

*A COMMERCIAL APPLICATION OF
VIROSOIL™ TECHNOLOGY*

TREATING HYDROCARBON CONTAMINATED SOIL USING RAPID SEQUESTRO-DEGRADATION (RSD)

TECHNICAL PAPER



OVERVIEW

Virotec's unique solution for contaminated soil remediation, called ViroSoil™ Technology, has been successfully applied around the world to treat acidity, heavy metals and hydrocarbons in contaminated soils.

ViroSoil™ Technology, utilising Rapid Sequestro-Degradation (RSD), a synergy between reagent additives and engineering know-how and design, has been successfully applied at: **operational and disused industrial sites where heavy metal contamination is a problem; contaminated soil at oil refineries and processing facilities; landfills; ports and marinas; and other industrial facilities that generate and spill hydrocarbon-based contaminants, such as PCE, PAH, oil, diesel and petrol.** Unlike the standard methods of excavating and dumping, incineration, sterilisation (e.g. thermal desorption), and soil washing technologies, which are expensive methods for treating hydrocarbon-contaminated soil and bioremediation which is a slow method for treating hydrocarbons contaminated soil, ViroSoil™ Technology is highly cost-effective and fast, rapidly destroying hydrocarbons, immediately binding heavy metals and neutralising acidity and objectionable odours.

There are two approaches to remediating contaminated soils: *in-situ* treatment (treat in place) and *ex-situ* treatment (remove soil and treat off site). The following sections apply to both *in-situ* and *ex-situ* treatment of soils using ViroSoil™ Technology.

Whether applied *in-situ* or *ex-situ*, ViroSoil™ Technology utilises the addition (through simple mixing or blending) of ViroBind™ or ViroBac™ reagents. ViroBind™ and ViroBac™ reagents are a unique combination of inorganic chemicals, nutrients, surfactants, enzymes and microbes that together neutralise acidity, bind heavy metals and metalloids, and destroy all forms of hydrocarbons.

For *in-situ* treatments, ViroBind™ reagent is added as a dry powder or slurry directly to the contaminated soil and then mixed or injected into the soil matrix to allow contact between the reagent and the contaminants, such as sulphides, heavy metals or hydrocarbons. After allowing the required reaction time, ViroBind™ reagent will neutralise

all acidity, permanently bind metals and destroy hydrocarbons in the soil. ViroBind™ reagent can also be added to contaminated soil that has been removed from a site for treatment at another location.

ViroSoil™ Technology has been successfully applied at operational and disused industrial sites where soil has been contaminated.



The pre-existing wastewater treatment plant at Beretta's Metal Finishing.

IN-SITU AND EX-SITU VIROSOIL™ TECHNOLOGY TREATMENTS

Where the disturbance of contaminated soil cannot be avoided, or where such soils have already been disturbed, ViroSoil™ Technology intervention strategies may be required to avoid adverse environmental impacts of the discharge of acidic and potentially metal-rich leachate and run off water. Where contaminated soil can be avoided, target loading injection may be appropriate.



ViroBind™ reagent.

ViroSoil™ Technology can involve the physical removal of sulphidic material from the soil controlling conditions so as to prevent the oxidation of sulphides, or the neutralisation of any acid that may be produced when sulphides in the soil oxidise. It can also involve binding any free metals and destroying hydrocarbons.

The decision to conduct *in-situ* or *ex-situ* treatments depends on the soil conditions at the site, site morphology and location, and the types and concentrations of contaminants concerned.

The advantages of *in-situ* ViroSoil™ Technology treatment are:

- > Rapidly destroys hydrocarbons, including:
 1. Single-bonded, alkaline hydrocarbons, such as benzene;
 2. Chlorinated hydrocarbons such as trichloroethylene and perchloroethylene; and,
 3. Polycyclic aromatic hydrocarbons (PAH) such as benzo(a)pyrene and naphthalene.
- > Immediately binds heavy metals;
- > Completely neutralises soil acidity and objectionable odours;
- > Contaminated soils do not require excavation before treatment;
- > Reduced dust;
- > Less volatilisation of contaminants;
- > Large volumes of soil can be treated at the same time;
- > Can be used to considerable depths; and
- > Effective on sites with permeable soils.

The advantages of *ex-situ* treatment are:

- > Rapidly destroys hydrocarbons;
- > Immediately binds heavy metals;
- > Completely neutralises soil acidity and objectionable odours;
- > Can be significantly faster;
- > Process is easier to control;
- > Wider range of contaminants and soil types can be treated;
- > Effectively promotes oxygen diffusion;
- > Enhances remediation results; and
- > Migration of liquids from the contaminated site is avoided.



