



Supplement of

Identifying the core bacterial microbiome of hydrocarbon degradation and a shift of dominant methanogenesis pathways in the oil and aqueous phases of petroleum reservoirs of different temperatures from China

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1 Supplementary Data

1.1 Characterization of geographic properties of sampling reservoirs

Petroleum fluids samples were collected from eight sampling sites across China covering oilfields of different geological properties. The reservoir and crude oil properties together with the aqueous phase chemical concentration characteristics were listed in Table 1. P1 represents the sample collected from Zhan3-26 well located in Shengli Oilfield. Zhan3 block region in Shengli Oilfield is located in the coastal area from the Yellow River Estuary to the Bohai Sea. It is a medium-high temperature reservoir of fluvial face, made of a thin layer of crossed sand-mudstones, pebbled sandstones and fine sandstones. P2 represents the sample collected from Ba-51 well, which is located in Bayindulan reservoir layer of Erlian Basin, east Inner Mongolia Autonomous Region. It is a reservoir with highly heterogeneous layers, high crude oil viscosity and low formation fluid temperature. It was dedicated to water-flooding, however, due to low permeability and high viscosity of crude oil, displacement efficiency of water-flooding driving process was slowed down along the increase of water-cut rate. P3 and P4 represents samples which were collected from Liuzhong and Qixi blocks from Karamay Oilfield which located about 30 km to the east of Karamay City. Liuzhong reservoir is located in a piedmont diluvial fan deposit area mainly consisted of conglomerates and uneven gravel bearing sandstones, and is characterized as a reservoir of moderate porosity, high permeability, high crude oil viscosity and high heterogeneity. The reservoir region is distributed in a triangle fault block surrounded by Karamay-Wuerhe fracture belt and northern Baijiantan fracture belt. Qixi reservoir is located at footwall of Baijiantan fracture belt and is characterized as a heterogeneous conglomerate reservoir containing complex pore structures with low porosity and permeability. Both reservoirs from Karamay Oilfield were relatively low temperature reservoirs. P5 represents the sample collected from Wei5 block reservoir located in Gaoyou depression area of Subei Basin (Jiangsu Oilfield). It is a thin sand-mud interbed towards the front margin of a delta region, containing viscous crude oil. Due to its small volume, irregular reserve layers and relatively thin oil-bearing structure, it is difficult to further exploit using commonly applied methods. Many approaches have been carried out on this reservoir, such as cyclic steam stimulation, microorganism and water flood stimulation, etc. P6 represents the sample collected from Gao6 block reservoir located in the middle region of the western slope of Jinhu depression area of Subei Basin. This is a small and thin interbedded reservoir with moderate porosity, low permeability and high inter- and intralayer heterogeneity. P7 represents the sample collected from Xing4 block from Xingbei Oilfield, located in Daqing City. The main reservoir layer is made of lake sedimentary clastic rocks, composed of feldspars and quartz sandstones. The sandstones consist of over half fine sands, second by silty sands, and then medium fine sands. This reservoir is a reservoir comprised of multiple and thin layers, characterized with high porosity and low permeability property. P8 represents the sample collected from Qinying area located in Yangcun fault block. This sampling reservoir is from south part of Jinhu depression area of Subei Basin, and is a newly developed reservoir subjected to production test since 2012. P6 and P8 were both collected from Jinhu depression area from Jiangsu Oilfield and the *in situ* temperatures were higher than rest samples.

1.2 Reservoir geophysical properties and physicochemical properties

Reservoir geophysical properties and ion concentrations of aqueous phase samples were shown in Table 1. The physicochemical properties from P1-P4 aqueous phase samples were derived from the previous work (Wang et al. 2012). P1-P6 samples consist of aqueous and oil phases, while P7 only contains aqueous phase sample and P8 only contains oil phase. P3 and P4 are grouped into low temperature samples; P1, P2, P5 and P7 are grouped into moderate temperature samples; P6 and P8 are characterized as high temperature samples. Meanwhile, P1-P4 samples were pH neutral, P5-P8

samples were slightly alkaline. The reservoir general properties, including depth, temperature, pH, effective porosity, average permeability, and crude oil viscosity, were measured by local oilfield management agencies while sampling. All the reservoirs were operated by water flooding for years, aiming to enhance oil recovery efficiency, except for P8, located at Qinying block, Jiangsu Oilfield, a newly exploited site; so that no aqueous phase sample could be extracted from P8 oil-water fluids. Due to very less oil phase sample extracted from oil-water fluids from Xing4 block, Daqing (Xingbei) Oilfield, P7 sample also only contains aqueous phase. The effective porosity indicates percentage of effective interconnected pore space (excluding the porosity which could not benefit connections between pores) in the total volume of rocks, which could facilitate fluids flowing through rocks or sediments. It is an important parameter indicating pore property of reservoirs, reflecting the formation degree and connectivity of a certain reservoir. Average permeability is a measure of general ability of fluids flowing through reservoir layers to the oilwell. Oil viscosity reflects property and composition of crude oil. In general, crude oil with higher oil viscosity means higher content of asphaltenes and resins, and also higher content of long carbon chain hydrocarbons.

1.3 Diversity of microbial 16S rRNA gene through MiSeq sequencing

To obtain microbial composition structure from 14 aqueous and oil phase samples, we separately amplified prokaryotic and archaeal 16S rRNA gene from DNA samples. Although, archaeal 16S rRNA gene products could also be amplified from the prokaryotic 16S rRNA gene targeting primer pair, quantities of obtained sequences were limited and biased primers pairs could underestimate certain groups of archaea. Hence, in this study, we firstly sequenced the prokaryotic 16S rRNA gene, and then screened out the archaeal 16S rRNA gene and retained the bacterial 16S rRNA gene library. Finally, after subsampling to make all the library acquire even sequencing depth, each bacterial 16S rRNA gene library consisted of 6100 unique, dereplicated sequences, which through the analysis of QIIME pipeline could achieve good coverage (Good's coverage value within 89.6 to 94.1%). Nevertheless, it might be for the reason that low specificity of archaeal 16S rRNA gene primer pair introduced erroneous amplification of non-archaeal sequence and microbial composition was dominated by bacteria, archaeal 16S rRNA gene profile reflected that the majorities of libraries were not archaeal sequences. Consequently, screening out non-archaeal sequences from each library was also conducted, and after sub-sampling, each archaeal 16S rRNA gene library consisted of 760 unique, dereplicated sequences, which through the analysis of QIIME pipeline could achieve Good's coverage values ranging from 93.8 to 98.4% ([Table S1](#)). To analyze composition of methanogens, archaeal 16S rRNA gene libraries were further screened to obtain methanogenic libraries with sequencing depth of 240 for each library, and Good's coverage values ranging from 90.5 to 98.4%. Alpha diversity pattern of bacterial, archaeal, methanogenic 16S rRNA gene libraries were summarized into [Table S1](#). From Good's coverage values and rarefaction curves of observed species which have been analyzed through QIIME pipeline for the individual library, it was observed that the majority (generally over 90%) of underlying species were estimated to be covered. According to the alpha diversity values from bacterial, archaeal and methanogenic libraries, bacterial communities had the largest average Chao1, Shannon and Simpson index value (2043, 5.8, 0.9) while archaeal communities had the second largest average Chao1 value (109.9), methanogenic communities had the smallest average Chao1 value (56.2). Archaeal communities had the same level of average Shannon and Simpson values as methanogenic communities (2.6, 0.6; 2.3, 0.6). Whereas, in terms of coefficient of variation of the above three indices (standard deviation over average value), the bacterial community acquired lower variation level of the three indices (2.4%, 13.5%, 5.3%), while, the archaeal and methanogenic communities acquired higher variation level of the three indices (51.5%, 38.1%, 33%; 65.9%, 43.3%, 40.5%). It is indicative that even though archaeal/methanogenic communities of 14 aqueous and oil samples show lower diverse patterns than bacterial communities, their intra-sample variations are larger than those of bacterial communities.

1.4 Taxonomic and compositional profiles of microbial 16S rRNA gene through MiSeq sequencing

The open-reference OTU picking method implemented in QIIME assures that all sequences are divided into genus level OTUs with the guidance of genus level reference sequences, thus offers an exhaustive OTU classification (Rideout et al. 2014). Average bacterial sequences unclassified into known genera could account for 31.91%; and average archaeal sequences unclassified into known genera could account for 9.59%, while the percentage of average methanogenic sequences unclassified into known genera was even as low as 0.38% ([Table S2](#)). Taxonomic compositional profiles of 14 aqueous and oil phase samples revealed that on the genus level, 931 bacterial genera and 56 archaeal genera were obtained among all the samples. There were 36 bacterial genera with average abundance percentage over 0.5% amongst all the bacterial communities, and there were 14 archaeal genera with the average abundance percentage over 0.5% amongst all the archaeal communities. The most abundant five genera among bacterial communities were *Pseudomonas* (16.12%), *Acinetobacter* (9.94%), uncultured genus within *Hydrogenophilaceae* (5.44%), *Proteiniphilum* (3.06%) and *Marinobacter* (2.91%). The most abundant five genera among archaeal communities were *Methanosaeta* (42.3%), *Methanothermobacter* (9.69%), *Methanolobus* (9.07%), *Methanocalculus* (8.05%) and *Methanoculleus* (5.01%) ([Table S3](#)).

1.5 Quantitation of *mcrA* gene abundance

Quantity units of *mcrA* gene abundance of aqueous and oil samples were gene copy numbers per microliter water sample and gene copy numbers per gram oil sample, respectively ([Figure S1](#)). The *mcrA* gene copies of all samples from this study varied substantially from 2.5×10^2 copies/g in P8O to 2.9×10^7 copies/g in P3O sample. The *mcrA* gene abundances in low temperature samples (P3 and P4) were the highest among all the samples in terms of both aqueous and oil phases, ranging from 2.8×10^5 to 4.3×10^5 copies/ml in aqueous phase, and 6.4×10^6 to 2.9×10^7 copies/g in oil phase. For moderate temperature samples (P1, P2, P5 and P7), the *mcrA* gene abundance among aqueous samples was ranging from 1.2×10^3 copies/ml in P5A to 3.3×10^5 copies/ml in P1A, while the highest *mcrA* gene abundance among oil samples was ranging from 1.7×10^3 copies/g in P5O to 1.1×10^6 copies/g in P1O. For high temperature samples (P6 and P8), the *mcrA* gene abundance of aqueous sample was 9.2×10^3 copies/ml in P6A, and the *mcrA* gene abundance of oil samples was ranging from 2.5×10^2 copies/g in P8O to 2.8×10^4 copies/g in P6O. Within aqueous and oil phases of one individual sample, the numerical value of *mcrA* gene copy number in oil phase was generally one to two orders of magnitude larger than that in aqueous phase.

2 Supplementary Figures and Tables

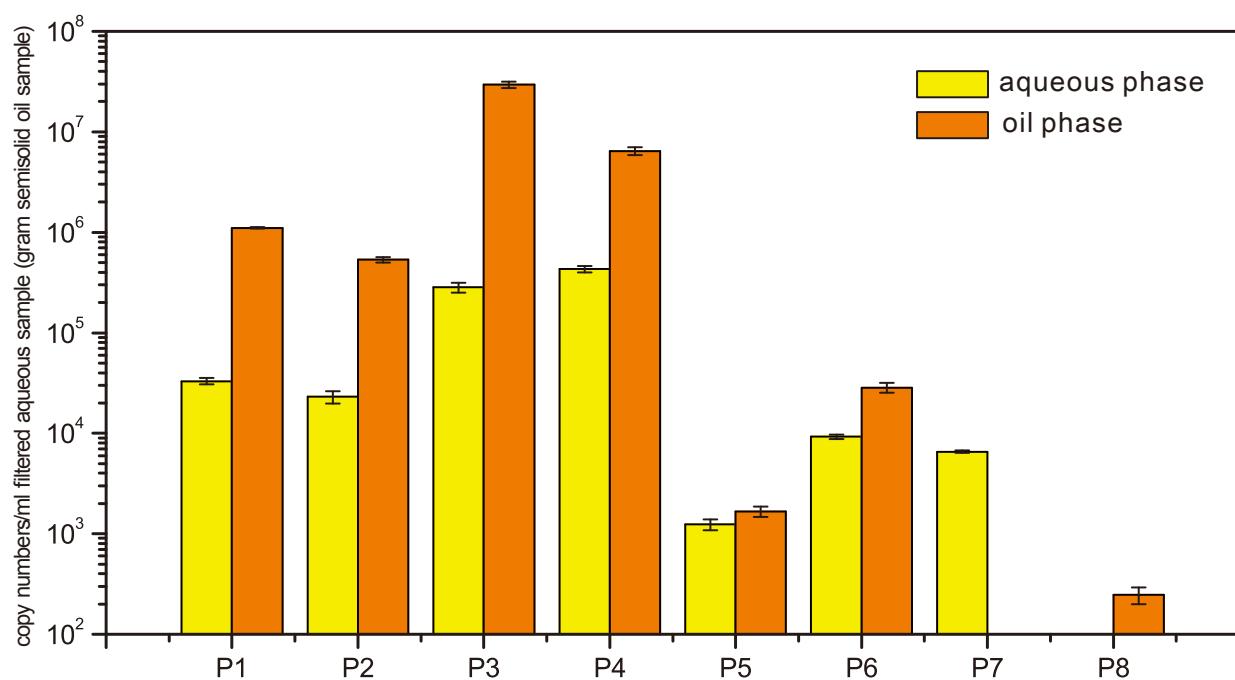


Figure S1. *mcrA* gene abundance of 14 aqueous and oil phase samples. Vertical coordinate was drawn in log-normalized label. The aqueous samples *mcrA* gene quantities were gene copy numbers/ml filtered aqueous sample; the oil samples *mcrA* gene quantities were gene copy numbers/gram semisolid oil sample.

