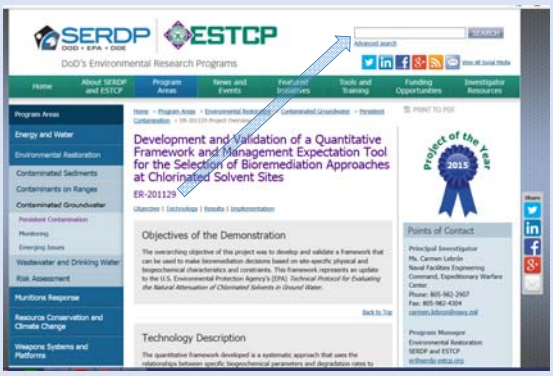
Data Needs for Effective Application of MNA and In-Situ Bioremediation Featuring *Framework to Apply Novel Molecular and Other Screening Tools for MNA Evaluations*

John Wilson, Principal Scientist,
Scissortail Environmental Solutions, LLC, Ada, OK
john@scissortailenv.com

FRTR General Meeting
USGS Headquarters, Reston, Virginia
November 2, 2016

1



https://www.serdp-estcp.org/Program-Areas/Environmental-Restoration/Contaminated-Groundwater/Persistent-Contamination/ER-201129/ER-201129

2

Products

Cost and Performance Report (Posted 01/16) Final Report (Posted 12/15)
Model/Software - BioPic Tool Guidance Document - BioPic Tool
Blog Post (01/19/2016) Blog Post (12/07/2015)
Webinar Series (03/19/2015)

You want the BioPIC Tool. Section 5 of the Final Report provides guidance of using a model to extract rate constants for biodegradation, and gives more detail than is provided in the decision criteria and help buttons of the BioPIC tool.

3

ESTCP Project ER-201129

Carmen A. Lebrón
Independent Consultant

Dr. John T. Wilson
Scissortail Environmental Solutions, LLC

T. Wiedemeier
Wiedemeier & Associates

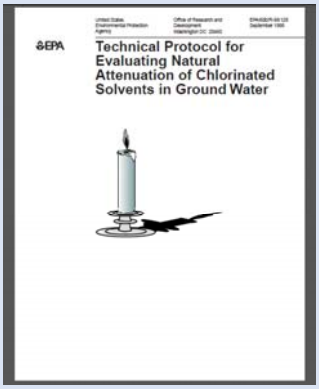
Dr. Frank Löffler
University of Tennessee

Yi Yang
Research Assistant UTK

Mike Singletary
NAVFAC SE

Dr. Rob Hinchee
Integrated Science & Technology, Inc.

4



EPA/600/R-98/128 September 1998

5

Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites

U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Directive 9200.4-17P

6

(1) Historical groundwater and/or soil chemistry data that demonstrate a clear and meaningful trend of decreasing **contaminant mass and/or concentration** over time at appropriate monitoring or sampling points.

(In the case of a groundwater plume, decreasing concentrations should not be solely the result of plume migration. In the case of inorganic contaminants, the primary attenuating mechanism should also be understood.)

7

(2) Hydrogeologic and geochemical data that can be used to demonstrate indirectly the type(s) of natural attenuation processes active at the site, and the rate at which such processes will reduce contaminant concentrations to required levels. For example, characterization data may be used to quantify the rates of contaminant sorption, dilution, or volatilization, or to demonstrate and quantify the **rates of biological degradation processes** occurring at the site.

8

Unless EPA or the overseeing regulatory authority determines that historical data (Number 1 above) are of sufficient quality and duration to support a decision to use MNA, data characterizing the nature and rates of natural attenuation processes at the site (Number 2 above) should be provided.

9

Is the entire plume required to meet the goal?

If so, at what date must concentrations in the plume meet the cleanup level?

The performance depends on the success of source treatment, and the kinetics of natural attenuation of the source.

These processes can **not** be evaluated or understood using Compound Specific Isotope Analysis (CSIA) or Molecular Biological Tools (MBT).

10

How far can the plume be allowed to extend?

