Electronic Supplementary Material (ESI) for Environmental Science: Nano.

SUPPLEMENTARY INFORMATION

ACUTE AND CHRONIC TOXICITY OF METAL OXIDE NANOPARTICLES IN CHEMICAL MECHANICAL PLANARIZATION SLURRIES WITH DAPHNIA MAGNA

Sarah Karimi,[a‡] Meiline Troeung,[b] Ruhung Wang,[ab] Rockford Draper,[ab] and Paul Pantano[a]*

[a] Department of Chemistry and Biochemistry, [b] Department of Biological Sciences

The University of Texas at Dallas, Richardson, TX 75080-3021, USA

‡ Current affiliation: Department of Chemistry, George Washington University, Washington, DC 20052, USA

* Corresponding author: pantano@utdallas.edu

Table S1. Chemical and physical properties of pristine model CMP slurries provided by the manufacturer.

	Colloidal Silica (*c*-SiO_2)	Fumed Silica (*f*-SiO_2)	Ceria (CeO_2)	Alumina (Al_2O_3)
Additive	<1% acetic acid	<1% KOH	none	<1% nitric acid
pH	2.5–4.5	10.0	3.0–4.0	4.5–5.0
Composition	3% SiO_2	5% SiO_2	1% CeO_2	3% Al_2O_3
Particle size (nm)	50–60	120–140	60–100	80–100

Table S2. Summary of conditions for acute and chronic toxicity tests with *Daphnia magna*.

Test parameter	Conditions	
Test type	Acute toxicity assessment, Static non-renewal	Chronic toxicity assessment, Static renewal
Test duration	4 d	21 d
Temperature	20 ± 1°C	20 ± 1°C
Photoperiod	16-h light / 8-h dark	16-h light / 8-h dark
Test chamber size	10 mL	250 mL
Test solution volume	8 mL	100 mL
Age of test organisms	<24-h old	<24-h old
Organisms/test chamber	5	10
Replicate test chambers	6	3
Number of organisms/trial	30	30
Feeding regime	48 µL of YCT and 32 µL of Pseudokirchnerilla subcapitata (1.1×10^6 cells)	500 µL of YCT and 2 mL of Pseudokirchnerilla subcapitata (7.0×10^7 cells)
Renewal of test solutions	Not required	After 96 h
Test chamber cleaning	Not required	After 96 h
End points	Morbidity and body size	Morbidity, body size, and reproductive output
Test acceptability	≥90% survival of controls	≥80% survival of controls and no ephippium (resting eggs) in controls

