



# Application and Management Instructions



## PetroFix Quick Reference Table

The following table is a quick reference guidance providing only the most relevant information. Review this entire document carefully, plus the product Safety Data Sheet, prior to any application. Please contact REGENESIS Technical Support if you need any further assistance.

<b>Viable application methods</b>	Direct push, In wells, In excavation.
<b>Typical dilution factor</b>	1:10 (exact dilution to be discussed with REGENESIS). 1 kg of concentrate PetroFix in 10 litres of wate.
<b>Mixing activities</b>	Homogenize concentrated product before transferring. Transfer concentrated product to tank already filled with water. Pour Electron Acceptors only after complete homogenization.
<b>Recommended injection pump</b>	Diaphragm pump.
<b>Recommended Injection pressure</b>	Low pressure injection. Typically 1-4 bar. DO NOT over-pressure the target matrix and DO NOT fracture. Adjust pressure using pressure regulator. Take note of pressure and flow rate for each step.
<b>Direct push injection</b>	Use a retractable screen tip; avoid pressure activated tip.
<b>In well application</b>	Low pressure injection; DO NOT gravity feed. Use single or double packer. Flush well with clean water after application.
<b>Excavation application</b>	Can be spray-applied or with an excavator.
<b>Other recommendations</b>	Always wash and flush with clean water. Seal injection direct push points after injection. Do not operate P&T or other activities likely to disturb groundwater in surrounding area during and after injection.
<b>Cleaning activities</b>	Black activated carbon suspension may remain in groundwater for weeks to few months. Cleaning and flushing of surrounding wells is recommended immediately after injection. Additional cleaning/purging/precipitation activities may be needed in injection and surrounding wells weeks after application. <a href="#">More info on well flushing.</a>
<b>Verification activities</b>	During the injection activities, onsite verification of PetroFix distribution is a priority. Use PetroFix verification toolkit on all surrounding wells. Allow for soil coring and/or direct push water sampling when possible.
<b>Recommended monitoring</b>	Wait for PetroFix settlement before starting sampling (groundwater back transparent): this can take weeks or few months. <a href="#">More info on representativity of samples and how to analyse samples containing PetroFix residues in suspension.</a> Consider cleaning/well flushing activities where needed. Typically monthly monitoring after observing clear well water. Results are to be expected quickly, but allow for at least 3-6 months. Parameters: contaminants of concern. Supporting evidence: nitrates, sulphates, methane. No major changes to be expected in physical-chemical parameters (pH, redox, O <sub>2</sub> , electrical conductivity). <a href="#">More info on monitoring parameters.</a>

## PetroFix Remediation Fluid

PetroFix<sup>™</sup> comprises a high-concentration water-based suspension of micron-scale activated carbon and biostimulating Electron Acceptor Blend (EAB). Once appropriately diluted, PetroFix can be mixed in soils, within excavations, or injected into the subsurface via direct push drilling or fixed wells.

PetroFix Safety Data Sheets will be supplied with all delivered products. These should be read and understood prior to PetroFix handling. It is assumed that the user is appropriately trained and competent and will have completed a comprehensive, site-specific health, safety & environmental risk assessment for the works they intend to carry out.

## Pre-Application Guidance

PetroFix is usually shipped in **181.4kg (155L)** drums, the EAB is supplied in separate, small tubs. PetroFix is generally delivered to site on pallets via a heavy goods vehicle. Please discuss any site access restrictions with REGENESIS, so an appropriately-sized delivery vehicle is used.

Prior to PetroFix application via direct push or wells, REGENESIS recommends completing a pre-application test injection across the target horizon, using clean water. This procedure is useful to determine the quantity of liquid the target zone is able to accept and will provide valuable flow rate and pressure information. REGENESIS recommends the injection test volume of water is in the range of 15-20% greater than the single-point design volume e.g. if the design specifies a PetroFix volume of 500L per point then the water test injection should aim for 575–600L.



