BIOREMEDIATION OF PETROLEUM HYDROCARBON SPILLS ON RAILROAD BALLAST WITH HC-2000

HC-2000 Multi-Media Applications

HC-2000 is Remtech's proprietary bioremediation accelerator/bio-surfactant that cleans, desorbs, and degrades fuels, oils, lubricants, and chlorinated and non-chlorinated solvents in soil, ballast, and other surfaces. HC-2000 (HC2) is particularly cost-effective where: service or business interruptions are costly, access is limited, areas are environmentally sensitive, and for sites that are geotechnically, hydrologically or structurally sensitive or unstable.

Diesel Release on Rail Siding

Diesel Stained Ballast from At-grade Lowboy Collision

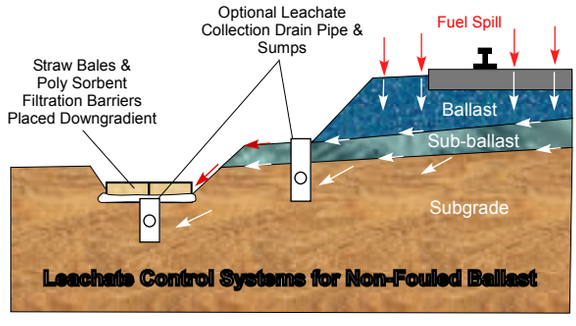
Fate of Spills in Ballast

Non-Fouled Ballast

Ballast systems are designed to drain water away from tracks. Large spills can migrate through rock and into subgrade soils. Permeability generally decreases with increased compaction of media with depth. Fines also accumulate in sub-ballast from ballast breakdown filling void spaces with foreign particulate matter from hopper cars (such as coal, granular or powdered fertilizer, clays, and other particulate products) further reducing permeability.

Releases of petroleum hydrocarbons from locomotives, track lubrication systems, and train consists cause fines to agglomerate reducing permeability by trapping water and providing a barrier to limit vertical migration. Non-fouled ballast is generally found on well maintained mainline track and on sidings where ballast and sub-ballast drain water away from track systems.

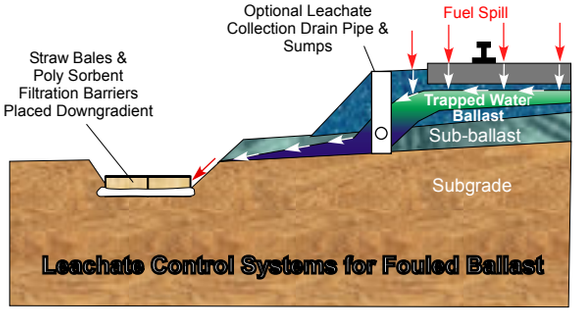
These environments generally require leachate control systems in drainage ditches and culverts using sorbent booms and straw bale filtration systems. Sometimes, interceptor trenches or drain pipe and collection sumps are installed in the subgrade to intercept subsurface migration of contaminants.



Fouled Ballast

Voids in fouled ballast are filled with fines and oil and grease from locomotives and train consists that trap water and create a barrier for petroleum hydrocarbons. As the degree of fouling increases, trapped water can limit the proper drainage of water away from tracks eventually resulting in trackbed flooding. In advanced track fouling, a tar like matrix can be formed that further limits permeability.

Fouled ballast is generally found in locomotive fueling yards, track sidings, and switching yards. These environments generally require loosening and/or removing of ballast next to and sometimes between ties to facilitate the recovery of free product and restore permeability. Interceptor trenches and other leachate recovery systems are generally shallow extending into the trapped water zone. Downgradient sorbent filtration and absorption systems may also be required in stormwater drainage features.



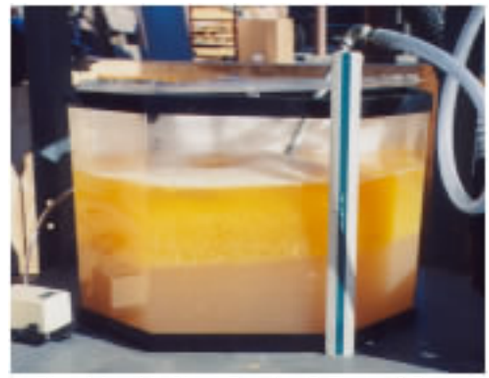
Ballast - A Trickling Filter?

Native heterotrophs are ubiquitous in the environment and are found in soil, ballast, water, groundwater, and waste in aerobic, facultative, and anaerobic zones. Heterotrophs have been demonstrated to be some of the most effective degraders of a variety of hazardous and non-hazardous wastes including petroleum hydrocarbons, chlorinated solvents, and other pollutants.

