# Supporting Information

**Material-specific properties applied to an environmental risk assessment of engineered nanomaterials – implications on grouping and read-across concepts**

Henning Wiggera\* and Bernd Nowacka

a Empa, Swiss Federal Laboratories for Materials Science and Technology, Technology and Society Laboratory, Lerchenfeldstrasse 5, 9014 St. Gallen, Switzerland

\*Corresponding author contact details: henning.wigger@googlemail.com

Table S1. Allocation of the applications to the nano-forms considered for nano-TiO2. All values are given as relative shares summing up to one.

|  |  |  |  |
| --- | --- | --- | --- |
| **application** | **nano-TiO2** | | **comment** |
|  | **anatase [-]** | **rutile[-]** |  |
| Paints | 0.089 |  |  |
| Plastic |  | 0.036 |  |
| Cosmetics |  | 0.594 |  |
| Coating | 0.019 | 0.019 | assumed 50/50 for both crystal forms |
| Batteries/Capacitors | 0.004 |  |  |
| Metals | 0.001 |  |  |
| Light bulbs | 0.002 |  |  |
| Glass&Ceramics | 0.017 |  |  |
| Filter | 0.058 |  |  |
| Consumer electronics | 0.069 |  |  |
| Textiles |  | 0.003 |  |
| Food |  | 0.004 |  |
| Ink |  |  |  |
| Cement | 0.001 |  |  |
| Cleaning agent |  | 0.061 |  |
| Spray | 0.002 |  |  |
| Paper |  | 0.000 |  |
| Sport goods |  | 0.015 |  |
| Wastewater treatment | 0.007 |  |  |
| **Total** | **0.269** | **0.732** |  |

Table S2. Allocation of the applications to the nano-forms considered for nano-Al2O3. All values are given as relative shares summing up to one.

|  |  |  |
| --- | --- | --- |
| **application** | **nano-form** | |
|  | **alpha-Al2O3** | **gamma-Al2O3** |
| Adhesive | 0.000003 |  |
| Automotive coating | 0.104148 |  |
| Catalyst |  | 0.002529 |
| Cement | 0.180767 |  |
| Ceramic material | 0.016281 |  |
| Cleaning agent | 0.102222 |  |
| Cosmetics | 0.090489 |  |
| Electronics | 0.000066 |  |
| Filter |  | 0.156909 |
| Health service |  | 0.000002 |
| Paint | 0.168698 |  |
| Plastic | 0.004938 |  |
| Polish | 0.062273 |  |
| Speciality paper | 0.106875 |  |
| Sporting good | 0.0038 |  |
| **Total** | **0.841** | **0.159** |

Table S3. Allocation of the applications to the nano-forms considered for multiwall carbon nanotubes (MWNTs) and single wall carbon nanotubes (SWNTs). All values are given as relative shares summing up to one.

|  |  |  |
| --- | --- | --- |
| **Application** | **MWNT-Share** | **SWNT Share** |
| Plastics | 0.84 |  |
| Paints | 0.01 |  |
| Textiles | 0.0002 |  |
| Automotive | 0.01 |  |
| Energy | 0.09 |  |
| Aerospace | 0.00625 |  |
| Electronics |  | 0.03 |
| Sensor |  | 0.004 |
| **Total** | **0.95645** | **0.034** |

