United Retek

A Guide to the Retek Process

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1. INTRODUCTION

In recent time in the UK and EEC Countries, there has been a move to risk-based assessment of contamination in soils and other media. This means the nature of the risk will determine the requirement for remediation, and the most suitable method of remediation, if any, that may be required.

For example, in the environment, Chromium exists mainly in two oxidation states, hexavalent and trivalent. Hexavalent chromium is highly mobile, severely toxic at moderate doses and classified as a respiratory carcinogen in humans.

The trivalent form is used as a dietary supplement, and in most environmental systems is immobile (Higgins et al., 1998).

Clearly, the key environmental risk is that any trivalent chrome in soil, if left untreated, could change into the toxic hexavalent form and escape from the soil.

Risk-based assessment means that methods of soil remediation that can treat the media on-site, and allow the treated materials to remain on site, are becoming very attractive from an environmental and commercial perspective.

The Retek Process is a well established on-site remediation approach that has been applied to a broad range of contaminated soils, dredge and other media, contaminated with substances classified as "hazardous" by the Environment Agency and US EPA.

At its simplest, the process involves mixing chemicals, reagents and binding agents, into the contaminated media in order to immobilise the contaminants within the treated material. The resulting chemical reactions and physical immobilisation within the material destroys or binds the contaminants, and so removes the risks to humans, animals, and even plant receptors.

The Retek Process has been approved by the EPA in the USA, and by the UK Environment Agency, and can be used to treat soils containing a wide variety of organic and inorganic contaminants (see Table 1).

The ability to treat multiple contaminant types within the same media is a key benefit of the process, and means it can be used in complex contamination situations, such as are found when treating industrial and coke/town gas sites.

Once the hazardous contaminants have been treated, the resulting materials have been approved for reuse on-site in the UK.

In the USA, the material may be re-sold as paving base / secondary aggregate, due to a beneficial use determination for the treated materials having been agreed by several State EPAs. In time, it is expected that a similar beneficial use determination will be agreed in Europe.

The remainder of this document is intended to discuss the physical, chemical and regulatory aspects of the technology, as well as to demonstrate how the process is being applied in the field.

2. THE RETEK PROCESS

2.1. Solidification and Chemical Stabilisation Techniques

The Retek Process employs a mixture of chemical and physical processes, including “solidification" and "stabilisation" techniques refined in the field over the past 20 years. Stabilisation and solidification sound similar, but describe different effects that occur in the process as the binding agents and reagents work to immobilise hazardous materials.

Solidification refers to changes in the physical properties of a waste. These changes may include binding free water in a waste, creating waste with more physical integrity, such as a granular solid or monolith, and reducing the hydraulic conductivity of the waste. The treatment also results in an increase in compressive strength, a decrease in permeability and the encapsulation of some hazardous constituents.

Solidification is a well known treatment for the geo-technical improvement of soils and dredge materials in the UK, but has led to many people misunderstanding the nature of the s/s techniques. What are often less well understood are the complex chemical interactions that can be engineered using these technologies.

Stabilisation refers to the chemical changes to the hazardous constituents in a waste, including converting the contaminants into a less soluble, mobile or toxic form. A good example is the approach to heavy metals. These may be precipitated from contaminated soils through the conversion of soluble heavy metal salts to insoluble salts, and these salts can in turn be bound in permanent matrices.

2.2. Process Chemistry

The Retek Process is used to treat wastes that have either, or both, inorganic and organic hazardous constituents. The process usually involves mixing multiple binding agents and reagents into contaminated media, and these can include asphalt Emulsions, phosphates, pH buffers, oxidizers, fillers, cement, cement kiln dust (CKD), lime, lime kiln dust (LKD), limestone, fly ash, slag and gypsum. When soils are being recycled for use on site, bitumen and or pozolonic products can be added to improve performance of the soils as a paving base for use beneath roads and car parks etc.

In addition, other reagents are used for their chemical reactivity especially phosphate mixtures and a number of proprietary reagents.

Taking the heavy metals as an example, they typically may be precipitated from soils as hydroxides, sulphides or carbonates. The precipitation process usually uses pH adjustment and the addition of suitable chemical reagents, but the nature and solubility of the specific metal contaminants will dictate the best process to use.