PetroFix is usually shipped in 181.4kg (155L) drums

## Mixing Instructions

The PetroFix concentrate should be thoroughly mixed within the delivered container prior to dilution. If supplied in drums, we would recommend using a hand-held paddle mixer to mix the product. Please note the EAB should only be added once the product has been diluted with water, and should not be added directly to the PetroFix concentrate. Ensure the mixer makes contact with the bottom of the container to adequately disturb any settled product, particularly in cold conditions.

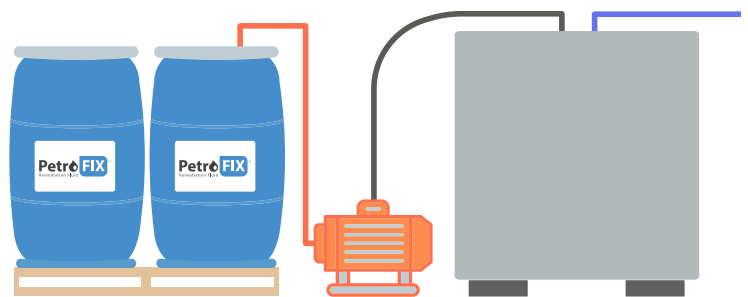
The required quantity of PetroFix, the dilution ratio and dose per point will be specified by REGENESIS at the design stage. The PetroFix should be mixed in an appropriately sized tank, preferably conical or flat bottomed to aid mixing. Mixing can be achieved using a high flow pump via recirculation or mechanically using a paddle mixer.

First, the required volume of water should be added to the mixing tank. Engage the mixing mechanism prior to adding the PetroFix concentrate. PetroFix concentrate is a relatively thick mixture (1500-3500cP) and a drum pump or similar capable of transferring thick substances should therefore be used. Once the required quantity of PetroFix has been added to and mixed with the water in the mixing tank, the EAB should be added to the diluted PetroFix at ratio of one EAB container to one container of PetroFix concentrate. Ensure the liquid is mixed thoroughly so the EAB dissolves fully.

A diaphragm pump, capable of producing a flow rate in the range of 10-40L/minute and 2-6 bar pressure would be suitable for application of PetroFix.



Homogenization of PetroFix using a hand-held paddle mixer



The image shows an example of PetroFix transfer and mixing setup

## Direct Push Application

PetroFix only requires one application per injection location, and therefore direct push is generally the preferred application option (assuming suitable geological conditions) due to lower project costs. REGENESIS would recommend use of retractable screened tips rather than pressure activated tips to facilitate ease of injection. The injection rods should be advanced to the target depth and the PetroFix injected, while note is taken of the flow rate and pressure. Once the requisite volume has been applied evenly over the target horizon, clean water should be used to flush through the pump, hoses and injection tip to ensure all PetroFix has been displaced into the target formation.

Once the point has been completed the injection hole should be sealed with bentonite or cement. The purpose of this effort is to seal off any potential pathways to the surface which may allow “daylighting” (upflow) of injected PetroFix and/or groundwater. If the PetroFix application is based on a grid design, the application should be performed by systematically working from the outside to the centre of the injection array to minimise local pressurisation of the groundwater. Where possible, a suitable distance should be maintained between consecutive injection locations to avoid overloading the formation with injected product (e.g. inject at every 3<sup>rd</sup> point in a barrier).



