NUMERICAL DATA

New insights into bioremediation strategies for oil-contaminated soil in cold environments (2019)

Cold-adaptive microorganisms for potent application in bioaugmentation.

Microorganisms	Hydrocarbon contaminants	Removal rates	References
1. For Consortia-Bioaugmentation:			
Pseudomonas G2-2; Pseudomonas G1-10; Pseudomonas Y1-4; Pseudomonas Gwa2; Pseudomonas Gwa5; Rhodococcus Y2-2;	crude oil, TPH	70.0–100.0%	Pham et al. (2014); Jeong et al. (2015)
Rhodococcus MS11	alkanes, chlorinated benzene	ND	Rapp and Gabriel-Jürgens (2003)
Roseovarius NS163; Halomoans NS159; Glaciecola NS168	crude oil, TPH, PAH	ND	Chronopoulou et al. (2015)
Sphingomonas Ant 20; Sphingomonas 43/03; Sphingomonas 44/02	phenanthrene, naphthalene, jet fuel	ND	Aislabie et al. (2000); Saul et al. (2005)
Pseudomonas ST41; Pseudomonas SB45	crude oil	45.0–100.0%	Stallwood et al. (2005)
Chryseobacterium X6; Bacillus GS0; Pseudomonas GS5	petroleum oil	62.3%; 61.6%;60.9%	Wang et al. (2016)
Rhodococcus ADH; Rhodococcus DM-21; Rhodococcus DM-22	alkanes, cyclohexane, crude oil, aromatic hydrocarbons, jet fuel	81.1%	Ruberto et al. (2005)
Rhodococcus erythropolis BZ4; Rhodococcus cercidiphyllus BZ22; Arthrobacter sulfureus BZ73; Pimelobacter simplex BZ91	n-alkanes, phenol, anthracene, pyrene	69.0%–92.0%	Margesin et al. (2013)
2. For Recombinant-Bioaugmentation:			
Pseudoalteromonas haloplanktis TAC125	benzene, toluene, phenol, xylene, naphthalene	ND	Parrilli et al. (2010)
Pseudomonas RE	2,4-Dinitrotoluene	90.0%	Monti et al. (2005)
3. For Biosurfactant-Bioaugmentation			
Pseudomonas G2-2; Rhodococcus Y2-2	crude oil, TPH	90.6%; 80.0%	Pham et al. (2014); Pham et al. (2018)
Pseudoalteromonas 93; Pseudomonas 235; Pseudomonas 280; Rhodococcus 176; Rhodococcus 179; Idiomarina 185	tetradecane, sunflower oi	ND	Malavenda et al. (2015)
Rhodococcus phenolicus N1–1P; Bacillus subtilis N2–3P; Rhodococcus erythropolis N2–4P; Rhodococcus erythropolis P6–5P; Pseudomonas peli N3–6P; Streptomyces venezuelae N3-6A; Halomonas variabilis N3-8A; Alcanivorax venustensis N3-7A; Exiguobacterium antarcticum N4–1P; Acinetobacter oleivorans P7-1A; Acinetobacter calcoaceticus P9-1A	petroleum hydrocarbons	ND	Cai et al. (2014)

ND: data not available

Source: https://sci-hub.tw/10.1016/j.ibiod.2019.05.001

Bioremediation of heavy metals by microbial process (2019)

GEMs that are used in heavy metal bioremediation.

