

Immobilising Soil Contaminants



RemBind is a powdered reagent that binds up and immobilises contaminants in soil. The product is typically added at less than 5% by weight using conventional soil blending equipment and binding occurs within 24hrs.

RemBind is designed to treat a range of organic contaminants including TPH, PAH, PFOS, PCBs, PCPs and various pesticides. The product can also bind up heavy metals such as arsenic, chromium and mercury.

The product is available in two grades: RemBind (standard) and RemBind Plus. RemBind is adequate for most applications, particularly for PAHs and TPHs. For contaminants with relatively low regulatory threshold values like PFCs, RemBind Plus is more suitable because it has a stronger binding capacity. Simple bench-scale trials will help to determine the right product for your situation.

The product was used to successfully treat more than 2,000 tonnes of gas works soil and the project team was awarded a National CCF Earth Award for environmental excellence.

Ziltek can also perform treatability trials and provide post-treatment validation testing and reporting where required.

Benefits

- Avoid landfill costs by leaving soil onsite
- Fast, low risk alternative to bioremediation
- Reclassify soil to a cheaper disposal category

Features

- High performance – meets stringent global standards
- Easy to apply using conventional equipment
- Developed in collaboration with the CSIRO

Applications

- Contaminated soil treatment
- Odour control
- Wastewater treatment
- Sediment remediation



“RemBind lived up to our technical expectations in reducing the leachability of PAHs and passed the most rigorous stability test”

Paul Bowden, General Manager
Integrated Waste Services



RemBind: Immobilising Soil Contaminants

1. What is RemBind?

RemBind is a powdered reagent for the chemical fixation (immobilisation) of organic and inorganic contaminants in soil. The product was developed by Ziltek in collaboration with CSIRO and contains a proprietary blend of reagents.

The main constituents of RemBind are:

- Activated carbon
- Aluminium hydroxide (amorphous)
- Kaolin clay and other proprietary additives

2. Target Contaminants

To date, RemBind has been used to successfully immobilise the following contaminants in soil:

- Organic contaminants: PAH, TPH, PFOS/PFOA, and a wide range of pesticides and herbicides
- Inorganic contaminants: arsenic, chromium, fluoride, mercury

3. Regulatory Approvals

RemBind has been granted regulatory approvals for use in several projects in Australia. A key example involved the remediation of 2,000 tonnes of gas work soil from Mead St, Birkenhead, South Australia. The South Australian EPA approved a treatment work plan based on extensive lab treatability trials. Treated soils were tested at an independent NATA accredited laboratory using TCLP analysis. The treated soil also passed the Multiple Extraction Procedure (MEP) test which is the most stringent leachability test used worldwide. The project team was awarded the National CCF Earth Award in 2011 for Environmental Excellence.



4. Application

- Low application rates minimising project costs. Application rates will vary with each situation, however the typical rate is from 2% to 10% (w/w). This ensures minimal bulking allowing for either reuse on site, or minimising landfill fees. Low addition rates directly relates to less reagent to be purchased. Low addition rates means less freight costs.
- RemBind flows easily and evenly within soil blending equipment. Even flow ensures a consistent result and minimises machine down time. Even flow minimises workers' direct exposure to processing equipment, reagents and contaminants by removing the need to intervene within the process.
- Provides a single pass solution, thus saving processing costs and complexities when dealing with multiple contaminants.

5. Shelf Life, Storage, Transport and Handling

- Shelf life: minimum of 3 years
- Temperature tolerance: Up to 60°C (storage and use)
- Classified: Non Dangerous Good – Non Hazardous
S22, S36, S24/25 – Do not breathe dust. Wear suitable protective clothing. Avoid contact with skin and eyes.
- The product is supplied in 1 m³ “bulky bags” and also available for bulk transport.

* Refer to MSDS for further details.