ViroBind™ reagent being added to a contaminated site prior to mixing.

ViroSoil™ Technology has been developed to meet the needs of the client and the site, and can be applied in both *in-situ* and *ex-situ* settings.

Environmental problems associated with contaminated soils involve both the direct effects of surficial soil acidification and contamination and the leaching of acid, metals, metalloids, and hydrocarbons through groundwater and surface run off into drains, aquifers and rivers. Near surface soil contamination can be treated by physically mixing ViroBind™ reagent with the soil at a mixing ratio determined by soil mineralogy and texture, particularly the sulphide mineral content of the soil, inorganic contaminant loads, the chemical speciation of inorganic contaminants, and the composition and abundance of hydrocarbons.

HYDROCARBON DESTRUCTION AND RSD

One of the most urgent problems faced by industry and governments worldwide is contamination of soil and water due to domestic and industrial pollution. Hydrocarbons, such as fuels, oil, grease, man made solvents, refinery and gas works by products, lubricants and coolants, are particularly common types of contaminants. Contaminated soils have been identified as the most important of the four main priority waste streams in most countries.

Hydrocarbon destruction using the Rapid Sequestro-Degradation features of ViroSoil™ Technology is a safe, cost-effective and environmentally responsible method for dealing with and eliminating hydrocarbon contamination. Excavating and dumping, incineration, sterilisation (e.g., thermal desorption), and soil washing technologies are expensive methods for treating hydrocarbon contaminated soil, and these methods can further damage already fragile ecosystems.

Moreover, these methods do not permanently solve the issue of heavy metals in soil. While costs for bioremediation vary from project to project, evidence suggests that not only is bioremediation more environmentally sound but it is a far more cost-effective option. To assist and enhance the natural processes and increase the rate of degradation of the organic contaminants, an inoculum of naturally occurring petrophilic microbes needs to be managed to develop a fully

established working population as rapidly as possible. ViroSoil™ Technology provides an ideal solution to achieve this objective.

Through RSD, hydrocarbon contaminants are rapidly absorbed into the fibres of ViroBind™ or ViroBac™ reagents, while indigenous microbes begin to consume and transform the hydrocarbon into simpler compounds. This process continues until eventually the hazardous hydrocarbon material is degraded to carbon dioxide, water and benign organic substances.

ViroSoil™ Technology uniquely combines several strengths. First, in addition to binding heavy metals, targets many different hydrocarbon contaminants simultaneously. Second, it preferentially absorbs hydrocarbons in the presence of water and contains nutrients that promote the growth of indigenous aerobic or anaerobic micro-organisms present in the ViroBind™ and ViroBac™ reagent matrix. Third, ViroBac™ reagent supports the growth of



Soil contaminated by hydrocarbons such as oils is just one of the many serious waste streams identified worldwide.

naturally occurring hydrocarbon-consuming microbes that rapidly degrade the sorbed hydro-carbons into simpler compounds. Fourth, leachate problems can be reduced or eliminated, thereby protecting ground waters and adjacent waterways, and effectively suppressing volatilization of flammable vapours. Finally, because there are no adverse health or safety concerns associated with ViroBind™ and ViroBac™ reagent, the product is very easy to apply.

The sorption properties of ViroBind™ and ViroBac™ reagents are based on its ability to draw the targeted contaminant liquids into its structure. The capillary action of the matrix encapsulates the liquid in such a way that leaching is inhibited. Once the hydrocarbon is encapsulated within the product matrix, it remains within the matrix during the degradation process. This is an advantage over liquid and gel applied systems, which often percolate through the matrix and into ground water without coming into contact with the hydrocarbon and thus not achieving their objective.

The quantity of ViroBind™ and ViroBac™ reagent required for a remediation project depends on the nature and extent of the contaminated soil, and is assessed on a project-by-project basis. However, ViroBind™ reagent can be effectively used *in-situ*, depending on soil type, pH, depth of contamination and site topography, or it can be applied to *ex-situ* soil to enhance the bioremediation function and soil quality of windrows, bio-piles and composting processes.

Following the procedure outlined in the following section titled Advanced Bioremediation Standards, the soil is tilled to break up the soil as much as possible. If the soil is a heavy clay type or tightly compacted, bulking agents may be required to improve permeability. When applying *ex-situ* treatments, ViroBind™ reagent is blended into the soil matrix and periodically turned to aerate and moisten so as to maximise the efficiency of the aerobic degradation process.

