**Table 1:** The number of vessels that arrived at Dhiba port from 2005 to 2019 as a part of the anthropogenic activities. (Saudi Ports Authority, 2005- 2019).

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Year | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | Total |
| Number of vessels | 969 | 692 | 868 | 636 | 811 | 727 | 697 | 679 | 827 | 640 | 887 | 1003 | 956 | 888 | 749 | 12029 |

**Table 2:** Concentrations in ppm of heavy metals in the fifth sites before bioremediation.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| HMs  Site | 1 | 2 | 3 | 4 | 5 |
| Al3+ | Bd | Bd | Bd | Bd | Bd |
| Sb3+ | 0.03168 | 0.42359 | 0.07546 | 0.1677 | Bd |
| As3+ | 0.04126 | Bd | 0.05709 | Bd | 0.13776 |
| Ba2+ | Bd | Bd | Bd | Bd | Bd |
| Be2+ | 0.08985 | 0.0903 | 0.09326 | 0.09032 | 0.09062 |
| Cd2+ | Bd | Bd | Bd | Bd | Bd |
| Cr3+ | Bd | Bd | Bd | Bd | Bd |
| Co3+ | Bd | Bd | Bd | Bd | Bd |
| Cu2+ | Bd | Bd | Bd | Bd | Bd |
| Fe+2 | Bd | Bd | Bd | Bd | Bd |
| Pb2+ | Bd | Bd | Bd | Bd | Bd |
| ‏Mn3+ | Bd | Bd | Bd | Bd | Bd |
| Mo2+ | Bd | Bd | Bd | Bd | Bd |
| Ni2+ | Bd | Bd | Bd | Bd | Bd |
| Se2+ | 0.199 | 0.3109 | 0.4618 | 0.3895 | 0.7756 |
| Ag1+ | Bd | Bd | Bd | Bd | Bd |
| Ti2+ | Bd | Bd | Bd | Bd | Bd |
| V1+ | Bd | Bd | Bd | Bd | Bd |
| ‏Zn2+ | Bd | Bd | 0.00979 | Bd | Bd |

Bd- Below detection

**Table 3:** Concentrations in ppm of hydrocarbons before experiment in each site.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Compound Name | Molecular formula | RT | 1 | 2 | 3 | 4 | 5 |
| 1-[2,4-Bis(trimethylsiloxy)phenyl]-2-[(4-trimethylsiloxy)phenyl]propan-1-one | C24H38O4Si3 | 8.055 | 0.006286 | ND | ND | ND | 0.005373 |
| Dodecamethylcyclohexasiloxane | C12H36O6Si6 | 9.496 | 0.223982 | 0.116268 | 0.135088 | 0.062591 | 0.008171 |
| Benzoic acid, 2,5-bis(trimethylsiloxy)-, trimethylsilyl ester | C16H30O4Si3 | 6.961 | ND | ND | 0.041696 | ND | ND |
| 1-Octyl trifluoroacetate | C10H17F3O2 | 11.515 | ND | 0.01067 | ND | ND | ND |
| Tetradecamethylcycloheptasiloxane | C14H42O7Si7 | 11.832 | 0.122201 | ND | 0.080506 | 0.052461 | 0.066303 |
| Benzeneethanamine, N-[(pentafluorophenyl)methylene]-.beta.,3,4-tris[(trimethylsilyl)oxy]- | C21H26F5NO2Si2 | 13.925 | 0.042756 | 0.021591 | ND | ND | ND |
| N-(Trifluoroacetyl)-N,O,O',O''-tetrakis(trimethylsilyl)norepinephrine | C22H42F3NO4Si4 | 13.930 | 0.086935 | ND | ND | 0.014265 | ND |
| Naphthalene | C10H8 | 7.514 | 0.034976 | 0.069676 | 0.04906 | 0.044342 | 0.059409 |
| Decamethylcyclopentasiloxane | C10H30O5Si5 | 10.243 | 0.005409 | 0.029016 | ND | 0.013531 | ND |
| 1,1,3-Trimethylcyclopentane | C8H16 | 11.511 | 0.010763 | ND | ND | ND | ND |
| Diethyl Phthalate | C12H14O4 | 13.089 | 0.015847 | ND | ND | ND | ND |
| 1-Iodononane | C9H19I | 7.667 | ND | 0.005839 | ND | ND | ND |
| 3,3-Dimethylhexane | C8H18 | 8.846 | ND | 0.013802 | ND | 0.018267 | 0.014985 |
| Fumarylacetoacetate diethoxime, bis(trimethylsilyl) ester | C18H34N2O6Si2 | 11.827 | ND | 0.072343 | ND | ND | ND |
| Phthalic acid, cyclobutyl tridecyl ester | C25H38O4 | 13.097 | ND | 0.006646 | ND | ND | 0.007563 |
| Hexadecamethylcyclooctasiloxane | C16H48O8Si8 | 13.940 | ND | ND | 0.027166 | ND | 0.021796 |
| Silanamine, N-[2,6-dimethyl-4-[(trimethylsilyl)oxy]phenyl]-1,1,1-trimethyl- | C14H27NOSi2 | 8.053 | ND | ND | ND | 0.004265 | ND |
| 3-Hexene, 2,2,5,5-tetramethyl-, (Z)- | C10H20 | 11.514 | ND | ND | ND | 0.005095 | ND |
| 2H-1,4-Benzodiazepin-2-one, 1,3-dihydro-7-chloro-5-phenyl-1-trimethylsilyl- | C18H19ClN2OSi | 9.494 | ND | ND | ND | ND | 0.054325 |
| 1-Tetradecanol | C14H30O | 11.506 | ND | ND | ND | ND | 0.035378 |
| Total concentrations |  |  | 0.549156 | 0.345851 | 0.333517 | 0.214817 | 0.273304 |