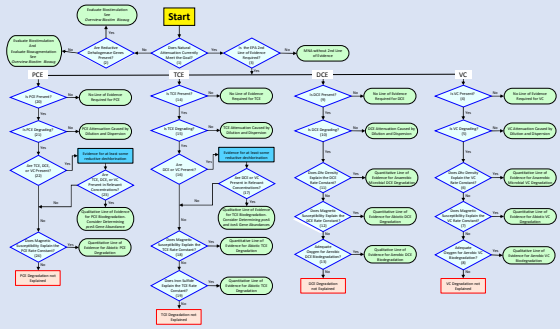
Will the rate of attenuation bring the highest concentrations in groundwater to acceptable concentrations before the groundwater reaches the receptor of the sentry well?

Evaluated by extracting a rate constant from field data for the rate of degradation necessary to meet the goal.

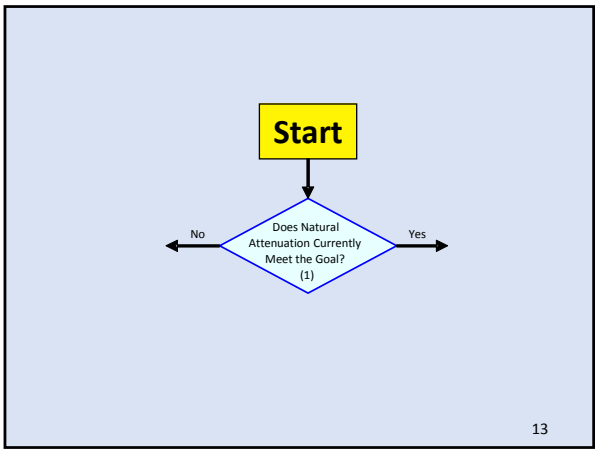
Compound Specific Isotope Analysis (CSIA) or Molecular Biological Tools (MBT) can provide a second line evidence to support a site conceptual model.

11

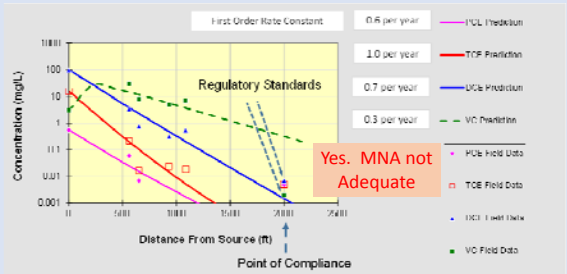
The decision logic in BioPIC



12

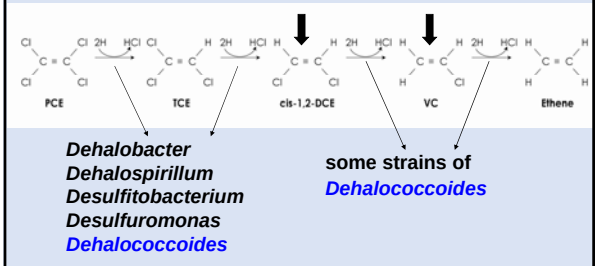


Use a computer model to project the previous behavior of the contamination forward in space and time.
Will contaminants in the plume extend past the point of compliance at unacceptable concentrations?



Microbiology of Reductive Dechlorination of Chloroethenes

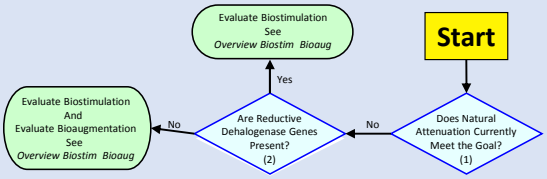
Can accumulate if requisite bacteria are not present



