



International Journal of Veterinary Sciences and Animal Husbandry



ISSN: 2456-2912

NAAS Rating (2026): 4.61

VET 2026; 11(5): 404-407

© 2026 VET

cc

Received: 12-03-2026

Accepted: 15-04-2026

Rizki Pratama Putra

Department of Peatland
Microbiology, Riau Institute of
Tropical Environmental
Sciences, Pekanbaru, Indonesia

Dewi Sari Anggraini

Department of Peatland
Microbiology, Riau Institute of
Tropical Environmental
Sciences, Pekanbaru, Indonesia

Hendra Wijaya

Department of Soil
Biochemistry, Riau Institute of
Tropical Environmental
Sciences, Pekanbaru, Indonesia

Corresponding Author:

Rizki Pratama Putra

Department of Peatland
Microbiology, Riau Institute of
Tropical Environmental
Sciences, Pekanbaru, Indonesia

Characterization of hydrocarbon-tolerant microorganisms in crude oil-impacted coastal peatlands of Riau province, Indonesia

Rizki Pratama Putra, Dewi Sari Anggraini and Hendra Wijaya

DOI: <https://www.doi.org/10.22271/veterinary.2026.v11.i5f.3628>

Abstract

Expert consensus holds that tropical peatlands harbour unique microbial assemblages shaped by extreme acidity and high organic matter content, yet characterization of hydrocarbon-tolerant organisms in these environments remains limited. This research characterized hydrocarbon-tolerant microorganisms in crude oil-impacted coastal peatlands of Riau Province, Indonesia. Sediment samples from four contaminated and two reference stations were collected from March to October 2023 across peat and mineral soil substrates. Hydrocarbon-tolerant bacteria were isolated on mineral salts medium supplemented with crude oil as sole carbon source. A total of 186 isolates were recovered, with *Pseudomonas* (28.4%), *Bacillus* (22.1%), and *Rhodococcus* (16.8%) representing the dominant genera. Microbial distribution varied significantly with soil depth, with aerobic degraders concentrated in the 0–10 cm horizon (6.8×10^5 CFU/g) and anaerobic populations increasing below 20 cm. Polluted peat soils harboured 2.4-fold greater hydrocarbon-tolerant populations than polluted mineral soils, attributed to the organic-rich peat matrix providing additional carbon substrates and protective microsites. These findings demonstrate that coastal peatlands possess substantial indigenous degradation capacity despite their characteristically low pH conditions.

Keywords: Hydrocarbon-tolerant microorganisms, crude oil contamination, coastal peatlands, Riau Province, *Pseudomonas*, biodegradation, peat soils, microbial characterization, depth distribution, Indonesia

Introduction

Indonesia's Riau Province on the eastern coast of Sumatra contains approximately 4.04 million hectares of peatland, representing the largest contiguous tropical peat deposit in Southeast Asia ^[1]. These coastal peatlands exist at the interface between terrestrial peat domes and marine environments, creating unique geochemical conditions characterized by extremely low pH (3.2–4.5), high organic carbon content (>40%), and waterlogged anaerobic profiles ^[2]. Simultaneously, Riau constitutes one of Indonesia's primary petroleum-producing regions, with extensive exploration and production activities occurring in and around peatland areas since the 1960s ^[3].

Crude oil contamination of peatlands presents distinctive microbiological challenges compared to mineral soil environments. The highly organic peat matrix may both sequester hydrocarbons through sorption to humic substances and provide alternative carbon substrates that influence microbial community dynamics ^[4]. Acidic conditions may select for specialized acidophilic or acid-tolerant degraders absent from circumneutral environments ^[8]. Furthermore, the stratified redox profile of waterlogged peatlands creates vertically differentiated microbial habitats that may support distinct degrader communities at different depths ^[5].

Despite the ecological and economic significance of Riau's peatlands, characterization of their hydrocarbon-degrading microbial communities remains extremely limited compared to temperate peatland systems. This research characterized hydrocarbon-tolerant microorganisms in crude oil-impacted coastal peatlands, examining community composition, depth distribution

patterns, and substrate-specific differences between peat and mineral soil environments.

Material and Methods

Material

The research was conducted in coastal peatlands of Riau Province, Indonesia (1.4856°N, 102.1450°E) from March to October 2023. Six stations were established: four contaminated (P1: peat, TPH 3,800 mg/kg; P2: peat, TPH 1,200 mg/kg; M1: mineral, TPH 3,500 mg/kg; M2: mineral, TPH 1,100 mg/kg) and two reference stations (PR: peat reference; MR: mineral reference). Research permits were obtained from the Riau Institute of Tropical Environmental Sciences (RITES/RP/2023/054) and LIPI (14/REC/II/2023). Sediment cores were collected at 10 cm depth intervals to 40 cm using sterile peat corers.