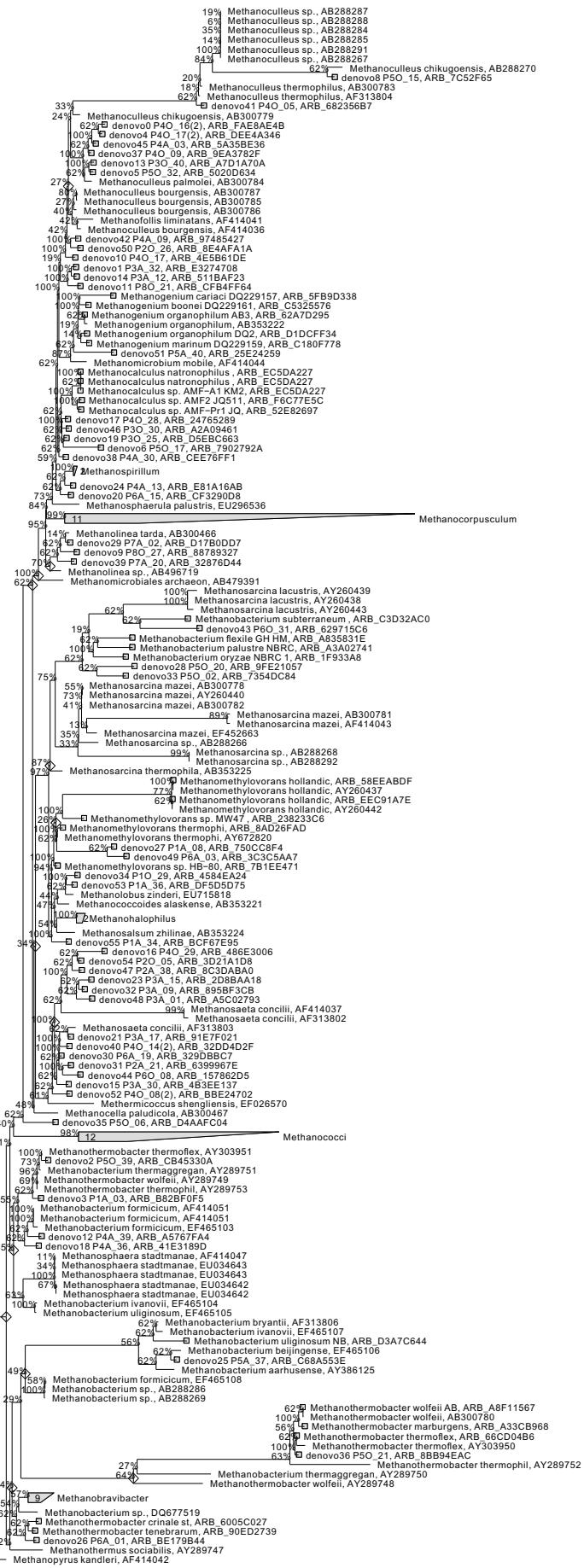


Figure S2. Phylogenetic tree based on clone library *mcrA* gene and reference gene sequences. The OTU representative *mcrA* gene clone sequences were obtained by 0.05 cutoff on nucleotide level, and then inserted into *mcrA* gene ARB database by maximum parsimony method without changing the initial tree topology. (*mcrA* gene ARB database: <http://www.mpi-marburg.mpg.de/downloads/conrad/>)

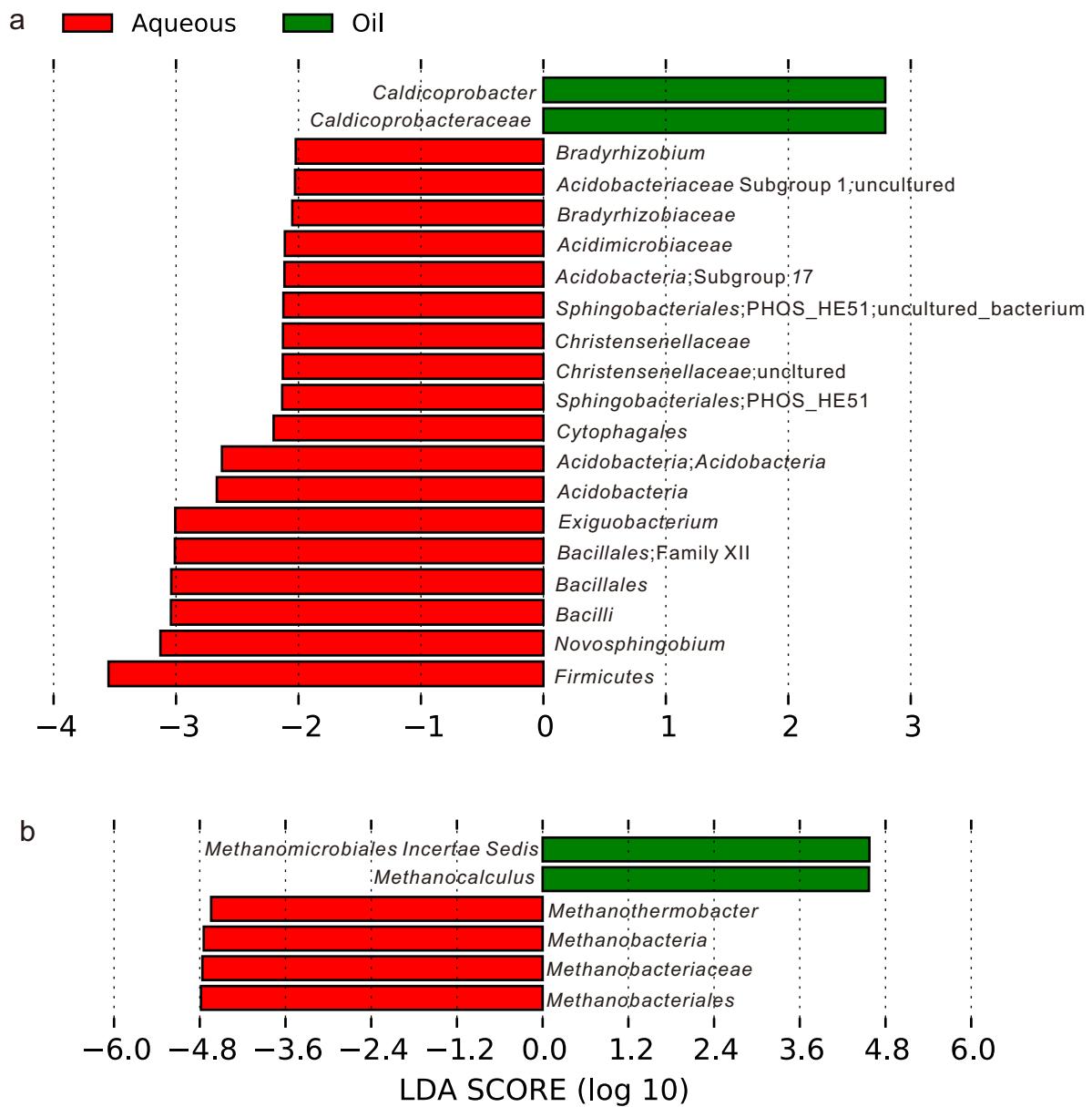


Figure S3. Differentially distributed features of microbial taxon abundance in aqueous and oil phases. LEfSe analysis with LDA effect score was applied. (a) bacterial community feature; (b) archaeal community feature.

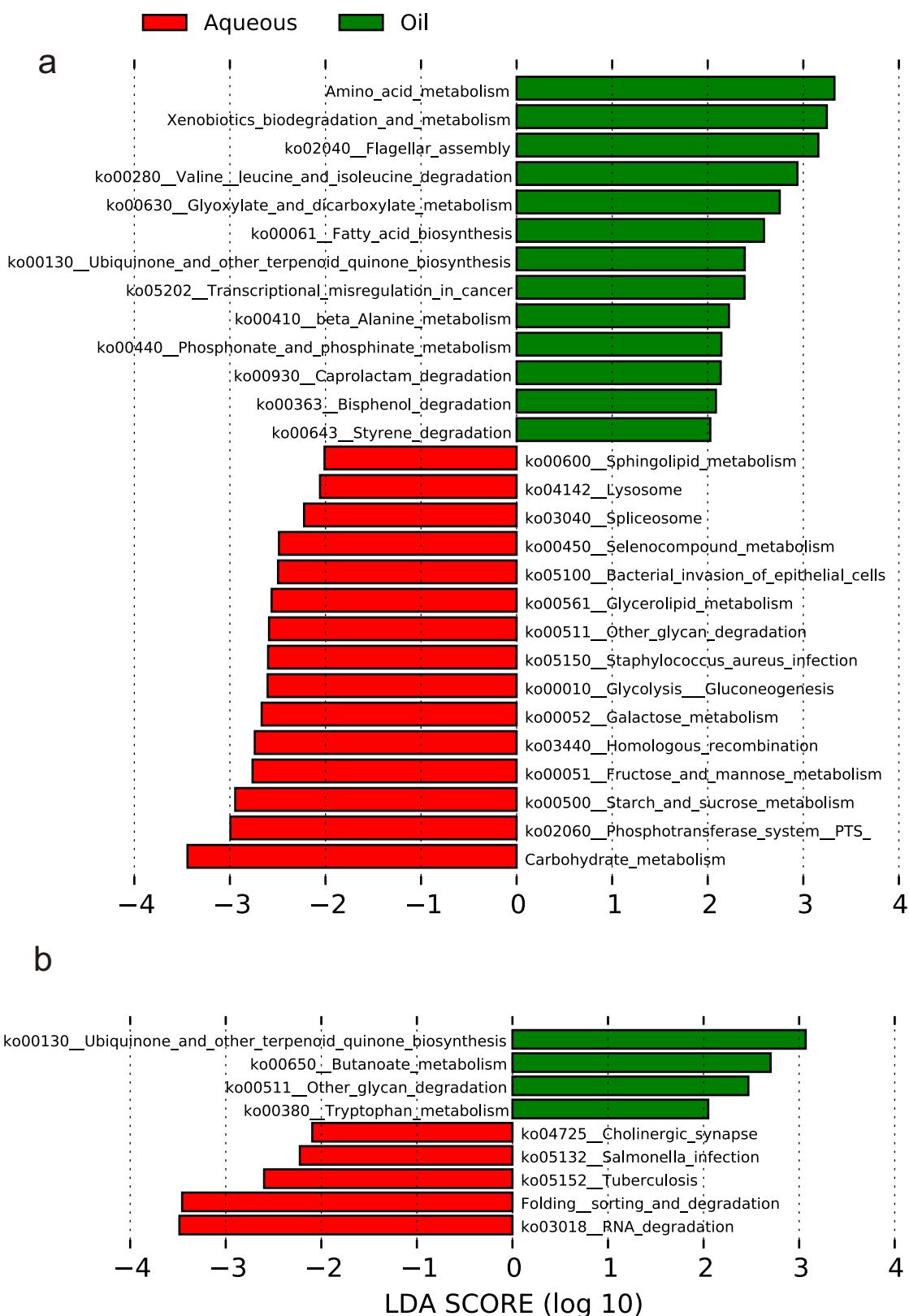


Figure S4. Differentially distributed feature of functional profiles in aqueous and oil phases. LEfSe analysis results based on the predicted functional profiles by Tax4Fun. (a) bacterial community feature; (b) archaeal community feature.

Table S1. Alpha diversity values of aqueous and oil phase samples including bacterial, archaeal, methanogenic microorganism communities based on MiSeq archaeal 16S rRNA gene sequencing, methanogenic 16S rRNA gene clone library and *mcrA* gene clone library construction.

Bacteria (MiSeq)

SampleID	Seqs/Sample	PD whole tree	Chao1	Good's coverage	observed species	Shannon	Simpson
P1A	6100	39.222	1951.164	0.918	742.2	5.868	0.939
P1O	6100	32.782	1378.172	0.941	552.6	4.727	0.873
P2A	6100	39.311	2137.544	0.915	720.4	4.886	0.872
P2O	6100	36.549	1869.683	0.923	669.6	5.003	0.875
P3A	6100	50.028	2183.686	0.903	921.3	6.194	0.932
P3O	6100	48.894	2098.391	0.903	972.5	6.653	0.941
P4A	6100	43.85	2081.336	0.913	794.5	5.475	0.876
P4O	6100	45.632	2156.457	0.906	843.4	4.765	0.794
P5A	6100	45.792	2468.217	0.9	891.2	6.499	0.961
P5O	6100	36.263	2112.554	0.923	669.7	5.396	0.915
P6A	6100	39.937	2006.069	0.916	769.7	6.157	0.941
P6O	6100	40.756	2196.376	0.91	826.6	6.5	0.959
P7A	6100	49.66	2195.145	0.896	1032.6	7.2	0.969
P8O	6100	39.205	1767.685	0.924	726.8	5.73	0.924

Archaea (MiSeq)

SampleID	Seqs/Sample	PD whole tree	Chao1	Good's coverage	observed species	Shannon	Simpson
P1A	760	3.089	262.751	0.938	77.4	3.747	0.86
P1O	760	2.265	39.79	0.984	26.7	1.774	0.512
P2A	760	2.7	66.741	0.977	42.5	2.297	0.557
P2O	760	2.697	102.594	0.958	51.7	1.529	0.327
P3A	760	2.615	96.15	0.966	63	4.121	0.896
P3O	760	4.15	144.067	0.948	58.7	2.263	0.584
P4A	760	2.733	125.857	0.952	65.4	2.791	0.668
P4O	760	3.542	147.413	0.94	84.2	3.862	0.843
P5A	760	2.732	130.623	0.958	56.3	3.262	0.829
P5O	760	2.714	99.733	0.96	61.7	3.861	0.886
P6A	760	2.105	108.36	0.968	35.8	1.282	0.306
P6O	760	2.288	100.186	0.962	50	2.75	0.746
P7A	760	2.569	91.164	0.962	50.7	1.735	0.393
P8O	760	1.682	23.15	0.992	15.9	1.494	0.518

Methanogen (MiSeq)

SampleID	Seqs/Sample	PD whole tree	Chao1	Good's coverage	observed species	Shannon	Simpson
P1A	240	1.135	71.814	0.911	36.2	3.391	0.846
P1O	240	0.3	15.65	0.984	12.9	1.695	0.508
P2A	240	1.16	32.463	0.951	21.5	1.492	0.361
P2O	240	0.98	60.625	0.928	25.3	1.506	0.349
P3A	240	0.918	63.343	0.926	39.6	3.932	0.881
P3O	240	1.288	107.15	0.926	24.6	2.1	0.602
P4A	240	1.156	144.65	0.905	31.9	2.435	0.621
P4O	240	1.356	62.492	0.926	32.6	3.336	0.823
P5A	240	1.242	37.325	0.942	25.7	2.72	0.756
P5O	240	1.393	83.467	0.916	34	3.559	0.874
P6A	240	0.986	23.1	0.971	12.9	1.049	0.277
P6O	240	1.228	37.39	0.95	24	2.649	0.733
P7A	240	0.865	31.808	0.954	21.8	1.547	0.375
P8O	240	0.825	15.1	0.98	9.8	0.798	0.218

