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ENVIRONMENTAL PRODUCTS™

New Integrated Biochemical / Electrochemical Method for Remediation of Contaminated Ground Water

REMTECH EXPO
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Electro Bioremediation, EBR®
22 September 2020

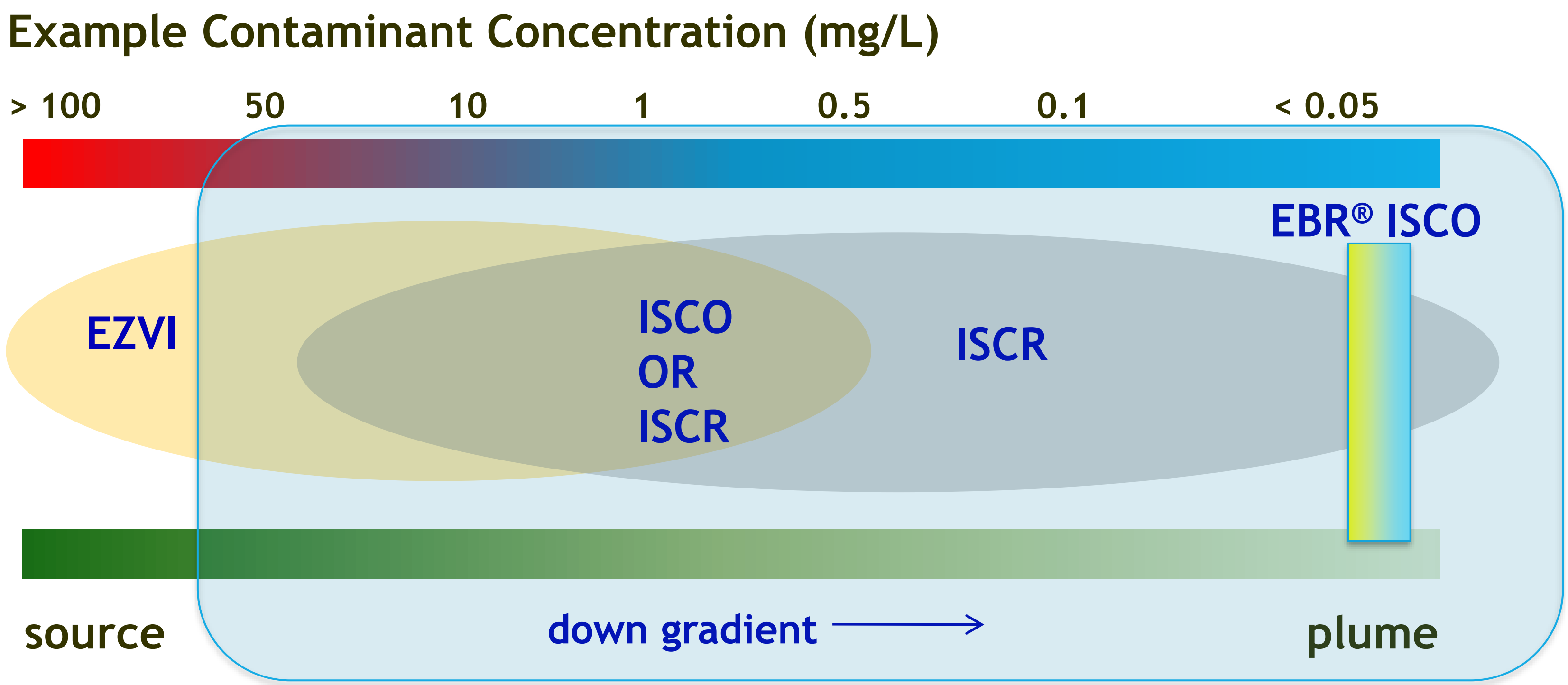
Why We Need A New ISCO Technology

- **Longevity**: Conventional ISCO amendments and means of generating reactive oxidant species (ROS) are limited by distribution, kinetics, and short environmental half-lives ($10E^{-9}$ to $10E^{-6}$ seconds) = need to be continuously generated / applied.
- **ISCO PRBs**: PRB applications using existing ISCO (candles, KPS, etc.) are limited
- **Sustained, *In Situ* Production of ROS could yield effective PRBs, especially for:**
  - COIs not conducive to ISCR/ZVI such as 1,4-dioxane, MTBE/TBA, perchlorate plumes.
  - Deep aquifers
  - Challenging lithologies (clays, silt)

Provect-“EBR®” ISCO PRB

***In Situ* ISCO Generator** to continuously produce Fenton’s type ROS yields an effective PRB technology for:

- Challenging lithologies (deep aquifers, clayey soils, fractured rock)
- Situations where sorption/sequestration is not considered an effective response
- Alternatives to hydraulic containment (long term O&M)

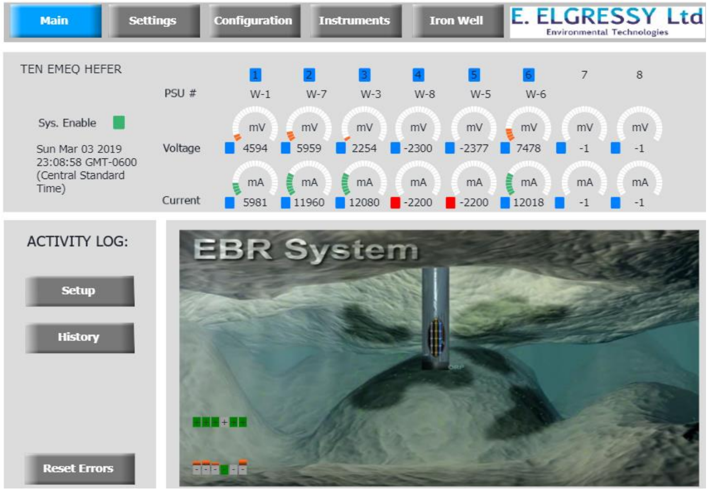


What is Provect-“EBR®”

