Nanomaterial safety for microbially-colonized hosts: Microbiota-mediated physisorption interactions and particle-specific toxicity

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References

A

Abràmoff MD, Magelhae PJ, Ram SJ. 2004. Image processing with ImageJ. Biophotonics Int. 11: 36-42.

Adachi O, Kawai T, Takeda K, Matsumoto M, Tsutsui H, Sakagami M, Nakanishi K, Akira S. 1998. Targeted disruption of the MyD88 gene results in loss of IL-1- and IL-18-mediated function. Immunity. 9: 143-150. DOI: 10.1016/s1074-7613(00)80596-8

Adamovsky O, Buerger AN, Wormington AM, Ector N, Griffitt RJ, Bisesi Jr JH, Martyniuk CJ. 2018. The gut microbiome and aquatic toxicology: an emerging concept for environmental health. Environ Toxicol Chem. 37: 2758-2775. DOI: 10.1002/etc.4249

Agans RT, Gordon A, Hussain S, Paliy O. 2019. Titanium dioxide nanoparticles elicit lower direct inhibitory effect on human gut microbiota than silver nanoparticles. Toxicol Sci. 172: 411-416. DOI: 10.1093/toxsci/kfz183

Ahmed B, Ameen F, Rizvi A, Ali K, Sonbol H, Zaidi A, Khan MS, Musarrat J. 2020. Destruction of cell topography, morphology, membrane, inhibition of respiration, biofilm formation, and bioactive molecule production by nanoparticles of Ag, ZnO, CuO, TiO_2, and Al_2O_3 toward beneficial soil bacteria. ACS Omega. 5: 7861-7876. DOI: 10.1021/acsomega.9b04084

Akin D, Sturgis J, Ragheb K, Sherman D, Burkholder K, Robinson JP, Bhunia AK, Mohammed S, Bashir R. 2007. Bacteria-mediated delivery of nanoparticles and cargo into cells. Nat Nanotechnol. 2: 441-449. DOI: 10.1038/nnano.2007.149

Alder BJ, Wainwright TE. 1957. Phase transition for a hard sphere system. J Chem Phys. 27: 1208-1209. DOI: 10.1063/1.1743957

Al-Johani H, Abou-Hamad E, Jedidi A, Widdifield CM, Viger-Gravel J, Sangaru SS, Gajan D, Anjum DH, Ould-Chikh S, Hedhili MN, et al. 2017. The structure and binding mode of citrate in the stabilization of gold nanoparticles. Nat Chem. 9: 890-895. DOI: 10.1038/nchem.2752

Arias-Andres M, Kettner MT, Miki T, Grossart H-P. 2018. Microplastics: new substrates for heterotrophic activity contribute to altering organic matter cycles in aquatic ecosystems. Sci Total Environ. 635: 1152-1159. DOI: 10.1016/j.scitotenv.2018.04.199

Atkinson MJ, Bingman C. 1996. Elemental composition of commercial seasalts. J Aquaric Aquat Sci. 8: 39-43.

Avellan A, Simonin M, McGivney E, Bossa N, Spielman-Sun E, Rocca JD, Bernhardt ES, Geitner NK, Unrine JM, Wiesner, MR, et al. 2018. Gold nanoparticle biodissolution by a freshwater macrophyte and its associated microbiome. Nat Nanotechnol. 13: 1072-1077. DOI: 10.1038/s41565-018-0231-y

B

Bambino K, Chu J. 2017. Zebrafish in toxicology and environmental health. Curr Top Dev Biol. 124: 331-367. DOI: 10.1016/bs.ctdb.2016.10.007

Banjare P, Matore B, Singh J, Roy PP. 2021. In silico local QSAR modeling of bioconcentration factor of organophosphate pesticides. In Silico Pharmacol. [accessed 2022 Jan 26]:[13 p.]. DOI: 10.1007/s40203-021-00087-w

Barnoud J, Monticelli L. 2015. Coarse-grained force fields for molecular simulations. In: Kukol A, editor. Molecular modeling of proteins. New York: Springer Science+Business Media; p. 125-151. DOI: 10.1007/978-1-4939-1465-4

Barradas NP, Jeynes C. 2008. Advanced physics and algorithms in the IBA DataFurnace. Nucl Instr Meth Phys B. 266: 1875-1879.

Batel A, Borchert F, Reinwald H, Erdinger L, Braunbeck T. 2018. Microplastic accumulation patterns and transfer of benzo[a]pyrene to adult zebrafish (*Danio rerio*) gills and zebrafish embryos. Environm Pol. 235: 918-930. DOI: 10.1016/j.envpol.2018.01.028

Battimelli G, Ciccotti G. 2018. Berni Alder and the pioneering times of molecular simulation. Eur Phys J H. 43: 303-335. DOI: 10.1140/epjh/e2018-90027-5

Behler J. 2017. First principles neural network potentials for reactive simulations of large molecular and condensed systems. Angew Chem Int Ed. 56: 12828-12840. DOI: 10.1002/anie.201703114

Beiras R, Bellas J, Cachot J, Cormier B, Cousin X, Engwall M, Gambardella C, Garaventa F, Keiter S, Le Bihanic F, et al. 2018. Ingestion and contact with polyethylene microplastics does not cause acute toxicity on marine zooplankton. J Hazard Mater. 360: 452-460. DOI: 10.1016/j.jhazmat.2018.07.101

Bennett CM, Kanki JP, Rhodes J, Liu TX, Paw BH, Kieran MW, Langenau DM, Delahaye-Brown A, Zon LI, Fleming MD, et al. 2001. Myelopoiesis in the zebrafish, *Danio rerio*. Blood. 98: 643-651. DOI: 10.1182/blood.V98.3.643

Bernard NJ, O'Neill LA. 2013. Mal, more than a bridge to MyD88. IUBMB Life. 65: 777-786. DOI: 10.1002/iub.1201

Birchenough GMH, Nyström EEL, Johansson MEV, Hansson GC. 2016. A sentinel goblet cell guards the colonic crypt by triggering Nlrp6-dependent Muc2 secretion. Science. 352: 1535-1542. DOI: 10.1126/science.aaf7419

Birdsall CK, Langdon, AB. 2018. Plasma physics via computer simulation. 1st ed. Boca Raton: CRC Press. DOI: 10.1201/9781315275048

Bliss, CI. 1939. The toxicity of poisons applied jointly. Ann Appl Biol. 26: 585-615. DOI: 10.1111/j. 1744-7348.1939.tb06990.x

Böhme S. 2015. Development and application of quantification and visualization techniques to investigate the uptake of nanoparticles by cells and ecotoxicological test organisms [dissertation]. Helmholtz: Helmholtz Centre for Environmental Research (UFZ).

Böhme S, Stärk H-J, Kühnel D, Reemtsma T. 2015. Exploring LA-ICP-MS as a quantitative imaging technique to study nanoparticle uptake in *Daphnia magna* and zebrafish (*Danio rerio*) embryos. Anal Bioanal Chem. 407: 5477-5485. DOI: 10.1007/s00216-015-8720-4

Bondarenko O, Ivask A, Käkinen A, Kurvet I, Kahru A. 2013. Particle-cell contact enhances antibacterial activity of silver nanoparticles. PLoS One. [accessed 2019 Oct 30]:[12 p.]. DOI: 10.1371/journal.pone.0064060

Bonomi M, Branduardi D, Bussi G, Camilloni C, Provasi D, Raiteri P, Donadio D, Marinelli F, Pietrucci F, Broglia RA, et al. 2009. Plumed: a portable plugin for free-energy calculations with molecular dynamics. Comput Phys Commun. 180: 1961–1972. DOI: 10.1016/j.cpc.2009.05.011

Bove P, Malvindi MA, Kote SS, Bertorelli R, Summa M, Sabella S. 2017. Dissolution test for risk assessment of nanoparticles: a pilot study. Nanoscale. 9: 6315-6326. DOI: 10.1039/c6nr08131b

Bradley J-C, Acree WE, Lang ASID. 2014 Sep 22. Compounds with known Abraham descriptors [data set]. Figshare. [accessed 2020 June 13]. DOI: 10.6084/m9.figshare.1176994

Brandelli A, Ritter AC, Veras FF. 2017. Antimicrobial activities of metal nanoparticles. In: Cravo-Laureau C, Cagnon C, Lauga B, Duran R, editors. Microbial Ecotoxicology. New York City: Springer; p. 337-363. DOI: 10.1007/978-3-319-61795-4

Brinkmann BW, Koch BEV, Spaink HP, Peijnenburg WJGM, Vijver MG. 2020. Colonizing microbiota protect zebrafish larvae against silver nanoparticle toxicity. Nanotoxicology. 14: 725-739. DOI: 10.1080/17435390.2020.1755469

Brooke JS. 2012. *Stenotrophomonas maltophilia:* an emerging global opportunistic pathogen. Clin Microbiol Rev. 25: 2-41. DOI: 10.1128/CMR.00019-11

Browning LM, Lee KJ, Huang T, Nallathamby PD, Lowman JE, Xu X-HN. 2009. Random walk of single gold nanoparticles in zebrafish embryos leading to stochastic toxic effects on embryonic developments. Nanoscale. 1: 138-152. DOI: 10.1039/b9nr00053d

Brugman S, Ikeda-Ohtsubo W, Braber S, Folkerts G, Pieterse CMJ, Bakker PAHM. 2018. A comparative review on microbiota manipulation: lessons from fish, plants, livestock, and human research. Front Nutr. [accessed 2019 Oct 11]:[15 p.]. DOI: 10.3389/fnut.2018.00080

Brun NR, Koch BEV, Varela M, Peijnenburg WJGM, Spaink HP, Vijver MG. 2018. Nanoparticles induce dermal and intestinal innate immune system responses in zebrafish embryos. Environ Sci: Nano. 5: 904-916. DOI: 10.1039/c8en00002f

C

Callens M, Macke E, Muylaert K, Bossier P, Lievens B, Waud M, Decaestecker E. 2016. Food availability affects the strengths of mutualistic host-microbiota interactions in *Daphnia magna.* ISME J. 10: 911-920. DOI: 10.1038/ismej.2015.166

Campbell GA. 2014. Rare earth metals: A strategic concern. Miner Econ. 27: 21-31. DOI: 10.1007/s13563-014-0043-y

Chen L, Qi N, Wang X, Chen L,You H, Li J. 2014a. Ultrasensitive surface-enhanced Raman scattering nanosensor for mercury ion detection based on functionalized silver nanoparticles. RSC Adv. 4: 15055-15060. DOI: 10.1039/c3ra47492e

Chen Y, Qiao L, Song X, Ma L, Dou X, Xu C. 2021. Protective effects of selenium nanoparticle-enriched *Lactococcus lactis* NZ9000 against enterotoxigenic *Escherichia coli* K88-induced intestinal barrier damage in mice. Appl Environ Microbiol. [accessed 2022 May 8]:[15 p.]. DOI: 10.1128/AEM.01636-21

Chen R, Riviere, JE. 2017. Biological and environmental surface interactions of nanomaterials: characterization, modeling and prediction. WIREs. [accessed 2021 Jan 19]:[31 p.]. DOI: 10.1002/wnan.1440

Chen R, Zhang Y, Monteiro-Riviere NA, Riviere JE. 2016. Quantification of nanoparticle pesticide adsorption: computational approaches based on experimental data. Nanotoxicology. 10: 1118-1128. DOI: 10.1080/17435390.2016.1177745

Chen R, Zhang Y, Sahneh FD, Scoglio CM, Wohlleben W, Haase A, Monteiro-Riviere NA, Riviere JE. 2014b. Nanoparticle surface characterization and clustering through concentration-dependent surface adsorption modeling. ACS Nano. 8: 9446-9456. DOI: 10.1021/nn503573s

Chen H, Zhao R, Wang B, Cai C, Zheng L, Wang H, Wang M, Ouyang H, Zhou X, Chai Z, et al. 2017. The effects of orally administered Ag, TiO_2, and SiO_2 nanoparticles on gut microbiota composition and colitis induction in mice. NanoImpact. 8: 80-88. DOI: 10.1016/j.impact.2017.07.005

Cheng X, Ivanov I, 2012. Molecular dynamics. In: Reisfeld B, Mayeno AN, editors. Computational toxicology. Vol 1. New York: Springer Science + Business Media; p. 243-289. DOI: 10.1007/978-1-62703-050-2

Claus S, Guillou H, Ellero-Simatos S. 2016. The gut microbiota: a major player in the toxicity of environmental pollutants? NPJ Biofilms Microbiomes. [accessed 2017 Nov 14]:[12 p.]. DOI: 10.1038/npjbiofilms.2017.1

Comer J, Chen R, Poblete H, Vergara-Jaque A, Riviere JE. 2015. Predicting adsorption affinities of small molecules on carbon nanotubes using molecular dynamics simulation. ACS Nano. 9: 11761-11774. DOI: 10.1021/acsnano.5b03592

Coyte KZ, Rakoff-Nahoum S. 2019. Understanding competition and cooperation within the mammalian gut microbiome. Curr Biol: 29, R538-R544. DOI: 10.1016/j.cub.2019.04.017

Cronin JG, Jones N, Thornton CA, Jenkins GJS, Doak SH, Clift MJD. 2020. Nanomaterials and innate immunity: a perspective of the current status in nanosafety. Chem. Res. Toxicol. 33: 1061-1073. DOI: 10.1021/acs.chemrestox.0c00051

D

Dai Y, Chen F, Yue L, Li T, Jiang Z, Xu Z, Wang Z, Xing B. 2020. Uptake, transport, and transformation of CeO_2 nanoparticles by strawberry and their impact on the rhizosphere bacterial community. Sustainable Chem Eng. 8: 4792-4800. DOI: 10.1021/acssuschemeng.9b07422

Dawson K, Yan Y. 2021. Current understanding of biological identity at the nanoscale and future prospects. Nat Nanotechnol. 16: 229-242. DOI: 10.1038/s41565-021-00860-0.

