**Appendix B**

**Supplementary Data**

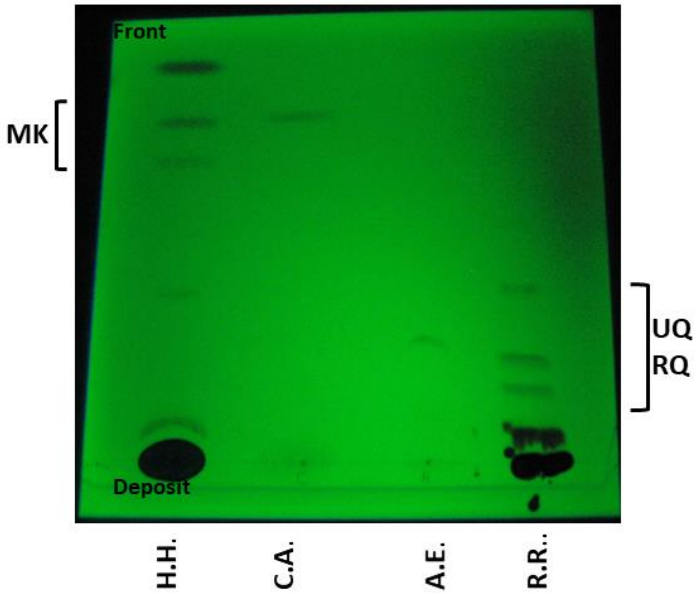


**Figure B.1: Thin Layer Chromatography of quinone extracts from membranes from diverse bacteria.** Quinones are extracted from membranes (Mb) by a mixing of 1.6 mL Mb/2mL chloroform/4 mL methanol. After a centrifugation of 20 min at 16000g, the lower phase is sampled. The solvent is evaporated under argon flux and in the absence of light. The sample is resuspended in ethanol for depositing on the TLC plate. *Halorhodospira halophila* (H.H), containing both MK and UQ, was grown under $Na_2S$/As(V) conditions. *Chrysiogenes arsenatis* (C.A.), containing only MK, was grown under As(V) conditions. *Alkalilimnicola ehrlichii I* (A.E.), containing only UQ, was grown under As(III) conditions. *Rhodospirillum rubrum* (R.R.), containing both UQ and RQ, is not an arsenicals-converting strain. To unambiguously identify the quinone from A.E as a high redox potential quinone, it has been studied by cyclic voltammetry determining its redox potential at $E_{mph7}$ = +65 mV.

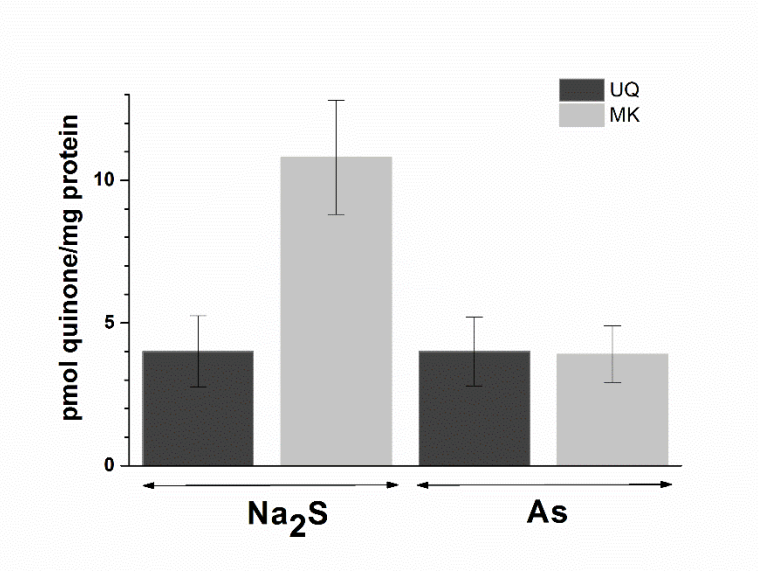


**Figure B.2: Quantification of cellular UQ- and MK-content in lipid extracts from *H. halophila*.** *H. halophila* has been grown anaerobically and photosynthetically on $Na_2S$ or $As^{III}$, as exclusive electron donor. Error bars show standard deviations.