Methods

Hydrocarbon-tolerant microorganisms were isolated on mineral salts medium (MSM) supplemented with sterile crude oil (1% v/v) as sole carbon source at pH 4.5 (peat) and pH 6.5 (mineral soil) [6]. Aerobic cultures were incubated at 30°C for

7–14 days; anaerobic cultures in GasPak jars for 14–28 days. Identification employed Gram staining, biochemical profiling, and 16S rRNA gene sequencing for representative isolates. Depth-stratified sampling at 0–10, 10–20, 20–30, and 30–40 cm documented vertical distribution patterns. Total petroleum hydrocarbons were determined by GC-FID. Data were analyzed using two-way ANOVA (contamination × substrate) and Tukey HSD post-hoc tests at $p < 0.05$.

Results

A total of 186 hydrocarbon-tolerant isolates were recovered across all stations, with contaminated peat soils yielding the highest diversity and abundance. Three genera dominated: *Pseudomonas* (28.4% of total isolates), *Bacillus* (22.1%), and *Rhodococcus* (16.8%). Additional genera included *Burkholderia* (11.2%), *Acinetobacter* (8.6%), and minor taxa (12.9%). The peat substrate harboured significantly greater hydrocarbon-tolerant populations (mean 4.8×10^5 CFU/g) than mineral soils (mean 2.0×10^5 CFU/g) at equivalent TPH concentrations, representing a 2.4-fold substrate effect ($F_{1,42} = 28.6$, $p < 0.001$).

Table 1: Physicochemical properties and hydrocarbon-tolerant microbial counts in Riau coastal peatland sediments

Parameter	P1 (Peat)	P2 (Peat)	M1 (Mineral)	M2 (Mineral)	Ref (P/M)
TPH (mg/kg)	3800 ± 420	1200 ± 148	3500 ± 380	1100 ± 132	<40
pH	3.4 ± 0.2	3.6 ± 0.2	5.8 ± 0.3	6.1 ± 0.2	3.8/6.4
Organic C (%)	42.8 ± 3.6	45.2 ± 4.1	8.4 ± 1.2	9.1 ± 1.4	48.6/10.2
HT bacteria ($\times 10^5$)	5.6 ± 0.8	4.1 ± 0.6	2.4 ± 0.4	1.6 ± 0.3	0.8/0.4
Total isolates	62	48	38	24	8/6