On soft surfaces, such as grassland soils, ViroBind™ reagent may not only fully absorb and arrest the progress of the contaminant into the environment, but will begin the bioremediation process immediately. For spills on hard surfaces, such as highways and concrete, ViroBind™ reagent will immediately stop the escape of VOCs and completely absorb the hydrocarbon, leaving the hard surface dry and residue free and preventing the contaminant from spreading into uncontaminated land or water. The resultant waste will not leach or release under compaction.

ViroBind™ reagent will absorb and/or destroy the following hydrocarbons:

Acetone, Acetonitrile, Benzene, Bromoform, Bunker C Fuel Oil, Butanol(s), Canola Oil, Carbon Disulphide, Cooking Oils, Cutting Oils, Cyclohexane, Diesel Fuels, Ethanol, Ethyl Benzene, Ethyl Ether, Ethylene Chloride (1,2-Dichloroethane), Ethylene Glycol, Gasoline/Petrol, Heptane, Hexane, Isoamyl Acetate, Isobutanol, Isoprene, Jet Fuels, Kerosene, Lube Oils, Methanol, Methyl Ethyl Ketone, Methylphenol, Mineral Oil (Paraffin Oil), Motor Oil, Nitrobenzene, Oil-based Fluids, Oilbased Paints, Pentene, PCE, TCE, PAHs (Polycyclic Aromatic Hydrocarbons), Resins, Toluene, Unleaded Petrol, Varsol, Water Flocculating Agents, Xylenes.

Clearly, ViroSoil™ Technology offers a wide range of different treatment and disposal options for contaminated soils across a wide range of different hydrocarbons types. Although most of the above are derived from refining processes, crude or unrefined oils containing asphaltine, for example, are also amenable to bioremediation using ViroSoil™ Technology, but typically take longer to be destroyed.



Soils contaminated by hydrocarbons such as jet fuel can be successfully treated by applying ViroBind™ reagent.

In summary, ViroSoil™ Technology absorbs and destroys hydrocarbons, absorbs between 6-10 times its own weight, utilises a naturally derived product from a totally renewable source, is completely safe to handle and apply, leaves surfaces dry and residue free, reduces the amount and hazardous nature of waste, does not release hydrocarbons under compaction, and does not leach, and offers multiple treatment and disposal options.

HEAVY METALS AND SOIL ACIDITY

As previously discussed, ViroSoil™ Technology is a combination of an engineered solution, application know-how and a unique reagent called ViroBind™ reagent. The ViroBind™ reagent added to metal laden soil is composed of fine grained particles, that trigger a chemical reaction with heavy metal contaminants (several different binding mechanisms are involved) and the heavy metals are sequestered by the product as insoluble minerals. At the same time, ViroBind™ reagent neutralises any acid in the soil.

When mixed with soil, the grains of ViroBind™ reagent simply remain where they are; their mineral constituents have a very low solubility. After treatment, the grains are inert and pose no environmental hazard. ViroBind™ reagent is an environmentally friendly treatment for intractable environmental problems such as acid, arsenic, and heavy metal contamination of soils. It is innovative, efficient and cost effective. The acid neutralising capacity of ViroBind™ reagent is provided by a mixture of carbonate, hydroxide and hydroxycarbonate minerals, but some of these react slowly providing a long term source of alkalinity.



An example of in-situ treatment of lead-contaminated soil at Westrock Development, a disused industrial site in Queensland.



An example of ex-situ treatment of As-, Cu-, and Cr-contaminated soil at Parkside Timber, a timber preservation site in Queensland, Australia. This site was a high-profile contaminated site with direct involvement and oversight by the Queensland Environmental Protection Agency.

As with acid neutralisation, the ability of ViroBind™ reagent to immobilise trace metals in soil increases over time, and over about 24 hours, 1.0 kg of ViroBind™ reagent has the ability to strip more than 1,500 milli-equivalents of metals from water in contact with it. Where the ViroBind™ reagent is in contact with metal contaminated soil in the presence of water, metals can be transferred to the ViroBind™ reagent through the fluid intermediary. Most trace metals are initially trapped by adsorption, which is particularly efficient because ViroBind™ reagent is dominated by particles with a very high surface area-to-volume ratio and a high charge-to-mass ratio. However, adsorption alone does not explain the ability of ViroBind™ reagent to immobilise trace metals, because when desorption tests (using compulsive exchange reagents) are carried out on ViroBind™ reagent after it has been fully loaded with metals and aged for seven days, much less than 20% of the metals taken up by ViroBind™ reagent (less than 5% for As, Cd, Cr, Cu and Zn) can be recovered. Furthermore, the longer the metal loaded ViroBac™ reagent is left to age, the lower the proportion of the bound metals that can be recovered.

