Application of biosolids-derived biochar for the bioremediation of hydrocarbon-contaminated soil

By

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Outline of Presentation

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1.1 Introduction
- Petroleum Hydrocarbon Contamination

- Massive and widespread use of petroleum hydrocarbon has increased the risk of oil spill (Balseiro-Romero et al., 2018).

Country	Reports	References
Canada	Petroleum hydrocarbon, BTEX, PAHs accounts for at least 50% of the number of active and suspected soils in the Federal contaminated site inventory. *	(Treasury Board of Canada Secretariat, Federal Contaminated Sites Inventory, 2022).
Nigeria	Between 2006 – June 2022, a total of 4102 spills on land related to crude oil and its refined product has been reported.	(National Oil Spill Detection and Response Agency, 2022).
Russia	In 2020 alone, 113 hectares of land was contaminated by petroleum and its derived product.	(Russian Statistical Bulletin as cited by Vasilyeva et al., 2022).

*BTEX: Benzene, Toluene, ethylbenzene and xylene; PAHs: Polycyclic aromatic hydrocarbons

- Impacts the soil, soil biota, animals, plants and human on exposure to contaminated soil.

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1.2 Introduction
- Methods for remediation of hydrocarbon contaminated soil

- Current methods to remove petroleum hydrocarbon:
  - Physicochemical e.g. soil washing, soil extraction;
  - Chemical: e.g. chemical oxidation-reduction, activated carbon
  - Acoustic and ultrasonic: e.g. ultrasound;
  - Thermal/Heat: e.g. incineration;
  - Electric/Electromagnetic: e.g. electrokinetic;

Disadvantages
- Expensive.
- Not environmentally friendly.
- Laborious.
- Sometimes, they only transfer.

- Biological e.g., bioremediation.-can be slow-opportunity for bioaugmentation?

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(Ossai et al., 2020; Xu & Lu, 2010)

2. Literature Review
- Biochar application in remediation -

- Several attempts have been made to assess the effect of biochar in remediation.
- Biochar is a dark and porous carbonaceous material.

Biomass → **High temp. & O_2-free environment**

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Review article

Can biochar be an effective and reliable biostimulating agent for the remediation of hydrocarbon-contaminated soils?

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Review

The co-application of biochar with bioremediation for the removal of petroleum hydrocarbons from contaminated soil

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3. Aim

Examination of the effect of biosolids-derived biochar in the bioremediation of hydrocarbon-contaminated Australian soil

Biochar Production from Biosolids

Heat at 350, 500, & 900$_o$C and a residence time of 3 hours.

Biochar Characterisation
Proximate analysis;
Ultimate analysis;
Surface area, pore volume, and average pore diameter;
pH;
Electrical Conductivity;
Elemental ratios.

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4. Taguchi Experimental Design

Soil Contamination

https://www.ecplaza.net/products/refined-fuel-oil-diesel-en590-diesel_4732846

Experimental Setup

Run	Biochar pyrolysis temp. (°C)	Biochar dose (%)	Fertiliser dose (%)
L1	350	2	0
L2	350	5	1
L3	350	10	2
L4	500	2	1
L5	500	5	2
L6	500	10	0
L7	900	2	2
L8	900	5	0
L9	900	10	1
L10 (Control) [a]	-	-	-
Clean [b]	-	-	-

