An Evaluation of Fire Suppression and Bioremediation Products
for Spill Control in Non-Fire Situations
{F-500 (formerly Fuel Buster), BioSolve, Alcoseal 3-6, and HC-2000}

Abstract

Fire departments are using non-foam wetting agents on fuel spills in non-fire situations, which increase runoff and the volume of contaminated soil and water. Accordingly, environmental cleanup costs are radically increased. In some cases, fire departments are washing down fuel spills and leaving them to break down rapidly in the environment due to exaggerated vendor biodegradation claims.

With 3M withdrawing from the foam market due to toxicity problems, fire departments are under increased pressure to find alternative fire and vapor suppression agents. Exaggerated claims for some products (like F-500 and BioSolve) have encouraged some fire departments to begin using these products.

These products claim to encapsulate or break apart fuel, which "neutralize" or eliminate flammable liquids and vapors. Currently there is no test protocols or uniform standards set by NFPA to verify the fire and vapor suppression performance of these products.

Remtech conducted an independent investigation of select fire suppression and bioremediation agents (F-500, BioSolve, Alcoseal 306 foam, and HC-2000) to attempt to quantify fire and vapor suppression, and environmental degradation performance.

Low expansion FFFP and alcohol resistant foams such as Alcoseal 3-6 or HC-2000VAP provide the best fire and vapor suppression performance and do not contain perfluorooctanyl sulfonate, which was the primary toxic constituent in 3M foams. Wetting agent suppressants (BioSolve and F-500) do not always prevent ignition or suppress flammable vapors, especially in confined spaces. These agents also require mixing energy to combine with water and additional energy to mix with fuel to effectively emulsify flammable liquids. Without continued agitation, these products loose their fire and vapor suppression properties.

Best management spill response practices require that spills are contained and spill volumes are minimized. Recovery of gross fuel contamination should take precedence over dispersing into the environment with wetting agents. Water and foam based fire suppressants are preferred over F-500 and BioSolve since they do not disperse contaminants as widely in the environment.

Remtech's bioremediation accelerator HC-2000 provided the best fuel degradation rates.

Remtech HC-2000S provides superior pavement cleaning when compared to F-500, BioSolve, and Alcoseal 3 -6. None of these agents address residues, which are adsorbed in asphalt or concrete pavements. For this reason, it is recommended that sand or oil dry be broadcast over spill areas to minimize skidding hazards.

An Evaluation of Fire Suppression and Bioremediation Products
for Spill Control in Non-Fire Situations
{F-500 (formerly Fuel Buster), BioSolve, Alcoseal 3-6, and HC-2000}

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PROBLEM -

Fire departments frequently apply fire suppression products containing wetting agents/dispersants in non-fire fuel and hazardous material spill incidents[1]. 3M Corporation recently (May of 2000) pulled its perfluorooctanyl sulfonate foams (its entire foam line) from the market place due to environmental toxicity problems. Many fire departments are shifting to non-foam based water additives containing wetting and encapsulating/emulsification agents which are currently not regulated as fire suppression agents by the National Fire Protection Association (NFPA).

Regulatory approval is required from EPA and State agencies prior to using these products on spills. Select product applications include; accident pavement washdown, injection into storm sewers to allegedly suppress flammable vapors, and application to containers/tanks and spills to suppress potential fire hazards. The practice of applying these agents is performed under the assumption that the fire hazard from flammable fuel and liquid spills will be neutralized (made non-flammable, biodegrade, and vapors will be reduced below the Lower Explosive Limit - LEL).

During the past 25 years, principals with Remtech Engineers have observed fire departments applying products such as BioSolve, F-500 (formerly Fuel Buster) and various foams to fuel and liquid spills. These products increase the mass and volumes of contaminated runoff and affected media (i.e., soil, sediment, and surface water) and significantly increase cleanup costs. Many fire extinguishing agents with wetting agent/surfactant properties are designed to increase the penetration of water into Class A materials or suppress the heat, fuel, and free radical components of the fire tetrahedron for Class B materials. By reducing the surface tension of water, the penetration or dispersion of fuels and liquids into soils, sediments, and water is also significantly increased. The emulsions, mixtures (or chemical cocoons) created by these products increases the dispersion of fuels in water and, consequently, in the environment.

> *The following Remtech case history is presented to illustrate the problem. A tanker carrying 7,600 gallons of No. 2 diesel fuel rolled over into a marsh area*

[1] In fire situations, the use of fire suppression agents to extinguish flammable liquid fires should be emphasized over the environmental concerns (expressed in this paper) to protect public health and safety first.

releasing an estimated 2,155 gallons. The fire department applied 15 gallons of F-500 and 15 gallons of AFFF foam along with 500 to 1,000 gallons of water. Strong diesel fuel odors and elevated petroleum hydrocarbon concentrations in surface soils were not present around the tanker. Information obtained from the manufacture indicated that the fuel might have been neutralized

Tanker Following Application of Foam & Fuel Buster

Excavation Following Removal of Saturated Soils

or destroyed by F-500. Further investigation revealed that the fuel had been dispersed ten feet into the ground and transported underground over 70 feet away from the tanker. The wide spread of the petroleum plume was apparently due to the soil washing and emulsion forming properties of the agents applied. Over 552 gallons of diesel fuel were recovered from site groundwater and over 800 cubic yards of fuel saturated soil were excavated. Using these fire suppression products radically increased cleanup volumes and associated costs.

Confusion exists in the marketplace between claims made by manufactures and perceptions of users (fire departments and environmental professionals) on product performance, benefits, and limitations. Product representations/perceptions include: neutralization of spills, rendering flammable liquids non-flammable, vapor suppression of flammable vapors, elimination of hazardous material spills, and enhanced degradation of petroleum hydrocarbons. NFPA has recently formed a new technical committee (December 1998) entitled "Water Additive for Fire Suppression and Vapor Mitigation" to evaluate these non-foam blanket forming products and to establish fire suppression standards and test protocols.

Several claims made by Hazard Control Technologies, Inc. (150 Walter Way, Fayetteville, GA 30214) for **F-500** (wetting agent based fire suppressant) in *F-500 Training and Recommended SOG Manual* are summarized below:

Page 2 … "F-500 is a hi-tech, Underwriters Laboratories, Inc. (UL) listed fire suppression agent used to extinguish Class A and B fires, eliminate hazardous spills, and reduce explosive vapors".

Page 5 … "When the proper mix ratios are achieved, the hydrocarbon fuel will be rendered non-flammable or locked-up".

Page 13 … "Washing the F-500 mixture into the spill will normally neutralize the hydrocarbons on contact, thus providing a safer environment to begin extrication of victims …".

Page 35 … "Again, history has shown that with a large flat spill, once mitigated with F-500, the solution can evaporate into the atmosphere without applying absorbents to the spill".

Page 36 …"When a ratio of 1 part of F-500 to 8 parts of hydrocarbon liquid to 32 parts of water are mixed and agitated, it has been consistently proven that the fuel becomes non-flammable and unable to support combustion".

Select claims made by The Westford Chemical Corporation (P. O. Box 798, Westford, Massachusetts) for their product **BioSolve (**wetting agent based fire suppressant) are presented below:

http://www.biosolve.com/spill.html . . . "BioSolve emulsifies and encapsulates the hydrocarbon almost instantly, helping to eliminate the danger of ignition, oily residue that causes slippery/unsafe surface area, or damage to asphalt, concrete or painted surfaces".