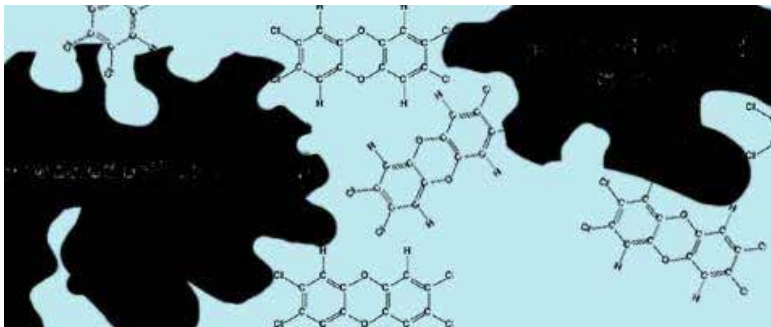
6. The Benefits

- Avoid landfill costs by leaving soil onsite.
- Fast, low risk alternative to bioremediation.
- Reclassify soil to a cheaper disposal category.

7. Mechanisms of Action

The RemBind product has two key mechanisms of action:

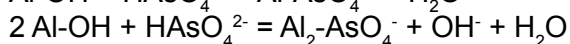
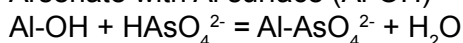
- The activated carbon component binds to organic compounds through adsorption, where the organic molecules adhere to the surface of the activated carbon through physical attraction forces. The exact mechanism of action depends on the type of molecule in question, but the adsorption process mainly involves Van der Waals forces but can also involve covalent bonding and/or electrostatic attraction. Due to its relatively large internal surface area, activated carbon is the most widely used adsorbent in the world.



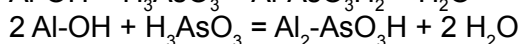
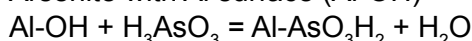
- The aluminium hydroxide component of RemBind is in an amorphous form which means it lacks a rigid crystalline structure. This results in an irregular, charged, and relatively large internal surface area which renders it suitable for binding a range of compounds, particularly the amphoteric metals.

An example of one of the binding mechanisms to arsenic are shown below:

Arsenate with Al surface (Al-OH)



Arsenite with Al surface (Al-OH)



RemBind enabled the safe disposal of 1,000 tonnes of Aqueous Film Forming Foam (AFFF) impacted soil

The Problem

Aqueous Film Forming Foams (AFFFs) are a class of fire-fighting foams that contain per- and polyfluoroalkyl substances (PFAS). In 2009, perfluorooctane sulfonate (PFOS) was listed as a Persistent Organic Pollutant (POP) by the Stockholm Convention due to its potential toxicity effects. Most PFASs are highly soluble in water and so tend to readily leach from contaminated soil into groundwater, thus posing a potential risk to human health and the environment.

In 2015, an Australian client was required to manage 1,000 tonnes of soil impacted with PFAS originating from infrastructure maintenance work at two airport sites.

In this study, RemBind was used to reduce PFAS leachability in the soil to allow for safe disposal to landfill with regulatory approval.



Adding RemBind to form the base of the burial pit

The RemBind Solution

Lab-scale trials determined that an addition rate of 5% (w/w) RemBind to the soil was adequate to reduce PFAS concentrations in soil leachates to below the target criteria of <math><0.2 \mu\text{g/L}</math>.

Soils were segregated into high and low contamination levels based on *in-situ* sampling and analysis for PFAS.

The highly contaminated soil 'hotspots' were treated with RemBind using a conventional loader and excavator, with water added to achieve a 40% (w/w) final moisture content.

After treatment, validation samples were sent to Australian Laboratory Services (ALS) and analysed for an extended suite of 20 PFAS compounds, including PFOS and perfluorooctanoic acid (PFOA), using LC-MS/MS for total concentrations (mg/kg) and leachate concentrations ($\mu\text{g/L}$). Leachates were prepared using the Toxicity Characteristic Leaching Procedure (TCLP; USEPA Method 1311) at pH 5.

Ziltek's client had previously demonstrated the long-term stability of the RemBind immobilization reaction using the Multiple Extraction Procedure (MEP) based on USEPA Method 1320. This method simulates 1,000 years of stability in acid rain conditions in an improperly designed sanitary landfill situation.

Approval for Safe Disposal

Validation results after treatment with RemBind confirmed that PFAS concentrations in soil leachates had been reduced to the level of reporting (LOR; 0.01 µg/L) in all treated samples.