The metals are ultimately trapped by a combination of precipitation, co-precipitation, isomorphous substitution and solid state diffusion reactions. TCLP tests or leaching of soil after treatment with solutions buffered at a pH of 2.88 are able to remove only a small proportion of the bound metals and this proportion decreases the longer ViroBac™ reagent is left in contact with the soil after use. Furthermore, if the ViroBac™ reagent is left to age after use it develops a renewed capacity to trap trace metals, even if its metal trapping capacity was fully saturated before it was left to age. Consequently, it is clear that elements, which may initially be bound by adsorption, are redistributed during aging to become structural components of new minerals during recrystallisation.

Part of the time dependence of metal uptake by ViroBac™ reagent reflects the freeing-up of adsorption sites as initially adsorbed metals are redistributed. Some trace elements also form low solubility precipitates (particularly sulphates, carbonates, hydroxides, hydroxycarbonates and hydroxysulphates) by direct reaction with minerals in ViroBind™ reagent; some of these neoformational minerals may also provide some new adsorption sites that can bind additional metals.

Geotechnically, solid ViroBac™ reagent particles have a plastic limit at 33% moisture and a liquid limit at 53% moisture (i.e., the plasticity index is 20%); the linear drying shrinkage is 7.5%. Particles in ViroBac™ reagent are very fine grained, with about 80% of the total mass having a particle size of less than 10 microns.

VIROSOIL™ TECHNOLOGY RESULTS

The results of applying ViroSoil™ Technology are numerous and relate to the regulatory authority treatment requirements on a region-by-region basis. The following is a general summary of results, however, these may not apply or be relevant to every jurisdiction in which ViroSoil™ Technology could be applied.

> CEC Constructions Queensland Rail, Townsville, Queensland #1



ViroSoil™ Technology, using RSD, was initially developed at the leachability study to show its ability to rapidly destroy hydrocarbons. About 8m³ of sandy soil was mixed thoroughly with diesel oil / mineral oil / spent motor oil / hydrocarbon oil, so that the mixture appears as contaminated soil. Heavy metals such as Al, Cu, Cr, Zn, Fe, Mn were added to the pile.

A control pile was set aside. Another pile was treated with ViroSoil™ Technology (using RSD) and water was added daily to keep the bacteria moist. Piles were turned on a weekly basis to ensure the bacteria had adequate oxygen to survive.

Prior to treatment, Total Petroleum Hydrocarbons (TPH) equalled 20,220 mg/kg with a treatment target of 10,000 mg/kg, this being the acceptable limit for disposal to landfill.

The results (see Tables 1 and 2) demonstrate that the RSD methodology using ViroSoil™ Technology can effectively treat

An example of in-situ treatment of Cu- and Zn-contaminated soil at Cobar Copper, a derelict mine site in New South Wales, Australia.

hydrocarbon contaminated soils.

ViroSoil™ Technology, using RSD, was used to treat about 50,000 tonnes of contaminated soil from the CEC Constructions site. The before and after results for several of the treatments performed are shown in Tables 3 and 4. Due to the large volume of contaminated soil requiring remediation, treatment was performed in batches or piles.

Westrock Developments, a large property development company, sought to find an economic solution to the remediation of an old contaminated industrial site.

TABLE 1 - ANALYTICAL TPH SAMPLE RESULTS OF HYDROCARBON CONCENTRATIONS IN MG/KG

Sample	1/12/2006	15/12/2006	2/01/2007	2/02/2007	2/03/2007
Control B	20,220	20,220	21,810	21,810	17,570
ViroSoil™ Technology	24,395	16,170	16,690	8,730	9,040

Treatment Target: 10,000 mg/kg

TABLE 2 - TOTAL TCLP RESULTS FOR CONTAMINATED SOIL

Parameter	Sample Date 9/11/06 TCLP before application of ViroSoil™ Technology (mg/L)	Sample Date 2/03/07 TCLP after application of ViroSoil™ Technology (mg/L)
TCLP As	0.005	<0.001
TCLP Cu	0.004	<0.001
TCLP Cr	0.0161	<0.001
TCLP Zn	0.23	0.12

This table shows the levels of metal contamination before and after treatment with ViroSoil™ Technology. While relatively low prior to treatment heavy metals nevertheless were reduced significantly.

> CEC Constructions Queensland Rail, Townsville, Queensland #2

The contaminated site, in an industrial area, could not be simply excavated and transferred directly to local landfill due to high leachable heavy metal loads, predominantly lead.

Table 7 shows total metals in contaminated soil and pH and TCLP metals in leachate prior to treatment with ViroSoil™ Technology, and pH and TCLP metals in leachate after application of ViroSoil™ Technology.