RT- Retention Time, ND-Not detected

**Table 4:** Mean±SEM levels of chlorophyll-*a* contents of immobilized and suspended cells during two weeks in both sites.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Suspended cells | | | | Immobilized cells | | | |
| 14th | 10th | 7th | 3rd | 14th | 10th | 7th | 3rd |
| 2.9531±1.000j | 2.7945±0.145g | 1.6714±0.069d | 3.8327±1.000i | 0.7261±0.279a | 0.7746±0.279a | 2.8603±0.145g | 1.7590±0.090de | Site 1 |
| 1.8361±0.090e | 8.6548±1.000k | 2.3724±1.000f | 3.5895±1.000h | 0.9944±0.271b | 1.7205±0.069d | 1.4280±1.000c | 1.0438±0.271b | Site 3 |

Values in the same column with different letters are significantly different at p ≤ 0.05 according to three-way ANOVA followed by Duncan’s test

**Table 5:** Mean±SEM levels of chlorophyll-*b* contents of immobilized and suspended cells during two weeks in both sites.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Suspended cells | | | | Immobilized cells | | | |
| 14th | 10th | 7th | 3rd | 14th | 10th | 7th | 3rd |
| 2.3913±1.000g | 4.3690±1.000k | 4.171±1.000j | 5.4971±1.000n | 0.5768±1.000c | 1.4355±1.000e | 3.5713±1.000o | 3.3528±0.376i | Site 1 |
| 1.2563±1.000d | 2.60±1.000a | 7.2719±1.000m | 6.2402±1.000l | 0.2538±1.000b | 3.2932±1.000i | 2.6673±1.000h | 1.8529±1.000f | Site 3 |

Values in the same column with different letters are significantly different at p ≤ 0.05 according to three-way ANOVA followed by Duncan’s test

**Table 6:** Mean±SEM levels of Carotenoids contents of immobilized and suspended cells during two weeks in both sites.

Values in the same column with different letters are significantly different at p ≤ 0.05 according to three-way ANOVA followed by Duncan’s test

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Suspended cells | | | | Immobilized cells | | | |
| 14th | 10th | 7th | 3rd | 14th | 10th | 7th | 3rd |
| 666.14±1.000o | 298.87±0.428i | 276.65±1.000h | 426.77±1.000n | 78.9526±1.000a | 97.3609±1.000b | 474.3±1.000l | 220.2±1.000g | Site 1 |
| 555.77±1.000n | 479.23±1.000m | 297.05±0.428i | 417.44±1.000k | 106.36±1.000c | 213.34±1.000f | 171.18±1.000h | 137.04±1.000d | Site 3 |