Methanogen (Methanogenic 16S rRNA gene clone library)

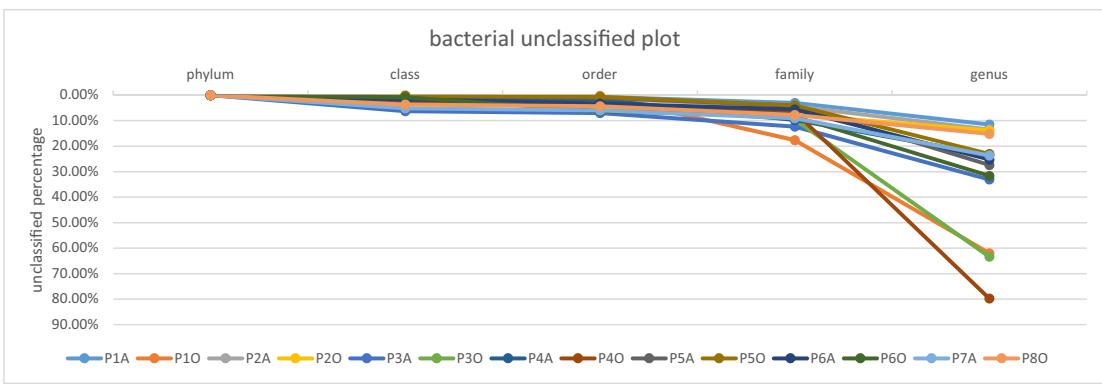
SampleID	Seqs/Sample	PD_whole_tree	Chao1	Good's coverage	observed_species	Shannon	Simpson
P1A	28	1.167	8.5	0.893	7	2.132	0.689
P1O	28	1.101	10	0.857	7	1.84	0.589
P2A	28	0.997	7.5	0.929	7	2.277	0.724
P2O	28	0.415	6.333	0.929	6	1.698	0.554
P3A	28	0.337	8.333	0.929	8	2.564	0.781
P3O	28	0.305	3	0.964	3	1.139	0.503
P4A	28	0.519	12.5	0.821	10	2.52	0.717
P4O	28	0.472	6	1	6	2.296	0.758
P5A	28	1.314	13.333	0.821	10	2.846	0.827
P5O	28	0.472	4	1	4	1.662	0.64
P6A	28	1.078	5	0.964	5	1.67	0.582
P6O	28	1.051	13	0.857	7	2.032	0.671
P7A	28	0.238	2	1	2	0.592	0.245
P8O	28	1.267	8	0.929	7	2.503	0.801

Methanogen (*mcrA* gene clone library)

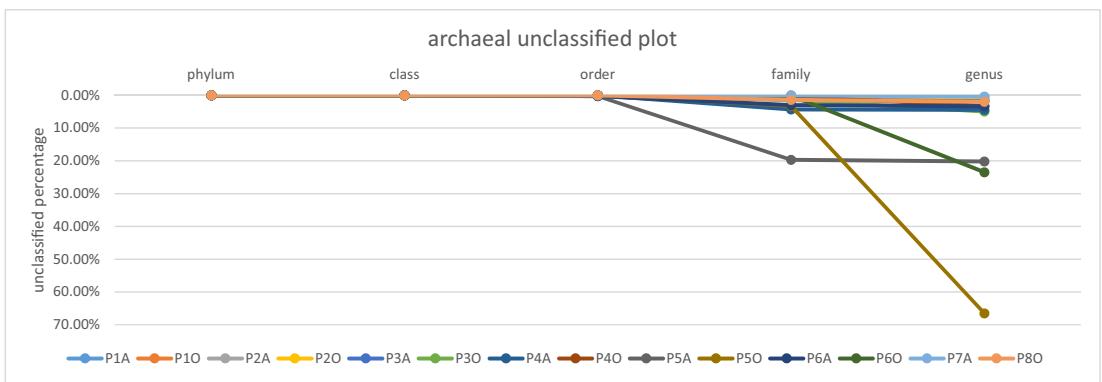
SampleID	Seqs/Sample	PD_whole_tree	Chao1	Good's coverage	observed_species	Shannon	Simpson
P1A	23	10	0.826	8	2.435	0.756	0.756
P1O	23	5	0.957	5	1.684	0.582	0.582
P2A	23	8	0.87	5	1.578	0.582	0.582
P2O	23	6	0.913	5	1.808	0.658	0.658
P3A	23	9.6	0.87	9	2.729	0.794	0.794
P3O	23	17	0.783	7	2.036	0.681	0.681
P4A	23	57	0.565	12	2.975	0.813	0.813
P4O	23	26	0.739	11	3.208	0.877	0.877
P5A	23	9	0.87	8	2.595	0.794	0.794
P5O	23	19	0.696	12	3.262	0.87	0.87
P6A	23	8	0.87	7	2.255	0.733	0.733
P6O	23	6.5	0.913	6	2.086	0.699	0.699
P7A	23	7.333	0.913	7	2.351	0.745	0.745
P8O	23	6.5	0.87	5	1.173	0.374	0.374

Table S2. Unclassified sequences percentage in each taxon level based on QIIME software applying SILVA compatible 119 release SSURef database as reference. a) bacterial community table and chart; b) archaeal community table and chart.

a	P1A	P1O	P2A	P2O	P3A	P3O	P4A	P4O	P5A	P5O	P6A	P6O	P7A	P8O	average
phylum	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
class	0.38%	0.15%	0.44%	0.23%	6.32%	2.85%	1.43%	2.92%	0.41%	0.20%	1.67%	0.84%	5.18%	3.65%	1.90%
order	0.69%	0.29%	1.28%	5.59%	7.01%	4.05%	1.77%	3.24%	0.95%	0.70%	3.26%	6.19%	5.96%	4.34%	3.24%
family	3.06%	17.66%	4.39%	7.72%	12.37%	9.52%	9.71%	6.62%	4.16%	3.98%	5.52%	8.40%	9.11%	7.75%	7.86%
genus	11.53%	61.99%	13.50%	13.76%	33.08%	63.37%	23.53%	79.77%	27.42%	23.05%	25.29%	31.65%	23.69%	15.17%	31.91%



b	P1A	P1O	P2A	P2O	P3A	P3O	P4A	P4O	P5A	P5O	P6A	P6O	P7A	P8O	average
phylum	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
class	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
order	0.13%	0.13%	0.00%	0.00%	0.13%	0.00%	0.00%	0.00%	0.26%	0.00%	0.26%	0.00%	0.00%	0.00%	0.07%
family	0.39%	0.91%	0.39%	0.00%	1.43%	1.43%	4.30%	0.39%	19.69%	3.26%	3.00%	0.13%	0.00%	1.43%	2.63%
genus	1.56%	1.17%	0.52%	0.65%	1.83%	4.95%	4.43%	3.26%	20.21%	66.49%	3.39%	23.47%	0.39%	1.96%	9.59%



	P1A	P1O	P2A	P2O	P3A	P3O	P4A	P4O	P5A	P5O	P6A	P6O	P7A	P8O	average
phylum	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
class	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
order	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
family	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
genus	1.22%	0.00%	0.00%	0.00%	0.00%	2.04%	0.00%	0.00%	0.00%	0.00%	0.41%	0.00%	0.00%	1.63%	0.38%

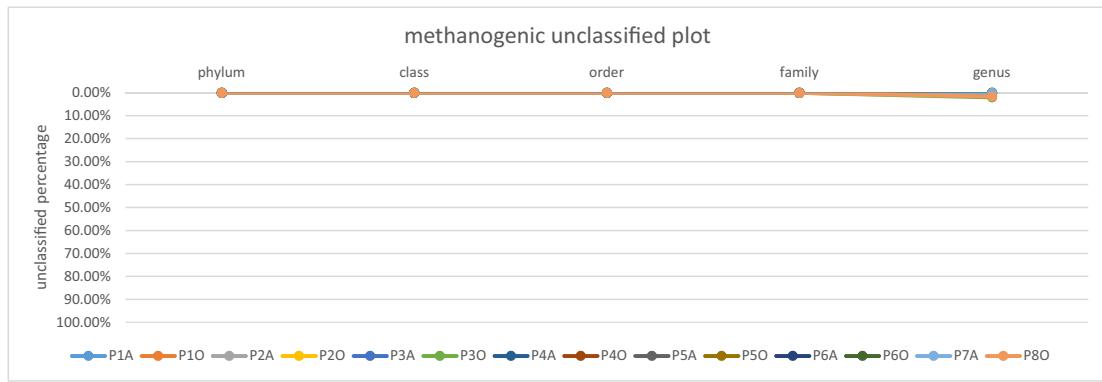


Table S3. Taxonomic composition of aqueous and oil phase samples based on MiSeq 16S rRNA gene sequencing. a) bacterial community composition in genus level; b) archaeal community composition in genus level.

a

b

Table S4. Shared OTU numbers of all pairs of samples (I). The statistical table of average shared OTU numbers and the percentages of shared OTU numbers in each sample's OTU numbers (II). a) bacterial community tables; b) archaeal community tables.

a I	P1A	P1O	P2A	P2O	P3A	P3O	P4A	P4O	P5A	P5O	P6A	P6O	P7A	P8O
	743	205	228	228	241	248	230	208	265	206	243	249	295	232
	205	553	195	184	183	207	201	168	235	179	188	218	234	202
	228	195	721	249	235	250	244	202	239	210	247	264	302	225
	228	184	249	670	226	237	234	203	254	214	239	237	278	216
	241	183	235	226	922	323	296	228	272	217	238	266	306	230
	248	207	250	237	323	973	286	338	307	238	269	282	325	240
	230	201	244	234	296	286	795	260	260	204	253	258	300	236
	208	168	202	203	228	338	260	844	227	176	220	231	259	194
	265	235	239	254	272	307	260	227	892	280	273	297	322	269
	206	179	210	214	217	238	204	176	280	670	213	245	249	220
	243	188	247	239	238	269	253	220	273	213	770	302	329	257
	249	218	264	237	266	282	258	231	297	245	302	827	330	259
	295	234	302	278	306	325	300	259	322	249	329	330	1033	272
	232	202	225	216	230	240	236	194	269	220	257	259	272	727

II	P1A	P1O	P2A	P2O	P3A	P3O	P4A	P4O	P5A	P5O	P6A	P6O	P7A	P8O	
	average shared OTU number	236.8	199.9	237.7	230.7	250.8	273.1	250.9	224.2	269.2	219.3	251.6	264.5	292.4	234.8
	OTU number	743	553	721	670	922	973	795	844	892	670	770	827	1033	727
	percentage	31.9%	36.2%	33.0%	34.4%	27.2%	28.1%	31.6%	26.6%	30.2%	32.7%	32.7%	32.0%	28.3%	32.3%

b I	P1A	P1O	P2A	P2O	P3A	P3O	P4A	P4O	P5A	P5O	P6A	P6O	P7A	P8O
	66	14	17	7	16	7	9	8	18	7	14	7	8	4
	14	26	4	1	1	2	1	3	3	6	4	5	2	2
	17	4	51	21	25	8	15	12	18	5	12	4	12	2
	7	1	21	52	12	3	9	6	8	2	5	2	10	0
	16	1	25	12	76	10	25	9	21	1	10	1	6	0
	7	2	8	3	10	57	11	20	7	2	4	1	2	0
	9	1	15	9	25	11	68	18	17	2	10	1	6	0
	8	3	12	6	9	20	18	72	10	4	5	1	6	0
	18	3	18	8	21	7	17	10	55	9	15	5	10	4
	7	6	5	2	1	2	2	4	9	63	5	19	3	5
	14	4	12	5	10	4	10	5	15	5	37	6	7	2
	7	5	4	2	1	1	1	1	5	19	6	52	8	3
	8	2	12	10	6	2	6	6	10	3	7	8	44	1
	4	2	2	0	0	0	0	0	4	5	2	3	1	16

II	P1A	P1O	P2A	P2O	P3A	P3O	P4A	P4O	P5A	P5O	P6A	P6O	P7A	P8O	
	average shared OTU number	10.5	3.7	11.9	6.6	10.5	5.9	9.5	7.8	11.2	5.4	7.6	4.8	6.2	1.8
	OTU number	66	26	51	52	76	57	68	72	55	63	37	52	44	16
	percentage	15.9%	14.2%	23.4%	12.7%	13.9%	10.4%	14.0%	10.9%	20.3%	8.5%	20.6%	9.3%	14.2%	11.1%

Table S5. Functional roles and corresponding reference of core bacterial microbiome in all petroleum samples. Core microbial OTUs (23 OTUs) were affiliated to the most abundant genera.

Genus name	Average Abundance	Function role				References			
Pseudomonas (Gamma.)	14.3%	Hydrocarbon degrader	Nitrate/Nitrite reducer						
Acinetobacter (Gamma.)	7.4%	Aerobic hydrocarbon degrader							
Hydrogenophilaceae UG (Beta.)	5.0%	Fermentative bacteria	Nitrate/Nitrite reducer						
Marinobacter (Gamma.)	2.8%	Hydrocarbon degrader	Nitrate/Nitrite reducer						
Nitrincola (Gamma.)	2.6%	Aerobic hydrocarbon degrader	Nitrate/Nitrite reducer						
Thermaceae UG (D.-T.)	2.4%	Fermentative bacteria	Nitrate/Nitrite reducer						
Proteiniphilum (Bac.)	2.4%	Hydrocarbon degrader							
Deferribacteraceae UG (Deferr.)	2.2%	Hydrocarbon degrader	Nitrate/Nitrite reducer	Sulfidogenic bacteria (SRB)					
Thauera (Beta.)	2.1%	Hydrocarbon degrader	Nitrate/Nitrite reducer						
Bacteriovoracaceae UG (Delta.)	2.1%								
Psychrobacter (Gamma.)	1.9%	Aerobic hydrocarbon degrader							
Sulfurovum (Epsilon.)	1.7%	Sulfur cycling bacteria							
Defluviimonas (Alpha.)	1.3%	Nitrate/Nitrite reducer							
Balneola (Bac.)	1.2%	Aerobic hydrocarbon degrader							
Mesotoga (Thermo.)	0.9%	Hydrocarbon degrader	Fermentative bacteria	Sulfidogenic bacteria (SRB)	Acetogen	(Nesbo et al., 2012; Ben Hania et al., 2013) (Rosenberg et al., 2014)			
VC2.1 Bac22 UG (Bac.)	0.8%								
Simplicispira (Beta.)	0.8%								
Stappia (Alpha.)	0.7%	Aerobic hydrocarbon degrader							
Glycocalis (Alpha.)	0.7%	Aerobic hydrocarbon degrader							
ML635J-40 aquatic group UG (Bac.)	0.6%	Fermentative bacteria							
Spirochaetaceae UG (Spiro.)	0.6%	Fermentative bacteria	Acetogen						
Novosphingobium (Alpha.)	0.6%	Hydrocarbon degrader	Nitrate/Nitrite reducer						
Clostridiales Family XI UG (Fir.)	0.5%	Fermentative bacteria	Sulfidogenic bacteria (SRB)	Syntrophic acetate oxidizer	Acetogen	(Jones and Vandecasteele, 2008; Müller et al., 2013)			
Others	44.4%								

Table S6. The taxonomic summary of shared OTUs of bacterial communities between a) aqueous samples, b) oil samples, c) all samples. Red labeled genera acquired average proportional size over 0.5%.