Table S4. Ecotoxicological data that were used for the generation of the PSSD of nano-TiO2 in the fresh water compartment.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **author** | **year** | **anatase  [%]** | **rutile [%]** | **duration  [h]** | **taxonomic group** | **test  organism** | **dose  descriptor** | **concentration  [µg/L]** | **AF short to long term  effect** | **AF dose descriptor** |
| Amiano et al. 1 | 2012 | 86 | 14 | 48 | Crustacean | Daphnia magna | EC50 | 1200 | 10 | 10 |
| Amiano et al. 1 | 2012 | 86 | 14 | 48 | Crustacean | Daphnia magna | EC50 | 3400 | 10 | 10 |
| Amiano et al. 1 | 2012 | 86 | 14 | 48 | Crustacean | Daphnia magna | EC50 | 29700 | 10 | 10 |
| Amiano et al. 1 | 2012 | 86 | 14 | 48 | Crustacean | Daphnia magna | EC50 | 33600 | 10 | 10 |
| Angelstorf et al. 2 | 2014 | 86 | 14 | 96 | Invertebrate | Caenorhabditis elegans | NOEC | 3000 | 10 | 1 |
| Angelstorf et al. 2 | 2014 | 86 | 14 | 96 | Invertebrate | Caenorhabditis elegans | EC82 | 100000 | 10 | 10 |
| Aruoja et al.3 | 2015 | 12.4 | 87.6 | 72 | Algae | Raphidocelis subcapitata | EC50 | 1260 | 1 | 10 |
| Bar-Ilan et al. 4 | 2012 | 75 | 25 | 120 | Vertebrate | Danio Rerio | EC50 | 300000 | 10 | 10 |
| Bar-Ilan et al. 4 | 2012 | 75 | 25 | 120 | Vertebrate | Danio Rerio | EC50 | 1000000 | 10 | 10 |
| Barreto et al.5 | 2016 | 82 | 18 | 96 | Algae | Scenedesmus bijugus | EC20 | 9.6 | 1 | 2 |
| Bundschuh et al.6 | 2011 | 80 | 20 | 168 | Crustacean | Gammarus fossarum | LOEC | 200 | 10 | 2 |
| Chen et al.7 | 2011 | 75 | NA | 4320 | Vertebrate | Danio rerio | LOEC | 4000 | 1 | 2 |
| Cherchi et al.8 | 2011 | 100 | NA | 96 | Unicellular | Anabaena variabilis | EC50 | 620 | 1 | 10 |
| Clement et al. 9 | 2013 | 100 | 0 | 72 | Crustacean | Daphnia magna | EC50 | 1300 | 10 | 10 |
| Clement et al. 9 | 2013 | 100 | 0 | 72 | Crustacean | Daphnia magna | EC50 | 3150 | 10 | 10 |
| Clement et al. 9 | 2013 | 100 | 0 | 72 | Crustacean | Daphnia magna | EC50 | 3440 | 10 | 10 |
| Clemente et al. 10 | 2014 | 100 | 0 | 48 | Crustacean | Daphnia similis | EC50 | 750000 | 10 | 10 |
| Clemente et al. 10 | 2014 | 100 | 0 | 48 | Crustacean | Daphnia similis | EC50 | 1000000 | 10 | 10 |
| Clemente et al. 10 | 2014 | 80 | 20 | 48 | Crustacean | Daphnia similis | EC50 | 60160 | 10 | 10 |
| Clemente et al. 10 | 2014 | 80 | 20 | 48 | Crustacean | Daphnia similis | EC50 | 1000000 | 10 | 10 |
| Cupi et al.11 | 2016 | 0 | 100 | 48 | Crustacean | Daphnia magna | EC10 | 900 | 10 | 2 |
| Cupi et al.12 | 2015 | 0 | 100 | 48 | Crustacean | Daphnia magna | NOEC | 100000 | 10 | 1 |
| Cupi et al.12 | 2015 | 0 | 100 | 48 | Crustacean | Daphnia magna | NOEC | 100000 | 10 | 1 |
| Cupi et al. 11 | 2016 | 0 | 100 | 48 | Crustacean | Daphnia magna | HONEC | 100000 | 10 | 1 |
| Dabrunz et al. | 2011 | 100 | 0 | 96 | Crustacean | Daphnia magna | EC50 | 730 | 10 | 10 |
| Dalai et al. 13 | 2014 | 99.7 | NA | 48 | Crustacean | Ceriodaphnia dubia | NOEC | 4000 | 10 | 1 |
| Das et al. 14 | 2013 | 80 | 20 | 48 | Crustacean | Daphnia magna | NOEC | 4100 | 10 | 1 |
| Fang et al. 15 | 2015 | 100 | 0 | 96 | Vertebrate | Danio rerio | NOEC | 100000 | 10 | 1 |
| Fang et al. 15 | 2015 | 100 | 0 | 96 | Vertebrate | Danio rerio | HONEC | 500000 | 10 | 1 |
| Federici et al. 16 | 2007 | 25 | 75 | 336 | Vertebrate | Oncorhynchus mykiss | HONEC | 1000 | 10 | 1 |
| Fu et al.17 | 2015 | 99 | NA | 96 | Algae | Raphidocelis subcapitata | EC50 | 6300 | 1 | 10 |
| Fu et al. 17 | 2015 | 99 | NA | 96 | Algae | Raphidocelis subcapitata | EC50 | 8700 | 1 | 10 |
| George et al.18 | 2014 | 100 | 0 | 116 | Vertebrate | Danio rerio(embryos) | EC20 | 2500 | 10 | 2 |
| George et al. 18 | 2014 | 100 | 0 | 116 | Vertebrate | Danio rerio(embryos) | HONEC | 5000 | 10 | 1 |
| Gökce et al. 19 | 2018 | 90 | NA | 96 | Crustacean | Daphnia magna | LC50 | 1000 | 10 | 10 |
| Gomes et al. 20 | 2015 | 100 | 0 | 120 | Invertebrate | Enchytraeus crypticus | LOEC | 300 | 10 | 2 |
| Gomes et al. 20 | 2015 | 86 | 14 | 120 | Invertebrate | Enchytraeus crypticus | NOEC | 100000 | 10 | 1 |
| Gomes et al. 20 | 2015 | 100 | 0 | 120 | Invertebrate | Enchytraeus crypticus | NOEC | 100000 | 10 | 1 |
| Gomes et al. 20 | 2015 | 100 | 0 | 120 | Invertebrate | Enchytraeus crypticus | NOEC | 100000 | 10 | 1 |
| Gomes et al. 20 | 2015 | 100 | 0 | 120 | Invertebrate | Enchytraeus crypticus | NOEC | 100000 | 10 | 1 |
| Gunawan et al. 21 | 2013 | 100 | 0 | 192 | Algae | Chlamydomonas reinhardtii | HONEC | 100000 | 1 | 1 |
| Hall et al. 22 | 2009 | 100 | 0 | 48 | Crustacean | Ceriodaphnia dubia | LC50 | 7600 | 10 | 10 |
| Hall et al. 22 | 2009 | 100 | 0 | 168 | Crustacean | Ceriodaphnia dubia | IC25 | 8500 | 10 | 5 |
| Hall et al. 22 | 2009 | 100 | 0 | 48 | Crustacean | Ceriodaphnia dubia | LC50 | 57600 | 10 | 10 |
| Hall et al. 22 | 2009 | 100 | 0 | 48 | Crustacean | Daphnia pulex | LC50 | 9200 | 10 | 10 |
| Hall et al. 22 | 2009 | 100 | 0 | 168 | Vertebrate | Pimephales promelas | IC25 | 452000 | 10 | 5 |
| Hall et al. 22 | 2009 | 100 | 0 | 48 | Vertebrate | Pimephales promelas | LC50 | 500000 | 10 | 10 |
| Hall et al. 22 | 2009 | 100 | 0 | 96 | Algae | Raphidocelis subcapitata | IC25 | 1500 | 1 | 5 |
| Hartmann et al. 23 | 2010 | 67.2 | 32.8 | 72 | Algae | Raphidocelis subcapitata | EC10 | 3300 | 1 | 2 |
| Hartmann et al. 23 | 2010 | 72.6 | 18.4 | 72 | Algae | Raphidocelis subcapitata | EC10 | 15500 | 1 | 2 |
| Hartmann et al. 23 | 2010 | 100 | 0 | 72 | Algae | Raphidocelis subcapitata | EC10 | 18000 | 1 | 2 |
| Hund-Rinke et al. 24 | 2006 | 75 | NA | 72 | Algae | Desmodesmus subspicatus | EC50 | 44000 | 1 | 10 |
| Hund-Rinke et al. 24 | 2006 | 100 | 0 | 72 | Algae | Desmodesmus subspicatus | HONEC | 50000 | 1 | 1 |
| Hurel et al. 25 | 2018 | 0 | 100 | 72 | Crustacean | Daphnia magna | EC50 | 303000 | 10 | 10 |
| Iswarya et al.26 | 2015 | 100 | 0 | 72 | Algae | Chlorella sp | EC10 | 53 | 1 | 2 |
| Iswarya et al. 26 | 2015 | 0 | 100 | 72 | Algae | Chlorella sp | EC10 | 67 | 1 | 2 |
| Iswarya et al.27 | 2016 | 100 | 0 | 48 | Crustacean | Ceriodaphnia dubia | LC50 | 22560 | 10 | 10 |
| Iswarya et al. 27 | 2016 | 0 | 100 | 48 | Crustacean | Ceriodaphnia dubia | LC50 | 23760 | 10 | 10 |
| Iswarya et al. 27 | 2016 | 100 | 0 | 48 | Crustacean | Ceriodaphnia dubia | LC50 | 37040 | 10 | 10 |
| Iswarya et al. 27 | 2016 | 0 | 100 | 48 | Crustacean | Ceriodaphnia dubia | LC50 | 48000 | 10 | 10 |
| Jacobasch et al. 28 | 2014 | 86 | 14 | 504 | Crustacean | Daphnia magna | EC10 | 4520 | 1 | 2 |
| Ji et al. 29 | 2011 | 100 | 0 | 144 | Algae | Chlorella sp | NOEC | 16000 | 1 | 1 |
| Jovanovic et al. 30 | 2011 | 100 | 0 | 168 | Vertebrate | Pimephales promelas | HONEC | 1000000 | 10 | 1 |
| Kim et al. 31 | 2014 | 76.9 | 23.1 | 504 | Crustacean | Daphnia magna | NOEC | 1000 | 1 | 1 |
| Kim et al. 31 | 2010 | 76.9 | 23.1 | 504 | Crustacean | Daphnia magna | LOEC | 500 | 1 | 2 |
| Li, C. et al. 32 | 2012 | 100 | 0 | 48 | Unicellular | Paramecium  multimicronucleatum | LC50 | 7215200 | 1 | 10 |
| Li, S. et al. 33 | 2016 | 86 | 14 | 48 | Crustacean | Daphnia magna | LC50 | 260 | 10 | 10 |
| Li, S. et al. 33 | 2016 | 86 | 14 | 48 | Crustacean | Daphnia magna | LC50 | 1030 | 10 | 10 |
| Li, S. et al. 33 | 2016 | 86 | 14 | 48 | Vertebrate | Oryzias latipes | LC50 | 26300 | 10 | 10 |
| Li, S. et al. 33 | 2016 | 86 | 14 | 48 | Vertebrate | Oryzias latipes | LC50 | 39900 | 10 | 10 |
| Li, S. et al. 33 | 2016 | 86 | 14 | 48 | Vertebrate | Oryzias latipes | LC50 | 250000 | 10 | 10 |
| Li, S. et al. 33 | 2016 | 86 | 14 | 48 | Vertebrate | Oryzias latipes | LC50 | 250000 | 10 | 10 |
| Li, S. et al. 33 | 2016 | 86 | 14 | 48 | Crustacean | Daphnia magna | LC50 | 250000 | 10 | 10 |
| Li, S. et al. 33 | 2016 | 86 | 14 | 48 | Crustacean | Daphnia magna | LC50 | 250000 | 10 | 10 |
| Li, S. et al.34 | 2014 | 86 | 14 | 48 | Crustacean | Daphnia magna | LC50 | 60 | 10 | 10 |
| Li, S. et al. 34 | 2014 | 86 | 14 | 48 | Vertebrate | Oryzias latipes | LC50 | 8500 | 10 | 10 |
| Li, S. et al. 34 | 2014 | 86 | 14 | 48 | Vertebrate | Oryzias latipes | LC50 | 500000 | 10 | 10 |
| Li, S. et al. 34 | 2014 | 86 | 14 | 48 | Crustacean | Daphnia magna | LC50 | 118000 | 10 | 10 |
| Li, S. et al. 35 | 2014 | 86 | 14 | 48 | Crustacean | Hyalella azteca | LC50 | 20000 | 10 | 10 |
| Li, S. et al. 35 | 2014 | 86 | 14 | 48 | Invertebrate | Lumbriculus variegatus | LC50 | 20000 | 10 | 10 |
| Li, Wallis et al.36 | 2014 | 86 | 14 | 96 | Crustacean | Hyalella azteca | LC50 | 29900 | 10 | 10 |
