Electronic Supplementary Material (ESI) for Environmental Science: Processes & Impacts.

Supplementary Material

Potential risks of antibiotic resistant bacteria and genes in bioremediation of petroleum hydrocarbon contaminated soils

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Table S1. Abundance of ARGs in most important hydrocarbon-degrading *Actinobacteria* genera (totally 13 genera, 851 species)

ARGs	Target antibiotics	Resistance mechanism/gene family	*Actinobacteria* genera – number of ARG-carrying species	Total number of ARG-carrying species
marR	Multidrug	Antibiotic target alteration, antibiotic efflux/resistance-nodulation-cell division (RND) antibiotic efflux pump	*Actinomyces* – 43; *Arthrobacter* – 21; *Corynebacterium* – 100; *Dietzia* – 8; *Gordonia* – 29; *Micrococcus* – 4; *Micromonospora* – 52; *Mycobacterium* – 76; *Nocardioides* – 21; *Nocardia* – 78; *Pseudonocardia* – 9; *Rhodococcus* – 30; *Streptomyces* – 314	785
acrR (tetR)	Multidrug	Antibiotic target lteration, antibiotic efflux/resistance-nodulation-cell division (RND) antibiotic efflux pump	*Actinomyces* – 41; *Arthrobacter* – 17; *Corynebacterium* – 93; *Dietzia* – 12; *Gordonia* – 30; *Micrococcus* – 3; *Micromonospora* – 52; *Mycobacterium* – 76; *Nocardioides* – 21; *Pseudonocardia* – 9; *Rhodococcus* – 27; *Streptomyces* – 317	698
rarD	Chloramphenicol	Antibiotic efflux/predicted chloramphenicol resistance permease	*Actinomyces* – 31; *Arthrobacter* – 20; *Corynebacterium* – 74; *Dietzia* – 8; *Gordonia* – 11; *Micrococcus* – 3; *Micromonospora* – 51; *Mycobacterium* – 9; *Nocardioides* – 18; *Nocardia* – 66; *Pseudonocardia* – 8; *Rhodococcus* – 26; *Streptomyces* – 262	587
aph	Aminoglycosides	Antibiotic inactivation/ aminoglycoside *O*-phosphotransferase (APH)	*Actinomyces* – 26; *Arthrobacter* – 13; *Corynebacterium* – 55; *Dietzia* – 5; *Gordonia* – 7; *Micrococcus* – 2; *Micromonospora* – 48; *Mycobacterium* – 48; *Nocardia* – 70; *Pseudonocardia* – 9; *Rhodococcus* – 13; *Streptomyces* – 277	573
sul1	Sulfonamides and sulfones	Antibiotic target replacement/ sulfonamide resistant dihydropteroate synthase	*Actinomyces* – 4; *Arthrobacter* – 17; *Corynebacterium* – 54; *Dietzia* – 7; *Gordonia* – 26; *Micrococcus* – 3; *Micromonospora* – 41; *Mycobacterium* – 63; *Nocardioides* – 17; *Nocardia* – 62; *Pseudonocardia* – 8; *Rhodococcus* – 18; *Streptomyces* – 253	573
msrA	MLSB	Antibiotic target protection/ABC-F ATP-binding cassette ribosomal protection protein	*Actinomyces* – 39; *Arthrobacter* – 12; *Corynebacterium* – 98; *Dietzia* – 8; *Gordonia* – 28; *Micrococcus* – 2; *Micromonospora* – 44; *Mycobacterium* – 15; *Nocardioides* – 21; *Nocardia* – 31; *Pseudonocardia* – 5; *Rhodococcus* – 23;	541

