# Supplementary file

**Table S1: Isotherm Equations.**

| Isotherm | Equation | Parameters |
|---|---|---|
| Langmuir | $\dfrac{C_e}{Q_e} = \left(\dfrac{1}{Q_m}\right)C_e + \left(\dfrac{1}{K_L Q_m}\right)$ | $Q_m$ = maximum adsorption capacity (mg/g) <br> $K_L$ = Langmuir constant (L/mg). |
| Freundlich | $log Q_e = log K_f + \dfrac{1}{n}log$ | $K_F$ is the Freundlich constant (represents performance) <br> 1/n is the heterogeneity factor (represents effectiveness). |
| Temkin | $Q_e = B ln K_T + B ln C$ | B = RT/b, T = temperature (K), <br> R = Gas constant (8.314 $JK^{-1}\,mol^{-1}$), <br> b = Temkin constant related to the heat of adsorption (J $mol^{-1}$), and $K_T$ = Equilibrium binding constant (L $mg^{-1}$ ) |

**Table S2: Physiochemical Characteristics of Seawater**

| S.No. | Physiochemical Characteristics | Quantity (Units) |
|---|---|---|
| 1. | Temperature | 27±0.3°C |
| 2. | pH | 8.1±0.07 |
| 3. | Salinity | 35±0.1 ppt |
| 4. | Dissolved Oxygen | 7.17 ±0.3 mg/L |
| 5. | Conductivity | 14.65±0.54 mS/cm |
| 6. | Total Hardness | 100±2.3 mg/L |
| 7. | Calcium | 400±1.2 mg/L |
| 8. | Magnesium | 1300±15.2 mg/L |
| 9. | Potassium | 380±0.8 mg/L |
| 10. | Sulphate | 3708±23.5 mg/L |

**Table S3: Zeta potential values of various PSNPs dispersed in Milli-Q and seawater**

| Particles | Zeta potential (mV) | |
|---|---|---|
| | In Milli-Q water | In Seawater |
| MH | 0.1±0.09 | -0.98±0.04 |
| PS-100 nm | -47.3±1.2 | -58.2±1.5 |
| PS-COOH | -64.5±1.0 | -75.6±0.8 |
| PS-NH$_2$ | -53.1±0.5 | -66.3±1.4 |
| PS-500 nm | -47.3±0.9 | -55.5±0.6 |

**Table S4: Hydrodynamic sizes of various PSNPs and PS-MH complexes dispersed in Milli-Q and seawater**

| Particles | Hydrodynamic Size (nm) | |
|---|---|---|
| | Milli-Q water | Sea water |
| PS-100 nm | 100±4 | 409±2 |
| PS-100 nm + MH | 114±2 | 570±5 |
| PS-COOH | 102±5 | 430±6 |
| PS-COOH + MH | 120±5 | 620±3 |
| PS-NH$_2$ | 100±7 | 415±7 |
| PS-NH$_2$ + MH | 115±3 | 585±6 |
| PS-500 nm | 501±9 | 895±2 |
| PS-500 nm + MH | 560±8 | 954±3 |

**Table. S5 Independent action model for the PSNPs+MH complex**

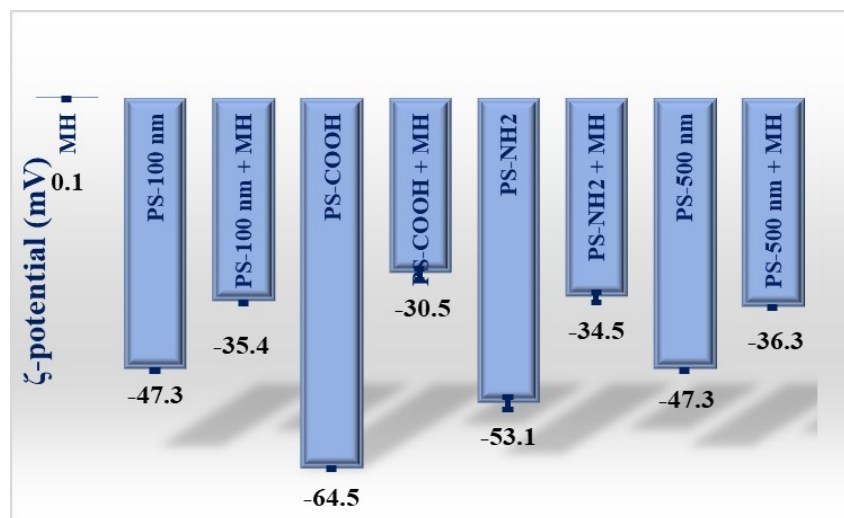| S.NO | Test samples | Concentration of Complex pollutants (µg/ml) | RI value | Mode of action |
|---|---|---|---|---|
| 1. | | 2.5 | 1.10 | Synergistic |
| 2. | PS-100 + MH | 5 | 1.14 | Synergistic |
| 3. | | 10 | 1.20 | Synergistic |
| 4. | | 2.5 | 1.06 | Synergistic |
| 5. | PS-COOH+MH | 5 | 1.14 | Synergistic |
| 6. | | 10 | 1.20 | Synergistic |
| 7. | | 2.5 | 1.06 | Synergistic |
| 8. | PS-NH$_2$+MH | 5 | 1.12 | Synergistic |
| 9. | | 10 | 1.17 | Synergistic |
| 10. | | 2.5 | 1.00 | Additive |
| 11. | PS-500 +MH | 5 | 1.68 | Synergistic |
| 12. | | 10 | 1.69 | Synergistic |

