Supplementary Information

Table S-1. ENMs used in case study. ENM = engineered nanomaterial; NP = nanoparticle; NA = not available or applicable; *Reported from commercial supplier

ENM (NPs)	**Size/ NP Diameter * (nm)**	**Specific Surface Area * (m^2/g)**	**Volume/ Mass/ Quantity Available* (g)**	**Price* ($)**	**Supplier**	**Commercial Name by Supplier**	**Product ID**
Al	60-80	NA	NA	116 (25g); 356 (100 g)	Alfa Aesar	Aluminum powder, spherical, APS 60-80nm	45546
Al_2O_3	60	NA	25	NA (Already in NC State inventory)	Alfa Aesar	Aluminum oxide, 99.9%	40456
CuO	30-50	13	50	34.7 (10g); 107 (50g)	Alfa Aesar	Copper (II) oxide, nanopowder	44663
Fe_2O_3	3	250	250	143 (50g); 547 (250g); 1592 (1kg)	Alfa Aesar	Iron (III) oxide, nanopowder, 99.95%	44119
MgO	100	>7.3	500	45.80 (25g); 135 (100g); 523 (500g)	Alfa Aesar	Magnesium oxide, nanopowder, 99+%	44733
MnO_2	50	NA	100	65 (25g); 135 (100g); 428 (500g); 685 (1kg)	NPs synthesized in NC State lab (grown on nanofibrous filter media); Can also be purchased[1]	Manganese dioxide MnO_2 nanoparticles (MnO_2, 98%, 50nm)	US3319 [1]
TiO_2 (anatase)	15	240	500	64.10 (25g); 146 (100g); 477 (500g)	Alfa Aesar	Titanium (IV) oxide, anatase, nanopowder, 99.7%	045603
ZrO_2	<100	>25	25	31.75 (5g); 112 (25g)	Sigma-Aldrich	Zirconium (IV) oxide, nanopowder, <100 nm particle size (TEM)	544760

Table S-2. NanoRiskCat Steps[2, 3]

Category	Step	Details
Problem Definition	1. Short titles for use scenario(s) and ENM identification	• ENM-enabled product clearly described in short title, defining the type of ENM(s) used, and intended use
Exposure	2. Exposure potential assessment	• User assesses potential exposure according to the location of the ENM in the product (e.g., ENM used on a structured surface, NPs suspended in liquids, NPs suspended in air, etc.) based on Hansen et al.[4] • If high exposure potential (e.g., NP suspended in liquid matrix intended for direct skin contact) a red dot triggered; if medium exposure a yellow dot triggered; if low exposure (e.g., NP suspended in solid matrix with very low potential for release) a green dot triggered; if unknown a grey dot triggered; • Same procedure performed for professional end-users, consumers, and environmental recipients
Human Hazard	3. Decision tree for potential human health hazard assessment	• Decision tree based on the following nodes: 1. ENM classification as High Aspect Ratio Nanoparticle (HARN)? 2. ENM in bulk form known or suspected to cause of serious detrimental effects based on EU's Regulation NO 1272/2008 (CLP Legislation[5]), such as e.g. acute toxicity category 1-4; germ cell mutagenicity category 1A, 1B, or 2, carcinogenicity category 1A, 1B, or 2, etc.? 3. ENM in bulk form classified for less severe effects based on EU's CLP Legislation, such as e.g., skin corrosion/irritation, specific target organ toxicity-single exposure category 3, serious eye damage/irritation category 2? 4. ENM induce acute toxicity? 5. ENM cause other serious effects, e.g., genotoxic, mutagenic, carcinogenic, respiratory, cardiovascular, neurotoxic, reproductive effects? • If "yes" to any of these questions, a red (high hazard potential) colored dot will be triggered; if "maybe" or inconclusive evidence but gives cause for concern a yellow (medium hazard potential) colored dot triggered; if "no" a green dot (low hazard potential); and if unknown or insufficient data a grey dot triggered
Ecological Hazard	4. Decision tree for potential ecological hazard assessment	• Decision tree based on the following nodes: 1. ENM in bulk form known or suspected to cause of serious detrimental effects based on EU's Regulation NO 1272/2008 (CLP Legislation[5]), such as e.g. acute 1 or chronic 1 and chronic 2 and level B CLP classifications.? 2. Is the ENM LC50 $\leq$10 mg/L? 3. ENM in bulk form classified for less severe effects based on EU's CLP Legislation, such as e.g., significant effect of ENM without EC50 or LC50 values? 4. Is the ENM LC50 $\leq$100 mg/L? 5. Does the ENM have a half-life > 40 days? 6. Does the ENM have a bioconcentration factor >0.1 or > 50? 7. Does the ENM readily disperse or have long range transport in the environment? 8. Is the ENM novel? • If "yes" to any of these questions, a red (high hazard potential) colored dot will be triggered; if "maybe" or inconclusive evidence but gives cause for concern a yellow (medium hazard potential) colored dot triggered; if "no" a green dot (low hazard potential); and if unknown or insufficient data a grey

Category	Step	Details
		dot triggered
Generated Output	5. Compile results	• User compiles the color-coded dots from the exposure potential for professional end-users, consumers, and environmental recipients (Step 2) and hazard potential for humans and environment (Steps 3-4); • End result is five color-coded dots for communication

Table S-3. LICARA nanoSCAN Steps[6]. The outlined steps are included in the 9 different tabs within the web-based tool.

Category	Step	Details
Welcome	1. Introduction	• Welcome page to LICARA nanoSCAN • Introductory information on overall scope and purpose of tool • User can view overall framework, including the different components used in the tool evaluation • User can start a new evaluation ("nanoSCAN") under "Start nanoSCAN" or can view, load, edit, or remove saved evaluations under "Your nanoSCANs"
Problem Definition	2. Start	• User provides identifying information on the nanoproduct, including name and date • Scenario can later be saved using this name and identifying information
	3. Nano product	• Box 0. Nano product and legislation • User responds to questions using drop-down menus and blank comment fields within three groups: "Type of nano material and application," "Nano-relevance," and "Legislation" • There are 12 questions total • This Box helps the user determine whether LICARA nanoSCAN is a relevant tool (i.e. ENM-relevance) and checks the compliance of the nanoproduct with current European regulation
Benefit Evaluation	4. Environmental benefits	• Box 1. Environmental benefits • All questions relate to the performance of a nanoproduct compared to a conventional product • User responds to questions using drop-down menus within three groups: "Manufacturing phase of the nanoproduct versus conventional product," "Use phase (only for final products and articles)," and "End-of-life (only for final products and articles)"; the latter two groups may be completed for intermediate nanoproducts to help improve quality of decision-making • There are 20 questions total
	5. Economic benefits	• Box 2. Economic benefits • All questions relate to the performance of a nanoproduct compared to a conventional product • User responds to questions using drop-down menus within three groups: "Market potential," "Profitability," and "Development stage" • There are 5 questions total
	6. Societal benefits	• Box 3. Societal benefits • All questions relate to the performance of a nanoproduct compared to a conventional product • User responds to questions using drop-down menus within three groups: "Technological breakthrough," "Highly qualified labour force,"

