Enhanced Bio-Remediation of Heavy PHCs and PAHs Through Dedicated Endogenous Micro-Organisms Biostimulation

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SMART Remediation
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CANADIAN LEADER IN ENVIRONMENTAL EXPERTISE & SPECIALIZED PRODUCTS

CHEMCO inc.

SMART Remediation

Enhanced Bio-Remediation of heavy petroleum hydrocarbons and PAHs through dedicated endogenous microorganisms bio-stimulation

Presented by Charles Lamontagne,PhD

February 2018

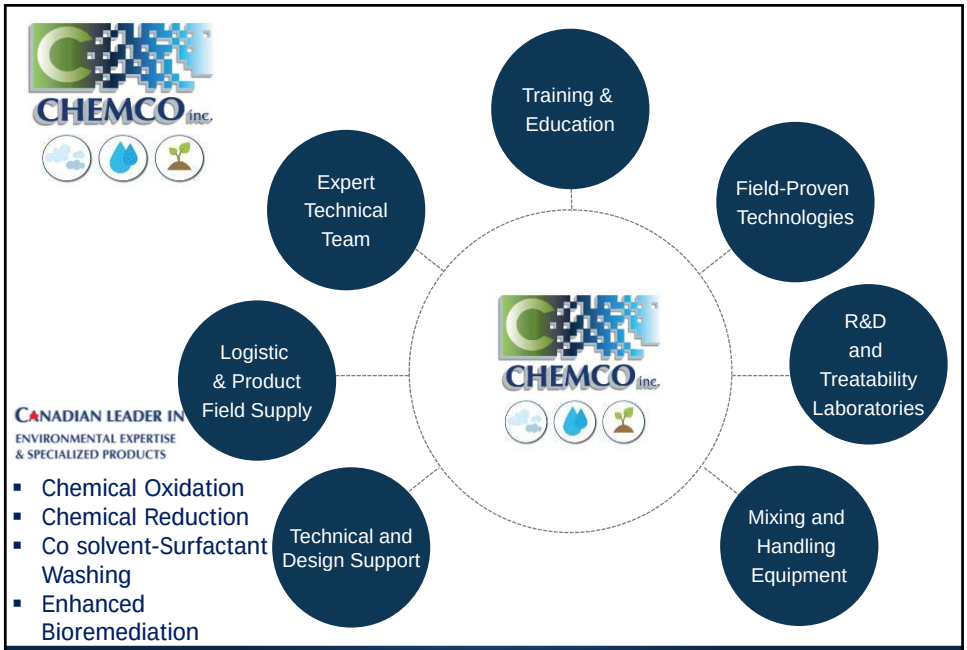
CHEMCO inc.

Presentation Outline

- *About us*
- *Bio-Remediation – Introduction*
- *ChemBio Formulation*
- *Laboratory Results*
- *Pilot Tests esign and Results*

About us

- Canadian Company founded in 1988
- **<u>Production</u> and warehouses throughout Canada**
  - Quebec
  - Ontario
  - Alberta
  - British Columbia
- **Sectors of activity:**
  - Industrial and Municipal Potable & Waste Water
  - Contaminated Soil and Groundwater
  - Air, Odours and Atmospheric Emissions (Activated Carbon, filtering medias)
  - Process Water & Thermal Exchange Fluids (Glycols)
  - Drilling Fluids (Oil and Gas & Diamond exploration)
  - Aircraft De-icing Fluids