Microbes	Modified gene expression	Heavy metals	References
Sphingomonas desiccabilis and Bacillus Idriensis strains	Over expression of arsM gene	Arsenic	Liu et al. (2011)
B. subtilis BR151 (pTOO24)	Luminescent Cadmium sensors	Cadmium	Ivask et al. (2011)
Methylococcus capsulatus (Bath)	CrR genes for Cr (VI) reductase activity	Chromium(VI)	Hasin et al. (2010)
Caulobacter crescentus JS4022/p723–6H	RsaA-6His fusion protein	Cadmium(II)	Patel et al. (2010)
Pseudomonas strain K-62	MerE protein encoded by transposon Tn21	Mercury	Kiyono et al. (2009)
Achromobacter sp AO22	Mercury reductase expressing mer gene	Mercury	Ng et al. (2009)
E. coli strain	Metallothionein	Arsenic	Singh et al. (2008)
E. coli strain	AsIII S-adenosylmethionine methyltransferase gene	Arsenic	Yuan et al. (2008)
Pseudomonas fluorescens OS8; Escherichia coliMC1061; Bacillus subtilisBR151; Staphylococcus aureus RN4220	MerR/CadC/ZntR/Pmer/PcadA/PzntA	Cadmium, Lead, Mercury, Zinc.	Bondarenko et al. (2008)
E .coli strain	PCS gene expression (SpPCS)	Cd2+	Kang et al. (2007)
E. coli JM109	Cadmium transport system and metallothionein	Cadmium	Deng et al. (2007)
P. putida 06909	Expression of metal binding peptide EC20	Cadmium	Wu et al. (2006)
Pseudomonas K-62	Expression of mercury transport system and Organomurcuriallyase	Mercury	Kiyono and Pan-Hou (2006)
E. coli SE5000	Nickel transport system and metallothionein	Nickel	Deng et al. (2005)
E. coli JM109	Hg2+ transporter and metallothionein	Mercury	Zhao et al. (2005)
E .coli strain	Over expression of Serin acetyl transferase	Nickel and cobalt	Freeman et al. (2005)
Acidithiobacillus ferrooxidans	Mercury ion transporter gene expression	Mercury	Sasaki et al. (2005)
E. coli	Metalloregulatory protein ArsR (over expressing ELP153AR)	Arsenic	Kostal et al. (2004)
Escherichia coli and Moraxella sp.	Expressing EC20	Mercury and Cadmium	Bae et al. (2003)
Mesorhizobium huakuii B3	Phytochelatin synthase (PCS) gene expression	Cd2+	Sriprang et al. (2003)
E. coli strain	Organomurcuriallyase gene expression	Mercury	Murtaza et al. (2002)
P. fluorescens 4F39	Nickel transport system	Nickel	Lopez et al. (2002)
Deinococcus radiodurans	Hg (II) resistance gene (merA)	Mercury (Radioactive waste from nuclear weapons)	Brim et al. (2000)

Source: https://sci-hub.tw/10.1016/j.eti.2019.100369

Rhamnolipid-enhanced solubilization and biodegradation of PAHs in soils after conventional bioremediation (2019)

Effect of the rhamnolipid on the biodegradation of PAHs in suspensions of soil 1.

PAH concentration (mg kg $^{-1}$)	Initial[a]	Predicted[b]	Control[c]	Rhamnolipid[d]
Phenanthrene	843.1 ± 17.2	224.3	11.9 ± 0.9	7.2 ± 0.5
Anthracene	264.9 ± 12.6	105.7	20.9 ± 1.9	5.5 ± 0.6
Fluoranthene	1246.6 ± 25.0	882.6	9.2 ± 1.1	6.2 ± 1.0
Pyrene	362.0 ± 28.6	187.9	9.0 ± 1.8	11.5 ± 5.9
Benzo(a)pyrene	56.5 ± 0.9	47.1	20.2 ± 1.8	23.5 ± 1.4
∑PAH[e]	2773.2 ± 84.3	1447.6	71.3 ± 7.6	53.9 ± 9.5

[a] Initial PAH concentration.
[b] Predicted concentration assuming that biodegradation acted only on fast-desorption PAHs.
[c] Final concentration obtained without rhamnolipid.
[d] Final concentration obtained with the rhamnolipid (1 g L $^{-1}$).
[e] Sum of five PAH: phenanthrene, anthracene, fluoranthene, pyrene and benzo(a)pyrene.
Source: https://sci-hub.tw/10.1016/j.scitotenv.2019.03.056

Phytoremediation: Halophytes as Promising Heavy Metal Hyperaccumulator (2018)

Examples of phytoremediation studies using species belong to Qatari flora and/or their relatives.

Sl. No.	Plant species	Metal (s)	Metal accumulation (mg/kg)
1	Atriplex halimus subsp. schweinfurthii	Cadmium	606.51
2	A. halimus L.	Cadmium	830
		Zinc	44
3	Arthrocnemum macrostachyum	Lead	620
4	Crucianella maritima	Zinc	390
5	Dittrichia viscosa	Lead	270
6	Tamarix smyrnensis Bunge	Lead	800
		Cadmium	800
7	Typha domingensis	Selenium	30
		Lead	59.13
8	T. lotifolia L	Cadmium	210
9	Paspalum conjugatum L. Prosopis laevigata	Lead	150

Source:https://www.researchgate.net/publication/326050399_Phytoremediation_Halophytes_as_Promising_Heavy_Metal_Hyperaccumulators

Sustainable remediation of heavy metal polluted soil: A biotechnical interaction with selected bacteria species (2017)

Table 1: Initial and residual mean concentrations of heavy metals from the bioremediation of leachate contaminated soil.