Based on these results, the local EPA gave written permission for the treated soil to be disposed to a lined landfill with no further remediation or management requirements.

For disposal, a burial pit was prepared in the landfill by laying down a 4-inch layer of pure RemBind in the bottom of a trench as an extra level of risk mitigation. The treated soil was then placed on top of the RemBind liner and capped with a 4-inch layer of pure RemBind.

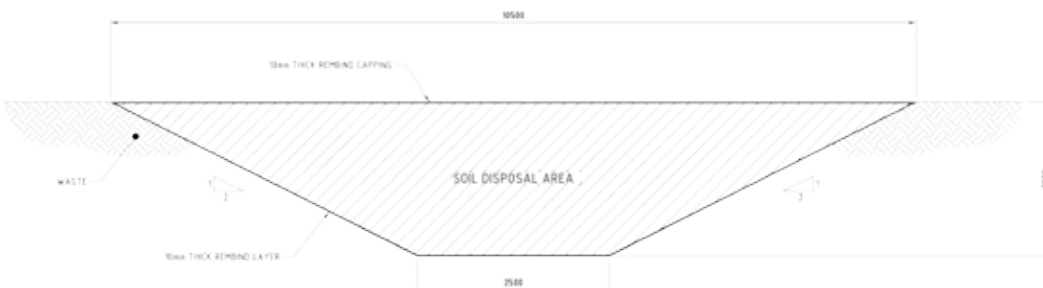
This is the first PFAS soil disposal project of this scale (1,000 tonnes) completed in Australia with EPA regulatory sign-off. This paves the way for the use of RemBind as a rapid, easy and cost-effective remediation strategy for mitigating the impact of PFAS contaminated soil on the environment. With proven long-term stability in a landfill situation, it also opens up the future possibility of re-using immobilized soil on site.



The finished RemBind cap on the burial pit



RemBind bulky bags being loaded



Design of burial pit with a pure RemBind liner and cap (mm)

Soil leachate concentrations of target PFAS compounds following RemBind treatment

	Hotspot 1 (µg/L)*	Hotspot 2 (µg/L)*	Compliance Limit (µg/L)*
PFOS	<0.01	<0.01	0.2
PFOA	<0.01	<0.01	
6:2 Fluorotelomer sulfonate	<0.1	<0.1	
8:2 Fluorotelomer sulfonate	<0.2	<0.2	

*Soil leachate concentrations as measured by TCLP at pH 5

RemBind used to Treat Firefighting Foam Contaminants

Background

An independent study was commissioned by a government airport authority to validate the effectiveness of RemBind to treat Aqueous Film Forming Foam (AFFF) contaminants in soil. AFFF contaminants include perfluorooctane sulfonate (PFOS) which was listed in 2009 as a chemical of major concern by the Stockholm Convention on persistent organic pollutants.

The trial was independently supervised and audited by the environmental consulting company SEMF. This included sealing sample containers, doorways and fume cupboards at the end of each trial day to maintain integrity of the process.

Methodology

PFOS contaminated soil was collected from two different commercial airport sites in Australia and sent to Ziltek's laboratory for processing (designated Soils 1 and 2).

Soils were air-dried, thoroughly mixed and screened in preparation for the treatment trials. RemBind or RemBind Plus was added to the soils at various rates and, after moisture adjustment, treatments were left to cure for 48 hours.

Treated samples (and untreated controls) were sent to an accredited commercial laboratory for leachability testing using ASLP (Australian Standard Leaching Procedure, based on US EPA Method 1311). Selected samples were subjected to the more rigorous Multiple Extraction Procedure (MEP; US EPA Method 1320) to test for longevity of binding.



Preparing soils for RemBind treatment

Results

A summary of the results are presented in Tables 1 to 3 below. Results show that PFOS was reduced by more than 98.5% for soil from both sites. PFOA reductions followed a similar trend. For both soils, RemBind Plus reduced PFOS leachability to below the stringent Minnesota Department of Health drinking water guidelines of 0.3ug/L.

MEP results show that Soil 1 treated with RemBind Plus passed the stringent MEP test which simulates 1,000 years of acid rain in an improperly designed sanitary landfill.