Category	Step	Details
		and "Improving global health or food situation" • There are 3 questions total
Risk Evaluation	7. Public and environmental risks	• Box 4. Public health & environmental risks • All questions based on Precautionary Matrix[7] • User responds to questions using drop-down menus within three groups: "System knowledge," "Potential effect," and "Potential input into the environment" • There are 9 questions total
	8. Occupational health risks	• Box 5. Occupational health risks • User is directed to Stoffenmanager Nano 1.0[8] which is a separate web-based tool. After accessing the site, the user needs to create an account and log in • User starts a new evaluation (termed "risk assessment") • User responds to questions using drop-down menus and blank comment fields within six steps: 1. General, 2. Product characteristics, 3. Handling/Process, 4. Working area, 5. Local controls measures and personal protective equipment, 6. Risk assessment • There are 27 questions total • The output in the final step is a summary of calculated exposure-hazard-class and risk scores in the Risk Assessment step • User can save the evaluation, export the results, and return to the evaluation if needed • Returning to LICARA nanoSCAN, the user enters the final task weighted hazard class (e.g. C) and exposure class (e.g. 2) scores from the Stoffenmanager Nano 1.0 evaluation in a matrix (e.g. C2) under the appropriate life cycle stage (i.e., manufacture, processing, application)
	9. Consumer risks	• Box 6. Consumer health risks • Relevant only for consumer or consumer/professional products, based on exposure potential using Hansen et al.[4] framework and NanoRiskCat exposure profile[9] • User responds to questions using drop-down menus within one group: "Hazard & exposure by consumers during use phase" • There are 2 questions total
Generated Output	10. Decision support	• Final generated output displayed according to separate benefit and risk evaluations as well as a combined benefit-risk evaluation • User can name and save the evaluation (nanoSCAN)

Table S-4. NanoGRID Steps[10]. The outlined steps are included in the 5 different tabs within the MS-excel tool.

Category	Step	Details
Welcome	1. Home tab	• Welcome page to NanoGRID • Overall framework of NanoGRID • User can start a new evaluation ("profile") under "Start" button or can view, load, edit, or remove saved evaluations
Problem Definition	2. ENM and ENM-product description	• Tier 1. Basic Information, Technology Category, and ENM Definition • Tier 1 helps the user determine whether the ENM is of concern, if ENM-specific test and methods are required (or if conventional chemical risk assessment methods would be suitable), and if Tiers 2-5 are necessary

Category	Step	Details
		to complete to characterize the environmental, health, and safety concerns of the ENM • User responds to questions or selects applicable options using drop-down menus, radio buttons, and blank comment fields within four tabs: "Basic information," "Technology Category," "Nanomaterial Definition," and "Special Properties" • "Basic information" tab has three sub-tabs: "Instructions," "Initial questions," and "Technical questions" that ask the user about the ENM, its properties, and how it is used in a product. • "Technology category" characterizes the location of the ENM in a product following Hansen et al.[4]; "Nanomaterial Definition" describes the ENM based on physico-chemical properties (i.e., ENM definitions used by regulatory agencies, size, aggregation, specific surface area, and unique/novel properties); "Special Properties" described the ENM based on special or unique properties correlated with environmental, health, or safety hazards (e.g., shape, charge, reactivity, dustiness, porosity) • There are a maximum of 42 questions or options to select in Tier 1
Exposure	3. Release potential	• Tier 2. Release, Hazard Identification, and Testing Identification • Tier 2 helps the user understand the release potential of the ENM from the ENM-enabled product, whether additional testing is needed to characterize potential risks/concerns, and helps the user better understand the release of ENM through various assumptions or laboratory-based tests • User responds to questions or selects applicable options using drop-down menus, radio buttons, and blank comment fields within three tabs: "Release," "Hazard Identification," and "Testing Identification" • "Release" characterizes the release of the ENM from the product, based on Hansen et al.[4], and describes a release scenario (e.g., release of 100% of ENM from product), also in reference to known hazard concentrations (three options); "Hazard Identification" screens the ENM for potential environmental and human health hazards • Predicted Environmental Concentration (PEC) can be estimated using the SimpleBoxforNano[11], Mend Nano[12], or existing values from the literature • Predicted No Effect Concentration (PNEC) is estimated using existing values from the literature, as calculated using choice of two approaches (US Army Method vs. EU ECHA Method[13,14]). For these values, the user enters acute and/or chronic data • If the PEC/PNEC < 1, no risk is expected; if PEC/PNEC > 1, a potential risk cannot be dismissed or neglected, and the user is guided to Tier 3 • There are a maximum of 15 questions or options to select in Tier 2
	4. Environmental persistence testing	• Tier 3. Environmental fate and persistence of ENMs in aqueous media • Tier 3 guides the user through various laboratory-based tests to understand the environmental fate and persistence of ENMs in aqueous media • User responds to questions, selects applicable options, or fills in blank comment fields in four main tabs, Levels 1-4, that correspond to different ENM fate and persistence tests the user can perform • Level 1 is an initial description of the media and ENM concentration; Level 2 is an initial characterization of ENM size and surface charge; Level 3 is a test of particle stability and dissolution over time; and Level

Category	Step	Details
		4 evaluate the results variability to provide further guidance and testing if needed • There are a maximum of approx. 20 questions or options to select in Tier 3, depending on the number and behavior of concentrations selected
Hazard	5. Environment and health hazard testing	• Tier 4. Aquatic, Terrestrial, Human Health hazard data • Tier 4 guides the user through various laboratory-based tests to understand environmental health and/or human health hazard assessment related to the ENM • User responds to questions or selects applicable options using drop-down menus, radio buttons, and blank comment fields within three main tabs: “Aquatic,” “Terrestrial,” “Human Health” (not yet functional) • In each tab, the user has the possibility to choose between "acute," "chronic," and "elutriate" toxicity tests for a maximum of two organisms by test type and three endpoints by organism • User has direct access to toxicity protocol link • For each toxicity test type (e.g. acute) NanoGRID calculates the PEC/PNEC ratio • There is a large number of questions or options that are possible (~100) for the user to select in Tier 4, depending on the number of test, organism and endpoints selected
	6. In depth product investigation	• Tier 5. In Depth Product investigation • Not yet available in current version
Generated Output	7. Decision Support	• After completing all necessary Tiers, user can click on “Generate Report” to produce the final output pdf file • Final report provides an overview of the evaluation according to each tier and guidance towards testing that may be needed related to the selected ENM
	8.-Credit/Point of Contact	• Contact information for individuals who contributed to the NanoGRID development according to subject matter expertise, technical development, and technical coordination (N=14)

Table S-5. Detailed results from NanoRiskCat applied to ENMs in case study. ENM = engineered nanomaterial; NP = nanoparticle.