| Li, Wallis et al. 36 | 2014 | 86 | 14 | 96 | Crustacean | Hyalella azteca | LC50 | 631000 | 10 | 10 |
| Lu et al.37 | 2017 | 80 | 20 | 48 | Crustacean | Daphnia magna | EC50 | 3580 | 10 | 10 |
| Lu et al. 37 | 2017 | 50 | 50 | 48 | Crustacean | Daphnia magna | EC50 | 5150 | 10 | 10 |
| Lu et al. 37 | 2017 | 100 | 0 | 48 | Crustacean | Daphnia magna | EC50 | 6830 | 10 | 10 |
| Lu et al. 37 | 2017 | 80 | 20 | 48 | Crustacean | Daphnia magna | EC50 | 27450 | 10 | 10 |
| Lu et al. 37 | 2017 | 0 | 100 | 48 | Crustacean | Daphnia magna | EC50 | 31250 | 10 | 10 |
| Lu et al. 37 | 2017 | 100 | 0 | 48 | Crustacean | Daphnia magna | HONEC | 100000 | 10 | 1 |
| Lu et al. 37 | 2017 | 50 | 50 | 48 | Crustacean | Daphnia magna | HONEC | 100000 | 10 | 1 |
| Lu et al. 37 | 2017 | 0 | 100 | 48 | Crustacean | Daphnia magna | HONEC | 100000 | 10 | 1 |
| Lu et al. 37 | 2017 | 80 | 20 | 48 | Crustacean | Daphnia magna | HONEC | 100000 | 10 | 1 |
| Lu et al. 37 | 2017 | 80 | 20 | 48 | Crustacean | Daphnia magna | HONEC | 100000 | 10 | 1 |
| Ma et al. 38 | 2012 | 86 | 14 | 48 | Crustacean | Daphnia magna | LC50 | 29.8 | 10 | 10 |
| Ma et al. 38 | 2012 | 86 | 14 | 96 | Vertebrate | Oryzias latipes | LC50 | 2460 | 10 | 10 |
| Ma et al. 38 | 2012 | 86 | 14 | 96 | Vertebrate | Oryzias latipes | LC50 | 294000 | 10 | 10 |
| Ma et al. 38 | 2012 | 86 | 14 | 48 | Crustacean | Daphnia magna | NOEC | 100000 | 10 | 1 |
| Mansfield et al.39 | 2015 | 99 | 1 | 8 | Crustacean | Daphnia magna | LC50 | 139 | 10 | 10 |
| Mansfield et al. 39 | 2015 | 99 | 1 | 8 | Crustacean | Daphnia magna | LC50 | 778 | 10 | 10 |
| Mansfield et al. 39 | 2015 | 99 | 1 | 8 | Crustacean | Daphnia magna | NOEC | 20000 | 10 | 1 |
| Marcone et al. 40 | 2012 | 70 | 30 | 48 | Invertebrate | Daphnia similis | EC50 | 7800 | 10 | 10 |
| Marcone et al. 40 | 2012 | 70 | 30 | 48 | Invertebrate | Daphnia similis | EC50 | 12500 | 10 | 10 |
| Marcone et al. 40 | 2012 | 70 | 30 | 48 | Invertebrate | Daphnia similis | HONEC | 100000 | 10 | 1 |
| Marcone et al. 40 | 2012 | 100 | 0 | 48 | Invertebrate | Daphnia similis | EC50 | 56900 | 10 | 10 |
| Marcone et al. 40 | 2012 | 0 | 100 | 48 | Invertebrate | Daphnia similis | HONEC | 100000 | 10 | 1 |
| Marcone et al. 40 | 2012 | 0 | 100 | 48 | Invertebrate | Daphnia similis | HONEC | 100000 | 10 | 1 |
| Metzler et al.41 | 2011 | 80-90 | 10 to 20 | 96 | Algae | Raphidocelis subcapitata | EC50 | 113000 | 1 | 10 |
| Nicolas et al.42 | 2016 | 98.5 | NA | 72 | Algae | Raphidocelis subcapitata | EC50 | 2700 | 1 | 10 |
| Nicolas et al. 42 | 2016 | ? | 89 | 72 | Algae | Raphidocelis subcapitata | NOEC | 4700 | 1 | 1 |
| Nicolas et al. 42 | 2016 | 98.5 | NA | 72 | Algae | Raphidocelis subcapitata | EC50 | 8500 | 1 | 10 |
| Nicolas et al. 42 | 2016 | ? | 89 | 72 | Algae | Raphidocelis subcapitata | EC50 | 39000 | 1 | 10 |
| Nicolas et al. 42 | 2016 | 98.5 | NA | 72 | Algae | Raphidocelis subcapitata | EC50 | 50000 | 1 | 10 |
| Nicolas et al. 42 | 2016 | ? | 89 | 72 | Algae | Raphidocelis subcapitata | EC50 | 50000 | 1 | 10 |
| Oleszczuk et al.43 | 2015 | 75 | NA | 48 | Crustacean | Daphnia magna | EC50 | 99000 | 10 | 10 |
| Ozkaleli et al.44 | 2018 | 100 | 0 | 72 | Algae | Raphidocelis subcapitata | EC50 | 4160 | 1 | 10 |
| Ozkaleli et al. 44 | 2018 | 100 | 0 | 72 | Algae | Raphidocelis subcapitata | EC50 | 3580 | 1 | 10 |
| Ozkaleli et al. 44 | 2018 | 100 | 0 | 72 | Algae | Raphidocelis subcapitata | EC50 | 9320 | 1 | 10 |
| Ozkaleli et al. 44 | 2018 | 100 | 0 | 72 | Algae | Raphidocelis subcapitata | EC50 | 12140 | 1 | 10 |
| Picado et al.45 | 2015 | 65 | 35 | 48 | Crustacean | Daphnia magna | NOEC | 5600 | 10 | 1 |
| Picado et al. 45 | 2015 | 65 | 35 | 504 | Vertebrate | Carassius auratus | HONEC | 100000 | 1 | 1 |
| Picado et al. 45 | 2015 | 65 | 35 | 168 | plant | Lemna minor | HONEC | 90000 | 1 | 1 |
| Rocco et al.46 | 2015 | 25 | 75 | 28d | Vertebrate | Danio rerio | HONEC | 10 | 1 | 1 |
| Rocheleau et al.47 | 2015 | 100 | 0 | 24 | invertebrate | Caenorhabditis elegans | HONEC | 500000 | 10 | 1 |
| Rocheleau et al. 47 | 2015 | 100 | 0 | 24 | invertebrate | Caenorhabditis elegans | HONEC | 500000 | 10 | 1 |
| Rocheleau et al. 47 | 2015 | 100 | 0 | 24 | invertebrate | Caenorhabditis elegans | HONEC | 500000 | 10 | 1 |
| Rocheleau et al. 47 | 2015 | 0 | 100 | 24 | invertebrate | Caenorhabditis elegans | HONEC | 500000 | 10 | 1 |
| Rocheleau et al. 47 | 2015 | 0 | 100 | 24 | invertebrate | Caenorhabditis elegans | HONEC | 500000 | 10 | 1 |
| Rocheleau et al. 47 | 2015 | 100 | 0 | 24 | invertebrate | Caenorhabditis elegans | HONEC | 500000 | 10 | 1 |
| Rocheleau et al. 47 | 2015 | 83 | 17 | 24 | invertebrate | Caenorhabditis elegans | HONEC | 500000 | 10 | 1 |
| Roy et al.48 | 2016 | 81.1 | 18.9 | 72 | Algae | Chlorella sp. | EC50 | 1565 | 1 | 10 |
| Roy et al. 48 | 2016 | 81.1 | 18.9 | 72 | Algae | Chlorella sp. | EC50 | 2160 | 1 | 10 |
| Roy et al. 48 | 2016 | 81.1 | 18.9 | 72 | Algae | Scenedesmus subspicatus | EC50 | 2752 | 1 | 10 |
| Roy et al. 48 | 2016 | 81.1 | 18.9 | 72 | Algae | Scenedesmus subspicatus | EC50 | 4139 | 1 | 10 |
| Roy et al. 48 | 2016 | 81.1 | 18.9 | 72 | Algae | Chlorella sp | EC50 | 5956 | 1 | 10 |
| Roy et al. 48 | 2016 | 81.1 | 18.9 | 72 | Algae | Scenedesmus subspicatus | EC50 | 7632 | 1 | 10 |
| Sadiq et al. 49 | 2011 | 75 | NA | 72 | Algae | Chlorella sp. | NOEC | 890 | 1 | 1 |
| Sadiq et al. 49 | 2011 | 75 | NA | 72 | Algae | Scenedesmus subspicatus | NOEC | 1200 | 1 | 1 |
| Salieri et al.50 | 2015 | 96 | 4 | 96 | Crustacean | Daphnia magna | EC50 | 32000 | 10 | 10 |
| Salieri et al. 50 | 2015 | 96 | 4 | 96 | Crustacean | Daphnia magna | EC50 | 33000 | 10 | 10 |
| Salieri et al. 50 | 2015 | 96 | 4 | 96 | Crustacean | Daphnia magna | EC50 | 82000 | 10 | 10 |
| Seitz et al.51 | 2016 | 70 | 30 | 96 | Crustacean | Daphnia magna | EC50 | 2980 | 10 | 10 |
| Seitz et al. 51 | 2016 | 100 | 0 | 96 | Crustacean | Daphnia magna | EC50 | 850 | 10 | 10 |
| Sendra et al.52 | 2018 | 79 | 21 | 72 | Algae | Chlamydomonas reinhardtii | EC50 | 2300 | 1 | 10 |
| Sendra et al. 52 | 2018 | 79 | 21 | 72 | Algae | Chlamydomonas reinhardtii | EC50 | 551700 | 1 | 10 |
| Wang, Hu et al. 53 | 2011 | 100 | 0 | 96 | Crustacean | Ceriodaphnia dubia | NOEC | 400000 | 10 | 1 |
| Wang et al. 54 | 2009 | 100 | 0 | 24 | Invertebrate | Caenorhabditis elegans | LC50 | 79900 | 10 | 10 |
| Wang et al. 55 | 2008 | 86 | 14 | 120 | Algae | Chlamydomonas reinhardtii | NOEC | 1000 | 1 | 1 |
| Warheit et al. 56 | 2007 | 21 | 79 | 48 | Crustacean | Daphnia magna | HONEC | 100000 | 10 | 1 |
| Warheit et al. 56 | 2007 | 21 | 79 | 72 | Algae | Raphidocelis subcapitata | EC50 | 21000 | 1 | 10 |
| Warheit et al. 56 | 2007 | 21 | 79 | 96 | Vertebrate | Oncorhynchus mykiss | HONEC | 100000 | 10 | 1 |
| Wiench et al. 57 | 2009 | 0 | 100 | 504 | Crustacean | Daphnia magna | NOEC | 3000 | 1 | 1 |
| Wormington et al.58 | 2016 | 100 | 0 | 48 | Crustacean | Daphnia magna | LC50 | 840 | 10 | 10 |
| Wormington et al.58 | 2016 | 100 | 0 | 48 | Crustacean | Daphnia magna | LOEC | 1500 | 10 | 2 |
| Wormington et al. 58 | 2016 | 100 | 0 | 48 | Crustacean | Daphnia magna | NOEC | 2000 | 10 | 1 |
| Wyrwoll et al.59 | 2016 | 100 | 0 | 48 | Crustacean | Daphnia magna | EC50 | 530 | 10 | 10 |
| Wyrwoll et al. 59 | 2016 | 100 | 0 | 48 | Crustacean | Daphnia magna | EC50 | 1100 | 10 | 10 |
| Wyrwoll et al. 59 | 2016 | 100 | 0 | 48 | Crustacean | Daphnia magna | EC50 | 1280 | 10 | 10 |
| Wyrwoll et al. 59 | 2016 | 100 | 0 | 48 | Crustacean | Daphnia magna | EC50 | 2900 | 10 | 10 |
| Wyrwoll et al. 59 | 2016 | 100 | 0 | 48 | Crustacean | Daphnia magna | EC50 | 3880 | 10 | 10 |
| Wyrwoll et al. 59 | 2016 | 100 | 0 | 48 | Crustacean | Daphnia magna | EC50 | 79520 | 10 | 10 |
| Xiong et al. 60 | 2011 | 100 | 0 | 96 | Vertebrate | Danio Rerio | LC50 | 124500 | 10 | 10 |
| Yang et al. 61 | 2013 | 75 | 25 | 24 | Vertebrate | Danio Rerio | LC50 | 156000 | 10 | 10 |
| Yang et al. 61 | 2013 | 75 | 25 | 24 | Vertebrate | Danio Rerio | LC50 | 290000 | 10 | 10 |
| Yu et al.62 | 2018 | 100 | 0 | 96 | Algae | Chlamydomonas reinhardtii | EC50 | 359822 | 1 | 10 |
| Zhu, Chang et al. 63 | 2010 | 80 | 20 | 72 | Crustacean | Daphnia magna | EC13 | 100 | 10 | 2 |
| Zhu, Chang et al. 63 | 2010 | 80 | 20 | 504 | Crustacean | Daphnia magna | EC50 | 460 | 1 | 10 |
| Zhu, Zhu et al. 64 | 2008 | 100 | 0 | 48 | Crustacean | Daphnia magna | EC50 | 35306 | 10 | 10 |