Electro Bioremediation (EBR) well(s) contain an air sparge plus 3 electrodes:

- H_2O_2 production
- Fe^{2+} release
- O_2 production

Computerized control panels for remote system / adjustment and real-time performance monitoring



US Patent No. 9,975,156 B2

US and EPC Patents

EPC 15 885 303.7-1014

21 MAY 2019

Europäisches Patentamt
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Application No.	Ref	Date
15 885 307.7 - 1014	17763P/EP	16.05.2019
Applicant: Elgressy, Elie		

Communication under Rule 71(3) EPC

1. Intention to grant

You are informed that the examining division intends to grant a European patent on the basis of the above application, with the text and drawings and the related bibliographic data as indicated below.

A copy of the relevant documents is enclosed.

1.1 In the text for the Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

US Patent No. 9,975,156 B2

US009975156B2

(12) **United States Patent**
Elgressy

(10) **Patent No.: US 9,975,156 B2**
(45) **Date of Patent: May 22, 2018**

(54) **BREAKDOWN OF FUEL COMPONENTS AND SOLVENTS IN GROUNDWATER AND CONTAMINATED SOIL**

(71) Applicant: **Elie Elgressy**, Netanya (IL)

(72) Inventor: **Elie Elgressy**, Netanya (IL)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days. days.

(21) Appl. No.: **15/559,053**

(22) PCT Filed: **Dec. 3, 2015**

(86) PCT No.: **PCT/IL2015/051175**

§ 371 (c)(1), (2) Date: **Sep. 17, 2017**

(87) PCT Pub. No.: **WO2016/147168**

PCT Pub. Date: **Sep. 22, 2016**

(65) **Prior Publication Data**

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(56) **References Cited**

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(Continued)

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(74) *Attorney, Agent, or Firm* — Ted Whitlock

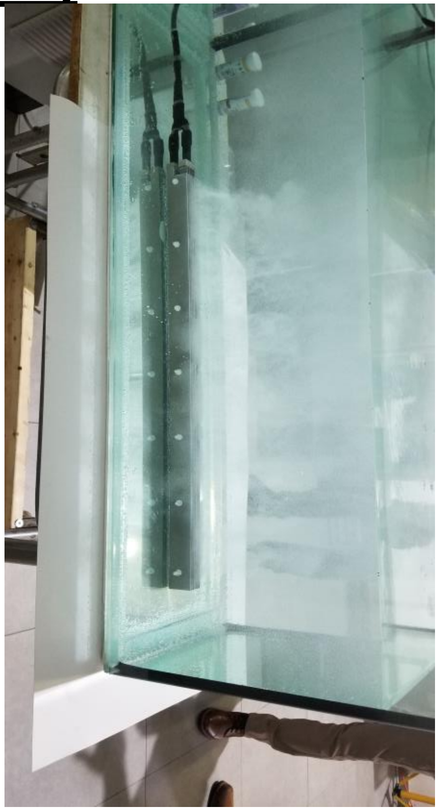
(57) **ABSTRACT**

A system and method for remediation of polluted sites,

Provectus is the Exclusive Provider in North America and Italy

How Does EBR Work?

<u>The EBR Well Generates Reactive Oxidant Species (ROS)</u> in a manner similar to other Electro-Fenton's (EF) type systems (Nazari *et al*., 2019; Rosales, *et.al,* 2012; Sires *et al*., 2014; Yuan et al., 2013):



Production of O_2: electrolytic reduction of water on a catalytic electrode yields molecular oxygen, O_2

Production of H_2O_2: two-electron reduction of oxygen on a cathode surface generates H_2O_2

Release of Iron: H_2O_2 interacts with ferrous iron (Fe^{2+}) released from a third cell to yield hydroperoxyl ($HO_2\cdot$)/superoxide ($O_2\cdot$) and hydroxyl radicals ($OH\cdot$), and likely ferrates

$$O_2 + 2H^+ + 2e^- \rightarrow H_2O_2$$

$$Fe^{2+} + H_2O_2 \rightarrow Fe^{3+} + HO^{\cdot} + OH^-$$

$$Fe^{3+} + H_2O_2 \rightarrow Fe^{2+} + HO_2^{\cdot} + H^+$$

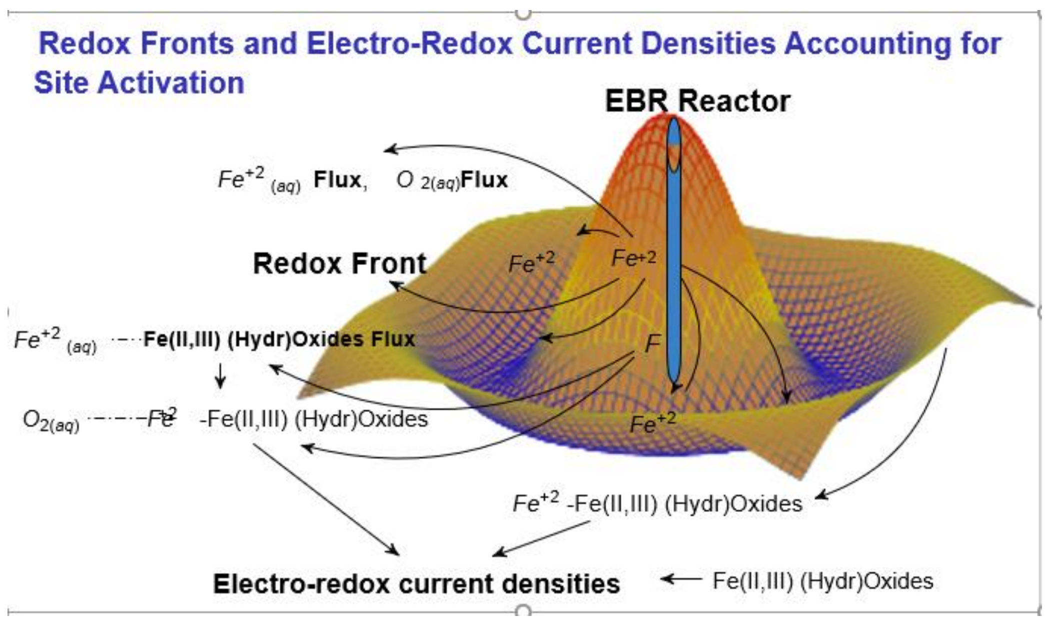
$$Fe^{3+} + HO_2^{\cdot} \rightarrow Fe^{2+} + O_2 + H^+$$