Defaye M, Gervason S, Altier C, Berthon J-Y, Ardid D, Filaire E, Carvalho FA. 2020. Microbiota: a novel regulator of pain. J Neural Trans. 127: 445-465. DOI: 10.1007/s00702-019-02083-z

DeGruttola, AK, Low D, Mizoguchi A, Mizoguchi E. 2016. Current understanding of dysbiosis in disease in human and animal models. Inflamm Bowel Dis. 22: 1137-1150. DOI: 10.1097/MIB.0000000000000750

DeLoid GM, Cohen JM, Pyrgiotakis G, Demokritou P. 2016. Preparation, characterization, and *in vitro* dosimetry of dispersed, engineered nanomaterials. Nat Protoc. 12: 355-371. DOI: 10.1038/nprot.2016.172

Deng L, Zeng H, Hu X, Xiao M, He D, Zhang Y, Jin Y, Hu Y, Zhu Y, Gong L, et al. 2021. Se@Albumin nanoparticles ameliorate intestinal mucositis caused by cisplatin *via* gut microbiota-targeted regulation. Nanoscale. 13: 11250-11261. DOI: 10.1039/d0nr07981b

Desmau M, Carboni A, Le Bars M, Doelsch E, Benedetti MF, Auffan M, Levard C, Gelabert A. 2020. How microbial biofilms control the environmental fate of engineered nanoparticles? Front Environ Sci. [accessed 2021 Nov 7]:[20 p.]. DOI: 10.3389/fenvs.2020.00082

Dierking K, Pita L. 2020. Receptors mediating host-microbiota communication in the metaorganism: the invertebrate perspective. Front Immunol. [accessed 2021 Dec 7]:[17 p.]. DOI: 10.3389/fimmu.2020.01251

Dinarello CA. 2018. Overview of the IL-1 family in innate inflammation and acquired immunity. Immunol Rev. 281: 8-27. DOI: 10.111/imr.12621

Doak SH, Clift MJ, Costa A, Delmaar C, Gosens I, Halappanavar S, Kelly S, Peijnenburg WJGM, Rothen-Rutishauser B, Schins RPF, et al. 2022. The road to achieving the European Commission's chemical strategy for nanomaterial sustainability – a PATROLS perspective on new approach methodologies. Small. [accessed 2022 May 20]:[11 p.]. DOI: 10.1002/smll.202200231

Douglas AE. 2020. The microbial exometabolome: ecological resource and architect of microbial communities. Phil Trans R Soc B. [accessed 2021 May 17]:[9 p.]. DOI: 10.1098/rstb.2019.0250

Duan Z, Duan X, Zhao S, Wang X, Wang J, Liu Y, Peng Y, Gong Z, Wang L. 2020. Barrier function of zebrafish embryonic chorions against microplastics and nanoplastics and its impact on embryo development. J Hazard Mater. [accessed 2020 May 11]:[7 p.]. DOI: 10.1016/j.jhazmat.2020.122621

Duperron S, Halary S, Gallet A, Marie B. 2020. Microbiome-aware ecotoxicology of organisms: relevance, pitfalls and challenges. Front Public Health. [accessed 2017 Feb 6]:[8 p.]. DOI: 10.3389/fpubh.2020.00407

E

Eduok S, Coulon F. 2017. Engineered nanoparticles in the environments: Interactions with microbial systems and microbial activity. In: Cravo-Laureau C, Cagnon C, Lauga B, Duran R, editors. Microbial Ecotoxicology. New York City: Springer; p. 63-109. DOI: 10.1007/978-3-319-61795-4

EFSA Scientific Committee. 2018. Guidance on risk assessment of the application of nanoscience and nanotechnologies in the food and feed chain: Part 1, human and animal health. EFSA J. [accessed 2022 Aug 2]:[95 p.]. 16: DOI: 10.2903/j.efsa.2018.5327

Elsabahy M, Wooley KL. 2013. Cytokines as biomarkers of nanoparticle immunotoxicity. Chem Soc Rev. 42: 5552-5576. DOI: 10.1039/c3cs600064

Engin AB, Hayes AW. 2018. The impact of immunotoxicity in evaluation of the nanomaterials safety. Toxicol Res Appl. [accessed 2022 Apr 21]:[9 p.]. DOI: 10.1177/2397847318755579

Essmann U, Perera L, Berkowitz ML, Darden T, Lee H, Pedersen LG. 1995. A smooth particle mesh Ewald method. J Chem Phys. 103: 8577–8593. DOI: 10.1063/1.470117

European Commission. 2011. Commission recommendation of 18 October 2011 on the definition of nanomaterial. Off J EU. L275: 38-40. ELI: http://data.europa.eu/eli/reco/2011/696/oj

European Commission. 2020. Chemicals strategy for sustainability. Towards a toxic-free environment. Brussels: European Commission. Report No.: COM(2020) 667 final. Available from: https://ec.europa.eu/environment/strategy/chemicals-strategy_en

Evans DJ, Holian BL. 1985. The Nose–Hoover thermostat. J Chem Phys. 83: 4069–4074. DOI: 10.1063/1.449071

F

Fent K, Weisbrod CJ, Wirth-Heller A, Pieles U. 2010. Assessment of the uptake and toxicity of fluorescent silica nanoparticles in zebrafish (*Danio rerio*) early life stages. Aquat Toxicol. 100: 218-228. DOI: 10.1016/j.aquatox.2010.02.019

Fernández-Bravo A, Figueras MJ. 2020. An update on the genus *Aeromonas*: Taxonomy, epidemiology, and pathogenicity. Microorganisms. [accessed 2020 July 10]:[39 p.]. DOI: 10.3390/microorganisms8010129

Fiori J, Turroni S, Candela M, Gotti R. 2020. Assessment of gut microbiota fecal metabolites by chromatographic targeted approaches. J Pharm Biomed Anal. [accessed 2021 May 2020]:[23 p.]. DOI: 10.1016/j.jpba.2019.112867

Fliege J, Svaiter BF. 2000. Steepest descent methods for multicriteria optimization. Math Methods Oper Res. 51: 479–494. DOI: 10.1007/s001860000043

Franzenburg S, Fraune S, Künzel S, Baines JF, Domazet-Lošo T, Bosch TCG. 2012. MyD88-deficient *Hydra* reveal an ancient function of TLR signaling in sensing bacterial colonizers. Proc Natl Acad Sci USA. 109: 19374-19379. DOI: 10.1073/pnas.1213110109

Fulaz S, Vitale S, Quinn L, Casey E. 2019. Nanoparticle-biofilm interactions: the role of the EPS matrix. Trends Microbiol. 27: 915-926. DOI: 10.1016/j.tim.2019.07.004

G

Garcés M, Cáceres L, Chiappetta D, Magnani N, Evelson P. 2021. Current understanding of nanoparticle toxicity mechanisms and interactions with biological systems. New J Chem. 45: 14328-14344. DOI: 10.1039/d1nj01415c

Garland JL, Mills AL. 1991. Classification and characterization of heterotrophic microbial communities on the basis of patterns of community-level sole-carbon-source utilization. Appl Environ Microbiol. 57: 2351-2359

Gaulke CA, Beaver LM, Armour CR, Humphreys IR, Barton CL, Tanguay RL, Ho E, Sharpton T. 2020. An integrated gene catalog of the zebrafish gut microbiome reveals significant homology with mammalian microbiomes. BioRxiv. [accessed 2020 June 24]:[37 p.]. DOI: 10.1101/2020.06.15.153924

Gebauer JS, Malissek M, Simon S, Knauer SK, Maskos M, Stauber RH, Peukert W, Treuel, L. 2012. Impact of nanoparticle-protein corona on colloidal stability and protein structure. Langmuir. 28: 9673-9679. DOI: 10.1021/la301104a

Gellatly SL, Hancock, REW. 2013. *Pseudomonas aeruginosa*: new insights into pathogenesis and host defenses. Pathog Dis. 67: 159-173. DOI: 10. 1111/2049-632X.12033

Ghiglione J-F, Martin-Laurant F, Pesce S. 2016. Microbial ecotoxicology: an emerging discipline facing contemporary environmental threats. Environ Sci Pollut Res. 23: 3981-3983. DOI: 10.1007/s11356-015-5763-1

Gini G. 2018. QSAR: What else? In: Nicolotti O, editor. Computational toxicology. New York: Springer Science+Business Media; p. 79-107. DOI: 10.1007/978-1-4939-7899-1

Gliga AR, De Loma J, Di Bucchianico S, Skoglund S, Keshavan S., Wallinder IO, Karlsson HL, Fadeel B. 2020. Silver nanoparticles modulate lipopolysaccharide-triggered Toll-like receptor signaling in immune competent human cell lines. Nanoscale Adv. 2: 648-658. DOI: 10.1039/c9na00721k

Gramatica P. 2008. A short history of QSAR evolution. ResearchGate. [accessed 2022 Sept 7]:[9 p.]. https://www.researchgate.net/publication/252172555

Gramatica P, Cassani S, Roy PP, Kovarich S, Yap CW, Papa E. 2012. QSAR modeling is not 'Push a button and find a correlation': a case study of toxicity of (benzo-)triazoles on algae. Mol Inf. 31: 817-835. DOI: 10.1002/minf.201200075

Grisoni F, Ballabio D, Todeschini R, Consonni V. 2018. Molecular descriptors for structure-activity applications: a hands-on approach. In: Nicolotti O, editor. Computational toxicology. New York: Springer Science+Business Media; p. 3-55. DOI: 10.1007/978-1-4939-7899-1

Grossart H-P, Simon M. 1998. Bacterial colonization and microbial decomposition of limnetic organic aggregates (lake snow). Aquat Microb Ecol. 15: 127-140. DOI: 10.3354/ame015127

Guha, R. 2007. Chemical informatics functionality in R. J Stat Softw. [accessed 2021 May 22]:[16 p.]. DOI: 10.18637/jss.v018.i05

H

Hachicho N, Reithel S, Miltner A, Heipieper HJ, Küster E, Luckenbach T. 2015. Body mass parameters, lipid profiles and protein contents of zebrafish embryos and effects of 2,4-dinitrophenol exposure. PLoS One. [accessed 2020 May 18]:[19 p.]. DOI: 10.1371/journal.pone.0134755

Hacquard S, Garrido-Oter R, González A, Spaepen S, Ackermann G, Lebeis S, McHardy AC, Dangl JL, Knight R, Ley R, et al. 2015. Microbiota and host nutrition across plant and animal kingdoms. Cell Host Microbe. 17: 603-616. DOI: 10.1016/j.chom.2015.04.009

Hansch C, Fujita T. 1964. *σ-ρ-π* Analysis. A method for the correlation of biological activity and chemical structure. J Am Chem Soc. 86: 1616-1626. DOI: 10.1021/ja01078a623

Hasegawa T, Hall CJ, Crosier PS, Abe G, Kawakami K, Kudo A, Kawakami A. 2017. Transient inflammatory response mediated by interleukin-1ß is required for proper regeneration in zebrafish fin fold. eLIFE. [accessed 2020 March 22]:[22 p.]. DOI: 10.7554/eLife.22716

Heinz H, Lin T-J, Mishra RK, Emami FS. 2013. Thermodynamically consistent force fields for the assembly of inorganic, organic, and biological nanostructures: the interface force field. Langmuir. 29: 1754–1765. DOI: 10.1021/la3038846

Herbomel P, Thisse B, Thisse C. 1999. Ontogeny and behaviour of early macrophages in the zebrafish embryo. Development. 126: 3735-3745. DOI: 10.1242/dev.126.17.3735

Hess B, Bekker H, Berendsen HJC, Fraaije JGEM. 1997. Lincs: a linear constraint solver for molecular simulations. J Comput Chem. 18: 1463-1472.

Hill JH, Franzosa EA, Huttenhower C, Guillemin K. 2016. A conserved bacterial protein induces pancreatic beta cell expansion during zebrafish development. eLife. [accessed 2017 Nov 14]:[18 p.]. DOI: 10.7554/eLife.20145

Hinderliter PM, Minard KR, Orr G, Chrisler WB. Thrall BD, Pounds JG, Teeguarden JG. 2010. ISSD: A computational model of particle sedimentation, diffusion and target cell dosimetry for *in vitro* toxicity studies. Part Fibre Toxicol. [accessed 2022 March 15]:[20 p.]. DOI: 10.1186/1743-8977-7-36

Hoffmann T, Lowry GV, Ghoshal S, Tufenkji N, Brambilla D, Dutcher JR, Gilbertson LM, Giraldo, JP, Kinsella JM, Landry MK, et al. 2020. Technology readiness and overcoming barriers to sustainably implement nanotechnology-enabled plant agriculture. Nat Food. 1: 416-425. DOI: 10.1038/s43016-020-0110-1

Hörmann N, Brandão I, Jäckel S, Ens N. Lillich M, Walter U. Reinhardt C. 2014. Gut microbial colonization orchestrates TLR2 expression, signaling and epithelial proliferation in the small intestinal mucosa. PLoS One. [accessed 2022 March 24]:[11 p.]. DOI: 10.1371/journal.pone.0113080

Horng J-L, Lee C-Y, Liu S-T, Hung G-Y, Lin L-Y. 2022. Differential effects of silver nanoparticles on two types of mitochondrion-rich ionocytes in zebrafish embryos. Comp Biochem Physiol C. [accessed 2022 March 24]:[8 p.]. DOI: 10.1016/j.cbpc.2021.109244

Horzmann KA, Freeman JL. 2018. Making waves: new developments in toxicology with the zebrafish. Toxicol Sci. 163: 5-12. DOI:10.1093/toxic/kfy044

Howe K, Clark MD, Torroja CF, Torrance J, Bertehlost C, Muffato M, Collins JE, Humphray S, McLaren K, Matthews L, et al. 2013. The zebrafish reference genome sequence and its relationship to the human genome. Nature. 496: 498-503. DOI: 10.1038/nature12111

Hu W, Yang S, Shimada Y, Münch M, Marín-Juez R, Meijer AH, Spaink HP. 2019. Infection and RNA-seq analysis of a zebrafish *tlr2* mutant shows a broad function of this toll-like receptor in transcriptional and metabolic control and defense to *Mycobacterium marinum* infection. BMC Genomics. [accessed 2022 Feb 8]:[18 p.]. DOI: 10.1186/s12864-019-6265-1

Huang J, Lopes PEM, Roux B, MacKerell Jr AD. 2014. Recent advances in polarizable force fields for macromolecules: microsecond simulations of proteins using the classical drude oscillator model. J Phys Chem Lett. 5: 3144–3150. DOI: 10.1021/jz501315h

Huang H, Zhu J-J. 2019. The electrochemical applications of rare earth-based nanomaterials. Analyst. 144: 6789-6811. DOI: 10.1039/c9an01562k

Hughes ZE, Tomásio SM, Walsh TR. 2014. Efficient simulations of the aqueous bio-interface of graphitic nanostructures with a polarisable model. Nanoscale. 6: 5438-5448. DOI: 10.1039/c4nr00468j

Humphrey W, Dalke A, Schulten K. 1996. VMD: Visual Molecular Dynamics. J Mol Graph. 14: 33-38. DOI: 10.1016/0263-7855(96)00018-5

Hussain N, Florence AT. 1998. Utilizing bacterial mechanisms of epithelial cell entry: invasion-induced oral uptake of latex nanoparticles. Pharm Res. 15: 153-156. DOI: 10.1023/a:10119160840

I

Iqbal MI, Lin K, Sun F, Chen S, Pan A, Lee HH, Kan C-W, Lin CSK, Tso CY. 2022. Radiative cooling nanofabric for personal thermal management. Appl Mater Interfaces. 14: 23577-23587. DOI: 10.1021/acsami.2c05115

J

Jensen KA. 2018a. SOP for intra- and interlaboratory reproducible measurement of hydrodynamic size-distribution and dispersion stability of manufactured nanomaterials using dynamic light scattering (DLS). Version 1.1. Bilthoven: Dutch National Institute for Public Health and the Environment (RIVM).

