Is ex situ soil bioremediation really sustainable?

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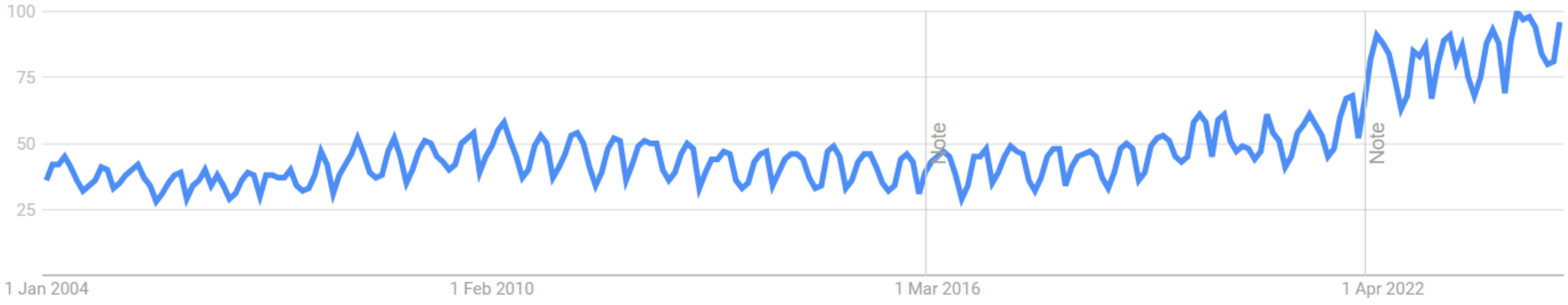
Google Trends (Worldwide) – ‘Sustainability’



Release the Value of Your Land

Specialist Site Investigation and Remediation Contractor

Sustainability of (bio)remediation

- Assumed
- Sustainability associated buzzwords e.g., bio-based
- No distinction made between in situ and ex situ bioremediation

In the last century, rapid industrialization and urbanization have left a large quantity of a wide range of pollutants emitted from both natural and anthropogenic sources. These pollutants have detrimental effects on the flora, fauna and natural environment. The persistence and prevalence of these pollutants virtually in all the ecosystems of Earth are of a major concern. Although a large number of conventional physical and chemical methods are available for cleaning up the environment, they are not sustainable and have inherent limitations. Hence, an alternate eco-sustainable, bio-based and environment-friendly approach recognized as *Bioremediation* has emerged. In bioremediation, biodiversity acts as a toolbox providing various processes/mechanisms to eliminate, immobilize/stabilize, degrade or transform various hazardous contaminants into innocuous and value-added products. This approach uses a vast array of biological agents, especially bacteria (microbial remediation), fungi (mycoremediation), algae (phycoremediation), higher plants (phytoremediation), biochar, nano-biomaterials, etc.

A B S T R A C T

Pesticides usage has tremendously increased to enhance crop production; however some pesticides are toxic and harmful to human health and the environment. This review discusses the eco-toxicological impacts of pesticides on the environment. This study extensively evaluates various sustainable remediation technologies such as advanced oxidation processes (AOPs), electrochemical processes, membrane separation, and adsorbent types (carbon nanotubes, carbon nanofiber, carbon aerogel, graphene oxide, carbon dot, biochar, biosorbents, polymers, metal-organic framework, and nanocomposite) that are used for removal of toxic pesticides from aqueous bodies. Further, various equilibrium isotherm and kinetic models that are used for understanding the mechanisms along with challenges in the techniques are discussed. From the studies, it is observed that the nanocomposites could degrade and remove pesticides efficiently due to their unique properties, making them promising adsorbents for water and wastewater remediation. This review will be an inclusive paper for readers to easily define research gaps and develop novel treatment methods for removing pesticide-contaminated waters.

Soils are polluted by both organic and inorganic substances. Plants growing in polluted soils suffer damages such as leaf rolls, chlorosis, growth inhibition, root tips browning, and death of plant. Soil pollutants such as hydrocarbon and heavy metals are absorbed by crops and such ends up being consumed by human posing health risk like cancer and respiratory abnormally. Conventional methods of remediation such as chemical and physical methods are very expensive and not sustainable. Excavation, which is a type of physical method, merely shifts the pollutant from one site to another. Bioremediation is a biological method of reclaiming polluted soils. Bioremediation is less expensive and more sustainable and safer when compared to the conventional methods of reclamation of polluted environment. This

What is ex situ soil bioremediation?

- Microbially driven process
- Ex situ remediation technique = mobile plant
- Suitable for range of hydrocarbon/organic contaminants
- Once treated, material can be reused onsite if meets site cleanup target(s)
- Cost effective treatment = sustainable?