Heavy metals	**Initial concentrations (mg/kg)**	**Mean residual concentrations (mg/kg) and level of reduction (%)**			
		Treatment A		Treatment B	
Al	51,200	14,143	72%	20,967	59%
Cd	1.70	1.00	41%	1.00	41%
Cu	24.10	3.00	88%	11.00	54%
Mn	129	45.00	65%	98.00	24%
Pb	206.8	60	71%	121	41%

Source:https://www.researchgate.net/publication/308961124_Sustainable_remediation_of_heavy_metal_polluted_soil_A_biotechnical_interaction_with_selected_bacteria_species

Sustainable remediation of heavy metal polluted soil: A biotechnical interaction with selected bacteria species

Heavy metals removal rate constants and half-life.

Heavy metals	Treatment A (TA)			Treatment B (TB)		
	Removal rate constant (K) (day^{-1})	Half-life ($t_{1/2}$) (days)		Removal rate constant (K) (day^{-1})	Half-life ($t_{1/2}$) (days)	
Al	0.0127	54.59		0.0089	77.88	
Cd	0.0053	130.78		0.0053	130.78	
Cu	0.0212	32.7		0.0078	88.87	
Mn	0.0105	66.01		0.0027	256.72	
Pb	0.0124	58.9		0.0053	130.78	

Source:https://www.researchgate.net/publication/308961124_Sustainable_remediation_of_heavy_metal_polluted_soil_A_biotechnical_interaction_with_selected_bacteria_species

Bioremediation techniques–classification based on site of application: principles, advantages, limitations and prospects (2016)

Some plants with phytoremediation potentials					
Plant	**Nature of pollutant**	**Initial concentration**	**Mechanism of removal**	**% Removal**	**Reference**
Ludwigia octovalvis	Gasoline	2,07,800 mg/kg TPH	Biosurfactant enhanced rhizodegradation	93.5	Almansoory et al. (2015)
Aegiceras corniculatum	Brominated diphenyl ethers (BDE-47)	5 lg/gdw	Biostimulated degradation	58.2	Chen et al. (2015)
Spartina maritima	As, Cu, Pb, Zn	5–2153 mg/kg	Bioaugmented rhizoaccumulatio n	19–65	Mesa et al. (2015)
Arundo donax	Cd and Zn	78.9 and 66.6 kBq/ dm^3 respectively	Rhizofiltration	100	Du¨resˇova´ et al. (2014)
Eichhorina crassipes (water	Heavy metals (Fe, Zn,	0.02–20 mg/L	Rhizofiltration	99.3	Elias et al. (2014)
hyacinth)	Cd, Cu, B, and Cr)				
Phragmites australis	PAHs	229.67 ± 15.56 lg/g	Rhizodegradatio n	58.47	Gregorio et al. (2014)
Plectranthus amboinicus	Pb	5–200 mg/kg	Rhizofiltration	50–100	Ignatius et al. (2014)
Luffa acutangula	Anthracene and fluoranthene	50 mg/kg	Phytostimulation a	85.9–99.5	Somtrakoon et al. (2014)
Dracaena reflexa	Diesel	1–5 wt%	Rhizodegradatio n	90–98	Dadrasnia and Agamuthu (2013)
Sparganium sp.	Polychlorinated biphenyls	6.260 ± 9.3 10^{-3} lg/g	Biostimulated	91.5	Gregorio et al. (2013)
			rhizodegradation		
Amaranthus paniculatus	Ni	25–150 lM	Phytoaccumulati on	25–60	Iori et al. (2013)
Rizophora mangle	TPH	33,215.16 mg/kg	Phytoextraction and phytostimulation	87	Moreira et al. (2013)
Populusdeltoides x nigra and Arabidopsis thaliana	Silver nanoparticles and Ag	0.01–100 mg/L	Phytoaccumulati on	20–70	Wang et al. (2013)
Carex pendula	Pb	1.0–10 mg/L	Rhizofiltration		Yadav et al. (2011)

PAHs polyaromatic hydrocarbons, TPH total petroleum hydrocarbon

[a] Hypothetical, needs further investigation

Source: https://link.springer.com/article/10.1007/s11274-016-2137-x