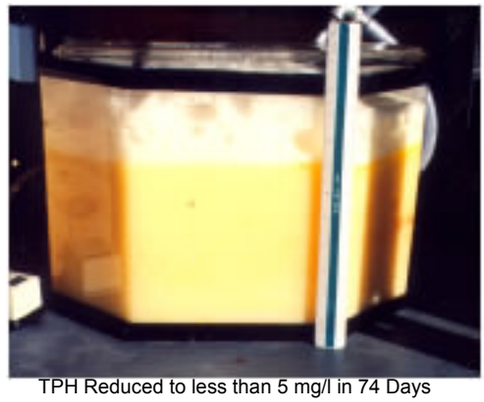
A myriad of degradation data was generated in the 1980's during research on land farming of hazardous wastes (1). Ross McKinney in his book *Micro-biology for Sanitary Engineers* states "…. the best source of micro-organisms is soil. The soil can furnish all the microorganisms ever needed in waste disposal. My advice to all sanitary bacteriologists who seek a special culture is to look under their feet; the supply is inexhaustible." (2) HC-2000 targets native heterotrophs that control the bio-remediation process.

Rail cross-sections function like a trickling filter and are teeming with heterotrophic life. Background total heterotrophic bacterial levels in ballast are typically 10 times higher than in soil (10's of millions of CFUs/gm). Fuel, lubricants, and greases released from locomotives, tankers, and hopper cars provide substrate to heterotrophic bacteria that become acclimated to petroleum hydrocarbons. HC-2000 supplies the limiting enzymes, co-factors, nutrients, electron donors, and biosurfactants that reduce degradation times to several months.

HC-2000 is an aerobically fermented product that is readily assimilated and eliminates long lag reaction periods. HC-2000 can be applied under various environmental conditions (aerobic, facultative, anaerobic, etc.) expanding the number of contaminants that can be treated.



Diesel Aerobic Slurry Reactor @ Time = 2 Days



TPH Reduced to less than 5 mg/l in 74 Days

Ballast Bioremediation Steps

HC-2000 desorbs and degrades contaminants. Enhanced bioremediation projects require adequate *reaction zones* and *retention* periods to complete degradation.

Remove free liquids - the first step in saturated petroleum hydrocarbon ballast spill cleanups is to remove as much of the free product (mobile phase) as possible. This may be accomplished through sumps, trenches, drain tile, or ballast washing. HC2 may be used to desorb and enhance free product removal.

Care must be exercised when installing treatment systems not to impair the structural integrity of track systems especially on main line tracks. A "rule of thumb" generally requires that ballast not be disturbed below the ties or below a 45% vertical slope moving away from the tracks.

For non-saturated fuel situations, HC-2000 is applied followed by an oxygen saturated water chase to ensure agent penetration, moisture, and oxygen.

Install Leachate Control Systems - During the bioremediation process, contaminants are desorbed and moved towards bacteria that are concentrated in ballast fines. Bound contaminates may account for over 60% of the total contamination. Fuels may become more mobile as they are desorbed and broken down into shorter hydrocarbon chains.

Lube Oil Desorbed from Ballast with HC-2000 and Pumped to Oil Water Separator

Waste Oil Desorbed from Ballast with HC-2000 and Collected on Poly Sorbent & Straw Filters

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Leachate control systems may be installed near the toe of ballast shoulders and/or in drainage swales. Leachate control systems include; filtration barriers constructed of straw bales and poly sorbent boom, interceptor drains and sumps, interceptor trenches lined with poly sorbent, or treating the downgradient runoff area.

Ballast Treatment - HC-2000 may be applied topically followed by a water chase or through injection probes driven into the ballast. For fouled ballast, mixing or agitation will enhance HC2 delivery and treatment efficiencies. Pressurized water (3,000 to 5,000 psi) or a narrow cribbing bucket may be used to loosen ballast between and next to ties.

Monitor Degradation - Monitoring usually consist of visual observation of stormwater runoff (no sheens) and may include sampling of ballast fines and downgradient soil and leachate for total petroleum hydrocarbons. Supplemental water may be required to maintain moisture levels at 70% of field holding capacity.

Technology Selection Factors

- Minimize Safety Hazards - HC-2000 is safe to use and contains no hazardous ingredients, hazards to personnel, or hazards to the environment.

- Service/Business Interruption Sensitive Applications - treat rail ballast in place without interrupting traffic. Treatment systems can be installed/ applied quickly in limited access areas while minimizing business interruptions.

- Cost-Effective Solution - HC-2000 doubles as a cleaner and biodegradation accelerator that offers several cost-benefits over many cleaners and alternative remediation technologies. (See Case Histories Cost-Benefit).

- Environmentally Sensitive Areas - food quality natural ingredients in HC-2000 accelerates bioremediation in environmentally fragile areas such as wetlands, marshes, beaches, national parks, dunes, nature preserves, and forests without adverse environmental impacts on flora or fauna. HC-2000 synergistically accelerates bioremediation in phytoremediation, rhizosphere (root zone), and organically enriched and microbial diverse environments.

- Critical Utilities - insitu treatment prevents damage to old water mains, fiber optics cables, telecommunication, and other underground utilities without service interruptions.

- Security Sensitive Facilities - in access restricted areas, applications can be made quickly and with minimal disruptions at airports and military installations.

HC-2000 Application Systems

For bioremedation or cleaning, a HC-2000 and water mixture may be applied by a diaphragm, roller, or centrifugal pump with a fire nozzle. Trace quantities of pulp may clog finer nozzles and piston pumps (especially pressure washers). HC-2000 may be injected past pressure washer pumps and applied with chemical feed nozzles followed up with a high pressure water (cold or hot - < 120 ^{O}F) chase to drive the HC2 into the media.