How Does EBR Differ From EF?

$Fe^{2+/3+}$ Nanoclusters: <u>At neutral pH</u> EBR uniquely generates "low" Fermi Level (highly oxidized) FeII/III oxyhydroxide nanoclusters (2 nM) as the sacrificial Fe source corrodes within the well (Ai *et al.*, 2013; Elgressy 2019).

<u>**Subsurface distribution of Fe nanoclusters throughout aquifer is driven by:**</u>

- Equilibration of differences in Fermi level energies
  self-generated
  self-propagated
- Induced redox fronts
- Electro-redox
  current densities
- Electroosmosis
- Electrophoresis
- Dynamic coupling
  between EBR wells



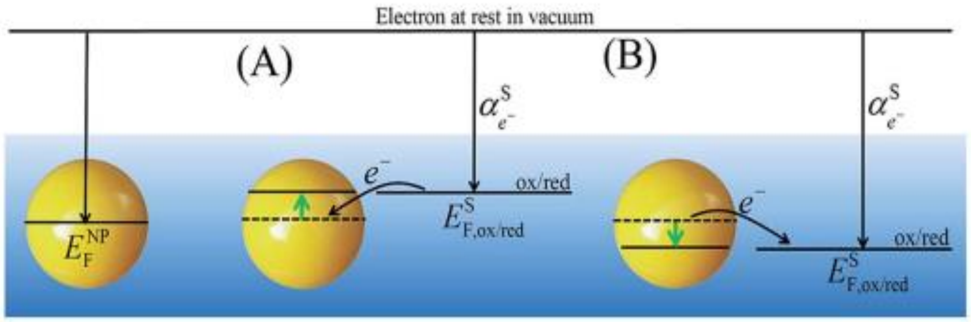
How Does EBR Differ From EF?

$Fe^{2+/3+}$ Nanoclusters: A critical and unique feature of the EBR is use of geophysical mechanisms to enhance subsurface distribution of low Fermi level Fe nanoclusters and propagate catalysis *in situ* to continuously generate reactive oxidants throughout its effective ROI.

Electrochemical Potential of an e- is the difference in potential between the oxidized and reduced species (Peljo *et al.*, 2017; Scanlon *et al.*, 2015)

Fermi Level is a thermodynamic "value" to define the electrochemical potential of an electron in a redox couple in solution

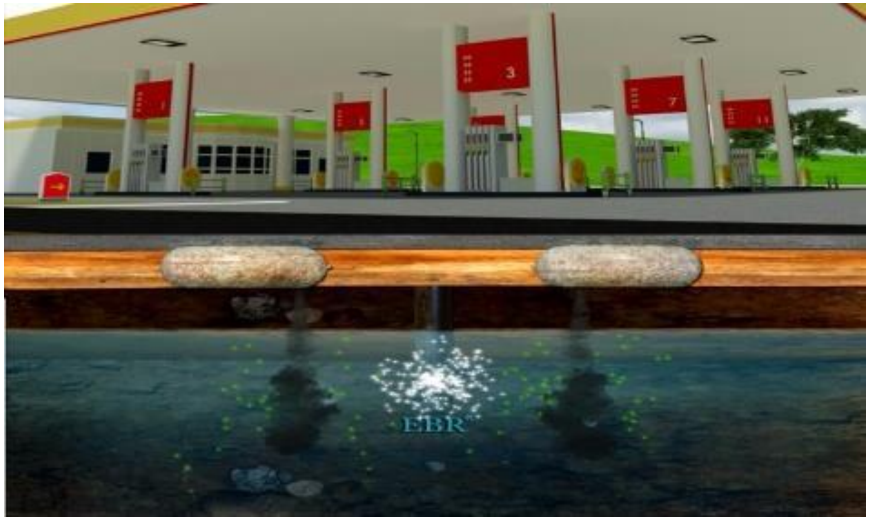
At +850mV ("low" Fermi Level electrochemical potential) electrons are essentially freely transferred from Fe^{3+} to Fe^{2+}



Scheme 3 Redox equilibria for metallic NPs in solution showing the capabilities of metallic NPs to be (A) charged and (B) discharged upon Fermi level equilibration with an excess of a single dominant redox couple in solution.