Legend: ECx = effective concentration at which a response of 'x' percent is observed; ICx = Inhibitory concentration at which an inhibition of 'x' percent is observed regarding a specific biological function.; LCx: lethal concentration that is expected to cause death to x% of the population. LOEC = lowest observed effect concentration; NOEC= no observed effect concentration; HONEC = highest observed no effect concentration.

Table S5. Ecotoxicological data that were used for the generation of the PSSD of nano-Al2O3 in the fresh water compartment.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **author** | **year** | **crystal form** | **test organism** | **taxonomic**  **group** | **duration [h]** | **dose  descriptor** | **concentration [µg/L]** | **AF acute to**  **chronic** | **AF dose descriptor** |
| Hu et al.65 | 2012 | gamma | Ceriodaphnia dubia | Crustacea | 48 | NOEC | 150000 | 10 | 1 |
| Li et al. 32 | 2012 | alpha | Paramecium multimicronucleatum | unicellular | 48h | LC50 | 9269200 | 1'000\* | |
| Li, Minghua et al. 66 | 2011 | gamma | Ceriodaphnia dubia | Crustacea | 168 | EC50 | 45000 | 10 | 10 |
| Pakrashi et al.67 | 2013 | gamma | Ceriodaphnia dubia | Crustacea | 72h | LC50 | 74300 | 10 | 10 |
| Stanley et al.68 | 2010 | gamma | Hyalella azteca | Crustacea | 240 | NOEC | 100000 | 10 | 1 |
| Stanley et al. 68 | 2010 | gamma | Tubifex tubifex | Invertebrate | 240 | NOEC | 100000 | 10 | 1 |
| Svartz et al. 69 | 2017 | gamma | Rhinella arenarum | Vertebrate | 504 | LC50 | 10500 | 1 | 10 |
| Wang et al. 54 | 2009 | gamma | Ceriodaphnia dubia | Crustacea | 48 | LC50 | 610000 | 10 | 10 |

\*Please note: For alpha Al2O3 was only one data point reported, the standard AF of 1000 was applied to convert the LC50 into a predicted no-effect concentration(cf. Echa 200870

Legend: ECx = effective concentration at which a response of 'x' percent is observed; ICx = Inhibitory concentration at which an inhibition of 'x' percent is observed regarding a specific biological function.; LCx: lethal concentration that is expected to cause death to x% of the population; NOEC= no observed effect concentration

Table S6: Ecotoxicological data that were used for the generation of the PSSD of multi-wall and single-wall carbon nanotubes in the fresh water compartment.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **authors** | **year** | **nano-form** | **dose descriptor** | **Tįtest organsim** | **taxonomic group** | **concentration [µg/l]** | **exposure  time [h]** | **AF time** | **AF  no-effect** |
| Mouchet et al.71 | 2008 | DWNT | HONEC | Ambystoma mexicanum | vertebrate | 100'000.0 | 288 | 10 | 1 |
| Alloy et al.72 | 2011 | MWNT | LOEC | Ceriodaphnia dubia | crustacea | 2'380.0 | 168 | 10 | 2 |
| Kennedy et al.73 | 2008 | MWNT | EC50 | Ceriodaphnia dubia | crustacea | 50'900.0 | 48 | 10 | 10 |
| Li et al.74 | 2011 | MWNT | LC50 | Ceriodaphnia dubia | crustacea | 8'000.0 | 24 | 10 | 10 |
| Long et al.75 | 2012 | MWNT | IC50 | Chlorella sp. | algae | 8'400.0 | 96 | 1 | 10 |
| Long et al. 75 | 2012 | MWNT | IC50 | Chlorella sp. | algae | 11'300.0 | 96 | 1 | 10 |
| Long et al. 75 | 2012 | MWNT | IC50 | Chlorella sp. | algae | 11'500.0 | 96 | 1 | 10 |
| Long et al. 75 | 2012 | MWNT | IC50 | Chlorella sp. | algae | 12'400.0 | 96 | 1 | 10 |
| Long et al. 75 | 2012 | MWNT | IC50 | Chlorella sp. | algae | 12'400.0 | 96 | 1 | 10 |
| Long et al. 75 | 2012 | MWNT | IC50 | Chlorella sp. | algae | 12'700.0 | 96 | 1 | 10 |
| Long et al. 75 | 2012 | MWNT | IC50 | Chlorella sp. | algae | 13'900.0 | 96 | 1 | 10 |
| Long et al. 75 | 2012 | MWNT | IC50 | Chlorella sp. | algae | 36'200.0 | 96 | 1 | 10 |
| Long et al. 75 | 2012 | MWNT | IC50 | Chlorella sp. | algae | 36'800.0 | 96 | 1 | 10 |
| Long et al. 75 | 2012 | MWNT | IC50 | Chlorella sp. | algae | 38'800.0 | 96 | 1 | 10 |
| Long et al. 75 | 2012 | MWNT | IC50 | Chlorella sp. | algae | 39'600.0 | 96 | 1 | 10 |
| Long et al. 75 | 2012 | MWNT | IC50 | Chlorella sp. | algae | 41'000.0 | 96 | 1 | 10 |
| Long et al. 75 | 2012 | MWNT | IC50 | Chlorella sp. | algae | 41'400.0 | 96 | 1 | 10 |
| Long et al. 75 | 2012 | MWNT | IC50 | Chlorella sp. | algae | 45'800.0 | 96 | 1 | 10 |
| Long et al. 75 | 2012 | MWNT | IC50 | Chlorella sp. | algae | 46'300.0 | 96 | 1 | 10 |
| Long et al. 75 | 2012 | MWNT | IC50 | Chlorella sp. | algae | 47'300.0 | 96 | 1 | 10 |
| Long et al. 75 | 2012 | MWNT | IC50 | Chlorella sp. | algae | 62'800.0 | 96 | 1 | 10 |
| Long et al. 75 | 2012 | MWNT | IC50 | Chlorella sp. | algae | 74'500.0 | 96 | 1 | 10 |
| Long et al. 75 | 2012 | MWNT | IC50 | Chlorella sp. | algae | 75'200.0 | 96 | 1 | 10 |
| Schwab et al.76 | 2011 | MWNT | NOEC | Chlorella vulgaris | algae | 42.0 | 96 | 1 | 1 |
| Schwab et al. 76 | 2011 | MWNT | NOEC | Chlorella vulgaris | algae | 180.0 | 96 | 1 | 1 |
| Schwab et al. 76 | 2011 | MWNT | NOEC | Chlorella vulgaris | algae | 1'000.0 | 96 | 1 | 1 |
| Schwab et al. 76 | 2011 | MWNT | NOEC | Chlorella vulgaris | algae | 3'000.0 | 96 | 1 | 1 |
| Schwab et al. 76 | 2011 | MWNT | NOEC | Chlorella vulgaris | algae | 3'000.0 | 96 | 1 | 1 |
| Sohn et al.77 | 2015 | SWNT | EC50 | Chlorella vulgaris | algae | 30'960.0 | 72 | 1 | 10 |
| Pereira et al.78 | 2014 | MWNT | EC44.67 | Chlorella vulgaris | algae | 50'000.0 | 96 | 1 | 10 |
| Pereira et al. 78 | 2014 | MWNT | EC54.4 | Chlorella vulgaris | algae | 100'000.0 | 96 | 1 | 10 |
| Simon-Deckers et al.79 | 2009 | MWNT | NOEC | Cupriavididus  metallidurans | bacteria | 100'000.0 | 24 | 10 | 1 |
| Asharani et al.80 | 2008 | MWNT | NOEC | Danio rerio | zebrafish | 40'000.0 | 72 | 10 | 1 |
| Cheng et al.81 | 2007 | SWNT | LOEC | Danio rerio | zebrafish | 120'000.0 | 72 | 10 | 2 |
| Cheng et al. 81 | 2007 | DWNT | LOEC | Danio rerio | zebrafish | 240'000.0 | 72 | 10 | 2 |
| Zhu et al.64 | 2008 | SWNT | EC50 | Daphnia magna | crustacea | 1'306.0 | 48 | 10 | 10 |
| Edgington et al.82 | 2010 | MWNT | LC50 | Daphnia magna | crustacea | 2'000.0 | 96 | 10 | 10 |
| Zhu et al. 64 | 2008 | MWNT | EC50 | Daphnia magna | crustacea | 8'723.0 | 48 | 10 | 10 |
| Petersen et al.83 | 2011 | MWNT | EC50 | Daphnia magna | crustacea | 9'600.0 | 48 | 10 | 10 |
| Baumerte et al.84 | 2013 | MWNT | LC50 | Daphnia magna | crustacea | 11'480.0 | 48 | 10 | 10 |
| Alloy et al.72 | 2011 | MWNT | LOEC | Daphnia magna | crustacea | 240.0 | 504 | 1 | 2 |
| Petersen et al. | 2011 | MWNT | EC50 | Daphnia magna | crustacea | 12'700.0 | 48 | 10 | 10 |
| Sanchis et al.85 | 2016 | MWNT | EC50 | Daphnia magna | crustacea | 14'000.0 | 0.5 | 10 | 10 |
| Petersen et al. | 2011 | MWNT | EC50 | Daphnia magna | crustacea | 17'000.0 | 24 | 10 | 10 |
| Petersen et al. | 2011 | MWNT | EC50 | Daphnia magna | crustacea | 25'100.0 | 24 | 10 | 10 |
| Stanley et al.86 | 2016 | MWNT | LC50 | Daphnia magna | crustacea | 29'300.0 | 48 | 10 | 10 |
| Stanley et al. 86 | 2016 | MWNT | LC50 | Daphnia magna | crustacea | 4'300.0 | 336 | 1 | 10 |
| Roberts et al.87 | 2007 | SWNT | NOEC | Daphnia magna | crustacea | 5'000.0 | 96 | 10 | 1 |
| Sohn et al.77 | 2015 | SWNT | NOEC | Daphnia magna | crustacea | 100'000.0 | 48 | 10 | 1 |
| Martinez et al.88 | 2014 | MWNT | NOEC | Daphnia similis | crustacea | 30'000.0 | 48 | 10 | 1 |
| Blaise et al. 89 | 2008 | SWNT | EC50 | Hydra attenuata | unicellular | 1'000.0 | 96 | 1 | 10 |
| Martinez et al. 88 | 2012 | MWNT | NOEC | Oreochromis niloticus | vertebrate | 3'000.0 | 96 | 10 | 1 |
| Sohn et al. 77 | 2015 | SWNT | NOEC | Oryzias latipes | vertebrate | 100'000.0 | 96 | 10 | 1 |
| Schwab et al. 76 | 2011 | MWNT | NOEC | Pseudokirchneriella  subcapitata | algae | 1'300.0 | 96 | 1 | 1 |
| Schwab et al.76 | 2011 | MWNT | NOEC | Pseudokirchneriella  subcapitata | algae | 3'000.0 | 96 | 1 | 1 |
| Sohn et al. 77 | 2015 | SWNT | EC50 | Raphidocelis  subcapitata | algae | 29'990.0 | 72 | 1 | 10 |
| Bayat et al.90 | 2014 | SWNT | LED | Saccharomyces  cerevisiae | bacteria | 7'800.0 | 16 | 10 | 2 |
| Zhu et al. 91 | 2006 | MWNT | NOEC | Stylonychia Mytilus | unicellular | 500.0 | 120 | 1 | 1 |
| Ghafari et al.92 | 2008 | SWNT | NOEC | Tetrahymena thermophila | protozoa | 6'800.0 | 72 | 1 | 1 |
| Ghafari et al. 92 | 2008 | SWNT | LOEC | Tetrahymena thermophila | protozoa | 3'600.0 | 72 | 1 | 2 |
| Blaise et al.89 | 2008 | SWNT | LC50 | Thamnocephalus platyurus | crustcea | 100'000.0 | 24 | 10 | 10 |
| Saria et al.93 | 2014 | MWNT | NOEC | Xenopus laevis | vertebrate | 10'000.0 | 24 | 10 | 10 |
| Bourdiol et al.94 | 2013 | MWNT | LOEC | Xenopus laevis | vertebrate | 10'000.0 | 288 | 10 | 2 |
| Mouchet et al.71 | 2008 | DWNT | LOEC | Xenopus laevis | vertebrate | 10'000.0 | 288 | 10 | 2 |
| Mouchet et al.95 | 2010 | MWNT | LOEC | Xenopus laevis | vertebrate | 50'000.0 | 288 | 10 | 2 |
| Cano et al.96 | 2017 | MWNT | EC50 | Daphnia magna | crustcea | 29'300.0 | 48 | 10 | 10 |