Diesel Fuel Collects in Trench for Leachate Control Pipe


Leachate Collection System Installed


Leachate Collection System Installed between Two Mainline Tracks

HC-2000 applied to Mainline Track


Straw Bale & Sorbent Boom Leachate Control System

For subsurface soil/ballast applications, HC-2000 may be applied through infiltration galleries, horizontal or vertical biovent systems or reaction trenches/fences or injection probes. HC-2000 may be applied as foam to enhance movement through and contact with soil/ballast. Soil moisture should be maintained at 70% of field holding capacity (or 20% moisture).

Suggested Monitoring & Dosage Rates

Optimal degradation conditions are present when total heterotrophic plate counts are elevated and maintained during the treatment period. Elevated plate counts indicate that sufficient nutrients, moisture, and environmental conditions are present.

Secondary parameters that may be monitored include respiration by-products, moisture, dissolved oxygen, pH, and redox potential. Monitoring the reduction of the contaminant(s) of concern determines when treatment is complete and/or when natural attenuation can complete the degradation process.

Dosage rates are site and contaminate(s) specific. Dosage "rules of thumb" range from three (3) to ten (10) cubic yards of contaminated media (soil, groundwater, railroad ballast, etc.) per gallon of concentrate over a five-week treatment period. Concentrate dilution ratios of one part of HC-2000 to sixteen parts of water is recommended for soil or ballast applications.

Regulatory Approvals

Regulatory authorities frequently favor (and quickly approve) the acceleration of natural degradation processes as apposed to addition of foreign microbes or toxic materials into the environment. Stimulating natural biochemical processes reduces the possibility toxic by-product formation and allows multiple species (operating under a variety of environmental conditions) to reduce contaminates to minimum levels. When treatment is complete, native conditions are restored.

HC-2000 has been approved by Georgia and Florida for the treatment of groundwater on a case-by-case basis. No specific approval is required for soil/ballast applications in Georgia. Georgia frequently only requires three (3) applications of HC-2000 to soil/ballast without performance sampling to complete a cleanup (due to the large number of successfully completed cleanups where performance sampling was required).

Federal EPA On-Scene Coordinators and National Park Service officials have approved HC-2000 on a case-by-case basis for projects in National Parks, navigable waterways, lakes, wetlands, and soil and groundwater environments.

All-Terrain HC-2000 Application System
No Track Time Required

Leachate Sump Between Mainline Tracks

HC-2000 Applied to Mainline Track

HC-2000 Removes Diesel Stains & Odors

HC-2000 Treatment System on
Dual Mainline Tracks

CASE HISTORIES

Over fifty (50) sites have been remediated using HC-2000. Eight (8) case histories are presented below to illustrate the effectiveness of HC-2000.

Diesel Release on Railroad Ballast Treated with HC-2000

Accelerated Diesel Bioremediation of Mainline Track

A Locomotive caught fire on a Class I southeastern railroad super elevated mainline track in Northwestern Georgia. An estimated 100-gallons of diesel fuel were released along a 100-foot section of track.

Remtech designed and installed a solar/battery powered mist system to supply oxygen saturated water (through sprinkler hoses). The ballast functioned as a biological trickling filter. HC-2000 was applied weekly to accelerate native fungi and bacteria biodegradation.

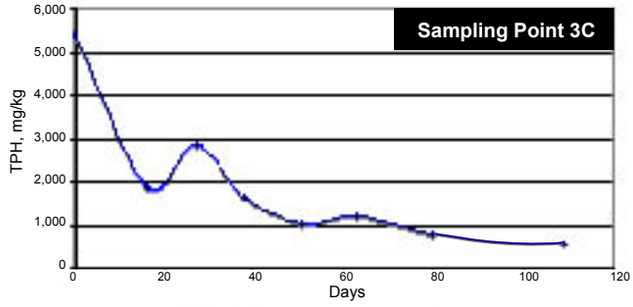
Solar/Battery Powered Watering System

Air sparge tips were driven into the ballast and a battery driven compressor was utilized to supply air. Four (4) sampling points were monitored over an 118-day period. Average TPH concentrations were reduced 90%.