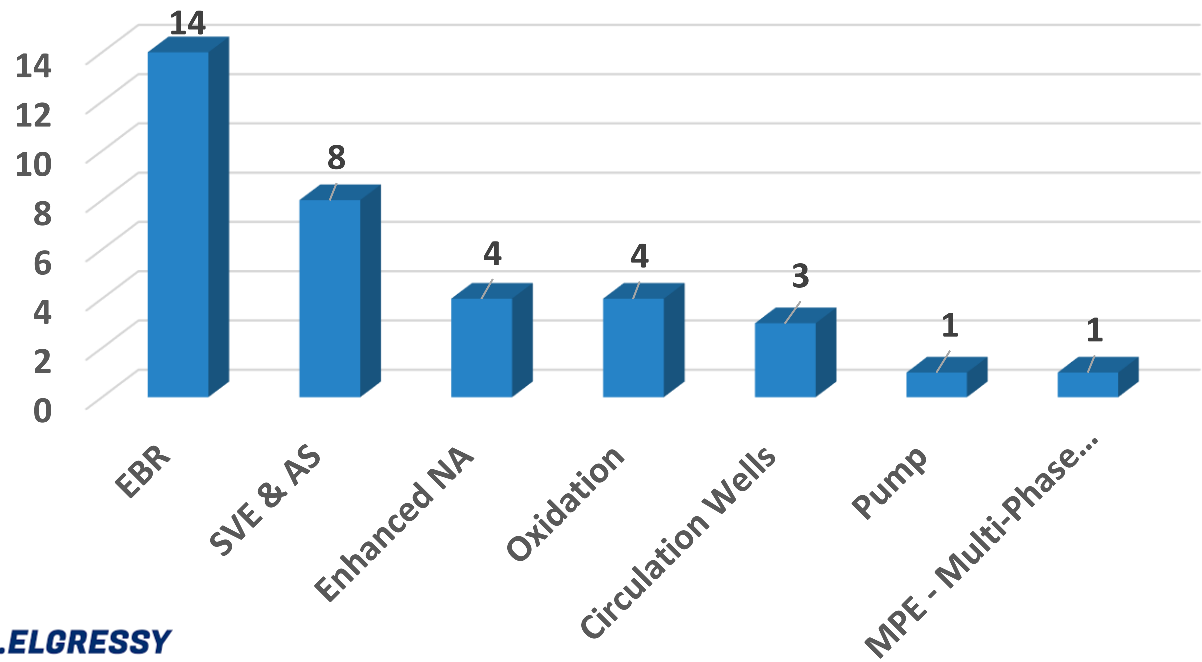
Summary of EBR Reactions

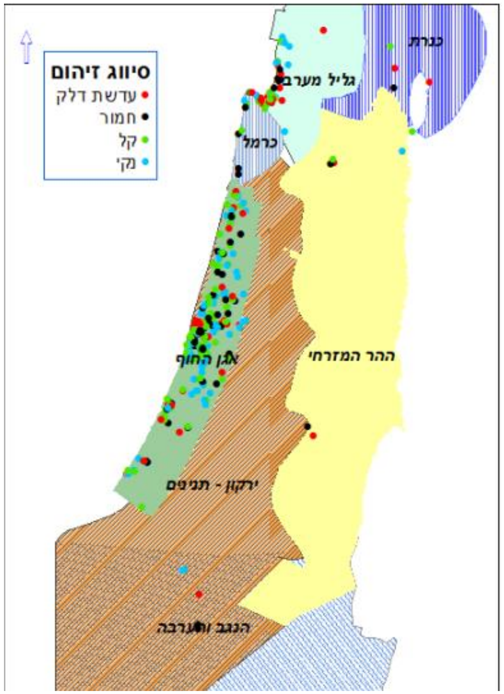
- Generation of H_2O_2
- Release of Fe^{2+}
- H_2O_2 interacts Fe^{2+} to yield ROS $HO_2\cdot/O_2\cdot$ and $OH\cdot$ (ferrate?)
- Release of O_2 and low Fermi Level Fe^{2+}/Fe^{3+} nanoclusters
- Self-propagation throughout ROI (less confined by lithology)
- Continuous *in situ* production of ROS catalyzed by O_2 activation from equilibration of Fermi levels of Fe
- Transition from ISCO to bioremediation (using oxygen and iron as electron acceptors)
- Process controlled remotely with real-time monitoring



Where has it been Used?

- In 2019 Israel had 35 gas stations undergoing active remediation
- EBR technology was employed at 14 (40%) + 2 chlorinated solvent sites
- Today, 7 sites are in clean-closure monitoring after 1 year of operation
- EBR is ISO-certified and approved by the Israeli Water Authority
- No PRB Applications. No USA applications.