ENM (NP)	**Exposure Potential**			**Hazard Evaluation**	
	Professional End-User	**Consumers**	**Environment**	**Health**	**Ecological**
Al	High: Due to dry, loose state of NPs as purchased from supplier and handled by end-users in laboratory settings	Medium: Due to loose (unbound) state of NPs used in water treatment application (hypothetical at this stage of innovation). Cannot rule out that NPs will not be released from water treatment application	Medium: Due to loose (unbound) state of NPs used in water treatment application (hypothetical at this stage of innovation). Cannot rule out that NPs will not be released from water treatment application	Medium: Cytotoxicity studies[15-17]; irritation[18-19]; pulmonary disease[20]	High: EC50, 4.7 μg/mL[16]; LD50 (48h), 7.483 mg/L[21]
Al_2O_3	High: Due to dry, loose state of NPs as purchased from supplier and handled by end-users in laboratory settings	Medium: Due to loose (unbound) state of NPs used in water treatment application (hypothetical at this stage of innovation). Cannot rule out that NPs will not be released from water treatment application	Medium: Due to loose (unbound) state of NPs used in water treatment application (hypothetical at this stage of innovation). Cannot rule out that NPs will not be released from water treatment application	High: Inflammatory effects[22]; expression of neuro-degeneration related genes[23]; impacts on lung, brain, liver, kidneys, intestines[22-24]	High: EC50 (72h), 0.162 mg/L[25]; EC50 (48h), 114.357 (mg/L)[26]; LC50 (48h), 162.392 mg/L[26]; some indications of persistency[9, 27]
CuO	High: Due to dry, loose state of NPs as purchased from supplier and handled by end-users in laboratory settings	Medium: Due to loose (unbound) state of NPs used in water treatment application (hypothetical at this stage of innovation). Cannot rule out that NPs will not be released from water	Medium: Due to loose (unbound) state of NPs used in water treatment application (hypothetical at this stage of innovation). Cannot rule out that NPs will not be released from water treatment application	High: Cytotoxicity and DNA damage, intracellular reactive oxygen species (ROS) generation, DNA lesions [28, 29]; respiratory irritation[30]	High: High ecotoxicity with long lasting effects[31]; EC50, 0.46 mg/L - >250 mg/L values reported[32]; EC50 (72h), 0.71 mg/L, NOEC, 0.421 mg/L[33]; LC50 (48h), 3.2 mg/L, LC50 (24h), 2.1 mg/L, NOEC (48h), 0.5 mg/L, NOEC

ENM (NP)	Exposure Potential			Hazard Evaluation	
	Professional End-User	Consumers	Environment	Health	Ecological
		treatment application			(24h), 0.5 mg/L[34]
Fe_2O_3	High: Due to dry, loose state of NPs as purchased from supplier and handled by end-users in laboratory settings	Medium: Due to loose (unbound) state of NPs used in water treatment application (hypothetical at this stage of innovation). Cannot rule out that NPs will not be released from water treatment application	Medium: Due to loose (unbound) state of NPs used in water treatment application (hypothetical at this stage of innovation). Cannot rule out that NPs will not be released from water treatment application	High: Accumulation in brain, liver, kidneys[35-37]; inflammatory effects[38]; severe damage in liver and lungs; tumorigenic effects[39]	High: LC50, 53.35 mg/L[40]; LC50, 99.064-259.956 mg/L[41]; Potentially persistent and not likely to be transported in environment[9, 42]
MgO	High: Due to dry, loose state of NPs as purchased from supplier and handled by end-users in laboratory settings	Medium: Due to loose (unbound) state of NPs used in water treatment application (hypothetical at this stage of innovation). Cannot rule out that NPs will not be released from water treatment application	Medium: Due to loose (unbound) state of NPs used in water treatment application (hypothetical at this stage of innovation). Cannot rule out that NPs will not be released from water treatment application	High: Serious eye damage; eye, skin, respiratory irritant[43]	High: Very toxic to aquatic life with long-lasting effects[43]; LC50 (96h), 428 mg/L, EC50 (48h), 175 mg/L[44]
MnO_2	Medium: Due to NPs grown on nanofibrous filter media by NC State researchers. The NPs are grown on surfaces of fibers, attached to fibers, as demonstrated by sonification experiments by NC	Medium: Due to loose (unbound) state of NPs used in water treatment application (hypothetical at this stage of innovation). Cannot rule out that NPs will not be released from water treatment application	Medium: Due to loose (unbound) state of NPs used in water treatment application (hypothetical at this stage of innovation). Cannot rule out that NPs will not be released from water treatment application	High: Acute Tox 4, Harmonized classification, Annex VI of Regulation EC No 1272/2008 (CLP) [45]	High: EC50, 10-100 mg/L[46]

ENM (NP)	Exposure Potential			Hazard Evaluation	
	Professional End-User	**Consumers**	**Environment**	**Health**	**Ecological**
	State. No release studies performed however from the nanofibers containing MnO_2 NPs				
TiO_2	High: Due to dry, loose state of NPs as purchased from supplier and handled by end-users in laboratory settings	Medium: Due to loose (unbound) state of NPs used in water treatment application (hypothetical at this stage of innovation). Cannot rule out that NPs will not be released from water treatment application	Medium: Due to loose (unbound) state of NPs used in water treatment application (hypothetical at this stage of innovation). Cannot rule out that NPs will not be released from water treatment application	High: Suspected human carcinogen for inhalation, (Carc. 2; H350[47]	High: EC50 (72h), 1.3-3.44 mg/L[48]; EC50 (72h), 3.8 mg/L[49]; EC50 (48h), 8.26 mg/L[50]; other LC50 values < 10mg/L[32]
ZrO_2	High: Due to dry, loose state of NPs as purchased from supplier and handled by end-users in laboratory settings	Medium: Due to loose (unbound) state of NPs used in water treatment application (hypothetical at this stage of innovation). Cannot rule out that NPs will not be released from water treatment application	Medium: Due to loose (unbound) state of NPs used in water treatment application (hypothetical at this stage of innovation). Cannot rule out that NPs will not be released from water treatment application	Medium: Conflicting findings; from no/low toxicity[51, 52] to neuronal developmental toxicity, behavioral changes, impacts on reproduction, and some cytotoxicity and genotoxicity[53-55]; Bulk ZrO2 may cause irritation (eyes, skin, ingestion, inhalation)[56]	Low: No ecotoxicity effects reports; not considered to be persistent, bioaccumulative, or toxic [56-58]

Table S-6. Detailed results from LICARA nanoSCAN applied to ENMs in case study. ENM = engineered nanomaterial; NP = nanoparticle; NA = not available or applicable. Note: the questions listed below are slightly abbreviated questions from the LICARA nanoSCAN methodology for brevity reasons.