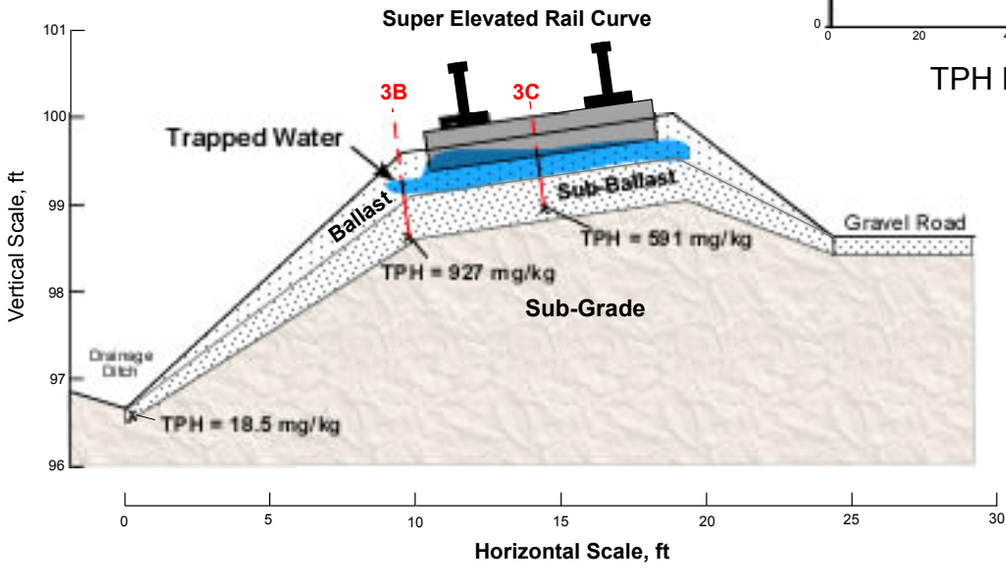
TPH at the toe of ballast next to a drainage ditch was recorded at 18.5 mg/kg at the end of the project indicating that fuel was being degraded in the ballast cross section.

Cost/Benefit Analysis

This project was conducted by Remtech on a demonstration basis with the State of Georgia and the railroad. Project costs were $41,000 and included extensive monitoring and site controls to obtain State approvals that resulted in reduced unit costs on future projects. The estimated cost to remove, dispose, and re-install 100 ft of mainline track is $46,000. Twenty-five (25) to 75 trains use this track each day. Track removal, excavation, and replacement would have interrupted rail service with substantial cost impacts.



TPH Degradation Curve



Cross Section Through Sample Location 3

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Accelerated HC-2000 Ballast Bioremediation

A passenger train struck a vehicle at a grade crossing in Northwestern Georgia. The sight glass on the main fuel tank was ruptured and an estimated 750-gallons of diesel fuel were released over 0.35 miles of track before the train came to a stop.

Remtech was called on an emergency basis to stop the leak from the fuel tank and treat over the 0.35 miles of fuel stained ballast and ties. The initial HC-2000 application was made from a high-rail dump truck supplied by the railroad. No supplementary air or water was applied to the site. Native microbial heterotrophic plate counts were elevated from 14,000,000 CFUs/gram to 1,00,000,000 CFUs/gram following three (3) days of treatment.

The highest fuel concentrations were recorded in the final 80 ft of ballast before the train came to a stop. Five (5) additional applications of HC-2000 were applied to the final track section over a 42-day period. TPH concentrations at three sampling points were monitored at one, 1.5, and 2.5 ft depths over 197 days. TPH concentrations were reduced 77.1%, 45.7%, and 80.1% respectively. Natural attenuation is expected to continue the degradation process.

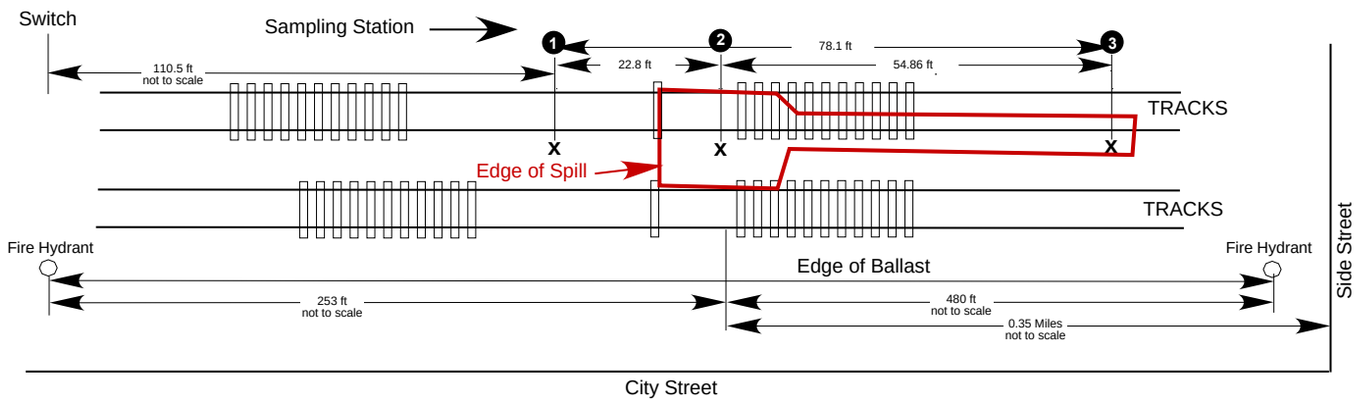
Cost-Benefit Analysis

This project cost $17,000 and includes a one time HC-2000 treatment of 0.35 miles of track. The estimated cost to remove and replace the last 110 ft of mainline track (including 30 ft of the adjacent track) and contaminated ballast media is $31,000. Removal and replacement does not include track service interruption costs.

Fuel Stains on Ties Prior to Treatment

High-Rail HC-2000 Application System

High Pressure HC-2000 Application



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Accelerated Motor Oil Bioremediation on Track Siding

Remtech Engineers was engaged to update a SPCC plan and bioremediate a fouled active track siding for a motor oil formulation plant in Atlanta, Georgia.