Taxon		average	P1A	P1O	P2A	P2O	P3A	P3O	P4A	P4O	P5A	P5O	P6A	P6O	P7A	P7O	
D_Bacteria D_1_Proteobacteria D_2_Gammaproteobacteria D_3_Pseudomonadales D_4_Pseudomonadaceae D_5_Pseudomonas		14.3%	22.5%	14.1%	36.8%	17.8%	4.0%	3.6%	2.0%	1.7%	6.0%	1.2%	30.1%	15.0%	20.0%	33.3%	
D_Bacteria D_1_Proteobacteria D_2_Gammaproteobacteria D_3_Pseudomonadales D_4_Moraxellaceae D_5_Acinetobacter		7.4%	1.4%	1.1%	24.5%	31.7%	1.1%	12.3%	3.8%	4.0%	0.8%	1.2%	1.0%	1.2%	2.4%	1.4%	
D_Bacteria D_1_Proteobacteria D_2_Gammaproteobacteria D_3_Pseudomonadales D_4_Hydrosphingiaceae D_5_Hydrosphingiaceae		0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	0.6%	
D_Bacteria D_1_Proteobacteria D_2_Gammaproteobacteria D_3_Pseudomonadales D_4_Achromobacteraceae D_5_Marinobacter		2.8%	0.3%	0.4%	0.4%	0.5%	0.3%	1.4%	0.3%	0.2%	9.9%	16.1%	0.2%	0.4%	0.3%	0.3%	
D_Bacteria D_1_Proteobacteria D_2_Gammaproteobacteria D_3_Oceanospirillales D_4_Oceanospirillaceae D_5_Nostocales		2.6%	0.3%	0.6%	0.8%	2.9%	0.2%	0.4%	0.3%	0.2%	11.8%	17.2%	0.3%	0.6%	0.6%	0.3%	
D_Bacteria D_1_Deltaproteobacteres D_2_Deltacidoces D_3_Thermales D_4_Thermaceae D_5_uncultured bacterium		2.4%	0.2%	27.7%	0.5%	0.6%	0.6%	0.3%	0.6%	0.5%	0.3%	0.8%	1.1%	0.2%	0.5%	0.3%	0.2%
D_Bacteria D_1_Deltaproteobacteres D_2_Bacteriales D_3_Bacteriales D_4_Polyphromonadaceae D_5_Proterophilum		2.4%	4.2%	2.7%	5.8%	8.3%	0.5%	0.8%	0.4%	2.0%	5.1%	8.9%	1.9%	1.1%	1.8%	1.1%	
D_Bacteria D_1_Deltaproteobacteres D_2_Deltaproteobacteres D_3_Deltaproteobacteres D_4_Defluvimonadaceae D_5_uncultured bacterium		2.2%	0.5%	0.4%	0.3%	0.3%	0.2%	0.6%	0.5%	0.5%	0.4%	0.9%	0.9%	0.5%	0.5%	0.8%	
D_Bacteria D_1_Deltaproteobacteres D_2_Deltaproteobacteres D_3_Bellolitoriaceae D_4_Bacteriovoracae D_5_uncultured bacterium		2.1%	0.5%	0.2%	0.2%	0.2%	0.4%	11.2%	0.2%	15.0%	0.3%	0.2%	0.2%	0.3%	0.3%	0.2%	
D_Bacteria D_1_Proteobacteria D_2_Gammaproteobacteria D_3_Pseudomonadales D_4_Moraxellaceae D_5_Psychrobacter		1.9%	23.9%	0.1%	0.2%	0.2%	0.1%	0.2%	0.2%	0.1%	0.2%	0.2%	0.3%	0.3%	0.2%	0.2%	
D_Bacteria D_1_Proteobacteria D_2_Epsilonproteobacteria D_3_Campylobacteriales D_4_Helicobacteraceae D_5_Sulfurovum		1.7%	0.2%	0.1%	0.2%	0.1%	21.2%	0.4%	0.2%	0.4%	0.2%	0.1%	0.1%	0.2%	0.2%	0.2%	
D_Bacteria D_1_Proteobacteria D_2_Alphaproteobacteria D_3_Rhizobiales D_4_Rhizobiaceae D_5_Defluvimonas		1.5%	0.3%	0.3%	0.3%	0.2%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.2%	0.2%	
D_Bacteria D_1_Proteobacteria D_2_Deltaproteobacteria D_3_Deltacidoces D_4_Underclass D_5_Balneus		1.2%	0.1%	15.4%	0.1%	0.1%	0.1%	0.1%	0.2%	0.1%	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	
D_Bacteria D_1_Deltaproteobacteres D_2_Deltaproteobacteres D_3_Thermatogales D_4_Thermatoga D_5_Mesotoga		0.9%	2.2%	2.2%	0.6%	0.5%	5.9%	3.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%	
D_Bacteria D_1_Bacteroides D_2_VC1 D_3_B22 D_4 uncultured bacterium D_5 uncultured bacterium D_6 uncultured bacterium		0.8%	0.0%	0.0%	0.6%	4.5%	0.0%	0.1%	0.0%	0.0%	0.0%	0.1%	2.1%	4.2%	0.1%	0.0%	
D_Bacteria D_1_Proteobacteria D_2_Beta proteobacteria D_3_Burkholderiales D_4_Commanducellaceae D_5_Simplicicula		0.8%	0.2%	0.1%	3.1%	1.6%	0.2%	0.2%	0.1%	0.1%	0.5%	0.3%	2.3%	1.0%	1.2%	0.1%	
D_Bacteria D_1_Proteobacteria D_2_Alphaproteobacteria D_3_Rhizobiales D_4_Rhizobacteriaceae D_5_Struppi		0.7%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	
D_Bacteria D_1_Proteobacteria D_2_Deltaproteobacteres D_3_Bacteroidales D_4_ML65140 aquatic group D_5 uncultured bacterium		0.7%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
D_Bacteria D_1_Bacteroides D_2_Bacteroides D_3_Bacteroides D_4_ML65140 aquatic group D_5 uncultured bacterium		0.6%	0.0%	0.0%	0.6%	0.3%	0.1%	0.1%	0.1%	0.1%	2.4%	2.7%	0.2%	2.0%	0.0%	0.1%	
D_Bacteria D_1_Sphaerotilus D_2_Sphaerotilus D_3_Sphaerotilus D_4_Sphaerotilaceae D_5_sicca		0.6%	0.0%	0.1%	0.1%	0.0%	0.1%	0.1%	0.5%	1.1%	0.1%	0.0%	0.5%	0.3%	0.1%	0.1%	
D_Bacteria D_1_Proteobacteria D_2_Alphaproteobacteria D_3_Sphingomonadales D_4_Sphingomonadaceae D_5_Novosphingiobium		0.6%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.0%	0.1%	1.0%	0.1%	1.4%	
D_Bacteria D_1_Fimicutes D_2_Clostridia D_3_Clostridiales D_4_Family XI D_5 uncultured bacterium		0.5%	0.3%	0.8%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%	
D_Bacteria D_1_Proteobacteria D_2_Deltaproteobacteres D_3_Deltaproteobacteres D_4_Underclass D_5 uncultured bacterium		0.4%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.5%	4.6%	0.3%	0.1%	0.0%	0.1%	0.1%	0.1%	
D_Bacteria D_1_Proteobacteria D_2_Gammaproteobacteria D_3_Xanthomonadales D_4_Xanthomonadaceae D_5_Salinimonas		0.4%	0.3%	4.7%	0.0%	0.1%	0.0%	0.1%	0.1%	0.1%	0.1%	0.2%	0.3%	0.0%	0.2%	0.0%	
D_Bacteria D_1_Proteobacteria D_2_Alphaproteobacteria D_3_Rhodobacterales D_4_Rhodobacteraceae D_5_Pannamicmbacter		0.4%	0.0%	0.1%	0.0%	0.1%	0.0%	0.1%	0.0%	0.0%	0.1%	0.1%	2.4%	0.8%	2.0%	0.0%	
D_Bacteria D_1_Arhodobacteres D_2_Coriobacteres D_3_Coriobacteriales D_4_Coriobacteraceae D_5 uncultured bacterium		0.4%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
D_Bacteria D_1_Proteobacteria D_2_Betaproteobacteria D_3_Betaproteobacteres D_4_Hydrosphingiaceae D_5_Tepidiphilus		0.3%	0.1%	0.1%	1.2%	0.6%	0.1%	0.1%	0.1%	0.0%	0.0%	0.5%	0.8%	0.0%	0.0%	2.0%	
D_Bacteria D_1_Proteobacteria D_2_Deltaproteobacteres D_3_Deltaproteobacteres D_4_Hydrosphingiaceae D_5 uncultured bacterium		0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
D_Bacteria D_1_Bacteroides D_2_Cytophagales D_3_Older II D_4_Htg-5 D_5 uncultured bacterium		0.3%	0.0%	0.3%	4.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	
D_Bacteria D_1_Proteobacteria D_2_Alphaproteobacteria D_3_Rhizobiales D_4_Bryndyshiaeaceae D_5_Bryndyshiaeaceae		0.1%	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.2%	0.1%	0.2%	0.1%	0.3%	0.1%	0.0%	
D_Bacteria D_1_Proteobacteria D_2_Gammaproteobacteria D_3_Xanthomonadales D_4 uncultured D_5 uncultured protobacterium		0.1%	0.1%	0.0%	0.1%	0.0%	0.0%	0.1%	0.1%	0.0%	0.1%	0.0%	0.1%	0.1%	0.1%	0.0%	
D_Bacteria D_1_Proteobacteria D_2_Deltaproteobacteres D_3_GR_WP33-304 D_4 uncultured bacterium D_5 uncultured bacterium		0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
D_Bacteria D_1_Proteobacteria D_2_Alphaproteobacteria D_3_Rhodospirillales D_4_Rhodospirillaceae D_5 uncultured bacterium		0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	
		51.8%	50.8%	71.6%	71.6%	70.3%	61.6%	61.6%	53.8%	61.6%	53.8%	62.8%	62.8%	56.1%	46.7%	57.8%	

Table S7. Statistical significance test based on unweighted UniFrac distance matrix which obtained from beta diversity analysis

		anosim		adonis	
		R statistic	p-value	R ²	p-value
bacteria	Group	0.5137**	0.007**	0.5773**	0.003**
	pH	0.1531	0.070	0.0949*	0.016*
	Phase	-0.0049	0.493	0.0741	0.625
	Temperature	0.5257**	0.002**	0.2001**	0.001**
archaea	Group	0.3255	0.050	0.5963*	0.024*
	pH	0.2297*	0.029*	0.1107*	0.034*
	Phase	0.2284*	0.020*	0.1142*	0.022*
	Temperature	0.1967	0.101	0.1948*	0.038*
methanogen	Group	0.3176*	0.031*	0.6302*	0.017*
	pH	0.0378	0.280	0.1054	0.090
	Phase	0.0894	0.115	0.0964	0.147
	Temperature	0.3421*	0.016*	0.2430**	0.003**

Scores with *p*-value less than 0.05 were labeled with one star, scores with *p*-value less than 0.01 were labeled with two stars.

Table S8. Mantel test based on the beta diversity results by unweighted & weighted UniFrac matrix and Bray-Curtis (non-phylogenetic) matrix measurement. The aqueous and oil phase samples were analyzed separately. The physiochemical parameter distance matrices were also separately used according to phase difference. The significant scores (p -value<0.05) were highlighted.