			Streptomyces – 200	
carB	MLSB	Antibiotic target alteration/23S ribosomal RNA methyltransferase	*Actinomyces* – 31; *Arthrobacter* – 19; *Corynebacterium* – 91; *Dietzia* – 7; *Gordonia* – 27; *Micrococcus* – 4; *Micromonospora* – 49; *Mycobacterium* – 73; *Nocardioides* – 19; *Nocardia* – 48; *Pseudonocardia* – 8; *Rhodococcus* – 17; *Streptomyces* – 120	513
folP	Sulfonamides	Antibiotic target alteration/antibiotic resistant dihydropteroate synthase	*Actinomyces* – 12; *Arthrobacter* – 16; *Corynebacterium* – 78; *Dietzia* – 4; *Gordonia* – 26; *Micrococcus* – 3; *Micromonospora* – 17; *Mycobacterium* – 39; *Nocardioides* – 8; *Nocardia* – 43; *Pseudonocardia* – 6; *Rhodococcus* – 16; *Streptomyces* – 190	458
pbp	β-Lactam antibiotics	Antibiotic target alteration/penicillin-binding protein	*Actinomyces* – 2; *Arthrobacter* – 3; *Corynebacterium* – 67; *Gordonia* – 24; *Nocardioides* – 20; *Pseudonocardia* – 8; *Streptomyces* – 314	438
folA	Trimethoprim	Antibiotic target alteration/ antibiotic resistant dihydrofolate reductase	*Actinomyces* – 11; *Arthrobacter* – 12; *Corynebacterium* – 46; *Gordonia* – 24; *Micrococcus* – 1; *Micromonospora* – 35; *Mycobacterium* – 24; *Nocardioides* – 12; *Nocardia* – 52; *Pseudonocardia* – 4; *Rhodococcus* – 16; *Streptomyces* – 172	409
emrB/qacA	Multidrug	Antibiotic efflux/ major facilitator superfamily (MFS) antibiotic efflux pump	*Actinomyces* – 16; *Arthrobacter* – 6; *Corynebacterium* – 33; *Gordonia* – 24; *Micrococcus* – 2; *Micromonospora* – 10; *Mycobacterium* – 19; *Nocardioides* – 10; *Nocardia* – 30; *Pseudonocardia* – 2; *Rhodococcus* – 11; *Streptomyces* – 159	322
mdtH	Multidrug	Antibiotic efflux/ major facilitator superfamily (MFS) antibiotic efflux pump	*Actinomyces* – 1; *Corynebacterium* – 14; *Gordonia* – 10; *Micrococcus* – 1; *Micromonospora* – 7; *Mycobacterium* – 5; *Nocardioides* – 1; *Nocardia* – 36; *Pseudonocardia* – 4; *Rhodococcus* – 15; *Streptomyces* – 179	273
acrB	Multidrug	Antibiotic efflux/resistance-nodulation-cell division (RND) antibiotic efflux pump	*Arthrobacter* – 13; *Corynebacterium* – 5; *Micrococcus* – 3; *Micromonospora* – 44; *Mycobacterium* – 6; *Nocardioides* – 2; *Nocardia* – 1; *Rhodococcus* – 1; *Streptomyces* – 173	248
mefA	MLSB	Antibiotic efflux/ major facilitator	*Micrococcus* – 1; *Nocardia* – 2; *Streptomyces* – 236	239

		superfamily (MFS) antibiotic efflux pump		
mecA	Penams (penicillins)	Antibiotic target replacement/ methicillin resistant penicillin-binding protein	*Micrococcus* – 1; *Streptomyces* – 236	237
ampC	Cephalosporins, p enams (penicillins)	Antibiotic inactivation/beta-lactamase	*Actinomyces* – 2; *Arthrobacter* – 2; *Corynebacterium* – 14; *Dietzia* – 5; *Gordonia* – 10; *Micromonospora* – 9; *Mycobacterium* – 55; *Nocardioides* – 8; *Nocardia* – 56; *Pseudonocardia* – 3; *Rhodococcus* – 4; *Streptomyces* – 67	235
vgb	Streptogramins	Antibiotic inactivation/ virginiamycin B lyase	*Arthrobacter* – 1; *Micromonospora* – 30; *Nocardioides* – 7; *Nocardia* – 6; *Pseudonocardia* – 2; *Streptomyces* – 130	176
vanB	Glycopeptide antibiotics	Antibiotic target alteration/vancomycin resistant ligase	*Actinomyces* – 2; *Corynebacterium* – 3; *Gordonia* – 1; *Micromonospora* – 51; *Mycobacterium* – 25; *Nocardioides* – 2; *Nocardia* – 2; *Pseudonocardia* – 5; *Streptomyces* – 27	118
acrA	Multidrug	Antibiotic efflux/resistance-nodulation-cell division (RND) antibiotic efflux pump	*Actinomyces* – 19; *Arthrobacter* – 4; *Corynebacterium* – 7; *Micrococcus* – 1; *Micromonospora* – 22; *Mycobacterium* – 2; *Nocardioides* – 2; *Pseudonocardia* – 1; *Rhodococcus* – 1; *Streptomyces* – 55	114
pbp5	β-Lactam antibiotics	Antibiotic target alteration/ penicillin-binding protein	*Rhodococcus* – 1; *Streptomyces* – 94	95
tetM	Tetracyclines	Antibiotic target protection/ ribosomal protection protein	*Actinomyces* – 1; *Corynebacterium* – 3; *Micromonospora* – 2; *Mycobacterium* – 1; *Nocardia* – 1; *Streptomyces* – 67	75
floR	Phenicols	Antibiotic efflux/ major facilitator superfamily (MFS) antibiotic efflux pump	*Mycobacterium* – 48; *Streptomyces* – 1	49
tnpA	Multidrug	ISNCY family-transposase	*Corynebacterium* – 12; *Gordonia* – 1; *Micrococcus* – 1; *Micromonospora* – 1; *Nocardia* – 4; *Rhodococcus* – 9; *Streptomyces* – 21	49
bacA	Peptide antibiotics	Antibiotic target alteration/undecaprenyl	*Actinomyces* – 15; *Dietzia* – 1; *Gordonia* – 2; *Micromonospora* – 6; *Mycobacterium* – 10; *Nocardia* – 1;	46