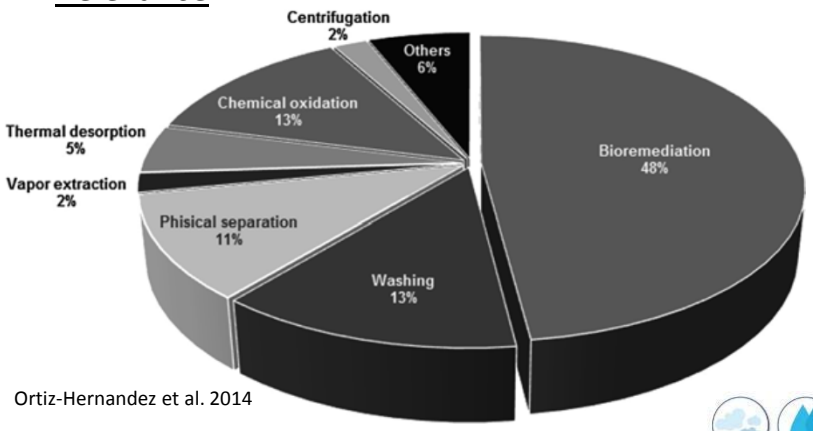
CANADIAN LEADER IN ENVIRONMENTAL EXPERTISE & SPECIALIZED PRODUCTS

- Chemical Oxidation
- Chemical Reduction
- Co solvent-Surfactant Washing
- Enhanced Bioremediation

Our product and services

Bio-Remediation – Introduction

- Relevance



Ortiz-Hernandez et al. 2014

Bio-Remediation – Introduction

- **Bio-Augmentation:** Addition of exogenous microorganisms.

  Issues:

  -Environmental concerns and regulations around the introduction of these organisms in an aquifer or soil matrix

  -Adaptability, competition

- **Bio-Stimulation:** Stimulation of endogenous microorganisms.

  Issues:

  -Targeting the specific organisms that are competent in the degradation of the contaminants

Bio-Remediation – Introduction

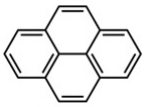
Optimizing Bio-degradation process:

1-Favoring the competent organisms:

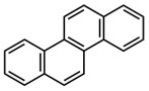
- Assuring the presence of proper growth conditions (pH, temperature) & all essential nutriments for optimal growth.
- In the soil, microorganisms cannot live exclusively on contaminants. They need large amoun to provide their energy source to func
- Different substrates = Different enzym
  - Simple carbohydrates and protein every living things
  - Starch: require amylases
  - Cellulose: require cellulases
  - Lignin: require special oxidative enzymes (peroxidase, laccase)

Bio-Remediation – PAHs

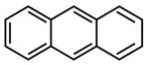
PAHs



Pyrene

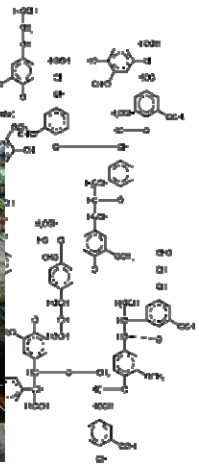


Chrysene



Anthracene

Lignin



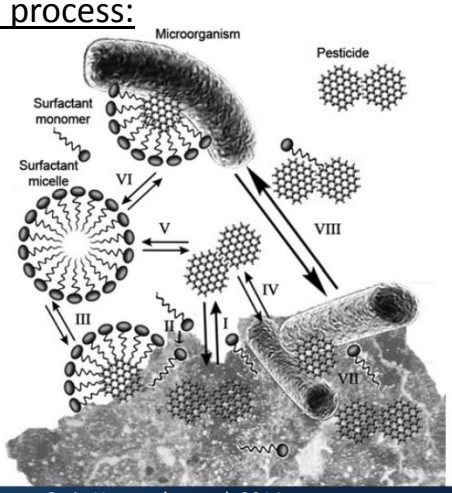
Review: **Mushroom as a product and their role in mycoremediation,** S. Kulsheshtha et all, 2014.