"BioSolve increases the enumeration of both heterotrophic and hydrocarbon degrading organisms in a recent study performed by NETAC at the University of Pittsburgh".

"Many responders' report that BioSolve introduced into the sanitary sewers effectively eliminates the explosion hazard when liquid fuels/solvents enter the municipal sewer systems".

Alcoseal 3-6 (non-perfluorooctanyl sulfonate containing foam) manufactured by Angus Fire Armour Ltd. (Thame Park Road, Thame, Oxfordshire, OX9 3RT) makes the following claims on their website http://www.angusinfo.co.uk:

"Alcoseal 3-6 is a superior quality Alcohol Resistant Film-Forming FluoroProtein (AR-FFFP) fire fighting foam concentrate for extinguishing and securing flammable hydrocarbon and polar solvent liquid fires".

"… Eliminates the need to stock a variety of foam types".

"Film-forming on hydrocarbons for fast flame knockdown and extinguishment".

"Stable and long-lasting foam blanket for excellent burnback resistance and post-fire security".

"Foam blanket re-seals when ruptured by personnel or equipment".

"Alcoseal 3-6 provides a vapor-suppressing foam blanket on spills of hazardous liquids. Produces a unique superstable foam blanket that suppresses vapors for much longer than conventional foams".

"… may be applied in gentle or forceful application to the burning liquid surface since it is able to withstand vigorous mixing with hydrocarbon fuel and maintain its extinguishing and vapor suppression properties".

"Alcoseal is biodegradable with more than 50% break-down after 5 days and has very low toxicity to aquatic life."

Remtech's **HC-2000** (bioremediation accelerator) is manufactured by Remtech Engineers (200 North Cobb Parkway, Suite 208, Marietta, Georgia 30062). The following claims are made for HC-2000:

> *"**HC-2000** is a propriety formulation of enzymes, micro-nutrients, and biodegradable wetting agents which catalyze or speed up the petroleum hydrocarbon and TCE bioremediation processes in soil, groundwater, and railroad ballast. Contaminated media may be treated insitu or exsitu with HC-2000 using bioventing and biosparge system, or surface application techniques".*
>
> *"Remtech's **HC-2000** works in three (3) ways – (1) direct enzyme breakdown of contaminates (2) acceleration of native microbe waste digestion (3) and desorption of contaminants from soil. HC-2000 typically breaks down petroleum hydrocarbons (jet fuel, diesel fuel, gasoline, kerosene, waste oil and other petroleum based hydrocarbons) to acceptable regulatory limits within three (3) to sixteen (16) weeks".*
>
> *"**HC-2000** is a non-toxic, non-allergenic, non-bacterial, and a biodegradable mixture of proteins, enzymes, micronutrients, and biodegradable emulsifiers. No special handling instructions are recommended for HC-2000. HC-2000 is on the approved list of innovative technologies with the Florida Underground Tank Program".*
>
> *"**HC-2000S** is an effective and economical alternative to traditional chemical cleansing and odor-masking treatments. HC-2000S is a complex mixture of proteins, enzymes, and emulsifiers, which is non-toxic. HC-2000S has the same natural bioremediation accelerators to speed up the degradation of petroleum compounds as HC-2000".*
>
> *"**HC-2000VAP** contains a vapor and fire suppressant foam (AR-FFFP) and the same natural bioremediation accelerators to speed up the degradation of petroleum compounds as HC-2000. HC-2000VAP is non-toxic, non-bacterial, and a biodegradable mixture of proteins, enzymes, micronutrients, and biodegradable emulsifiers".*

APPROACH -

Remtech conducted an independent investigation to attempt to clarify (and quantify) some of the product performance issues on select suppression agents. Note there is currently no fire or vapor suppression standardized test or evaluation methods set by NFPA for wetting agent based products. This investigation addresses fuel releases in non-fire situations. Questions addressed include:

- do these products render flammable liquids non-flammable, i.e. non-ignitable or prevent ignition?
- do these products suppress flammable vapors below the LEL?
- do these products accelerate bioremediation rates of fuels in the environment?
- do these products increase the dispersion of petroleum hydrocarbons in soil, surface water, sediments, and groundwater?
- do these products eliminate or cause petroleum hydrocarbons to disappear?
- do these products clean pavement surfaces to prevent vehicle skidding or loss of traction?

PRODUCTS EVALUATED -

Fire suppression products selected for this evaluation included: F-500 (formerly Fuel Buster), BioSolve, Alcoseal 3-6 [alcohol resistant film-forming fluoroprotein (AR-FFFP) foam concentrate], HC-2000VAP, and dry chemical extinguishing media (from an ABC extinguisher containing monoamonium phosphate, mica, ammonium sulfate, talc). Remtech's bioremediation accelerant HC-2000, and chipped clay (Oil Dry) were also evaluated.

EXPERIMENTAL METHOD -

Ignitability - ignitability is defined as the ability of a material to sustain combustion following removal of the ignition source. The ignitibility of a product/fuel/water mixture was determined by preparing a mixture of product, gasoline, and water (according to the ratios specified or implied by the manufacture). This mixture was placed in a glass container, shaken vigorously, and poured into a metal test burn pan. A propane torch was employed to attempt to ignite the vapors above the test pan. If combustion persisted following removal of the ignition source, the product was deemed ignitable.

Vapor Suppression - to measure the capacity of a product to suppress vapors below the Lower Explosive Limit (LEL), a product/gasoline/water mixture (as specified by the manufacturer) was placed in a glass container. The lid was placed on the container and the mixture was shaken vigorously. The lid was removed, and a combustible gas meter (AIM 601 multigas meter) was used to measure explosive gases in the headspace above the liquid. Headspace explosive vapors were recorded as a function of time. To simulate product performance in a confined space, the lid was replaced on the container between each measurement. To simulate product performance in a ventilated ambient air environment, the lid was left off the container. The generally accepted safe vapor suppression level of flammable liquids is 10% of the LEL.

Biodegradation - the principal degraders of petroleum hydrocarbons and contaminants in the environment are heterotrophic bacteria. Water and soil reactors were charged with native soil spiked with diesel fuel (see Figure 24). A 3% solution of HC-2000 and F-500 were added to two five (5) liter liquid reactors. A 6% solution of BioSolve was added to a third liquid reactor. Soil reactors were prepared by adding 0.5 gallons of soil spiked with diesel fuel and spraying the soil with a 3% solution of HC-2000 and F-500 and 6% solution of BioSolve. Measuring the change in heterotrophic bacteria colony counts and total petroleum hydrocarbon concentrations prior to and following product application was used to rank the product's capacity to break down diesel fuel in the environment. Total Petroleum Hydrocarbon (TPH) concentrations were determined using EPA Method 418.1 and heterotrophic plate counts by SM 9215B. Laboratory analyses were performed by independent testing laboratories (TPH -Advanced Chemistry Labs, plate counts - Analytical Services, Inc.).

Increased Fuel Distribution - many fire suppression agents emulsify or mix fuel with water. This is a temporary state induced, in part, by mixing. Fuel will separate from the mixture following an adequate period of stagnation. Fire suppressants disperse fuels over a larger volume of water and increases the availability of these mixtures to move off site via water transport or increased soil penetration. The increased fuel distribution potential was determined by placing a mixture of product/gasoline/water in a glass container (according to the manufacturer's specified ratios), shaken vigorously until a homogeneous mixture was formed, and recording the time for gasoline phase separation to be

re-established. The longer a mixture remains as an emulsion, the longer the mixture is available to migrate into soil or water columns.