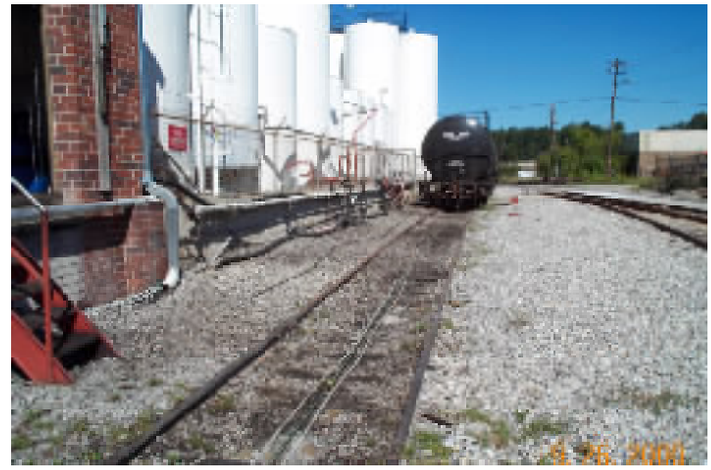
Rail car unloading pumps were moved inside the secondary containment area for the bulk storage tank farm. Remtech's native bioremediation accelerator HC-2000 was used to degrade over 30 years of oil deposits on the rail siding.

During a four (4) month treatment period, total petroleum hydrocarbons were reduced by over 60%. During the treatment program, additional oil releases were observed during unloading operations and from runoff from tank car overfills. A continued monthly enzyme application program was developed to prevent oil buildup on the siding. The rail car shipper was required to clean cars prior to transport to cut down on runoff from overfills.

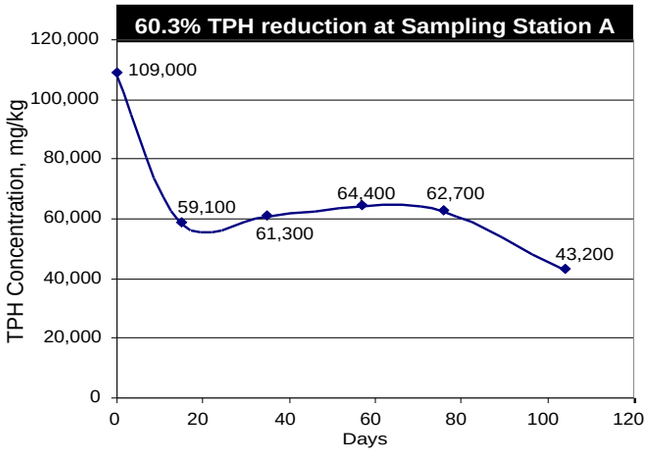
Cost-Benefit Analysis

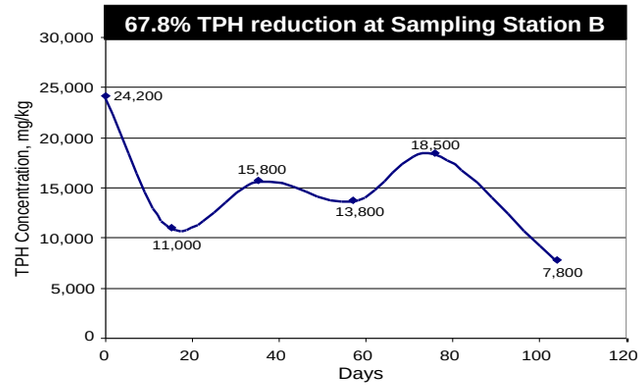
The cost of this project was $26,000. The treatment area was 164 feet x 15 ft wide x 3 feet deep or 274 cy. The estimated cost to remove and replace the track siding and dispose of contaminated media is $44,000. Note that this cost does not include business interruption costs associated with removal/replacement.

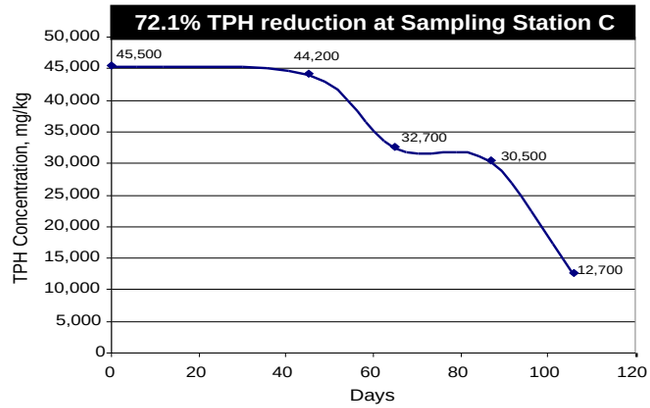
Rail Siding prior to Treatment



Rail Siding Following Four Months of Treatment







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Hydraulic Oil & Diesel Fuel Accelerated Bioremediation of Rail Spur

Railroad track maintenance equipment (tie removal machine) was struck by lightening in Northwestern Georgia on a railroad siding. This equipment had two 40-gallon diesel fuel tanks of and one 60 - 70 gallon hydraulic oil tank. Burnt hydraulic oil and diesel fuel were released.