Jensen KA. 2018b. The NANOGENOTOX standard operational procedure for preparing batch dispersions for in vitro and in vivo toxicological studies. Version 1.2. Paris: French Agency for Food, Environmental and Occupational Health & Safety (ANSES).

Jensen KA, Kembouche Y, Loeschner K., Correia M. 2018. SOP for probe-sonicator calibration of delivered acoustic power and de-agglomeration efficiency for *in vitro* an *in vivo* toxicological testing. Version 1.1. Bilthoven: Dutch National Institute for Public Health and the Environment (RIVM).

Jo S, Kim T, Iyer VG, Im W. 2008. CHARMM-GUI: a web-based graphical user interface for Charmm. J Comput Chem. 29: 1859–1865. DOI: 10.1002/jcc.20945

Jochum L, Stecher B. 2020. Label or concept – what is a pathobiont? Trends Microbiol. 28: 789-792. DOI: 10.1016/j.tim.2020.04.011

Johnston HJ, Verdon R, Gillies S, Brown DM, Fernandes TF, Henry TB, Rossi AG, Tran L, Tucker C, Tyler CR, Stone V. 2018. Adoption of *in vitro* systems and zebrafish embryos as alternative models for reducing rodent use in assessments of immunological and oxidative stress responses to nanomaterials. Crit Rev Toxicol. 48: 252-271. DOI: 10.1080/10408444.2017.1404965

Jovanović B. 2015. Review of titanium dioxide nanoparticle phototoxicity: developing a phototoxicity ratio to correct the endpoint values of toxicity tests. Environ Toxicol Chem. 34: 1070-1077. DOI: 10.1002/etc.2891

Ju Z, Ren G, Zhou M, Jing J, Xiang J, Liu X, Huang R, Zhou P-K. 2020. Exposure to a combination of silica nanoparticles and low-dose radiation aggravates lung fibrosis in mice via gut microbiota modulation. Environ Sci: Nano. 7: 3979-3998. DOI: 10.1039/d0en01021a

K

Kämpfer AAM, Busch M, Schins RPF. 2020. Advanced *in vitro* testing strategies and models of the intestine for nanosafety research. Chem Res Toxicol. 33: 1163-1178. DOI: 10.1021/acs.chemrestox.0c00079

Kang JS, Bong J, Choi J-S, Henry TB, Park JW. 2016. Differentially transcriptional regulation on cell cycle pathway by silver nanoparticles from ionic silver in larval zebrafish (*Danio rerio*). Biochem Biophys Res Commun. 479: 753-758. DOI: 10.1016/j.bbrc.2016.09.139

Karplus M, Porter RN, Sharma RD. 1965. Exchange reactions with activation energy. I. Simple barrier potential for (H,H_2). J Chem Phys. 43: 3259-3287. DOI: 10.1063/1.1697301

Kennedy EA, King KY, Baldridge MT. 2018. Mouse microbiota models: comparing germ-free mice and antibiotics treatment as tools for modifying gut bacteria. Front Physiol. 9: 1534. DOI: 10.3389/fphys.2018.01534

Kietz C, Pollari V, Meinander A. 2018. Generating germ-free *Drosophila* to study gut-microbe interactions: protocol to rear *Drosophila* under axenic conditions. Curr Protoc Toxicol. [accessed 2022 June 1]:[12 p.]. DOI: 10.1002/cptx.52

Kirstein IV, Kirmizi S, Wichels A, Garin-Fernandez A, Erler R, Löder M, Gerdts G. 2016. Dangerous hitchhikers? Evidence for potentially pathogenic *Vibrio* spp. on microplastic particles. Marine Environ Res. [accessed 2020 June 3]:[8 p.]. DOI: 10.1016/j.marenvres.2016.07.004

Klein CL, Comero S, Stahlmecke B, Romazanov J, Kuhlbusch TAJ, Van Doren E, De Temmerman P-J, Mast J, Wick P, Krug H, et al. 2011. NM-Series of representative manufactured nanomaterials: NM300 silver, characterization, stability, homogeneity. Luxembourg (Luxembourg): Publications Office of the European Union. Report No.: EUR 24693 EN. Available from: https://doi.org/10.2788/23079

Knight R, Vrbanac A, Taylor BC, Aksenov A, Callewaert C, Debelius J, Gonzalez A, Kosciolek T, McCall L-I, McDonald D, et al. 2018. Best practices for analysing microbiomes. Nat Rev Microbiol. 16: 410-422. DOI: 10.1038/s41579-018-0029-9

Knösel DH. 1984. Genus IV. *Phyllobacterium* (ex Knösel 1962) nom. rev. (*Phyllobacterium* Knösel 1962, 96). In: Krieg NR, Holt JG, editors. Bergey's manual of systematic bacteriology. Vol 1. Baltimore: Williams & Wilkins; p. 254-256.

Koch BEV, Yang S, Lamers G, Stougaard J, Spaink HP. 2018. Intestinal microbiome adjusts the innate immune setpoint during colonization through negative regulation of MyD88. Nat Commun. [accessed 2019 Oct 30]:[11 p.]. DOI: 10.1038/s41467-018-06658-4

Krautkramer KA, Fan J, Bäckhed F. 2021.Gut microbial metabolites as multi-kingdom intermediates. Nat Rev. 19: 77-94. DOI: 10.1038/s41579-020-0438-4

Kurtz CC, Mitchell S, Nielsen K, Crawford KD, Mueller-Spitz, SR. 2020. Acute high-dose titanium dioxide nanoparticle exposure alters gastrointestinal homeostasis in mice. J Appl Toxicol. 40: 1384-1395. DOI: 10.1002/jat.3991

L

Laio A, Gervasio FL. 2008. Metadynamics: a method to simulate rare events and reconstruct the free energy in biophysics, chemistry and material science. Rep Prog Phys. [accessed 2022 Feb 26]:[22 p.] DOI: 10.1088/0034-4885/71/12/126601

LaLone CA, Villeneuve DL, Lyons D, Helgen HW, Robinson SL, Swintek JA, Saari TW, Ankley GT. 2016. Sequence alignment to predict across species susceptibility (SeqAPASS): a web-based tool for addressing the challenges of cross-species extrapolation of chemical toxicity. Toxicol Sci. 153: 228-245. DOI: 10.1093/toxsci/kfw119

Lam SH, Chua HL, Gong Z, Lam TJ, Sin YM. 2004. Development and maturation of the immune system in zebrafish, *Danio rerio*: a gene expression profiling, in situ hybridization and immunological study. Dev Comp Immunol. 28: 9-28. DOI: 10.1016/S0145-305X(03)00103-4

Lane DJ. 1991. 16S/23S rRNA sequencing. In: Stackebrandt E, Goodfellow, M, editors. Nucleic acid techniques in bacterial systematics. New York City: John Wiley and Sons; p. 115-175.

Larsson DGJ, Flach C-F. 2021. Antibiotic resistance in the environment. Nat Rev. 20: 257-269. DOI: 10.1038/s41579-021-00649-x

Lee KJ, Browning LM, Nallathamby PD, Xu X-HN. 2013. Study of charge-dependent transport and toxicity of peptide-functionalized silver nanoparticles using zebrafish embryos and single nanoparticle plasmic spectroscopy. Chem Res Toxicol. 26: 904-917. DOI: 10.1021/tx400087d

Lee WS, Cho H-J, Kim E, Huh YH, Kim H-J, Kim B, Kang T, Lee J-S, Jeong J. 2019. Bioaccumulation of polystyrene nanoplastics and their effect on the toxicity of Au ions in zebrafish embryos. Nanoscale. 11: 3173-3185. DOI: 10.1039/c8nr09321k

Lee Y-L, Shih Y-S, Chen Z-Y, Cheng F-Y, Lu J-Y, Wu Y-H, Wang Y-J. 2022. Toxic effects and mechanisms of silver and zinc oxide nanoparticles on zebrafish embryos in aquatic ecosystems. Nanomaterials. [accessed 2022 Mar. 24]:[18 p.]. DOI: 10.3390/nano12040717

Li S-D, Huang L. 2010. Stealth nanoparticles: High density but sheddable PEG is a key for tumor targeting. J Control Release. 145: 178-181. DOI: 10.1016/j.jconrel.2010.03.016

Li Y, Li Y, Cao X, Jin X, Jin T. 2017. Pattern recognition receptors in zebrafish provide functional and evolutionary insight into innate immune signaling pathways. Cell Mol Immunol. 14: 80-89. DOI: 10.1038/cmi.2016.50

Li Y, Wang W-X, Liu H. 2022. Gut-microbial adaptation and transformation of silver nanoparticles mediated the detoxification of *Daphnia magna* and their offspring. Environ Sci: Nano. 9: 361-374. DOI: 10.1039/d1en00765c

Li Y, Yan N, Wong TY, Wang W-X, Liu H. 2019a. Interaction of antibacterial silver nanoparticles and microbiota-dependent holobionts revealed by metatranscriptomic analysis. Environ Sci: Nano. 6: 3242-3255. DOI: 10.1039/c9en00587k

Li X, Zhang Y, Li B, Cui J, Gao N, Sun H, Meng Q, Wu S, Bo J, Yan L, et al. 2019b. Prebiotic protects against anatase titanium dioxide nanoparticles-induced microbiota-mediated colonic barrier defects. NanoImpact. [accessed 2022 May 3]:[9 p.]. DOI: 10.1016/j.impact.2019.100164

Lietschke GJ, Oates AC, Crowhurst MO, Ward AC, Layton JE. 2001. Morphologic and functional characterization of granulocytes and macrophages in embryonic and adult zebrafish. Blood. 98: 3087-3096. DOI: 10.1182/blood.V98.10.3087

Lin S-C, Lo Y-C, Wu H. 2010. Helical assembly in the MyD88-IRAK4-IRAK2 complex in TLR/IL-1R signalling. Nature. 465: 885-890. DOI: 10.1038/nature09121

Lin IW-S, Lok C-N, Che C-M. 2014. Biosynthesis of silver nanoparticles from silver(I) reduction by periplasmic nitrate reductase c-type cytochrome subunit NapC in a silver-resistant E. coli. Chem Sci. 5: 3144-3150. DOI: 10.1039/C4SC00138A

Lin M, Tseng Y-H, Huang C-P. 2015. Interactions between nano-TiO_2 particles and algal cells at moderate particle concentration. Front Chem Sci Eng. 9: 242-257. DOI: 10.1007/s11705-015-1513-7

Lin S, Zhao Y, Xia T, Meng H, Ji Z, Liu R, George S, Xiong S, Wang X, Zhang H, et al. 2011. High content screening in zebrafish speeds up hazard ranking of transition metal oxide nanoparticles. ACS Nano. 5: 7284-7295. DOI: 10.1021/nn202116p.

Lindahl E. 2015. Molecular dynamics simulations. In: Kukol A, editor. Molecular modeling of proteins. New York: Springer Science+Business Media; p. 3-27. DOI: 10.1007/978-1-4939-1465-4

Llewellyn MS, Boutin S, Hoseinifar SH, Derome N. 2014. Teleost microbiomes: the state of the art in their characterization, manipulation and importance in aquaculture and fisheries. Front Microbiol. [accessed 30 Oct. 2019]:[17 p.]. DOI: 10.3389/fmic.2014.00207

Liu X, Dumitrescu E, Kumar A, Austin D, Goia D, Wallace KN, Andreescu S. 2019. Differential lethal and sublethal effects in embryonic zebrafish exposed to different sizes of silver nanoparticles. Environ Pollut. 248: 627-634. DOI: 10.1016/j.envpol.2019.02.085

Lowry GV, Gregory KB, Apte SC, Lead JR. 2012. Transformations of nanomaterials in the environment. Environ Sci Technol. 46: 63893-6899. DOI: 10.1021/es300839e

Lozano O, Mejia J, Masereel B, Toussain O, Lison D, Lucas S. 2012. Development of a PIXE analysis method for the determination of the biopersistence of SiC and TiC nanoparticles in rat lungs. Nanotoxicology. 6: 263-271. DOI: 10.3109/17435390.2011.572301

M

Madigan MT, Martinko JM, Stahl DA, Clark DP. 2011. Brock biology of microorganisms. 13th ed. San Francisco (CA): Pearson.

Makabenta JMV, Nabawy A, Li C-H, Schmidt-Malan S, Patel R, Rotello VM. 2021. Nanomaterial-based therapeutics for antibiotic-resistant bacterial infections. Nat Rev Microbiol. 19: 23-36. DOI: 10.1038/s41579-020-0420-1

Manakul P, Peerakietkhajorn S, Matsuura T, Kato Y, Watanabe H. 2017. Effects of symbiotic bacteria on chemical sensitivity of *Daphnia magna*. Mar Environ Res. 128: 70-75. DOI: 10.1016/j.marenvres.2017.03.001.