Pavement Cleaning Potential - the inside of glass containers were coated with a petroleum-based grease. Fire suppression product/water mixtures (3% F-500 solution, 6% BioSolve solution, and 10% HC-2000S solution) were placed in the jars and multiple shake tests were performed. The percent of the jar's surface area cleaned by each product was recorded.

Pavement surfaces were simulated with one-foot square concrete slabs. The concrete slabs were coated with hydraulic oil on half of the block surface and diesel fuel on the other half. Fire suppression product/water mixtures were applied to the block surfaces (3% F-500 solution, 6% BioSolve solution, and 10% HC-2000S solution), brushed and rinsed with water. Rinsing operations were video taped and observations for sheens, water beading, and residual petroleum films were documented.

Fuel Elimination - fire suppression product/gasoline/water mixtures were placed in closed glass containers, shaken, and allowed to stand to determine if gasoline would separate from solution.

FINDINGS -

Test Result Summary

Product	Ignition Prevention	Vapor Suppression		Average Degradation Efficiency	Average Plate Count Increase	Pavement Cleaning Potential	Phase Separation Time, min
		Ambient Air	Confined Space				
F-500 @ 3%	no	partial	no	58.90%	0.3%	Fair	264
F-500 @ 6%	no	partial	no	No Data	No Data	No Data	No Data
BioSolve	no	partial	no	-57.2% (increase)	-86.3% (decrease)	Poor	84
Alcoseal 3-6	yes	yes	yes	No Data	No Data	Poor	13
HC-2000S	no	no	no	93.90%	95.9%	Good	14
HC-2000VAP	yes	yes	yes	93.90%	95.9%	Poor	15
Dry Chemical	yes - no mix	No Data	No Data	No Data	No Data	No Data	N/A
Chipped Clay	yes - no mix	No Data	No Data	No Data	No Data	No Data	N/A

Ignition Test Results (Photoplates 1 through 12)
Alcoseal 3-6 provided the best ignition prevention of the agents tested. It flashed initially, but did not support combustion at a 1:8:32 product to gasoline to water ratio. Direct flame impingement on the foam blanket did not result in foam breakdown or cause ignition for a period exceeding four (4) hours.

HC-2000VAP provided the next best ignition prevention. It flashed initially, but did not support combustion at 1:8:32 and 2:8:32 rations (3 & 6%). Ignition prevention persisted for more than four (4) hours at the 3% and 6% application rates.

F-500 flashed initially, and did support combustion at 1:8:32 and 2:8:32 ratios (3 & 6%). Fuel appeared to be coming out of solution in the test pan at the end of both tests. When a new mixture was prepared and allowed to stand for approximately 10+ minutes, vapors flashed, although did not burn continuously. This may be explained, in part, by evaporation of a portion of the gasoline from solution prior to attempting ignition. Note

that the manufacturer claims that for fuel spills less than 50 gallons a 1% solution of F-500 suppresses ignition.

BioSolve flashed initially, and did support ignition at a 1:6:33 ratio. When a new mixture was prepared and allowed to stand for approximately 10+ minutes, vapors flashed, but did not burn continuously. This may be explained, in part, by evaporation of a portion of the gasoline from solution prior to attempting ignition.

ABC dry chemical extinguishing media was used cover to a mixture of gasoline/water (8:32 ratio). Vapors did not ignite until the particulate blanket was stirred.

Oil dry was used to cover a gasoline/water (8:32 ratio) mixture. Vapors did not ignite until the sorbent was stirred.

Vapor Suppression Test Results (Figures 1 & 2, Photoplate 13)
Alcoseal 3-6 (3%) provided the best vapor suppression in both the confined space and ambient air test conditions, i.e., < 20% LEL for the first 110 minutes.

HC-2000VAP (6%) provided the next best vapor suppression in both the confined space and ambient air test conditions, i.e., < 20% LEL for the first 100 minutes.

BioSolve (6%) did not suppress vapors below 100% of the LEL during the initial fourteen- (14) minutes under the confined space test condition. BioSolve suppressed vapors below 25% of the LEL after three (3) minutes under the ambient air test condition.

F-500 (3%) did not suppress vapors below 100% of the LEL during the first twenty-five (25) minutes under the confined space test condition. F-500 suppressed vapors below 20% of the LEL after three (3) minutes under the ambient air test condition.

Vapor suppression tests were not run on the ABC fire extinguishing powder or Oil Dry.

Biodegradation Test Results (Figures 5 - 10, Photoplate 23)
HC-2000 - Heterotrophic plate counts were found to increase from 50,000,000 cfu/ml (prior to product application) to 9,380,000,000 cfu/ml (99.5% increase) after a four (4) day contact time in the liquid reactor. TPH concentrations were observed to drop from 2,530 mg/l to 216 mg/l (91.5% reduction) during the same four (4) day period. In the soil reactor, plate counts increased from 110,000,000 cfu/gm to 1,440,000,000 cfu/gm (92.4% increase) and TPH concentrations were reduced from 1,000,000 mg/kg to 35,900 mg/kg (96.4% reduction) during a seven (7) day test period. HC-2000 provided the best overall diesel fuel degradation of the products tested, with an average degradation rate for both soil and liquid reactors of 93.9%.

F-500 - Heterotrophic plate counts were found to drop from 80,000,000 cfu/ml to 550,000 cfu/ml (99.3% reduction) after a three (3) day contact time in the liquid reactor. Over a four (4) day period, TPH concentrations were reduced from 3,540 mg/l to 2,700 mg/l (23.7% reduction). In the soil reactor, plate counts increased from 6,000,000 cfu/gm to 1,680,000,000 cfu/gm (99.6% increase) and TPH concentrations dropped from 272,000 mg/kg to 15,900 mg/kg (94.2% reduction) during a seven (7) day test period. F-500 provided an average diesel biodegradation rate of 58.9% for both soil and liquid reactors.

BioSolve - plate counts dropped from 240,000,000 cfu/ml to 4,000,000 cfu/ml (98.3% reduction) one (1) day after inoculation of the liquid reactor. TPH concentrations dropped from 762 mg/l to 669 mg/l (12.2% reduction) over a seven (7) day period. In the

soil reactor, plate counts fell from 180,000,000 cfu/gm to 44,000,000 cfu/gm (75.6% reduction) one (1) day after BioSolve application. The TPH concentration increased from 23,100 mg/kg to 338,000 mg/kg (93.2% increase) over a seven (7) day period. BioSolve appeared to be adding petroleum hydrocarbons to the soil reactor and/or was interfering with the TPH analytical method. BioSolve provided the worst degradation rate of the agents tested, with an average of –86.9%.

Increased Fuel Distribution Test Results (Figures 3 & 4, Photoplates 14 - 17)
F-500 remained in solution the longest, i.e. phase separation of a floating gasoline layer was first observed at 264 minutes.

BioSolve - phase separation was first observed at 19 minutes when three separate layers were formed. The layers continued to reduce in thickness until 84 minutes had elapsed when a single floating layer of gasoline was formed.

Alcoseal 3-6 - a single floating layer of gasoline was formed at 13 minutes under the foam blanket.