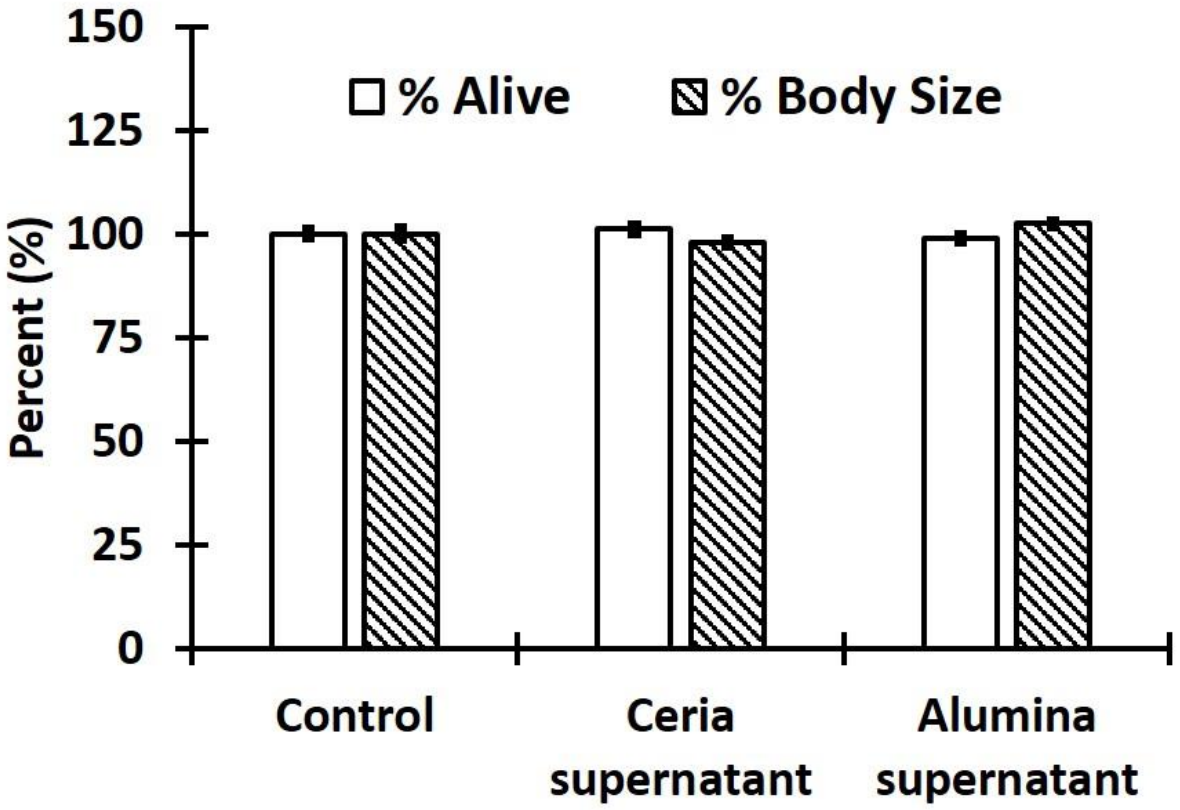

Figure S1. Acute morbidity and effects on *D. magna* size after a 96-h exposure to the supernatant collected from a 2.0-mg/mL model CeO_2 CMP slurry or a 3.0-mg/mL model Al_2O_3 CMP slurry. Clear bars: Percent survival of control *D. magna* not exposed to a CMP slurry supernatant (set to 100%), *D. magna* exposed to the CeO_2 CMP slurry supernatant, or *D. magna* exposed to the Al_2O_3 CMP slurry supernatant. **Patterned bars:** Percent body sizes of control *D. magna* not exposed to a CMP slurry supernatant (set to 100%), *D. magna* exposed to the CeO_2 CMP slurry supernatant, or *D. magna* exposed to the Al_2O_3 CMP slurry supernatant. 30 daphnids were used per each sample in an experiment and at least three independent experiments were conducted. The bars are the mean values and the error bars represent the standard error of mean (SEM).