[a]Diesel-contaminated soil; [b]Uncontaminated soil

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5. 1 Results – TPH removal

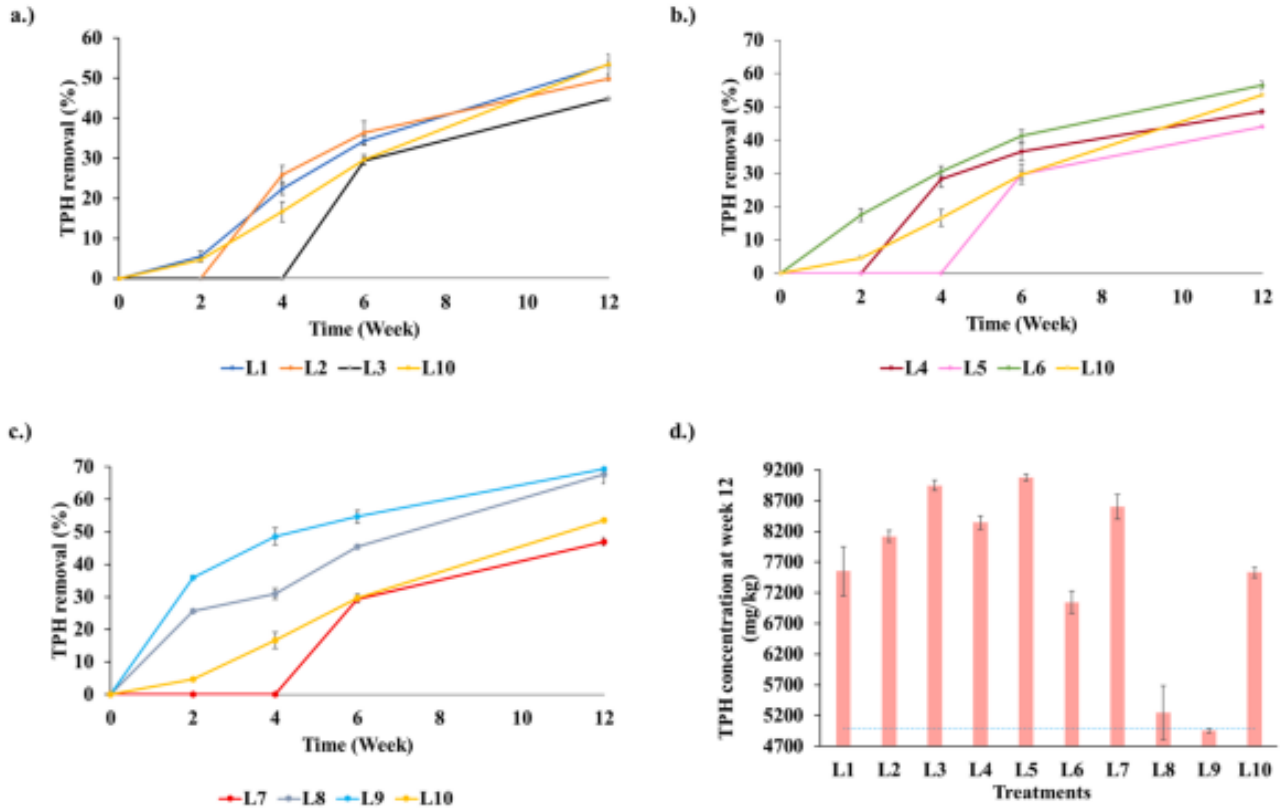

Fig. 1. TPH removal over 12 weeks for a.) L1-L3; b.) L4-L6; c.) L7-L9 in comparison to L10 (control); d.) Residual TPH concentration for treatments L1-L10 at week 12. With exception to week 0 in Figs. 1a-1c, values are the mean of three replicates in the four figures, while the error bar represents the standard deviation of the mean. The blue dotted line in the Fig. 1d represents the maximum TPH threshold value for Category D soil waste (5000 mg/kg), based on EPA Victoria Guidelines. L1: 350/2/0; L2: 350/5/1; L3: 350/10/2; L4: 500/2/1; L5: 500/5/2; L6: 500/10/0; L7: 900/2/2; L8: 900/5/0; L9:900/10/1; L10: Diesel contaminated control; The key in biochar treatments are interpreted as pyrolysis temperature/biochar application dose/fertiliser application dose as per Table S2.

