond to the fibrous structure of the absorbent is efficient and the ratio of oxide is extremely small.

How does this product improve upon competitive technologies? –Other Technologies

Traditional oil removal approaches also include the use of microorganisms or biological agents to breakdown or remove oil, sorbents, in-situ burning, the use of dispersants and dredging and skimming techniques. These methods, however, are often difficult, expensive and inefficient. This is particularly the case because oil can spread outwardly upon contacting water, making it difficult to control and transport.

With respect to dispersants, chemicals are mixed into the environment to attempt to facilitate a cleanup. Introducing chemicals, however, has shown to have significant negative impacts on marine life and aqueous environments.

In a traditional boom and skimmer system the contaminated area is isolated by a boom, and a mechanical skimmer is used to remove only oil located at the surface of the water. This process is time consuming and inefficient. In addition, skimming is susceptible to waves, currents, debris, seaweed, kelp and other water elements which can reduce skimmer efficiency.

Product Limitations

As opposed to traditional absorbents, magnetizable absorbents require, of course, the sourcing, mixing and packaging of magnetite (or iron oxide). However, magnetite is widely available globally and, given the small quantities of magnetite required for optimal results relative to the absorbent, the shipping costs of both the raw magnetite and the combined product are minimal compared to the absorbent-only product. In addition, we have sourced vendors which are eager to mix and package the combined product at competitive prices.

The magnetite in the absorbent is environmentally benign and therefore does not complicate traditional disposal methodologies.

Advantages/Disadvantages of Various Methodologies

Introduction

Every year there are countless oil spills alone in the U.S. and globally. Particularly with large oil spills, a multitude of technologies are brought to bear. In addition, cleaning up industrial solvents, dissolved chemicals and fuel oils continue to be a long and expensive process using multiple technologies to minimize groundwater contamination leaking into drinking water wells, wetlands, streams and other natural resources. The table below compares the competitive advantages of the MAT system to traditional sorbent technologies.

Competitive Strengths [1]

FEATURE	TRADITIONAL ABSORBENTS	MAT
Containment	Distribution of sorbents on oil contained in booms can effectively suppress the effects of waves and prevents oil from splashing over the boom. Use of traditional sorbents is usually only appropriate during final stages of a cleanup or to aid in the removal of thin films of oil	Much broader applications including at the early stages of spill cleanup Magnetized absorbent controls and attracts oil
Collection	Sorption time for saturation is much longer for viscous oils Recovery rate decreases as oil film becomes thinner	Magnetized absorbents have high collection rates without regard to oil viscosity Provides ability to retrieve saturated material in confined spaces
Handling/Disposal	Typically, must be managed by hand or other mechanical means	Magnetic handling provides for easier manipulations and disposal methods. Avoiding manual interaction or exposure to any harmful waste
Environmental Impact	Oil is often left behind due to inefficient recovery methods	Oil and solid waste are magnetically removed efficiently and the waste product is non-leaching

Price of Product

There are many types and brands of absorbents available in the marketplace. Suppliers with whom we have been discussing joint venture opportunities typically price their products commercially at $4 to $15 per pound. We would expect to receive discounts to their normal pricing. Without any such discounts, the price of magnetizable absorbent (not including shipping costs) would be in the range of $5 to $7 per pound. Product is available via our website: www.naturalscienceusa.com

References

[1] See, e.g., ExxonMobil Oil Spill Response Field Manual, Revised 2014, Copyright [c] 2014, ExxonMobil Research and Engineering Company

Patents/Patents Pending

[1] A. Warner, Inventor "Magnetization Control and Transportation of Oil," U.S. Provisional Patent Application No. 15/662,451

[2] A. Warner, Inventor, "Electromagnetic Pulse-Waved System for Oil Manipulation," U.S. Provisional Patent Application No. 15/700,720

[3] A. Warner, Inventor, "Magnetization and Manipulation of Hydrophobic Absorbents," U.S. Provisional Patent Application No. 62/698,619

[4] A. Warner, Inventor, "Magnetization Control and Transportation of Oil," PCT/US 2017/055140

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