Dehalobacter
Dehalospirillum
Desulfitobacterium
Desulfuromonas
Dehalococcoides

some strains of *Dehalococcoides*

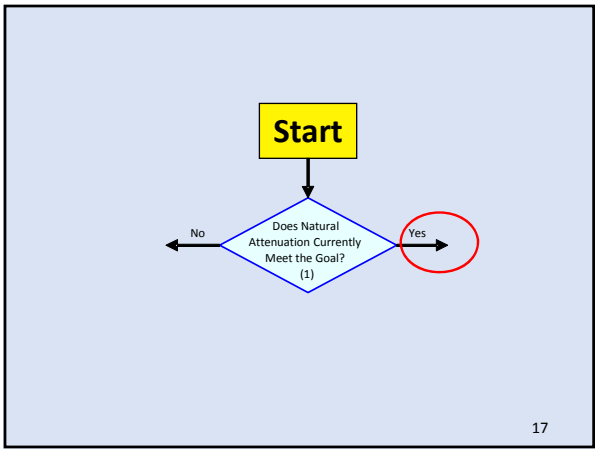
15



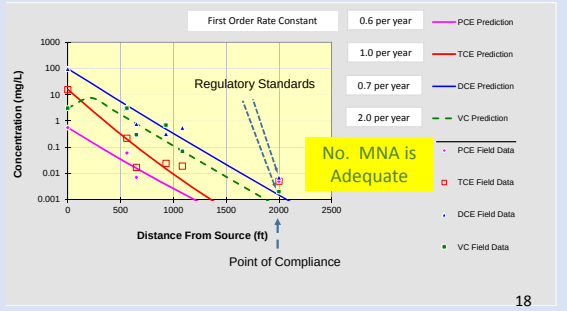
Assays based on the Quantitative Polymerase Chain Reaction (qPCR) are used to identify the presence of organisms with genes that can degrade chlorinatred alkenes to harmless end products.

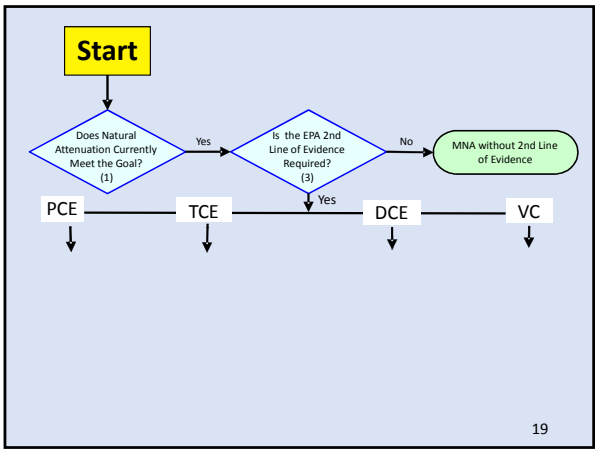
If the density of the pceA, tceA, bvcA, or vcrA genes are greater than 1000 gene copies per liter of groundwater, that gene is considered to be present.

16

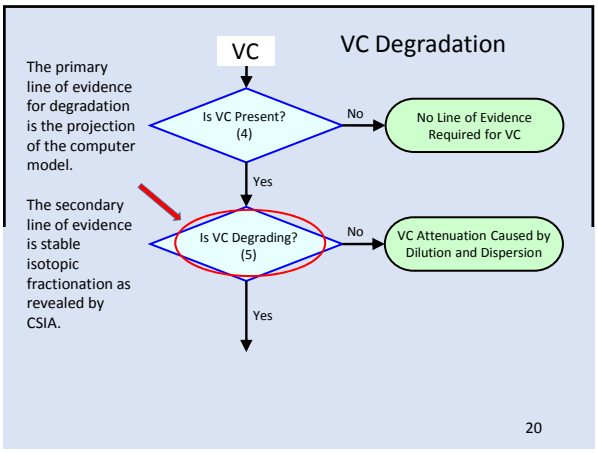


Use a computer model to project the previous behavior of the contamination forward in space and time.
Will contaminants in the plume extend past the point of compliance at unacceptable concentrations?



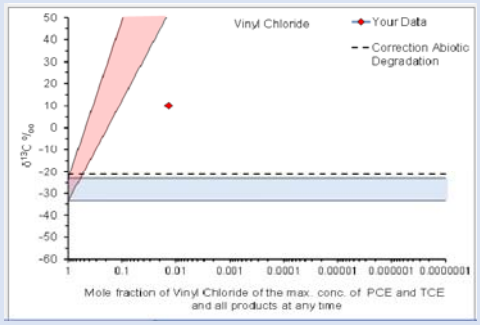


19

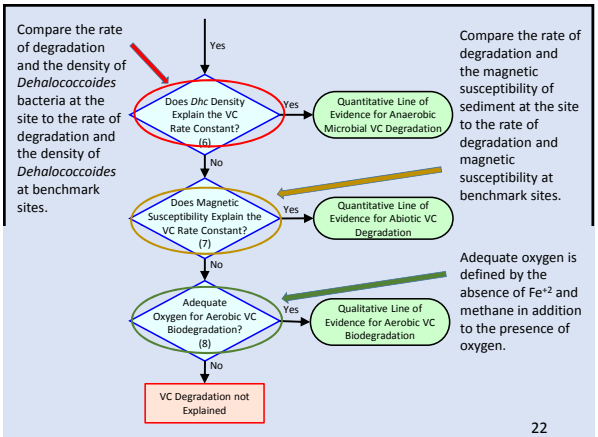


20

The secondary line of evidence is stable isotopic fractionation as revealed by CSIA.