Bio-Remediation – Introduction

Optimizing Bio-degradation process:

2-Enhancing Bio-availability:

- Adding tension-active compounds (surfactants)
- Favoring the production of Bio-surfactants
- Increasing and maintaining high temperatures (35-55° C)



Ortiz-Hernandez et al. 2014

Bio-Stimulation – Introduction

Optimizing Bio-degradation process:

1-Favoring the competent organisms

2-Enhancing Bio-availability

3-Controling the pH & ORP

-Extremes: 1-4 and 9-12 ➔ Lower biological activity

-Slightly alkaline: 8-9 ➔ Discourage fungi and potential NH_3 toxicity

-Slightly acidic to neutral: 5-8 ➔ Promote Bio-diversity

4-Modifying the ORP and the populations

-Support aerobic organisms while recovering in soils coming from anaerobic conditions

Bio-Stimulation – Introduction

Optimizing Bio-degradation process:

1-Favoring the competent organisms

2-Enhancing Bio-availability

3-Controling the pH & ORP

4-Provide sufficient oxygenation:

-Bio-degradation efficiency of THP: α [O_2] in soils and waters.

-Air movement allows for the elimination of gaseous and toxic by-products.

5-Targeting the right water content:

- ↑ (Too much water): Air movement is impaired, anaerobic conditions take place, process slow down.

- ↓ (Not enough water): Molecules stop to move and process stall

ChemBio-Formulation

ChemBio composition: Integration of the bio-degradation principles

- Feeding the competent species: Specific carbon and nitrogen sources and a large panel of nutriments
- Surfactant presence that further increase Bio-surfactants production
- Initiate slightly acidic conditions
- Increasing the ORP and challenging the populations
- **Low cost**

Note: Addition of wood chips for improved soil structure and induce PAHs degradation (for fine grain geology and/or contaminant type)

ChemBio-Formulation

Changing formulation = Changing the nature of the predominant microorganisms

Bacteria driven Remediation →

Fungi driven Remediation →

ChemBio-Formulation

Enhanced Bio-Remediation - Tools, testing and tricks

Adjusting the formulation before you get to the field

- Are competent microorganisms naturally present in the soil?
- What is the pH and the buffering capacity of the soil?
- Calibrating the C/N ratio around 30, including the contribution of the contaminants
- To which extent the structure of the soil need to be improved? (rough wood splices)
- Are PAHs present in the soil? (finer wood chips)

Enhanced Bio-Remediation - Tools, testing and tricks

Adjusting the formulation: Laboratory Bench Testing

Duration: one week (growth pattern, pH Control, etc.)

Enhanced Bio-Remediation – Bench Laboratory Results

Mixte-L01 Silty sand

	T0	T28	M1 40-1-1	M1 40-1-1	M1 40-1-1 BP	M1 40-1-1 BP	Mean	Reduction %	Reduction mg/Kg
F2 (10-16 C)	**240**	20	0	0	0	0	**0**	**-100**	**240**
F3 (16-34 C)	**1935**	1605	980	840	790	820	**820**	**-58**	**1115**
F4 (34-50 C)	**6170**	4650	2810	2330	2300	2370	**2370**	**-62**	**3800**
Total F2-F4	8345	6275	3790	3170	3090	3190	**3190**	**-62**	**5155**
PAHs	212,5	240,5	242	181	**122**	**136**	**129**	**-39**	84

THP-25 Heavy

	T0	T28	T1 40-1-1	T1 40-1-1	T1 40-1-1 BP	T1 40-1-1 BP	Mean	Reduction %	Reduction mg/Kg
F2 (10-16 C)	**10**	15	50	40	30	40	**40**	300	-30
F3 (16-34 C)	**2315**	1530	210	180	290	210	**222,5**	**-90**	**2093**
F4 (34-50 C)	**660**	720	20	30	100	50	**50**	**-92**	**610**
Total	**2985**	2265	280	250	420	300	**312,5**	**-90**	**2673**

Data in mg/Kg T0: Initial concentration BP: Wood chips

Enhanced Bio-Remediation – Full Scale Pilot tests with Biostimulant

Getting to the field: Preliminary design

- Passive aeration: applicable in remote areas
- Wood chips covering: Isolation, O_2 and NH_3 exchange, watering, monitoring…
- 1.5m height: reduce compaction

Enhanced Bio-Remediation – FS Pilot tests

Preliminary results

- Heat

Enhanced Bio-Remediation – FS Pilot tests

Preliminary results

- Two layers of microorganisms populations (Mixte-L01)