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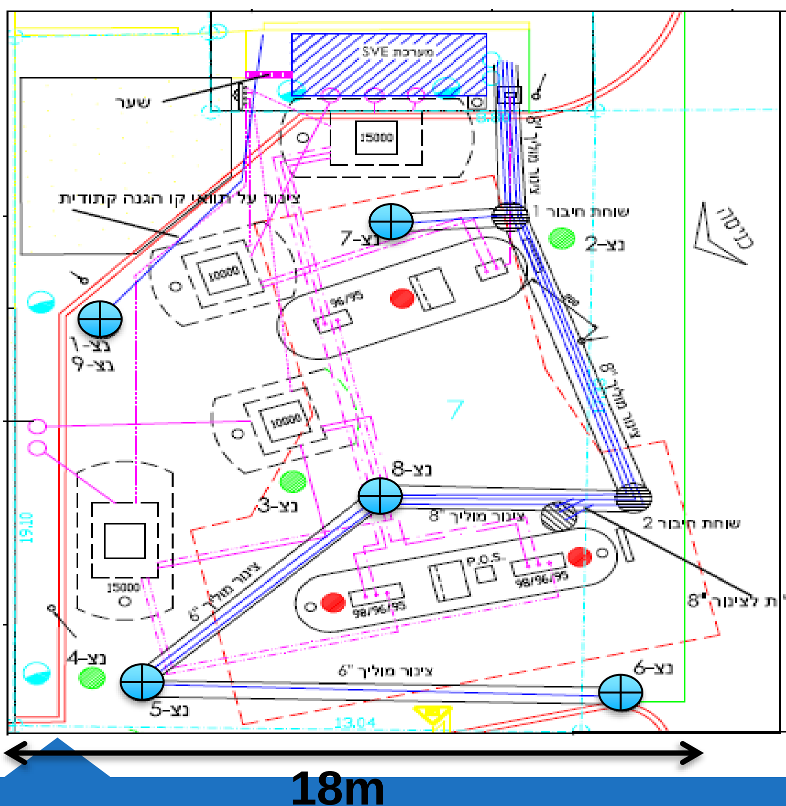
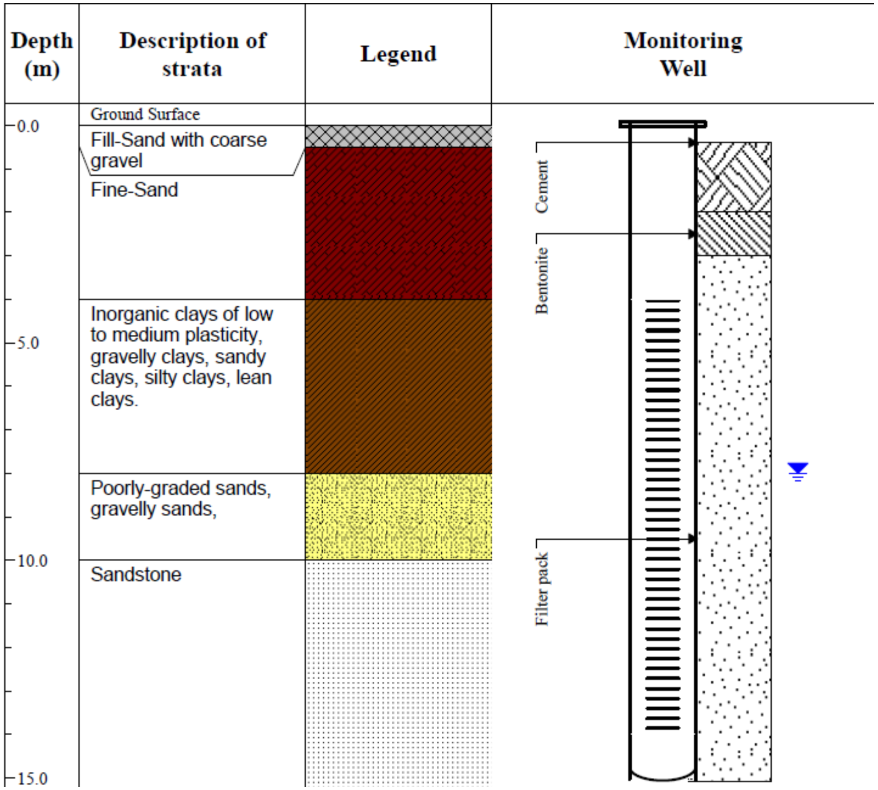
Case Study – Neve Tzedik Site

- Operating Gasoline Station
  - Groundwater at 7 to 8 m bgs
  - sandy aquifer with si cl lenses
  - MTBE >50 mg/L; TPH >100 mg/L
  - 242 m^2 impacted area