These chemical reactions offer essentially permanent solutions to the fixation of heavy metals such as lead, cadmium, arsenic, zinc, chromium, copper and others. The technology reduces the leachability of metals allowing treated material to pass the Toxicity Characteristic Leaching Procedure (TCLP), Synthetic Precipitation Leaching Procedure (SPLP) and the Multiple Extraction Procedure (MEP).

Due to the great variation of waste constituents and media, any individual remediation project will usually require a mixture of reagents and processing conditions. Typically, such site-specific treatments are based on mixes derived from a database of formulae compiled from the treatment of contaminated wastes in thousands of prior projects.

Mix designs are also often modified to include other products or additives to supplement the main reagents, in order to adjust pH, to drive off water, for bulking or for greater economy.

The reagent formulas used in *The Retek Process* are selected to:

- chemically react with hazardous constituents to form insoluble products
- facilitate reactions of some contaminants to form products of lower toxicity
- chemically bind free liquids in an irreversible matrix
- reduce the permeability of the total waste form
- encapsulate individual waste particles with an impermeable coating

2.3. Equipment and Processing Rates

At present, the process is carried out exclusively on-site using compact mobile plant. Key equipment includes pugmills and reagent storage and delivery plant, and these are scaled up or down dependent on site and project size, and speed requirements.

Combined with fast road transport and rapid set-up, this means that the process may be used on virtually any site, for any quantity of soil, and in very tight timescales.

In use, the process is fast, treating 60 -150 tonnes of soil per hour (each pugmill) and creating a dry inert product. Since, in many cases, the soil can be replaced on-site; there is no need to bring in costly backfill to replace the contaminated soil. In addition, where binding reagents are used in processing, the treated material makes an excellent paving base for use under access roads and car parks etc., providing additional value and savings.

2.4. Treatment of Free Liquids

Land disposal of liquid waste or solid-form waste with a free liquid portion is usually prohibited by land disposal restrictions. An unconfined compressive strength is often specified to verify that free liquids have been bound chemically rather than absorbed. *The Retek Process* can solidify sludge and dredge materials straight from excavation, and without prior dewatering.

2.5. Contaminated Dredge and Waterlogged Soils

Commercial harbours, industrialised estuaries and canal side gas-works; whatever the location, *The Retek Process* can be applied. The combination of wet material processing, together with the speed of the process, delivers fast effective results.

For example, New Bedford Harbour is a major commercial fishing port and industrial centre on Buzzards Bay in Massachusetts. Up to the 1970s, electrical parts manufacturers discharged wastes containing toxic metals into the harbour, resulting in high levels of contamination throughout the sediments across the bay.

United Retek became involved with the clean-up of the site, under the direction of the EPA, in an area which required the creation of a series of seven circular bulkhead cells connected together with steel arcs, and which required the removal and treatment of substantial volumes of the contaminated harbour sediments.

The Retek Process was chosen specifically because it was a long trusted treatment for the high levels of heavy metal and other contaminants found in the dredge materials, as well as being proven to greatly improve the physical and chemical composition of the saturated dredge material.

On site the Retek process was found to be so effective at dealing with the water content of the material, that the dredged sediments were lifted straight from the harbour and transferred directly into hoppers for immediate processing.

The material exiting the process was seen to be immediately drier, friable and capable of machine handling. Just 3 days of further curing in stockpiles, resulted in further improvements in character giving an unconfined compressive strength of over 5 tons/square foot.

As a result, the material was able to be used to reclaim previously un-useable land on the site, and to backfill behind the sheet piled cells, saving thousands of dollars on purchasing and transporting backfill material.

3. TREATMENT OF INORGANIC CONTAMINANTS

The Retek Process treats waste contaminated with multiple, and varied, inorganic hazardous constituents. Generally, in these wastes the hazard resides in the heavy metals content.

Heavy metals-contaminated wastes are frequently determined to be hazardous due to the leaching potential of the metals. Typically, these wastes have failed the Toxicity Characteristic Leaching Procedure (TCLP).

The Retek Process is used to remove the risk posed by the contaminants, and works by reducing its leaching potential from the waste. This means that, after treatment, the waste no longer exhibits the hazardous leaching and can be replaced or re-used on site, or disposed of as a non hazardous waste in landfills.