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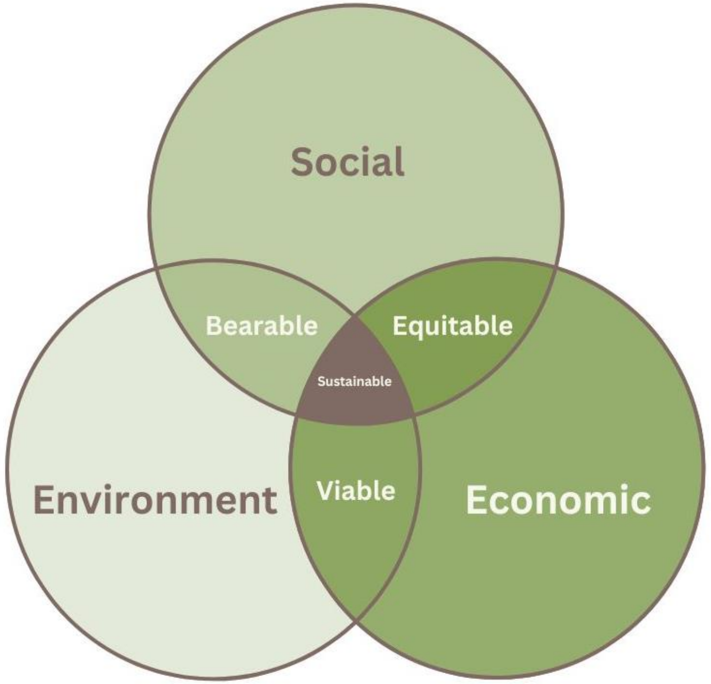
Sustainable remediation - SuRF

- the practice of demonstrating, in terms of environmental, economic and social indicators, that the benefit of undertaking remediation is greater than its impact and that the optimum remediation solution is selected through the use of a balanced decision-making process (SuRF UK, 2010)

Environmental	Social	Economic
Air	Human health and safety	Direct economic costs and benefits
Soil and ground conditions	Ethics and equality	Indirect economic costs and benefits
Groundwater and surface water	Neighbourhood and locality	Employment and employment capital
Ecology	Communities and community involvement	Induced economic costs and benefits
Natural resources and waste	Uncertainty and evidence	Project lifespan and complexity



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Factors affecting the holistic sustainability assessment

- At what point in the project?
- Who is making the assessment?
  - Consultant on behalf of client (awareness of project as a whole)
  - Remediation contractor
- Client/project type
  - Planning system projects
- Stakeholders
- What are contractors being asked for?

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Sustainable remediation – ISO standard

- Elimination and/or control of unacceptable risk in a safe and timely manner whilst optimising the environmental, social and economic value of the work (ISO 18504:2017 - Soil quality: Sustainable remediation)

Qualitative	Semiquantitative	Quantitative
Narrative or ranking e.g., ‘better’, ‘neutral’, ‘worse’ or ‘1’, ‘2’, ‘3’	Quantify some but not all indicators (e.g., quantitative assessment of CO_2 footprint and direct cost)	LCA or environmental (footprint) analysis

Adapted from ISO 18504:2017

(Bio)remediation carbon footprinting

- Develop a simple quantitative tool to determine CO_2 emissions for our ex-situ soil (bio)remediation approach(es)

- Objective – compare CO_2 emissions for a commercial ex situ bioremediation project using actual project data and compare with the theoretical emissions of haulage and landfill disposal

- MSc project – Emmanuel Bello (Teeside University)

Glasgow Commonwealth Games Athletes' village case study

Element	Sub element	kgCO2e	% of total
Staff transport		162120	7.0
Plant total		251499	10.8
	Plant transport	*33341*	
	Plant embodied	*218158*	
Material total		321184	13.8
	Material transport	*88382*	
	Material embodied	*232802*	
Exploratory locations		4394	0.2
Testing		237	0.0
Fuel use total		1588307	68.2
	Fuel delivery	*3401*	
	Plant use (soil washing)	*1027850*	
	Soil washing	*131862*	
	Compound energy	*425193*	
Total		2328171	100%

Adapted from Sampson et al., 2013

- Post project assessment
- 175,000 m^3 (of which 116,000 m^3 treated by soil washed)
- Hypothetical landfill disposal scenario estimated as 14% higher CO_2 emissions
- Models mentioned in the paper no longer publicly available

ERS ex situ bioremediation project – CO_2 emissions

Element	Description	CO_2 emissions (kg)	% of total
1	Haul onsite to treatment area	2896	8.5
2	Screening oversize	1068	3.1
3	Treatment (excavator)	20324	59.9
4	Hauling (extra)	2040	6.0
5	Staff travel to/from site	2185	6.4
6	Nutrient	648	1.9
7	Welfare facilities	4197	12.4
8	Sample testing	90	0.3
9	Supply of biopile covers	473	1.4
Total		33921	