	DM1	DM2	Mantel r statistic	p-value		DM1	DM2	Mantel r statistic	p-value		DM1	DM2	Mantel r statistic	p-value		
aqueous phase bacteria	unweighted_unifrac_dm	aqueous phase parameter 1	0.4081	0.176		unweighted_unifrac_dm	aqueous phase parameter 1	-0.1562	0.678		unweighted_unifrac_dm	aqueous phase parameter 1	0.74583	0.019		
	unweighted_unifrac_dm	aqueous phase parameter 2	0.64753	0.013		unweighted_unifrac_dm	aqueous phase parameter 2	-0.07316	0.806		unweighted_unifrac_dm	aqueous phase parameter 2	0.69711	0.007		
	unweighted_unifrac_dm	aqueous phase parameter 3	0.28869	0.081		unweighted_unifrac_dm	aqueous phase parameter 3	0.20278	0.273		unweighted_unifrac_dm	aqueous phase parameter 3	0.14591	0.42		
	unweighted_unifrac_dm	aqueous phase parameter 4	-0.27129	0.203		unweighted_unifrac_dm	aqueous phase parameter 4	0.4013	0.079		unweighted_unifrac_dm	aqueous phase parameter 4	0.06402	0.812		
	unweighted_unifrac_dm	aqueous phase parameter 5	-0.16333	0.457		unweighted_unifrac_dm	aqueous phase parameter 5	0.19431	0.417		unweighted_unifrac_dm	aqueous phase parameter 5	-0.136	0.651		
	unweighted_unifrac_dm	aqueous phase parameter 6	0.31944	0.15		unweighted_unifrac_dm	aqueous phase parameter 6	-0.16586	0.552		unweighted_unifrac_dm	aqueous phase parameter 6	-0.31355	0.228		
	unweighted_unifrac_dm	aqueous phase parameter 7	-0.23419	0.277		unweighted_unifrac_dm	aqueous phase parameter 7	-0.17779	0.483		unweighted_unifrac_dm	aqueous phase parameter 7	-0.32314	0.366		
	unweighted_unifrac_dm	aqueous phase parameter 8	-0.12684	0.67		unweighted_unifrac_dm	aqueous phase parameter 8	-0.12593	0.783		unweighted_unifrac_dm	aqueous phase parameter 8	-0.19238	0.549		
	unweighted_unifrac_dm	aqueous phase parameter 9	-0.24162	0.239		unweighted_unifrac_dm	aqueous phase parameter 9	-0.24737	0.241		unweighted_unifrac_dm	aqueous phase parameter 9	-0.35846	0.529		
	unweighted_unifrac_dm	aqueous phase parameter 10	0.7289	0.018		unweighted_unifrac_dm	aqueous phase parameter 10	-0.19016	0.500		unweighted_unifrac_dm	aqueous phase parameter 10	0.55066	0.121		
aqueous phase archaea	unweighted_unifrac_dm	aqueous phase parameter 11	-0.19852	0.386		unweighted_unifrac_dm	aqueous phase parameter 11	-0.16362	0.497		unweighted_unifrac_dm	aqueous phase parameter 11	-0.24717	0.396		
	unweighted_unifrac_dm	aqueous phase parameter 12	-0.10469	0.629		unweighted_unifrac_dm	aqueous phase parameter 12	0.19952	0.438		unweighted_unifrac_dm	aqueous phase parameter 12	0.06981	0.836		
	unweighted_unifrac_dm	aqueous phase parameter 13	-0.05797	0.812		unweighted_unifrac_dm	aqueous phase parameter 13	0.13495	0.592		unweighted_unifrac_dm	aqueous phase parameter 13	0.08523	0.78		
	unweighted_unifrac_dm	aqueous phase parameter 14	0.1986	0.317		unweighted_unifrac_dm	aqueous phase parameter 14	-0.00463	0.984		unweighted_unifrac_dm	aqueous phase parameter 14	0.10257	0.683		
	unweighted_unifrac_dm	aqueous phase parameter 15	0.25858	0.163		unweighted_unifrac_dm	aqueous phase parameter 15	0.07193	0.714		unweighted_unifrac_dm	aqueous phase parameter 15	0.03119	0.862		
	unweighted_unifrac_dm	aqueous phase parameter 16	0.24449	0.263		unweighted_unifrac_dm	aqueous phase parameter 16	-0.24024	0.403		weighted_unifrac_dm	aqueous phase parameter 1	0.51684	0.13		
	weighted_unifrac_dm	aqueous phase parameter 1	0.34545	0.363		weighted_unifrac_dm	aqueous phase parameter 1	0.47496	0.117		weighted_unifrac_dm	aqueous phase parameter 2	0.44544	0.129		
	weighted_unifrac_dm	aqueous phase parameter 2	0.33405	0.352		weighted_unifrac_dm	aqueous phase parameter 2	0.81873	0.045		weighted_unifrac_dm	aqueous phase parameter 3	0.432	0.049		
	weighted_unifrac_dm	aqueous phase parameter 3	-0.01151	0.974		weighted_unifrac_dm	aqueous phase parameter 4	0.02559	0.931		weighted_unifrac_dm	aqueous phase parameter 4	0.13816	0.616		
	weighted_unifrac_dm	aqueous phase parameter 4	-0.15934	0.652		weighted_unifrac_dm	aqueous phase parameter 5	0.15647	0.508		weighted_unifrac_dm	aqueous phase parameter 5	0.11883	0.643		
oil phase bacteria	weighted_unifrac_dm	aqueous phase parameter 5	-0.08061	0.751		weighted_unifrac_dm	aqueous phase parameter 6	-0.06455	0.881		weighted_unifrac_dm	aqueous phase parameter 6	-0.29556	0.299		
	weighted_unifrac_dm	aqueous phase parameter 6	0.02407	0.959		weighted_unifrac_dm	aqueous phase parameter 7	-0.08697	0.663		weighted_unifrac_dm	aqueous phase parameter 7	-0.07679	0.74		
	weighted_unifrac_dm	aqueous phase parameter 7	-0.092	0.72		weighted_unifrac_dm	aqueous phase parameter 8	-0.15558	0.598		weighted_unifrac_dm	aqueous phase parameter 8	-0.10082	0.851		
	weighted_unifrac_dm	aqueous phase parameter 8	-0.06267	0.93		weighted_unifrac_dm	aqueous phase parameter 9	0.03186	0.882		weighted_unifrac_dm	aqueous phase parameter 9	0.06059	0.713		
	weighted_unifrac_dm	aqueous phase parameter 9	-0.10384	0.795		weighted_unifrac_dm	aqueous phase parameter 10	-0.37540	0.144		weighted_unifrac_dm	aqueous phase parameter 10	-0.28104	0.194		
	weighted_unifrac_dm	aqueous phase parameter 10	0.94397	0.006		weighted_unifrac_dm	aqueous phase parameter 11	-0.02853	0.895		weighted_unifrac_dm	aqueous phase parameter 11	-0.09072	0.69		
	weighted_unifrac_dm	aqueous phase parameter 11	-0.2112	0.314		weighted_unifrac_dm	aqueous phase parameter 12	-0.03156	0.878		weighted_unifrac_dm	aqueous phase parameter 12	0.05044	0.797		
	weighted_unifrac_dm	aqueous phase parameter 12	-0.04413	0.899		weighted_unifrac_dm	aqueous phase parameter 13	0.15106	0.558		weighted_unifrac_dm	aqueous phase parameter 13	0.21596	0.389		
	weighted_unifrac_dm	aqueous phase parameter 13	-0.05078	0.81		weighted_unifrac_dm	aqueous phase parameter 14	0.0783	0.726		weighted_unifrac_dm	aqueous phase parameter 14	0.05518	0.86		
	weighted_unifrac_dm	aqueous phase parameter 14	-0.06254	0.712		weighted_unifrac_dm	aqueous phase parameter 15	-0.0195	0.92		weighted_unifrac_dm	aqueous phase parameter 15	-0.03789	0.868		
oil phase archaea	weighted_unifrac_dm	aqueous phase parameter 15	0.00921	0.95		weighted_unifrac_dm	aqueous phase parameter 16	0.01354	0.963		weighted_unifrac_dm	aqueous phase parameter 16	0.11778	0.772		
	weighted_unifrac_dm	aqueous phase parameter 16	0.59905	0.044		bray_curtis_dm	aqueous phase parameter 1	0.06242	0.779		bray_curtis_dm	aqueous phase parameter 1	0.18127	0.562		
	bray_curtis_dm	aqueous phase parameter 2	-0.11603	0.705		bray_curtis_dm	aqueous phase parameter 2	0.10464	0.707		bray_curtis_dm	aqueous phase parameter 2	0.17923	0.503		
	bray_curtis_dm	aqueous phase parameter 3	-0.13263	0.438		bray_curtis_dm	aqueous phase parameter 3	-0.08756	0.57		bray_curtis_dm	aqueous phase parameter 3	-0.05747	0.726		
	bray_curtis_dm	aqueous phase parameter 4	-0.08299	0.797		bray_curtis_dm	aqueous phase parameter 4	0.37592	0.086		bray_curtis_dm	aqueous phase parameter 4	0.37654	0.102		
	bray_curtis_dm	aqueous phase parameter 5	0.15813	0.643		bray_curtis_dm	aqueous phase parameter 5	0.11778	0.705		bray_curtis_dm	aqueous phase parameter 5	0.11246	0.683		
	bray_curtis_dm	aqueous phase parameter 6	0.25085	0.358		bray_curtis_dm	aqueous phase parameter 6	-0.05611	0.884		bray_curtis_dm	aqueous phase parameter 6	-0.11124	0.668		
	bray_curtis_dm	aqueous phase parameter 7	0.24613	0.609		bray_curtis_dm	aqueous phase parameter 7	-0.28674	0.316		bray_curtis_dm	aqueous phase parameter 7	-0.35733	0.169		
	bray_curtis_dm	aqueous phase parameter 8	0.25904	0.306		bray_curtis_dm	aqueous phase parameter 8	-0.2785	0.557		bray_curtis_dm	aqueous phase parameter 8	-0.34202	0.23		
	bray_curtis_dm	aqueous phase parameter 9	0.03822	0.981		bray_curtis_dm	aqueous phase parameter 9	-0.41457	0.115		bray_curtis_dm	aqueous phase parameter 9	-0.48724	0.106		
oil phase methanogen	bray_curtis_dm	aqueous phase parameter 10	0.43431	0.011		bray_curtis_dm	aqueous phase parameter 10	-0.25901	0.504		bray_curtis_dm	aqueous phase parameter 10	-0.13699	0.75		
	bray_curtis_dm	aqueous phase parameter 11	0.30985	0.276		bray_curtis_dm	aqueous phase parameter 11	0.13512	0.653		bray_curtis_dm	aqueous phase parameter 11	0.07328	0.812		
	bray_curtis_dm	aqueous phase parameter 12	0.34957	0.303		bray_curtis_dm	aqueous phase parameter 12	0.00884	0.983		bray_curtis_dm	aqueous phase parameter 12	-0.02739	0.959		
	bray_curtis_dm	aqueous phase parameter 13	0.40396	0.106		bray_curtis_dm	aqueous phase parameter 13	-0.07579	0.803		bray_curtis_dm	aqueous phase parameter 13	-0.10301	0.688		
	bray_curtis_dm	aqueous phase parameter 14	0.47986	0.044		bray_curtis_dm	aqueous phase parameter 14	-0.15899	0.446		bray_curtis_dm	aqueous phase parameter 14	-0.15058	0.465		
	bray_curtis_dm	aqueous phase parameter 15	0.47902	0.028		bray_curtis_dm	aqueous phase parameter 15	-0.17954	0.337		bray_curtis_dm	aqueous phase parameter 15	-0.18157	0.339		
	bray_curtis_dm	aqueous phase parameter 16	-0.04687	0.884		bray_curtis_dm	aqueous phase parameter 16	-0.17079	0.557		bray_curtis_dm	aqueous phase parameter 16	-0.02709	0.923		
	unweighted_unifrac_dm	oil phase parameter 1	0.01351	0.97		unweighted_unifrac_dm	oil phase parameter 1	0.00286	0.997		unweighted_unifrac_dm	oil phase parameter 1	0.19509	0.564		
	unweighted_unifrac_dm	oil phase parameter 2	0.3428	0.153		unweighted_unifrac_dm	oil phase parameter 2	0.38221	0.08		unweighted_unifrac_dm	oil phase parameter 2	0.36776	0.101		
	unweighted_unifrac_dm	oil phase parameter 3	0.26224	0.198		unweighted_unifrac_dm	oil phase parameter 3	0.33502	0.096		unweighted_unifrac_dm	oil phase parameter 3	-0.10447	0.625		
oil phase methanogen	unweighted_unifrac_dm	oil phase parameter 4	0.10013	0.789		unweighted_unifrac_dm	oil phase parameter 4	-0.31264	0.106		unweighted_unifrac_dm	oil phase parameter 4	0.46194	0.203		
	unweighted_unifrac_dm	oil phase parameter 5	0.13235	0.763		unweighted_unifrac_dm	oil phase parameter 5	-0.01977	0.910		unweighted_unifrac_dm	oil phase parameter 5	0.74692	0.002		
	unweighted_unifrac_dm	oil phase parameter 6	0.39099	0.109		unweighted_unifrac_dm	oil phase parameter 6	0.22681	0.351		unweighted_unifrac_dm	oil phase parameter 6	0.23154	0.374		
	weighted_unifrac_dm	oil phase parameter 1	-0.20549	0.561		weighted_unifrac_dm	oil phase parameter 1	0.09281	0.596		weighted_unifrac_dm	oil phase parameter 1	0.4746	0.02		
	weighted_unifrac_dm	oil phase parameter 2	-0.01431	0.973		weighted_unifrac_dm	oil phase parameter 2	0.38597	0.064		weighted_unifrac_dm	oil phase parameter 2	0.60094	0.025		
	weighted_unifrac_dm	oil phase parameter 3	-0.17587	0.434		weighted_unifrac_dm	oil phase parameter 3	0.56527	0.021		weighted_unifrac_dm	oil phase parameter 3	0.44532	0.044		
	weighted_unifrac_dm	oil phase parameter 4	0.60031	0.073		weighted_unifrac_dm	oil phase parameter 4	-0.15186	0.461		weighted_unifrac_dm	oil phase parameter 4	-0.13356	0.66		
	weighted_unifrac_dm	oil phase parameter 5	0.62552	0.054		weighted_unifrac_dm	oil phase parameter 5	0.11992	0.539		weighted_unifrac_dm	oil phase parameter 5	0.1592	0.591		
	weighted_unifrac_dm	oil phase parameter 6	0.24391	0.348		weighted_unifrac_dm	oil phase parameter 6	0.38103	0.063		weighted_unifrac_dm	oil phase parameter 6	0.57385	0.015		
	bray_curtis_dm	oil phase parameter 1	-0.01036	0.95		bray_curtis_dm	oil phase parameter 1	0.01248	0.945		bray_curtis_dm	oil phase parameter 1	-0.04154	0.878		
oil phase methanogen	bray_curtis_dm	oil phase parameter 2	0.24591	0.297		bray_curtis_dm	oil phase parameter 2	0.24514	0.303		bray_curtis_dm	oil phase parameter 2	0.19544	0.399		
	bray_curtis_dm	oil phase parameter 3	0.14685	0.627		bray_curtis_dm	oil phase parameter 3	0.35803	0.103		bray_curtis_dm	oil phase parameter 3	0.33993	0.146		
	bray_curtis_dm	oil phase parameter 4	0.23029	0.259		bray_curtis_dm	oil phase parameter 4	0.10095	0.622		bray_curtis_dm	oil phase parameter 4	0.078	0.67		
	bray_curtis_dm	oil phase parameter 5	0.36859	0.054		bray_curtis_dm	oil phase parameter 5	0.27525	0.163		bray_curtis_dm	oil phase parameter 5	0.30857	0.091		
	bray_curtis_dm	oil phase parameter 6	0.50466	0.018		bray_curtis_dm	oil phase parameter 6	0.3878	0.055		bray_curtis_dm	oil phase parameter 6	0.40252	0.047		
	aqueous phase parameter 1	Depth(m)			aqueous phase parameter 2	Temp(°C)			aqueous phase parameter 3	pH			aqueous phase parameter 4	Effective porosity (%)		
	aqueous phase parameter 5	Average permeability ($\times 10^3 \mu\text{m}^2$)			aqueous phase parameter 6	Water flooding operation (years)			aqueous phase parameter 7	CT(mg l^{-1})			aqueous phase parameter 8	$\text{SO}_4^{2-}(\text{mg l}^{-1})$		
	aqueous phase parameter 9	$\text{PO}_4^{3-}(\text{mg l}^{-1})$			aqueous phase parameter 10	$\text{NO}_3^{-(\text{mg l}^{-1})}$			aqueous phase parameter 11	$\text{Na}^+(\text{mg l}^{-1})$			aqueous phase parameter 12	$\text{K}^+(\text{mg l}^{-1})$		
	aqueous phase parameter 13	$\text{Ca}^{2+}(\text{mg l}^{-1})$			aqueous phase parameter 14	$\text{Mg}^{2+}(\text{mg l}^{-1})$			aqueous							