HC-2000VAP - a single floating layer of gasoline was formed at 15 minutes under the foam blanket.

The longer the phase separation time, the longer the emulsion is available to be dispersed in the environment. **F-500** has the greatest potential to increase spill volumes, followed by **BioSolve**, then **HC-2000VAP**, and **Alcoseal 3-6**.

Phase separation tests were not performed on the ABC extinguishing media or oil dry. These materials would only increase the spill volume by the amount of material added.

Pavement Cleaning Potential Results (Photoplates 18 - 22)
HC-2000S provided the best degreasing results with over 50% of glass container surface area cleaned, followed by F-500 with 30%, and BioSolve with 20%.

Results of the concrete block cleaning tests (block coated with hydraulic oil and diesel fuel) were as follows - **HC-2000S** cleaned the best with a slight sheen in rinse waters and no beaded water forming on the block surface. A very slight slippery texture was observed on the block surface. **F-500** was the next best cleaner, with rinse water beading up on the block surface (indicating a film of hydrocarbons persisted) and a slippery texture remaining on the block surface. **BioSolve** came in last with water beading up on the block surface and a pronounced slippery texture remaining on the block surface. None of the agents tested removed diesel fuel or hydraulic oil, which absorbed into the block face.

Fuel Elimination Test Results (Photoplates 14 – 17)
None of the products tested eliminates or destroys fuel. Emulsions/mixtures of **BioSolve**, **F-500**, **HC-2000**, and **Alcoseal** (when mixed with gasoline and water) all produced a single floating layer of gasoline (following a sufficient stagnation period) which was ignitable and had explosive vapors exceeding 100% of the LEL.

CONCLUSION -

The application of wetting agent based fire suppression and bioremediation agents (**BioSolve**, **F-500**, **Alcoseal 3-6**, and **HC-2000**) to non-fire spill situations will increase the runoff volume of contaminates and the volume of impacted environmental media

including water, soil, and sediment, etc. Care must be exercised to provide containment and recovery of the resulting mixtures to avoid increasing environmental cleanup costs. **F-500** had the longest phase separation time (264 minutes), suggesting that it has the greatest potential to disperse contamination in the environment. **BioSolve** had the second longest phase separation time of 84 minutes.

F-500 (Fuel Buster) and **BioSolve** may not always prevent ignition of flammable liquids or suppress flammable vapors, especially in confined spaces such as sewers. These materials require adequate mixing with water and fuel and ventilation to provide ignition and vapor suppression. Fuel phase separation will occur over time (with a sufficient stagnation period) thereby reducing product ignition and vapor suppression performance.

To control ignition of flammable liquids, apply an appropriate foam such as **Alcoseal 3 - 6**, **HC-2000VAP,** or blanket the spill with dry sand or oil dry. Foam should not be abandoned over wetting agent based suppressants, especially until uniform standards and test procedures are established by NFPA. A water spray may also be used to suppress vapors providing runoff is contained.

None of these products will completely eliminate vehicle skidding hazards. Sand, oil dry, or another appropriate abrasive granular material should be broadcast over the spill area to provide adequate traction following initial cleanup operations. Asphalt pavement absorbs and is softened by gasoline and diesel fuel releases. This makes surface fuel removal difficult and may require pavement removal and replacement. **HC-2000S** appeared to provide the best glass surface degreasing performance at 50%, followed by **F-500** at 30% and **BioSolve** at 20%. Hydraulic oil proved to be the most difficult to remove from the concrete test blocks. **HC-2000S** cleaned the blocks the best, followed by **F-500**, then **BioSolve**. **HC-2000S** may be applied to spills on pavement, followed with a power or manual broom, water flushing, and runoff containment and recovery.

None of the agents investigated by Remtech cause petroleum hydrocarbons to be eliminated or destroyed on contact. The emulsions or mixtures formed by fire suppression agents are temporary, with fuel separating from solution within a few minutes to several hours.

HC-2000 has been shown to degrade various fuels in full-scale soil and groundwater treatment applications over time periods ranging from three (3) to sixteen (16) weeks. Comparative liquid and soil bench-scale bioremediation tests presented herein indicated that **HC-2000** provided the highest average diesel fuel degradation efficiency (93.9%), followed by **F-500** (58.9%). **BioSolve** appeared to be adding petroleum hydrocarbons to the soil or interfering with the TPH analytical method.