Legend: ECx = effective concentration at which a response of 'x' percent is observed; ICx = Inhibitory concentration at which an inhibition of 'x' percent is observed regarding a specific biological function.; LCx: lethal concentration that is expected to cause death to x% of the population. LOEC = lowest observed effect concentration; NOEC= no observed effect concentration;

Table S7. Results for the calculation of the PECs for each nano-form considered in Europe, Northern Europe and South Eastern Europe.



Table S8: Assessment factors used to convert acute to chronic values (AFt).97

|  |  |  |  |
| --- | --- | --- | --- |
| **Type of organism** | **Exposure time (days)** | **AFt** | **Reference** |
| Bacteria/Yeast | < 1 | 10 | (Berger, 2012, Cassidy-Hanley, 2012, Ron et al., 2010, Fok and Allen, 1979)98-101 |
| ≥ 1 | 1 |
| Algae | < 3 | 10 | (OECD, 2006a)102 |
| ≥ 3 | 1 |
| Plants (*L. minor*) | < 2.5 | 10 | (OECD, 2006b)103 |
| ≥ 2.5 | 1 |
| Other plants | < 28 | 10 | (OECD, 2006c)104 |
| ≥ 28 | 1 |
| Crustacea | < 21 | 10 | (OECD, 2004, OECD, 2012)105, 106 |
| ≥ 21 | 1 |
| Mollusca | < 28 | 10 | (OECD, 2016a, OECD, 2016b)107, 108 |
| ≥ 28 | 1 |
| Fish | < 28 | 10 | (OECD, 2000, OECD, 2009)109, 110 |
| ≥ 28 | 1 |

Table S9: Assessment factors used to convert dose descriptors into NOECs 70, 97

|  |  |
| --- | --- |
| **Type of dose-descriptor** | **AFdd** |
| LC25-50; EC25-50; IC25-50 | 10 |
| LC10-20; EC10-20; IC10-20 | 2 |
| LOEC |
| LED |
| MIC |
| HONEC | 1 |

# References

1. I. Amiano, J. Olabarrieta, J. Vitorica and S. Zorita, Acute toxicity of nanosized TiO2 to Daphnia magna under UVA irradiation, *Environmental Toxicology and Chemistry*, 2012, **31**, 2564-2566.

2. J. S. Angelstorf, W. Ahlf, F. von der Kammer and S. Heise, Impact of particle size and light exposure on the effects of TiO2 nanoparticles on Caenorhabditis elegans, *Environmental Toxicology and Chemistry*, 2014, **33**, 2288-2296.

3. V. Aruoja, S. Pokhrel, M. Sihtmäe, M. Mortimer, L. Mädler and A. Kahru, Toxicity of 12 metal-based nanoparticles to algae, bacteria and protozoa, *Environ. Sci.: Nano*, 2015, **2**, 630-644.

4. O. Bar-Ilan, K. M. Louis, S. P. Yang, J. A. Pedersen, R. J. Hamers, R. E. Peterson and W. Heideman, Titanium dioxide nanoparticles produce phototoxicity in the developing zebrafish, *Nanotoxicology*, 2012, **6**, 670-679.

5. D. M. Barreto and A. T. Lombardi, Environmentally Relevant Concentrations of TiO2 Nanoparticles Affected Cell Viability and Photosynthetic Yield in the Chlorophyceae Scenedesmus bijugus, *Water, Air, & Soil Pollution*, 2016, **227**.

6. M. Bundschuh, J. P. Zubrod, D. Englert, F. Seitz, R. R. Rosenfeldt and R. Schulz, Effects of nano-TiO(2) in combination with ambient UV-irradiation on a leaf shredding amphipod, *Chemosphere*, 2011, **85**, 1563-1567.

7. J. Chen, X. Dong, Y. Xin and M. Zhao, Effects of titanium dioxide nano-particles on growth and some histological parameters of zebrafish (Danio rerio) after a long-term exposure, *Aquat Toxicol*, 2011, **101**, 493-499.

8. C. Cherchi, T. Chernenko, M. Diem and A. Z. Gu, Impact of nano titanium dioxide exposure on cellular structure of Anabaena variabilis and evidence of internalization, *Environmental Toxicology and Chemistry*, 2011, **30**, 861-869.