| Accronym | Enzyme | strain name | phylum | A SU accession number | C type SU | Predicted Q pathway | | biochemical Q analysis |
|---|---|---|---|---|---|---|---|---|
| SheAN | Arr | *Shewanella sp. ANA-3* | gamma Proteobateria | AAQ01672.1 | CymA | Ubi- | Men | |
| ShePu | Arr | *Shewanella putrefaciens/Aliivibrio salmonicida LFI1238* | gamma Proteobateria | WP_014610142 | CymA | Ubi- | Men | |
| ShePi | Arr | *Shewanella piezotolerans WP3* | gamma Proteobateria | ACJ28932 | CymA | Ubi- | Men | |
| SheW3 | Arr | *Shewanella sp. W3-18-1* | gamma Proteobateria | WP_011790217.1 | CymA | Ubi- | Men | |
| SheP1 | Arr | *Shewanella sp. P1-14-1* | gamma Proteobateria | WP_055024219.1 | CymA | Ubi- | Men | |
| SheWa | Arr | *Shewanella waksmanii* | gamma Proteobateria | WP_028773911.1 | CymA | Ubi- | Men | |
| FerBa | Arr | *Ferrimonas balearica DSM 9799* | gamma Proteobateria | WP_013345579.1 | CymA | Ubi- | Men | |
| FerFu | Arr | *Ferrimonas futtsuensis* | gamma Proteobateria | WP_028109898.1 | CymA | Ubi- | Men | |
| FerKy | Arr | *Ferrimonas kyonanensis* | gamma Proteobateria | WP_028113667.1 | CymA | Ubi- | Men | |
| FerSe | Arr | *Ferrimonas senticii* | gamma Proteobateria | WP_028116765.1 | CymA | Ubi- | Men | |
| ThiTh | Arr | *Thioalkalivibrio paradoxus Arh 4* | gamma Proteobateria | WP_006746746.1 | ArrC | Ubi-Rqu | Men | |
| AerHy | Arr | *Aeromonas hydrophila* | gamma Proteobateria | WP_017788451.1 | ArrC | Ubi- | Men | |
| PhoGa | Arr | *Photobacterium ganghwense* | gamma Proteobateria | WP_047886784.1 | ArrC | Ubi- | Men | |
| PsyAq | Arr | *Psychromonas aquimarina* | gamma Proteobateria | WP_028865486.1 | ArrC | Ubi- | Men | |
| HalALS9 | Arr | *Halomonas sp. ALS9* | gamma Proteobateria | WP_064235365.1 | No | Ubi- | Men | |
| BurBa | Arr | *Burkholderiales bacterium 1_1_47* | beta Proteobacteria | ZP_07342827.1 | ArrC | Men partial | | |
| ParEx | Arr | *Parasutterella excrementihominis YIT 11859* | beta Proteobacteria | ZP_08322656.1 | CymA | Ubi- | Men | |
| SulHy | Arr | *Sulfuritalea hydrogenivorans sk43H* | beta Proteobacteria | BAO28251 | ArrC | Ubi- | | UQ |
| DesThAS | Arr | *Desulfonatronospira thiodismutans ASO3-1* | delta Proteobacteria | ZP_07017810.1 | ArrC | Mqn | | |
| MLMS | Arr | *delta proteobacterium MLMS-1* | delta Proteobacteria | ZP_01288668.1 | ArrC | Mqn | | |
| GeoLo | Arr | *Geobacter lovleyi SZ* | delta Proteobacteria | WP_012469220.1 | No | Mqn | | MK |
| DesAl | Arr | *Desulfovibrio alkalitolerans DSM 16529* | delta Proteobacteria | EPR32287.1 | ArrC | Mqn | | |
| DesHal | Arr | *Desulfovermiculus halophilus* | delta Proteobacteria | WP_051564251.1 | ArrC | Mqn | | |
| DesBR | Arr | *Desulfatitalea sp. BRH_c12* | delta Proteobacteria | KJS28921 | No | Mqn | | |
| DesThio | Arr | *Desulfonatronum thioautotrophicum* | delta Proteobacteria | WP_045221492.1 | No | Mqn | | |
| DesTh | Arr | *Desulfonatronum thiodismutans* | delta Proteobacteria | WP_031387844 | ArrC | Mqn | | |
| DesLa | Arr | *Desulfonatronum lacustre* | delta Proteobacteria | WP_028572649.1 | ArrC | Mqn | | |