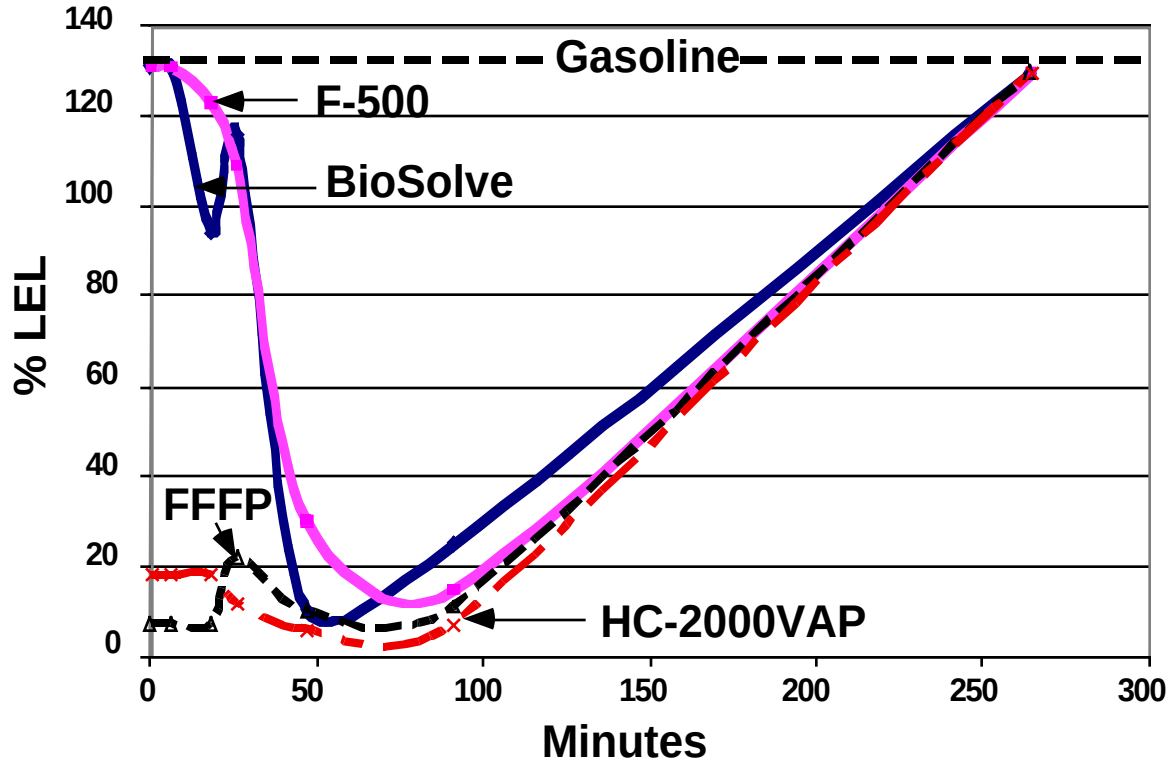

Figure 1: Gasoline Vapor Suppression in Confined Space

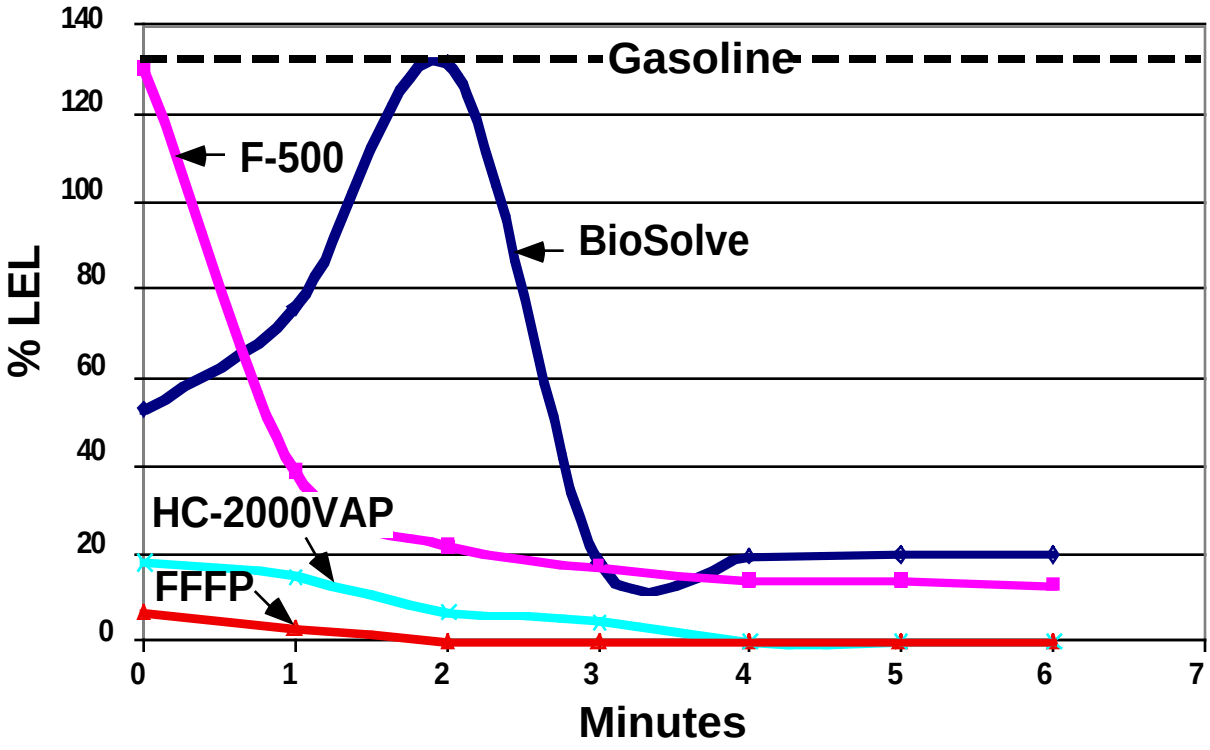

Figure 2: Gasoline Vapor Suppression in Ventilated Area

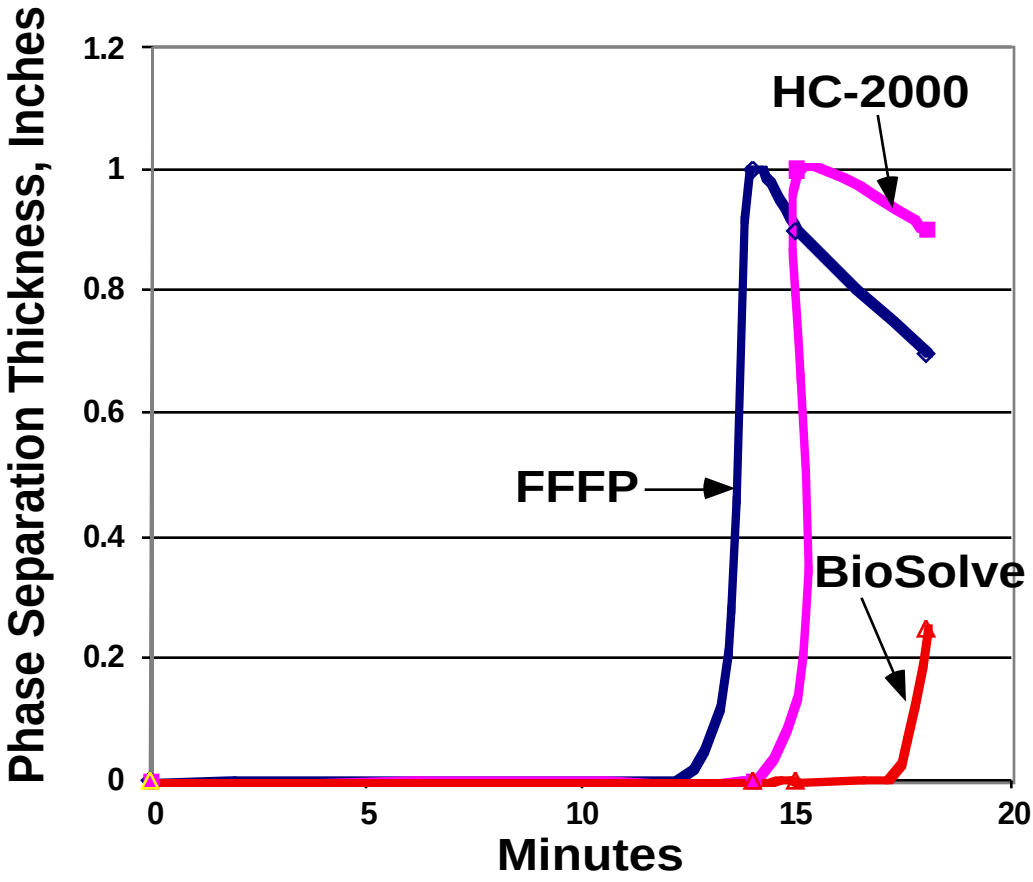

Figure 3: Mixture Phase Separation Times

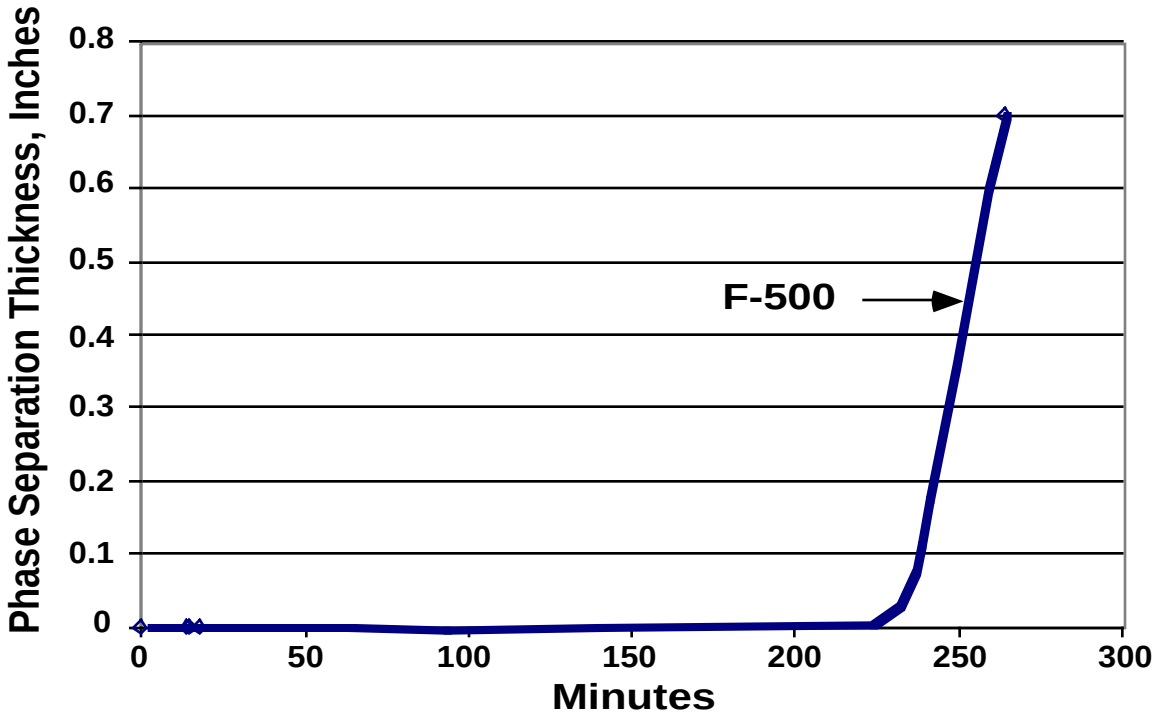