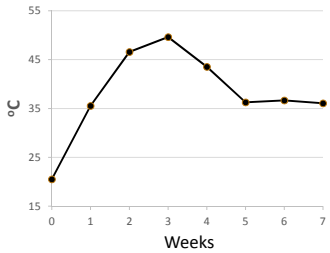
7 days 14 days 21 days

Enhance Bio-Remediation – FS Pilot tests

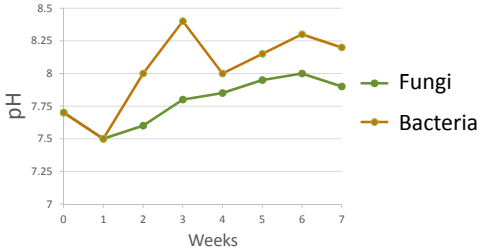
SOIL 1

Mixte-L01 Silty Sand

Temperature



Ph



Enhanced Bio-Remediation – FS Pilot tests

SOIL 1 - Mixte-L01

Total petroleum hydrocarbon
(mg/Kg)

Before treatment

C>10-C16 (F2)	**327**
C>16-C34 (F3)	**2438**
C>34-C50 (F4)	**3815**
C>C50 (F4g)	9893
Total	**6579**

Days after treatment

7	14	21	28	35	49	%
335	185	224	182	164	136	**58**
1730	1525	2110	1860	1840	1500	**38**
1048	1155	1320	1215	945	789	**79**
3113	**2865**	**3654**	**3257**	**2948**	**2425**	**63**

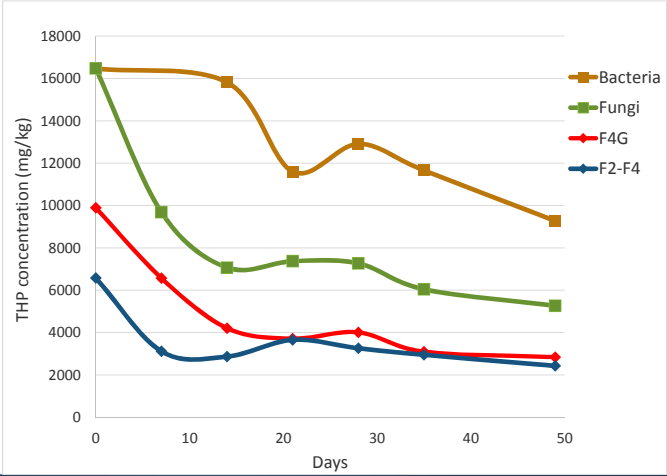
ND	ND	ND	ND	331,5	352	**-8**
ND	ND	ND	ND	2525	2340	**4**
ND	ND	ND	ND	1285	1080	**72**
ND	ND	ND	ND	**4142**	**3772**	**43**

NA	456	411	407	418	317	**3**
NA	2240	2350	2495	2950	2385	**2**
NA	1020	1130	1475	1455	1060	**72**
NA	**3716**	**3891**	**4377**	**4823**	**3762**	**43**

Enhanced Bio-Remediation – FS Pilot tests

SOIL 1 - Mixte-L01

Total petroleum hydrocarbon



Enhanced Bio-Remediation – FS Pilot tests

SOIL 1 - Mixte-L01

Total HAPs (mg/Kg)

Before Traitement

Total	**186**

Days after treatment

7	21	49	
160	120	**95**	**48%**
N/A	195	180	

Enhanced Bio-Remediation – FS Pilot tests

SOIL 1 - Mixte-L01 **Results after mixing the entire Bio-pile**

Total petroleum hydrocarbon (mg/Kg)

	T0	12 weeks	%
C>10-C16 (F2)	**327**	238	**28**
C>16-C34 (F3)	**2438**	1570	**36**
C>34-C50 (F4)	**3815**	753	**80**
C>C50 (F4g)	9893	2405	**76**
Total	**6579**	**2561**	**61**

Total PAHs (mg/Kg)