In the case of many remediation projects, *The Retek Process* is often the only cost effective process to treat large volumes of heavy metals contaminated soil, sludge, or sediment, especially where organic contamination is also present.

The Retek Process is uniquely suited for use on metal contaminants because it irreversibly reacts with metals to give:

1. the formation of insoluble hydroxides, carbonates and silicates
2. substitution of the metal into a mineral structure
3. physical encapsulation
4. reduction of toxicity by changes in valence (e.g. hex-chrome reduced to tri-chrome)

4. TREATMENT OF ORGANIC CONTAMINANTS

The Retek Process is an effective treatment for a wide variety of hazardous organic contaminants, including halogenated and non-halogenated semi-volatiles, non-volatiles, polychlorinated biphenyls (PCBs), pesticides, organic cyanides and organic corrosives.

Due to the varied nature of these contaminants, various formulations and approaches may be adopted in order to produce effects ranging from the chemical destruction of the contaminant, to the absorption or encapsulation of the materials.

The Retek Process can also remediate high concentrations of difficult organics (e.g. concentrations of oils and greases >20%) although these may require additional attention to ensure adequate mixing of reagents. In these cases, the process uses specialised mixing techniques refined over its 20 years of field experience.

It is also recognised that some organic contaminants can affect the curing time of the treated material, and may require additional additives and field techniques to moderate these undesirable effects.

In addition, some binding reagents can produce a significant amount of heat quickly when mixed with water due to exothermic reactions. The fast evolution heat can pose challenges in the treatment of materials contaminated with volatile organic compounds (VOCs) and other compounds, such as PCBs. Bench scale testing will determine the likelihood of these outcomes and, where required, specialist air-collection equipment can be used in order to avoid transfer of the VOC's from the waste into the atmosphere.

5. VERIFICATION TESTING

Most United Retek projects require treatability studies and final performance testing of the treated waste. These tests can be placed into two groups: physical and chemical.

It is important to note that normally the only tests that are required by regulators are TCLP to determine leachability characteristics and the unconfined compressive strength tests such as CBR (California Bearing Ratio), Proctor, etc.

Regulators generally select the appropriate physical and/or chemical tests for a specific project using best professional judgment and risk based determinations based on the contaminants and media (soil, sludge or sediment) and the planned use of the site.

5.1. Physical Tests.

The commonly specified physical tests in project performance standards include the Paint Filter Test (pass/fail), Hydraulic Conductivity (<1x10-5 cm/sec), and Unconfined Compressive Strength (0.34 MPa (>50psi)).

5.2. Chemical Tests

The most commonly specified chemical test is the TCLP. However, there has been considerable discussion about the appropriateness of applying the TCLP to United Retek treated waste, when this treated waste is managed other than in a municipal Landfill.

The TCLP relies on extracting the sample waste with a diluted organic acid (acetic add), thus simulating conditions of co-disposed organic waste, such as found in municipal landfills. Many United Retek treated wastes are disposed in mono-fills or treated and left onsite. The TCLP therefore, may not be the best simulation of these disposal scenarios.

To address this concern, regulators may prefer to use the Synthetic Precipitation Leaching Procedure (SPLP) in lieu of the TCLP. The SPLP is designed to simulate waste exposure to acid rain. This procedure is similar to the TCLP, except that a weak solution of inorganic acid (sulphuric and nitric) is used.

Ultimately, project managers and regulators will consider the final disposal environment of the treated waste to determine the appropriate test to use.