21

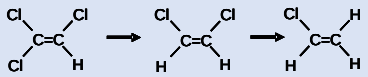


22

Carried out by Biological Reductive Dechlorination

Sequential Reductive Dechlorination

also called Hydrogenolysis



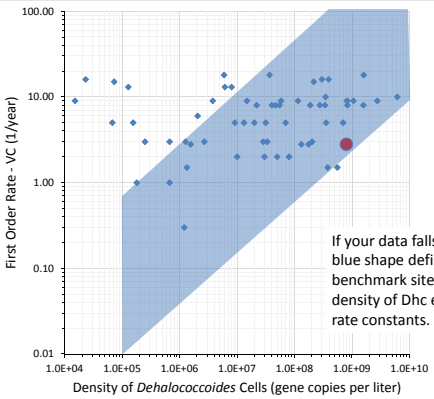
23

Can biotic degradation by *Dehalococcoides* bacteria explain the field-scale rate constant for degradation?

	Overwrite Input Cells with Data Specific to Your Site			
	Input			
	First order rate constant for degradation per year			pCR Assay Gene Copies per Liter
TCE			*Dehaloccoides* 16sRNA	8.00E+08
cis-DCE	2.5			
Vinyl Chloride	2.8			

Excel Spreadsheet ***Dhc explain rates.xlsx***.

24



25

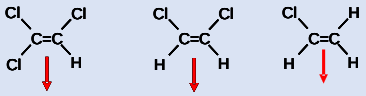
Magnetite ($FeO.Fe_2O_3$) often occurs naturally in sediments formed by weathering of igneous or metamorphic rock.

Magnetite can also be produced in situ by iron-reducing bacteria.

26

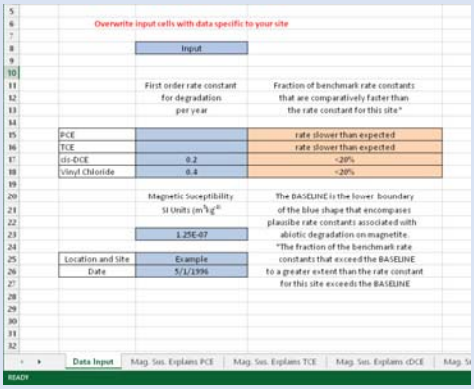
Magnetite can degrade TCE or *cis*-DCE or Vinyl Chloride to oxidized products under either aerobic or anaerobic conditions.

If the TCE or *cis*-DCE is degraded by magnetite, there is no production of Vinyl Chloride.

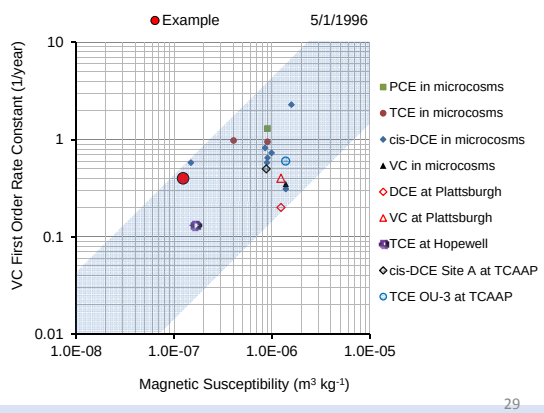


CO_2 and other oxidized products

27



28



29

For the purposes of this decision support system, oxygen is considered to be available for aerobic biodegradation of VC when all of the following criteria are met:

Dissolved oxygen concentrations measured in the field exceed 0.1 mg/L.

Ferrous iron (Fe^{2+}) concentrations are below 0.5 mg/L.

Methane concentrations are below 0.005 mg/L.

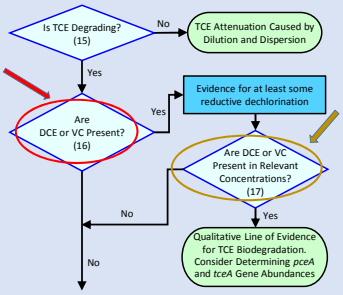
30

The decision logic for DCE parallels the decision logic for Vinyl Chloride.