- 5 EBR/SVE Systems (2017)
- Monitoring wells

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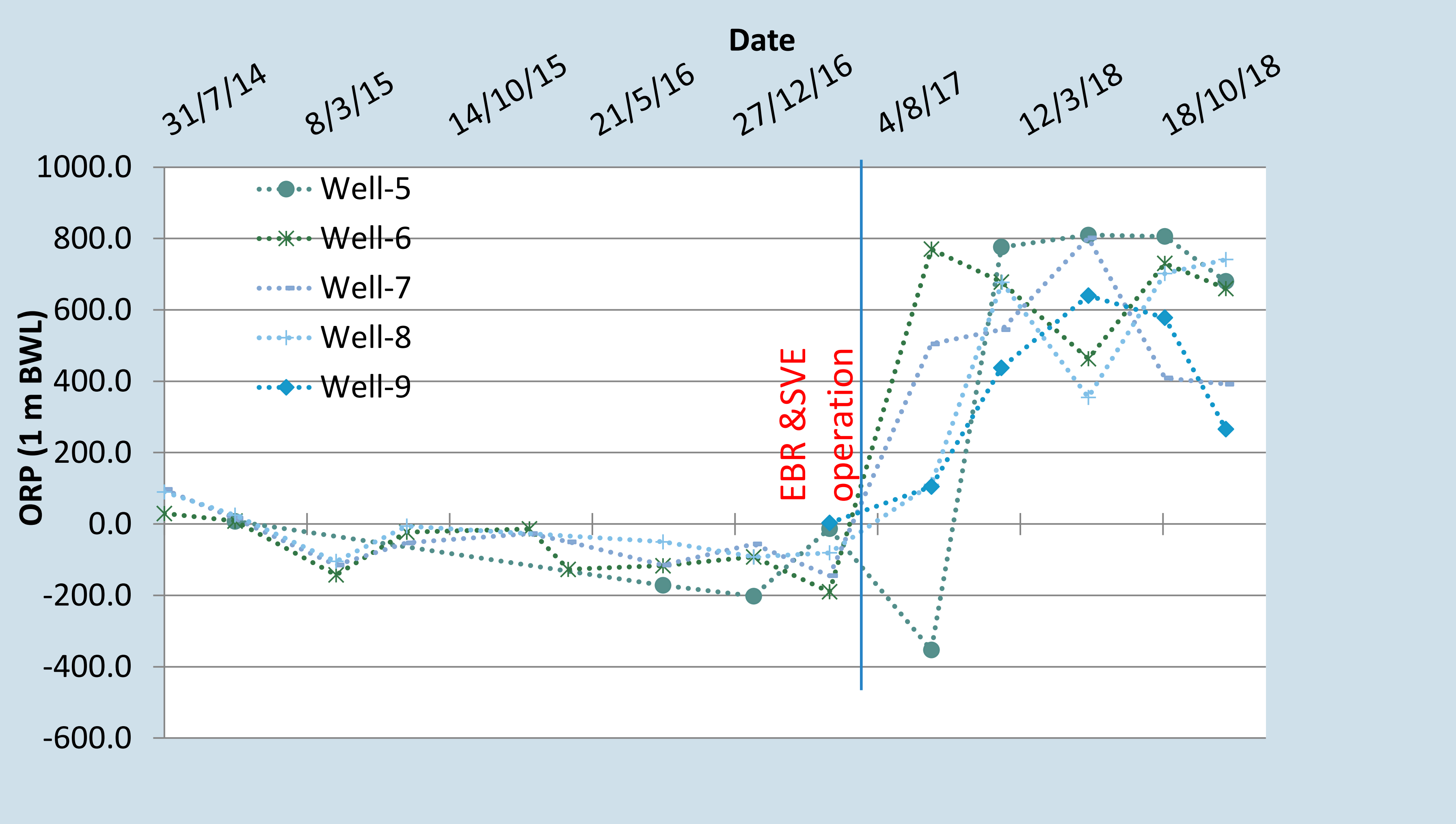
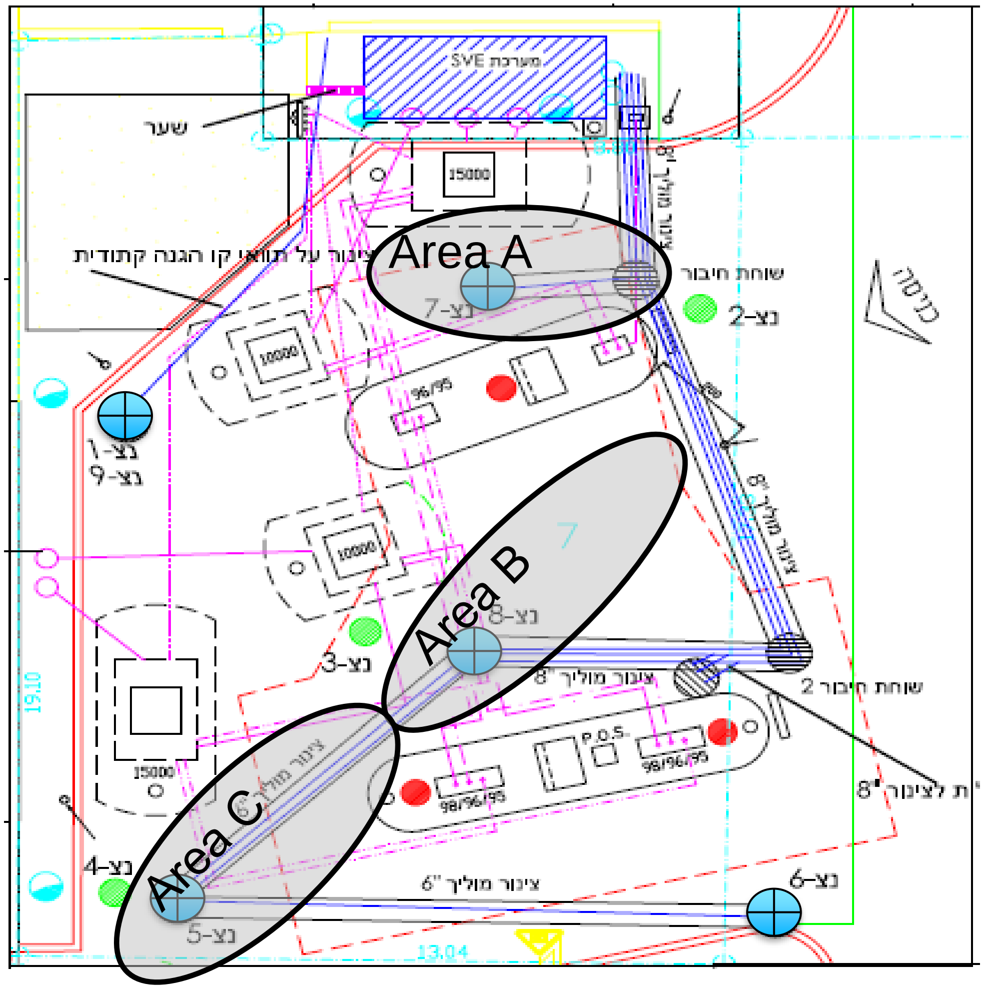
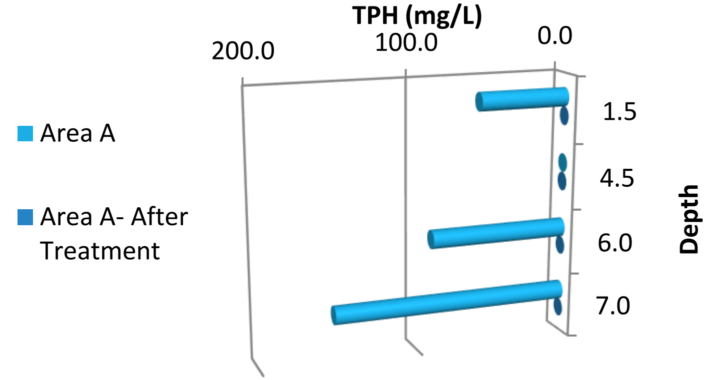
GW field parameters (ORP)