Direct push injection



Retractable screen tip

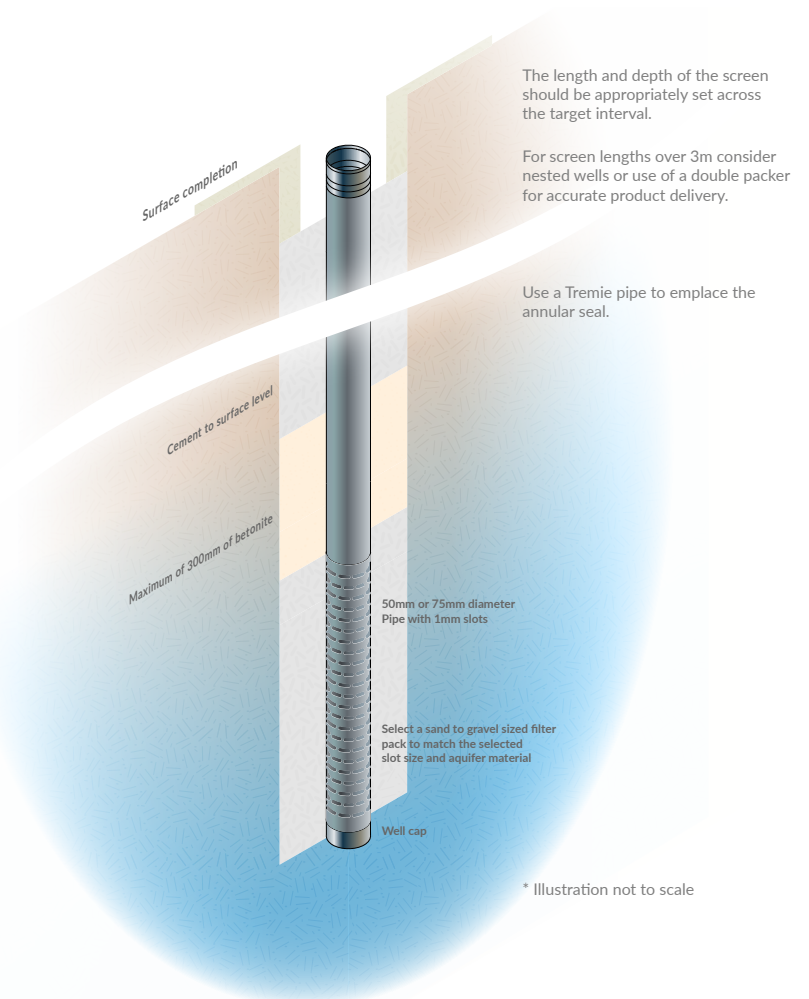
## Well Application

PetroFix can be injected via fixed injection wells where direct push is not considered practical. REGENESIS recommends that injection wells should generally be constructed using  $\geq 50\text{mm}$  diameter HDPE with a slot size in the range of 0.5-1.0 mm. Where possible, the well seal above the slotted section should consist of a maximum of 300mm of bentonite pellets, above which a sand & cement mix should be applied to seal to the surface.

Prior to injection of any remedial reagent, REGENESIS recommends that the injection wells be purged of fine-grained particles present in the well bore to the extent practicable.

When wells are used for PetroFix injection, the injection wells and nearby groundwater monitoring wells should be either tightly capped or alternatively equipped with a pressure gauge and relief valve. This will reduce potential for short circuiting to the surface.

Once the requisite volume has been applied to the well, clean water should be used to flush through the pump, hoses and well to ensure all PetroFix has been displaced into the target formation.



Injection well construction diagram

## Excavation Application



Example of a PetroFix application in an excavation

The diluted PetroFix mixture can be applied directly to excavation sides and base using a high-volume pump. Application should be targeted at areas of the excavation where full excavation of contaminated soils was not possible or there is concern for contamination rebound. Application can be coincided with excavation backfill to achieve good PetroFix distribution on excavation sidewalls. Alternatively, PetroFix can be mixed in the base of the excavation mechanically using an excavator attachment such as a rotary tool, auger, or toothed bucket.

**Remediation products should not be applied by hand from within the excavation unless this has been specifically assessed by the user as a safe method.**

REGENESIS would advise that all equipment is flushed through with clean water at the end of each working day and on completion of the injection works.

## Radius of Influence Testing

Where PetroFix has been applied via direct push or wells, visual verification of its distribution in the subsurface can typically be completed easily onsite, due to its black colour.

Prior to the injection works commencing, take a baseline soil core covering the target injection depth. This is best done on the outer edge of the injection zone. Backfill the point with bentonite and cement so this does not become a preferential pathway to the surface during the injection works.