TABLE 3 - CEC CONSTRUCTIONS RESULTS AND TREATMENT TARGETS

Contaminant	Before application of ViroSoil™ Technology (mg/L)	After application of ViroSoil™ Technology (mg/L)	Treatment Targets (mg/L)
TPH (C ₆ - C ₉)	7,600	20	100
TPH (C ₁₀ - C ₁₄)	12,500	55	100
TPH (C ₁₅ - C ₂₈)	52,000	780	1,000
TPH (C ₂₉ - C ₃₆)	35,000	560	1,000
TPH	107,100	1,415	-

TABLE 4 - CEC CONSTRUCTIONS RESULTS AND TREATMENT TARGET

Contaminant	Before application of ViroSoil™ Technology (mg/L)	After application of ViroSoil™ Technology (mg/L)	Treatment Targets (mg/L)
TPH (C ₆ - C ₉)	<10	<10	100
TPH (C ₁₀ - C ₁₄)	2,394	<50	100
TPH (C ₁₅ - C ₂₈)	16,607	<100	1,000
TPH (C ₂₉ - C ₃₆)	52,097	<100	1,000
TPH	71,108	<260	-



Mixing at the CEC Construction site.

> Former Building and Construction Company, South Australia

Virotec also recently completed a large-scale treatment of PCE contaminated soil. The contaminated soil was stabilised using ViroBind reagent to enable safe landfill disposal.

TABLE 5: FORMER BUILDING AND CONSTRUCTION COMPANY, SOUTH AUSTRALIA

Replicate Sample		Replicate Sample 2		Replicate 3	
PCE Treatment Targets: ASLP Leachate* and MEP Leachate** - 0.7mg/L					
Raw Sample	0.769	Raw Sample	0.01	Raw Sample	0.417
Treatment 1	0.005	Treatment 1 - ALSP	0.005	Treatment 1 - ASLP	0.005
Treatment 1 - MEP	-	Treatment 1 - MEP	-	Treatment 1 - MEP	-

* Method of Analysis AS 4439.2 - 1197

** MEP: Multiple Extraction Procedure - USA EPA 1320 Method

- MEP leachate analysis for raw and treated samples are currently being processed. All results provided in mg/L

> Former Gasworks Site, SA

Virotec has been working with a State Government agency to treat soils contaminated with PAH's. Using Virotec's RSD Technology, the contaminants were degraded to below NEPM soil investigation levels.

TABLE 6: FORMER GASWORKS SITE, SOUTH AUSTRALIA

Treatment ID	Initial pH	Final pH	ViroBind™ Reagent	
			BaP Total Concentration (mg/kg)	BaP ASLP Leachate (mg/L)
Raw Sample	11.9	-	919	-
Treatment 1	11.2	9.0	676	<0.0005
Treatment 2	10.5	7.5	579	<0.0005
Treatment 3	11	8.4	716	<0.0005
Treatment 4	10.7	7.4	528	<0.0005
Treatment 5	11.1	7.8	585	<0.0005

* Method of analysis AS 4439.2 - 1197

TABLE 7: BLUESCOPE STEEL - TOTAL HYDROCARBONS IN TREATED SLUDGE

Parameter	Concentration after treatment with ViroSoil Technology™ (mg/L)	Allowable Concentration prior to Disposal (mg/kg)
Benzene	<0.2	1.0
Toluene	<0.5	28.8
Ethylbenzene	<0.5	60
Xylenes	<1.0	100
C ₆ - C ₉ Hydrocarbons	<10	650
C ₁₀ - C ₃₆ Hydrocarbons	<260	5,000



The BlueScope Steel site.

This table shows the total concentration of hydrocarbons in a contaminated oily sludge after treatment with ViroSoil™ Technology.

> **Parkside Timber Preservation Site, Bullyan Mill, Queensland**

TABLE 8: TOTAL METALS AND TCLP RESULTS FOR CONTAMINATED SOIL

Contaminant	Total Metals (mg/kg)	TCLP Metals before Treatment (mg/L)	TCLP after application of ViroSoil™ Technology (mg/L)	TCLP Limits for Acceptable Landfill in Queensland (mg/L)
Arsenic	1,305	2.8	<0.001	5.0
Chromium	1,343	6.0	0.007	5.0
Copper	2,835	19	0.005	5.0

This table shows total metals in contaminated soil, TCLP metals in leachate prior to treatment with ViroSoil™ Technology, and TCLP metals in leachate after application of ViroSoil™ Technology.



Contaminated soil stockpile at Parkside Timber.

> Westrock Development Disused Cannery Site, Townsville, Queensland

Table below shows total metals and oil and grease concentrations in contaminated sludge, TCLP metals in leachate prior to treatment with ViroSoil™ Technology, and TCLP metals and oil and grease in leachate after application of ViroSoil™ Technology.

