## **Supplementary information**

## Omics approaches in environmental effect assessment of engineered nanomaterials and nanoplastics

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| Phylum (species)                  | Cyano                               | Cyanobacteria |  | Fungi      |   | Protozoa |          |               | Mollusca                 |              | Annelida  |         | Nematoda (C. |           |              | Arthro       | poda   |       | Chordata<br>(C. carpio, D. rerio) |            |             |           |            |  |
|-----------------------------------|-------------------------------------|---------------|--|------------|---|----------|----------|---------------|--------------------------|--------------|-----------|---------|--------------|-----------|--------------|--------------|--------|-------|-----------------------------------|------------|-------------|-----------|------------|--|
|                                   | (N. sphaeroides,<br>aeruginosa, Nos |               | s, M. (S. cerevisiae, A.<br>stoc tetracladia, F. |            | (E. vannus, T. themophila, P.<br>malhamensis, P. multimicronucleatum) |          |          | (M.           | (E. fetie                | da, E. crypt | icus, L.  | eleg    | gans)        | (D. m)    | agna, D. sir | nilis, B. mo | ri, P. |       |                                   |            |             |           |            |  |
|                                   |                                     |               |  |            |   |          |          | galloprovinci | i rubellus, P. guillemi) |              |           |         |              |           | hawai        | ensis)       |        |       |                                   |            |             |           |            |  |
|                                   | S                                   | p.)           | sola   | ani)       |   |          |          |               | alis)                    |              |           |         |              |           |              |              |        |       |                                   |            |             |           |            |  |
| Physiological effects measured    | No                                  | LC50 and      | EC20   | LC50.      | No effect   | EC15     | 1/2 LC50 | LC50          | No change                | Intes-tinal  | Oxidative | Repro-  | Repro-       | Reduced   | No effect    | Increased    | Midout | ~1/10 | Viability                         | Tran-      | Gill histo- | 1/10 LC50 | 1/2 LC50   |  |
|                                   | observ-                             | 20%           | based on   | oxida-tive | on b  | ased on  |          |               | in gonadal               | damage.      | stress    | duction | duction      | loco-     | on           | body         | tissue | LC50  | or growth                         | sient epi- | patho-      |           | telangi-   |  |
|                                   | able                                | growth        | growth   | stress     | viability (   | growth,  |          |               | index                    | no effect    |           | EC20    | EC50         | motion    | viability    | length, de-  | damage |       | not                               | thelial    | logy        |           | ectasia    |  |
|                                   | effects                             | inhi-bition   |  |            |   | increa-  |          |               |                          | on           |           | and/or  |              | velocity, | or mor-      | creased      |        |       | affected                          | hyper-     |             |           | and epi-   |  |
|                                   |                                     |               |  |            |   | sed      |          |               |                          | viability or |           | EC50    |              | body      | phology      | repro-       |        |       |                                   | plasia     |             |           | thelial    |  |
|                                   |                                     |               |  |            |   | ROS,     |          |               |                          | repro-       |           |         |              | rength,   |              | duction      |        |       |                                   | and        |             |           | cell       |  |
|                                   |                                     |               |  |            |   | oxida-   |          |               |                          | ducation     |           |         |              | ductive   |              |              |        |       |                                   | fusion in  |             |           | plasia in  |  |
|                                   |                                     |               |  |            |   | tion     |          |               |                          |              |           |         |              | capacity  |              |              |        |       |                                   | gills      |             |           | fish gills |  |
| Omics methods used                | P. M                                | м             | T.P  | T. M       | т   | M        | т        | т             | т                        | M            | M         | 3 x T.  | т            | т         | T. M         | M            | мо     | т     | т                                 | мо         | т           | M         | P          |  |
|                                   |                                     |               |  |            |   |          | •        |               |                          |              |           | MO      |              |           |              |              | (T, P) |       |                                   | (T, M)     |             |           | -          |  |
|                                   |                                     |               |  |            |   |          |          |               |                          |              |           | (P, M)  |              |           |              |              |        |       |                                   |            |             |           |            |  |