The baseline core is taken so subsequent confirmatory cores can be compared to this for the presence of PetroFix. This is particularly useful in areas where the soil is dark in colour or there is heavy hydrocarbon staining. Start the injection work as described above. After 2-3 points have been applied with PetroFix, take a confirmatory soil core over the target depth, halfway between two adjacent points. A black colour should be seen coating the permeable zones of the aquifer. If a black coating is observed, then you have the desired radius of influence and can continue with the injection. We would ideally recommend taking a core intermittently through the injection works to check the distribution of PetroFix.

If a black coating on a core is not observed check the following and discuss with your REGENESIS contact:

1. Did the geology in the baseline and confirmatory cores match what was expected to be found onsite?
2. The injection pressure and flow rate – is the pressure and flow steady? Does it vary with depth? Consider increasing the injection pressure.
3. Is daylighting from the point of injection (or nearby) being observed?
4. Check injection point spacing – does it match the design?
5. Check the amount of PetroFix concentrate used and the amount of dilution water – does it match the design?
6. What injection tip is being used – is it providing even distribution?
7. Has black coloured water been observed in nearby monitoring wells?



The photo on the top shows a soil core collected before a PetroFix application. The photo below shows a soil core collected after a PetroFix application exhibiting black soil where the PetroFix was successfully distributed



## Well flushing information

PetroFix is injected using low pressure and high volume to minimize hydraulic fracturing and preferential channeling of the product into wells, infrastructure corridors, etc. However, as PetroFix flows in the same channels that contain groundwater contamination, it is common to observe PetroFix in monitoring wells as it flows through and past that well. This is true of all liquid remedial amendments and in the case of PetroFix is easily resolved, if needed, by performing a Clean Water Monitoring Well Flushing Event. If monitoring well impact is a concern, then the remediation practitioner should be prepared to conduct clean water flushing events on monitoring wells at the end of a PetroFix application. The following sections outline this process.

## Triggers for Clean Water Monitoring Well Flushing Events

The conditions that trigger the possible need to perform a clean water flush in a monitoring well include:

1. PetroFix was applied in application points within 1.5m of a monitoring well (potential zone of direct influence); and/or,
2. Visual evidence of PetroFix is observed in a monitoring well prior to the end of the workday or end of the injection event.

Because PetroFix turns the aquifer black as it distributes it acts as its own tracer. We recommend taking a baseline sample and observing groundwater colour before PetroFix injections. If no visible PetroFix is observed in a well at the end of the injection works (compared to baseline) or no more than a light grey colour is observed, then a monitoring well flush is not needed.

If you do observe PetroFix in wells, we do recommend flushing impacted wells. If you do not flush PetroFix from wells, the product will eventually fully drop out of groundwater and the groundwater itself will clear after a few weeks to a few months (e.g. turning to background colours versus grey or black). In some cases, this process can happen more slowly compared to what is observed on average, making sampling activities potentially more difficult. More information on this is provided in the section "[PetroFix Groundwater Sampling Information](#)".

When the need for a PetroFix flushing event is triggered for a specific well first complete all injection locations before proceeding with flushing operations. It is advisable to perform flushing operations at the end of all field activities if any event triggers are experienced.

## Performing a Clean Water Flushing Event

Determine the volume of flush water and pumping rate to be used for each monitoring well. We recommend contacting REGENESIS Technical Support for an estimate of volume of clean water to be used. As an alternative, it is possible to use as a support tool the following equation, that provides the minimum volume of water to be considered for flushing:

$$V_{min} = 3[V_{int} + V_{drain}]$$

$$V_{int} = \pi \times r_{int}^2 \times L_{fen}$$

$$V_{drain} = \pi \times (r_{drain}^2 - r_{int}^2) \times L_{drain} \times n_{ed}$$

Where:

$V_{min}$  = Minimum recommended flushing volume [m<sup>3</sup>]

$V_{int}$  = Internal volume of the well, considering only the screened section [m<sup>3</sup>]

$V_{drain}$  = Volume of sand pack along the section in which it is present (an effective porosity  $n_e$  of the sand pack  $n_{ed}$  is considered to be equal to 35%) [m<sup>3</sup>]

$R_{int}$  = Internal radius of the well [m]

$R_{drain}$  = External radius of the well (drilling radius) [m]

$L_{fen}$  = Length of screened layer [m]

$L_{tot}$  = Length of the layer in which the sand pack is present [m]

If you require support, or if some of the data above is not available, please contact REGENESIS Technical Support.