**Fig. S1.** Zeta potential of NPs, MH, and their corresponding complexes. [NPs], [MH],
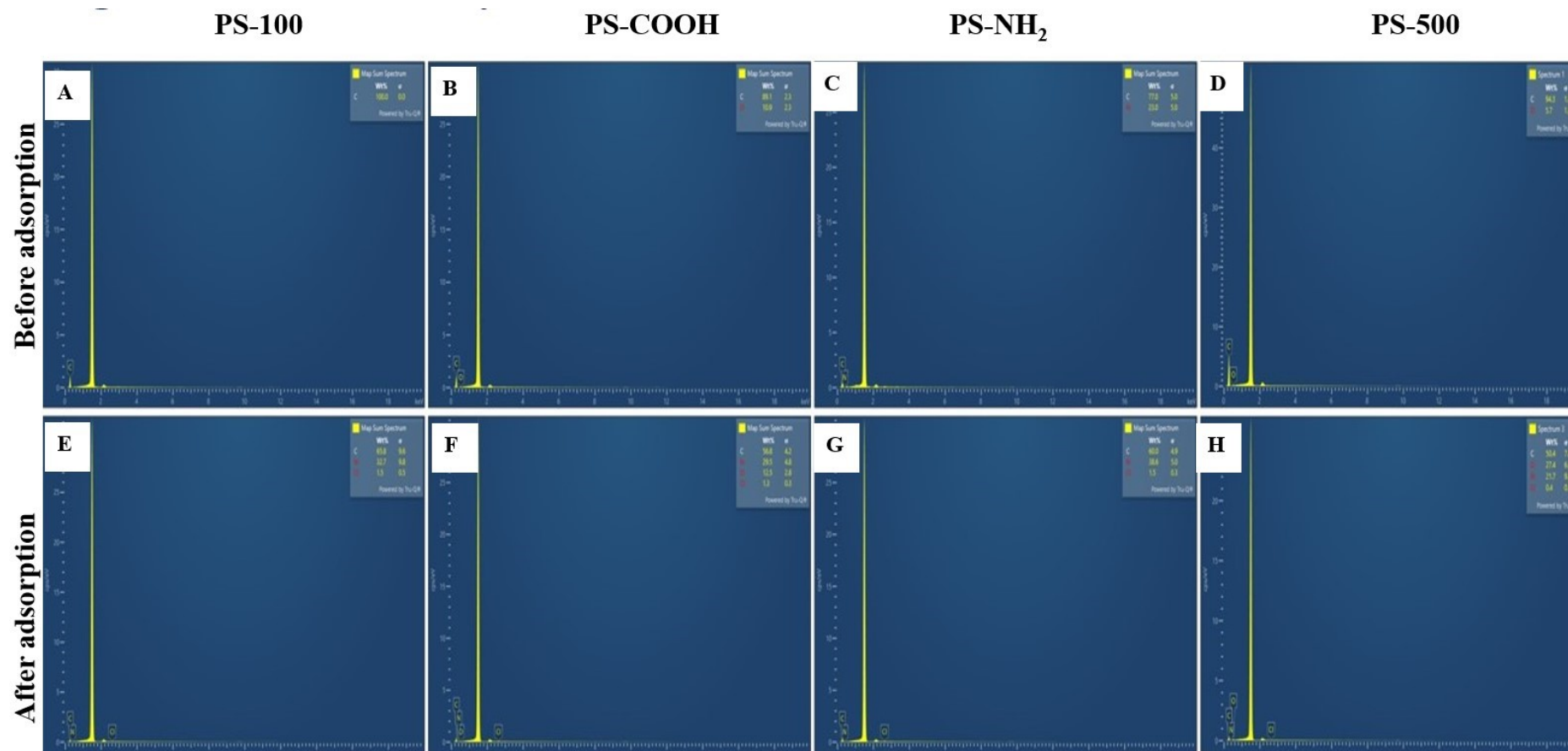[NPs, MH – 1:0.5] = 10mg/L, pH=7. Data were the mean of triplicate experiments with SD.