Typically the application of ViroSoil™ Technology is no more than one third the cost of alternative technologies, and is highly suitable for use where heavy metal contamination is also a problem.

TABLE 7: TOTAL METALS AND TCLP RESULTS FOR CONTAMINATED SOIL

Contaminant	Total Metals, Oils and Grease (mg/kg)	TCLP Metals before Treatment (mg/L)	TCLP after application of ViroSoil™ Technology (mg/L)	TCLP Limits for Acceptable Landfill in Queensland (mg/L)
pH	-	5.5	9.2	6.0 - 10.0
Copper	1,000	0.24	0.01	5.0
Lead	3,300	10	0.04	5.0
Zinc	920	18	0.02	100

> Worth Oil, Oily Sludge, New South Wales

TABLE 8: TOTAL METALS AND TCLP RESULTS FOR CONTAMINATED OILY SLUDGE

Parameter	Total Metals and Oils and Grease (mg/kg)	TCLP Metals before Treatment (mg/L)	TCLP after Application of ViroSoil™ Technology (mg/L)	TCLP Limits for Acceptable Landfill in Queensland (mg/L)
pH	5.6	-	8.76	6.0 - 10.0
Arsenic	41	0.010	0.005	1.0
Chromium	115.7	0.033	0.016	3.0
Copper	364	0.332	0.077	5.0
Mercury	0.1	0.003	0.002	0.003
Manganese	1,453	6.95	0.722	10
Nickel	141	0.098	0.027	3.0
Lead	77.3	0.050	0.003	2.0
Zinc	1,958	10.12	0.129	5.0
Oil & Grease*	75.7	-	10.3	20

SUITABILITY OF VIROSOIL™ TECHNOLOGY

Like standard bioremediation methods, ViroSoil™ Technology is not an entirely new concept and is being increasingly used as an economical environmental remediation technology. It differs from standard bioremediation in that it speeds up the degradation process and rapidly binds heavy metals. *Ex-situ* ViroSoil™ Technology treatment of soil is generally undertaken in contained and managed bio-piles or, subject to limitations, by land-farming.

For the purpose of this document, ViroSoil™ Technology is defined as an accelerated process using micro-organisms (indigenous and introduced) and other chemical and physical manipulations to degrade and detoxify organic substances to harmless compounds, such as carbon dioxide and water, in a confined and controlled environment.

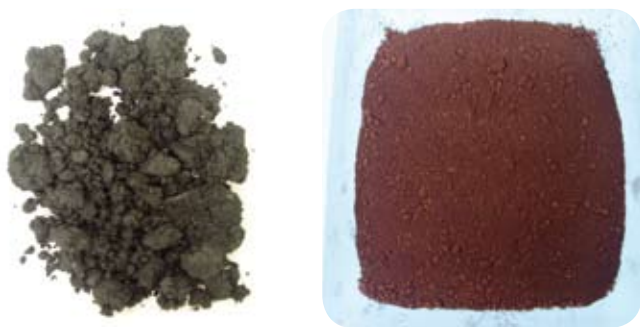
Bioremediation is suitable for the treatment of many organic chemicals, including:

- > Volatile organic compounds;
- > Benzene, toluene, ethyl benzene, xylene (BTEX) compounds;
- > Phenolic compounds;
- > Polycyclic aromatic hydrocarbons (PAHs) (particularly the simpler aromatic compounds);
- > Petroleum hydrocarbons; and
- > Nitro-aromatic compounds.

There are generally three stages to a soil treatment project:

1. **A laboratory-based study** to determine the biodegradability of chemical substances and the ability of the indigenous or introduced micro-organisms to degrade them; generally performed off site.
2. **A pilot trial**, either on site or in the laboratory or a combination of both, to provide further data necessary for the design of the full-scale treatment.
3. **Full-scale treatment**, conducted on site or at an approved facility.

The first two stages of ViroSoil™ Technology treatment may not be necessary for some small-scale bioremediation processes. However, for large-scale projects, the completion of stages one and two may result in considerable cost and time savings.



This figure shows the properties of the Worth Oil oily sludge before treatment. and after treatment with ViroSoil™ Technology.