Please note that the calculated amount of flush water is a good, calculated starting point for the minimum volume needed, and will need to be adjusted based on field evidence and on the effects obtained during the procedures outlined below.

Connect the clean water supply to the monitoring well with a closed system using a compression coupling, a threaded connection (if available) or an inflatable packer. Alternatively, applying water through the open top of the monitoring well via gravity feed is acceptable (but this should be considered the last option in case all other methods are not available).

For the closed water system, monitor the water pressure and flow rate constantly. Do not exceed 1.5 bar for clean water flushing into monitoring wells (MWs). Document the water flushing procedure used on each well including rate at which each MW accepts the clean water and closed system pressures over the course of the flushing event.

It is recommended to collect and photo document colour of water from monitoring well at the following intervals, for undiluted sample and samples diluted using a 10x and 100x dilution factor:

Monitoring Well:	Undiluted sample	10x dilution	100x dilution
Prior to PetroFix Injection (baseline)		NA	NA
Post PetroFix Injection			
Right after flush			
15-30 minutes after flush			
The following work day or end of injection			

10x dilution = 1 ml undiluted sample into 9 ml clear water

100x dilution = 1 ml of 10x diluted water into 9 ml clear water

After completing the clean water flushing event and corresponding sampling events in each well, close well with a torque well plug, J-plug or similar water-tight well cap.

## Groundwater sampling information

### PetroFix In Monitoring Wells Post Injection

During injection, PetroFix may flow into nearby monitoring wells, as evidenced by sampling the well and finding the water colour to be black. This occurrence is common and is simply the result of the PetroFix material transporting through the natural flux zones of the aquifer. To ensure that PetroFix in monitoring wells doesn't interfere with commercial analytical methods, several things can be done. This section describes the best practices for analysis of PetroFix-impacted water in monitoring wells.

## What should be done?

If a well is impacted, the best solution is to delay sampling and analysis until PetroFix has had more time to deposit onto the soil which will result in clarified groundwater samples. At many sites, two to four weeks is enough, although it can take up to three months or more. The time to equilibrate in the subsurface is correlated with soil clay and silt content. In general, a high clay and silt content will decrease the time for PetroFix to sorb and equilibrate. Divalent cations (e.g. calcium or magnesium) in groundwater also speed up the clarification process.

If PetroFix is observed in a groundwater well during application, the well can be flushed with clear water (i.e. no reagent). More information on a clear water well flush can be found in the paragraph "[PetroFix Well Flushing Information](#)". If sampling at least four weeks post-PetroFix application, extended low-flow purging of the monitoring well may improve the water clarity.

As a rule of thumb, if a sample is placed in a 40-mL glass vial and you can see through the vial it is probably safe to sample. The inability to effectively see through a vial is approximately 100 mg/L of PetroFix (see image of various PetroFix concentrations below for reference). Regenesis does provide simple in-field PetroFix testing kits that can be used to measure in-well concentrations to assess whether a sample should be sent to a lab or if sampling should be delayed. This test kit has a pre-made 50 mg/L standard used to estimate your groundwater concentrations. Plotting concentrations over time might provide some sense on when your site might reach a suitable condition to sample. Please contact Regenesis Technical Support or [europa@regenesis.com](mailto:europa@regenesis.com) to obtain a test kit.