31

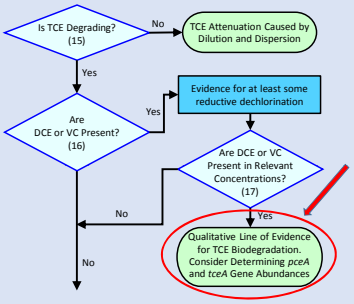
TCE Degradation

If the sum of cDCE, tDCE and VC is more than 5% of the concentration of TCE on a mole basis, then cDCE, tDCE and VC are present.



If the sum of cDCE, tDCE and VC is more than 25% of the concentration of TCE on a mole basis, then cDCE, tDCE and VC are present at relevant concentrations.

32



Many organisms can degrade TCE.

There is no simple association of the rate of degradation and the density of *Dehalococcoides* bacteria at the site.

The density of the reductase genes provides a qualitative line of evidence.

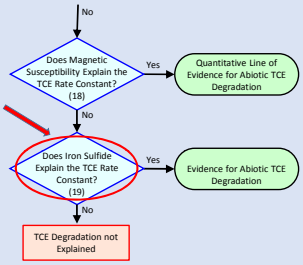
33

Reactive iron sulfide minerals are formed during sulfate reduction and will form over time as sulfate reduction progresses and ferrous iron is dissolved in the groundwater.

However, the reactive iron sulfide minerals are inactivated over time at a rate that is proportional to the amount of reactive minerals that have already accumulated.

The pool of reactive iron sulfide will increase until the rate of production from sulfate reduction is balanced by the rate of inactivation.

The rate of TCE degradation mediated by reactive iron sulfide minerals is related to the steady-state pool of reactive iron sulfide.

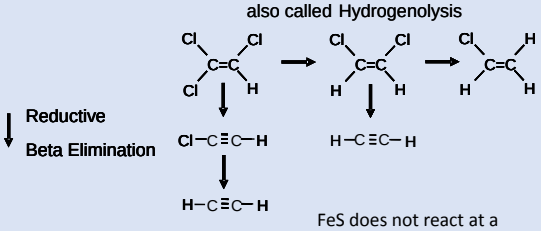


34

Carried out by FeS and Pyrite (FeS_2) and Green Rusts

Sequential Reductive Dechlorination

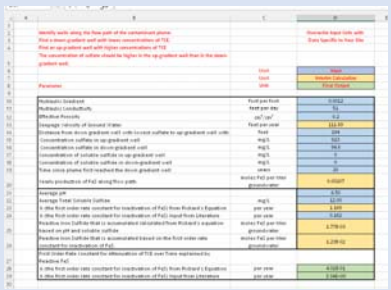
also called Hydrogenolysis



FeS does not react at a significant rate with DCE or Vinyl Chloride.

35

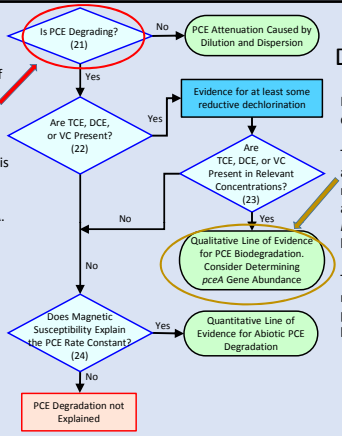
The spreadsheets use data on the effective porosity, hydraulic gradient and hydraulic conductivity, distance between wells, concentrations of sulfate and sulfide in groundwater, and pH.



36

The primary line of evidence for degradation is the projection of the computer model.

The secondary line of evidence is stable isotopic fractionation as revealed by CSIA.



PCE Degradation

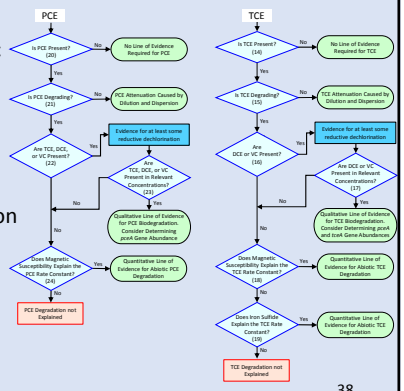
Many organisms can degrade TCE.