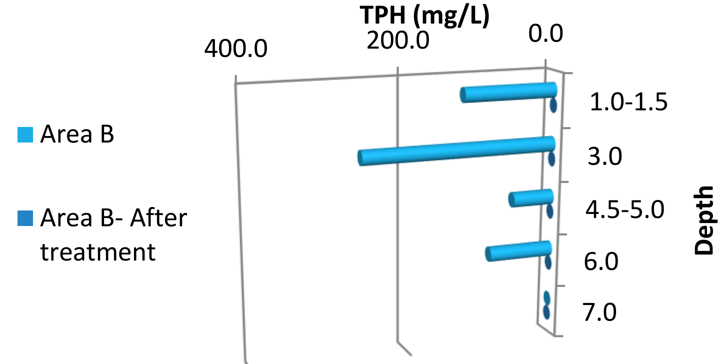


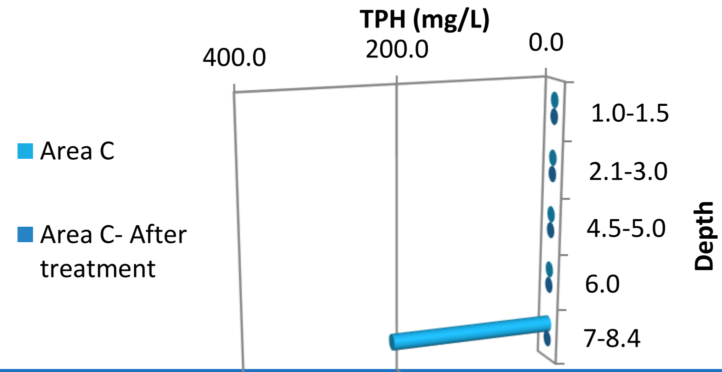
Soil / Groundwater TPH (18 mo)

TPH from >100,000 to <5 ppb (RAO <400 ppb)









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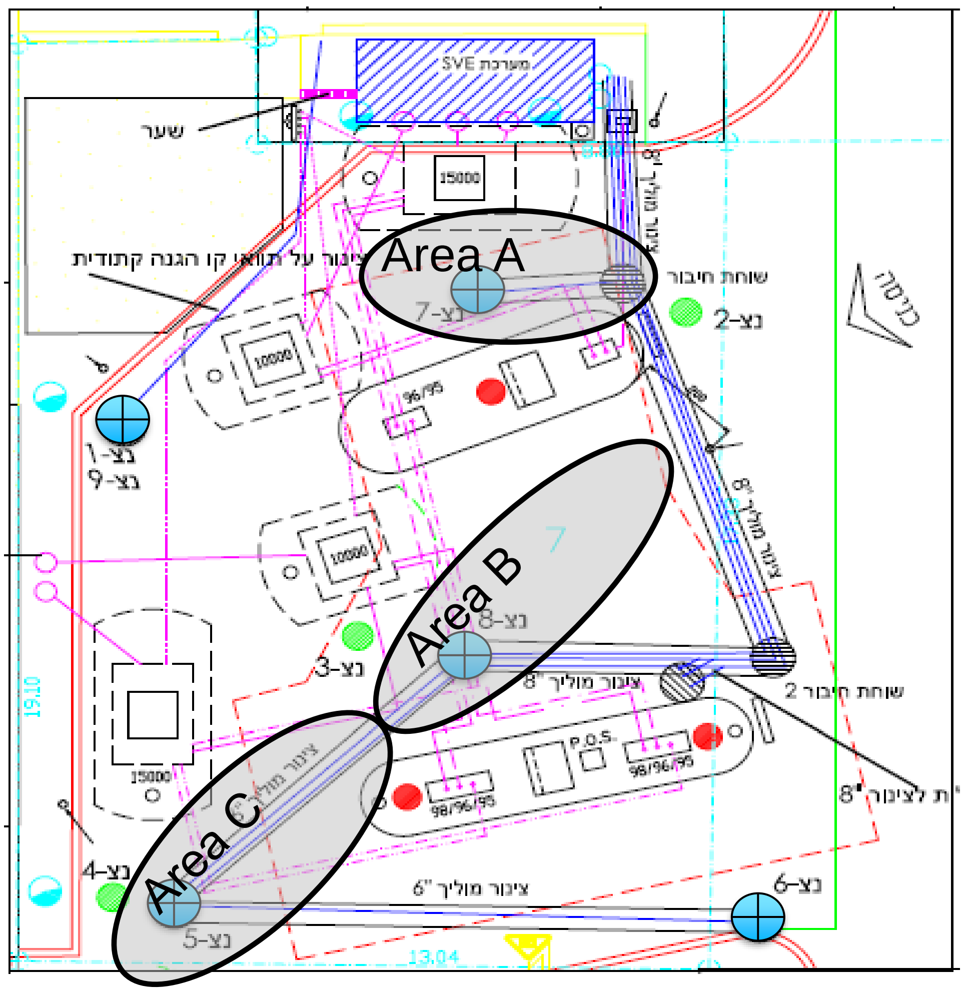
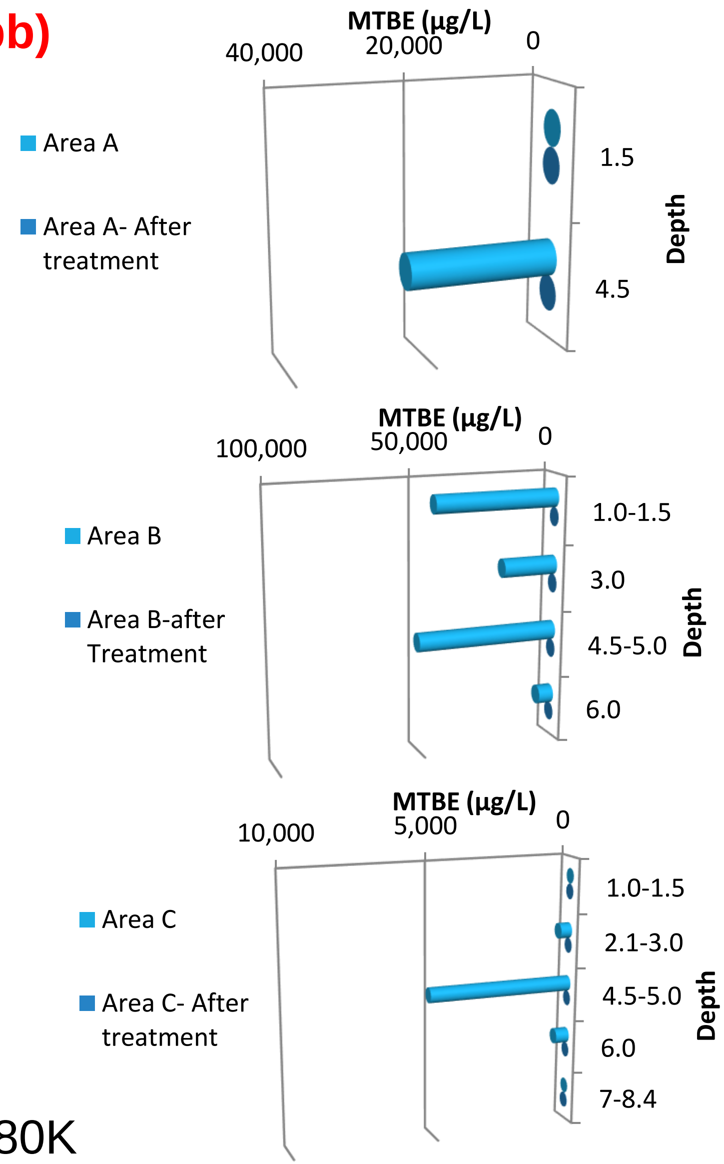
Soil / Groundwater MTBE (18 mo)