- Post project assessment
- 1500 m^3 material
- Hypothetical haulage for landfill disposal scenario estimated as 4-19% higher CO_2 emissions
- Further developed since this project and applied on wider range of waste/remediation projects including pre-project assessments

Open access CO_2 calculators

This worksheet allows the user to define material production, transportation, equipment use, and residual handling variables for the remedial alternative
Yellow cells require the user to choose an input from a drop down menu
White cells require the user to type in a value

BASELINE INFORMATION

Reset All Values

COMPONENT 1 DURATION AND COST	Entire Site
Input duration of the component (unit time)	1
Input component cost per unit time ($)	

MATERIAL PRODUCTION

WELL MATERIALS	Well Type 1	Well Type 2	Well Type 3	Well Type 4	Well Type 5	Well Type 6	Well Type 7	Well Type 8	Well Type 9	Well Type 10	Well Type 11	Well Type 12
Input number of wells												
Input depth of wells (ft)												
Choose specific casing material schedule from drop down menu	Sch 40 PVC	Sch 40 PVC	Sch 40 PVC	Sch 40 PVC	Sch 40 PVC	Sch 40 PVC	Sch 40 PVC	Sch 40 PVC	Sch 40 PVC	Sch 40 PVC	Sch 40 PVC	Sch 40 PVC
Choose well diameter (in) from drop down menu	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8	1/8
Input total quantity of Sand (kg)												
Input total quantity of Gravel (kg)												
Input total quantity of Bentonite (kg)												
Input total quantity of Typical Cement (kg)												
Input total quantity of General Concrete (kg)												
Input total quantity of Steel (kg)												

TREATMENT CHEMICALS & MATERIALS	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Treatment 5	Treatment 6	Treatment 7	Treatment 8	Treatment 9	Treatment 10	Treatment 11	Treatment 12
Input number of injection points												
Choose material type from drop down menu	Hydrogen Peroxide	Hydrogen Peroxide	Hydrogen Peroxide	Hydrogen Peroxide	Hydrogen Peroxide	Hydrogen Peroxide	Hydrogen Peroxide	Hydrogen Peroxide	Hydrogen Peroxide	Hydrogen Peroxide	Hydrogen Peroxide	Hydrogen Peroxide
Input amount of material injected at each point (pounds dry mass)												
Input number of injections per injection point												

TREATMENT MEDIA	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Treatment 5	Treatment 6	Treatment 7	Treatment 8	Treatment 9	Treatment 10	Treatment 11	Treatment 12
Input weight of media used (lbs)												
Choose media type from drop down menu	Virgin GAC	Virgin GAC	Virgin GAC	Virgin GAC	Virgin GAC	Virgin GAC	Virgin GAC	Virgin GAC	Virgin GAC	Virgin GAC	Virgin GAC	Virgin GAC

CONSTRUCTION MATERIALS	Material 1	Material 2	Material 3	Material 4	Material 5	Material 6	Material 7	Material 8	Material 9	Material 10	Material 11	Material 12
Choose material type from drop down menu	HDPE Liner	HDPE Liner	HDPE Liner	HDPE Liner	HDPE Liner	HDPE Liner	HDPE Liner	HDPE Liner	HDPE Liner	HDPE Liner	HDPE Liner	HDPE Liner
Input area of material (ft2)												
Input depth of material (ft)												

WELL DECOMMISSIONING	Well Type 1	Well Type 2	Well Type 3	Well Type 4	Well Type 5	Well Type 6	Well Type 7	Well Type 8	Well Type 9	Well Type 10	Well Type 11	Well Type 12
Input number of wells												
Input depth of wells (ft)												
Input well diameter (in)												
Choose material from drop down menu	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil	Soil

SILT CURTAIN MATERIALS	Curtain 1	Curtain 2	Curtain 3	Curtain 4	Curtain 5	Curtain 6	Curtain 7	Curtain 8	Curtain 9	Curtain 10	Curtain 11	Curtain 12
Input length or perimeter of silt curtain (ft)												
Input depth of silt curtain (ft)												

Conclusions

- Remediation sustainability assessments are project, time, viewpoint specific
- CO_2 accounting of value to increased number of client types
- Ex situ bioremediation is a cost-effective treatment which can also reduce project CO_2 emissions when compared to landfill disposal
- By going through this process, we are optimising our ex-situ (bio)remediation soil treatment from a CO_2 emissions perspective

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Questions?

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