| Biological processes affected     |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              |        |       |                                   |            |             |           |            |  |
| energy metabolism                 |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              |        |       |                                   |            |             |           |            |  |
| amino acid and protein metabolism |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              |        |       |                                   |            |             |           |            |  |
| lipid metabolism                  |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              |        |       | -                                 |            |             |           |            |  |
| carbohydrate metabolism           |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              | -      |       |                                   |            |             |           |            |  |
| antioxidant defense               |                                     |               |  |            |   |          |          |               |                          | -            |           |         |              |           |              |              |        |       |                                   |            |             |           |            |  |
| stress response                   |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              |        |       |                                   |            |             |           |            |  |
| cell cycle regulation             |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              |        |       |                                   |            |             |           |            |  |
| DNA damage                        |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              |        |       |                                   |            |             |           |            |  |
| translation machinery             |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              |        |       |                                   |            |             |           |            |  |
| apoptosis                         |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              |        |       |                                   |            |             |           | _          |  |
| endocytosis/phagocytosis          |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              |        |       |                                   |            |             |           |            |  |
| cytoskeleton function             |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              |        |       |                                   |            |             |           |            |  |
| nitrogen metabolism               |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              |        |       |                                   |            |             |           |            |  |
| nucleotide metabolism             |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              |        |       |                                   |            |             |           |            |  |
| innate immune response            |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              |        |       |                                   |            |             |           |            |  |
| signaling mechanisms              |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              |        |       |                                   |            |             |           |            |  |
| transmembrane transport           |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              |        |       |                                   |            |             |           |            |  |
| photosynthesis                    |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              |        |       |                                   |            |             |           |            |  |
| inflammation                      |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              |        |       |                                   |            |             |           |            |  |
| iron homeostasis                  |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              |        |       |                                   |            |             |           |            |  |
| post-translational modifications  |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              |        |       |                                   |            |             |           |            |  |
| ciliarfunction                    |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              |        |       |                                   |            |             |           |            |  |
| transcription machinery           |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              |        |       |                                   |            |             |           |            |  |
| ion binding                       |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              |        |       |                                   |            |             |           |            |  |
| phototransduction system          |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              |        |       |                                   |            |             |           |            |  |
| circadian clock regulation        |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              |        |       |                                   |            |             |           |            |  |
| photoreception                    |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              |        |       |                                   | I.,        |             |           |            |  |
| reproductive process              |                                     |               |  |            |   |          |          |               |                          |              |           |         |              |           |              |              |        |       |                                   |            |             |           |            |  |