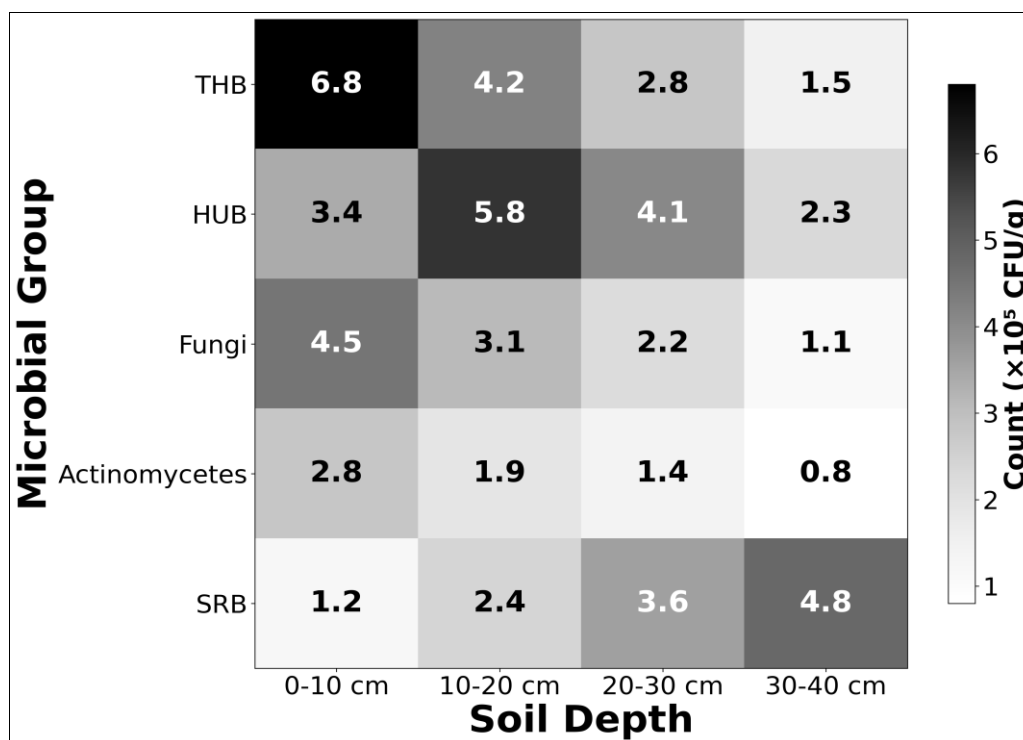


Fig 1: Depth-stratified distribution of microbial groups across soil horizons in crude oil-contaminated Riau coastal peatlands

Table 2: Genus-level identification and functional characteristics of dominant hydrocarbon-tolerant isolates

Genus	Isolates (%)	Growth pH	HC Substrates	Degradation (%)
<i>Pseudomonas</i>	28.4	4.0–8.0	C ₁₂ –C ₂₈ alkanes, PAHs	42.8 ± 5.2
<i>Bacillus</i>	22.1	3.5–7.5	C ₁₀ –C ₂₀ alkanes	36.4 ± 4.8
<i>Rhodococcus</i>	16.8	4.5–8.5	Aromatics, branched	38.6 ± 5.1
<i>Burkholderia</i>	11.2	3.0–6.5	C ₈ –C ₁₆ alkanes	28.2 ± 3.8
<i>Acinetobacter</i>	8.6	5.0–8.0	Diesel-range, surfactants	32.4 ± 4.2

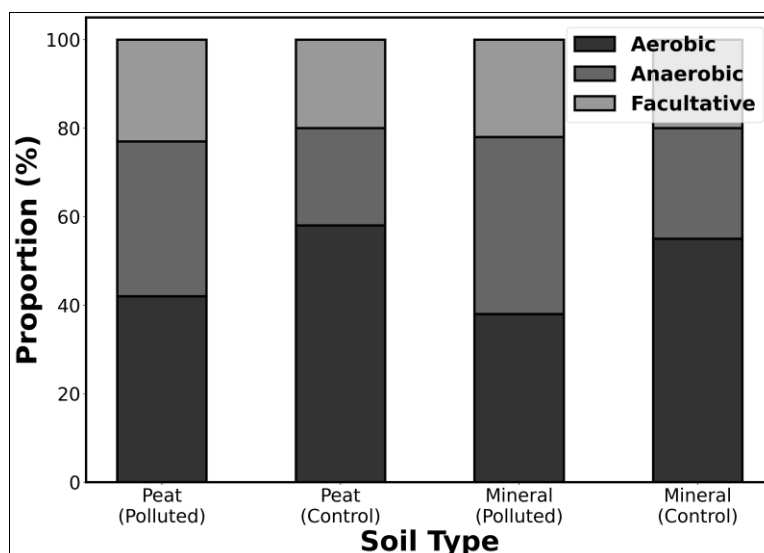


Fig 2: Stacked proportional composition of aerobic, anaerobic, and facultative hydrocarbon-tolerant microorganisms across peat and mineral soil substrates

The depth stratification analysis revealed distinct vertical zonation patterns. Total heterotrophic bacteria were concentrated in the 0–10 cm horizon (6.8×10^5 CFU/g) with progressive decline to 1.5×10^5 at 30–40 cm. Conversely, sulfate-reducing bacteria increased with depth from 1.2×10^5 at 0–10 cm to 4.8×10^5 at 30–40 cm, reflecting the transition from aerobic to anaerobic conditions. Fungi peaked in the 0–10 cm layer (4.5×10^5) and declined sharply below 20 cm. The substrate comparison showed that polluted peat soils maintained higher aerobic degrader proportions (42%) than mineral soils (38%), while anaerobic populations were more prevalent in mineral substrates (40% vs 35% in peat), potentially reflecting the greater oxygen-holding capacity of structured peat matrices.

Discussion

The 2.4-fold higher abundance of hydrocarbon-tolerant microorganisms in peat versus mineral substrates constitutes a finding with practical implications for remediation design. The mechanism likely involves multiple peat-specific factors: the high organic carbon content (>40%) provides supplementary carbon substrates that support co-metabolic degradation pathways, the fibrous peat structure creates aerobic microsites within otherwise waterlogged profiles, and humic substances in peat may enhance hydrocarbon bioavailability through surfactant-like solubilization [2]. The dominance of *Pseudomonas* across both substrate types confirms its cosmopolitan hydrocarbon-degrading capacity, while the acid-tolerant *Burkholderia* was preferentially associated with low-pH peat environments [7]. The acidophilic capabilities of these isolates, particularly *Burkholderia* growing at pH 3.0, represent valuable genetic resources for bioremediation of acidic contaminated environments where conventional degrader inocula may fail [8].