LICARA nanoSCAN questions			Al	Al_2O_3	CuO	Fe_2O_3	MgO	MnO_2	TiO_2	ZrO_2
Box 0. Nano product and legislation	Type of ENM and application	0.1. Which ENM will be used? Please specify additional ENM subtype or indications / properties:	Other; Al NP; 60-80nm	Other; Al2O3 NP; 60nm	Other; CuO NP; 30-50nm	Iron NPs; Fe2O3 NP; 3nm	Other; MgO NP; 100nm	Other; MnO2 NP; 50nm	Titanium dioxide (TiO2); anatase, 15nm	Other; ZrO2 NP; <100 nm
		0.2. In which type of application is the ENM used?	Water / waste water treatment	Water / waste water treatment	Water / waste water treatment	Water / waste water treatment	Water / waste water treatment	Water / waste water treatment	Water / waste water treatment	Water / waste water treatment
		0.3a. Is this a completely new product with a new functionality? 0.3b. If not, what conventional product is being replaced?	No	No	No	No	No	No	No	No
		0.4. The product under evaluation is: (for consumer use, for professional use, etc.)	Professional market only	Professional market only	Professional market only	Professional market only	Professional market only	Professional market only	Professional market only	Professional market only
		0.5. What is the main function that the ENM provides?	Water treatment; phosphate removal	Water treatment; phosphate removal	Water treatment; phosphate removal	Water treatment; phosphate removal	Water treatment; phosphate removal	Water treatment; phosphate removal	Water treatment; phosphate removal	Water treatment; phosphate removal
		0.6. What is the appropriate unit to compare the nanoproduct with the conventional product?	1kg	1kg	1kg	1kg	1kg	1kg	1kg	1kg
	Nano-relevance	0.7. Approach 1 (precautionary approach): Ranges of sizes of primary particles contained in the ENM?	1-500nm	1-500nm	1-500nm	1-500nm	1-500nm	1-500nm	1-500nm	1-500nm
		0.8. Approach 2 (EU-proposed definition 2011/696/EU)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Legislation	0.9. Are you aware of existing legislation (e.g. EU REACH)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		0.10. Is your ENM approved or notified according to relevant EU-legislation (e.g. EU REACH)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		0.11. Do you use the ENM below its specific concentration limits recommended in the legal framework?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Box 1.	Manufactu	1.1. Energy consumption of manufacturing process?	Worse[59, 60]	Worse[59, 60]	Worse[59, 60]	Worse[59, 60]	Worse[59, 60]	Better, as NPs	Worse[59, 60]	Worse[59, 60]

LICARA nanoSCAN questions			Al	Al_2O_3	CuO	Fe_2O_3	MgO	MnO_2	TiO_2	ZrO_2
		Note: conservative potential proxies (macro/micro scale powders) were used to check if energy use were worse for the ENMs than activated carbon						grown on non-woven fibers		
		1.2a. Materials consumption in manufacturing process? 1.2b. Amounts of hazardous substances used in manufacturing?	Worse; Worse[59, 60]	Worse; Worse[59, 60]	Worse; Worse[59, 60]	Worse; Worse[59, 60]	Worse; Worse[59, 60]	Better, as NPs grown on non-woven fibers; Unknown	Worse; Worse[59, 60]	Worse; Worse[59, 60]
		1.3. Efforts needed to produce product using the ENM?	Worse[59, 60]	Worse[59, 60]	Worse[59, 60]	Worse[59, 60]	Worse[59, 60]	Better, as NPs grown on non-woven fibers	Worse[59, 60]	Worse[59, 60]
	phase	1.4a. Amount of solid waste from manufacturing process? 1.4b. Amount of wastewater from manufacturing process? 1.4c. Emissions to air or (waste)water from manufacturing process? Note: conservative potential proxies (macro/micro scale powders) were used to check if energy use were worse for the ENMs than activated carbon	Worse; Worse; Worse[59, 60]	Worse; Worse; Worse[59, 60]	Worse; Worse; Worse[59, 60]	Worse; Worse; Worse[59, 60]	Worse; Worse; Worse[59, 60]	Better, as NPs grown on non-woven fibers; Unknown ; Unknown	Worse; Worse; Worse[59, 60]	Worse; Worse; Worse[59, 60]
	Use phase	1.5. Product lifetime (use phase)?	Better, assumed from research team	Better, assumed from research team	Better, assumed from research team	Better, assumed from research team	Better, assumed from research team	Better, assumed from research team	Better, assumed from research team	Better, assumed from research team
		1.6a. Need for maintenance? 1.6b. Amounts of hazardous substances used in maintenance?	Equal; Equal, assumed from research team	Equal; Equal, assumed from research team	Equal; Equal, assumed from research team	Equal; Equal, assumed from research team	Equal; Equal, assumed from research team	Equal; Equal, assumed from research team	Equal; Equal, assumed from research team	Equal; Equal, assumed from research team
Envi ron me		1.7a. Amounts of hazardous substances used in maintenance? 1.7b. Amount of solid waste from using	Equal; Equal; Unknown,	Equal; Equal; Unknown,	Equal; Equal; Unknown,	Equal; Equal; Unknown,	Equal; Equal; Unknown,	Equal; Unknown ;	Equal; Equal; Unknown,	Equal; Equal; Unknown,

LICARA nanoSCAN questions			Al	Al_2O_3	CuO	Fe_2O_3	MgO	MnO_2	TiO_2	ZrO_2
		product? 1.7c. Amount of wastewater resulting from use of product?	assumed from research team	assumed from research team	assumed from research team	assumed from research team	assumed from research team	Unknown, assumed from research team	assumed from research team	assumed from research team
		1.8. Efficiency of use?	Better, as NPs are often reported to be more reactive than bulk scale materials	Better, as NPs are often reported to be more reactive than bulk scale materials	Better, as NPs are often reported to be more reactive than bulk scale materials	Better, as NPs are often reported to be more reactive than bulk scale materials	Better, as NPs are often reported to be more reactive than bulk scale materials	Better, as NPs are often reported to be more reactive than bulk scale materials	Better, as NPs are often reported to be more reactive than bulk scale materials	Better, as NPs are often reported to be more reactive than bulk scale materials
	End-of-life	1.9. Volume of waste?	Equal, assumed from research team	Equal, assumed from research team	Equal, assumed from research team	Equal, assumed from research team	Equal, assumed from research team	Equal, assumed from research team	Equal, assumed from research team	Equal, assumed from research team
		1.10a. Amounts of other hazardous substances released from wastewater treatment? 1.10b. Amounts of other hazardous substances released during incineration?	Unknown ; Unknown	Unknown ; Unknown	Unknown ; Unknown	Unknown ; Unknown	Unknown ; Unknown	Unknown ; Unknown	Unknown ; Unknown	Unknown ; Unknown
		1.11. Established recycling systems exposed to the ENM in the product?	Equal; this is expected to be a minor issue for both the NP and activated carbon	Equal; this is expected to be a minor issue for both the NP and activated	Equal; this is expected to be a minor issue for both the NP and activated	Equal; this is expected to be a minor issue for both the NP and activated	Equal; this is expected to be a minor issue for both the NP and activated	Equal; this is expected to be a minor issue for both the NP and activated	Equal; this is expected to be a minor issue for both the NP and activated	Equal; this is expected to be a minor issue for both the NP and activated
		1.12a. Can the wastewater treatment facility elimination the nanoproduct's emissions? 1.12b. Can the waste incineration facility eliminate the nanoproduct's	No[61, 62]; No[63]	No[64]; No[63]	No[64]; No[63]	No[64]; No[63]	No[64]; No[63]	No[64]; No[63]	No[61, 65]; No[63, 66]	No [61]; No[63]