Mark P, Nilsson L. 2001. Structure and dynamics of the TIP3P, SPC, and SPC/E water models at 298 K. J Phys Chem A. 105: 9954–9960. DOI: 10.1021/jp003020w

Martin AM, Sun EW, Keatling DJ. 2020. Mechanisms controlling hormone secretion in human gut and its relevance to metabolism. J. Endocrinol. [accessed 2022 May 17]:[15 p.]. DOI: 10.1530/JOE-19-0399

Mazzini M, Callaini G, Mencarelli C. 1984. A comparative analysis of evolution of the egg envelopes and the origin of the yolk. Ital J Zool. 51: 35-101. DOI: 10.1080/1125000849439457

McCammon JA, Gelin BR, Karplus M. 1977. Dynamics of folded proteins. Nature. 267: 585-590. DOI: 10.1038/267585a0

McMillan DB. 2007. Ovulation. In: McMillan DB, editor. Fish histology, Female reproductive systems. Dordrecht: Springer; p. 209-284. DOI: 10.1007/978-1-4020-5715-1

Mech A, Gottardo S, Amenta V, Amodio A, Belz S, Bøwadt S, Drbohlavová J, Farcal L, Jantunen P, Małyska A, et al. 2022. Safe- and sustainable-by-design: the case of smart nanomaterials. A perspective based on a European workshop. Regul Toxicol Pharmacol [accessed 2022 April 28]:[14 p.]. DOI: 10.1016/j.yrtph.2021.105093

Meijer AH, Krens SFG. Rodriguez IAM, He S, Bitter W, Snaar-Jagalska BE, Spaink HP. 2004. Expression analysis of the Toll-like receptor and TIR domain adaptor families of zebrafish. Mol Immunol. 40: 773-783. DOI: 10.1016/j.molimm.2003.10.003

Meijer AH, Van der Vaart M, Spaink HP. 2014. Real-time imaging and genetic dissection of host-microbe interactions in zebrafish. Cell Microbiol. 16: 39-49. DOI: 10.1111/cmi.12236

Mergaert J, Cnockaert MC, Swings J. 2002. *Pyllobacterium myrsinacearum* (subjective synonym *Phyllobacterium rubiacearum*) emend. Int J Syst Evol Microbiol. 52: 1821-1823. DOI: 10.1099/00207713-52-5-1821

Monopoli MP, Åberg C, Salvati A, Dawson KA. 2012. Biomolecular coronas provide the biological identity of nanosized materials. Nat Nanotechnol. 7: 779-786. DOI: 10.1038/NNANO.2012.207

Monti S, Barcaro G, Sementa L, Carravetta V, Ågren H. 2017. Characterization of the adsorption dynamics of trisodium citrate on gold in water solution. RSC Adv. 7: 49655-49663. DOI: 10.1039/c7ra10759e

Mu W, Wang Y, Huang C, Fu Y, Li J, Wang H, Jia X, Ba Q. 2019. Effect of long-term intake of dietary titanium dioxide nanoparticles on intestine inflammation in mice. J Agric Food Chem. 67: 9382-9389. DOI: 10.1021/acs.jafc.9b02391

Muir DR, Kampa BM. 2015. FocusStack and StimServer: a new open source MATAB toolchain for visual stimulation and analysis of two-photon calcium neuronal imaging data. Front Neuroinform. [accessed 2016 Aug 22]:[13 p.]. DOI: 10.3389/fninf.2014.00085

N

Naha PC, Liu Y, Hwang G, Huang Y, Gubara S, Jonnakuti V, Simon-Soro A, Kim D, Gao L, Koo H, et al. 2019. Dextran-coated iron oxide nanoparticles as biomimetic catalysts for localized and pH-activated biofilm disruption. ACS Nano. 13: 4960-4971. DOI: 10.1021/acsnano.8b08702.

Nair S, Sasidharan A, Rani VVD, Menon D, Nair S, Manzoor K, Raina S. 2009. Role of size scale of ZnO nanoparticles and microparticles on toxicity toward bacteria and osteoblast cancer cells. J Mater Sci: Mater Med. 20: S235-S241. DOI: 10.1007/s10856-008-3548-5

Nasir A, Wang S, Friedman A. 2011. The emerging role of nanotechnology in sunscreens: an update. Expert Rev Dermatol. 6: 437-439. DOI: 10.1586/EDM.11.49

Nasser F, Constantinou J, Lynch I. 2019. Nanomaterials in the environment acquire an 'eco-corona' impacting their toxicity to *Daphnia magna* – a call for updating toxicity testing policies. Proteomics. [accessed 2020 April 1]:[15 p.]. DOI: 10.1002/pmic.201800412

Nel A, Mädler L, Velegol D, Xia T, Hoek EMV, Somasundaran P, Klaessig F, Castranova V, Thompson M. 2009. Understanding biophysicochemical interactions at the nano-bio interface. Nat Mater. 8: 543-557. DOI: 10.1038/NMAT2442

Nguyen-Chi M, Phan QT, Gonzalez C, Dubremetz JF, Levraud JP, Lutfalla G. 2014. Transient infection of the zebrafish notochord with *E. coli* induces chronic inflammation. Dis Model Mech. 7: 871-882. DOI: 10.1242/dmm.014498

Nielsen FH. 2014. Update on the possible nutritional importance of silicon. J Trace Elem Med Biol. 28: 379-382. DOI: 10.1016/j.jtemb.2014.06.024

Nilakantan R, Nunn DS, Greenblatt L, Walker G, Haraki K, Mobilio DA. 2006. Family of ring system-based structural fragments for use in structure-activity studies: database mining and recursive partitioning. J Chem Inf Model. 46: 1069-1077. DOI: 10.1021/ci050521b

Novoselov AA, Serrano P, Pacheco MLAF, Chaffin MS, O'Malley-James JT, Moreno SC, Ribeiro FB. 2013. From cytoplasm to environment: the inorganic ingredient for the origin of life. Astrobiology. 13: 294-302. DOI: 10.1089/ast.2012.0836

Novotný F, Wang H, Pumera M. 2020. Nanorobots: machines squeezed between molecular motors and micromotors. Chem. 6: 867-884. DOI: 10.1016/j.chempr.2019.12.028

O

OECD. 2013. Fish Embryo Acute Toxicity (FET) test. OECD guidelines for the testing of chemicals Paris: OECD. Test No.: 236. Available from: https://doi.org/10.1787/20745761

Odum EP. 1969. The strategy of ecosystem development. Science. 164: 262-270. DOI: 10.1126/science.164.3877. 262

Oehlers SH, Flores MV, Okuda KS, Hall CJ, Crosier KE, Crosier PS. 2011. A chemical enterocolitis model in zebrafish larvae that is dependent on microbiota and responsive to pharmacological agents. Dev Dyn. 240: 288-298. DOI: 10.1002/dvdy.22519

Ogle D, Wheeler P, Briand C. 2021. droglenc/FSA: Released v0.8.3.2 to CRAN [R package]. Version 0.8.32. Zenodo. [accessed 2021 Jan 16] DOI: 10.5281/zenodo.4443369

Osborne OJ, Johnston BD, Moger J, Balousha M., Lead JR, Kudoh T, Tyler CR. 2013. Effects of particle size and coating on nanoscale Ag and TiO_2 exposure in zebrafish (*Danio rerio*) embryos. Nanotoxicology. 7: 1315-1324. DOI: 10.3109/17435390.2012.737484

Osborne OJ, Mukaigasa K, Nakajima H, Stolpe B, Romer I, Philips U, Lynch I, Mourabit S, Hirose S, Lead JR, et al. 2016. Sensory systems and ionocytes are targets for silver nanoparticle effects in fish. Nanotoxicology. 10:1276-1286. DOI: 10.1080/17435390.2016.1206147

Ostadhossein F, Moitra P, Altun E, Dutta D, Sar D, Tripathi I, Hsiao S-H, Kravchuk V, Nie S, Pan D. 2021. Function-adaptive clustered nanoparticles reverse *Streptococcus mutans* dental biofilm and maintain microbiota balance. Commun Biol. 4: 846. DOI: 10.1038/s42003-021-02372-y

Otto M. 2009. "*Staphylococcus epidermis* – the 'Accidental' Pathogen." Nat Rev Microbiol. 7: 555–567. DOI: 10.1038/nrmicro2182

P

Panáček A, Kvítek L, Smékalová M, Večeřová R, Kolář M, Röderová M, Dyčka F, Šebela M, Prucek R, Tomanec O, et al. 2018. Bacterial resistance to silver nanoparticles and how to overcome it. Nat Nanotechnol. 13: 65-71. DOI: 10.1038/s41565-017-0013-y

Panigrahi P, Parida S, Nanda NC, Satpathy R, Pradhan L, Chandel DS, Baccaglini L, Mohapatra A, Mohapatra SS, Misra PR, et al. 2017. A randomized symbiotic trial to prevent sepsis among infants in rural India. Nature. 548: 407-412. DOI: 10.1038/nature23480

Paone P, Cani PD. 2020. Mucus barrier, mucins and gut microbiota: the expected slimy partners? Gut. 69: 2232-2243. DOI: 10.1136/gutjnl-2020-322260

Parrinello M, Rahman A. 1981. Polymorphic transitions in single crystals: a new molecular dynamics method. J Appl Phys. 52: 7182–7190. DOI: 10.1063/1.328693

Pastor RW, MacKerell Jr AD. 2011. Development of the CHARMM force field for lipids. J Phys Chem. 2: 1526–1532. DOI: 10.1021/jz200167q

Pearce SC, Coia HG, Karl JP, Pantoja-Feliciano IG, Zachos NC, Racicot K. 2018. Intestinal *in vitro* and *ex vivo* models to study host-microbiome interactions and acute stressors. Front Physiol. [accessed 2022 April 18]:[17 p.]. DOI: 10.3389/fphys.2018.01584

Pham LN, Kanther I, Semova I, Rawls JF. 2008. Methods for generating and colonizing gnotobiotic zebrafish. Nat Protoc. 3: 1862-1875. DOI: 10.1038/nprot.2008.186

Phelps D, Brinkman NE, Keely SP, Anneken EM, Catron TR, Betancourt D, Wood CE, Espenschied ST, Rawls JF, Tal T. 2017. Microbial colonization is required for normal neurobehavioral development in zebrafish. Sci Rep. [accessed 2017 Nov 27]:[13 p.]. DOI: 10.1038/s41598-017-10517-5

Philip AM, Wang Y, Mauro A, El-Rass S, Marshall JC, Lee WL, Slutsky AS, Dos Santos CC, Wen, X-Y. 2017. Development of a zebrafish sepsis model for high-throughput drug discovery. Mol Med. 23: 134-148. DOI: 10.2119/molmed.2016.00188

Poon W-L, Lee JC-Y, Leung KS, Alenius H, El-Nezami H, Karisola P. 2019. Nanosized silver, but not titanium dioxide or zinc oxide, enhances oxidative stress and inflammatory response by inducing 5-HETE activation in THP-1 cells. Nanotoxicology. 27: 453–467. DOI: 10.1080/17435390.2019.1687776

Preiswerk B, Ullrich S, Speich R, Bloemberg GV, Hombach M. 2011. Human infection with *Delftia tsuruhatensis* isolated from a central venous catheter. J Med Microbiol. 60: 246-248. DOI: 10.1099/jmm.0.021238-0

Q

Qin Y, Zhao R, Qin H, Chen L, Chen H, Zhao Y, Nie G. 2021. Colonic mucus accumulating tungsten oxide nanoparticles improve the colitis therapy by targeting Enterobacteriaceae. Nano Today. [accessed 2022 May 5]:[14 p.]. DOI: 10.1016/j.nantod.2021.101234

Qv L, Yang Z, Yao M, Mao S, Li Y, Zhang J, Li L. 2020. Methods for establishment and maintenance of germ-free rat models. Front Microbiol. [accessed 2022 April 8]:[13 p.]. DOI: 10.3389/fmicb.2020.01148

R

Rajpoot S, Wary KK, Ibbott R, Liu D, Saqib U, Thurnston TLM, Baig MS. 2021. TIRAP in the mechanism of inflammation. Front Immunol. [accessed 2021 Sept. 15]:[12 p.]. DOI: 10.3389/fimmu.2021.697588

Rakoff-Nahoum S, Paglino J, Eslami-Varzaneh F, Edberg S, Medzhitov R. 2004. Recognition of commensal microflora by Toll-like receptors is required for intestinal homeostasis. Cell. 118: 229-241. DOI: 10.1016/j.cell.2004.07.002

Rasmussen K, Mast J, De Temmerman P-J, Verleysen E, Waegeneers N, Van Steen F, Pizzolon JC, De Temmerman L, Van Doren E, Jensen KA, et al. 2014. Titanium dioxide, NM-100, NM-101, NM-102, NM-103, NM-104, NM-105: Characterisation and phyisco-chemical properties. Ispra: JRC Science and Policy Reports. Report No.: JRC 86291. DOI: 10.2788/79554

Rawls JF, Buck SS, Gordon JI. 2004. Gnotobiotic zebrafish reveal evolutionarily conserved responses to the gut microbiota. Proc Natl Acad Sci USA. 101: 4596-4601. DOI: 10.1073/pnas.0400706101

Rawls JF, Mahowald MA, Ley RE, Gordon JI. 2006. Reciprocal gut microbiota transplants from zebrafish and mice to germ-free recipients reveal host habitat selection. Cell. 127: 422-433. DOI: 10.1016/j.cell.2006.08.043

Reeßing F, Szymanski W. 2017. Beyond photodynamic therapy: light-activated cancer chemotherapy. Curr Med Chem. 24: 4905-4950. DOI: 10.2174/0929867323666160906103223

Ritz C, Baty F, Streibig JC, Gerhard D. 2015. Dose-response analysis using R. *PLoS One* [accessed 2019 Oct. 30]:[13 p.]. DOI: 10.1371/journal.pone.0146021

Roeselers G, Mittge EK, Stephens WZ, Parichy DM, Cavanaugh CM, Guillemin K, Rawls JF. 2011. Evidence for a core gut microbiota in the zebrafish. The ISME J. 5: 1595–1608. DOI: 10.1038/ismej.2011.38

Round JL, Lee SM, Li J, Tran G, Jabri B, Chatila TA, Mazmanian SK. 2011. The Toll-like receptor 2 pathway establishes colonization by a commensal of the human microbiota. Science. 332: 974-977. DOI: 10.1126/science.1206095

Roy J, Ghosh S, Ojha PB, Roy K. 2019. Predictive quantitative structure-property relationship (QSPR) modeling for adsorption of organic pollutants by carbon nanotubes (CNTs). Environ. Sci: Nano. 6: 224-247. DOI: 10.1039/c8en01059e

Ruan W, Engevik MA, Spinler JK, Versalovic J. 2020. Healthy human gastrointestinal microbiome: composition and function after a decade of exploration. Dig Dis Sci. 65: 695-705. DOI: 10.1007/s10620-020-06118-4

S

Sauma S, Casaccia P. 2020. Does the gut microbiota contribute to the oligodendrocyte progenitor niche? Neurosci Lett. [accessed 2021 May 17]:[6 p.]. DOI: 10.1016/j.neulet.2019.134574

Schmidt AF, Finan C. 2018. Linear regression and the normality assumption. J Clin Epidemiol. 98: 146-151. DOI: 10.1016/j.jclinepi.2017.12.006

Schür C, Rist S, Baun A, Mayer P, Hartmann NB, Wagner M. 2019. When fluorescence is not a particle: The tissue translocation of microplastics in *Daphnia magna* seems an artifact. Env Toxicol Chem. 38: 1495-1503. DOI: 10.1002/etc.4436