Figure 4: Mixture Phase Separation Time

HC-2000 Liquid Reactor

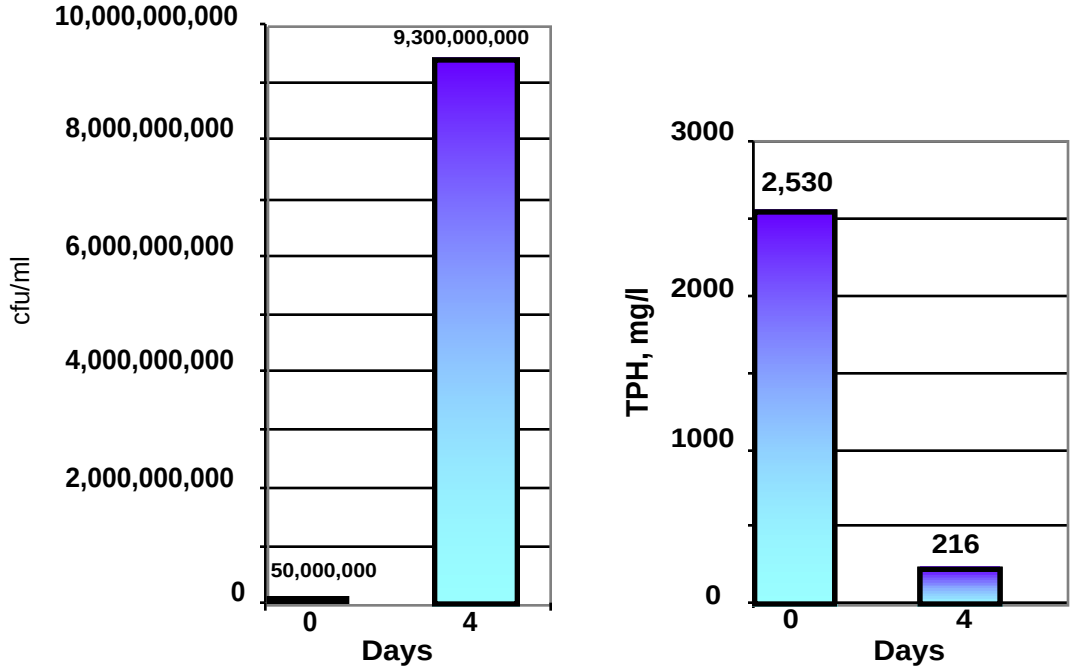

Figure 5: Increases Heterotrophs by 99.5% and Decreases TPH by 91.5% in 4 Days

HC-2000 Soil Reactor

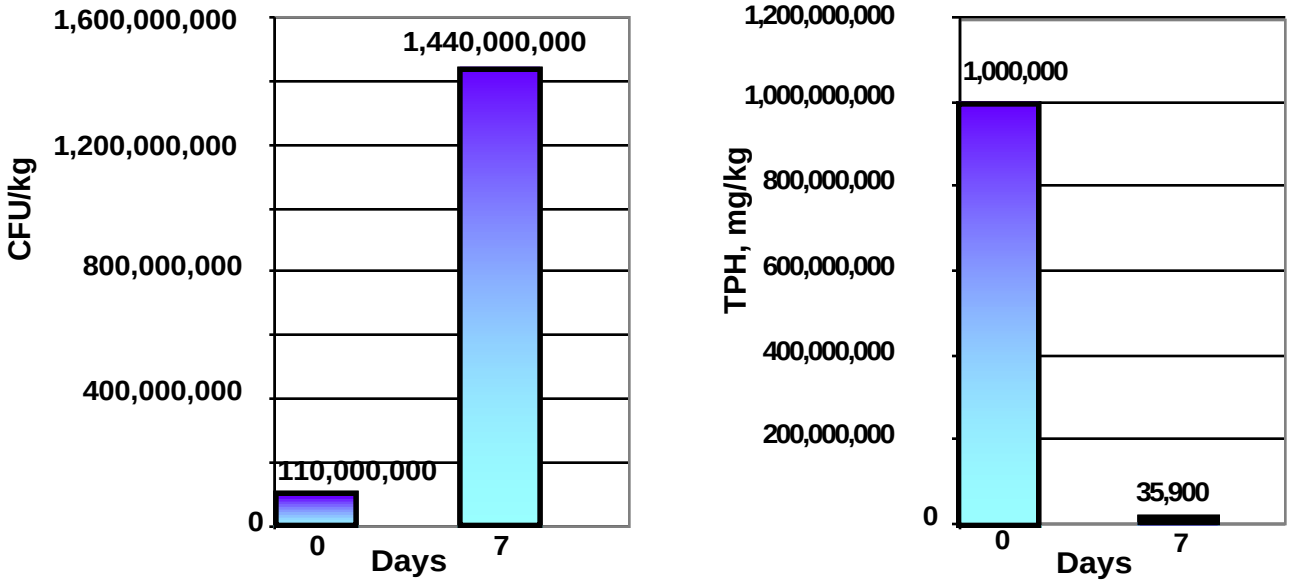

Figure 6: HC-2000 Increases Heterotrophs by 92.4% and Reduces TPH by 96.4% in 7 Days