Approximately 100 feet of track and 40 ft of railroad ROW were impacted. Seven (7) weekly treatments of HC-2000 over a period of 53 days were applied. Monitoring continued for an additional 31 days. No supplementary air or water was applied (relied on natural weather conditions).

Sampling Station 1 had a TPH concentration of 63.3 mg/kg. Sampling Stations 3 and 4 had concentrations of 85.9 and 93.5 respectively. Soil in the area of points 3 & 4 was tilled and treated with HC-2000. No additional sampling was conducted in this area since TPH concentrations were below State cleanup criteria of 100 mg/kg.

Petroleum hydrocarbon concentrations in the center of the tracks (Sampling points 1.5 T, 2.5 T, and 4 T) were reduced from a high of 110,000 mg/kg to less than 20,000 mg/kg. TPH concentrations were reduced by an average of over 61% over a 84 days. Natural attenuation is expected to continue the degradation process.

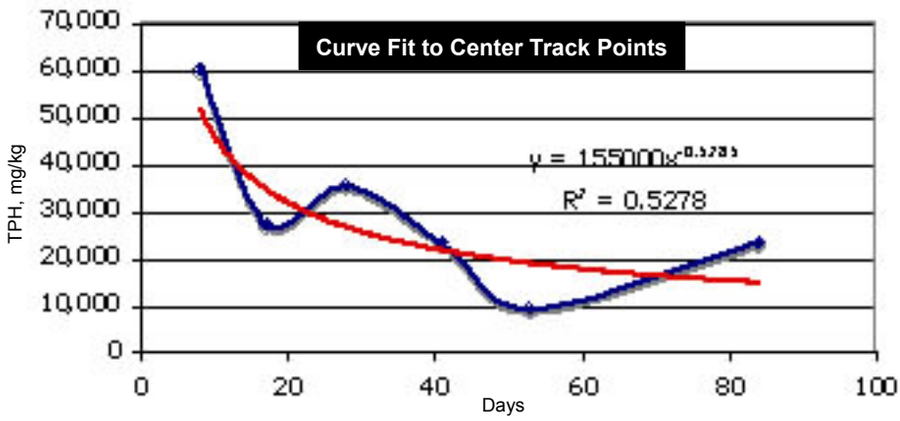
Cost-Benefit Analysis

This project cost $13,000. The estimated cost to remove and replace the track siding and dispose of the contaminated ballast and subgrade is $35,000. Removal and disposal costs do not include track interruption costs.

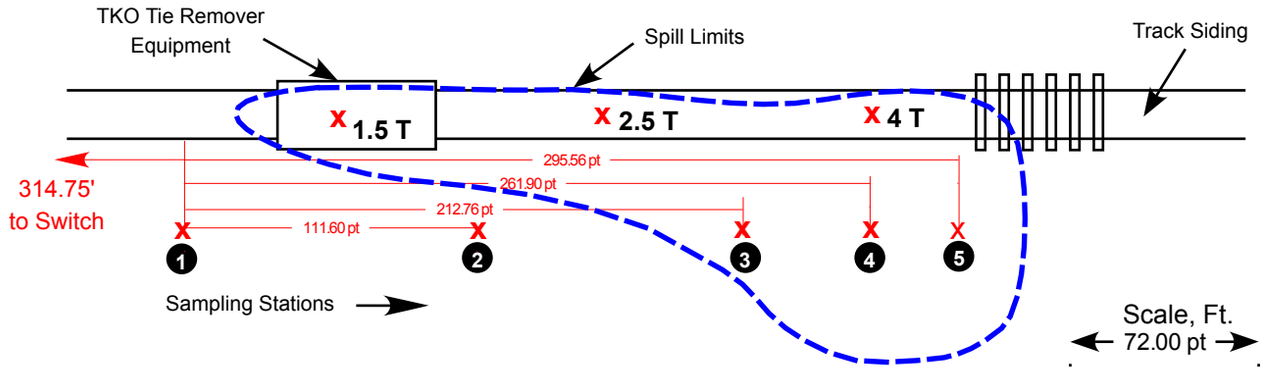
Tie Removal Equipment Struck by Lightening

HC-2000 Application to Rail ROW

HC-2000 Application to Rail Spur



Bioremediation Curve Fit to Center of Track Sampling Points (1.5 T, 2.5 T & 4 T)



Track Equipment Fire Bioremediation
@ Mile Mark 107.8

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Pilot Pavement & Ballast Cleaning Program at Railroad Fueling Yard

Remtech conducted a pilot program to determine the effectiveness of HC-2000 in cleaning concrete and ballast with continual diesel fuel, lube oil, and gear oil leaks at a railroad fueling pad.

Bench-scale degradation tests were conducted on oil/water separator waste oil and sludge. Waste oil was degraded 96.2% and sludge 86.9% during a 30-day period with HC-2000.

The test cleaning area was 269 feet long with the concrete fueling pad 184 ft in length. Sampling point S1 was setup on the south end and S2 on the north end of the concrete pad in ballast. Following seven (7) applications of HC-2000 during a 50-day test period, TPH concentrations at S2 were reduced 75%.