Table S9. Predicted functional profiles based on microbial 16S taxonomic abundance dataset. a) bacterial community functional profiles; b) archaeal community functional profiles. FTU:Fraction of OTUs that could not be mapped to KEGG organisms.

a

Samples		average	P1A	PIO	P2A	P2O	P3A	P3O	P4A	P4O	P5A	P5O	P6A	P6O	P7A	P8O
FTU		0.4697	0.3716	0.7009	0.4282	0.5890	0.5215	0.3540	0.7713	0.2426	0.4920	0.5324	0.3486	0.5064	0.3655	0.3519
Environmental Information Processing/Signal Transduction/ko0220 Two-component system		8.85%	8.65%	7.20%	9.38%	9.21%	7.50%	9.4%	8.69%	9.11%	9.42%	9.84%	8.93%	9.52%	9.21%	8.19%
Environmental Information Processing/Metabolism transport/ko0210 ABC transporters		8.85%	8.65%	9.02%	7.98%	9.15%	8.08%	8.64%	7.96%	7.73%	8.09%	8.05%	8.02%	8.29%	8.11%	8.29%
Metabolism/Nucleotides metabolism/ko0220 Purine metabolism		3.29%	3.20%	3.22%	3.19%	3.25%	3.86%	3.39%	3.22%	3.11%	3.29%	3.12%	3.2%	3.1%	3.2%	3.2%
Genetic Information Processing/translation/ko0970 Asparagyl-tRNA biosynthesis		2.78%	2.86%	2.73%	2.58%	2.69%	3.63%	2.81%	2.84%	2.69%	2.75%	2.58%	2.76%	2.56%	2.57%	2.80%
Metabolism/Energy metabolism/ko00910 Nitrogen metabolism		2.15%	2.00%	2.06%	2.13%	2.08%	2.83%	2.10%	2.00%	2.08%	2.09%	2.25%	2.02%	2.20%	2.15%	2.05%
Metabolism/Nucleotide metabolism/ko02240 Pyrimidine metabolism		2.05%	2.07%	2.07%	1.98%	2.06%	2.46%	2.07%	2.10%	2.02%	2.05%	1.91%	2.05%	1.90%	1.94%	2.07%
Environmental Information Processing/Membrane transport/ko3700 Bacterial secretion system		2.00%	1.96%	1.67%	2.22%	2.07%	1.69%	1.97%	1.83%	2.13%	2.02%	2.23%	2.19%	2.17%	2.11%	2.00%
Metabolism/Amino acid metabolism/ko01300 Arginine and proline metabolism		1.88%	1.76%	1.91%	1.76%	1.82%	2.00%	1.81%	1.91%	1.91%	1.95%	1.74%	1.80%	1.78%	1.81%	1.81%
Metabolism/Amino acid metabolism/ko01300 Arginine and proline metabolism		1.80%	1.79%	2.10%	1.49%	1.80%	1.82%	1.68%	1.31%	1.05%	2.13%	1.79%	1.79%	1.82%	1.80%	1.80%
Metabolism/Metabolism of cofactors and vitamins/ko08960 Phosphoryl and chlorophyll metabolism		1.69%	1.52%	1.96%	1.62%	1.62%	1.55%	1.60%	1.64%	1.57%	1.80%	1.77%	1.71%	1.67%	1.71%	1.77%
Metabolism/Energy metabolism/ko00520 Amino sugar and nucleotide sugar metabolism		1.65%	1.58%	1.46%	1.63%	1.76%	2.03%	1.77%	1.76%	1.64%	1.63%	1.48%	1.70%	1.54%	1.56%	1.58%
Genetic Information Processing/translation/ko03100 Ribosome		1.62%	1.67%	1.69%	1.51%	1.58%	2.09%	1.68%	1.63%	1.62%	1.62%	1.51%	1.61%	1.46%	1.49%	1.64%
Cellular Processes/Cell growth and death/ko4112 Cell cycle - Caulobacter		1.58%	1.47%	1.55%	1.50%	1.52%	1.75%	1.65%	1.52%	1.59%	1.66%	1.74%	1.54%	1.52%	1.51%	1.64%
Metabolism/Carbohydrate metabolism/ko00584 Starch and sucrose metabolism		1.54%	1.41%	1.35%	1.62%	1.63%	1.59%	1.40%	1.81%	1.65%	1.54%	1.71%	1.59%	1.55%	1.61%	1.61%
Metabolism/Amino acid metabolism/ko00060 Alanine, aspartate and glutamate metabolism		1.53%	1.45%	1.45%	1.41%	1.50%	1.59%	1.33%	1.60%	1.66%	1.54%	1.52%	1.49%	1.50%	1.49%	1.50%
Cellular Processes/Protein processing/ko02100 Bacterial chaperones		1.45%	1.39%	1.39%	1.46%	1.50%	1.05%	1.59%	1.33%	1.60%	1.66%	1.84%	1.45%	1.50%	1.44%	1.45%
Metabolism/Glycan biosynthesis and metabolism/ko04500 Peptidoglycan biosynthesis		1.39%	1.37%	1.33%	1.35%	1.40%	1.59%	1.46%	1.41%	1.37%	1.24%	1.42%	1.42%	1.30%	1.32%	1.38%
Metabolism/Energy metabolism/ko00980 Methane metabolism		1.34%	1.16%	1.18%	1.19%	1.24%	1.71%	1.34%	1.48%	1.24%	1.27%	1.43%	1.46%	1.29%	1.40%	1.24%
Cellular Processes/Cell motility/ko2040 Flagellar assembly		1.30%	1.22%	1.16%	1.26%	1.28%	1.52%	1.53%	1.28%	1.67%	1.39%	1.61%	1.19%	1.30%	1.27%	1.45%
Genetic Information Processing/Folding, sorting and degradation/ko3018 RNA degradation		1.29%	1.26%	1.33%	1.28%	1.32%	1.21%	1.28%	1.23%	1.26%	1.29%	1.32%	1.29%	1.29%	1.29%	1.29%
Metabolism/Carbohydrate metabolism/ko04500 Glycogen metabolism in prokaryotes		1.29%	1.31%	1.33%	1.34%	1.32%	1.21%	1.28%	1.23%	1.25%	1.27%	1.28%	1.23%	1.24%	1.24%	1.22%
Genetic Information Processing/Replication and repair/ko4340 Mismatch repair		1.20%	1.28%	1.08%	1.22%	1.23%	1.40%	1.13%	1.19%	1.05%	1.27%	1.23%	1.24%	1.13%	1.13%	1.18%
Metabolism/Carbohydrate metabolism/ko00051 Fructose and mannose metabolism		1.19%	1.13%	1.15%	1.18%	1.24%	1.50%	1.12%	1.30%	1.03%	1.17%	1.09%	1.22%	1.18%	1.19%	1.18%
Metabolism/Amino acid metabolism/ko02520 Alanine, aspartate and glutamate metabolism		1.07%	1.10%	1.07%	1.06%	1.06%	1.19%	1.08%	1.05%	1.07%	1.05%	1.10%	1.03%	1.04%	1.03%	1.06%
Metabolism/Amino acid metabolism/ko02700 Cysteine and methionine metabolism		1.06%	1.07%	1.07%	1.05%	1.05%	1.23%	1.03%	1.10%	1.00%	1.07%	1.03%	1.09%	1.03%	1.03%	1.05%
Metabolism/Amino acid metabolism/ko04040 Phenylalanine, tyrosine and tryptophan biosynthesis		1.06%	1.07%	1.05%	1.07%	1.03%	1.24%	0.96%	1.05%	1.04%	1.04%	1.09%	1.06%	1.04%	1.01%	1.10%
Genetic Information Processing/Repair and recombination/ko2150 Nucleotide excision repair		1.00%	0.96%	0.92%	0.95%	0.99%	0.99%	0.99%	0.98%	0.98%	0.98%	0.98%	0.98%	0.98%	0.98%	0.98%
Metabolism/Lipid metabolism/ko0544 Glycero-phospholipid metabolism		0.99%	0.95%	0.91%	1.04%	1.02%	0.65%	1.03%	0.95%	1.04%	0.95%	0.95%	0.95%	0.95%	0.95%	0.94%
Metabolism/Energy metabolism/ko0720 Carbon fixation pathways in prokaryotes		0.98%	0.98%	1.02%	0.93%	0.92%	1.10%	1.03%	0.95%	1.05%	0.93%	0.95%	0.91%	0.98%	0.93%	0.94%
Genetic Information Processing/Replication and repair/ko4340 Mismatch repair		0.96%	0.92%	0.88%	0.93%	0.98%	1.11%	1.00%	0.99%	0.96%	0.99%	0.90%	0.1%	0.90%	0.92%	0.96%
Metabolism/Amino acid metabolism/ko03000 Lysine biosynthesis		0.91%	0.96%	0.89%	0.87%	0.88%	1.09%	0.89%	0.95%	0.89%	0.87%	0.88%	0.89%	0.88%	0.89%	0.91%
Metabolism/Carbohydrate metabolism/ko00041 Pentose phosphate pathway		0.90%	0.91%	0.93%	0.93%	0.95%	0.84%	0.84%	0.99%	0.78%	0.90%	0.89%	0.95%	0.89%	0.90%	0.94%
Metabolism/Carbohydrate metabolism/ko00040 Glucuronate-1-deoxyhexose biosynthesis		0.89%	0.87%	1.05%	0.99%	0.87%	0.74%	0.84%	0.84%	0.92%	0.83%	0.83%	0.94%	0.95%	0.96%	0.96%
Metabolism/Carbohydrate metabolism/ko00010 Glycolysis / Gluconeogenesis		0.88%	0.86%	0.84%	0.88%	0.90%	0.94%	0.89%	0.78%	0.82%	0.77%	0.91%	0.81%	0.83%	0.83%	0.83%
Metabolism/Amino acid metabolism/ko04300 Histidine metabolism		0.85%	0.93%	0.92%	0.81%	0.79%	0.89%	0.82%	0.87%	0.79%	0.83%	0.87%	0.81%	0.86%	0.87%	0.86%
Metabolism/Methabolism of other amino acids/ko04300 Glutathione metabolism		0.84%	0.92%	1.07%	0.88%	0.84%	0.69%	0.84%	0.74%	0.89%	0.83%	0.84%	0.80%	0.85%	0.83%	0.83%
Metabolism/Methabolism of terpenoids and polyketides/ko00040 Terpenoid backbone biosynthesis		0.79%	0.74%	0.75%	0.71%	0.74%	0.76%	0.94%	0.95%	0.75%	0.75%	0.72%	0.71%	0.75%	0.78%	0.78%
Metabolism/Carbohydrate metabolism/ko00030 Lipopolysaccharide biosynthesis		0.78%	0.74%	0.74%	0.73%	0.71%	0.75%	0.74%	0.75%	0.74%	0.76%	0.75%	0.75%	0.75%	0.75%	0.75%
Metabolism/Amino acid metabolism/ko03070 Valine, leucine and isoleucine degradation		0.74%	0.73%	0.74%	0.78%	0.72%	0.75%	0.81%	0.70%	0.72%	0.65%	0.74%	0.71%	0.73%	0.73%	0.75%
Metabolism/Methabolism of cofactors and vitamins/ko00770 Pantethein and CoA biosynthesis		0.70%	0.79%	0.85%	0.68%	0.65%	0.43%	0.80%	0.63%	0.94%	0.61%	0.59%	0.65%	0.80%	0.79%	0.65%
Metabolism/Carbohydrate metabolism/ko00020 Citrate cycle (TCA cycle)		0.66%	0.66%	0.63%	0.66%	0.67%	0.65%	0.63%	0.68%	0.62%	0.63%	0.63%	0.67%	0.67%	0.66%	0.68%
Metabolism/Carbohydrate metabolism/ko00020 Citrate cycle (TCA cycle)		0.65%	0.65%	0.63%	0.65%	0.62%	0.78%	0.65%	0.64%	0.65%	0.60%	0.63%	0.62%	0.63%	0.62%	0.62%
Genetic Information Processing/Regulation and repair/ko4180 Base excision repair		0.62%	0.66%	0.68%	0.63%	0.60%	0.65%	0.64%	0.65%	0.60%	0.65%	0.63%	0.64%	0.65%	0.64%	0.65%
Metabolism/Xenobiotics biodegradation and metabolism/ko0362 Benzene degradation		0.59%	0.65%	0.70%	0.58%	0.56%	0.42%	0.58%	0.55%	0.57%	0.57%	0.55%	0.66%	0.66%	0.61%	0.61%
Genetic Information Processing/Replication and repair/ko0360 Protein export		0.59%	0.61%	0.58%	0.56%	0.57%	0.74%	0.63%	0.59%	0.61%	0.58%	0.58%	0.54%	0.54%	0.59%	0.59%
Metabolism/Methabolism of cofactors and vitamins/ko00790 Folate biosynthesis		0.58%	0.58%	0.56%	0.56%	0.54%	0.74%	0.58%	0.56%	0.58%	0.57%	0.61%	0.55%	0.55%	0.54%	0.59%
Metabolism/Energy metabolism/ko04970 Sulfur relay system		0.57%	0.60%	0.58%	0.58%	0.54%	0.34%	0.72%	0.54%	0.57%	0.55%	0.53%	0.55%	0.55%	0.55%	0.55%
Metabolism/Methabolism of cofactors and vitamins/ko00790 Folate biosynthesis		0.55%	0.75%	0.72%	0.61%	0.69%	0.29%	0.44%	0.51%	0.51%	0.45%	0.56%	0.61%	0.62%	0.55%	0.55%
Metabolism/Amino acid metabolism/ko03500 Tyrosine metabolism		0.54%	0.58%	0.63%	0.54%	0.53%	0.40%	0.54%	0.53%	0.58%	0.52%	0.52%	0.53%	0.58%	0.55%	0.55%
Metabolism/Methabolism of other amino acids/ko04250 Selenocysteine metabolism		0.54%	0.51%	0.50%	0.54%	0.54%	0.76%	0.65%	0.57%	0.50%	0.54%	0.50%	0.51%	0.52%	0.52%	0.52%
Genetic Information Processing/Replication and repair/ko0413 DNA repair		0.53%	0.50%	0.52%	0.50%	0.50%	0.35%	0.35%	0.35%	0.35%	0.35%	0.35%	0.35%	0.35%	0.35%	0.35%
Metabolism/Methabolism of cofactors and vitamins/ko01040 Lipopolysaccharide biosynthesis		0.52%	0.50%	0.52%	0.50%	0.50%	0.28%	0.28%	0.28%	0.28%	0.28%	0.28%	0.28%	0.28%	0.28%	0.28%
Metabolism/Biosynthesis of secondary metabolites/ko0333 Nitroaromatic degradation		0.51%	0.52%	0.50%	0.52%	0.50%	0.28%	0.28%	0.28%	0.28%	0.28%	0.28%	0.28%	0.28%	0.28%	0.28%
Metabolism/Xenobiotics biodegradation and metabolism/ko0633 Nitroaromatic degradation		0.50%	0.20%	0.20%	0.22%	0.20%	0.25%	0.25%	0.25%	0.25%	0.25%	0.25%	0.25%	0.25%	0.25%	0.25%
Metabolism/Biosynthesis of secondary metabolites/ko03111 Penicillin and cephalosporin biosynthesis		0.49%	0.20%	0.16%	0.18%	0.19%	0.26%	0.20%	0.19%	0.19%	0.19%	0.19%	0.18%	0.18%	0.19%	0.19%
Metabolism/Biosynthesis of other secondary metabolites/ko04044 Phosphate and phosphonate metabolism		0.48%	0.19%	0.23%	0.17%	0.17%	0.12%	0.12%	0.12%	0.12%	0.12%	0.12%	0.12%	0.12%	0.12%	0.12%
Metabolism/Biosynthesis of other secondary metabolites/ko03611 Tetracycline biosynthesis		0.48%	0.15%	0.15%	0.15%	0.15%	0.18%	0.18%	0.18%	0.18%	0.18%	0.18%	0.18%	0.18%	0.18%	0.18%
Metabolism/Biosynthesis of other secondary metabolites/ko03611 Tetracycline biosynthesis		0.47%	0.15%	0.15%	0.15%	0.15%	0.18%	0.18%	0.18%	0.18%	0.18%	0.18%	0.18%	0.18%	0.18%	0.18%
Metabolism/Biosynthesis of other secondary metabolites/ko03611 Tetracycline biosynthesis		0.46%	0.15%	0.15%	0.15%	0.15%	0.18%	0.18%	0.18%	0.18%	0.18%	0.18%	0.18%	0.18%	0.18%	0.18%
Metabolism/Biosynthesis of other secondary metabolites/ko03611 Tetracycline biosynthesis		0.45%	0.15%	0.15%	0.15%	0.15%	0.18%	0.18%	0.18%	0.18%	0.18%	0.18%	0.18%	0.18%	0.18%	0.18%
Metabolism/Biosynthesis of other secondary metabolites/ko03611 Tetracycline biosynthesis		0.44%	0.15%	0.15%	0.15%	0.15%	0.18%	0.18%	0.18%	0.18%	0.18%	0.18%	0.18%	0.18%	0.18%	0.18%
Metabolism/Biosynthesis of other secondary metabolites/ko03611 Tetracycline biosynthesis		0.43%	0.15%	0.15%	0.15%	0.15%	0.18%	0.18								