Conclusion

In conclusion, this was a totally independent study that showed that RemBind Plus treatments reduced PFOS leachability by >99.2% to below the Minnesota drinking water guidelines of 0.3ug/L and that this binding was stable longterm as determined by the most stringent soil leachability test available (US EPA Method 1320).

Table 1: Leachability reduction of PFOS and PFOA for Soil 1

Site 1	ASLP Analysis			
	PFOS ug/L	%	PFOA ug/L	%
Untreated Soil	34.15	-	0.65	-
RemBind	0.50	98.5	0.04	93.8
RemBind Plus	0.29	99.2	<0.02	>96.9

Table 2: Leachability reduction of PFOS and PFOA for Soil 2

Site 2	ASLP Analysis			
	PFOS ug/L	%	PFOA ug/L	%
Untreated Soil	376	-	5.51	-
RemBind	1.76	99.5	0.27	95.1
RemBind Plus	0.10	99.9	<0.02	>99.6

Table 3: Multiple Extraction Procedure results for Soil 1 treated with RemBind Plus

Site 1 - RemBind Plus Treatment										
Leach	EP	1	2	3	4	5	6	7	8	9
PFOS ug/L	0.04	0.02	<0.02	<0.02	0.02	<0.02	<0.02	<0.02	<0.02	<0.02

RemBind outperforms granular activated carbon in binding perfluorinated compounds in water

Background

Sensatec GmbH of Germany carried out independent lab-scale trials to test the ability of Ziltek's RemBind Plus versus granular activated carbon (GAC) to treat water contaminated with perfluorinated compounds (PFCs).

Methodology

A column filter was set up using a mixture of 10% quartz sand and 90% RemBind Plus by weight. A second column contained GAC as a comparison.

Firstly, a tracer test using sodium chloride was run to determine hydraulic breakthrough rates and the column pore volume.

Next a water solution with a total PFC concentration of 1.85 mg/L (510 µg/L PFOS) was run through the column with continuous flow to determine breakthrough rates.

Water samples were taken from the column outlet after the following numbers of pore volume exchange: 1, 5, 10, 20, 30, 50, and 100 and analyzed for the PFC compounds perfluorooctane sulfonate (PFOS), perfluorooctanoic acid (PFOA), potassium perfluorobutane sulfonate (PFBS) and Perfluorobutyric acid (PFBA).

Results

From the tracer test with sodium chloride, a flow rate of 3.1 mL per min was determined and the required time for one exchange of pore volume was 54 minutes.

Results in Figures 1 and 2 show that there was minimal breakthrough of all tested compounds after 100 pore volumes of water had passed through the RemBind Plus column. For the GAC column, the smaller PFC compounds PFBS and PFBA broke through immediately after only 1 pore volume.

Conclusion

The binding capacity of RemBind Plus for the smaller chain PFC compounds PFBA and PFBS is superior to that of GAC. This is likely due to the presence of the non-carbon components of RemBind Plus creating unique physicochemical interactions with the smaller chain PFC compounds.



Residual PFC concentration after different column passages - RemBind Plus

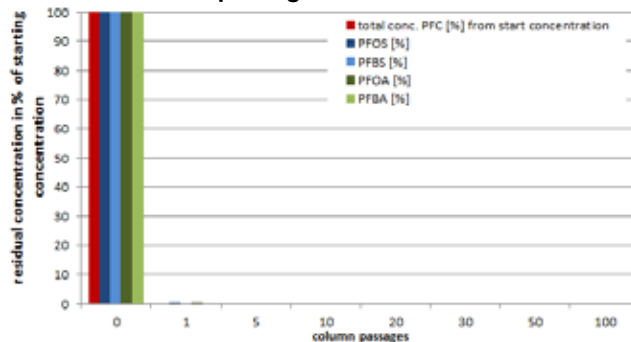


Figure 1: Residual PFC concentrations (% of starting concentration) after 0, 1, 5, 10, 20, 30, 50 and 100 column pore volumes of RemBind Plus.