		pyrophosphate phosphatase	*Pseudonocardia* – 1; *Rhodococcus* – 1; *Streptomyces* – 9	
aac	Aminoglycosides	Antibiotic inactivation/ aminoglycoside acetyltransferase	*Mycobacterium* – 19; *Pseudonocardia* – 2; *Streptomyces* – 20	41
mdtL	Multidrug	Antibiotic efflux/ major facilitator superfamily (MFS) antibiotic efflux pump	*Corynebacterium* – 5; *Dietzia* – 1; *Gordonia* – 2; *Mycobacterium* – 2; *Nocardia* – 3; *Pseudonocardia* – 1; *Rhodococcus* – 4; *Streptomyces* – 11	29
fosB	Fosfomycin	Antibiotic inactivation/thiol transferase	*Gordonia* – 1; *Mycobacterium* – 6; *Nocardia* – 1; *Pseudonocardia* – 1; *Rhodococcus* – 1; *Streptomyces* – 18	28
penA	β-Lactam antibiotics	Antibiotic target alteration/ penicillin-binding protein	*Actinomyces* – 2; *Corynebacterium* – 3; *Micrococcus* – 1; *Mycobacterium* – 3; *Nocardia* – 4; *Rhodococcus* – 3; *Streptomyces* – 7	23
tetA	Tetracyclines	Antibiotic efflux/ major facilitator superfamily (MFS) antibiotic efflux pump	*Corynebacterium* – 7; *Gordonia* – 2; *Micrococcus* – 1; *Mycobacterium* – 3; *Nocardioides* – 1; *Nocardia* – 2; *Pseudonocardia* – 1; *Rhodococcus* – 2; *Streptomyces* – 3	22
tetC	Tetracyclines	Antibiotic efflux/ major facilitator superfamily (MFS) antibiotic efflux pump	*Corynebacterium* – 3; *Gordonia* – 1; *Mycobacterium* – 7; *Nocardioides* – 1; *Nocardia* – 2; *Pseudonocardia* – 1; *Rhodococcus* – 2; *Streptomyces* – 2	19
mdtG	Fosfomycin	Antibiotic efflux/ major facilitator superfamily (MFS) antibiotic efflux pump	*Arthrobacter* – 1; *Corynebacterium* – 1; *Mycobacterium* – 5; *Nocardia* – 1; *Rhodococcus* – 2; *Streptomyces* – 7	17
pmrA	Fluoroquinolones	Antibiotic efflux/ major facilitator superfamily (MFS) antibiotic efflux pump	*Rhodococcus* – 2; *Streptomyces* – 15	17
tetD	Tetracyclines	Antibiotic efflux/ major facilitator superfamily (MFS) antibiotic efflux pump	*Arthrobacter* – 1; *Corynebacterium* – 1; *Dietzia* – 1; *Micrococcus* – 1; *Mycobacterium* – 1; *Nocardia* – 1; *Pseudonocardia* – 1; *Rhodococcus* – 2; *Streptomyces* – 8	17
lmrA	MLSB	Antibiotic target alteration, antibiotic efflux/ATP-binding cassette (ABC) antibiotic efflux pump	*Actinomyces* – 1; *Corynebacterium* – 3; *Dietzia* – 1; *Nocardia* – 1; *Rhodococcus* – 1; *Streptomyces* – 9	16
mepA	Multidrug	Antibiotic efflux/multidrug and toxic compound extrusion (MATE) transporter	*Corynebacterium* – 11; *Mycobacterium* – 1; *Nocardia* – 1; *Streptomyces* – 3	16