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|---|---|---|---|---|---|---|---|
| DesBRc16 | Arr | *Desulfobulbaceae bacterium BRH_c16a* | delta Proteobacteria | KJS00427 | No | Mqn | |
| DesWTL | Arr | *Desulfuromonas soudanensis* | delta Proteobacteria | WP_053552011.1 | No | Mqn | |
| WolSu | Arr | *Wolinella succinogenes DSM 1740* | epsilon Proteobacteria | WP_011138677.1 | ArrC | Mqn | |
| SulBa | Arr | *Sulfurospirillum barnesii SES-3* | epsilon Proteobacteria | WP_014770549 | ArrC | Mqn | MK |
| SulMu | Arr | *Sulfurospirillum multivorans* | epsilon Proteobacteria | WP_025346199.1 | ArrC | Mqn | |
| SulAr | Arr | *Sulfurospirillum arsenophilum* | epsilon Proteobacteria | WP_041956283.1 | ArrC | Mqn | |
| AnaAr | Arr | *Anaerobacillus arseniciselenatis* | Firmicutes | WP_071313526.1 | ArrC | Mqn | MK |
| DesHaDCB | Arr | *Desulfitobacterium hafniense DCB-2* | Firmicutes | WP_015943299.1 | ArrC | Men | |
| AlkOr | Arr | *Alkaliphilus oremlandii OhILAs* | Firmicutes | WP_012158954.1 | No | None Full | MK |
| BacSeMLS10 | Arr | *Bacillus selenitireducens MLS10* | Firmicutes | WP_013173528.1 | ArrC | Mqn | |
| HalSi | Arr | *Halarsenatibacter silvermanii* | Firmicutes | ACF74513 | No | None | cultivation failed |
| NatTh | Arr | *Natranaerobius thermophilus JW/NM-WN-LF* | Firmicutes | WP_012447122.1 | No | None Full | None |
| DesHaY51 | Arr | *Desulfitobacterium hafniense Y51* | Firmicutes | BAE85920.1 | ArrC | Men | |
| DesYo | Arr | *Desulfosporosinus youngiae DSM 17734* | Firmicutes | WP_007781366.1 | ArrC | Mqn | |
| DesDi | Arr | *Desulfitobacterium dichloroeliminans LMG P-21439* | Firmicutes | WP_015261495.1 | ArrC | None Full | MK imported |
| AlkMe | Arr | *Alkaliphilus metalliredigens QYMF* | Firmicutes | WP_012062249.1 | No | None Full | |
| BacZY | Arr | *Bacillus sp. ZYK* | Firmicutes | WP_017755305.1 | ArrC | Men | |
| BacMa | Arr | *Bacillus massiliosenegalensis* | Firmicutes | WP_019156627.1 | ArrC | Men | |
| BacBo | Arr | *Bacillus boroniphilus JCM 21738/Bacillus sp. 17376* | Firmicutes | GAE44117 +GAE44118 | ArrC | Men | |
| CloBR | Arr | *Clostridiaceae bacterium BRH_c20a* | Firmicutes | KJS19576 | CymA | Men partial | |
| PepBR | Arr | *Peptococcaceae bacterium BRH_c23* | Firmicutes | KJS46169 | ArrC | Mqn | |
| PepBIC | Arr | *Peptococcaceae bacterium BICA1-8* | Firmicutes | KJS88232 | ArrC | Men partial | |
| GraBR | Arr | *Gracilibacter sp. BRH_c7a* | Firmicutes | KUO58299 | ArrC | Men | |
| DesBRc19 | Arr | *Desulfitibacter sp. BRH_c19* | Firmicutes | KUO49382 | ArrC | Men partial | |
| BacSe | Arr | *Bacillus selenatarsenatis* | Firmicutes | WP_041964264.1 | ArrC | Men | |
| TepZ9 | Arr | *Tepidibacillus decaturensis* | Firmicutes | KXG44095 | ArrC | Men | |
| SpiJC | Arr | *Spirochaeta sp. JC202* | Spirochaetes | WP_052080012.1 | No | Men partial | |
| DenAc | Arr | *Denitrovibrio acetiphilus DSM 12809* | Deferribacteria | WP_013011386.1 | No | Mqn | |
| GeoL21 | Arr | *Geovibrio sp. L21-Ace-BES* | Deferribacteria | WP_022851114 .1 | No | Mqn | |