**Table 7:** Three-way variance (ANOVA) among site, alga treatments and incubation days on the Chl *a, b* and carotene contents of the agla used (*C. vulgaris*)

| Source | Chla | | | Chl b | | | Carotene | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| df | F | Sig. | df | F | Sig. | df | F | Sig. |
| Intercept | 1 | 105.372 | .000 | 1 | 10.684 | .047 | 1 | 577500 | .000 |
| site | 1 | 3.122 | .087 | 1 | 57.299 | .005 | 1 | 4863 | .000 |
| Alga treatments | 1 | 9.104 | .005 | 1 | 1.911 | .261 | 1 | 86380 | .000 |
| Incubation periods (days) | 3 | 1.222 | .318 | 3 | 19.783 | .000 | 3 | 975.415 | .000 |
| site \* alga treatments | 1 | .033 | .858 | 1 | .031 | .870 | 1 | 33.563 | .000 |
| site \* Incubation periods (days) | 3 | 2.821 | .054 | 3 | .010 | .998 | 3 | 7232 | .000 |
| Alga treatments \* Incubation periods (days) | 3 | 4.216 | .013 | 3 | .415 | .755 | 3 | 15530 | .000 |
| site \* alga treatments \* Incubation periods (days) | 3 | 5.290 | .004 | 3 | 4506 | .000 | 3 | 6406 | .000 |
|  |  |  |  |  |  |  |  |  |  |

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Chl a | | | Chl b | | | Carotene | | |
| Source | df | F | Sig. | df | F | Sig. | df | F | Sig. |
| Site 1 | Intercept | 1 | 31770 | .000 | 1 | 45760 | .000 | 1 | 257600 | .000 |
| Alga treatments | 1 | 3539 | .000 | 1 | 881.459 | .000 | 1 | 31070 | .000 |
| days | 3 | 258.122 | .000 | 3 | 3537 | .000 | 3 | 4744 | .000 |
| Alga treatments \* incubation periods | 3 | 1356 | .000 | 3 | 2527 | .000 | 3 | 15550 | .000 |
| Site 3 | Intercept | 1 | 36.213 | .000 | 1 | 42420 | .000 | 1 | 358700 | .000 |
| Alga treatments | 1 | 2.559 | .129 | 1 | 3673 | .000 | 1 | 67640 | .000 |
| Incubation perioeds (days) | 3 | 1.876 | .174 | 3 | 5078 | .000 | 3 | 2816 | .000 |
| Alga treatments \* Incubation perioeds (days) | 3 | 3.984 | .027 | 3 | 4417 | .000 | 3 | 1747 | .000 |

**Table 8:** Tests of between-subjects effects in related to site dependent pigments contents of alga (*C. vulgaris*).

**Table 9:** HMs concentrations in ppm of site 3 after bioremediation with suspended and immobilized *C. vulgaris* cells.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| HMs | Al3+ | Sb3+ | As3+ | Ba2+ | Be2+ | Cd2+ | Cr3+ | Co3+ | Cu2+ | Fe+2 | Pb2+ | ‏Mn3+ | Mo2+ | Ni2+ | Se2+ | Ag1+ | Ti2+ | V1+ | ‏Zn2+ |
| Suspended cells | Bd | Bd | Bd | Bd | Bd | Bd | Bd | Bd | Bd | Bd | Bd | Bd | Bd | Bd | Bd | Bd | Bd | Bd | Bd |
| Immobilized cells | Bd | Bd | Bd | Bd | Bd | Bd | Bd | Bd | Bd | Bd | Bd | Bd | Bd | Bd | Bd | Bd | Bd | Bd | Bd |

Bd- Below detection

**Table 10:** Concentrations in ppm of hydrocarbons after experiment with both suspended and immobilized *C. vulgaris* cells.

|  |  |  |  |
| --- | --- | --- | --- |
| Compound Name | Molecular formula | Suspended *C. vulgaris* | Immobilized *C. vulgaris* |
| 7,9-Di-tert-butyl-1-oxaspiro(4,5)deca-6,9-diene-2,8-dione | C17H24O3 | 8.054702 | 2.845451 |
| 1-Docosene | C22H44 | ND | 3.646065302 |
| 9-Octadecenamide, (Z)- | C18H35NO | 15.82382 | 6.322348652 |
| Hexadecanoic acid, 2-hydroxy-1-(hydroxymethyl)ethyl ester | C19H38O4 | 37.79498 | 3.058358 |
| Hexatriacontane | C36H74 | 20.76870683 | 7.992108 |
| Tetrapentacontane | C54H110 | 40.48991343 | 3.985724123 |
| Tetratriacontane | C34H70 | 8.444043 | ND |
| n-Heptadecanol-1 | C17H36O | 5.708477 | ND |
| Octacosanol | C28H58O | 8.281868 | ND |
| 13-Docosenamide | C22H43NO | 26.94995 | ND |
| Tetracosane | C24H50 | 5.985861 | ND |
| Octadecanoic acid, 2,3-dihydroxypropyl ester | C25H46O6 | 14.97093 | ND |

ND-Not detected