Science for Environmental Policy. 2017. Assessing the environmental safety of manufactured nanomaterials. Bristol: Science Communication Unit, UWE. Report No.: In-depth report 14. Available from https://doi.org/10.2779/690478

Seil JT, Webster TJ. 2012. Antimicrobial applications of nanotechnology: methods and literature. Int J Nanomed. 7: 2767-2781. DOI: 10.2147/IJN.S24805

Sender R., Fuchs S, Milo R. 2016. Revised estimates for the number of human and bacteria cells in the body. PloS Biol. [accessed 2021 June 17]:[14 p.]. DOI: 10.1371/journal.pbio.1002533

Senftle T, Hong S, Islam M Md, Kylasa SB, Zheng Y, Shin YK, Junkermeier C, Engel-Herbert R, Janik MJ, Aktulga HM, et al. 2016. The ReaxFF reactive force-field: development, applications and future directions. npj Comput Mater. [accessed 2022 Aug 24]:[14 p.]. DOI: 10.1038/npjcompumats.2015.11

Shah RM, McKenzie EJ, Rosin MT, Jadhav SR, Gondalia SV, Rosendale D, Beale DJ. 2020. An integrated multi-disciplinary perspective for addressing challenges of the human gut microbiome. Metabolites. [accessed 2020 Oct. 29]:[35 p.]. DOI: 10.3390/metabo10030094

Sharma VK, Prateeksha, Gupta SC, Singh BN, Rao CV, Barik SK. 2022. *Cinnamomum verum*-derived bioactives-functionalized gold nanoparticles for prevention of obesity through gut microbiota reshaping. Mater Today. [accessed 2020 May 6]:[15 p.]. DOI: 10.1016/j.mtbio.2022.100204

Shcherbakova EN, Scherbakov AV, Andronov EE, Gonchar LN, Kalenskaya SM, Chebotar VK. 2017. Combined pre-seed treatment with microbial inoculants and Mo nanoparticles changes composition of root exudates and rhizosphere microbiome structure of chickpea (*Cicer arietinum L.*) plants. Symbiosis. 73: 57-69. DOI: 10.1007/s13199-016-0472-1

Shih Y-J, Su C-C, Chen C-W, Dong C-D, Liu W, Huang CP. 2016. Adsorption characteristics of nano-TiO_2 onto zebrafish embryos and its impacts on egg hatching. Chemosphere. 154: 109-117. DOI: 10.1016/j.chemosphere.2016.03.061

Shin SY, Choi JY, Ko KS. 2012. Four cases of possible human infections with *Delftia lacustris.* Infection. 40: 709-712. DOI:10.1007/s1501-012-0339-1

Shropshire JD, Van Opstal EJ, Bordenstein SR. 2016. An optimized approach to germ-free rearing in the jewel wasp *Nasonia.* PeerJ. [accessed 2022 April 28]:[20 p.]. DOI: 10.771/peerj.2316

Sillen WMA, Thijs S, Abbamondi GR, Janssen J, Weyens N, White JC, Vangronsveld J. 2015. Effects of silver nanoparticles on soil microorganisms and maize biomass are linked in the rhizosphere. Soil Biol Biochem. 91: 14-22. DOI: 10.1016/j.soilbio.2015.08.2019

Silva YP, Bernardi A, Frozza RL. 2020. The role of short-chain fatty acids from gut microbiota in gut-brain communication. Front Endocrinol. [accessed 2021 May 17]:[14 p.]. DOI: 10.3389/fendo.2020.00025

Silver S. 2003. Bacterial silver resistance: molecular biology and use and misuses of silver compounds. FEMS Microbiol Rev. 27: 341-353. DOI: 10.1016/S0168-6445(03)00047-0

Singh C, Friedrichs S, Levin M, Birkedal R, Jensen KA, Pojana G, Wohlleben W, Schulte S, Wiench K, Turney T, et al. 2011. Zinc oxide NM-110, NM- 111, NM-112, NM-113: characterisation and test item preparation. Brussels: European Commission. Report No.: EUR 25066 EN. Available from https://doi.org/10.2787/55008

Sison-Mangus MP, Mushegian AA, Ebert D. 2015. Water fleas require microbiota for survival, growth and reproduction. ISME J. 9: 59-67. DOI: 10.1038/ismej.2014.116

Song M, Liu S, Yin J, Wang H. 2011. Interaction of human serum album and C_{60} aggregates in solution. Int J Mol Sci. 12: 4964-4974. DOI: 10.3390/ijms12084964

Spurgeon D, Lahive E, Robinson A, Short S, Kille P. 2020. Species sensitivity to toxic substances: evolution, ecology and applications. Front Environ Sci. [accessed 2022 May 1]:[25 p.]. DOI: 10.3389/fenvs.2020.588380

Stephens WZ, Burns AR, Stagaman K, Wong S, Rawls JF, Guillemin K, Bohannan BJM. 2016. The composition of the zebrafish intestinal microbial community varies across development. ISME J. 10: 644-654. DOI: 10.1038/ismej.2015.140

Stephens WZ, Wiles TJ, Martinez ES, Jemielita M, Burns AR, Parthasarathy R, Bohannan BJM, Guillemin K. 2015. Identification of population bottlenecks and colonization factors during assembly of bacterial communities within the zebrafish intestine. mBio. [accessed 2018 April 6]:[11 p.]. DOI: 10.1128/mBio.01163-15

Sukhanova A, Bozrova S, Sokolov P, Berestovoy M, Karaulov A, Nabiev I. 2018. Dependence of nanoparticle toxicity on their physical and chemical properties. Nanoscale Res Lett. [accessed 2019 Nov 17]:[21 p.]. DOI: 10.1186/s11671-018-2457-x

Sun D, Ding A. 2006. MyD88-mediated stabilization of interferon-γ-induced cytokine and chemokine mRNA. Nat Immunol. 7: 375-381. DOI: 10.1038/ni1308

Suzuki N, Kato K. 1953. Studies on suspended materials marine snow in the sea: Part I. Sources of marine snow. Bull Fac Fish Hokkaido Univ. 4: 132-137.

T

Teleki A, Wengeler R, Wengeler L, Nirschl H, Pratsinis SE. 2008. Distinguishing between aggregates and agglomerates of flame-made TiO_2 by high pressure dispersion. Powder Technol. 181: 292-300. DOI: 10.1016/j.powtec.2007.05.016

Thepphankulngarm N, Wonganan P, Sapcharoenkun C, Tuntulani T, Leeladee P. 2017. Combining vitamin B_{12} and cisplatin-loaded porous silica nanoparticles *via* coordination: a facile approach to prepare a targeted drug delivery system. New J Chem. 41: 13823-13829. DOI: 10.1039/c7nj02754k

Tian L, Wang X-W, Wu A-K, Fan Y, Friedman J, Dahlin A, Waldor MK, Weinstock GM, Weiss ST, Liu Y-Y. 2020. Deciphering functional redundancy in the human microbiome. Nat Commun. [2021 Oct. 20]:[11 p.]. DOI: 10.1038/s41467-020-19940-1

Tierney BT, Yang Z, Luber JM, Beaudin M, Wibowo MC, Baek C, Mehlenbacher E, Patel CJ, Kostic D. 2019. The landscape of genetic content in the gut and oral human microbiome. Cell Host Microbe. 26: 285-295. DOI: 10.1016/j.chom.2019.07.008

Trevelline BK, Fontaine SS, Hartup BK. 2019. Conservation biology needs a microbial renaissance: a call for the consideration of host-associated microbiota in wildlife management practices. Proc R Soc B. [accessed 2019 Oct. 30]:[9 p.]. DOI: 10.1098/rspb.2018.2448

V

Van den Broek B, Ashcroft B, Oosterkamp TH, Van Noort J. 2013. Parallel nanometric 3D tracking of intracellular gold nanorods using multifocal two-photon microscopy. Nano Lett. 13: 980-986. DOI: 10.1021/nl3040509

Van der Spoel D, Lindahl E, Hess B, Groenhof G, Mark AE, Berendsen HJC. 2005. GROMACS: Fast, Flexible, and Free. J Comput Chem. 26: 1701–1718. DOI: 10.1002/jcc.20291

Van Pomeren M, Brun NR, Peijnenburg WJGM, Vijver MG. 2017a. Exploring uptake and biodistribution of polystyrene (nano)particles in zebrafish embryos at different developmental stages. Aquat Toxicol. 190: 40-45. DOI: 10.1016/j.aquatox.2017.06.017

Van Pomeren M, Peijnenburg WJGM, Brun NR, Vijver MG. 2017b. A novel experimental and modeling strategy for nanoparticle toxicity testing enabling the use of small quantities. Int J Environ Res Public Health. [accessed 2017 Nov. 22]:[14 p.]. DOI: 10.3390/ijerph14111348

Van Pomeren M, Peijnenburg WJGM, Vlieg RC, Van Noort SJT, Vijver MG. 2019. The biodistribution and immuno-responses of differently shaped non-modified gold particles in zebrafish embryos. Nanotoxicology. 13: 558-571. DOI: 10.1080/17435390.2018.1564079

Vassaux M, Sinclair C, Richardson RA, Suter JL, Coveney PV. 2020. Toward high fidelity materials property prediction from multiscale modeling and simulation. Adv Theory Simul. [accessed 2022 Aug 22]:[12 p.]. DOI: 10.1002/adts.201900122

Venegas DP, De la Fuente MK, Landskron G, González MJ, Quera R, Dijkstra G, Harmsen HJM, Faber KN, Hermoso MA. 2019. Short chain fatty acids (SCFAs)-mediated gut epithelia and immune regulation and its relevance for inflammatory bowel diseases. Front Immunol. [accessed 2022 June 16]:[16 p.]. DOI: 10.3389/fimmu.2019.00277

Verbruggen B, Gunnarsson L, Kristiansson E, Österlund T, Owen SF, Snape JR, Tyler CR. 2017. ECOdrug: a database connecting drugs and conservation of their targets across species. Nucleic Acids Res. 46: D930-D936. DOI: 10.1093/nar/gkx1024

W

Walczyk D, Bombelli FB, Monopoli MP, Lynch I, Dawson K. 2010. What the cell ‘sees’ in bionanoscience. J Am Chem Soc. 132: 5761-5768. DOI: 10.1021/ja910675v

Wang G-H. Brucker RM. 2022. An optimized method for *Nasonia* germ-free rearing. Sci Rep. [accessed 2022 April 28]:[5 p.]. DOI: 10.1038/s41598-021-04363-9

Wang Y, Han R, Zhang H, Liu H, Li J, Liu H, Gramatica P. 2017. Combined ligand/structure-based virtual screening and molecular dynamics simulations of steroidal androgen receptor antagonists. BioMed Res Int. [accessed 2022 Jan. 23]:[18 p.]. DOI: 10.1155/2017/3572394

Wang C, Yue L, Cheng B, Chen F, Zhao X, Wang Z, Xing B. 2022. Mechanisms of growth-promotion and Se-enrichment in *Brassica chinensis* L. by selenium nanomaterials: beneficial rhizosphere microorganisms, nutrient availability, and photosynthesis. Environ Sci: Nano. 9, 302-312. DOI: 10.1039/d1en00740h

Westmeier D, Hahlbrock A, Reinhardt C, Fröhlich-Nowoisky J, Wessler S, Vallet C, Pöschl U, Knauer SK, Stauber RH. 2019. Nanomaterial-microbe cross-talk: physicochemical principles and (phatho)biological consequences. Chem Soc Rev. 47: 5312-5337. DOI: 10.1039/C6CS00691D

Wiles TJ, Jemielita M, Baker RP, Schlomann BH, Logan SL, Ganz J, Melancon E, Eisen JS, Guillemin K, Parthasarathy R. 2016. Host gut motility promotes competitive exclusion within a model intestinal microbiota. PLoS Biol. [accessed 2018 April 6]:[24 p.]. DOI: 10.1371/journal.pbio.1002517

Wilkins LJ, Monga M, Miller AW. 2019. Defining dysbiosis for a cluster of chronic diseases. Sci Rep. [accessed 2022 May 27]:[10 p.]. DOI: 10.1038/s41598-019-49452-y

Wilkinson JL, Boxall ABA, Kolpin DW, Leung KMY, Lai RWS, Galbán-Malagón C, Adell AD, Mondon J, Metian M, Marchant RA, et al. 2022. Pharmaceutical pollution of the world’s rivers. Proc Natl Acad Sci USA. [accessed 2022 April 27]:[10 p.]. DOI: 10.1073/pnas.2113947119

Willing BP, Russel SL, Finlay BB. 2011. Shifting the balance: antibiotic effects on host-microbiota mutualism. Nat Rev Microbiol. 9: 233-243. DOI: 10.1038/nrmicro2536

Willner MR, Vikesland PJ. 2018. Nanomaterial enabled sensors for environmental contaminants. J Nanobiotechnol. 16: 95. DOI: 10.1186/s12951-018-0419-1

Wu W-K, Hsu C-C, Sheen L-Y, Wu M-S. 2020**.** Measurement of gut microbial metabolites in cardiometabolic health and translational research. Rapid Commun Mass Spectrom. [accessed 2021 May 17]:[7 p.]. DOI: 10.1002/rcm.8537

Wu Z, Jiang Y, Kim T, Lee K. 2007. Effects of surface coating on the controlled release of vitamin B_1 from mesoporous silica tablets. J Control Release. 119: 215–221. DOI: 10.1016/j.jconrel.2007.03.001

X

Xia T, Lai W, Han M, Han M, Ma X, Zhang L. 2017. Dietary ZnO nanoparticles alters intestinal microbiota and inflammation response in weaned piglets. Oncotarget. 8: 64878-63891. DOI: 10.18632/oncotarget.17612

Xia X-R, Monteiro-Riviere NA, Riviere JE. 2010. An index for characterization of nanomaterials in biological systems. Nat Nanotechnol. 5: 671-675. DOI: 10.1038/NNANO.2010.164

Xing PY, Pettersson S, Kundu P. 2020. Microbial metabolites and intestinal stem cells tune intestinal homeostasis. Proteomics. [accessed 2022 May 17]:[16 p.]. DOI: 10.1002/pmic.201800419

Y

Yan W, Chen X, Li X, Feng X, Zhu J-J. 2008. Fabrication of a label-free electrochemical immunosensor of low-density lipoprotein. J Phys Chem B. 112: 1275-1281. DOI: 10.1021/jp0765594