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|---|---|---|---|---|---|---|---|---|
| DesIn | Arr | *Desulfurispirillum indicum S5* | Chrysiogenetes | WP_013505023.1 | No | Mqn | | |
| ChrAr | Arr | *Chrysiogenes arsenatis DSM 11915* | Chrysiogenetes | WP_027389593.1 | No | Mqn | | MK |
| NatGr | Arr | *Natronobacterium gregoryi SP2* | Archaea; Euryarchaeota; Halobacteria | WP_005576997.1 | ArrC | Men | | |
| HalNi | Arr | *Halobiforma nitratireducens* | Archaea; Euryarchaeota; Halobacteria | WP_006671188.1 | ArrC | Men partial | | |
| cMetNi1 | Arr | *Candidatus Methanoperedens nitroreducens* | Archaea; Euryarchaeota; Methanomicrobia | WP_048088693.1 | ArrC | Mqn | | |
| | | | | | | | | |
| AlkEh | Arx | *Alkalilimnicola ehrlichii MLHE-1* | gamma Proteobateria | WP_011627967.1 | ArrC | Ubi | | UQ |
| HalHa | Arx | *Halorhodospira halophila SL1* | gamma Proteobateria | WP_011813170.1 | ArrC | Ubi- | Men | UQ/MK |
| EctPH | Arx | *Ectothiorhodospira sp. PHS-1* | gamma Proteobateria | WP_008932021.1 | ArrC | Ubi-Rqu | Men | |
| ThiALM | Arx | *Thioalkalivibrio sp. ALMg11* | gamma Proteobateria | WP_018950173.1 | ArrC | Ubi-Rqu | | |
| HalA3 | Arx | *Halomonas sp. A3H3* | gamma Proteobateria | WP_022524225.1 | ArrC | Ubi- | Men | |
| ThiNi | Arx | *Thioalkalivibrio nitratireducens DSM 14787* | gamma Proteobateria | WP_015257777.1 | ArrC | Ubi-Rqu | Men | |
| ThiALJ | Arx | *Thioalkalivibrio sulfidiphilus* | gamma Proteobateria | WP_018952916 | ArrC | Ubi-Rqu | | |
| HalCh | Arx | *Halomonas chromatireducens* | gamma Proteobateria | AMD01645 | ArrC | Ubi | | |
| HalBo | Arx | *Halomonas boliviensis* | gamma Proteobateria | WP_040480658.1 | ArrC | Ubi- | Men | |
| MagMa | Arx | *Magnetospirillum magnetotacticum MS-1* | alpha Proteobacteria | WP_041039509.1 | ArrC | Ubi | | |
| AzoCIB | Arx | *Azoarcus sp. CIB* | beta Proteobacteria | WP_050415005.1 | ArrC | Ubi-Rqu | | |
| RIF67 | Arx | Rhodospirillales bacterium RIFCSPLOWO2_12_FULL_67_15 | alpha Proteobacteria | OHC82914.1 | ArrC | Ubi? | ? | |
| HydWC | Arx | Hydrogenophilales bacterium CG18_big_fil_WC_8_21_14_2_50_58_12 | Proteobacteria | PIQ11014.1 | ArrC | Ubi-Rqu | Men | |
| MuRBG | Arx | *Candidatus Muproteobacteria bacterium RBG_16_65_34* | Proteobacteria | OGI47522.1 | ArrC | Ubi | | |
| AzoTo | Arx | *Azoarcus tolulyticus* | beta Proteobacteria | WP_076602992.1 | ArrC | Ubi | | |
| Gal59 | Arx | *Gallionellales bacterium* RIFCSPLOWO2_02_FULL_59_110 | beta Proteobacteria | OGS99566.1 | ArrC | Ubi | | |
| RIF62 | Arx | ***Betaproteobacteria bacterium* RIFCSPLOWO2_12_FULL_62_13** | beta Proteobacteria | OGA50751.1 | ArrC | Ubi | | |
| SulDe | Arx | ***Sulfuricella denitrificans*** | beta Proteobacteria | WP_009207744.1 | ArrC | Ubi-Rqu | Men | |
| ThioKS | Arx | ***Thiocapsa* sp. KS1** | gamma Proteobateria | WP_093186008.1 | ArrC | Ubi-Rqu | Men | |
| EctBL | Arx | ***Ectothiorhodospira* sp. BSL-9** | gamma Proteobateria | WP_063465591.1 | ArrC | Ubi-Rqu | Men | |
| MarCe | Arx | ***Marinospirillum celere*** | gamma Proteobateria | WP_091965171.1 | ArrC | Ubi- | Men | |