Methabolism_ipi/metabolismk00121	Secondary bile acid biosynthesis	0.00%	0.00%	0.005%	0.005%	0.000%	0.000%	0.01%	0.00%	0.00%	0.005%	0.005%	0.000%	0.000%	0.01%	0.01%
Human Diseases/Immune diseases	Primary immunodeficiency	0.00%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Human Diseases/Infectious diseases	Parasitick01545 Toxoplasmosis	0.00%	0.01%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Human Diseases/Cancers	Overviewk05204 Chemical carcinogenesis	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.01%	0.005%	0.005%	0.005%	0.005%	0.000%	0.000%	0.01%	0.005%
Methabolism/Glycerol metabolism and metabolismk00551 Glycosaminoglycan degradation	Fatty acid metabolism	0.00%	0.01%	0.01%	0.005%	0.005%	0.000%	0.005%	0.005%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Organisms/Systems/Nervous systemk02737 Retrigrade endocannabinoid signaling	Cellular Processes	0.00%	0.01%	0.01%	0.005%	0.005%	0.000%	0.005%	0.005%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Human Diseases/Cancer	Specific typek02222 Small cell lung cancer	0.00%	0.01%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Cellular Processes/Cell growth and deathk04115 p53 signaling pathway	Cellular Processes	0.00%	0.01%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Human Diseases/Cancer	Specific typek05210 Colorectal cancer	0.00%	0.01%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Human Diseases/Cardiovascular diseasesk04516 Viral myocarditis	Metabolism	0.00%	0.01%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Methabolism_ipi/metabolismk00142 D-Glutamine and D-Glutamate metabolism	Precursor and metabolite metabolism	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Methabolism_ipi/metabolismk00147 Glycan biosynthesis and metabolismk00142 Glycan-phospholipid-linked (GPI)-anchor biosynthesis	Protein modification, localization, storage and degradation	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Organisms/Systems/Excretory systemk04982 Vacuole regulation	Organisms/Systems/Nervous systemk04721 Synaptic vesicle cycle	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Organisms/Systems/Immune systemk04623 Cytosolic DNA-sensing pathway	Metabolism/Biosynthesis of other secondary metabolitesk00495 Stilbenoids, diarylheptanoid and ginkgolide biosynthesis	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Methabolism/Metabolism of terpenoids and polyketidesk01052 Biosynthesis of type II polyketide backbone	Methabolism/Metabolism of terpenoids and polyketides	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Human Diseases/Substance dependencek01000	Alcohol dependence	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Methabolism_ipi/metabolismk00180 Aspartate and glutamate metabolism	Metabolism	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Human Diseases/Substance dependencek01511 Amphetamine addiction	Metabolism	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Organisms/Systems/Nervous systemk04728 Dopamineergic synapse	Organisms/Systems/Immune systemk04728 Dopaminergic synapse	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Human Diseases/Infectious diseases	Parasitick01542 Chagas disease (American trypanosomiasis)	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Environmental Information Processing/Signaling molecules and interactionk04512 ECM-receptor interaction	Environmental Information Processing	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Human Diseases/Substance dependencek01530 Cocaine addiction	Metabolism	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Organisms/Systems/Nervous systemk04729 Acetylcholinergic synapse	Organisms/Systems/Immune systemk04729 Acetylcholinergic synapse	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Methabolism/Biosynthesis of other secondary metabolitesk00494 Isopentenyl pyrophosphate	Methabolism/Biosynthesis of other secondary metabolites	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Human Diseases/Cancer	Specific typek02515 Prostate cancer	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Organisms/Systems/Endocrine systemk04914 Prostaglandin-mediated oocyte maturation	Organisms/Systems/Immune systemk04612 Antigen processing and presentation	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Organisms/Systems/Immune systemk04621 NOD-1 receptor signaling pathway	Organisms/Systems/Immune systemk04621 NOD-1 receptor signaling pathway	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Methabolism_ipi/metabolismk00141 Flavonoid biosynthesis	Methabolism	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Methabolism/Biosynthesis of other secondary metabolitesk00495 Batain alkaloid biosynthesis	Methabolism/Biosynthesis of other secondary metabolites	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Methabolism/Biosynthesis of other secondary metabolitesk00495 Batatin biosynthesis	Methabolism/Biosynthesis of other secondary metabolites	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Human Diseases/Neurodegenerative diseasesk05102 Prion diseases	Metabolism	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Organisms/Systems/Immune systemk04610 Complement and coagulation cascades	Organisms/Systems/Immune systemk04610 Complement and coagulation cascades	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Methabolism/Glycerol metabolism and metabolismk00551 Glycosphingolipid biosynthesis - ganglio series	Methabolism	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Human Diseases/Cancers	Overviewk05204 Chemical carcinogenesis	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Human Diseases/Infectious diseases	Bacterialk01511 Shigelloid	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Environmental Information Processing/Signal transductionk00909 Calcium signaling pathway	Environmental Information Processing	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Methabolism/Metabolism of terpenoids and polyketidesk00908 Zearin biosynthesis	Methabolism/Metabolism of terpenoids and polyketides	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Cellular Processes/Cell motilityk04810 Regulation of actin cytoskeleton	Cellular Processes	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Human Diseases/Cardiovascular diseasesk05140 Hypertrophic cardiomyopathy (HCM)	Human Diseases/Cardiovascular diseases	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Cellular Processes/Cell growth and deathk04114 Oocyte meiosis	Cellular Processes	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Organisms/Systems/Circulatory systemk04720 Long-term potentiation	Organisms/Systems/Circulatory systemk04720 Long-term potentiation	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Methabolism_ipi/metabolismk00551 Glycosphingolipid biosynthesis - ganglio series	Methabolism	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Human Diseases/Cancer	Specific typek02522 Caffeine metabolism	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Methabolism/Biosynthesis of other secondary metabolitesk00322 Caffeine metabolism	Methabolism/Biosynthesis of other secondary metabolites	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Environmental Information Processing/Signaling molecules and interactionk04080 Neuronegative ligand-receptor interaction	Environmental Information Processing	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Methabolism/Metabolism of terpenoids and polyketidesk00902 Monoterpenoid biosynthesis	Methabolism/Metabolism of terpenoids and polyketides	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Environmental Information Processing/Signaling molecules and interactionk04514 Cell adhesion molecules (CAMs)	Environmental Information Processing	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Human Diseases/Cardiovascular diseasesk05142 Arhythmogenic right ventricular cardiomyopathy (ARVC)	Human Diseases/Cardiovascular diseases	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Cellular Processes/Transport and catabolismk04144 Endocytosis	Cellular Processes	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Environmental Information Processing/Signal transductionk04330 Wnt signaling pathway	Environmental Information Processing	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Human Diseases/Cancer	Specific typek05220 Chronic myeloid leukemia	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Methabolism/Biosynthesis of other secondary metabolitesk00944 Flavone and flavonol biosynthesis	Methabolism/Biosynthesis of other secondary metabolites	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Cellular Processes/Transport and catabolismk04144 Endocytosis	Cellular Processes	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%
Organisms/Systems/Endocrine systemk04912 HIF-1 signaling pathway	Organisms/Systems/Immune systemk04666 Fc gamma R-mediated phagocytosis	0.00%	0.005%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%	0.00%	0.005%	0.005%	0.000%	0.000%	0.005%	0.005%

References:

- Addison, S.L., Foote, S.M., Reid, N.M., and Lloyd-Jones, G. (2007). Novosphingobium nitrogenifigens sp. nov., a polyhydroxyalkanoate-accumulating diazotroph isolated from a New Zealand pulp and paper wastewater. *Int. J. Syst. Evol. Microbiol.* 57, 2467-2471. doi: doi:10.1099/ijss.0.64627-0.
- Al-Awadhi, H., Sulaiman, R.H.D., Mahmoud, H.M., and Radwan, S.S. (2007). Alkaliphilic and halophilic hydrocarbon-utilizing bacteria from Kuwaiti coasts of the Arabian Gulf. *Appl. Microbiol. Biotechnol.* 77, 183-186. doi: 10.1007/s00253-007-1127-1.
- Ben Hania, W., Postec, A., Auello, T., Ranchou-Peyruse, A., Erauso, G., Brochier-Armanet, C., Hamdi, M., Ollivier, B., Saint-Laurent, S., Magot, M., and Fardeau, M.-L. (2013). *Mesotoga infera* sp nov., a mesophilic member of the order *Thermotogales*, isolated from an underground gas storage aquifer. *Int. J. Syst. Evol. Microbiol.* 63, 3003-3008. doi: 10.1099/ijss.0.047993-0.
- Bowman, J.S., and Deming, J.W. (2014). Alkane hydroxylase genes in psychrophile genomes and the potential for cold active catalysis. *BMC Genomics* 15. doi: 10.1186/1471-2164-15-1120.
- Chen, S.Y., and Dong, X.Z. (2005). *Proteiniphilum acetatigenes* gen. nov., sp nov., from a UASB reactor treating brewery wastewater. *Int. J. Syst. Evol. Microbiol.* 55, 2257-2261. doi: 10.1099/ijss.0.63807-0.
- Cheng, L., Ding, C., Li, Q., He, Q., Dai, L.-R., and Zhang, H. (2013). DNA-SIP Reveals That *Syntrophaceae* Play an Important Role in Methanogenic Hexadecane Degradation. *PLoS One* 8. doi: 10.1371/journal.pone.0066784.
- Deppe, U., Richnow, H.H., Michaelis, W., and Antranikian, G. (2005). Degradation of crude oil by an arctic microbial consortium. *Extremophiles* 9, 461-470. doi: 10.1007/s00792-005-0463-2.
- Dicello, F., Pepi, M., Baldi, F., and Fani, R. (1997). Molecular characterization of an *n*-alkane-degrading bacterial community and identification of a new species, *Acinetobacter venetianus*. *Res. Microbiol.* 148, 237-249. doi: 10.1016/s0923-2508(97)85244-8.
- Dimitriu, P.A., Shukla, S.K., Conradt, J., Marquez, M.C., Ventosa, A., Maglia, A., Peyton, B.M., Pinkart, H.C., and Mormile, M.R. (2005). *Nitrincola lacisaponensis* gen. nov., sp nov., a novel alkaliphilic bacterium isolated from an alkaline, saline lake. *Int. J. Syst. Evol. Microbiol.* 55, 2273-2278. doi: 10.1099/ijss.0.63647-0.
- Dubbels, B.L., Sayavedra-Soto, L.A., Bottomley, P.J., and Arp, D.J. (2009). *Thauera butanivorans* sp nov., a C-2-C-9 alkane-oxidizing bacterium previously referred to as '*Pseudomonas butanovora*'. *Int. J. Syst. Evol. Microbiol.* 59, 1576-1578. doi: 10.1099/ijss.0.000638-0.
- Foesel, B.U., Drake, H.L., and Schramm, A. (2011). *Defluviimonas denitrificans* gen. nov., sp nov., and *Pararhodobacter aggregans* gen. nov., sp nov., non-phototrophic *Rhodobacteraceae* from the biofilter of a marine aquaculture. *Syst. Appl. Microbiol.* 34, 498-502. doi: 10.1016/j.syapm.2011.08.006.
- Foss, S., and Harder, J. (1998). *Thauera linaloolentis* sp. nov. and *Thauera terpenica* sp. nov., isolated on oxygen-containing monoterpenes (linalool, menthol, and eucalyptol) and nitrate. *Syst. Appl. Microbiol.* 21, 365-373.