There is no simple association of the rate of degradation and the density of *Dehalococcoides* bacteria at the site.

The density of the reductase genes provides a qualitative line of evidence.

37

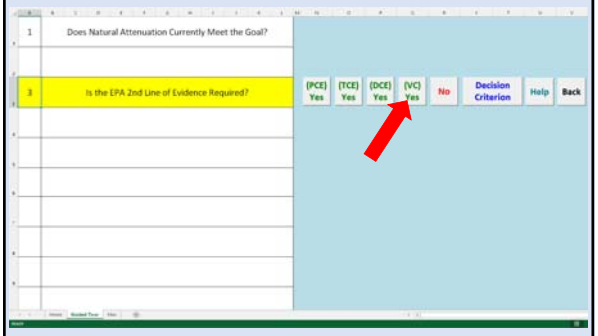
The decision logic for PCE parallels the decision logic for TCE, except there is no evaluation of abiotic degradation on FeS.



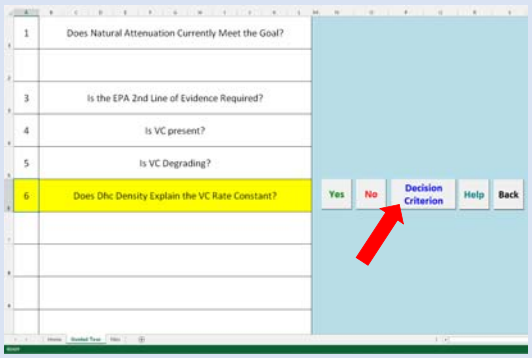
38

It is all organized in a decision guide.

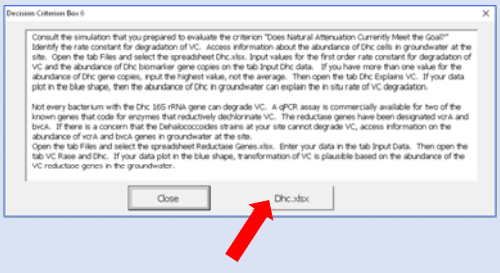
39



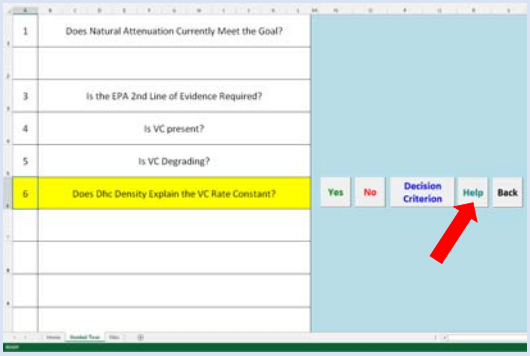
40



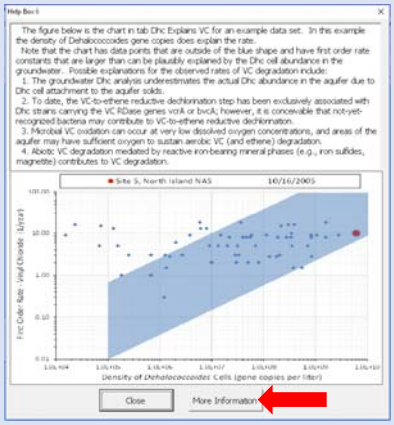
41



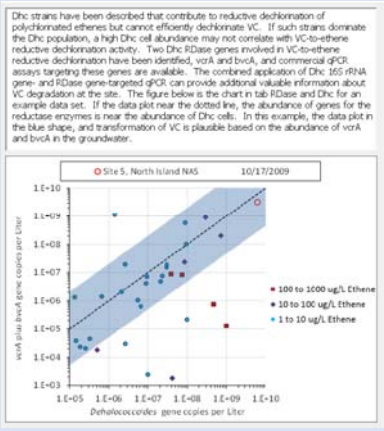
42



43



44



45

John Wilson is a Principal Scientist with Scissortail Environmental Solutions, LLC.

He worked for 35 years for the U.S. Environmental Protection Agency.

Search the Internet for Remediapedia!

Monitored Natural Attenuation (MNA)
- MNA of Petroleum Hydrocarbons and Fuel Components
- MNA of Chlorinated Solvents

46