MTBE from >50,000 to <50 ppb (RAO <1,600 ppb)





- 5 EBR Wells, Control Panel, O&M < $180K

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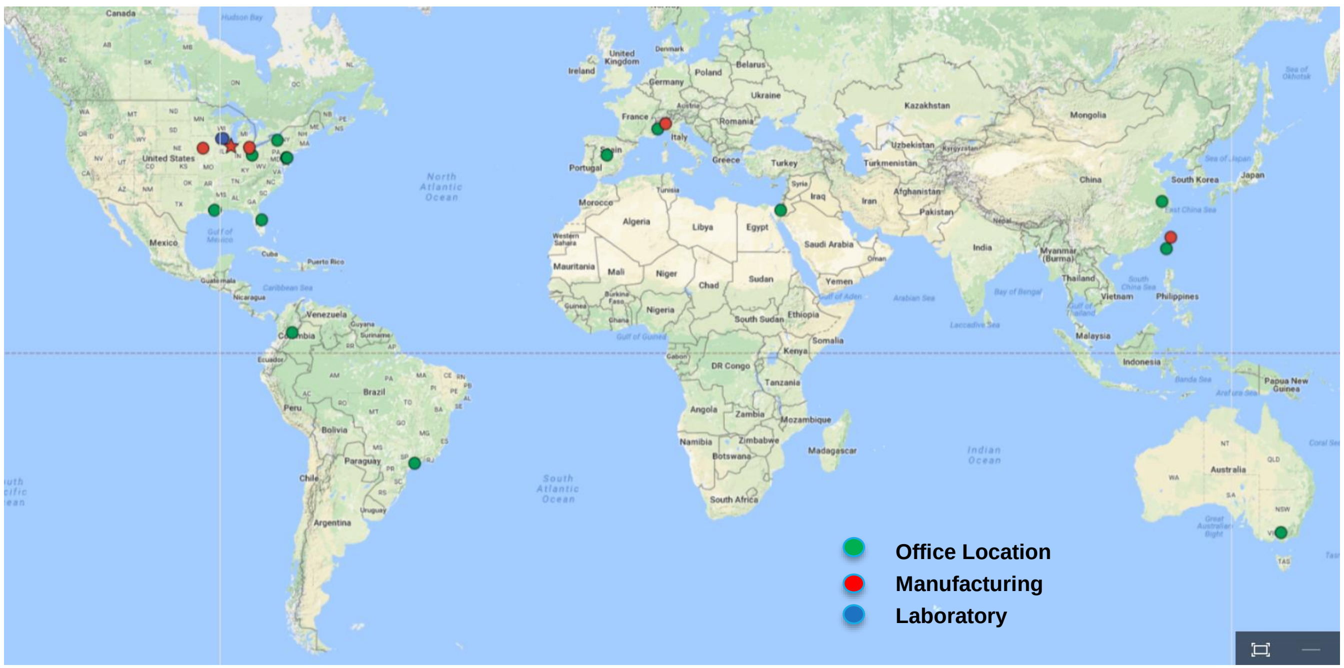
Provectus Environmental Products

- Complimentary Site Evaluation
- Complimentary review of quarterly field performance data with every project
- Laboratory Treatability Studies
- Turn-Key, Pay-for-Performance Contracting Options
- Project Specific Guarantees and Warranties



- USA (Illinois, New Jersey, Ohio, Pennsylvania)
- Australia, Brazil, China, Colombia, Israel, Italy, Spain and Taiwan

Contact Information

Thank You!

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