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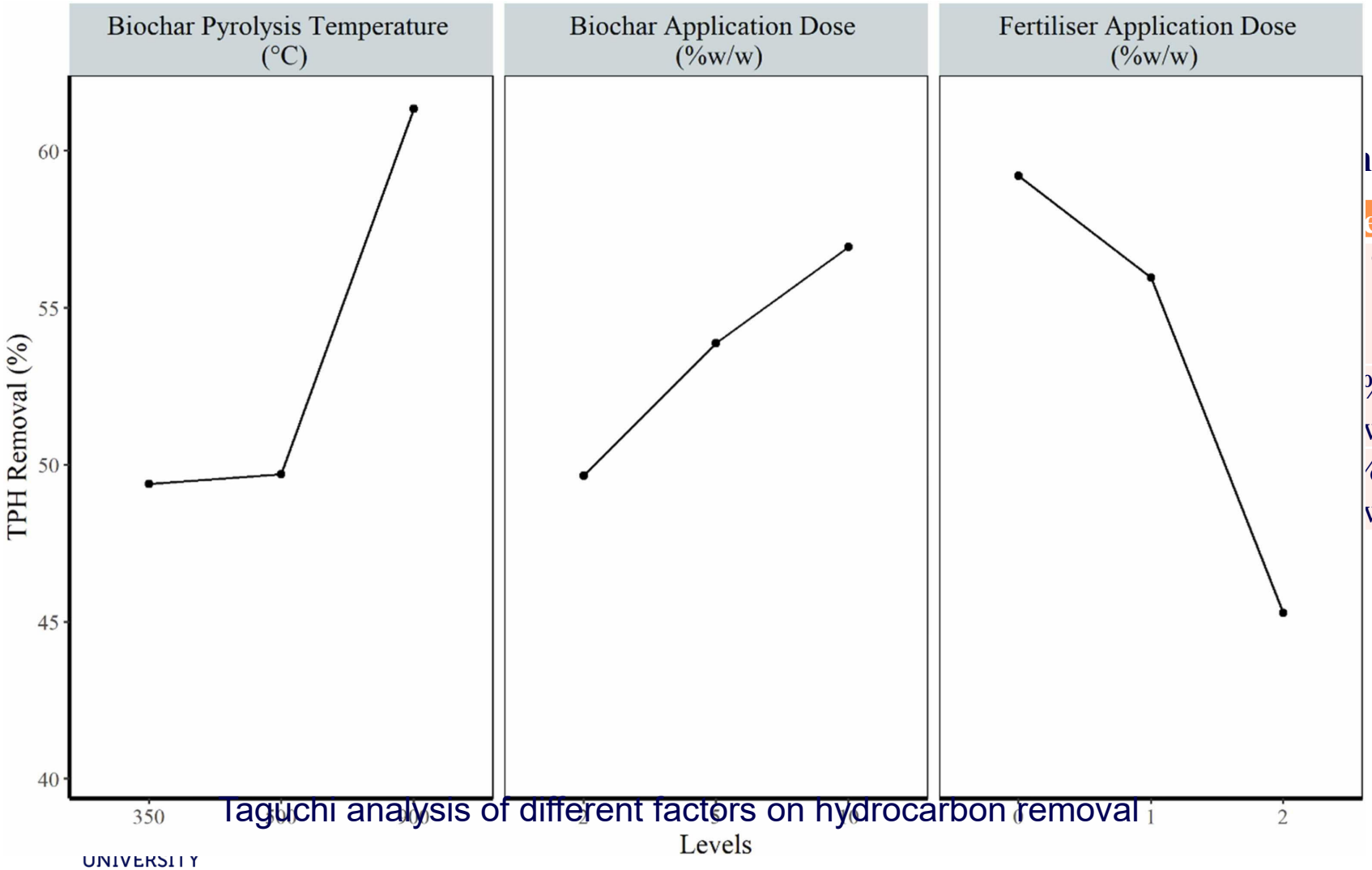
5.2 Results-Taguchi analysis



Taguchi analysis of different factors on hydrocarbon removal

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Dike et al. (2022)

5.3 Results-Biochar analysis

Table 1 : Properties of biochar at different temperatures

Properties	Pyrolysis Temperature (°C) 350	500	900
Surface area (m^2/g)[b]	2.25	24.46	108.75
Total pore volume (cm^3/g)[b]	0.0070	0.036	0.13
Average pore diameter (nm)[b]	3.05	3.80	3.80
pH	7.54 ± 0.001	7.57 ± 0.0007	6.75 ± 0.13
Proximate analysis (wt% d.b)[c]			
Moisture content (%)	2.36 ± 0.46	3.78 ± 0.59	2.95 ± 0.40
Volatile matter (%)	24.67 ± 1.75	15.54 ± 1.54	5.07 ± 0.38
Fixed carbon (%)	32.11 ± 1.69	30.38 ± 2.12	28.42 ± 1.26
Ash content (%)	40.72 ± 0.23	50.47 ± 0.32	63.60 ± 1.82
Elemental analysis (wt% d.b)			
Carbon (%)	34.11 ± 1.45	32.51 ± 0.59	26.27 ± 3.79
Hydrogen (%)	2.82 ± 0.24	1.43 ± 0.042	0.42 ± 0.035
Oxygen (%)[d]	17.02 ± 1.26	10.30 ± 0.47	8.49 ± 3.82
Nitrogen (%)	5.34 ± 0.05	5.29 ± 0.17	1.23 ± 0.0071

[b]Not analysed in duplicate; [c]d.b-dry basis; [d]obtained by difference 100-(C+H+N+Ash). Unless otherwise stated, values are the mean of at least duplicate measurements, while the error bar when stated represents the standard deviation of the mean.**(Dike et al. 2022)**

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6. Conclusions

- The study showed that generally, the addition of biochar enhanced the removal of petroleum hydrocarbons from contaminated soils.
- At the end of incubation (12 weeks), the TPH concentration in the best biochar treatment was lower than the EPA Victoria maximum threshold for Category D waste (5000 mg/kg);
- Taguchi analysis showed that biochar pyrolysis temperature, biochar application dose and fertiliser dose affected hydrocarbon removal.
- Overall, this study confirms the potential of biosolids derived biochar in enhancing bioremediation and reducing soil toxicity.
- This study further demonstrates the need for the biosolids-derived biochar production and application conditions to be selected carefully.
- The application od biochar to bioremediation of TPH impacted soils has been demonstrated in a Pilot Scale Trial in Singapore.
- Discussions are underway to conduct a similar study in the US.

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Biosolids-derived biochar can enhance the bioremediation of diesel-contaminated soil

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Biosolids-derived biochar enhances the bioremediation of diesel-contaminated soil

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