LICARA nanoSCAN questions			Al	Al_2O_3	CuO	Fe_2O_3	MgO	MnO_2	TiO_2	ZrO_2
		emissions?								
Box 2. Economic benefits	Market potential	2.1. Does the nanoproduct have increased marketability due to an improved or new functionality or a clear image advantage compared to conventional product?	Equal, based on current knowledge	Equal, based on current knowledge	Equal, based on current knowledge	Equal, based on current knowledge	Equal, based on current knowledge	Equal, based on current knowledge	Equal, based on current knowledge	Equal, based on current knowledge
		2.2. What is the foreseen market potential of nanoproduct or -application in Europe?	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
	Profitability	2.3. What is the purchase price per unit of the nanobased product or material compared to the conventional one?	Higher (see Table S-1)	Higher (see Table S-1)	Higher (see Table S-1)	Higher (see Table S-1)	Higher (see Table S-1)	Higher (see Table S-1)	Higher (see Table S-1)	Higher (see Table S-1)
		2.4. What are the operational costs during the use phase of the nanobased product or application compared to the conventional one?	Equal, assumed from research team	Equal, assumed from research team	Equal, assumed from research team	Equal, assumed from research team	Equal, assumed from research team	Equal, assumed from research team	Equal, assumed from research team	Equal, assumed from research team
	Development stage	2.5. What is the time-to-market to manufacture the nanoproduct on a commercial scale?	Medium (1- <5 year)	Medium (1- <5 year)	Medium (1- <5 year)	Medium (1- <5 year)	Medium (1- <5 year)	Medium (1- <5 year)	Medium (1- <5 year)	Medium (1- <5 year)
Box 3. Societal benefits	Technological break-through	3.1. Could the use or application of nanoproduct be considered a technological breakthrough compared to conventional alternative?	Yes; improved phosphate adsorption capacity compared to activated carbon (1-2 mg/g)	Yes; improved phosphate adsorption capacity compared to activated carbon (1-2 mg/g)	Yes; improved phosphate adsorption capacity compared to activated carbon (1-2 mg/g)	Yes; improved phosphate adsorption capacity compared to activated carbon (1-2 mg/g)	Yes; improved phosphate adsorption capacity compared to activated carbon (1-2 mg/g)	Yes; improved phosphate adsorption capacity compared to activated carbon (1-2 mg/g)	Yes; improved phosphate adsorption capacity compared to activated carbon (1-2 mg/g)	Yes; improved phosphate adsorption capacity compared to activated carbon (1-2 mg/g)
	Highly qualified labour force	3.2. Does production of the application lead to a substantial improvement in the development of a highly qualified labour force compared to conventional alternative?	More or less equal	More or less equal	More or less equal	More or less equal	More or less equal	More or less equal	More or less equal	More or less equal

LICARA nanoSCAN questions			Al	Al_2O_3	CuO	Fe_2O_3	MgO	MnO_2	TiO_2	ZrO_2
	Improving global health or food situation	3.3. Compared to conventional alternative... OR Does the use or application of nano-based product lead to improvements in people's health, particularly the direct user, e.g. by improvements in water purity, sanitation or medicines and pharmaceuticals?	Yes, case study focused on sustainable water treatment solutions	Yes, case study focused on sustainable water treatment solutions	Yes, case study focused on sustainable water treatment solutions	Yes, case study focused on sustainable water treatment solutions	Yes, case study focused on sustainable water treatment solutions	Yes, case study focused on sustainable water treatment solutions	Yes, case study focused on sustainable water treatment solutions	Yes, case study focused on sustainable water treatment solutions
Box 4. Public health & environmental risks	**System knowledge**	4.1. Is the origin of the (ENM) starting materials known?	Yes (see Table S-1)	Yes (see Table S-1)	Yes (see Table S-1)	Yes (see Table S-1)	Yes (see Table S-1)	Yes (see Table S-1)	Yes (see Table S-1)	Yes (see Table S-1)
		4.2. Are the next users of the ENM known?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		4.3. How accurately is material system known or can disturbing factors (e.g. impurities) be estimated?	Not accurately, still in early innovation stages	Not accurately, still in early innovation stages	Not accurately, still in early innovation stages	Not accurately, still in early innovation stages	Not accurately, still in early innovation stages	Not accurately, still in early innovation stages	Not accurately, still in early innovation stages	Not accurately, still in early innovation stages
	Potential effect	4.4. Do the ENMs cause redox activity, catalytic activity or have a potential for oxygen radical formation or to induce inflammation reactions?	Medium[18, 19]	Medium[22]	High[28, 29]	High[38]	High[43]	Medium[67]	High[47]	Low[53, 56]
		4.5. What is stability (half-life) of NPs present in the ENM under ambient environmental conditions?	Months, given its water solubility not determined[18]	Months, given its insolubility in water[68]	Months, given its insolubility in water[69]	Months, given its insolubility in water[70]	Months, given it is slightly soluble in water[71]	Months, given its insolubility in water[1]	Months, given its insolubility in water[72]	Months, given its water solubility = 0.1 g/L)[73]
	Potential input into environment	4.6. What is annual quantity of NPs from the manufacturing phase that reaches the environment via wastewater, exhaust gases or solid waste?	<5kg (see Table S-1)	<5kg (see Table S-1)	<5kg (see Table S-1)	<5kg (see Table S-1)	<5kg (see Table S-1)	<5kg (see Table S-1)	<5kg (see Table S-1)	<5kg (see Table S-1)
		4.7. What is the physical surrounding or carrier material of NPs in the product during the use phase?	Liquid media	Liquid media	Liquid media	Liquid media	Liquid media	Solid matrix, not stable under conditions of use	Liquid media	Liquid media