- Gargouri, B., Karray, F., Mhiri, N., Aloui, F., and Sayadi, S. (2014). Bioremediation of petroleum hydrocarbons-contaminated soil by bacterial consortium isolated from an industrial wastewater treatment plant. *J. Chem. Technol. Biotechnol.* 89, 978-987. doi: 10.1002/jctb.4188.
- Gauthier, M.J., Lafay, B., Christen, R., Fernandez, L., Acquaviva, M., Bonin, P., and Bertrand, J.C. (1992). *Marinobacter hydrocarbonoclasticus* gen. nov., sp. nov., a new, extremely halotolerant, hydrocarbon-degrading marine bacterium. *Int. J. Syst. Bacteriol.* 42, 568-576.
- Geng, S., Pan, X.-C., Mei, R., Wang, Y.-N., Liu, X.-Y., Wang, X.-B., Tang, Y.-Q., and Wu, X.-L. (2015). *Glycocalus alkaliphilus* sp nov., a dimorphic prosthecate bacterium isolated from crude oil. *Int. J. Syst. Evol. Microbiol.* 65, 838-844. doi: 10.1099/ijss.0.000023.
- Graber, J.R., and Breznak, J.A. (2004). Physiology and nutrition of *Treponema primitia*, an H₂/CO₂ acetogenic Spirochete from termite hindguts. *Appl. Environ. Microbiol.* 70, 1307-1314. doi: 10.1128/aem.70.3.1307-1314.2004.
- Greene, A.C., Patel, B.K.C., and Sheehy, A.J. (1997). *Deferrribacter thermophilus* gen nov, sp nov, a novel thermophilic manganese- and iron-reducing bacterium isolated from a petroleum reservoir. *Int. J. Syst. Bacteriol.* 47, 505-509.
- Hayashi, N.R., Ishida, T., Yokota, A., Kodama, T., and Igarashi, Y. (1999). *Hydrogenophilus thermoluteolus* gen. nov., sp. nov., a thermophilic, facultatively chemolithoautotrophic, hydrogen-oxidizing bacterium. *Int. J. Syst. Bacteriol.* 49, 783-786.
- Inagaki, F., Takai, K., Nealson, K.H., and Horikoshi, K. (2004). *Sulfurovum lithotrophicum* gen. nov., sp nov., a novel sulfur-oxidizing chemolithoautotroph within the *epsilon-Proteobacteria* isolated from Okinawa Trough hydrothermal sediments. *Int. J. Syst. Evol. Microbiol.* 54, 1477-1482. doi: 10.1099/ijss.0.03042-0.
- Jones, T., and Vandecasteele, J.-P. (2008). *Petroleum Microbiology*. Editions OPHRYS.
- Lai, Q., Qiao, N., Wu, C., Sun, F., Yuan, J., and Shao, Z. (2010). *Stappia indica* sp nov., isolated from deep seawater of the Indian Ocean. *Int. J. Syst. Evol. Microbiol.* 60, 733-736. doi: 10.1099/ijss.0.013417-0.
- Lal, B., and Khanna, S. (1996). Degradation of crude oil by *Acinetobacter calcoaceticus* and *Alcaligenes odorans*. *J. Appl. Bacteriol.* 81, 355-362.
- Li, H., Zhang, Q., Wang, X.-L., Ma, X.-Y., Lin, K.-F., Liu, Y.-D., Gu, J.-D., Lu, S.-G., Shi, L., Lu, Q., and Shen, T.-T. (2012). Biodegradation of benzene homologues in contaminated sediment of the East China Sea. *Bioresour. Technol.* 124, 129-136. doi: 10.1016/j.biortech.2012.08.033.
- Liu, Z.P., Wang, B.J., Liu, Y.H., and Liu, S.J. (2005). *Novosphingobium taihuense* sp nov., a novel aromatic-compound-degrading bacterium isolated from Taihu Lake, China. *Int. J. Syst. Evol. Microbiol.* 55, 1229-1232. doi: 10.1099/ijss.0.63468-0.
- Lv, X.-L., Xie, B.-S., Cai, M., Geng, S., Tang, Y.-Q., Wang, Y.-N., Cui, H.-L., Liu, X.-Y., Ye, S.-Y., and Wu, X.-L. (2014). *Glycocalus albus* sp nov., a moderately halophilic dimorphic prosthecate bacterium isolated from petroleum-contaminated saline soil. *Int. J. Syst. Evol. Microbiol.* 64, 3181-3187. doi: 10.1099/ijss.0.063537-0.
- Müller, B., Sun, L., and Schnürer, A. (2013). First insights into the syntrophic acetate-oxidizing bacteria – a genetic study. *MicrobiologyOpen* 2, 35-53. doi: 10.1002/mbo3.50.
- Ma, Y.F., Wang, L., and Shao, Z.Z. (2006). *Pseudomonas*, the dominant polycyclic aromatic hydrocarbon-degrading bacteria isolated from Antarctic soils and the role of large

- plasmids in horizontal gene transfer. *Environ. Microbiol.* 8, 455-465. doi: 10.1111/j.1462-2920.2005.00911.x.
- Mechichi, T., Stackebrandt, E., Gad'on, N., and Fuchs, G. (2002). Phylogenetic and metabolic diversity of bacteria degrading aromatic compounds under denitrifying conditions, and description of *Thauera phenylacetica* sp nov., *Thauera aminoaromatica* sp nov., and *Azoarcus buckelii* sp nov. *Arch. Microbiol.* 178, 26-35. doi: 10.1007/s00203-002-0422-6.
- Mehboob, F., Junca, H., Schraa, G., and Stams, A.J.M. (2009). Growth of *Pseudomonas chloritidismutans* AW-1^T on *n*-alkanes with chlorate as electron acceptor. *Appl. Microbiol. Biotechnol.* 83, 739-747. doi: 10.1007/s00253-009-1985-9.
- Mino, S., Kudo, H., Arai, T., Sawabe, T., Takai, K., and Nakagawa, S. (2014). *Sulfurovum aggregans* sp nov., a hydrogenoxidizing, thiosulfate-reducing chemolithoautotroph within the *Epsilonproteobacteria* isolated from a deep-sea hydrothermal vent chimney, and an emended description of the genus *Sulfurovum*. *Int. J. Syst. Evol. Microbiol.* 64, 3195-3201. doi: 10.1099/ijss.0.065094-0.
- Miroshnichenko, M.L., L'haridon, S., Jeanthon, C., Antipov, A.N., Kostrikina, N.A., Tindall, B.J., Schumann, P., Spring, S., Stackebrandt, E., and Bonch-Osmolovskaya, E.A. (2003a). *Oceanithermus profundus* gen. nov., sp nov., a thermophilic, microaerophilic, facultatively chemolithoheterotrophic bacterium from a deep-sea hydrothermal vent. *Int. J. Syst. Evol. Microbiol.* 53, 747-752. doi: 10.1099/ijss.0.02367-0.
- Miroshnichenko, M.L., L'haridon, S.L., Nercessian, O., Antipov, A.N., Kostrikina, N.A., Tindall, B.J., Schumann, P., Spring, S., Stackebrandt, E., Bonch-Osmolovskaya, E.A., and Jeanthon, C. (2003b). *Vulcanithermus mediatlanticus* gen. nov., sp nov., a novel member of the family Thermaceae from a deep-sea hot vent. *Int. J. Syst. Evol. Microbiol.* 53, 1143-1148. doi: 10.1099/ijss.0.02579-0.
- Nesbo, C.L., Bradnan, D.M., Adebusuyi, A., Dlutek, M., Petrus, A.K., Foght, J., Doolittle, W.F., and Noll, K.M. (2012). *Mesotoga prima* gen. nov., sp nov., the first described mesophilic species of the *Thermotogales*. *Extremophiles* 16, 387-393. doi: 10.1007/s00792-012-0437-0.
- Niharika, N., Moskalikova, H., Kaur, J., Sedlackova, M., Hampl, A., Damborsky, J., Prokop, Z., and Lal, R. (2013). *Novosphingobium barchaimii* sp nov., isolated from hexachlorocyclohexane-contaminated soil. *Int. J. Syst. Evol. Microbiol.* 63, 667-672. doi: 10.1099/ijss.0.039826-0.
- Nolla-Ardevol, V., Strous, M., and Tegetmeyer, H.E. (2015). Anaerobic digestion of the microalga *Spirulina* at extreme alkaline conditions: biogas production, metagenome, and metatranscriptome. *Front. Microbiol.* 6. doi: 10.3389/fmicb.2015.00597.
- Pan, X.-C., Geng, S., Lv, X.-L., Mei, R., Jiangyang, J.-H., Wang, Y.-N., Xu, L., Liu, X.-Y., Tang, Y.-Q., Wang, G.-J., and Wu, X.-L. (2015). *Defluviimonas alba* sp nov., isolated from an oilfield. *Int. J. Syst. Evol. Microbiol.* 65, 1805-1811. doi: 10.1099/ijss.0.000181.
- Rosenberg, E., Delong, E.F., Lory, S., Stackebrandt, E., and Thompson, F. (2014). *The Prokaryotes: Other Major Lineages of Bacteria and The Archaea*. Springer Berlin Heidelberg.
- Salinas, M.B., Fardeau, M.L., Cayol, J.L., Casalot, L., Patel, B.K.C., Thomas, P., Garcia, J.L., and Ollivier, B. (2004). *Petrobacter succinatimandens* gen. nov., sp nov., a

- moderately thermophilic, nitrate-reducing bacterium isolated from an Australian oil well. *Int. J. Syst. Evol. Microbiol.* 54, 645-649. doi: 10.1099/ijss.0.02732-0.
- Sohn, J.H., Kwon, K.K., Kang, J.H., Jung, H.B., and Kim, S.J. (2004). *Novosphingobium pentaromaticivorans* sp nov., a high-molecular-mass polycyclic aromatic hydrocarbon-degrading bacterium isolated from estuarine sediment. *Int. J. Syst. Evol. Microbiol.* 54, 1483-1487. doi: 10.1099/ijss.0.02945-0.
- Song, B.K., Palleroni, N.J., Kerkhof, L.J., and Haggblom, M.M. (2001). Characterization of halobenzoate-degrading, denitrifying *Azoarcus* and *Thauera* isolates and description of *Thauera chlorobenzoica* sp nov. *Int. J. Syst. Evol. Microbiol.* 51, 589-602.
- Sun, W., and Cupples, A.M. (2012). Diversity of Five Anaerobic Toluene-Degrading Microbial Communities Investigated Using Stable Isotope Probing. *Appl. Environ. Microbiol.* 78, 972-980. doi: 10.1128/aem.06770-11.
- Takai, K., Kobayashi, H., Nealson, K.H., and Horikoshi, K. (2003). *Deferriribacter desulfuricans* sp nov., a novel sulfur-, nitrate- and arsenate-reducing thermophile isolated from a deep-sea hydrothermal vent. *Int. J. Syst. Evol. Microbiol.* 53, 839-846. doi: 10.1099/ijss.0.02479-0.
- Takai, K., Moyer, C.L., Miyazaki, M., Nogi, Y., Hirayama, H., Nealson, K.H., and Horikoshi, K. (2005). *Marinobacter alkaliphilus* sp nov., a novel alkaliphilic bacterium isolated from subseafloor alkaline serpentine mud from Ocean Drilling Program Site 1200 at South Chamorro Seamount, Mariana Forearc. *Extremophiles* 9, 17-27. doi: 10.1007/s00792-004-0416-1.
- Tiquia, S.M. (2010). Salt-adapted bacteria isolated from the Rouge River and potential for degradation of contaminants and biotechnological applications. *Environ. Technol.* 31, 967-978. doi: 10.1080/09593331003706226.
- Urios, L., Agogue, H., Lesongeur, F., Stackebrandt, E., and Lebaron, P. (2006). *Balneola vulgaris* gen. nov., sp nov., a member of the phylum *Bacteroidetes* from the north-western Mediterranean Sea. *Int. J. Syst. Evol. Microbiol.* 56, 1883-1887. doi: 10.1099/ijss.0.64285-0.
- Urios, L., Intertaglia, L., Lesongeur, F., and Lebaron, P. (2008). *Balneola alkaliphila* sp nov., a marine bacterium isolated from the Mediterranean Sea. *Int. J. Syst. Evol. Microbiol.* 58, 1288-1291. doi: 10.1099/ijss.0.65555-0.
- Wentzel, A., Ellingsen, T.E., Kotlar, H.-K., Zotchev, S.B., and Throne-Holst, M. (2007). Bacterial metabolism of long-chain *n*-alkanes. *Appl. Microbiol. Biotechnol.* 76, 1209-1221. doi: 10.1007/s00253-007-1119-1.
- Zhang, Q., Wang, D., Li, M., Xiang, W.-N., and Achal, V. (2014). Isolation and characterization of diesel degrading bacteria, *Sphingomonas* sp and *Acinetobacter junii* from petroleum contaminated soil. *Front. Earth Sci.* 8, 58-63. doi: 10.1007/s11707-013-0415-6.
- Zhang, Z., Hou, Z., Yang, C., Ma, C., Tao, F., and Xu, P. (2011). Degradation of *n*-alkanes and polycyclic aromatic hydrocarbons in petroleum by a newly isolated *Pseudomonas aeruginosa* DQ8. *Bioresour. Technol.* 102, 4111-4116. doi: 10.1016/j.biortech.2010.12.064.