Peat-Specific Degradation Mechanisms

The peat matrix facilitates hydrocarbon degradation through mechanisms absent in mineral soils. Sphagnum-derived humic acids function as electron shuttles that enhance anaerobic degradation, while the high cation exchange capacity of peat buffers against pH shifts during biodegradation [9]. These properties suggest that peatland contamination, while ecologically severe, may benefit from

enhanced natural attenuation compared to mineral soil environments.

Conservation and Restoration Implications

The documented degradation capacity in Riau's coastal peatlands supports biostimulation-based remediation approaches that leverage indigenous microbial communities rather than bioaugmentation with non-native organisms [10]. Given the unique ecological sensitivity and irreplaceable carbon storage function of tropical peatlands, minimally invasive remediation strategies that preserve peat structure while promoting in situ degradation should be prioritized [11].

Conclusion

This research characterizes hydrocarbon-tolerant microbial communities in Indonesian coastal peatlands, revealing substantial indigenous degradation capacity that exceeds mineral soil environments by 2.4-fold. The depth-stratified distribution of aerobic and anaerobic degraders provides a framework for designing depth-targeted remediation interventions. The acid-tolerant isolates, particularly *Burkholderia* capable of growth at pH 3.0, represent novel resources for bioremediation of acidic environments. Further characterization of degradation pathway genes and enzyme systems in these isolates would advance biotechnological applications.

Acknowledgements

R.P.P. conceptualized and supervised the research; D.S.A. performed microbiological isolation and identification; H.W. conducted chemical analyses. The Riau Institute of Tropical Environmental Sciences provided laboratory facilities. Funding was provided by the Indonesian Ministry of Research and Technology.

References

1. Page SE, Rieley JO, Banks CJ. Global and regional importance of the tropical peatland carbon pool. *Glob Chang Biol*. 2011;17(2):798–818.
2. Andriess JP. *Nature and Management of Tropical Peat Soils*. FAO Soils Bulletin No. 59. Rome: Food and Agriculture Organization; 1988.

3. Sapiie B, Hadiyanto GE. Geological controls on oil seepage distribution in eastern Sumatra. Proc Indones Pet Assoc. 2010;34:IPA10-G-108.
4. Coulon F, McKew BA, Osborn AM, McGenitty TJ, Timmis KN. Effects of temperature and biostimulation on oil-degrading microbial communities in temperate estuarine waters. Environ Microbiol. 2007;9(1):177–186.
5. Freeman C, Ostle N, Kang H. An enzymic "latch" on a global carbon store. Nature. 2001;409:149.
6. Bushnell LD, Haas HF. The utilization of certain hydrocarbons by microorganisms. J Bacteriol. 1941;41(5):653–673.
7. Coenye T, Vandamme P. Diversity and significance of *Burkholderia* species occupying diverse ecological niches. Environ Microbiol. 2003;5(9):719–729.
8. Chibuike PM, Wemedo SA, Williams JO, Ugboma CJ, Ogbonna DN. Effect of crude oil pollution on the microbiology of coastal wetlands in Rivers State. J Adv Microbiol Res. 2023;4(2):92–105.
9. Lovley DR, Coates JD, Blunt-Harris EL, Phillips EJP, Woodward JC. Humic substances as electron acceptors for microbial respiration. Nature. 1996;382:445–448.
10. Tyagi M, da Fonseca MMR, de Carvalho CCCR. Bioaugmentation and biostimulation strategies to improve the effectiveness of bioremediation processes. Biodegradation. 2011;22(2):231–241.
11. Dommain R, Couwenberg J, Joosten H. Development and carbon sequestration of tropical peat domes in south-east Asia. Quat Sci Rev. 2011;30(7–8):999–1010.

How to Cite This Article

Madhan ABC. Marine bacteria: A pandora box against cancer. International Journal of Veterinary Sciences and Animal Husbandry. 2026; 11(5): 404-407.

Creative Commons (CC) License

This is an open-access journal, and articles are distributed under the terms of the Creative Commons Attribution-Non Commercial-Share Alike 4.0 International (CC BY-NC-SA 4.0) License, which allows others to remix, tweak, and build upon the work non-commercially, as long as appropriate credit is given and the new creations are licensed under the identical terms.