TPH concentrations at S1 increased 30% during the same period (indicating that petroleum hydrocarbon deposition rates were faster than degradation rates).

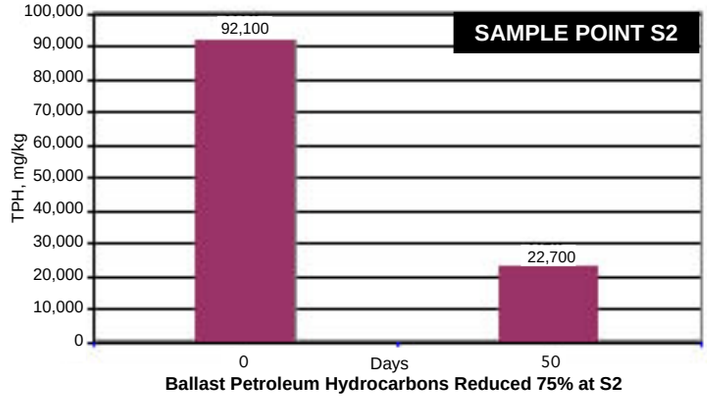
The initial cleaning of ballast was conducted using a pallet mounted enzyme application system consisting of a small compressor, diaphragm pump, and mix tank (moved by a forklift). A hot pressure washer was initially utilized to increase the penetration of petroleum hydrocarbons into sub-ballast fines (with increased microbial activity).

Treatment of ballast on the north and south ends of the fueling pad continued for 64 days. Following seven (7) applications of HC-2000, a 10 to 30% petroleum hydrocarbon stain reduction was observed on the south end.

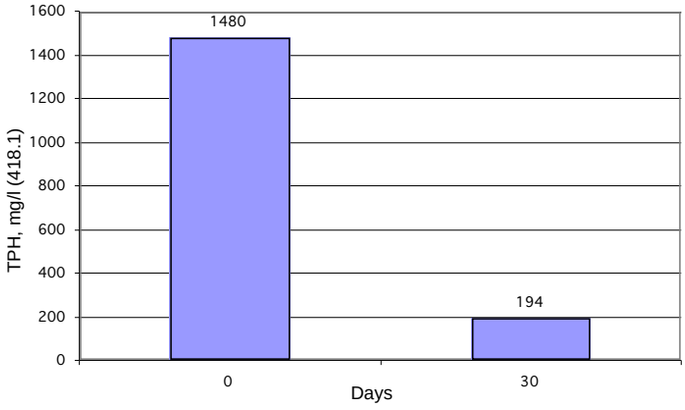
A continual HC-2000 application program has the potential to degrade petroleum hydrocarbons on concrete and ballast and minimize waste sludge and oil generation in oil/water separators.

Ballast Prior to Treatment

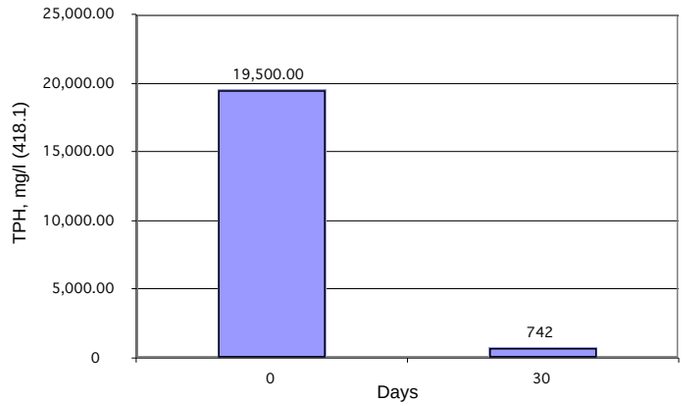
10 to 30% Ballast Stain Reduction During Test Period



Ballast Petroleum Hydrocarbons Reduced 75% at S2



Oil/Water Separator Sludge Degraded 86.9% in 30 days by HC-2000



Waste oil degraded 96.2% in 30 days by HC-2000

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Accelerated Lube Oil Industrial Rail Bioremediation

An estimated 350 gallons of lube oil were released from a locomotive over 1,745 linear feet of track and fouled ballast on an industrial siding. Remtech excavated oil saturated ballast from the edges of ties (from the last 85 linear feet) that served as free product interceptor trenches.

Lube oil was flushed from the ballast with HC-2000 (an enzyme based native bioremediation accelerator and cleaning agent). A 2,000 psi hot pressure washer was used to lance product from the ballast followed by a water rinse. An estimated 150 gallons of lube oil were recovered and pumped to an on site oil/water separator. Clean ballast was used to fill in the trenches after the completion of ballast flushing operations.

Nine hundred and eighty (980) linear feet of ballast were treated with HC-2000 and 680 linear feet of asphalt were cleaned with HC-2000 and a power boom with a water mist applicator.

Cost-Benefit Analysis

The ballast treatment part of this project cost $18,000 and did not require track time. The cost estimate to remove, dispose, and replace 85 feet of track and contaminated ballast is $23,000. Removal and replacement costs do not include track interruption costs.