F-500 Liquid Reactor

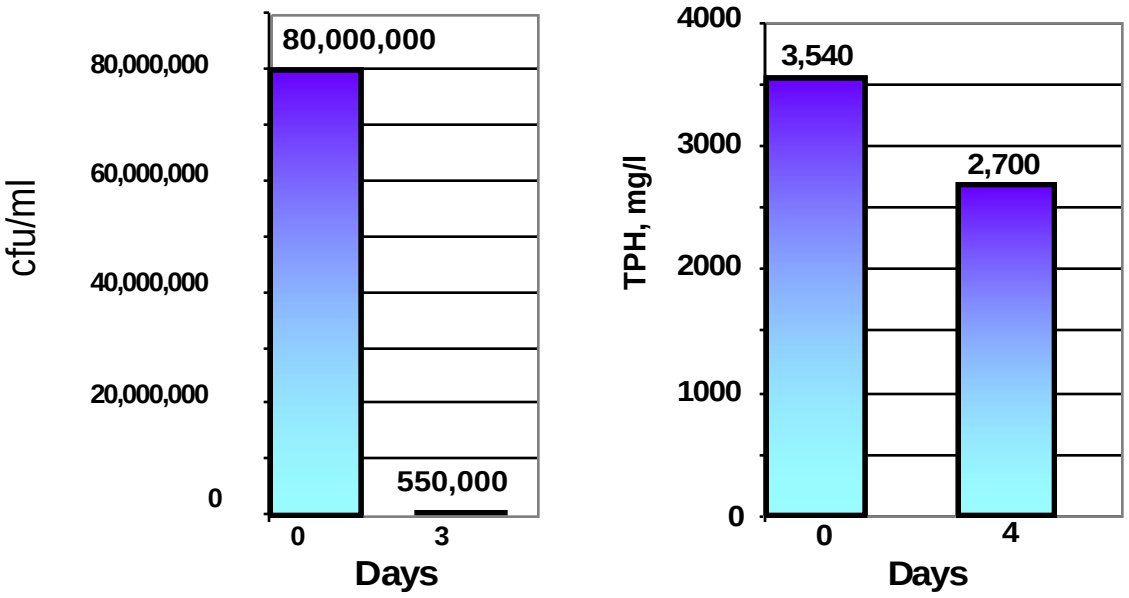

Figure 7: F-500 Reduces Heterotrophs by 99.3% and TPHConcentration by 23.7% over 4 Days.

F-500 Soil Reactor

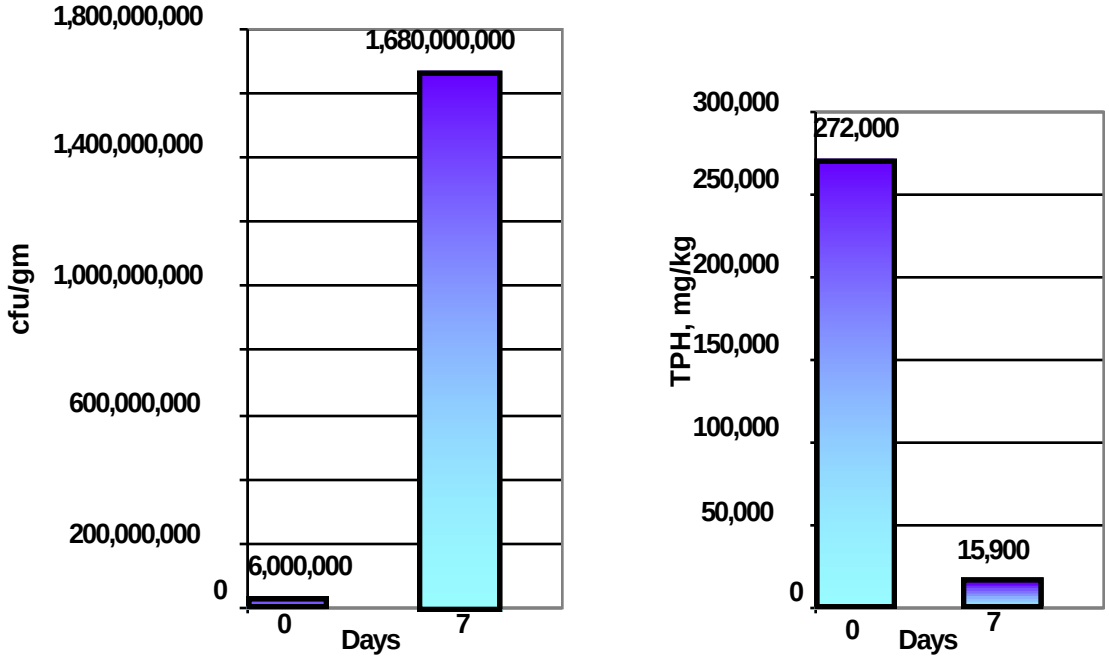

Figure 8: F-500 Increases Heterotrophs by 99.6% and Reduces TPH Concentrations by 94.4% over 7 Days

BioSolve Liquid Reactor

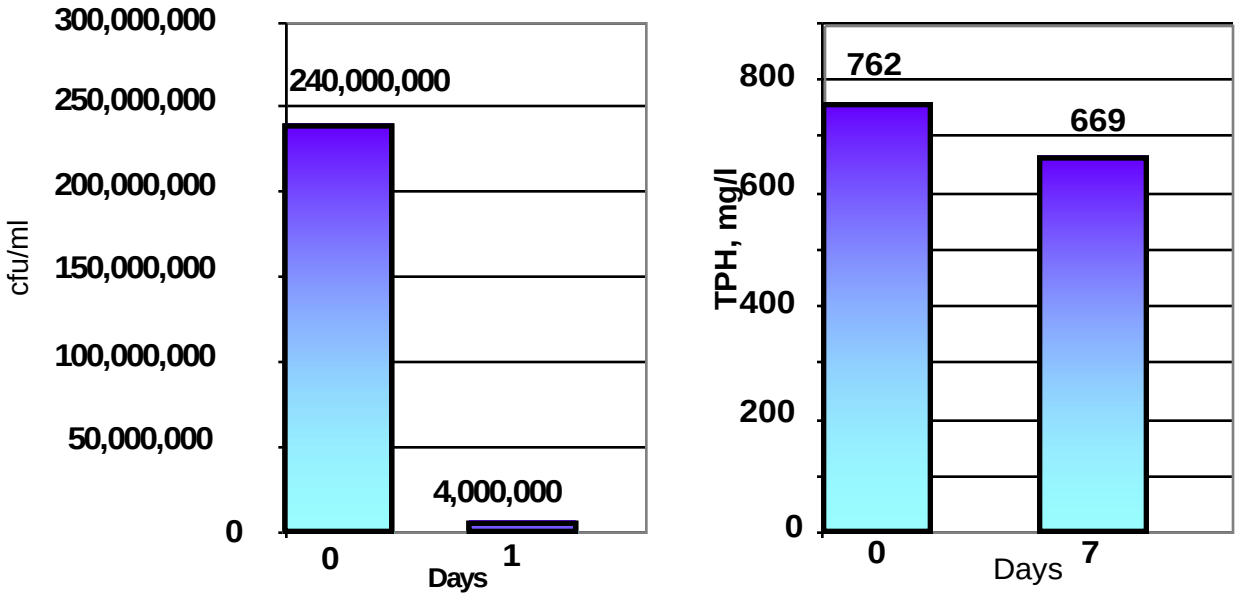

Figure 9: BioSolve Reduces Soil Heterotrophs by 98.3% and TPH Concentration by 12.2% in 7 Days.