**Figure S1**. Biological processes perturbed by Ag NPs in different phyla at various physiological effect levels. The perturbed pathways are indicated by blue boxes. P – proteomics, M – metabolomics, T- transcriptomics, MO – multiomics,  $3 \times T$  – transcriptomics was used in three separate studies.

| Phylum (species)               | Cyan                 | Chlorophyta                      |           |             |           | Protozoa                |          |                | Rotifera           | Mollusca | Annelida   | Nematoda  |           | Arthropoda |          |           |  |          | Chordata |          |                 |                |           |          |                |
|--------------------------------|----------------------|----------------------------------|-----------|-------------|-----------|-------------------------|----------|----------------|--------------------|----------|--|-----------|-----------|------------|----------|-----------|--|----------|----------|----------|-----------------|----------------|-----------|----------|----------------|
|                                | (S. elongatus, M. ae | (C. pyrenoidosa, C. vulgaris, P. |           |             |           | (T. thermophila, E.     |          |                | (B.                | (S.      | (E. fetida) (C. (D. magna, D. pulex, P. clarkii) |           |           |            |          | kii)      | (D. rerio, O. aureus, O. mossambicus, M. piceus) |          |          |          |                 |                |           |          |                |
|                                | sp. An               | tricornutum)                     |           |             |           | gracilis, K. mikimotoi) |          |                | koreanu constricta |          | · 1  | elegans)  |           |            |          |           |  |          |          |          |                 |                |           |          |                |
|                                |                      |                                  |           | ,           |           |                         | g,       |                |                    | s) )     |  |           |           |            |          |           |  |          |          |          |                 |                |           |          |                |
| Physiological effects measured | No effect Growth     | EC20 EC50                        | EC50      | 7%          | EC20      | Reduced                 | Membrane | No             | Reduced            | EC50     | No effect  | No        | No effect | Oxydative  | No       | No        | Mild   | Change   | Decrea   | No       | Oxida- Syste    | nic Swimmin    | g Decrea- | Brain    | Liver Gill and |
|                                | on inhibition,       | based based                      | based on  | growth      | based on  | growth,                 | damage,  | effect         | growth             | based    | on   | change    | on        | stress,    | effect   | effect    | stress   | in the   | sed      | change   | tive respon     | se hyperacti   | sed       | damage o | lamage liver   |
|                                | growth, oxidative    | on on                            | growth,   | inhibition, | growth,   | chloro-                 | ROŠ      | on             | and                | on       | growth   | after 2-  | viability | impaired   | after 4- | after 37- |  | sex      | growth   | after 7- | stress after lo | calvity, but n | b heart   | and      | and damage     |
|                                | decrease stress, o   | growth, growth                   | ROS,      | reduced     | impaired  | phyll                   |          | growth,        | photosyn           | growth   | after 24   | day       | or body   | locomotion | day      | day       |  | ratio of | and      | day      | inject          | on effect on   | rate and  | disrup-  | oxida-         |
|                                | in chloro- memb-     | oxida-                           | lipid     | photosyn    | photo-    | content                 |          | memb-          | -thesis,           | -        | h  | exposure  | weight,   | and repro- | expo-    | expo-     |  | neo-     | cumu-    | expo-    | of              | mortality.     | loco-     | tion in  | tive           |
|                                | phyll rane           | tive                             | peroxi-   | -thesis,    | synthesis | and                     |          | rane           | increa-            |          | exposur  | to 0.005, | decrease  | duction    | sure to  | sure to   |  | nates    | lative   | sure to  | polys           | v- hatching    | motor     | circa-   | stress         |
|                                | content damage, s    | stress                           | dation.   | increa-     | , memb-   | photo-                  |          | damage         | sed                |          | e to 1   | 0.05.0.5  | in gut    |            | 1 mg/L   | 3 ug/L    |  |          | off-     | 20 mg/L  | rené N          | ́Рs rate.or    | activity  | dian     |                |
|                                | after 4- impaired    |                                  | memb-     | sed         | rane      | cvnthetic               |          | after 3-       | oxidative          |          | ma/L   | and 50    | micro-    |            |          | 5         |  |          | sprina   | 5        | in th           | e develop-     |           | rhvthm   |                |
|                                | dav memb-            |                                  | rane      | oxidative   | damage.   | svstem                  |          | dav            | stress             |          | 5  | ma/L      | biota     |            |          |           |  |          | producti |          | volk            | of mentante    | r         | ,        |                |
|                                | exposure rane        |                                  | damage.   | stress      | oxidative | -,                      |          | expo-          |                    |          |  |           | diversity |            |          |           |  |          | on (21-  |          | embry           | os 5-dav       |           |          |                |
|                                | to 50 or transport   |                                  | decrease  |             | stress    |                         |          | sure to        |                    |          |  |           | ,         |            |          |           |  |          | dav      |          | ,               | expo-sure      |           |          |                |
|                                | 100 ma/l             |                                  | in photo- |             |           |                         |          | 10 ma/l        |                    |          |  |           |           |            |          |           |  |          | expo-    |          |                 | to 10 ma/      |           |          |                |
|                                |                      |                                  | synthesis |             |           |                         |          | · • · · · g. = |                    |          |  |           |           |            |          |           |  |          | sure to  |          |                 |                |           |          |                |
|                                |                      |                                  | • ;       |             |           |                         |          |                |                    |          |  |           |           |            |          |           |  |          | 1  mg/l  |          |                 |                |           |          |                |
|                                |                      |                                  |           |             |           |                         |          |                |                    |          |  |           |           |            |          |           |  |          | ·        |          |                 |                |           |          |                |





**Figure S2.** Biological processes perturbed by polystyrene NPs in different phyla at various physiological effect levels. The perturbed pathways are indicated by blue boxes. M – metabolomics, T- transcriptomics, P – proteomics, MO – multiomics.