strA	Aminoglycosides	Antibiotic inactivation/ aminoglycoside phosphotransferase	*Corynebacterium* – 4; *Streptomyces* – 12	16
cphA	Carbapenems	Antibiotic inactivation/beta-lactamase	*Corynebacterium* – 1; *Mycobacterium* – 6; *Nocardioides* – 2; *Nocardia* – 1; *Pseudonocardia* – 1; *Streptomyces* – 4	15
vanA	Glycopeptide antibiotics	Antibiotic target alteration/ vancomycin resistant ligase	*Corynebacterium* – 3; *Gordonia* – 4; *Rhodococcus* – 1; *Streptomyces* – 7	15
vatD	Streptogramins	Antibiotic inactivation/ streptogramin vat acetyltransferase	*Nocardia* – 4; *Rhodococcus* – 2; *Streptomyces* – 7	13
tolC	Multidrug	Antibiotic efflux/many multidrug efflux pumps	*Arthrobacter* – 1; *Micromonospora* – 2; *Mycobacterium* – 2; *Streptomyces* – 7	12
cmx	Phenicols	Antibiotic efflux/major facilitator superfamily (MFS) antibiotic efflux pump	*Corynebacterium* – 9; *Streptomyces* – 1	10
mdtA	Multidrug	Antibiotic efflux/resistance-nodulation-cell division (RND) antibiotic efflux pump	*Actinomyces* – 1; *Arthrobacter* – 1; *Mycobacterium* – 2; *Streptomyces* – 6	10
oprD	Multidrug	Reduced permeability to antibiotic/outer membrane porin	*Arthrobacter* – 1; *Mycobacterium* – 3; *Streptomyces* – 6	10
cmr	Phenicols	Antibiotic efflux/major facilitator superfamily (MFS) antibiotic efflux pump	*Corynebacterium* – 3; *Mycobacterium* – 4; *Nocardioides* – 1; *Streptomyces* – 1	9
pbp2a	Penams (penicillins)	Antibiotic target replacement/methicillin resistant penicillin-binding protein	*Corynebacterium* – 9	9
fabK	Triclosan	Antibiotic target alteration/3-oxoacyl-acyl carrier protein reductase	*Mycobacterium* – 2; *Streptomyces* – 6	8
strB	Aminoglycosides	Antibiotic inactivation/ aminoglycoside phosphotransferase	*Corynebacterium* – 4; *Nocardia* – 1; *Streptomyces* – 3	8
tetB	Tetracyclines	Antibiotic efflux/ major facilitator superfamily (MFS) antibiotic efflux pump	*Corynebacterium* – 8	8
tetO	Tetracyclines	Antibiotic target protection/	*Nocardia* – 1; *Streptomyces* – 7	8