LICARA nanoSCAN questions			Al	Al_2O_3	CuO	Fe_2O_3	MgO	MnO_2	TiO_2	ZrO_2
		4.8. What is the annual quantity of NPs in products that reaches from production or use phase the environment via utility products, waste water, exhaust gases or solid waste?	<5kg (see Table S-1)	<5kg (see Table S-1)	<5kg (see Table S-1)	<5kg (see Table S-1)	<5kg (see Table S-1)	<5kg (see Table S-1)	<5kg (see Table S-1)	<5kg (see Table S-1)
		4.9. What is the annual quantity of disposed ENM (from the production or use phase)?	<5kg (see Table S-1)	<5kg (see Table S-1)	<5kg (see Table S-1)	<5kg (see Table S-1)	<5kg (see Table S-1)	<5kg (see Table S-1)	<5kg (see Table S-1)	<5kg (see Table S-1)
Box 5. Occupational health	**Stoffenmanager Nano 1.0**	Hazard & exposure during: 5.1a. Manufacture of ENM 5.1b. Processing of ENM 5.1c. Application of nanoproduct	B1 (see Table S-7)	B1 (see Table S-7)	B1 (see Table S-7)	B1 (see Table S-7)	B1 (see Table S-7)	C1 (see Table S-7)	D1 (see Table S-7)	B1 (see Table S-6)
Box 6. Consumer health risks	**Hazard & exposure by consumers during use phase**	6.1. At what location is the nanoelement situated in the article or the product?	NA: Product for professional market only	NA: Product for professional market only	NA: Product for professional market only	NA: Product for professional market only	NA: Product for professional market only	NA: Product for professional market only	NA: Product for professional market only	NA: Product for professional market only
		6.2. What is the size of the consumer population using the nanoproduct and hence which may be exposed?	NA: Product for professional market only	NA: Product for professional market only	NA: Product for professional market only	NA: Product for professional market only	NA: Product for professional market only	NA: Product for professional market only	NA: Product for professional market only	NA: Product for professional market only

Table S-7. Detailed results from Stoffenmanager 1.0 applied to ENMs in case study relevant for occupational risks (Box 5 of LICARA nanoSCAN). Details shown in table reflect generated output from Stoffenmanager 1.0, and some questions/responses are slightly abbreviated for brevity reasons. ENM = engineered nanomaterial; NP = nanoparticle; NA = not available or applicable.

Stoffenmanager questions		**Al**	**Al_2O_3**	**CuO**	**Fe_2O_3**	**MgO**	**MnO_2**	**TiO_2**	**ZrO_2**
General data	**Product**	Al water	Al2O3 water	CuO water	Fe2O3 water	MgO water	MnO2 water	TiO2 water	ZrO2 water
	NP	Al	Al2O3	CuO	Fe2O3	MgO	MnO2	TiO2	ZrO2
	Concentration of NP in product	50-99% (based on supplier info)	50-99% (based on supplier info)	50-99% (based on supplier info)	99% (based on supplier info)	100% (based on supplier info)	50-99% (based on supplier info)	99.97% (based on supplier info)	100% (based on supplier info)
	Name risk assessment	Al NP	Al2O3 NP	MgO NP	Fe2O3 NP	MgO NP	MnO2 NP	TiO2 NP	ZrO2 NP
Result risk assessment	**Hazard class**	B	B	B	B	B	C	D	B
	Exposure class	1	1	1	1	1	1	1	1
	Risk score	III	III	III	III	III	III	II	III
Question	**Entered data**	Handling of NP	Handling of NP	Handling of NP	Handling of NP	Handling of NP	Handling of NP	Handling of NP	Handling of NP
	Source domain	NA	NA	NA	NA	NA	NA	NA	NA
	Appearance	Powder	Powder	Powder	Powder	Powder	Powder	Powder	Powder
	Product dustiness	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown
	Product moisture content	Dry (< 5% moisture content)	Dry (< 5% moisture content)	Dry (< 5% moisture content)	Dry (< 5% moisture content)	Dry (< 5% moisture content)	Dry (< 5% moisture content)	Dry (< 5% moisture content)	Dry (< 5% moisture content)
	Dilution	NA	NA	NA	NA	NA	NA	NA	NA
	Viscosity	NA	NA	NA	NA	NA	NA	NA	NA
	Fibers	No	No	No	No	No	No	No	No
	Fiber size	No	No	No	No	No	No	No	No
	Hazardous properties	Harmful and/or irritating	Harmful and/or irritating	Harmful and/or irritating	Harmful and/or irritating	Harmful and/or irritating	Toxic, corrosive and/or respiratory allergens	Carcinogenic, reprotoxic and/or very toxic	Harmful and/or irritating
	NP type	NA	NA	NA	NA	NA	NA	NA	NA
	No. employees that can be exposed	3	3	3	3	3	3	3	3
	Production or usage	1	1	1	1	1	1	1	1

Stoffenmanager questions		Al	Al_2O_3	CuO	Fe_2O_3	MgO	MnO_2	TiO_2	ZrO_2
	volume								
	Start date of product work period	8/1/2017	8/1/2017	8/1/2017	8/1/2017	8/1/2017	8/1/2017	8/1/2017	8/1/2017
	End data of product work period	8/1/2018	8/1/2018	8/1/2018	8/1/2018	8/1/2018	8/1/2018	8/1/2018	8/1/2018
	Actualisation date	NA	NA	NA	NA	NA	NA	NA	NA
Task	**Task**	Handling small amts (up to 100 g) or low quantities likely to be released	Handling small amts (up to 100 g) or low quantities likely to be released	Handling small amts (up to 100 g) or low quantities likely to be released	Handling small amts (up to 100 g) or low quantities likely to be released	Handling small amts (up to 100 g) or low quantities likely to be released	Handling small amts (up to 100 g) or low quantities likely to be released	Handling small amts (up to 100 g) or low quantities likely to be released	Handling small amts (up to 100 g) or low quantities likely to be released
	Duration of task	1-30 min/day	1-30 min/day	1-30 min/day	1-30 min/day	1-30 min/day	1-30 min/day	1-30 min/day	1-30 min/day
	Frequency of task	~1day/2wks	~1day/2wks	~1day/2wks	~1day/2wks	~1day/2wks	~1day/2wks	~1day/2wks	~1day/2wks
	Task in breathing zone	No	No	No	No	No	No	No	No
	Multiple employees	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Regular cleaning of working room	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Regular inspections and maintenance	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Control measures at source	Local exhaust ventilation	Local exhaust ventilation	Local exhaust ventilation	Local exhaust ventilation	Local exhaust ventilation	Local exhaust ventilation	Local exhaust ventilation	Local exhaust ventilation
	Segregation of employee	Mechanical and/or natural ventilation	Mechanical and/or natural ventilation	Mechanical and/or natural ventilation	Mechanical and/or natural ventilation	Mechanical and/or natural ventilation	Mechanical and/or natural ventilation	Mechanical and/or natural ventilation	Mechanical and/or natural ventilation
	Protection of employee	Filter mask P2	Filter mask P2	Filter mask P2	Filter mask P2	Filter mask P2	Filter mask P2	Filter mask P2	Filter mask P2

Table S-8. Detailed results from NanoGRID applied to ENMs in case study. ENM = engineered nanomaterial; NP = nanoparticle; NA = not available or applicable. Note: the questions listed below are slightly abbreviated questions from the NanoGRID methodology for brevity reasons.