**Fig. S2.** A-D: EDX analysis of NPs before the adsorption process. (A) PS-100, (B) PS-COOH, (C) PS-NH$_2$, (D) PS-500.
E-H: EDX analysis of NPs after adsorption of MH. (E) PS-100+MH, (F) PS-COOH+MH, (G) PS-NH$_2$+MH, (H) PS-500+MH.

| Decapsulation | Instar 1 | Instar 2 | Instar 3 | | Observation |
|---|---|---|---|---|---|
| | | | | PS-100nm | Greater intake of PS compared to PS-200, 500 and PS-COOH, with slight difference in the body structure. |
| | | | | PS-COOH-100 nm | Intake of PS-COOH is also visible, however it is least significant than PS and PS-NH$_2$ |
| | | | | PS-NH$_2$-100 nm | Intake of particles is observed greater with developmental abnormality in the Instar 1 and 2 stages. |
| | | | | PS-500 nm | Morphology was not affected but the accumulation of the particles is found in the gut region. |
| | | | | PS-200 nm (FI) | The fluorescent particles are seen attached to the cyst and up taken by larvae. |
| | | | | PS-100+MH | When adsorbed with MH, PS-100 nm delayed the hatching at 16 h followed by intake, developmental deformity at the 1st instar stage and accumulation in the gut region. |
| | | | | PS-COOH-100+MH | Similar to PS-100 nm with a slightly reduced toxicity |
| | | | | PS-NH$_2$-100+MH | Highly significant among all others, where the cyst is observed to completely spherical showing delayed hatching. Delay in developmental growth as seen in 2$^{nd}$ instar stages and 3$^{rd}$ instar stages. |
| | | | | PS-500 +MH | Accumulation of particles are visible. |
| | | | | PS-200 (FI)+MH | Accumulation of complex were observed in the gut region |
| | | | | MH | No toxic effects observed But little accumulation |
| | | | | CONTROL | No developmental abnormalities |

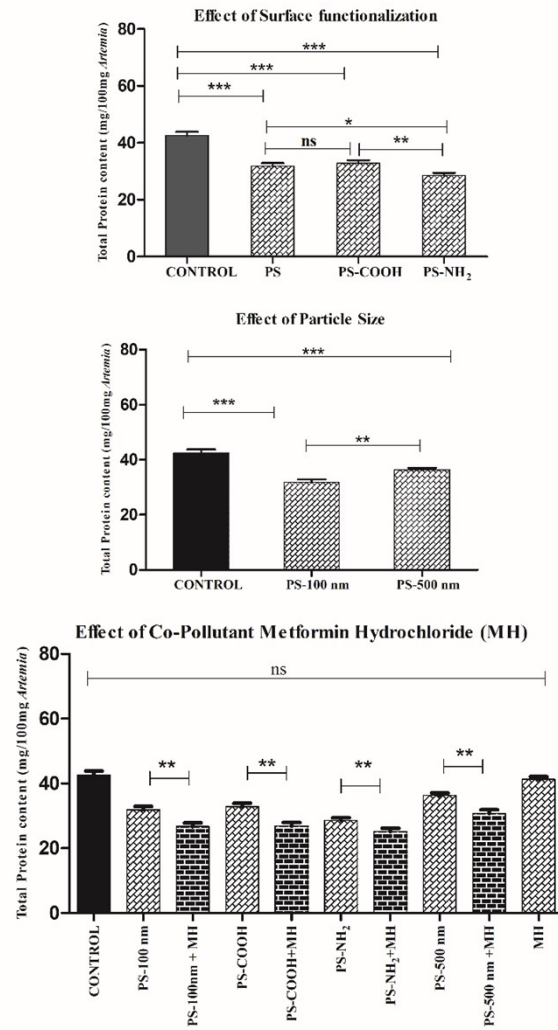**Fig. S3:** Developmental changes of *A. salina* on exposure to different NPs and MH complexes.

**Fig. S4:** Total protein content of A. salina on interaction with NPs and MH complexes (n=3). All values expressed as mean±SD. (***P<0.0001)