5.3. Typical Results

Table 1 – Some Actual Results – Before and After Treatment

		Original Concentration		Original Leachability		After Concentration		After Leachability	
TPH									
	EPH (DRO) (C10-C40)	12161	ug/kg	1056	ug/l	14457	ug/kg	95	ug/l
	GRO (C4-C10)	38484	ug/kg	14442	ug/l	120	ug/kg	<10	ug/l
	GRO (C10-C12)	26774	ug/kg	15571	ug/l	2541	ug/kg	<10	ug/l
	Benzene	<10	ug/kg	<10	ug/l	<10	ug/kg	<10	ug/l
	Toluene	<10	ug/kg	<10	ug/l	<10	ug/kg	<10	ug/l
	Ethyl benzene	850	ug/kg	266	ug/l	<10	ug/kg	<10	ug/l
	m & p Xylene	1921	ug/kg	874	ug/l	<10	ug/kg	<10	ug/l
	o Xylene	1464	ug/kg	521	ug/l	<10	ug/kg	<10	ug/l
	MTBE	51	ug/kg	<10	ug/l	<10	ug/kg	<10	ug/l
Metals									
	Arsenic	N/A		50	mg/l	N/A		0.002	mg/l
	Cadmium	N/A		2	mg/l	N/A		0.002	mg/l
	Chromium	N/A		27	mg/l	N/A		<0.01	mg/l
	Copper	N/A		190	mg/l	N/A		0.01	mg/l
	Lead	N/A		180	mg/l	N/A		0.004	mg/l
	Mercury	N/A		1	mg/l	N/A		<0.001	mg/l
	Nickel	N/A		21	mg/l	N/A		<0.01	mg/l
	Selenium	N/A		5	mg/l	N/A		<0.005	mg/l
	Zinc	N/A		790	mg/l	N/A		0.04	mg/l
PAH									
	Acenaphthene	N/A		110	ug/l	N/A		0.7	ug/l
	Acenaphthylene	N/A		5.3	ug/l	N/A		0.06	ug/l
	Anthracene	N/A		300	ug/l	N/A		1.3	ug/l
	Benzo(a)Anthracene	N/A		400	ug/l	N/A		1.8	ug/l
	Benzo(a)Pyrene	N/A		260	ug/l	N/A		1.5	ug/l
	Benzo(b/k)Fluoranthene	N/A		410	ug/l	N/A		2.8	ug/l
	Benzo(ghi)Perylene	N/A		96	ug/l	N/A		0.7	ug/l
	Chrysene	N/A		320	ug/l	N/A		1.8	ug/l
	Dibenzo(ah)Anthracene	N/A		33	ug/l	N/A		0.29	ug/l
	Fluoranthene	N/A		430	ug/l	N/A		5.1	ug/l
	Fluorene	N/A		150	ug/l	N/A		0.67	ug/l
	Indeno(123-cd)Pyrene	N/A		140	ug/l	N/A		0.74	ug/l
	Naphthalene	N/A		180	ug/l	N/A		1.2	ug/l
	Phenanthrene	N/A		560	ug/l	N/A		2.2	ug/l
	Pyrene	N/A		370	ug/l	N/A		4.1	ug/l
	PAH (Total)	N/A		3800	ug/l	N/A		25	ug/l

6. UNITED RETEK

In July 2004 the EU Landfill Directive effectively banned the disposal of hazardous waste at the vast majority of landfill sites. Within a matter of months, landowners and developers saw escalating costs for “dig and dump”, until then the preferred means of dealing with contaminated soils, and an undermining of the economics of many redevelopment projects.

While this regulatory tightening has caused problems for some, it has however, been the perfect stimulus for United Retek (UK).

The U.S. based United Retek Corporation was amongst the pioneers of on-site recycling of contaminated soils, as the Environmental Protection Agency tightened U.S. brownfield regulations in the mid-1980s. Since that time, United Retek has stabilized and recycled around two million tonnes of soil at hundreds of sites for a broad spectrum of private and public sector clients.

Having such a long track record of soil remediation in such a highly regulated market, it was almost inevitable that following a growing number of enquiries for their services, that the Retek Process should be brought to the UK.

Ian Hadfield, MD United Retek, saw that many development projects seem to have stalled as the rapid rise in landfill and transport costs caused remediation budgets to overshoot. Even worse, some “remediation” specialists had to go back to a client to ask for more money.

Our solution was to introduce *The Retek Process*, and this was fully licensed in 2005. Initial discussions with the Environmental Agency allowed us to demonstrate the effectiveness of the process, but also how our recycling technology eliminates the cost and risks associated with transportation of contaminated soils, and their landfill disposal.

The extensive and varied case studies on the UR web site confirm for the EA that the Retek Process is ideal for media, contaminated with petroleum, oils, heavy metals, VOC’s, coal tars & manufactured gas plant waste.

To summarise the value of the United Retek approach:

Everyday we see projects where rising costs and time slippage are robbing developers and owners of part of their investment. We think that the effectiveness, speed and lower costs of the Retek Process are good ways of returning real value to projects, and winning back large amounts of lost time.