9. L. Clement, C. Hurel and N. Marmier, Toxicity of TiO(2) nanoparticles to cladocerans, algae, rotifers and plants - effects of size and crystalline structure, *Chemosphere*, 2013, **90**, 1083-1090.

10. Z. Clemente, V. L. Castro, C. M. Jonsson and L. F. Fraceto, Minimal levels of ultraviolet light enhance the toxicity of TiO2 nanoparticles to two representative organisms of aquatic systems, *J Nanopart Res*, 2014, **16**, 2559.

11. D. Cupi, N. B. Hartmann and A. Baun, Influence of pH and media composition on suspension stability of silver, zinc oxide, and titanium dioxide nanoparticles and immobilization of Daphnia magna under guideline testing conditions, *Ecotoxicol Environ Saf*, 2016, **127**, 144-152.

12. D. Cupi, N. B. Hartmann and A. Baun, The influence of natural organic matter and aging on suspension stability in guideline toxicity testing of silver, zinc oxide, and titanium dioxide nanoparticles with Daphnia magna, *Environmental Toxicology and Chemistry*, 2015, **34**, 497-506.

13. S. Dalai, V. Iswarya, M. Bhuvaneshwari, S. Pakrashi, N. Chandrasekaran and A. Mukherjee, Different modes of TiO2 uptake by Ceriodaphnia dubia: relevance to toxicity and bioaccumulation, *Aquat Toxicol*, 2014, **152**, 139-146.

14. P. Das, M. A. Xenopoulos and C. D. Metcalfe, Toxicity of silver and titanium dioxide nanoparticle suspensions to the aquatic invertebrate, Daphnia magna, *Bull Environ Contam Toxicol*, 2013, **91**, 76-82.

15. T. Fang, L. P. Yu, W. C. Zhang and S. P. Bao, Effects of humic acid and ionic strength on TiO(2) nanoparticles sublethal toxicity to zebrafish, *Ecotoxicology*, 2015, **24**, 2054-2066.

16. G. Federici, B. J. Shaw and R. D. Handy, Toxicity of titanium dioxide nanoparticles to rainbow trout (Oncorhynchus mykiss): gill injury, oxidative stress, and other physiological effects, *Aquat Toxicol*, 2007, **84**, 415-430.

17. L. Fu, M. Hamzeh, S. Dodard, Y. H. Zhao and G. I. Sunahara, Effects of TiO2 nanoparticles on ROS production and growth inhibition using freshwater green algae pre-exposed to UV irradiation, *Environ Toxicol Pharmacol*, 2015, **39**, 1074-1080.

18. S. George, H. Gardner, E. K. Seng, H. Chang, C. Wang, C. H. Yu Fang, M. Richards, S. Valiyaveettil and W. K. Chan, Differential effect of solar light in increasing the toxicity of silver and titanium dioxide nanoparticles to a fish cell line and zebrafish embryos, *Environ Sci Technol*, 2014, **48**, 6374-6382.

19. D. Gökçe, S. Köytepe and İ. Özcan, Effects of nanoparticles on Daphnia magna population dynamics, *Chemistry and Ecology*, 2018, **34**, 301-323.

20. S. I. Gomes, G. Caputo, N. Pinna, J. J. Scott-Fordsmand and M. J. Amorim, Effect of 10 different TiO2 and ZrO2 (nano)materials on the soil invertebrate Enchytraeus crypticus, *Environmental Toxicology and Chemistry*, 2015, **34**, 2409-2416.

21. C. Gunawan, A. Sirimanoonphan, W. Y. Teoh, C. P. Marquis and R. Amal, Submicron and nano formulations of titanium dioxide and zinc oxide stimulate unique cellular toxicological responses in the green microalga Chlamydomonas reinhardtii, *J Hazard Mater*, 2013, **260**, 984-992.

22. S. Hall, T. Bradley, J. T. Moore, T. Kuykindall and L. Minella, Acute and chronic toxicity of nano-scale TiO2particles to freshwater fish, cladocerans, and green algae, and effects of organic and inorganic substrate on TiO2toxicity, *Nanotoxicology*, 2009, **3**, 91-97.

23. N. B. Hartmann, F. Von der Kammer, T. Hofmann, M. Baalousha, S. Ottofuelling and A. Baun, Algal testing of titanium dioxide nanoparticles--testing considerations, inhibitory effects and modification of cadmium bioavailability, *Toxicology*, 2010, **269**, 190-197.

24. K. Hund-Rinke and M. Simon, Ecotoxic Effect of Photocatalytic Active Nanoparticles (TiO2) on Algae and Daphnids (8 pp), *Environmental Science and Pollution Research - International*, 2006, **13**, 225-232.

25. C. Hurel, C. Bignon, C. Said-Mohamed, S. Amigoni, T. Devers and F. Guittard, Functionalized and grafted TiO2, CeO2, and SiO2 nanoparticles-ecotoxicity on Daphnia magna and relevance of ecofriendly polymeric networks, *Environ Sci Pollut Res Int*, 2018, **25**, 21216-21223.

26. V. Iswarya, M. Bhuvaneshwari, S. A. Alex, S. Iyer, G. Chaudhuri, P. T. Chandrasekaran, G. M. Bhalerao, S. Chakravarty, A. M. Raichur, N. Chandrasekaran and A. Mukherjee, Combined toxicity of two crystalline phases (anatase and rutile) of Titania nanoparticles towards freshwater microalgae: Chlorella sp, *Aquat Toxicol*, 2015, **161**, 154-169.

27. V. Iswarya, M. Bhuvaneshwari, N. Chandrasekaran and A. Mukherjee, Individual and binary toxicity of anatase and rutile nanoparticles towards Ceriodaphnia dubia, *Aquat Toxicol*, 2016, **178**, 209-221.

28. C. Jacobasch, C. Volker, S. Giebner, J. Volker, H. Alsenz, T. Potouridis, H. Heidenreich, G. Kayser, J. Oehlmann and M. Oetken, Long-term effects of nanoscaled titanium dioxide on the cladoceran Daphnia magna over six generations, *Environmental pollution*, 2014, **186**, 180-186.

29. J. Ji, Z. Long and D. Lin, Toxicity of oxide nanoparticles to the green algae Chlorella sp, *Chemical Engineering Journal*, 2011, **170**, 525-530.

30. B. Jovanovic, L. Anastasova, E. W. Rowe, Y. Zhang, A. R. Clapp and D. Palic, Effects of nanosized titanium dioxide on innate immune system of fathead minnow (Pimephales promelas Rafinesque, 1820), *Ecotoxicol Environ Saf*, 2011, **74**, 675-683.

31. K. T. Kim, S. J. Klaine and S. D. Kim, Acute and chronic response of Daphnia magna exposed to TiO2 nanoparticles in agitation system, *Bull Environ Contam Toxicol*, 2014, **93**, 456-460.

32. K. Li, Y. Chen, W. Zhang, Z. Pu, L. Jiang and Y. Chen, Surface interactions affect the toxicity of engineered metal oxide nanoparticles toward Paramecium, *Chem Res Toxicol*, 2012, **25**, 1675-1681.

33. S. B. Li, H. B. Ma, L. K. Wallis, M. A. Etterson, B. Riley, D. J. Hoff and S. A. Diamond, Impact of natural organic matter on particle behavior and phototoxicity of titanium dioxide nanoparticles, *The Science of the total environment*, 2016, **542**, 324-333.

34. S. Li, X. Pan, L. K. Wallis, Z. Fan, Z. Chen and S. A. Diamond, Comparison of TiO2 nanoparticle and graphene-TiO2 nanoparticle composite phototoxicity to Daphnia magna and Oryzias latipes, *Chemosphere*, 2014, **112**, 62-69.

35. S. Li, L. K. Wallis, S. A. Diamond, H. Ma and D. J. Hoff, Species sensitivity and dependence on exposure conditions impacting the phototoxicity of TiO(2) nanoparticles to benthic organisms, *Environmental Toxicology and Chemistry*, 2014, **33**, 1563-1569.

36. S. Li, L. K. Wallis, H. Ma and S. A. Diamond, Phototoxicity of TiO(2) nanoparticles to a freshwater benthic amphipod: are benthic systems at risk?, *Science of the total environment*, 2014, **466-467**, 800-808.

37. H. Lu, W. Fan, H. Dong and L. Liu, Dependence of the irradiation conditions and crystalline phases of TiO2 nanoparticles on their toxicity to Daphnia magna, *Environ. Sci.: Nano*, 2017, **4**, 406-414.

38. H. B. Ma, A. Brennan and S. A. Diamond, Phototoxicity of TiO2 nanoparticles under solar radiation to two aquatic species: Daphnia magna and Japanese medaka, *Environmental Toxicology and Chemistry*, 2012, **31**, 1621-1629.

39. C. M. Mansfield, M. M. Alloy, J. Hamilton, G. F. Verbeck, K. Newton, S. J. Klaine and A. P. Roberts, Photo-induced toxicity of titanium dioxide nanoparticles to Daphnia magna under natural sunlight, *Chemosphere*, 2015, **120**, 206-210.

40. G. P. Marcone, A. C. Oliveira, G. Almeida, G. A. Umbuzeiro and W. F. Jardim, Ecotoxicity of TiO2 to Daphnia similis under irradiation, *J Hazard Mater*, 2012, **211-212**, 436-442.