		ribosomal protection protein		
msrC	MLSB	Antibiotic target protection/ABC-F ATP-binding cassette ribosomal protection protein	*Micrococcus* – 1; *Mycobacterium* – 1; *Nocardia* – 3; *Rhodococcus* – 2	7
catA1	Chloramphenicol	Antibiotic inactivation/ chloramphenicol acetyltransferase	*Corynebacterium* – 1; *Rhodococcus* – 5	6
ermA	MLSB	Antibiotic target alteration/23S ribosomal RNA methyltransferase	*Corynebacterium* – 4; *Nocardia* – 1	5
ermB	MLSB	Antibiotic target alteration/23S ribosomal RNA methyltransferase	*Mycobacterium* – 3; *Nocardia* – 1	4
aacC	Aminoglycosides	Antibiotic inactivation/ aminoglycoside acetyltransferase	*Streptomyces* – 3	3
cfiA	Carbapenems	Antibiotic inactivation/beta-lactamase	*Corynebacterium* – 1; *Mycobacterium* – 1; *Nocardia* – 1	3
spcN	Aminoglycosides	Antibiotic inactivation/ aminoglycoside phosphotransferase	*Streptomyces* – 3	3
aphA1	Aminoglycosides	Antibiotic inactivation/ aminoglycoside phosphotransferase	*Corynebacterium* – 2	2
aac(6')-II	Aminoglycosides	Antibiotic inactivation/ aminoglycoside acetyltransferase	*Streptomyces* – 2	2
aadA1	Aminoglycosides	Antibiotic inactivation/ aminoglycoside nucleotidyltransferase	*Corynebacterium* – 2	2
bla1	Penams (penicillins)	Antibiotic inactivation/beta-lactamase	*Mycobacterium* – 2	2
emrD	Multidrug	Antibiotic efflux/ major facilitator superfamily (MFS) antibiotic efflux pump	*Mycobacterium* – 1; *Rhodococcus* – 1	2
qacB	Fluoroquinolones	Antibiotic efflux/ major facilitator superfamily (MFS) antibiotic efflux pump	*Corynebacterium* – 1; *Streptomyces* – 1	2
tetW	Tetracyclines	Antibiotic target protection/ ribosomal protection protein	*Actinomyces* – 1; *Corynebacterium* – 1	2

vanYB	Glycopeptide antibiotics	Antibiotic target alteration/vancomycin resistant ligase	*Nocardia* – 1; *Rhodococcus* – 1	2
aacC4	Aminoglycosides	Antibiotic inactivation/ aminoglycoside acetyltransferase	*Streptomyces* – 1	1
aadA2	Aminoglycosides	Antibiotic inactivation/ aminoglycoside nucleotidyltransferase	*Corynebacterium* – 1	1
aadA9	Aminoglycosides	Antibiotic inactivation/ aminoglycoside nucleotidyltransferase	*Corynebacterium* – 1	1
ceoA	Multidrug	Antibiotic efflux/resistance-nodulation-cell division (RND) antibiotic efflux pump	*Mycobacterium* – 1	1
cmrA	Phenicols	Antibiotic efflux/ major facilitator superfamily (MFS) antibiotic efflux pump	*Rhodococcus* – 1	1
dfrA1	Diaminopyrimidine antibiotic	Antibiotic target replacement/ trimethoprim resistant dihydrofolate reductase	*Corynebacterium* – 1	1
ermC	MLSB	Antibiotic target alteration/23S ribosomal RNA methyltransferase	*Nocardia* – 1	1
fosB2	Fosfomycin	Antibiotic inactivation/thiol transferase	*Rhodococcus* – 1	1
mdtE	Multidrug	Antibiotic efflux/resistance-nodulation-cell division (RND) antibiotic efflux pump	*Mycobacterium* – 1	1
nisB	Nisin	Antibiotic efflux/nisin dehydratase	*Streptomyces* – 1	1
picA	Macrolides	Antibiotic efflux/unknown	*Streptomyces* – 1	1
pikR1	MLSB	Antibiotic target alteration/23S ribosomal RNA methyltransferase	*Streptomyces* – 1	1

pikR2	MLSB	Antibiotic target alteration/23S ribosomal RNA methyltransferase	*Streptomyces* – 1	1
qacH	Fluoroquinolones	Antibiotic efflux/small multidrug resistance (SMR) antibiotic efflux pump	*Corynebacterium* – 1	1
sulA	Sulfonamides	Antibiotic target replacement/ sulfonamide resistant dihydropteroate synthase	*Mycobacterium* – 1	1
sul2	Sulfonamides	Antibiotic target replacement/ sulfonamide resistant dihydropteroate synthase	*Nocardia* – 1	1
tetL	Tetracyclines	Antibiotic efflux/ major facilitator superfamily (MFS) antibiotic efflux pump	*Nocardia* – 1	1
yceL	Fosfomycin	Antibiotic efflux/ major facilitator superfamily (MFS) antibiotic efflux pump	*Streptomyces* – 1	1

MLSB - Macrolide-Lincosamide-Streptogramin B.