NanoGRID questions			Al	Al_2O_3	CuO	Fe_2O_3	MgO	MnO_2	TiO_2	ZrO_2
Tier 1. Screening criteria	**1.1.1 Basic information**	Name of ENM-enabled product	Al water treatment	Al_2O_3 water treatment	CuO water treatment	Fe_2O_3 water treatment	MgO water treatment	MnO2 water treatment	TiO_2 water treatment	ZrO_2 water treatment
		ENM chemical composition	Al	Al_2O_3	CuO	Fe_2O_3	MgO	MnO2	TiO2	ZrO2
		Commercial name of product	Aluminum powder, spherical, APS 60-80nm	Aluminum oxide, 99.9%	Copper (II) oxide, nanopowder	Iron (III) oxide, nanopowder, 99.95%	Magnesium oxide, nanopowder, 99+%	Manganese dioxide MnO_2 nanoparticles (MnO_2, 98%, 50nm)	Titanium (IV) oxide, anatase, nanopowder, 99.7%	Zirconium (IV) oxide, nanopowder, <100 nm particle size (TEM)
		Stage of development	Lab scale	Lab scale	Lab scale	Lab scale	Lab scale	Lab scale	Lab scale	Lab scale
		Vendor, if ENM purchased	Alfa Aesar	Alfa Aesar	Alfa Aesar	Alfa Aesar	Alfa Aesar	NPs synthesized in NC State lab (grown on nanofibrous filter media)	Alfa Aesar	Sigma-Aldrich
		Manufacturer	Vendor	Vendor	Vendor	Vendor	Vendor	NA	Vendor	Vendor
		Primary use of ENM	Absorbant	Absorbant	Absorbant	Absorbant	Absorbant	Absorbant	Absorbant	Absorbant
		Purpose of manufacturing material in nano-scale	Increased surface area, reactivity	Increased surface area, reactivity	Increased surface area, reactivity	Increased surface area, reactivity	Increased surface area, reactivity	Increased surface area, reactivity	Increased surface area, reactivity	Increased surface area, reactivity
		Multiple types of ENMs?	No	No	No	No	No	No	No	No
		List other types of ENMs	NA	NA	NA	NA	NA	NA	NA	NA

NanoGRID questions			Al	Al_2O_3	CuO	Fe_2O_3	MgO	MnO_2	TiO_2	ZrO_2
		Test these separately?	No	No	No	No	No	No	No	No
		Rationale for not testing all ENMs	Outside scope	Outside scope	Outside scope	Outside scope	Outside scope	Outside scope	Outside scope	Outside scope
	1.1.2 Technical questions	ENM particulate or part of structure?	NP	NP	NP	NP	NP	NP	NP	NP
		List all similar materials	NA	NA	NA	NA	NA	NA	NA	NA
		ENM received as dry powder or wet suspension?	Dry powder	Dry powder	Dry powder	Dry powder	Dry powder	NPs grown on nanofibrous filter media	Dry powder	Dry powder
		If "Other," describe	NA	NA	NA	NA	NA	NA	NA	NA
		Size of ENM	60-80nm	60nm	30-50nm	3nm	100nm	50nm	15nm	<100nm
		Shape of ENM	Sphere	Sphere	Sphere	Sphere	Sphere	Sphere	Sphere	Sphere
		Chemical composition of ENM	Al	Al_2O_3	CuO	Fe_2O_3	MgO	MnO_2	TiO_2	ZrO_2
		Multiple chemical components ?	No	No	No	No	No	No	No	No
		Other chemical components	No	No	No	No	No	No	No	No
		Describe product	Water treatment application that involves water	Water treatment application that involves water	Water treatment application that involves	Water treatment application that involves	Water treatment application that involves	Water treatment application that involves water	Water treatment application that involves water	Water treatment application that involves water

NanoGRID questions			Al	Al_2O_3	CuO	Fe_2O_3	MgO	MnO_2	TiO_2	ZrO_2
			flowing through ENMs in closed container	flowing through ENMs in closed container	water flowing through ENMs in closed container	water flowing through ENMs in closed container	water flowing through ENMs in closed container	flowing through ENMs in closed container	flowing through ENMs in closed container	flowing through ENMs in closed container
	1.2 Technology category	Select location of ENM[4]	Category 3B. Fluid Suspended Nano-Object, 3-D structure	Category 3B. Fluid Suspended Nano-Object, 3-D structure	Category 3B. Fluid Suspended Nano-Object, 3-D structure	Category 3B. Fluid Suspended Nano-Object, 3-D structure	Category 3B. Fluid Suspended Nano-Object, 3-D structure	Category 3A. Surface Bound Nano-Object, 3-D structure	Category 3B. Fluid Suspended Nano-Object, 3-D structure	Category 3B. Fluid Suspended Nano-Object, 3-D structure
	1.3 ENM definition	Select best ENM definition[74-76]	US EPA TSCA Section 8, and/or EU 2011 definition[75,76]	US EPA TSCA Section 8, and/or EU 2011 definition[75,76]	US EPA TSCA Section 8, and/or EU 2011 definition[75,76]	US EPA TSCA Section 8, and/or EU 2011 definition[75,76]	US EPA TSCA Section 8, and/or EU 2011 definition[75,76]	US EPA TSCA Section 8, and/or EU 2011 definition[75,76]	US EPA TSCA Section 8, and/or EU 2011 definition[75,76]	US EPA TSCA Section 8, and/or EU 2011 definition[75,76]
	Tier 1 Conclusion		Proceed to Tier 2	Proceed to Tier 2	Proceed to Tier 2	Proceed to Tier 2	Proceed to Tier 2	Proceed to Tier 2	Proceed to Tier 2	Proceed to Tier 2
Tier 2. Potential release	**2.1 Release** **Product classification and use**	Is ENM a freely dispersed particle (product class 3B or 3D)?	Yes (Category IIIB)	Yes (Category IIIB)	Yes (Category IIIB)	Yes (Category IIIB)	Yes (Category IIIB)	No (Category IIIA)	Yes (Category IIIB)	Yes (Category IIIB)
	Conservative release scenario	Does ENM have known hazard concentrations?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Complete “Hazard	Ok, continue	Ok, continue	Ok, continue	Ok, continue	Ok, continue	Ok, continue	Ok, continue	Ok, continue