7. A DETAILED CASE STUDY

7.1. A Road Haulage Fuel Refilling and Garage Site

This study report has been prepared to document the treatment of samples taken from a proposed remediation site located in Lancashire.

Contractors provided samples of contaminated soils, identified during a site investigation carried out by **Cooper Associates** and analysed by **Scientific Analysis Laboratories Ltd**.

The contaminated sample obtained was comprised of ash, clinker and slag fill. These fill strata had elevated concentrations of contaminants as follows:

- **Arsenic** (24mg/kg to 50mg/kg),
- **Copper** (l90mg/kg aud 460mg/kg),
- **Zinc** (790mg/kg and 1,100mglkg)
- **Lead** (850mg/kg)
- **PAH** (polycyclic aromatic hydrocarbons) were also significantly elevated with the marker compound benzo(a)pyrene at concentrations of between 3.9mg/kg to 260mg/kg.

This case study describes the results of a bench scale treatability study designed to show the effectiveness of the reagents proposed for ex-situ treatment of the soils. Further details of the site and the detailed laboratory results are held on file, and are available on request, subject to client approval and suitable confidentiality arrangements.

7.2. Treatment Process

In the laboratory, the soil sample was split into three 500-gram portions.

Based on prior experience of the successful recycling of similarly contaminated soils, and based on the analytical data provided, three specific reagent formulations were applied to the samples. These were designated S1, S2 & S3.

The sample were allowed to cure for four days at ambient temperature open to the air, prior to submission for testing to Scientific Analysis Laboratories Ltd.

In addition, a further sample of 2.5kg of the supplied material was also treated (with reagents used in S3) and compacted into a California Bearing Ratio (CBR) mould; extruded and left to cure.

7.3. Post Treatment Results

Analysis: Heavy Metals

WS 2006 UNTREATED SOIL SAMPLES	Retek Process TREATED SOIL SAMPLES
SAL Reference: 68620 Material: Analysed as Soil	SAL Reference: 71639 Leachate: Analysed as Water

SAL Reference	68620 004	68620 008	71639 001	71639 002	71639 003
Customer Sample Reference	TP4 100 Ash & Gravel Fill	TP7 200 Slag & Ash Fill	S1	S2	S3

Determinant	Technique	LOD	Unit	Symbol					
Arsenic	ICP/OES (Preconc.)	0.002	mg/l	U	50	24	0.002	0.002	0.005
Cadmium	ICP/OES (Preconc.)	0.001	mg/l	U	2	<1	0.002	0.099	0.002
Chromium	ICP/OES	0.01	mg/l	U	27	18	<0.01	<0.01	<0.01
Copper	ICP/OES	0.01	mg/l	U	190	74	0.01	0.01	<0.01
Lead	ICP/OES (Preconc.)	0.002	mg/l	U	180	82	0.004	0.002	0.004
Mercury	ICP/OES (Preconc.)	0.001	mg/l	U	1	<1	<0.001	<0.001	<0.001
Nickel	ICP/OES	0.01	mg/l	U	21	30	<0.01	<0.01	<0.01
Selenium	ICP/OES (Preconc.)	0.005	mg/l	U	5	<2	<0.005	<0.005	<0.005
Zinc	ICP/OES	0.01	mg/l	U	790	320	0.04	0.03	0.02

Clearly, in the case of heavy metals the leaching levels shows all the treated samples have been reduced to values that are at or below the limits of the Leachate test.

Analysis: PAH US EPA 16

WS 2006 UNTREATED SOIL SAMPLES	Retek Process TREATED SOIL SAMPLES
SAL Reference: 68620 Material: Analysed as Soil	SAL Reference: 71639 Leachate: Analysed as Water