TABLE 9 - VIROSOIL™ TECHNOLOGY COMPREHENSIVELY PASSES THE THREE POINT TEST

Requirement	ViroSoil™ Technology	ViroSoil™ Technology Pass/Fail
1. The waste must go through a physical, thermal, chemical or biological process including sorting	Qualifies as a: A. Physical process—absorbs and immobilises heavy metals B. Thermal—ViroSoil™ Technology increases soil temperature C. Chemical—ViroSoil™ Technology changes the chemical properties of the soil treated including pH and leachable heavy metals D. Biological process—ViroBac™ reagent contains hydrocarbon-reducing microbes that rapidly degrade sorbed hydrocarbon into simpler compounds and eventually, carbon dioxide, water and benign inorganics	Pass
2. The characteristics of the waste must change to reduce its hazardous nature	A. Produces negligible leachate B. Will not release contaminants under compaction C. Reduces flammable vapours D. Degrades the contaminant E. Changes the physical, chemical and biological properties of soil	Pass
3. The process must facilitate the waste handling or recovery	Encapsulates and immobilises heavy metals and destroys hydrocarbons	Pass

USE OF VIROSOIL™ TECHNOLOGY

Environmental regulators typically endorse the use of controlled remediation, particularly when the treated soil is suitable for reuse (e.g. on-site backfill), thereby reducing disposal of waste soil to landfill. Consideration should be given to the hierarchy for site remediation or management, outlined below from the most preferred to the least preferred:

1. On-site treatment of the chemical substances to reduce risk to an acceptable level;
2. Off-site treatment of excavated soil to reduce risk to an acceptable level, after which the treated soil is returned to the site;
3. Containment of soil on site with a properly designed barrier; and
4. Disposal of affected soil to an approved landfill.

Before starting a ViroSoil™ Technology project, the nature and extent of the chemical substances in the soil must be assessed; then the need for remediation can be considered along with the treatment options available. An appropriate remediation strategy can then be developed and implemented where appropriate.

It is important to recognise that chemical-affected soils may contain substances that are not suitable for treatment. This should be considered when determining the feasibility of ViroSoil™ Technology, the need for alternative remediation treatments, and the reuse or disposal of treated soil.

The management of a ViroSoil™ Technology project will depend on the nature and concentration of chemical substances, as well as the proximity of the bioremediation process to sensitive environments and human activities. Environmental regulators typically consider that any proposal for remediation strategy should demonstrate adequate safeguards for the protection of human health and the environment. Considerations include the control, minimisation and monitoring of emissions or discharges from the treatment process and the potential toxicity of those emissions.

A flowchart outlining the strategy involved in ViroSoil™ Technology activities is provided in the figure below.

FEASIBILITY ASSESSMENT (LABORATORY AND PILOT TRIALS)

A preliminary feasibility assessment should be made on a site-and-soil-specific basis to establish the likelihood of success, practicability and effectiveness of the proposed ViroSoil™ Technology treatment. This assessment will determine the presence of heavy metals, acidity, and indigenous micro-organisms, whether there is a need to introduce other species (because there are insufficient or unsuitable indigenous organisms), and the time frame required.

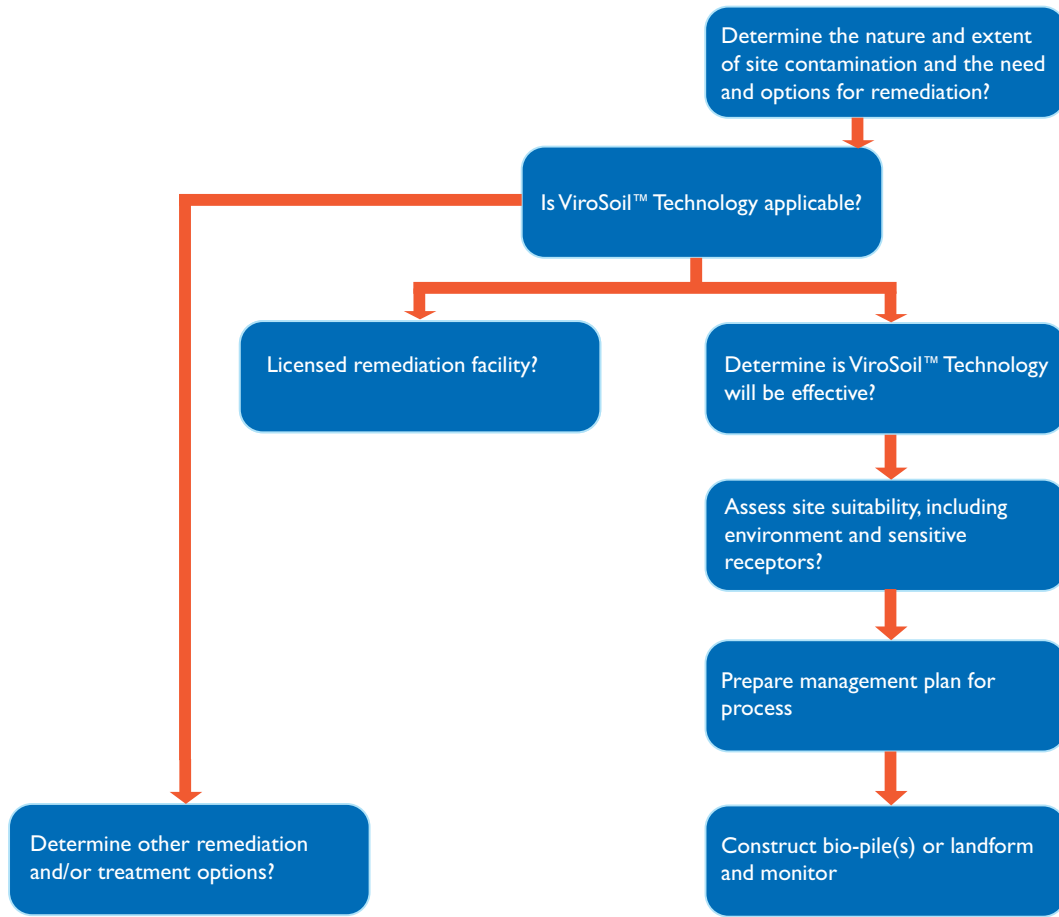
Feasibility assessments should be conducted in the laboratory and/or in the field. Laboratory assessments provide an indication of the ability of indigenous soil organisms to degrade the chemical substance(s) of concern under controlled conditions.