Yang JH, Bhargava P, McCLoskey D, Mao N, Palsson BO, Collins JJ. 2017a. Antibiotic-induced changes to the host metabolic environment inhibit drug efficacy and alter immune function. Cell Host Microbe. 22: 757-765. DOI: 10.1016/j.chom.2017.10.020

Yang J, Cao W, Rui Y. 2017b. Interactions between nanoparticles and plants: phytotoxicity and defense mechanisms. J Plant Interact. 12: 158-169. DOI:10.1080/17429145.2017.1310944

Yin N, Gao R, Knowles B, Wang J, Wang P, Sun G, Cui Y. 2019. Formation of silver nanoparticles by human gut microbiota. Sci Total Environ. 651: 1489-1494. DOI: 10.1016/j.scitotenv.2018.09.312

Z

Zhai Y, Hunting ER, Liu G, Baas E, Peijnenburg WJGM, Vijver MG. 2019. Compositional alterations in soil bacterial communities exposed to TiO_2 nanoparticles are not reflected in functional impacts. Environ Res. [accessed 2020 June 22]:[9 p.]. DOI: 10.1016/j.envres.2019.108713

Zhai Y, Hunting ER, Wouters M, Peijnenburg WJGM, Vijver MG. 2016. Silver nanoparticles, ions, and shape governing soil microbial functional diversity: Nano shapes micro. Front Microbiol. [accessed 2019 Oct. 30]:[9 p.]. DOI: 10.3389/ fmicb.2016.01123

Zhang X, Chen L, Yuan L, Liu R, Li D, Liu X, Ge G. 2019. Conformation-dependent coordination of carboxylic acids with Fe_3O_4 nanoparticles Studied by ATR-FTIR spectral deconvolution. Langmuir. 35: 5770-5778. DOI: 10.1021/acs.langmuir.8b03303

Zhao Y, Liu S, Tang Y, You T, Xu H. 2021. *Lactobacillus rhamnosus* GG ameliorated long-term exposure to TiO_2 nanoparticles induced microbiota-mediated liver and colon inflammation and fructose-caused metabolic abnormality in metabolism syndrome mice. J Agric Food Chem. 69: 9788-9799. DOI: 10.1021/acs.jafc.1c03301

Zhao Y, Tang Y, Chen L, Lv S, Liu S, Nie P, Aguilar ZP, Xu H. 2020. Restraining the TiO_2 nanoparticles-induced intestinal inflammation mediated by gut microbiota in juvenile rats via ingestion of *Lactobacillus rhamnosus* GG. Ecotoxicol Environ Saf. [accessed 2022 May 4]:[11 p.]. DOI: 10.1016/j.ecoenv.2020.111393

Zheng H, Gu Z, Pan Y, Chen J, Xie Q, Xu S, Gao M, Cai X, Liu S, Wang W, et al. 2021. Biotransformation of rare earth oxide nanoparticles eliciting microbiota imbalance. Part Fibre Toxicol. [accessed 2022 May 5]:[14 p.]. DOI: 10.1186/s12989-021-00410-5

Zhu S, Zeng M, Feng G, Wu H. 2019. Platinum nanoparticles as a therapeutic agent against dextran sodium sulfate-induced colitis in mice. Int J Nanomed. 14: 8361-8378. DOI: 10.2147/IJN.S210655

Zhu X, Zhao L, Liu Z, Zhou Q, Zhu Y, Zhao Y, Yang X. 2021. Long-term exposure to titanium dioxide nanoparticles promotes diet-induced obesity through exacerbating intestinal mucus layer damage and microbiota dysbiosis. Nano Res. 14: 1512-1522. DOI: 10.1007/s12274-020-3210-1

Curriculum vitae

Bregje was born in 1993 in Haarlem, where she followed pre-university education (VWO) at Lyceum Sancta Maria (2006-2011). In September 2011, she started her academic training at Leiden University by following the BSc program in Biology. Here, she developed a particular interest in research investigating biological phenomena at different, interconnected scales in time and space. In February 2014, Bregje concluded her BSc degree at Naturalis Biodiversity Center with a research project 'looking for cryptic species in Pontoniine shrimps', under the supervision of dr. Charles H.J.M. Fransen. After graduating (*summa cum laude*) Bregje was awarded the 'Professor Kees Bakker prijs 2014' for her BSc degree, which, in combination with the ISME16 travel grant, supported her visit to the 16th International Symposium on Microbial Ecology in Montreal (Canada).

In September 2014, Bregje continued her academic training by following the MSc degree in Limnology & Oceanography (Biological Sciences) at the University of Amsterdam. In two research projects, she developed a growing interest in the effects of microbial activity on water quality and ecosystem functioning. In a first project, supervised by dr. J. Merijn Schuurmans and dr. Hans C.P. Matthijs, she studied the role of cyanotoxin microcystin in the sensitivity of cyanobacteria to strong oxidative stress. In a second project, supervised by dr. J. Arie Vonk and dr. Harm G. van der Geest, she studied algal survival in limnetic aggregates from the turbid water column of large and shallow delta lake Markermeer (the Netherlands). By way of a literature study, supervised by dr. Eva S. Deutekom, she also investigated the role of host-microbiota interactions in the adaptive potential of the coral holobiont to the negative impacts of ocean acidification on coral calcification. Bregje graduated (*cum laude*) for her MSc degree in November 2016.

In October 2017, Bregje returned to Leiden University as PhD candidate at the Institute of Environmental Sciences (CML). Here, she joined the Ecotox team led by prof. dr. Martina G. Vijver and prof. dr. Willie J.G.M. Peijnenburg, to study the effects of host-associated microbiota on particle-specific nanomaterial toxicity. Her research contributed to the Horizon 2020 project PATROLS (www.patrols-h2020.eu), awarded to Martina Vijver and fellow researchers. Bregje presented her work at the PATROLS General Assembly in Fribourg (Switzerland, 2019), at the PATROLS Early Career Researcher Webinar (online, 2020), at the Society of Environmental Toxicology and Chemistry Europe 30th Annual Meeting (SETAC SciCon, online, 2020), and at the 10th International Conference on Nanotoxicology (NanoTox, online, 2021). The results of her PhD research are presented in this thesis.

List of publications

Brinkmann BW, Singhal A, Sevink GJA, Neeft L, Vijver MG, Peijnenburg WJGM. 2022. Predicted adsorption affinity for enteric microbial metabolites to metal and carbon nanomaterials. J Chem Inf Model. 62: 3589-3603. DOI: 10.1021/acs.jcim.2c00492

Brinkmann BW, Koch BEV, Peijnenburg WJGM, Vijver MG. 2022. Microbiota-dependent TLR2 signaling reduces silver nanoparticle toxicity to zebrafish larvae. Ecotox Environ Saf. 237: 113522. DOI: 10.1016/j.ecoenv.2022.113522

Brinkmann BW, Beijk WF, Vlieg RC, Van Noort SJT, Mejia J, Colaux JL, Lucas S, Lamers G, Peijnenburg WJGM, Vijver MG. 2021. Adsorption of titanium dioxide nanoparticles onto zebrafish eggs affects colonizing microbiota. Aquat Toxicol. 232: 105744. DOI: 10.1016/j.aquatox.2021.105744

Brinkmann BW, Koch BEV, Spaink HP, Peijnenburg WJGM, Vijver MG. 2020. Colonizing microbiota protect zebrafish larvae against silver nanoparticle toxicity. Nanotoxicology. 14: 725-739. DOI: 10.1080/17435390.2020.1755469

Dovidat LC, Brinkmann BW, Vijver MG, Bosker T. 2020. Plastic particles adsorb to the roots of freshwater vascular plant *Spirodela polyrhiza* but do not impair growth. Limnol Oceanogr Lett. 5: 37-45. DOI: 10.1002/lol2.10118

Brinkmann BW, Vonk JA, Van Beusekom SAM, Ibanez M, De Lucas Pardo MA, Noordhuis R, Manders EMM, Verspagen JMH, Van der Geest HG. 2019. Benthic hotspots in the pelagic zone: Light and phosphate availability alter aggregates of microalgae and suspended particles in a shallow turbid lake. Limnol Oceanogr. 64: 585-596. DOI: 10.1002/lno.11062

Schuurmans JM, Brinkmann BW, Makower AK, Dittmann E, Huisman J, Matthijs HCP. 2018. Microcystin interferes with defense against high oxidative stress in harmful cyanobacteria. Harmful Algae. 78: 47-55. DOI: 10.1016/j.hal.2018.07.008

Brinkmann BW, Fransen CHJM. 2016. Identification of a new stony coral host for the anemone shrimp *Periclimenes rathbunae* Schmitt, 1924 with notes on the host-use pattern. Contrib Zool. 85: 437-456. DOI: 10.1163/18759866-08504004

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Bregje

September 2022

APPENDIX

Supplementary tables for **Chapter 1** and **Chapter 6**.

Table S1: Experimental investigations on the effects of nanoparticles on host-associated microbiota.[a)] Experiments are sorted by the experimental context ('environmental health', or 'human and animal health'), the presence or absence ('N.D.') of identified effects on microbiota composition, nanoparticle core material, and host species. Literature that has been published before or in March 2022 is presented.

ENVIRONMENTAL HEALTH: AQUEOUS EXPOSURE									
Effect on microbiota	*Nanoparticle*				*Host*	*Microbiota*	*Concentration ($\mu g \cdot L^{-1}$)*	*Exposure time (d)*	*Reference (DOI)*
	Core[b)]	*Coating*[c)]	*Shape*[d)]	*Size*[e)]					
Yes	Ag	none	S	51	*Danio rerio*	Gut	10 - 100	45	Ma et al. 2018 (10.1039/c7en00740j)
Yes	Ag	none	S	15	*Danio rerio*	Body	250	2	Brinkmann et al. 2020 (10.1080/17435390.2020.1755469)
Yes	Ag	none	S	60	*Danio rerio*	Gut	100	15 -75	Chen et al. 2021 (10.1128/mSystems.00630-21)
Yes	Ag	citrate	S	20	*Daphnia magna*	Gut	0.43 - 4.3	1 - 21	Li et al. 2019 (10.1039/c9en00587k)
Yes	Ag	none	S	20	*Daphnia magna*	Gut	0.43	21 - 84	Li et al. 2022 (10.1039/d1en00765c)
Yes	Ag	none	A	20	*Drosophila melanogaster*	Gut	$450 \cdot 10^3$	1.68	Han et al. 2014 (10.1016/j.scitotenv.2013.12.129)

Yes	Ag	carbon	A	25	*Populus nigra*	Phyllo-sphere	$1\cdot10^3$	70	Vitali et al. 2019 (10.1007/s00253-019-10071-2)
Yes	Ag	none	S	35	*Schmidtea mediterranea*	Body	$10\cdot10^3$	7	Bijnens et al. 2021 (10.1016/j.aquatox.2020.105672)
Yes	Ag	PVP	S	33	*Schmidtea mediterranea*	Body	$10\cdot10^3$	7	Bijnens et al. 2021 (10.1016/j.aquatox.2020.105672)
Yes	CeO_2	none	I	15	*Fragaria ananassa*	Rhizo-sphere	$0.3\cdot10^6$-$2\cdot10^6$	45	Dai et al. 2020 (10.1021/acssuschemeng.9b07422)
Yes	Mo	none	NA	60	*Cicer arientinum*	Rhizo-sphere	$10\cdot10^3$	40	Shcherbakova et al. 2017 (10.1007/s13199-016-0472-1)
Yes	Se	none	A	40	*Danio rerio*	Gut	100	90	Chen et al. 2022 (10.1016/j.scitotenv.2021.150963)
Yes	TiO_2	none	A	8	*Danio rerio*	Gut	100	90	Chen et al. 2022 (10.1016/j.scitotenv.2021.150963)
Yes	TiO_2	none	I	21	*Mytilus gallo-provincialis*	Hemo-lymph	100	4	Auguste et al. 2019 (10.1016/j.scitotenv.2019.03.133)
Yes	ZnO	none	A	30	*Danio rerio*	Gut	100	90	Chen et al. 2022 (10.1016/j.scitotenv.2021.150963)

ENVIRONMENTAL HEALTH: FOOD EXPOSURE

Effect on microbiota	*Nanoparticle*				*Host*	*Microbiota*	*Concentration*	*Exposure time (d)*	*Reference (DOI)*
	Core[b)]	*Coating* [c)]	*Shape*[d)]	*Size* [e)]			*(mg·kg⁻¹)*[f)]		
N.D.	TiO_2	none	A	31	*Oreochromis niloticus*	Gut	1 mg·kg $bw^{-1}\cdot d^{-1}$	28	Sherif et al. 2021 (10.1111/are.15539)
N.D.	TiO_2	none	A	53	*Oreochromis niloticus*	Gut	1 mg·kg $bw^{-1}\cdot d^{-1}$	28	Sherif et al. 2021 (10.1111/are.15539)
N.D.	ZnO	none	S	28	*Cyprinus carpio*	Gut	500	42	Chupani et al. 2019 (10.1007/s11356-019-05616-x)
Yes	Ag	none	S	20	*Cyprinus carpio*	Gut	50 to 150	60	Khorshidi et al. 2018 (10.1007/s40995-016-0130-8)
Yes	Ag	none	S	50	*Folsomia candida*	Gut	200	28	Zhu et al. 2018 (10.1021/acs.est.8b02825)
Yes	Ag	none	A	28	*Spodoptera litura*	Gut	6.4	1	Bharani and Namasivayam 2017 (10.1016/j.jece.2016.12.023)
Yes	CuO	none	S	40	*Bombyx mori*	Gut	10	5	Muhammad et al. 2022 (10.1016/j.scitotenv.2021.152608)

Yes	MoO_3	none	S	92	*Danio rerio*	Gut	0.2 to 0.4 (lyosol mass·kg $water^{-1}$)	7	Aleshina et al. 2020 (10.1007/s13762-019-02509-x)
Yes	MoO_3	none	S	92	*Danio rerio*	Gill	0.2 to 0.4 (lyosol mass·kg $water^{-1}$)	7	Aleshina et al. 2020 (10.1007/s13762-019-02509-x)
Yes	TiO_2	none	A	8	*Bombyx mori*	Gut	Leaves soaked in 5 $mg·L^{-1}$	4	Li et al. 2020 (10.1016/j.scitotenv.2019.135273)
Yes	TiO_2	none	A	13	*Oreochromis niloticus*	Gut	1 $mg·kg\ bw^{-1}·d^{-1}$	28	Sherif et al. 2021 (10.1111/are.15539)
Yes	ZnO	none	A	50	*Bombyx mori*	Gut	10	5	Muhammad et al. 2022 (10.1016/j.scitotenv.2021.152608)