Residual PFC concentration after different column passages - Activated Carbon

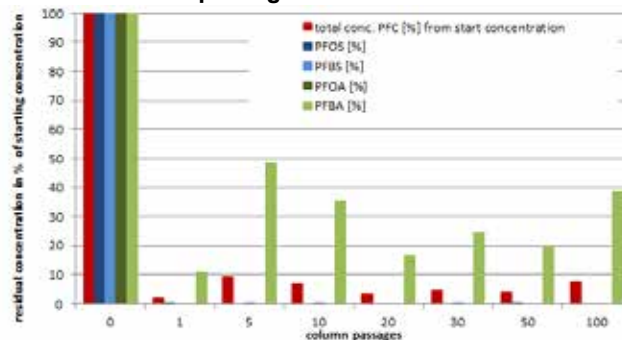


Figure 2: Residual PFC concentrations (% of starting concentration) after 0, 1, 5, 10, 20, 30, 50 and 100 column pore volumes of granular activated carbon.

RemBind used to immobilise PFOS

Perfluorooctane Sulfonate (PFOS) and Perfluorooctanoic Acid (PFOA) are man-made chemicals that are extremely persistent in the environment. In 2009, PFOS was listed as a chemical of concern by the Stockholm Convention on persistent organic pollutants.

These chemicals are common in Aqueous Film Forming Foams (AFFF) used for fire fighting and their manufacture has been restricted or banned in several countries.

Ziltek collected PFOS/PFOA containing soil and groundwater samples from a contaminated site in Australia for treatment feasibility trials.

Ziltek's immobilisation reagent RemBind was mixed at various ratios with the soil and water samples, and after 24 hours the treated samples were sent to an independent accredited laboratory for analysis.

Results show that RemBind reduced the leachability of the PFOS/PFOA compounds by up to >99% thus providing a cost-effective solution for the management of these contaminants.



Soil Treatment Results

	PFOS* µg/L	PFOS % Reduction	PFOA* µg/L	PFOA % Reduction
Control	62.5	-	2.7	-
RemBind	0.39	99%	0.12	95%
RemBind Plus	<0.02	>99%	<0.02	>99%

*Australian Standard Leaching Protocol

Water Treatment Results

	PFOS µg/L	PFOS % Reduction	PFOA µg/L	PFOA % Reduction
Control	8,800	-	398	-
RemBind	74.4	99%	28.8	93%

Chemical Fixation of Greasy Ash Waste using RemBind™

Ziltek was contracted by Flinders University to design a treatment process for the remediation of approximately 500m³ of greasy ash waste. The waste was stored at the Southern Waste ResourceCo (SWR) landfill site and treated within the specialised undercover waste soil treatment facility located in McLaren Vale, South Australia.

The waste contained grease and soda ash and was classified as exceeding Low Level Contaminated Waste (LLCW) due to the presence of Total Petroleum Hydrocarbons (TPH) at concentrations well above the maximum disposal threshold of 10,000 mg/kg.

Previous efforts to reduce TPH concentrations below LLCW criteria using bioremediation methods proved to be unsuccessful due to the high salt and alkaline characteristics of the soda ash for this project.

Ziltek recommended a chemical fixation reagent RemBind to bind the TPH in the waste to prevent leaching. RemBind contains an activated carbon component which binds strongly to organic contaminants including TPH and Poly Aromatic Hydrocarbons (PAH).

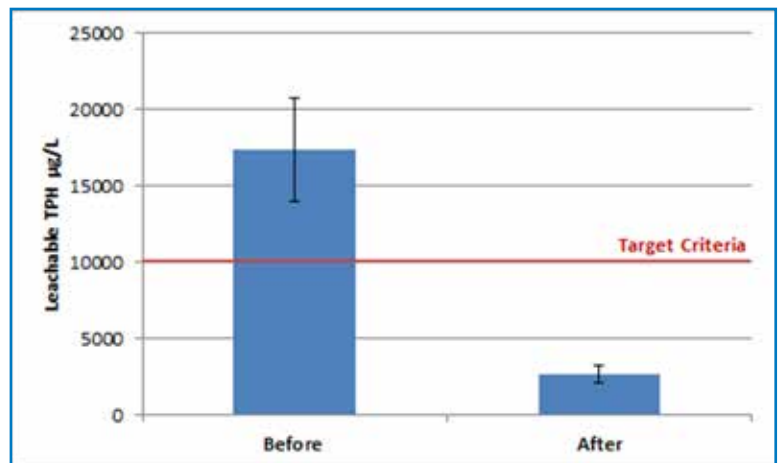
Based on a review of fresh and marine water guidelines and New South Wales service station guidelines, Ziltek derived a TPH leachability criteria of 10mg/L which was subsequently accepted by the South Australian EPA.