41. D. M. Metzler, M. Li, A. Erdem and C. Huang, Responses of algae to photocatalytic nano-TiO 2 particles with an emphasis on the effect of particle size, *Chemical Engineering Journal*, 2011, **170**, 538-546.

42. M. Nicolas, L. M. Séverine, B.-N. Anne and P. Pascal, Effect of two TiO2nanoparticles on the growth of unicellular green algae using the OECD 201 test guideline: influence of the exposure system, *Toxicological & Environmental Chemistry*, 2015, **98**, 860-876.

43. P. Oleszczuk, I. Josko and E. Skwarek, Surfactants decrease the toxicity of ZnO, TiO2 and Ni nanoparticles to Daphnia magna, *Ecotoxicology*, 2015, **24**, 1923-1932.

44. M. Ozkaleli and A. Erdem, Biotoxicity of TiO(2) Nanoparticles on Raphidocelis subcapitata Microalgae Exemplified by Membrane Deformation, *Int J Environ Res Public Health*, 2018, **15**.

45. A. Picado, S. M. Paixão, L. Moita, L. Silva, M. S. Diniz, J. Lourenço, I. Peres, L. Castro, J. B. Correia, J. Pereira, I. Ferreira, A. P. A. Matos, P. Barquinha and E. Mendonca, A multi-integrated approach on toxicity effects of engineered TiO2 nanoparticles, *Frontiers of Environmental Science & Engineering*, 2015, **9**, 793-803.

46. L. Rocco, M. Santonastaso, F. Mottola, D. Costagliola, T. Suero, S. Pacifico and V. Stingo, Genotoxicity assessment of TiO2 nanoparticles in the teleost Danio rerio, *Ecotoxicol Environ Saf*, 2015, **113**, 223-230.

47. S. Rocheleau, M. Arbour, M. Elias, G. I. Sunahara and L. Masson, Toxicogenomic effects of nano- and bulk-TiO2 particles in the soil nematode Caenorhabditis elegans, *Nanotoxicology*, 2015, **9**, 502-512.

48. R. Roy, A. Parashar, M. Bhuvaneshwari, N. Chandrasekaran and A. Mukherjee, Differential effects of P25 TiO2 nanoparticles on freshwater green microalgae: Chlorella and Scenedesmus species, *Aquat Toxicol*, 2016, **176**, 161-171.

49. I. M. Sadiq, S. Dalai, N. Chandrasekaran and A. Mukherjee, Ecotoxicity study of titania (TiO(2)) NPs on two microalgae species: Scenedesmus sp. and Chlorella sp, *Ecotoxicol Environ Saf*, 2011, **74**, 1180-1187.

50. B. Salieri, A. Pasteris, J. Baumann, S. Righi, J. Köser, R. D'Amato, B. Mazzesi and J. Filser, Does the exposure mode to ENPs influence their toxicity to aquatic species? A case study with TiO2 nanoparticles and Daphnia magna, *Environ Sci Pollut Res*, 2015, **22**, 5050-5058.

51. F. Seitz, R. R. Rosenfeldt, M. Muller, S. Luderwald, R. Schulz and M. Bundschuh, Quantity and quality of natural organic matter influence the ecotoxicity of titanium dioxide nanoparticles, *Nanotoxicology*, 2016, **10**, 1415-1421.

52. M. Sendra, I. Moreno-Garrido, M. P. Yeste, J. M. Gatica and J. Blasco, Toxicity of TiO2, in nanoparticle or bulk form to freshwater and marine microalgae under visible light and UV-A radiation, *Environmental pollution*, 2017, **227**, 39-48.

53. D. Wang, J. Hu, D. R. Irons and J. Wang, Synergistic toxic effect of nano-TiO and As(V) on Ceriodaphnia dubia, *Science of the total environment*, 2011, **409**, 1351-1356.

54. H. Wang, R. L. Wick and B. Xing, Toxicity of nanoparticulate and bulk ZnO, Al2O3 and TiO2 to the nematode Caenorhabditis elegans, *Environmental pollution*, 2009, **157**, 1171-1177.

55. J. Wang, X. Zhang, Y. Chen, M. Sommerfeld and Q. Hu, Toxicity assessment of manufactured nanomaterials using the unicellular green alga Chlamydomonas reinhardtii, *Chemosphere*, 2008, **73**, 1121-1128.

56. D. B. Warheit, R. A. Hoke, C. Finlay, E. M. Donner, K. L. Reed and C. M. Sayes, Development of a base set of toxicity tests using ultrafine TiO2 particles as a component of nanoparticle risk management, *Toxicol Lett*, 2007, **171**, 99-110.

57. K. Wiench, W. Wohlleben, V. Hisgen, K. Radke, E. Salinas, S. Zok and R. Landsiedel, Acute and chronic effects of nano- and non-nano-scale TiO(2) and ZnO particles on mobility and reproduction of the freshwater invertebrate Daphnia magna, *Chemosphere*, 2009, **76**, 1356-1365.

58. A. M. Wormington, J. Coral, M. M. Alloy, C. L. Damare, C. M. Mansfield, S. J. Klaine, J. H. Bisesi and A. P. Roberts, Effect of natural organic matter on the photo-induced toxicity of titanium dioxide nanoparticles, *Environmental Toxicology and Chemistry*, 2016, DOI: 10.1002/etc.3702.

59. A. J. Wyrwoll, P. Lautenschlager, A. Bach, B. Hellack, A. Dybowska, T. A. Kuhlbusch, H. Hollert, A. Schaffer and H. M. Maes, Size matters--The phototoxicity of TiO2 nanomaterials, *Environmental pollution*, 2016, **208**, 859-867.

60. D. Xiong, T. Fang, L. Yu, X. Sima and W. Zhu, Effects of nano-scale TiO2, ZnO and their bulk counterparts on zebrafish: acute toxicity, oxidative stress and oxidative damage, *Science of the total environment*, 2011, **409**, 1444-1452.

61. S. P. Yang, O. Bar-Ilan, R. E. Peterson, W. Heideman, R. J. Hamers and J. A. Pedersen, Influence of humic acid on titanium dioxide nanoparticle toxicity to developing zebrafish, *Environ Sci Technol*, 2013, **47**, 4718-4725.

62. Z. Yu, R. Hao, L. Zhang and Y. Zhu, Effects of TiO2, SiO2, Ag and CdTe/CdS quantum dots nanoparticles on toxicity of cadmium towards Chlamydomonas reinhardtii, *Ecotoxicol Environ Saf*, 2018, **156**, 75-86.

63. X. Zhu, Y. Chang and Y. Chen, Toxicity and bioaccumulation of TiO2 nanoparticle aggregates in Daphnia magna, *Chemosphere*, 2010, **78**, 209-215.

64. X. Zhu, L. Zhu, Y. Chen and S. Tian, Acute toxicities of six manufactured nanomaterial suspensions to Daphnia magna, *Journal of Nanoparticle Research*, 2008, **11**, 67-75.

65. J. Hu, D. Wang, B. E. Forthaus and J. Wang, Quantifying the effect of nanoparticles on As(V) ecotoxicity exemplified by nano-Fe2 O3 (magnetic) and nano-Al2 O3, *Environmental Toxicology and Chemistry*, 2012, **31**, 2870-2876.

66. M. Li, K. J. Czymmek and C. P. Huang, Responses of Ceriodaphnia dubia to TiO2 and Al2O3 nanoparticles: a dynamic nano-toxicity assessment of energy budget distribution, *J Hazard Mater*, 2011, **187**, 502-508.

67. S. Pakrashi, S. Dalai, C. P. T, S. Trivedi, R. Myneni, A. M. Raichur, N. Chandrasekaran and A. Mukherjee, Cytotoxicity of aluminium oxide nanoparticles towards fresh water algal isolate at low exposure concentrations, *Aquat Toxicol*, 2013, **132-133**, 34-45.

68. J. K. Stanley, J. G. Coleman, C. A. Weiss, Jr. and J. A. Steevens, Sediment toxicity and bioaccumulation of nano and micron-sized aluminum oxide, *Environmental Toxicology and Chemistry*, 2010, **29**, 422-429.

69. G. Svartz, M. Papa, M. Gosatti, M. Jordan, A. Soldati, P. Samter, M. M. Guraya, C. Perez Coll and S. Perez Catan, Monitoring the ecotoxicity of gamma-Al2O3 and Ni/gamma-Al2O3 nanomaterials by means of a battery of bioassays, *Ecotoxicol Environ Saf*, 2017, **144**, 200-207.

70. ECHA, Guidance on information requirements and chemical safety assessment Chapter R.10 : Characterisation of dose [concentration]-response for environment.*Journal*, 2008, 1-65.

71. F. Mouchet, P. Landois, E. Sarremejean, G. Bernard, P. Puech, E. Pinelli, E. Flahaut and L. Gauthier, Characterisation and in vivo ecotoxicity evaluation of double-wall carbon nanotubes in larvae of the amphibian Xenopus laevis, *Aquat Toxicol*, 2008, **87**, 127-137.

72. M. M. Alloy and A. P. Roberts, Effects of suspended multi-walled carbon nanotubes on daphnid growth and reproduction, *Ecotoxicol Environ Saf*, 2011, **74**, 1839-1843.

73. A. J. Kennedy, M. Hull, J. A. Steevens, K. M. Dontsova, M. Chappell, J. C. Gunter and C. A. Weiss, Factors influencing the partitioning and toxcitiy of nanotubes in the aquativ environment, *Environmental Toxicology and Chemistry*, 2008, **27**, 1932-1941.