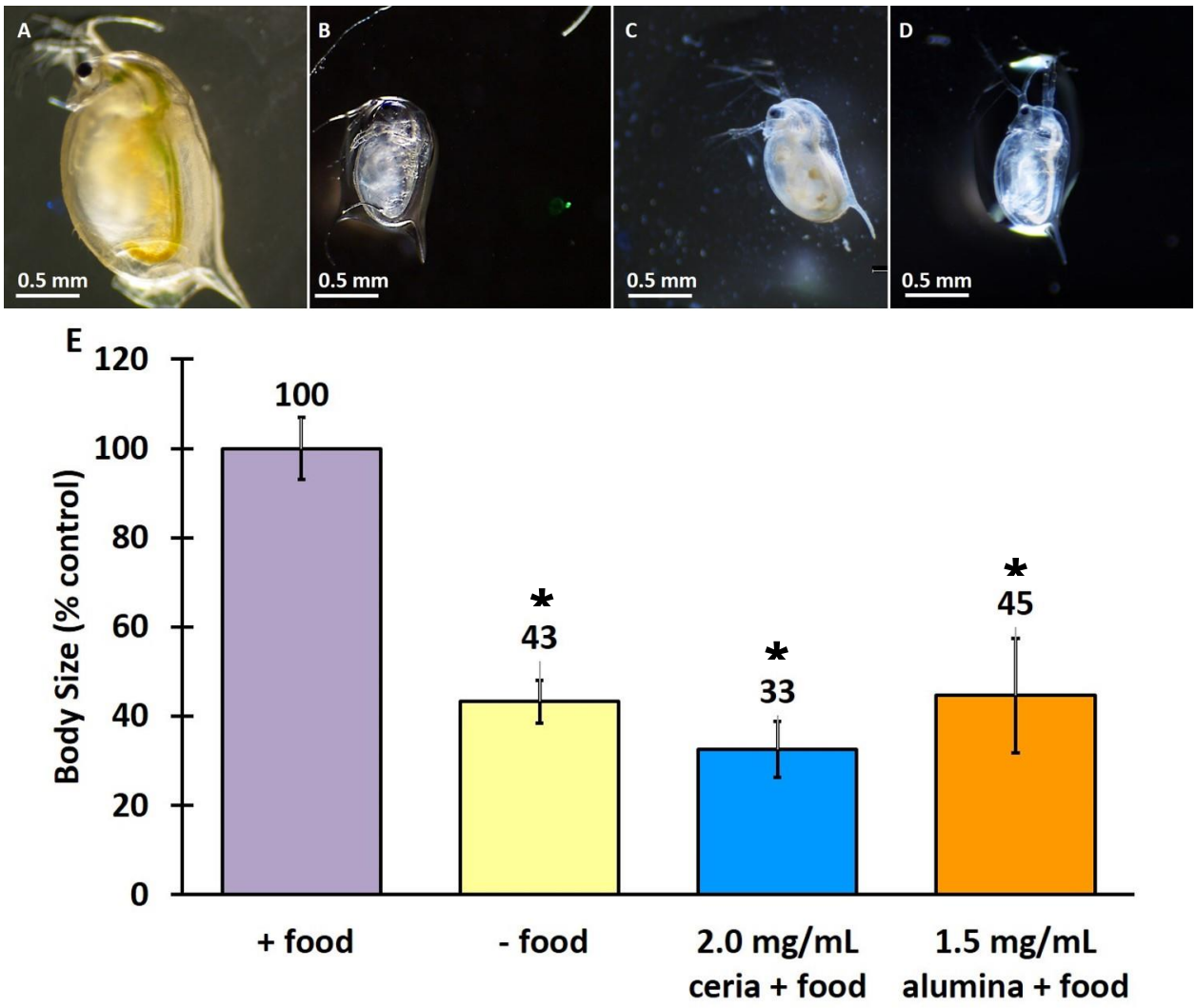

Figure S2. Sizes of starved *D. magna* are similar to those that are fed and exposed to model CeO_2 or Al_2O_3 CMP slurries for 72 h. Representative optical images (5× magnification) of: **(A)** control *D. magna* that were fed but not exposed to a CMP slurry; **(B)** *D. magna* that were starved but not exposed to a CMP slurry; **(C)** *D. magna* that were fed and exposed to 2.0 mg/mL of the CeO_2 CMP slurry; and, **(D)** *D. magna* that were fed and exposed to 1.5 mg/mL of the Al_2O_3 CMP slurry. **(E)** Summary plot where the body sizes of the starved *D. magna* and fed *D. magna* exposed to the CeO_2 or Al_2O_3 CMP slurries are shown relative to control *D. magna* that were fed but not exposed to a CMP slurry (set to 100%). 30 daphnids were used per each test condition in an experiment and at least three independent experiments were conducted. The bars are the mean values and the error bars represent the SEM. * represents $p < 0.05$ relative to the control.