If you are interested in independent research on showing if and when suspended carbon from PlumeStop (or PetroFix since they are the same form of carbon) interferes with laboratory samples, please view the webinar entitled "[Remediation of Chlorinated Solvents in Groundwater with PlumeStop: Analytical Challenges and Solutions](#)" which was given by Heather Lord, PhD, the Environmental Research and Development Manager for Maxxam Labs. Starting at roughly 15 minutes the presenter begins discussing the ranges up to where PlumeStop (or PetroFix) does not cause significant lab interference (roughly 100 mg/L) and positive results from passive diffusion bag samplers.

Passive diffusion bag (PDB) samplers can be used to sample groundwater where PetroFix is present. The PetroFix cannot diffuse through these bags so the groundwater collected will be free of PetroFix. More information on PDB samplers is discussed in the next section.

Unfortunately, there are no commercial laboratory prep procedures that can easily remove PetroFix from samples prior to analysis without deviating from standard methods. Filtering the 1 to 2 micrometer diameter particles from suspension is possible, although difficult and not always an accepted approach by every regulatory agency.



While centrifuging is an option, commercial labs typically do not have one with the necessary centrifugal force to effectively separate PetroFix. If you need further technical assistance addressing interference of PetroFix when sampling, please contact Regenesys Technical Support or [europe@regenesys.com](mailto:europe@regenesys.com).

### **Passive Diffusion Bags and PetroFix Sampling**

The big advantage of PDBs is confidence that you can sample groundwater for VOCs at any time post injection based on your desired sampling time frames and without interference from any suspended PetroFix. Furthermore, PDB sampling is considered a cost-effective and a viable alternative to standard or low-flow purge and sample techniques for collecting volatile organic compound (VOC) data at monitoring wells. The majority of sites won't need PDBs, particularly if you plan to sample a 3 months or more post PetroFix injection. However, if there is any concern about potential sampling delays because of suspended PetroFix in a well, then we recommend that you consider using PDBs.

PDB samplers, which are typically low-density polyethylene bags filled with water, have been shown in multiple studies to provide accurate groundwater VOC measurements. These bags come in 30 to 120 cm lengths and are filled with clean water and hung into a well for a minimum of two weeks. PDB sampling is achieved as VOCs in groundwater diffuse through the wall of the bag and into the bag water, which eventually comes to equilibrium with the surrounding well water. Because the solid, colloidal activated carbon particles from PetroFix cannot penetrate bag, they are excluded from the PDB water and do not interfere with this sampling technique. Regulatory agencies might ask you to compare PDB's to normal groundwater samples (i.e. low-flow sampling or bailing) to prove that they correlate. With this in mind, we recommend you take baseline samples alongside PDB samples prior to any PetroFix application where time-critical monitoring will begin shortly afterwards.

To get accurate groundwater VOC values that compare to past or present results it is critical to hang a PDB from the same vertical sampling interval in a monitoring well used from other sampling efforts. This is because groundwater contamination can stratify in an aquifer and a plume may have different vertical groundwater concentrations intersecting a monitoring well screen and those difference can be detected by PDBs hanging in a well. This phenomenon also is true for common low-flow sampling. For example, at a hydrocarbon site it is common for higher groundwater concentrations to be present in the aquifer near the surface of the aquifer where the smear zone resides versus at the bottom of a well where it is not likely present. However, multiple studies do show that when PDBs are hung in the same zone that you normally collect standard or low-flow purge and sample techniques they will correlate and provide accurate VOC concentrations.

Please note PDBs are not suitable for monitoring certain organic (MTBE, TBA) or ionic (nitrate, sulfate) species. These parameters should be measured using normal sampling techniques after the PetroFix suspension has mostly clarified from groundwater. The ITRC FAQ document linked below provides a list of compounds showing good correlation in laboratory tests.