ENVIRONMENTAL HEALTH: SOIL EXPOSURE

Effect on microbiota	*Nanoparticle*				*Host*	*Microbiota*	*Concentration*	*Exposure time (d)*	*Reference (DOI)*
	Core[b]	*Coating*[c]	*Shape*[d]	*Size*[e]			*($mg·kg^{-1}$)*[f]		
Yes	Ag	none	S	50	*Eisenia fetida*	Gut	10 - 400	28	Swart et al. 2020 (10.1016/j.envpol.2020.115633)
Yes	Ag	none	S	15	*Lactuca sativa*	Rhizo-sphere	1 - 50	63	Wu et al. 2021 (10.1021/acssuschemeng.1c04987)
Yes	Ag	none	NA	16	*Linum usitatissimum*	Rhizo-sphere	0.125 (+ sprayed with 100 $µg·L^{-1}$ after 7 d)	21	Gorczyca et al. 2018 (10.1007/s11356-018-3346-7)
Yes	Ag	carbon	A	25	*Populus nigra*	Rhizo-sphere	1 $mg·L^{-1}$ pot water	70	Vitali et al. 2019 (10.1007/s00253-019-10071-2)
Yes	Ag	none	NA	16	*Triticum aestivum*	Rhizo-sphere	0.125 (+ sprayed with 100 $µg·L^{-1}$ after 7 d)	21	Gorczyca et al. 2018 (10.1007/s11356-018-3346-7)
Yes	Ag	citrate	S	11	*Triticum aestivum*	Rhizo-sphere	3	14	Feng et al. 2021 (10.1016/j.scitotenv.2021.149200)
Yes	Ag	none	I	20	*Zea mays*	Rhizo-sphere	100	117	Sillen et al. 2020 (10.1186/s40168-020-00904-y)
Yes	Ag_2S	none	S	95	*Eisenia fetida*	Gut	114 - $34·10^3$	60	Wu et al. 2020 (10.1021/acs.est.0c01241)
Yes	Ag_2S	none	S	95	Pontocolex corethrurus	Gut	114 - 34·103	60	Wu et al. 2020 (10.1021/acs.est.0c01241)
Yes	CuO	none	S	9	*Carya illinoinensis*	Rhizo-sphere	10 - $1·10^3$	45	Salas-Leiva et al. 2021 (10.1016/j.apsoil.2020.103772)

Yes	CuO	none	CB	20	*Eisenia fetida*	Gut	160	28	Swart et al. 2020 (10.3390/nano10071337)
Yes	CuO	none	CB	20	*Eisenia fetida*	Gut	10 - 400	28	Swart et al. 2020 (10.1016/j.envpol.2020.115633)
Yes	CuO	none	I	23	*Enchytraeus crypticus*	Gut	100	21	Ma et al. 2020 (10.1016/j.envpol.2019.113463)
Yes	CuO	none	A	50	*Folsomia candida*	Gut	100	28	Ding et al. 2020 (10.1016/j.chemosphere.2020.127347)
Yes	CuO	none	NA	28	*Triticum aestivum*	Rhizo-sphere	50	28	Guan et al. 2020 (10.1021/acs.est.0c00036)
Yes	Se	none	S	62	*Brassica chinensis*	Rhizo-sphere	0.5	60	Wang et al. 2022 (10.1039/d1en00740h)
Yes	TiO_2	none	NA	68	*Linum usitatissimum*	Rhizo-sphere	0.125 (+ sprayed with 100 $\mu g \cdot L^{-1}$ after 7 d)	21	Gorczyca et al. 2018 (10.1007/s11356-018-3346-7)
Yes	TiO_2	none	NA	68	*Triticum aestivum*	Rhizo-sphere	0.125 (+ sprayed with 100 $\mu g \cdot L^{-1}$ after 7 d)	21	Gorczyca et al. 2018 (10.1007/s11356-018-3346-7)

HUMAN AND ANIMAL HEALTH: AIR EXPOSURE

Effect	*Nanoparticle*				*Host*	*Microbiota*	*Concentration*	*Exposure time (d)*	*Reference (DOI)*
	Core[b)]	*Coating*[c)]	*Shape*[d)]	*Size*[e)]			*($mg \cdot kg\ bw^{-1} \cdot d^{-1}$)*[f)]		
Yes	La_2O_3	none	S	23	Mus musculus	Lung	2	1	Zheng et al. 2021 (10.1186/s12989-021-00410-5)
Yes	NiO	none	NA	5	Rattus norvegicus	Lung	0.05-0.16 mg (one dose)	1-28	Jeong et al. 2022 (10.3390/ijerph19010522)
Yes	SiO_2	none	S	49	Mus musculus	Gut	2.5	45	Ju et al. 2020 (10.1039/d0en01021a)

HUMAN AND ANIMAL HEALTH: AQUEOUS EXPOSURE

Effect on microbiota	*Nanoparticle*				*Host*	*Microbiota*	*Concentration*	*Exposure time (d)*	*Reference (DOI)*
	Core[b)]	*Coating*[c)]	*Shape*[d)]	*Size*[e)]			*($\mu g \cdot L^{-1}$)*[f)]		
N.D.	Ag	glutha-thione	S	20	*Homo sapiens*	Gut	$7.6 \cdot 10^3$	2	Cueva et al. 2019 (10.1016/j.fct.2019.110657)

N.D.	Ag	PEG	S	4	*Homo sapiens*	Gut	$11\cdot10^3$	2	Cueva et al. 2019 (10.1016/j.fct.2019.110657)
N.D.	IO	carboxymethyl-dextran	A	7	*Rattus norvegicus*	Mouth	$1\cdot10^6$	21	Liu et al. 2018 (10.1038/s41467-018-05342-x)
N.D.	IO	dextran	S	35	*Rattus norvegicus*	Mouth	$1\cdot10^6$	21	Naha et al. 2019 (10.1021/acsnano.8b08702)
Yes	Ag	citrate	NA	14	*Homo sapiens*	Gut	$1\cdot10^3$	1	Catto et al. 2019 (10.1016/j.envpol.2018.11.019)
Yes	Ag	none	S	10	*Homo sapiens*	Mouth	$5.2\cdot10^3$	2	Espinosa-Cristoba et al. 2019 (10.1155/2019/3205971)
Yes	Ag	none	S	29	*Homo sapiens*	Mouth	$5.2\cdot10^3$	2	Espinosa-Cristoba et al. 2019 (10.1155/2019/3205971)
Yes	Ag	citrate	S	14	*Homo sapiens*	Gut	1-30	42	Li et al. 2021 (10.1016/j.scitotenv.2020.143983)
Yes	CHX PR_4^+	PS_{64}-*b*-$PDMA_{53}$	S	26	*Rattus norvegicus*	Mouth	$5\cdot10^5$ - $8\cdot10^5$	13	Ostadhossein et al. 2021 (10.1038/s42003-021-02372-y)
Yes	CeO_2	none	R	8	*Homo sapiens*	Gut	0.01	5	Taylor et al. 2015 (10.1089/ees.2014.0518)
Yes	CuO	none	A	40	*Homo sapiens*	Mouth	$10\cdot10^3$-$100\cdot10^3$	0.67	Kahn et al. 2013 (10.1016/j.matlet.2013.01.085)
Yes	Se	Polystyrene-4-sulfonate	S	46	*Gallus domesticus*	Gut	$9\cdot10^2$	2	Gangadoo et al. 2019 (10.1016/j.aninu.2019.06.004)
Yes	TiO_2	none	S	27	*Homo sapiens*	Gut	$3\cdot10^3$	5	Taylor et al. 2015 (10.1089/ees.2014.0518)
Yes	TiO_2	none	A	25	*Homo sapiens*	Gut	0.1 $\mu g\cdot d^{-1}$	7	Agans et al. 2019 (10.1093/toxsci/kfz183)
Yes	ZnO	none	A	35	*Homo sapiens*	Mouth	$10\cdot10^3$-$100\cdot10^3$	0.67	Kahn et al. 2013 (10.1016/j.matlet.2013.01.085)
Yes	ZnO	none	S	24	*Homo sapiens*	Gut	0.01	5	Taylor et al. 2015 (10.1089/ees.2014.0518)
Yes	ZnO	alcohol/ alkene	S	32	*Homo sapiens*	Gut	20	NA	Zhou et al. 2021 (10.3389/fmicb.2021.700707)

HUMAN AND ANIMAL HEALTH: FOOD EXPOSURE

	Nanoparticle								

Effect on microbiota	*Core*[b)]	*Coating*[c)]	*Shape*[d)]	*Size*[e)]	*Host*	*Microbiota*	*Concentration ($mg \cdot kg^{-1}$)*[f)]	*Exposure time (d)*	*Reference (DOI)*
N.D.	Ag	none	C	4	*Gallus domesticus*	Gut	50 (drinking water)*	30	Vadalasetty et al. 2018 (10.1186/s12917-017-1323-x)
N.D.	CeO_2	none	S	35	*Mus musculus*	Gut	$10 \cdot 10^3$	21	Bredeck et al. 2021 (10.1080/17435390.2021.1940339)
Yes	Ag	none	A	58	*Danio rerio*	Gut	500	14	Merrifield et al. 2013 (10.1016/j.envpol.2012.11.017)
Yes	Ag	PVP	A	55	*Mus musculus*	Gut	0.046-4.6	28	Van den Brule et al. 2016 (10.1186/s12989-016-0149-1)
Yes	Ag	PVP	S	40	*Mus musculus*	Gut	$2 \cdot 10^3$	28	Bredeck et al. 2021 (10.1080/17435390.2021.1940339)
Yes	Ag	PVP	A	55	*Mus musculus*	Gut	0.004-0.4	168	Perez et al. 2021 (10.1016/j.fct.2021.112352)
Yes	Au	*C. verum* bio-actives	S	15	*Mus musculus*	Gut	10 (drinking water) *	56	Sharma et al. 2022 (10.1016/j.mtbio.2022.100204)
Yes	Chitosan	none	A	50	*Sus domesticus*	Gut	100-400	28	Xu et al. 2020 (10.1111/jpn.13283)
Yes	Cu	none	A	87	*Danio rerio*	Gut	500	14	Merrifield et al. 2013 (10.1016/j.envpol.2012.11.017)
Yes	Cu	chitosan	NA	95	*Gallus domesticus*	Gut	50-150	42	Wang et al. 2011 (10.3382/ps.2011-01511)
Yes	Cu	none	NA	55	*Gallus domesticus*	Gut	1.7	28	Yausheva et al. 2018 (10.1007/s11356-018-1991-5)
Yes	Cu	none	S	50	*Rattus norvegicus*	Gut	3.25-6.5	28	Cholewinska et al. 2018 (10.1371/journal.pone.0197083)
Yes	CuZn	none	NA	65	*Gallus domesticus*	Gut	2.84	28	Yausheva et al. 2018 (10.1007/s11356-018-1991-5)
Yes	Fe	none	NA	50	*Gallus domesticus*	Gut	8	28	Yausheva et al. 2018 (10.1007/s11356-018-1991-5)
Yes	Pectin	none	NA	64	*Mus musculus*	Gut	$7.5 \cdot 10^3$ (drinking water)*	28	Chandrarathna et al. 2020 (10.3390/md18030175)
Yes	Spore coat	none	S	100	*Mus musculus*	Gut	$10 \cdot 10^6$ CFUs (drinking water)*	42	Song et al. 2021 (10.1002/adfm.202104994)
Yes	SiO_2	none	A	13	*Mus musculus*	Gut	$10 \cdot 10^3$	21	Bredeck et al. 2021 (10.1080/17435390.2021.1940339)
Yes	SiO_2	none	A	15.5	*Mus musculus*	Gut	0.8-80	168	Perez et al. 2021 (10.1016/j.fct.2021.112352)

Yes	Thyme	chitosan	S	90	*Gallus domesticus*	Gut	60	42	Hosseini et al. 2018 (10.1080/00071668.2018.1521511)
Yes	TiO_2	none	NA	10	*Mus musculus*	Gut	$1 \cdot 10^3$	91	Mu et al. 2019 (10.1021/acs.jafc.9b02391)
Yes	TiO_2	none	NA	50	*Mus musculus*	Gut	$1 \cdot 10^3$	91	Mu et al. 2019 (10.1021/acs.jafc.9b02391)
Yes	TiO_2	none	NA	100	*Mus musculus*	Gut	$1 \cdot 10^3$	91	Mu et al. 2019 (10.1021/acs.jafc.9b02391)
Yes	TiO_2	none	A	33	*Mus musculus*	Gut	1	56	Cao et al. 2020 (10.1002/smll.202001858)
Yes	TiO_2	none	A	26	*Mus musculus*	Gut	$10 \cdot 10^3$	28	Bredeck et al. 2021 (10.1080/17435390.2021.1940339)
Yes	TiO_2	none	S	25	*Mus musculus*	Gut	20	56	Zhao et al. 2021 (10.1021/acs.jafc.1c03301)
Yes	ZnO	none	NA	30	*Gallus domesticus*	Gut	25-100	63	Feng et al. 2017 (10.3389/fmicb.2017.00992)
Yes	ZnO	none	NA	90	*Gallus domesticus*	Gut	5	28	Yausheva et al. 2018 (10.1007/s11356-018-1991-5)
Yes	ZnO	none	NA	23	*Sus domesticus*	Gut	$600\text{-}2 \cdot 10^3$	14	Xia et al. 2017 (10.18632/oncotarget.17612)

HUMAN AND ANIMAL HEALTH: GAVAGE EXPOSURE

Effect on microbiota	*Nanoparticle*				*Host*	*Microbiota*	*Concentration*	*Exposure time (d)*	*Reference (DOI)*
	Core[b)]	*Coating*[c)]	*Shape*[d)]	*Size*[e)]			*(mg·kg bw^{-1}·d^{-1})*[f)]		
N.D.	Ag	PVP	20	A	*Mus musculus*	Gut	10	28	Wilding et al. 2016 (10.3109/17435390.2015.1078854)
N.D.	IO	dextran	50	NA	*Sus domesticus*	Gut	1.5**	23	Mazgaj et al. 2021 (10.3390/ijms22189930)
N.D.	IO	phospho-lipid	100	NA	*Sus domesticus*	Gut	1.5**	23	Mazgaj et al. 2021 (10.3390/ijms22189930)
N.D.	ZnO	none	40	A	*Mus musculus*	Gut	250	49	Wang et al. 2017 (10.1007/s12011-017-0934-1)
Yes	Ag	none	20	NA	*Mus musculus*	Gut	$2 \cdot 10^{-3}$	45	Wu et al. 2020 (10.1039/c9en01387c)