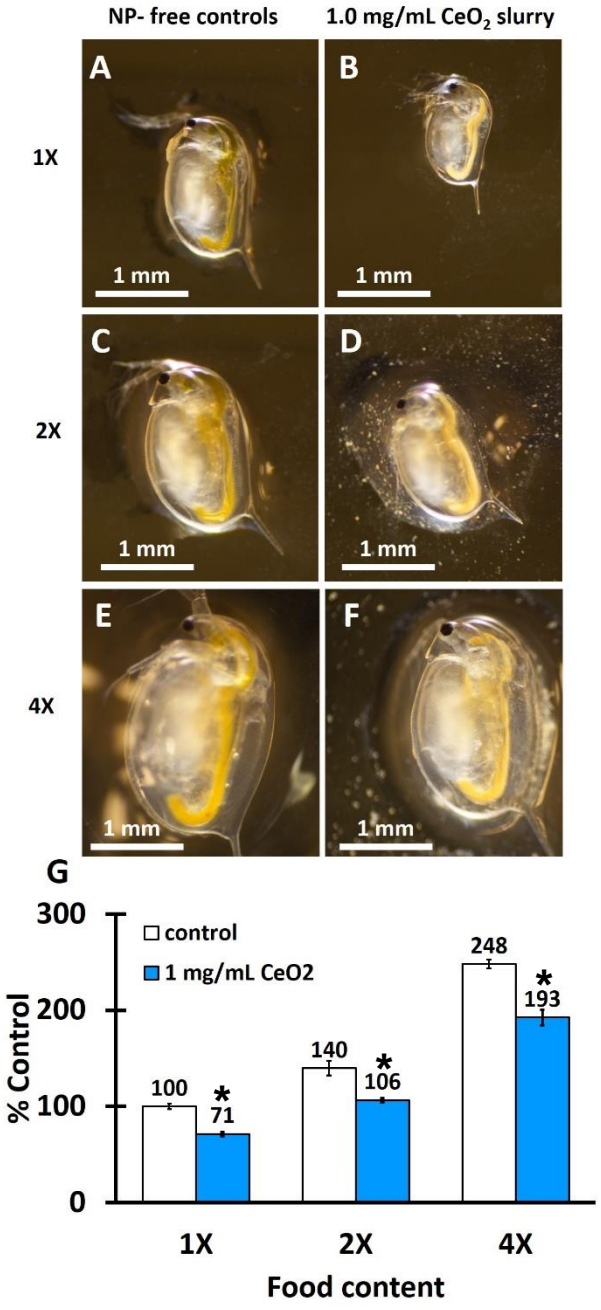

Figure S3. Acute effects on *D. magna* size after a 96-h exposure to the model CeO_2 CMP slurry under different feeding conditions. Representative optical images (3× magnification) of: **(A)** control *D. magna* fed 1X food (normal feeding regimen) and not exposed to a CMP slurry; **(B)** *D. magna* fed 1X food and exposed to 1.0 mg/mL of the CeO_2 CMP slurry; **(C)** *D. magna* fed 2X

food and not exposed to a CMP slurry; **(D)** *D. magna* fed 2X food and exposed to 1.0 mg/mL of the CeO_2 CMP slurry; **(E)** *D. magna* fed 4X food and not exposed to a CMP slurry; and, **(F)** *D. magna* fed 4X food and exposed to 1.0 mg/mL of the CeO_2 CMP slurry. **(G)** Summary plot where the body sizes of *D. magna* exposed to the CeO_2 CMP slurry **(shaded bars)** and *D. magna* controls not exposed to CMP slurries **(clear bars)** are shown relative to the 1X *D. magna* control not exposed to a CMP slurry (set to 100%). 30 daphnids were used per each test condition in an experiment and at least three independent experiments were conducted. The bars are the mean values and the error bars represent the SEM. * represents $p < 0.05$ relative to the control.