We recommend you become familiar with available resources on PDBs (in particular the first ITRC FAQ listed below) and guidelines from the suppliers of PDBs. Here are some helpful links:

### **PDB Guidance Documents**

ITRC FAQ On PDBs And List Of VOC's Showing Good Sample Correlation: <https://www.itrcweb.org/Documents/PDBFAQs2.pdf>

Users Guide for Polyethylene-Based PDBs: <https://www.itrcweb.org/GuidanceDocuments/DSP-1a.pdf>

USEPA Clu-In.org guidance on Diffusion Samplers: [https://clu-in.org/characterization/technologies/default.focus/sec/Passive\\_\(no\\_purge\)\\_Samplers/cat/Diffusion\\_Samplers/](https://clu-in.org/characterization/technologies/default.focus/sec/Passive_(no_purge)_Samplers/cat/Diffusion_Samplers/)

### **PDB Suppliers**

To our knowledge, no suppliers/distributors are currently present in Europe. Here is a list of US suppliers:

ALS: <https://www.alsglobal.com/en-us/services-and-products/environmental/sampling/passive-diffusion-bags-pdb>

EON Products Incorporated: <https://store.eonpro.com/store/c/71-Water-Sampling-Pumping.aspx>

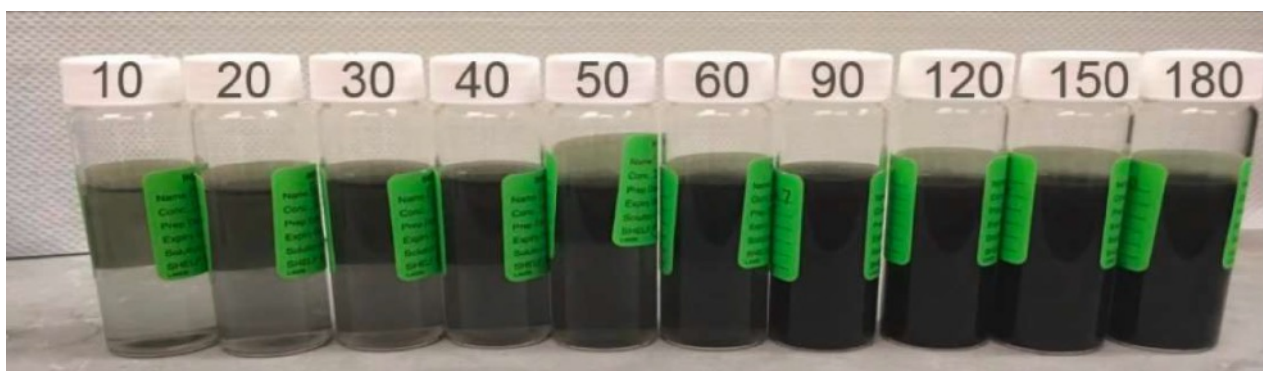


Figure 1 - PetroFix concentrations in 40 mL VOA vials. If a vial can be seen through (< 100 mg/L), it is safe to sample and send to the lab.

## PetroFix Performance Monitoring Parameters

### Analytical Parameters

#### *Recommended:*

- Contaminants of Concern (COC's)
- pH
- Dissolved Oxygen (DO)
- Oxidation Reduction Potential (ORP)
- Methane and CO<sub>2</sub>
- Sulfate
- Nitrate
- Visual Confirmation of PetroFix in Wells\*

#### *Optional:*

- Total Fe
- Total Mn
- Dissolved Fe
- Dissolved Mn
- Sulfide
- Chemical Oxygen Demand (COD)
- Biological Oxygen Demand (BOD)
- Evaluation of biodegradation response through measurement of functional genes

REGENESIS recommends that baseline samples of all monitoring parameters be taken before injection. Please check any local- or country specific regulation or guidelines for parameters that may also need to be collected, that are not included in this table.

\*As is normal in any injection PetroFix may flow into adjacent wells during application. Observation in wells is helpful in knowing that you are achieving product distribution. As an option, PetroFix can be flushed from wells post injection with a clearwater flush. PetroFix normally takes a few weeks/months to attach to soils and clarify from groundwater and sampling precautions should be taken if sampling is needed during the attachment phase. Please refer to Flushing Well Information and Groundwater Sampling Information sections for more details.