Field trials are useful for optimising process parameters, including the method and concentration of nutrient application, the effectiveness of maintaining soil moisture content, airflow rates, and leachate generation.

Feasibility assessments are made to determine:

- > Biodegradability of key contaminant(s);
- > Biological activity indicated by the rate of oxygen consumption or carbon dioxide generation;
- > Degradation rates of chemical substance(s);
- > The need for additional microbial species and their effects on degradation rates;
- > Any metal and biological complexes;
- > Addition rates and methods; and
- > On-site engineering and logistics requirements.

THE STRATEGY INVOLVED IN VIROSOIL™ TECHNOLOGY ACTIVITIES



MANAGEMENT PLANS

Two management plans may be prepared for ViroSoil™ Technology processes—a Remediation Management Plan (RMP), which outlines the management and control of the treatment process itself; and an Environmental Management Plan (EMP), which addresses all known and potential environmental management problems. RMPs and EMPs may be prepared separately or together as a remediation management plan. If prepared as a single document, the same level of detail is required, but duplication may be reduced.

VALIDATION OF VIROSOIL™ TECHNOLOGY

The time frame for applying ViroSoil™ Technology is case-specific. Treatment is complete only when targets have been achieved, or it can be demonstrated that the contaminants of concern do not pose a risk to human health or the environment. In determining the end-use suitability of soil, environmental regulators generally recommend that:

- > Treated soils are sampled and tested to determine their suitability for reuse or landfill.
- > If the treated materials are only suitable for disposal to landfill, the classification of the materials for disposal is to be made by an environmental consultant

- > The suitability of treated soils for use as a resource is assessed and the results are compared with suitable criteria.
- > The concentrations of contaminants should be less than, or equal to, the target criteria. Criteria should demonstrate that the residual concentration of a contaminant will not pose a risk to human health and/or the environment, including leaching to groundwater.
- > The number of samples collected and analysed for the validation of treated and stockpiled soil should be adequate to provide a statistically reliable result, taking into account the intended use of the soil.
- > Sampling procedures should take into account sampling and investigation of potentially contaminated soil.
- > Leachate validation testing should be undertaken in accordance with regulatory guidelines on wastes, sediments and contaminated soils. Other testing may be required depending on the soil and chemical characteristics.

REPORTING

Most environmental regulators recommend that, on completion of the treatment program, a report be issued which documents all of the activities undertaken, particularly:

- > The final concentrations of contaminants in the soil following treatment;
- > The fate of the treated soil and the details of how it was, or is to be, managed to ensure the adequate protection of human health and the environment; and
- > If material was disposed of to a licensed facility, the classification of the materials for disposal and evidence of disposal.

CONCLUSION

ViroSoil™ Technology, utilising Rapid Sequestro-Degradation, is a unique method for the treatment of contaminated soil. ViroSoil™ Technology binds heavy metals, neutralises soil acidity, and rapidly destroys all forms of hydrocarbons and objectionable and noxious odours.

ViroSoil™ Technology is cost-effective when compared to traditional forms of soil treatment, and has the added advantage of permanently binding heavy metals.

ViroSoil™ Technology is a complete solution for both *in-situ* and *ex-situ* treatment scenarios.