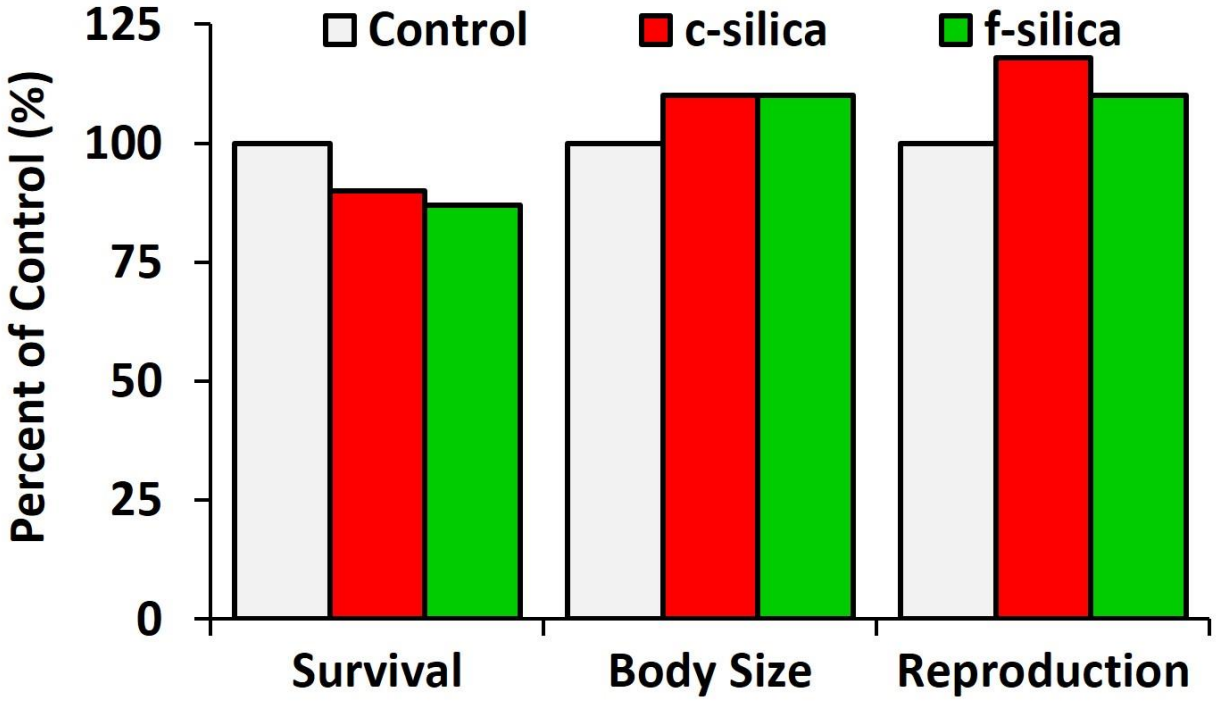

Figure S4. Chronic morbidity and effects on *D. magna* size and reproduction after a 21-d exposure to the model *c*-SiO_2 or *f*-SiO_2 CMP slurries. Percent survival, body size, and reproductive output of adult *D. magna* exposed to 0.1 mg/mL of either the *c*-SiO_2 **(red bars)** or the *f*-SiO_2 **(green bars)** CMP slurry for 21 d are plotted relative to the control *D. magna* that were not exposed to a CMP slurry (set to 100%; **clear bars**). 30 daphnids were used per each test condition in an experiment and two independent experiments were conducted; the bars are the mean values.