Lube Oil Flushed from Ballast with HC-2000

Diesel Fuel Bioremediation on Mainline Track

An estimated 1,500 gallons of diesel fuel were released from a locomotive that struck a lowboy trailer at a grade crossing. Fuel spilled (sprayed) from the engine's fuel tank over 1,790 ft of track before coming to a stop. The spill foot print was 5 ft wide starting at the side rail and extending to the ballast shoulder at a depths ranging from 2 to 4-inches.

The remedial program consists of 3 to 5 applications of HC-2000 applied topically to the ballast outside the track four-foot safety zone. HC-2000 was applied from a premix tank and broadcast with a fire nozzle with a throw distance of 40 ft. Application intervals are being extended from the standard 7 days to 10 to 14 days to determine the effect on degradation kinetics. Treatment will continue until TPH concentrations are reduced below State cleanup levels.

Cost-Benefit Analysis

This project is anticipated to cost $25,000 without interrupting train traffic. The treatment area covers 9,000 sf or 110 cy of ballast. Ballast removal and replacement costs are estimated at $105,000 to $175,000 depending on available track time. Track revenues are estimated at $10,000/hr according to railroad officials. A minimum of two (2) days working around the clock would be required to remove and replace the contaminated ballast. Insitu treatment is estimated to save the railroad between $80,000 to $150,000.

Ballast Stained by Diesel Fuel Release

HC-2000 Applied with Fire Nozzle

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Waste Oil Bioremediation Between Two Mainline Tracks

An estimated 600 gallons of waste oil were released from a tanker overfill at an oil company. Oil migrated through a storm drain and into ballast between two mainline tracks next to a drainage ditch on a Class I railroads' ROW in northwestern Georgia. The spill area was 150 ft long by 40 ft at it widest point. Oil penetrated to at depth of 12 to 24 inches where it floated on trapped water above the subgrade.

Remtech constructed a leachate control system consisting of a 70 ft long by 6-inch diameter drain pipe connected to a sump. This system was installed at a depth of approximately two feet between the two mainline tracks. A second leachate collection system and sump were installed in the drainage ditch at the lower end of the site. Multiple straw/poly sorbent boom filtration barriers were placed in the drainage ditch to control leachate during the treatment period.

The mobile phase free product was desorbed from the ballast using HC-2000 followed by a water rinse. An estimated 167 gallons of waste oil were recovered during the first four days.

A system maintenance and operation manual and training program was conducted for the responsible party to complete the bioremediation program. Specific tasks included weekly HC-2000 applications and periodic leachate system pumping and maintenance of ditch leachate control system. The treatment program will be continued until regulatory clean-up limits are achieved.

Cost-Benefit Analysis

This project is anticipated to cost $40,000. The treatment area covers 1,500 sf or 110 cy of track and ballast. The estimated cost to remove and replace the tracks and dispose of contaminated media is $50,000. Track revenues are estimated at $250,000/day and is not included in the track removal/replacement.

Completed Treatment System


Installation of Drain Pipe & Sump


Leachate Collection System in Ditch

Application of HC-2000


Desorption of Waste Oil From Ballast


Desorption of Oil into Sump Between Tracks

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Summary and HC-2000 Benefits

Other remedial technologies may leave residual contaminants that require additional treatment. These technologies include; pump and treat, soil venting and air sparging, total fluids extraction, and excavation & replacement. Why not start with a technology that can finish the job?

Site remediation costs with HC-2000 range from $15 to $225/cy of contaminated media. Costs are site specific and are affected by the type of contamination, local geology, project size, and contaminant location. HC-2000 performs best in formations where adequate communication and mixing can be established.

HC-2000 is non-toxic, non-allergenic, and contains food quality ingredients, Accelerating the natural degradation process with HC-2000 is generally received favorably by regulatory authorities and the general public, and heterotrophs are already acclimated and distributed in the environment. All that is required is to deliver HC-2000 to the degraders.

HC-2000 goes right to work by energizing native heterotrophs. Chemical oxidization with permanganate, peroxide, and ozone frequently oxidize materials other than target contaminants, i.e., a significant mass of reagents are wasted. Chemical oxidization may form toxic by-products that are not normally associated with cometabolic native biochemical reactions.

Oxygen and hydrogen release compounds generally rely on passive slow release mechanisms and depend on advection and dispersion to transport the reagent to the contaminant. Limiting nutrient deficiencies are not addressed. Adsorbed and soil pore bound contaminates are only addressed by sufficient concentration gradients to draw reactants to contaminants. HC-2000 provides contaminant desorption with biosurfactants that is generally more effective than concentration gradients. Aggressive pulsed reagent injection (used with HC- 2000) generally provides better mass transfer and mixing.

HC-2000 is easily assimilated by native bacteria without a lag time. Commercial fertilizers and surfactants may initially inhibit microbial degradation. Nutrient and carbon sources such as molasses, sugars, and vegetable oil need to be broken down further prior to assimilation by microbes. Organic nitrogen and proteins (contained in HC-2000) are a preferred source of nitrogen over nitrates, ammonia, and other compounds containing nitrogen.

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