	T0	12 weeks	%
Total	186	82	56

Enhanced Bio-Remediation – FS Pilot tests

SOIL 1 - Mixte-L01

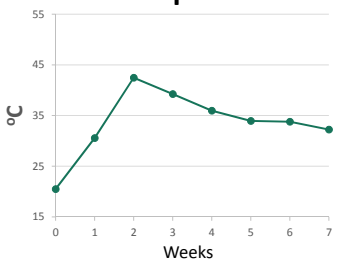
Good results despite difficult site conditions

Enhanced Bio-Remediation – FS Pilot tests

SOIL 2 - THP-25

Heavy Clay

Temperature



Ph

Enhanced Bio-Remediation – FS Pilot tests

SOIL 2 - THP-25

Total petroleum hydrocarbon

(mg/Kg)

Before treatment

C>10-C16 (F2)	**750**
C>16-C34 (F3)	**10950**
C>34-C50 (F4)	**5740**
C>C50 (F4g)	24250
Total	**17440**

Days after treatment

7	14	21	28	35	49	%
328	442	262	585	261	315	**58**
5250	6075	7380	9235	6285	5890	**46**
1960	2420	3100	3470	2400	2135	**63**
7538	**8937**	**10742**	**13290**	**8946**	**8340**	**52**

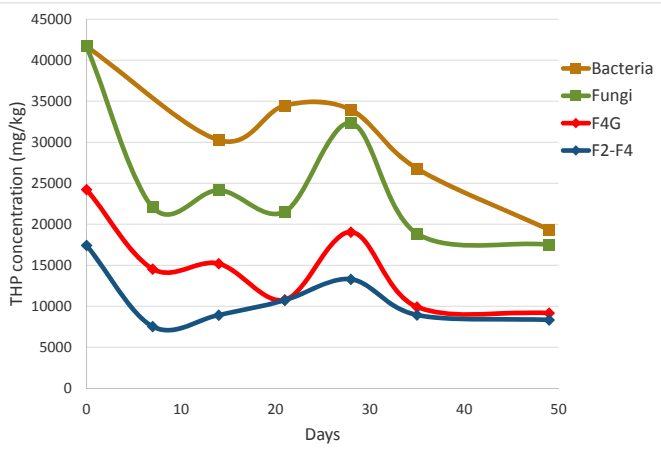
NA	NA	NA	NA	449	480	**36**
NA	NA	NA	NA	8095	7280	**34**
NA	NA	NA	NA	3010	2750	**52**
NA	NA	NA	NA	**11554**	**10510**	**40**

NA	500	619	616	446	369	**51**
NA	7040	9395	9270	8050	5985	**45**
NA	2625	3615	3560	3095	2270	**60**
NA	**10165**	**13629**	**13446**	**11591**	**8624**	**51**

Enhanced Bio-Remediation – FS Pilot tests

SOIL 2 - THP-25

Total petroleum hydrocarbon



Enhanced Bio-Remediation- Conclusions

Pros:

- A promising cost effective process of particular interest for difficult contaminants
- A strategy based on the possibility to sequentially harness different populations of indigenous microorganisms
- A formulation that encompasses many ingredients that cope with the presented principles of Bio-Remediation
- 50-60 % degradation in 2 weeks (3500 to 8500 ppm reduction)
- Pilot tests underway for further understand large scale potential of the research

Enhanced Bio-Remediation- Conclusions

Cons:

- In this pilot tests: Difficulties to maintain optimal sol structure and low humidity. (Forced ventilation or shelter needed)
- F4G degradation. Nevertheless, it show the effectiveness of the technic in term of enhanced Bio-availability and Bio-degradation.

Next steps:

- Recovery of the biological activity after frost ? (Spring 20018)

Acknowledgement

SOILTEC

SIGNATERRE ENVIRONNEMENT

CENTRE DE TRAITEMENT BAS-SAINT-LAURENT

terrapure

CHEMCO inc.

Thank you for your attention !

Questions ?!?

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