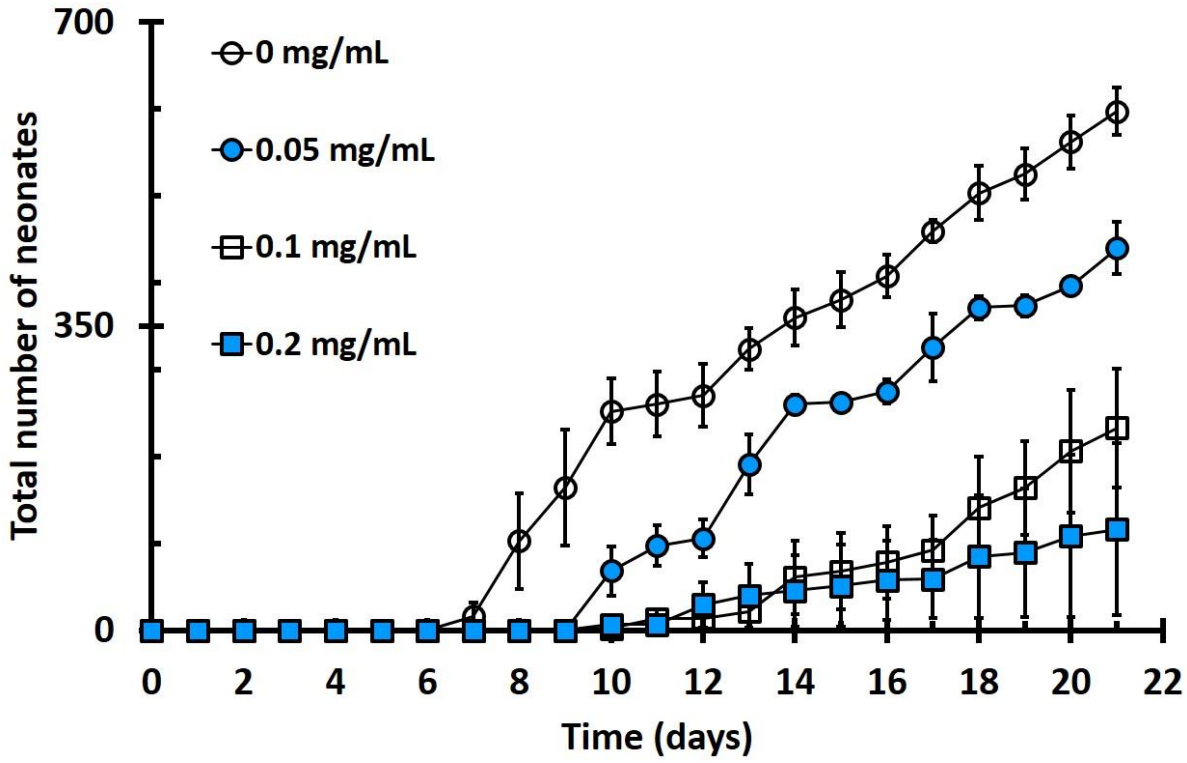

Figure S5. Chronic effects on *D. magna* reproduction during a 21-d exposure to various concentrations of the model CeO_2 CMP slurry. **Clear circles** show the reproductive output of control *D. magna* not exposed to a CMP slurry; **blue circles** show the reproductive output of *D. magna* exposed to 0.05 mg/mL of the CeO_2 CMP slurry; **clear squares** show the reproductive output of *D. magna* exposed to 0.10 mg/mL of the CeO_2 CMP slurry; and, **blue squares** show the reproductive output of *D. magna* exposed to 0.20 mg/mL of the CeO_2 CMP slurry. 30 daphnids were used per each NP concentration in an experiment and at least three independent experiments were conducted; the data symbols are the mean values and the error bars represent the SEM.

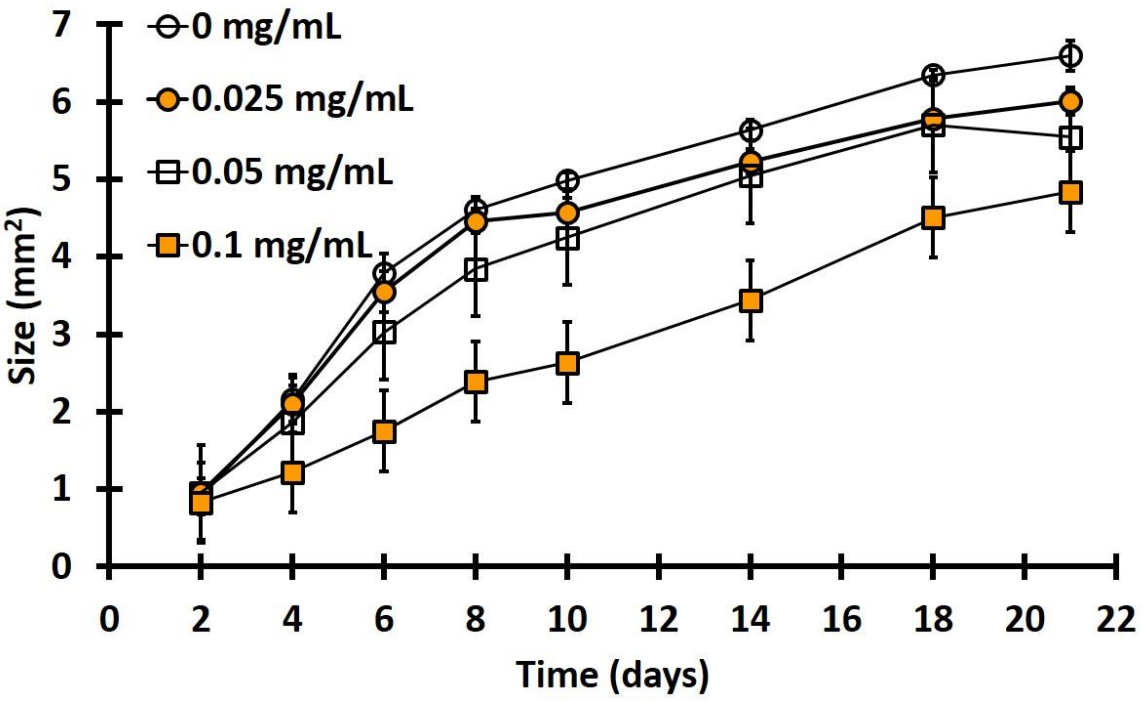

Figure S6. Chronic effects on *D. magna* size during a 21-d exposure to various concentrations of the model Al_2O_3 CMP slurry. Control *D. magna* not exposed to a CMP slurry **(clear circles)** reached a mean body size of 6.6 ± 0.2 mm^2 by day 21. *D. magna* exposed to 0.025 mg/mL of the Al_2O_3 CMP slurry **(orange circles)** reached a mean body size of 6.0 ± 0.2 mm^2 by day 21. *D. magna* exposed to 0.05 mg/mL of the Al_2O_3 CMP slurry **(clear squares)** reached a mean body size of 5.5 ± 0.3 mm^2 by day 21. *D. magna* exposed to 0.1 mg/mL **(orange squares)** reached a mean body size of 4.8 ± 0.0 mm^2 by day 21. 30 daphnids were used per each NP concentration in an experiment and at least three independent experiments were conducted; the data symbols are the mean values and the error bars represent the SEM.