Yes	Ag	citrate	18	S	*Mus musculus*	Gut	3	7	Lyu et al. 2021 (10.1038/s41598-021-85919-7)
Yes	Ag	PVP	10	NA	*Mus musculus*	Gut	1-5	36	Meier et al. 2021 (10.1016/j.impact.2021.100343)
Yes	Ag	citrate	10	NA	*Rattus norvegicus*	Gut	9-36	91	Williams et al. 2014 (10.3109/17435390.2014.921346)
Yes	Ag	citrate	75	NA	*Rattus norvegicus*	Gut	9-36	91	Williams et al. 2014 (10.3109/17435390.2014.921346)
Yes	Ag	PVP	84	CB	*Rattus norvegicus*	Gut	3.6	14	Javurek et al. 2017 (10.1038/s41598-017-02880-0)
Yes	Ag	PVP	93	S	*Rattus norvegicus*	Gut	3.6	14	Javurek et al. 2017 (10.1038/s41598-017-02880-0)
Yes	Au	Tannic acid	5	S	*Mus musculus*	Gut	0.025	8	Zhu et al. 2018 (10.1186/s12951-018-0415-5)
Yes	Fullerenol	none	95	S	*Mus musculus*	Gut	20	28	Li et al. 2018 (10.1186/s12989-018-0241-9)
Yes	HAHp/ZnO	HAHp	50	H	*Mus musculus*	Gut	$1 \cdot 10^3$	14	Song et al. 2018 (10.3390/md16010023)
Yes	Hydro-phobic segment (hydro-carbon)	PEG-catechol	100	S	*Rattus norvegicus*	Gut	$4 \cdot 10^3$	5	Zhao et al. 2021 (10.1038/s41467-021-27463-6)
Yes	IO	Ginseno-side-R3	8	I	*Mus musculus*	Gut	70	84	Ren et al. 2020 (10.1002/smll.201905233)
Yes	Polystyrene	none	47	S	*Mus musculus*	Gut	0.2-10	30	Xiao et al. 2022 (10.1016/j.envpol.2021.118184)
Yes	Pt	citrate	5	S	*Mus musculus*	Gut	0.025	8	Zhu et al. (201910.2147/IJN.S210655)
Yes	Se	none	40	S	*Mus musculus*	Gut	0.1	10	Deng et al. 2021 (10.1039/d0nr07981b)
Yes	Se	Albumin	96	S	*Mus musculus*	Gut	0.1	10	Deng et al. 2021 (10.1039/d0nr07981b)
Yes	Se	none	39	S	*Rattus norvegicus*	Gut	$3 \cdot 10^{-3}$	1	Lin et al. (202110.1016/j.nantod.2020.101010)
Yes	SiO_2	none	27	A	*Mus musculus*	Gut	$3 \cdot 10^3$	28	Diao et al. 2021 (10.1186/s12951-021-00916-2)
Yes	TiO_2	none	29	A	*Mus musculus*	Gut	100	28	Li et al. 2018 (10.1039/c8nr00386f)

Yes	TiO_2	none	25	A	*Mus musculus*	Gut	1	7	Li et al. 2019 (10.1016/j.impact.2019.100164)
Yes	TiO_2	none	85	I	*Mus musculus*	Gut	$1{\cdot}10^3$	1-14	Kurtz et al. 2020 (10.1002/jat.3991)
Yes	TiO_2	none	21	A	*Mus musculus*	Gut	150	30	Zhang et al. 2020 (10.1007/s00204-020-02698-2)
Yes	TiO_2	none	38	S	*Mus musculus*	Gut	100	10	Gao et al. 2021 (10.1039/d0nr08106j)
Yes	TiO_2	none	30	I	*Mus musculus*	Gut	40	56	Zhu et al. 2021 (10.1007/s12274-020-3210-1)
Yes	TiO_2	none	29	A	*Rattus norvegicus*	Gut	2-50	30	Chen et al. 2019 (10.1039/c9nr07580a)
Yes	TiO_2	none	29	A	*Rattus norvegicus*	Gut	2-50	90	Chen et al. 2019 (10.1186/s12989-019-0332-2)
Yes	TiO_2	none	21	A	*Rattus norvegicus*	Gut	5	13	Mao et al. 2019 (10.1186/s11671-018-2834-5)
Yes	TiO_2	none	25	A	*Rattus norvegicus*	Gut	1-100	14	Zhao et al. 2020 (10.1016/j.ecoenv.2020.111393)
Yes	WO_3	none	48	S	*Mus musculus*	Gut	0.3 $mmol{\cdot}kg\ bw^{-1}$	7	Qin et al. (202110.1016/j.nantod.2021.101234)
Yes	ZnO	none	50	S	*Mus musculus*	Gut	26	30	Chen et al. 2020 (10.1039/d0nr04563b)

HUMAN AND ANIMAL HEALTH: OTHER EXPOSURES

Effect on microbiota	*Nanoparticle*				*Host*	*Microbiota*	*Concentration*	*Exposure time (d)*	*Reference (DOI)*
	Core[b)]	*Coating*[c)]	*Shape*[d)]	*Size*[e)]					
Yes	Ag	protein	sphere	49	*Homo sapiens*	Gut	396 mg (capsule)	8.5	Vamanu et al. 2018 (10.3390/nu10050607)
Yes	$AgVO_3$	Ag nano-particle	wire	10	*Homo sapiens*	Mouth	10-50 $mg{\cdot}L\ resin^{-1}$	7	De Castro et al. 2021 (10.1007/s10266-020-00582-0)

[a)] Literature was retrieved from the Web of Science Core Collection database, accessed on 27 March 2022 through Leiden University's library, using the search string '(nanomaterial* OR nanoparticle*)' for the title, and the search string '(microbiome OR microbiota)' for the abstract of articles.

b) Nanoparticle core abbreviations: Ag, silver; Ag_2S, silver sulfide; Au, gold; $AgVO_3$, silver vanadate; CeO_2, cerium dioxide; CHX PR_4^+, cationic phenyl-bis biguanide chlorhexidine tributylhexadecylphosphonium bromide; Cu, copper; CuO, copper oxide; Fe, iron; HAHp, half-fin anchovy hydrolysates; La_2O_3, lanthanum oxide; Mo, molybdenum; MoO_3, molybdenum trioxide; NiO, nickel oxide; IO, iron oxide;; Pt, platinum; Se, selenium; SiO_2, silicium dioxide; TiO_2, titanium dioxide; WO_3, tungsten trioxide ;ZnO, zinc oxide.

c) Nanoparticle coating abbreviations: HAHp, half-fin anchovy hydrolysates; PEG, polyethylene glycol; PS-PDMA, polystyrene-poly(*N*,*N*-dimethylacrylamide); PVP, polyvinylpyrrolidone.

d) Nanoparticle shape abbreviations: A, amorphous; C, crystal; CB, cuboid; H, hexagonal; I, irregular; R, rods; S, (semi)-spherical.

e) For cuboids and wires, the smallest external dimension is presented.

f) In case different concentration units were reported, this is specified at the concerning rows.

* For drinking water exposures, 1 L water is expressed as 1 kg 'food'.

** The concentration was based on the average weight of exposed piglets over the exposure time.

Supplementary table S2 starts at the next page.

Table S2: Relative abundances of bacterial taxa in zebrafish larvae microbiota as determined based on 16S rRNA sequencing. Replicates 1, 2 and 3 correspond to the pooled DNA of 30 larvae at 3 days post-fertilization. Mean and standard error of the mean (SEM) are given in the final column. Sequence data can be retrieved from the Sequence Read Archive under BioProject PRJNA860062 (BioSamples SAMN29820940, SAMN29820941 and SAMN29820942). Genus and species level identification was based on the SILVA 138 small subunit (16S/18S) rRNA database Ref NR 99, and family to phylum level classifications were retrieved from NCBI Taxonomy Browser. The total number of amplicon sequence variants upon filtering of sequences from a negative control (BioSample SAMN29820946), chloroplasts and mitochondria for replicate 1, 2 and 3 were 2950, 1948, and 3874, respectively. The corresponding QIIME2 pipeline is available via Zenodo (DOI: 10.5281/zenodo.6891712).

					Relative abundance (%)			
Phylum	*Class*	*Order*	*Family*	*Species*	*1*	*2*	*3*	*Mean ± SEM*
Actinobacteriota	Actinobacteria	Bifidobacteriales	Bifidobacteriaceae	*Bifidobacterium* sp.	1.9	0	0	0.6 ± 0.6
		Propionibacteriales	Propionibacteriaceae	*Cutibacterium* sp.	0	0.6	0	0.2 ± 0.2
	Coriobacteriia	Coriobacteriales	Coriobacteriaceae	*Collinsella* sp.	0.6	0	0	0.2 ± 0.2
Bacteroidota	Bacteroidia	Bacteroidales	Barnesiellaceae	*Barnesiella* sp.	0.2	0	0	0.1 ± 0.1
		Cytophagales	Prevotellaceae	*Prevotella* sp.	0.6	0	0	0.2 ± 0.2
				Prevotella nigrescens	0.3	0	0	0.1 ± 0.1
				Flectobacillus sp.	0	0	3.1	1.0 ± 1.0
		Flavobacteriales	Weeksellaceae	*Chryseobacterium* sp.	0.2	0	0	0.1 ± 0.1
				Candidatus *Chryseobacterium* sp.	0	1.4	0	0.5 ± 0.5
Firmicutes	Bacilli	RF39	RF39	RF39 bacterium	0.1	0	0	0.1 ± 0.03
	Clostridia	Eubacteriales	Eubacteriaceae	*Eubacterium coprostanoligenes*	0.8	0	0	0.3 ± 0.3
			Lachnospiraceae	*Agathobacter rectale*	0.7	0	0	0.2 ± 0.2
				Blautia sp.	0.6	0	0	0.2 ± 0.2
				Coprococcus sp.	0.9	0	0	0.3 ± 0.3
				Dorea sp.	0.4	0	0	0.2 ± 0.1
				Fusicatenibacter sp.	0.9	0	0	0.3 ± 0.3
			Oscillospiraceae	*Ruminococcus* sp.	0.6	0	0	0.2 ± 0.2
				Subdoligranulum sp.	0.6	0	0	0.2 ± 0.2
				UCG-002 bacterium	1.1	0	0	0.4 ± 0.4
				UCG-005 bacterium	0.2	0	0	0.1 ± 0.1
			Peptostreptococcaceae	*Romboutsia* sp.	0.8	0	0	0.3 ± 0.3

		Tissierellales	Peptoniphilaceae	*Anaerococcus* sp.	0.2	0	0	0.1 ± 0.1
				Parvimonas sp.	0	0	0.7	0.2 ± 0.2
	Negativicutes	Veillonellales	Veillonellaceae	*Dialister invisus*	1.3	0	0	0.4 ± 0.4
Proteobacteria	Alpha-proteobacteria	Caulobacterales	Caulobacteraceae	*Caulobacter* sp.	0	2.3	0	0.8 ± 0.8
				Unassigned	1.3	0	0	0.4 ± 0.4
		Hyphomicrobiales	Boseaceae	*Bosea* sp.	0	0	1.1	0.4 ± 0.4
			Bradyrhizobiaceae	*Bradyrhizobium* sp.	1.4	0	0	0.5 ± 0.5
			Methylobacteriaceae	*Methylobacterium jeotgali*	0	1.3	0	0.4 ± 0.4
			Pleomorphomonadaceae	Unassigned	0.9	0	0	0.3 ± 0.3
			Rhizobiaceae Bradyrhizobiaceae	*Allorhizobium-Neorhizobium-Pararhizobium-Rhizobium* sp.	2.3	6.0	0.9	3.1 ± 1.5
		Rhodospirillales	Rhodospirallaceae	*Taonella* sp.	0.2	3.0	0	1.1 ± 1.0
		Sphingomonadales	Sphingomonadaceae	*Sphingomonas* sp.	0.5	4.2	0	1.6 ± 1.3
	Beta-proteobacteria	Burkholderiales	Burkholderiaceae	*Limnobacter humi*	0	0.3	0	0.1 ± 0.1
				Ralstonia sp.	5.0	5.4	0	3.5 ± 1.7
				Unassigned	0.2	2.0	3.2	1.8 ± 0.9
			Chromatiaceae	*Rheinheimera* sp.	0.5	0	0	0.2 ± 0.2
			Comamonadaceae	*Delftia* sp.	0	1.5	1.4	1.0 ± 0.5
				Pelomonas sp.	1.8	6	0.4	2.7 ± 1.7
				Pelomonas puraquae	0.6	0	0	0.2 ± 0.2
			Oxalobacteraceae	*Massilia* sp.	0	0.8	0	0.3 ± 0.3
				Pseudoduganella sp.	0	1.4	0	0.5 ± 0.5
				Unassigned	0.7	2.6	4.4	2.5 ± 1.1
				Undibacterium sp.	0.4	0	0	0.1 ± 0.1
		Neisseriales	Chromobacteriaceae	*Vogesella* sp.	58.4	53.6	69.9	60.6 ± 4.8
		Rhodocyclales	Azonexaceae	*Dechloromonas* sp.	1.8	0.9	0	0.9 ± 0.5
	Gamma-proteobacteria	Aeromonadales	Aeromonadaceae	*Aeromonas* sp.	0.4	0	0.7	0.4 ± 0.2
			Unassigned	Unassigned	0.4	0	0	0.1 ± 0.1
		Cardiobacteriales	Cardiobacteriaceae	*Cardiobacterium hominis*	0.5	0	0	0.2 ± 0.2
		Enterobacteriales	Enterobacteriaceae	*Escherichia/Shigella* sp.	0	0	0.6	0.2 ± 0.2
		Nevskiales	Solimonadaceae	Unassigned	1.1	0	0	0.4 ± 0.4
		Pseudomodales	Pseudomonadaceae	*Pseudomonas* sp.	0.6	0	4.5	1.7 ± 1.4

				Pseudomonas luteola	0	0	0.9	0.3 ± 0.3
		Xanthomonadales	Xanthomonadaceae	*Stenotrophomonas* sp.	4.3	0	3.1	2.5 ± 1.3
Verrucomicrobiota	Verrucomicrobiae	Puniceicoccales	Puniceicoccaceae	Unassigned	0.4	0	0	0.1 ± 0.1
Unassigned bacteria	Unassigned	Unassigned	Unassigned	Unassigned	2.1	3.6	2.3	2.7 ± 0.5
Unassigned	Unassigned	Unassigned	Unassigned	Unassigned	0.9	3.2	2.8	2.3 ± 0.7