SAL Reference					68620 004	68620 008	71639 001	71639 002	71639 003
Customer Sample Reference					TP4 100 Ash & Gravel Fill	TP7 200 Slag & Ash Fill	S1	S2	S3
Determinant	Technique	LOD	Unit	Symbol					
Acenaphthene	GC/MS (SIR)	0.01	µg/l	U	2.30	110	1.50	0.70	0.90
Acenaphthylene	GC/MS (SIR)	0.01	µg/l	U	2.70	5.30	0.06	0.06	0.05
Anthracene	GC/MS (SIR)	0.01	µg/l	U	26	300	6.80	1.30	1.70
Benzo(a)Anthracene	GC/MS (SIR)	0.01	µg/l	U	150	400	3.20	1.80	3.00
Benzo(a)Pyrene	**GC/MS (SIR)**	**0.01**	**µg/l**	**U**	**150**	**260**	**2.70**	**1.50**	**2.60**
Benzo(b/k)Fluoranthene	GC/MS (SIR)	0.01	µg/l	U	250	410	4.80	2.80	4.80
Benzo(ghi)Perylene	GC/MS (SIR)	0.01	µg/l	U	62	96	1.20	0.70	1.10
Chrysene	GC/MS (SIR)	0.01	µg/l	U	130	320	3.60	1.80	2.90
Dibenzo(ah)Anthracene	GC/MS (SIR)	0.01	µg/l	U	17	33	0.43	0.29	0.32
Fluoranthene	GC/MS (SIR)	0.01	µg/l	U	250	430	8.00	5.10	6.40
Fluorene	GC/MS (SIR)	0.01	µg/l	U	3.70	150	2.20	0.67	0.93
Indeno(123-cd)Pyrene	GC/MS (SIR)	0.01	µg/l	U	85	140	1.30	0.74	1.10
Naphthalene	GC/MS (SIR)	0.01	µg/l	U	0.48	180	5.20	1.20	1.30
Phenanthrene	GC/MS (SIR)	0.01	µg/l	U	34	560	5.30	2.20	3.10
Pyrene	GC/MS (SIR)	0.01	µg/l	U	210	370	6.30	4.10	5.10
PAH (Total)	GC/MS (SIR)	0.01	µg/l	U	1400	3800	53	25	35

All PAH Leachate values have been reduced to safe levels. The "Marker" and main contaminant of concern (Benzo(a)pyrene) is leaching at only 1.5 to 2.7 ug/l.

Analysis: Total Petroleum Hydrocarbons (C6-C35 aliphatic/aromatic)

WS 2006 UNTREATED SOIL SAMPLES	Retek Process TREATED SOIL SAMPLES
SAL Reference: 68620 Leachate: Analysed as Soil	SAL Reference: 71639 Leachate: Analysed as Water

SAL Reference	68620 008	71639 001	71639 002	71639 003
Customer Sample Reference	TP7 200 Slag & Ash Fill	S1	S2	S3

Determinant	Technique	LOD	Units	Symbol				
TPH (C6-C7 aromatic)	GC/MS	20	µg/l	N	<100	<20	<20	<20
TPH (C6-C8 aliphatic)	GC/MS	20	µg/l	N	<100	<20	<20	<20
TPH (C7-C8 aromatic)	GC/MS	20	µg/l	N	<100	<20	<20	<20
TPH (C8-C10 aliphatic)	GC/MS	20	µg/l	N	<1	<20	<20	<20
TPH (C8-C10 aromatic)	GC/MS	20	µg/l	N	<1	<20	<20	<20
TPH DW (C10-C12 aliphatic)	GC/FID (LV)	0.01	mg/l	N	21	<0.01	<0.01	<0.01
TPH DW (C10-C12 aromatic)	GC/FID (LV)	0.01	mg/l	N	84	<0.01	<0.01	<0.01
TPH DW (C12-C16 aliphatic)	GC/FID (LV)	0.01	mg/l	N	40	<0.01	<0.01	<0.01
TPH DW (C12-C16 aromatic)	GC/FID (LV)	0.01	mg/l	N	340	<0.01	<0.01	<0.01
TPH DW (C16-C21 aliphatic)	GC/FID (LV)	0.01	mg/l	N	25	<0.01	<0.01	0.01
TPH DW (C16-C21 aromatic)	GC/FID (LV)	0.01	mg/l	N	1100	0.01	0.01	0.03
TPH DW (C21-C35 aliphatic)	GC/FID (LV)	0.01	mg/l	N	190	<0.01	<0.01	0.03
TPH DW (C21-C35 aromatic)	GC/FID (LV)	0.01	mg/l	N	1600	0.01	0.02	0.09