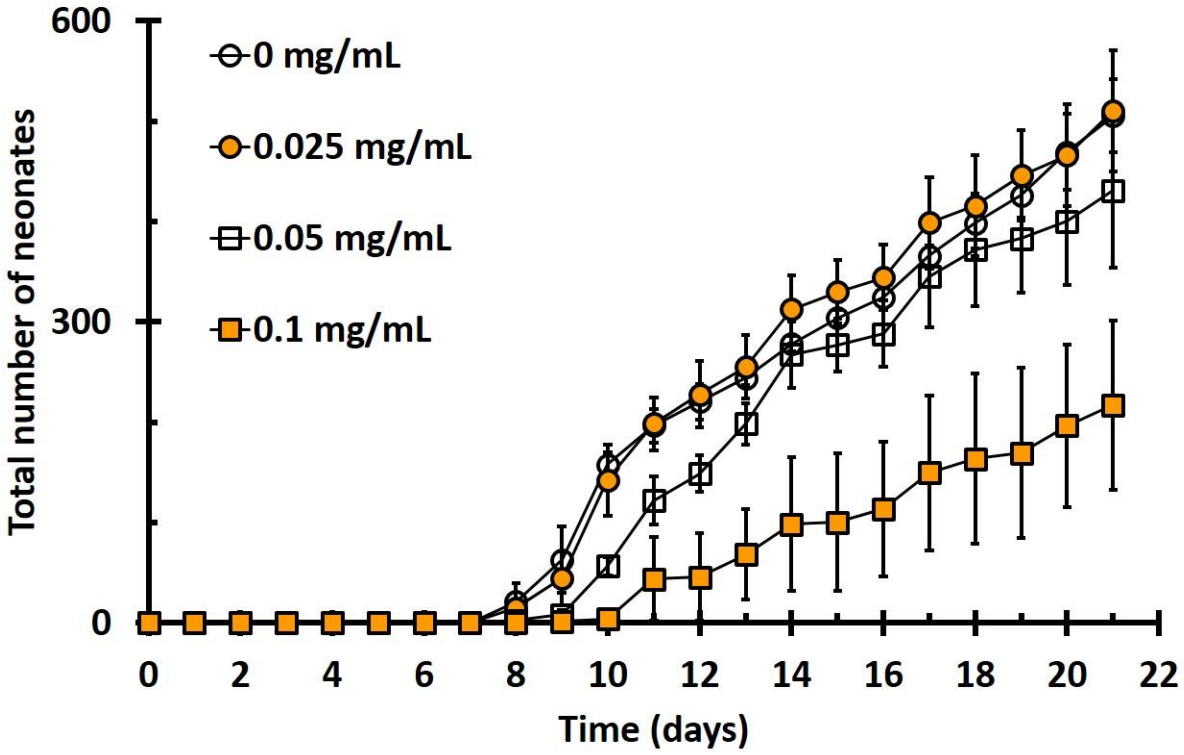

Figure S7. Chronic effects on *D. magna* reproduction during a 21-d exposure to various concentrations of the model Al_2O_3 CMP slurry. Clear circles show the reproductive output of control *D. magna* not exposed to a CMP slurry; **orange circles** show the reproductive output of *D. magna* exposed to 0.025 mg/mL of the Al_2O_3 CMP slurry; **clear squares** show the reproductive output of *D. magna* exposed to 0.50 mg/mL of the Al_2O_3 CMP slurry; and, **orange squares** show the reproductive output of *D. magna* exposed to 0.10 mg/mL of the Al_2O_3 CMP slurry. 30 daphnids were used per each NP concentration in an experiment and at least three independent experiments were conducted; the data symbols are the mean values and the error bars represent the SEM.