BioSolve Soil Reactor

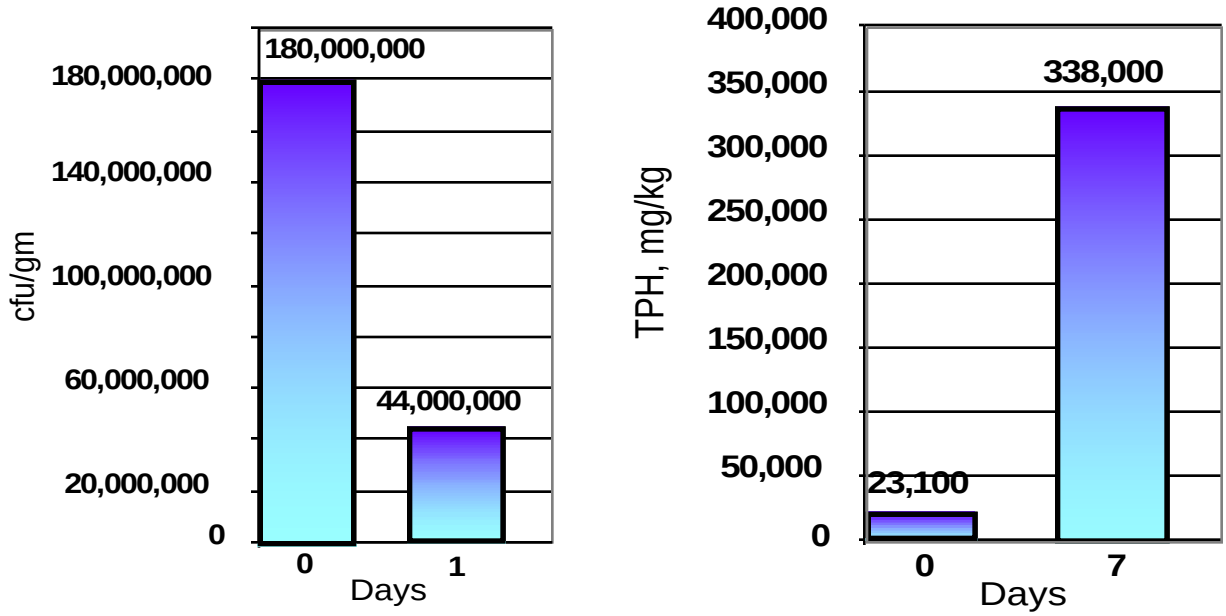

Figure 10: BioSolve Reduces Heterotrophs by 75.6% and Increases TPH Concentration by 93.2%

Photo 1: F-500 1:8:32 (product:gasoline:water) ratio ignites

Photo 2: F-500 2:8:32 (product:gasoline:water) ratio ignites

Photo 3: Gasoline Separates from F-500 Solution following Test Burn

Photo 4: Alcoseal 3-6 Does Not Burn at 1:8:32 ratio.

Photo 5: HC-2000VAP does not burn at 1:8:32 ratio (3%)

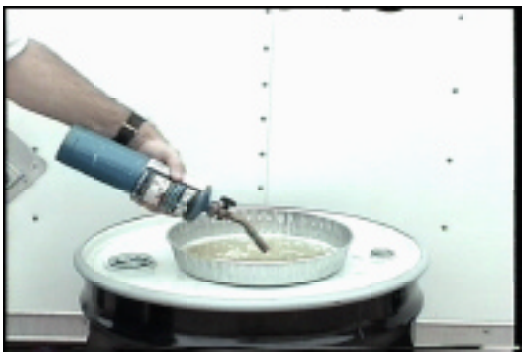

Photo 6: HC-2000VAP does not burn at 1:8:32 ratio (3%) after Four (4) Hours

Photo 7: BioSolve ignites at 1:6:33 ratio (3%)

Photo 8: Gasoline Separates from BioSolve Solution following Test Burn

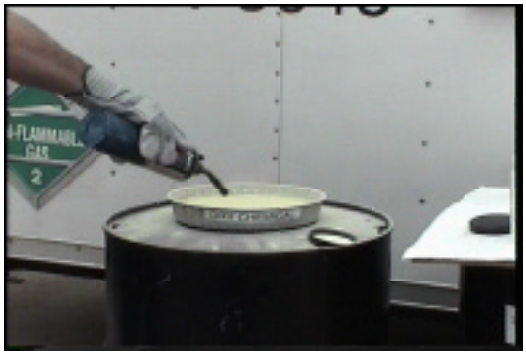

Photo 9: Dry Chemical Extinguisher Media Prevents Gasoline/ Water Mixture from Igniting

Photo 10: Dry Chemical Media Ignites on Stirring

Photo 11: Oil Dry Blanket Prevents Gasoline/Water Ignition

Photo 12: Stirring Clay Blanket Allows Gasoline to Ignite

Photo 13: Gasoline Vapor Suppression Tests with AIM 601 Multigas Meter

Photo 14: Gasoline Separates from F-500 Emulsion

Photo 15: Gasoline Separates from BioSolve Emulsion

Photo 16: Gasoline Separates from Alcoseal Foam Blanket

Photo 17: Gasoline Separates from HC-2000 Foam Blanket

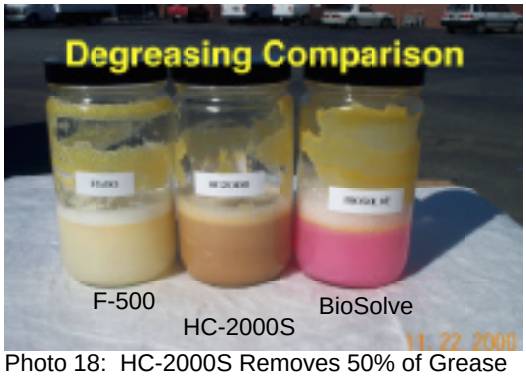

Photo 18: HC-2000S Removes 50% of Grease from Glass Surface Area, F-500 - 30%, and BioSolve - 20%

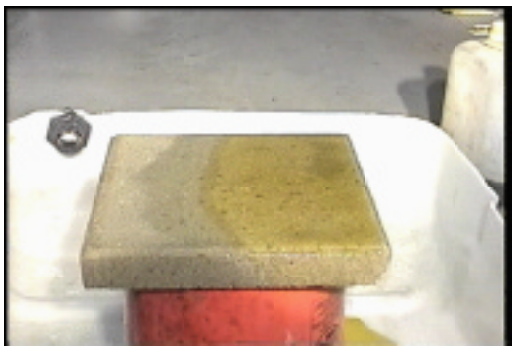

Photo 19: Concrete Block Prior to Cleaning. Left Side of Block Covered with Diesel and Right Side with Hydraulic Oil

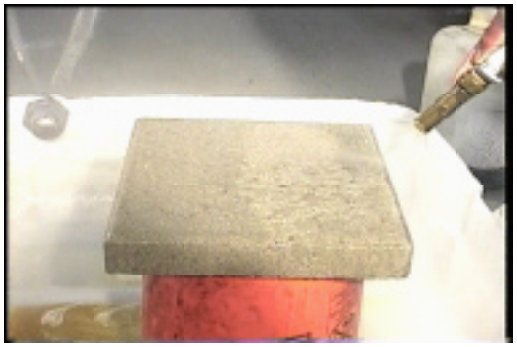

Photo 20: BioSolve Cleaning - Lett Side of Block - Diesel, Right Side - Hydraulic Oil. Note Water Beading Up on Block Face Indicating Oil Film Remaining

Photo 21: HC-2000S Cleaning - Left Side of Block - Diesel, Right Side - Hydraulic Oil. Slight Sheenand No Water Beading.

Photo 22: F-500 Cleaning - Left Side of Block - Diesel, Right Side - Hydraulic Oil. Note Water Beading Up on Block Face Indicating Oil Film Remaining

Photo 23: Soil & Liquid BioReactors