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|---|---|---|---|---|---|---|---|---|
| ThiDe | **Arx** | ***Thioalkalivibrio denitrificans*** | **gamma Proteobateria** | WP_077279016.1 | **ArrC** | **Ubi-Rqu** | **Men** | |
| ThiTh | **Arx** | ***Thioalkalivibrio thiocyanodenitrificans*** | **gamma Proteobateria** | WP_018231946.1 | **ArrC** | **Ubi-Rqu** | **Men** | |
| HalBC | **Arx** | ***Halomonas* sp. BC04** | **gamma Proteobateria** | WP_043513786.1 | **ArrC** | **Ubi-** | **Men partial** | |
| ThiAR | **Arx** | ***Thioalkalivibrio* sp. ARh3** | **gamma Proteobateria** | **WP_018864019.1** | **ArrC** | **Ubi-Rqu** | | |
| NitLa | **Arx** | ***Nitrincola lacisaponensis*** | **gamma Proteobateria** | WP_036549261.1 | **ArrC** | **Ubi** | | |
| DelGW | **Arx** | **Deltaproteobacteria bacterium GWC2_42_11** | **delta Proteobateria** | OGP31207.1 | **ArrC** | **Ubi** | | |
| cMetNiBLZ1 | Unk | *Candidatus Methanoperedens nitroreducens* | Archaea; Euryarchaeota; Methanomicrobia | KPQ43588 | ArrC | Mqn | | |
| cMetNi2 | Unk | *Candidatus Methanoperedens spBLZ1* | Archaea; Euryarchaeota; Methanomicrobia | WP_048088677 | ArrC | Mqn | | |
| HR01 | Unk | archaeon HR1 | Archaea | GBC69680.1 | No | none Full | | |
| HR02 | Unk | archaeon HR2 | Archaea | GBC70990.1 | No | none Full | | |

**Table B.1:** Arr/Arx sequences used for reconstruction of the phylogenetic trees shown in Figure 1 and Figure A.2 and analysis of the quinone content of the related strains.

| Strain | *arr* or *arx* genes | Quinone content | $As^{III}$ conversion around pH7 | $As^{III}$ conversion around pH9 | $As^{V}$ conversion around pH7 | $A^{V}$ conversion around pH 9 |
|---|---|---|---|---|---|---|
| *A. ehrlichii* | *arx* | UQ | NO | YES, with growth | NO | NO |
| *D. hafniense* | *arr* | MK | NO | NO | YES, with growth | NO |
| *S. hydrogenivorans* | *arr* | UQ | NO | n.d. | YES, with growth | n.d. |
| with gramicidin | | | n.d. | n.d. | NO | n.d. |
| *H. halophila* | *arx* | MK and UQ | NO | YES, with growth | YES, no growth | NO |
| with gramicidin | | | n.d. | n.d. | NO | n.d. |

**Table B.2:** Summary of the results of growth- and arsenical-conversion-experiments performed on the four strains tested, in relation to their quinone- and Arr- or Arx-enzyme-content. n.d. indicates that the experiment has not been performed.