74. M. Li and C. P. Huang, The responses of Ceriodaphnia dubia toward multi-walled carbon nanotubes: Effect of physical–chemical treatment, *Carbon*, 2011, **49**, 1672-1679.

75. Z. Long, J. Ji, K. Yang, D. Lin and F. Wu, Systematic and quantitative investigation of the mechanism of carbon nanotubes' toxicity toward algae, *Environ Sci Technol*, 2012, **46**, 8458-8466.

76. F. Schwab, T. D. Bucheli, L. P. Lukhele, A. Magrez, B. Nowack, L. Sigg and K. Knauer, Are carbon nanotube effects on green algae caused by shading and agglomeration?, *Environ Sci Technol*, 2011, **45**, 6136-6144.

77. E. K. Sohn, Y. S. Chung, S. A. Johari, T. G. Kim, J. K. Kim, J. H. Lee, Y. H. Lee, S. W. Kang and I. J. Yu, Acute toxicity comparison of single-walled carbon nanotubes in various freshwater organisms, *Biomed Res Int*, 2015, **2015**, 323090.

78. M. M. Pereira, L. Mouton, C. Yepremian, A. Coute, J. Lo, J. M. Marconcini, L. O. Ladeira, N. R. Raposo, H. M. Brandao and R. Brayner, Ecotoxicological effects of carbon nanotubes and cellulose nanofibers in Chlorella vulgaris, *J Nanobiotechnology*, 2014, **12**, 15.

79. A. Simon-Deckers, S. Loo, M. Mayne-L’hermite, N. Herlin-Boime, N. Menguy, C. Reynaud, B. Gouget and M. Carrière, Size-, Composition- and Shape-Dependent Toxicological Impact of Metal Oxide Nanoparticles and Carbon Nanotubes toward Bacteria, *Environmental Science & Technology*, 2009, **43**, 8423-8429.

80. P. V. Asharani, N. G. B. Serina, M. H. Nurmawati, Y. L. Wu, Z. Gong and S. Valiyaveettil, Impact of Multi-Walled Carbon Nanotubes on Aquatic Species, *Journal of Nanoscience and Nanotechnology*, 2008, **8**, 3603-3609.

81. J. Cheng, E. Flahaut and S. H. Cheng, Effect of carbon nanotubes on developing zebrafish (Danio rerio) embryos, *Environmental Toxicology and Chemistry*, 2007, **26**, 708-716.

82. A. J. Edgington, A. P. Roberts, L. M. Taylor, M. M. Alloy, J. Reppert, A. M. Rao, J. Mao and S. J. Klaine, The influence of natural organic matter on the toxicity of multiwalled carbon nanotubes, *Environmental Toxicology and Chemistry*, 2010, **29**, 2511-2518.

83. E. J. Petersen, R. A. Pinto, D. J. Mai, P. F. Landrum and W. J. Weber, Jr., Influence of polyethyleneimine graftings of multi-walled carbon nanotubes on their accumulation and elimination by and toxicity to Daphnia magna, *Environ Sci Technol*, 2011, **45**, 1133-1138.

84. A. Baumerte, G. Sakale, J. Zavickis, I. Putna, M. Balode, A. Mrzel and M. Knite, Comparison of effects on crustaceans: carbon nanoparticles and molybdenum compounds nanowires, *Journal of Physics: Conference Series*, 2013, **429**, 012041.

85. J. Sanchis, M. Olmos, P. Vincent, M. Farre and D. Barcelo, New Insights on the Influence of Organic Co-Contaminants on the Aquatic Toxicology of Carbon Nanomaterials, *Environ Sci Technol*, 2016, **50**, 961-969.

86. J. K. Stanley, J. G. Laird, A. J. Kennedy and J. A. Steevens, Sublethal effects of multiwalled carbon nanotube exposure in the invertebrate Daphnia magna, *Environmental Toxicology and Chemistry*, 2016, **35**, 200-204.

87. A. P. Roberts, A. S. Mount, B. Seda, J. Souther, R. Qiao, S. Lin, P. C. Ke, A. M. Rao and S. J. Klaine, In vivo biomodification of lipid-coated carbon nanotubes by Daphnia magna, *Environ Sci Technol*, 2007, **41**, 3025-3029.

88. D. S. T. Martinez, A. F. Faria, E. Berni, A. G. Souza Filho, G. Almeida, A. Caloto-Oliveira, M. J. Grossman, L. R. Durrant, G. A. Umbuzeiro and O. L. Alves, Exploring the use of biosurfactants from Bacillus subtilis in bionanotechnology: A potential dispersing agent for carbon nanotube ecotoxicological studies, *Process Biochemistry*, 2014, **49**, 1162-1168.

89. C. Blaise, F. Gagne, J. F. Ferard and P. Eullaffroy, Ecotoxicity of selected nano-materials to aquatic organisms, *Environ Toxicol*, 2008, **23**, 591-598.

90. N. Bayat, K. Rajapakse, R. Marinsek-Logar, D. Drobne and S. Cristobal, The effects of engineered nanoparticles on the cellular structure and growth of Saccharomyces cerevisiae, *Nanotoxicology*, 2014, **8**, 363-373.

91. Y. Zhu, Q. Zhao, Y. Li, X. Cai and W. Li, The interaction and toxicity of multi-walled carbon nanotubes with Stylonychia mytilus., *J Nanosci Nanotechnol*, 2006, **6**, 1357-1364.

92. P. Ghafari, C. H. St-Denis, M. E. Power, X. Jin, V. Tsou, H. S. Mandal, N. C. Bols and X. S. Tang, Impact of carbon nanotubes on the ingestion and digestion of bacteria by ciliated protozoa, *Nat Nanotechnol*, 2008, **3**, 347-351.

93. R. Saria, F. Mouchet, A. Perrault, E. Flahaut, C. Laplanche, J. C. Boutonnet, E. Pinelli and L. Gauthier, Short term exposure to multi-walled carbon nanotubes induce oxidative stress and DNA damage in Xenopus laevis tadpoles, *Ecotoxicol Environ Saf*, 2014, **107**, 22-29.

94. F. Bourdiol, F. Mouchet, A. Perrault, I. Fourquaux, L. Datas, C. Gancet, J.-C. Boutonnet, E. Pinelli, L. Gauthier and E. Flahaut, Biocompatible polymer-assisted dispersion of multi walled carbon nanotubes in water, application to the investigation of their ecotoxicity using Xenopus laevis amphibian larvae, *Carbon*, 2013, **54**, 175-191.

95. F. Mouchet, P. Landois, P. Puech, E. Pinelli, E. Flahaut and L. Gauthier, Carbon nanotube ecotoxicity in amphibians: assessment of multiwalled carbon nanotubes and comparison with double-walled carbon nanotubes *Nanomedicine*, 2010, **5**, 963-974.

96. A. M. Cano, J. D. Maul, M. Saed, S. A. Shah, M. J. Green and J. E. Canas-Carrell, Bioaccumulation, stress, and swimming impairment in Daphnia magna exposed to multiwalled carbon nanotubes, graphene, and graphene oxide, *Environmental Toxicology and Chemistry*, 2017, **36**, 2199-2204.

97. H. Wigger, D. Kawecki, B. Nowack and V. Adam, Systematic consideration of parameter uncertainty and variability in probabilistic species sensitivity distributions, *Integrated environmental assessment and management*, submitted.

98. H. Berger, *Monograph of the Oxytrichidae (Ciliophora, Hypotrichia)*, Springer Science & Business Media, 2012.

99. D. Cassidy-Hanley, Tetrahymena in the laboratory: Strain resources, methods for culture, maintenance, and storage, *Methods in Cell Biology*, 2012, **109**, 237-276.

100. M. Ron, J. Paul and S. Mike, BioNumbers.*Journal*, 2010.

101. A. K. Fok and R. D. Allen, Axenic Paramecium caudatum. I. Mass Culture and Structure, *Journal of Eukaryotic Microbiology*, 1979, **26**, 463-470.

102. OECD, OECD Guidelines for the testing of chemicals - Freshwater Alga and Cyanobacteria, Growth Inhibition Test - TG 201, 2006, 25.

103. OECD, OECD Guidelines for the testing of chemicals - Lemna sp. growth inhibition test - TG 221, 2006, 22.

104. OECD, OECD Guidelines for the Testing of Chemicals -Terrestrial Plant Test: Vegetative Vigour Test - TG 227, 2006, DOI: 10.1787/9789264067295-en.

105. OECD, OECD Guideline for testing of chemicals - Daphnia sp., Acute Immobilisation Test - TG 202, 2004, 12.

106. OECD, OECD Guideline for the testing of chemicals - Daphnia magna Reproduction Test - TG 211, 2012, 25.

107. OECD, OECD Guideline for the testing of chemicals - Lymnaea stagnalis Reproduction Test - TG 243, 2016, 31.

108. OECD, OECD Guideline for the testing of chemicals - Potamopyrgus antipodarum Reproduction Test. TG 242, 2016, 23.

109. OECD, OECD Guideline for the testing of chemicals - Fish, Juvenile Growth Test - TG 215, 2000, 16.

110. OECD, OECD Guideline for the testing of chemicals - 21-day Fish Assay: A Short-Term Screening for Oestrogenic and Androgenic Activity, and Aromatase Inhibition - TG 230, 2009, 38.