Full-scale treatment involved a single pass addition of RemBind. Treated samples were sent to a NATA-accredited laboratory for independent validation. All samples returned leachable TPH concentrations below the target criteria and the soil was appropriately disposed to landfill.

“The RemBind product provided a practical solution for the effective treatment of greasy ash waste and achieved the desired treatment outcome for the appropriate disposal of the waste to landfill.

Use of the RemBind product provided SWR an alternative treatment methodology to that of bioremediation to manage this uncommon waste stream”.

Wayne Freer - Group Operations Manager
Southern Waste ResourceCo



Chemical Fixation of Contaminated Soil from Gasworks Site

A former gas works site located at Mead St, Birkenhead in South Australia, contained around 2,000 tonnes of PAH-contaminated soils that required off-site treatment and disposal.

Ziltek's product RemBind was used to immobilise the PAH contaminants to allow for safe disposal.

McMahon Services provided specialist soil mixing equipment and the treatment was conducted at a purpose built treatment shed located at the Integrated Waste Services landfill site in Dublin, South Australia.

The treatment process involved adding RemBind and a solidification agent at 5% by weight. A single pass reduced the leachability of the PAHs and BaP to below the landfill criteria for Low level Contaminated Waste (LLCW) to allow the safe disposal of the treated soil.



Soil Treatment Results

Leachability (mg/L TCLP)	Before Treatment	After Treatment (5% w/w)
B(a)P	0.0083	0.0013
Total PAH	4.435	0.0351

In addition, the treated soil passed the Multiple Extraction Procedure (MEP) which is recognised as one of the world's most stringent soil leachability test. The test simulates the worst case leaching scenario - 100 years of acid rain in an unlined sanitary landfill.

Overall, the project took out a prestigious National prize at the Civil Contractors Federation (CCF) Earth Awards in 2011. The award recognised Ziltek and project partners McMahon Services and Integrated Waste Services for expert management of high-level contaminated soils.



Managing Leachable Arsenic for Sustainable On-Site Retention

A former rail yard site in South Australia was required to be developed into a new public transport hub by the Department of Planning, Transport and Infrastructure (DPTI). The site hosted rail platforms within which was 4,500 m³ of soil with elevated concentrations of arsenic resulting from historical rail operations.

Although, the concentrations of arsenic did not exceed tier 1 human health soil screening criteria for commercial/industrial land use, they significantly exceeded waste soil classification criteria, and arsenic was significantly leachable in a proportion of the material.

The cost to remove the soil via the traditional dig and dump approach was calculated as in excess of \$1.75 million AUD. Retention of the leachable soil on-site would have presented an unacceptable long term risk to groundwater.

An alternative approach/scope was developed by Land and Water Consulting which involved cut and fill balancing of site materials coupled with selective treatment of leachable material to enable on site retention.

This involved the removal and on site storage of impacted soils prior to treatment. Excess clean materials were removed and re-used as fill at a non-sensitive site. The leachable soils were isolated and treated on site using the proprietary immobilization agent RemBind.

Bench scale tests, using US EPA Methods 1311 and 1320, showed that treatment with RemBind resulted in a 96% reduction in leachable arsenic compared to untreated soil.

A total of 1,600 tonnes of impacted soil was treated with RemBind. Initial levels of arsenic leachability as high as 2,700 mg/L were reduced to <5 mg/L after treatment with RemBind. I.e. 99% reduction.

All treated soil was reused on site under Level 1 supervision, creating a new development platform for the transport hub. The approach saved DPTI \$1.1 million AUD and avoided more than 700 truck movements, minimising the carbon footprint. The land is now suitable for use as a bus depot.





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