NanoGRID questions			Al	Al_2O_3	CuO	Fe_2O_3	MgO	MnO_2	TiO_2	ZrO_2
		identification" page								
		If 100% of ENM in product were released, would it be below screening thresholds?	No	No	No	No	No	Yes	No	No
	2.2 Hazard identification	Relevant hazard values found for ENM?	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	2.2.1 Environmental hazard screening	PNEC method	ECHA method	ECHA method	ECHA method	ECHA method	ECHA method	ECHA method	ECHA method	ECHA method
		PNEC: Enter <u><</u>4 effect levels, at least 1 acute or chronic is required	**Acute:** Species 1: 219000 ppb, LC50, Daphnia, immobilization, 24H[21] Species 2: 7483 ppb, LC50, Daphnia, immobilization, 48H[21] **Chronic:** None	**Acute:** Species 1: 162392 ppb, LC50, Daphnia, mortality, 48H[26] Species 2: 162392 ppb, EC50, Daphnia, Immobilization, 48H[26] **Chronic:** None	**Acute:** Species 1: 92700 ppb, EC50, Daphnia, mortality, 48H[77] Species 2: 80000 ppb, EC50, Tetrahymena thermophila, 24H, viability (atp content)[78] Species 3: 28000ppb,	**Acute:** Species 1: 36060 ppb, EC50, Danio rerio, 48H, hatching rate[40] Species 2: 53350 ppb, LC50, Danio rerio, 168H mortality [40] **Chronic:** Species 1, 100000	**Acute:** Species 1: 174000 ppb, IC50, Hela cells, 72H, cell viability [81] Species 2: 240030 ppb, IC50, SNU-16, cell viability[81] Species 3: 233330ppb, IC50, AGS, cell viability[81]	**Acute:** Species 1: 10000 ppb, EC50, Chlorella Pyrenoidosa, 48H, mortality[46] Species 2: 170000 ppb, EC 50, Saccharomyces cerevisae, oxygen consumption [82] **Chronic:**	**Acute:** Species 1: 10910 ppb, Phaeodactylum tricornutum, 72H, growth inhibition[48] Species 2: 35306 ppb, EC50, Daphnia Magma, 48H, immobilization [26] Species 3: 800 ppb, EC50,	**Acute:** Species 1: 10000 ppb, EC50, Saccharomyces cerevisae, oxygen content[82]

NanoGRID questions			Al	Al_2O_3	CuO	Fe_2O_3	MgO	MnO_2	TiO_2	ZrO_2
					LC50, Nitellopsis Obtusa, 96H, mortality, [79] **Chronic:** None	ppb, NOEC, Ceriodaphnia dubia, 48H, mortality, [80]	**Chronic:** None	None	Daphnia Magma, 48H, mortality[83] **Chronic:** Species 1: NOEC, Cyprinus carpio, mortality[84] Species 2: NOEC, Danio rerio [85]	
		Calculated PNEC from NanoGRID (ppb)	40.41	136.27	59.21	1000	213.57	41.20	20	100
		PEC: Model to compute PEC	None	57,000 ppb (mg/kg), sediment[86]	None	16,000 ppb, sediment (mg/kg)[86]	None	None	65,000 ppb (mg/kg), sediment[87]	None
	2.2 Hazard identification **2.2.2 Human health**	Effect values for: Inhalation Dermal Ingestion	None	None	None	None	None	None	Inhalation: 5 mg/cm3 Dermal: below detection limit Ingestion: 15 mg/kg	None

NanoGRID questions		Al	Al_2O_3	CuO	Fe_2O_3	MgO	MnO_2	TiO_2	ZrO_2
								88	
	Tier 2 Conclusion	Proceed to Tier 3. Based on: Unbound, loose NPs; Assume 100% release potential and persistency; Potential risks cannot be dismissed; More information needed on fate	Proceed to Tier 3. Based on: Unbound, loose NPs; Assume 100% release potential and persistency; Potential risks cannot be dismissed; More information needed on fate	Proceed to Tier 3. Based on: Unbound, loose NPs; Assume 100% release potential and persistenc y; Potential risks cannot be dismissed; More informatio n needed on fate	Proceed to Tier 3. Based on: Unbound, loose NPs; Assume 100% release potential and persistenc y; Potential risks cannot be dismissed; More informatio n needed on fate	Proceed to Based on: Unbound, loose NPs; Assume 100% release potential and persistenc y; Potential risks cannot be dismissed; More informatio n needed on fate	Perform ENM release tests, using corrosion- and aqueous- based tests and different aging times to get more information on ENM release	Proceed to Tier 3. Based on: Unbound, loose NPs; Assume 100% release potential and persistency; Potential risks cannot be dismissed; More information needed on fate	Proceed to Tier 3. Based on: Unbound, loose NPs; Assume 100% release potential and persistency; Potential risks cannot be dismissed; More information needed on fate

Table S-9. Detailed results from NanoGRID applied to MnO_2 NP for release potential (category IIIA, surface bound NP using[4]). Each question is scored from 0 to 5 by the user, where 0 indicates no probability and 5 indicates high probability of occurrence. The Total Release Score (90th Percentile) reflects the average score from the associated questions in each category. *Aging is not well-defined in NanoGRID and no specific release tests are identified; rather the user is recommended to perform several potential ENM release tests over time to characterize aging factors on ENM release.

Category	Question	Question Score	Total Release Score (90th Percentile)
Aqueous	1. The material will be immersed in water or be submerged during use	5	3

Category	Question	Question Score	Total Release Score (90th Percentile)
	2. The material will be used in an external setting and have the potential to be rained on	0	
	3. The material will be used in an environment that is subjected to acid rain	0	
	4. The material will be used in an environment that is subjected to large changes in humidity	5	
	5. The material will be exposed to water periodically via some other means (e.g., washing, rinsing, splashing, etc.)	5	
Ultraviolet	6. The material will be used outdoors	0	0
	7. The material will be exposed to sunlight or artificial UV light either directly or intermittently	0	
Thermal	8. The product will be exposed to temperature fluctuations (e.g.-used outdoors and indoors)	3	0.8
	9. Any process that uses heat (e.g., hot air, sunlight, resistive heating, etc.) to remove liquid from the surface or interior of the product. This includes air dryers, clothes dryers, and other thermal processes	0	
	10. The product will experience temperatures exceeding room temperature	0	
	11. The product/material will experience temperatures associated with a freezing event	0	
Mechanical	12. Mechanical stress caused by a singular sharp or angular object coming into contact with the surface of the material	0	0.8
	13. Mechanical stress caused by intentional abrasion with a sanding or polishing surface (e.g., sandpaper, cloth, etc.)	0	
	14. Mechanical stress caused by externally applied force compressing the material	2	
	15. Mechanical stress caused by jarring or impact from release of gravitational potential energy (being dropped)	0	
	16. Mechanical stress from multiple abrasive interactions (e.g., exposure to dirt, grit, friction with other objects, etc.)	5	
	17. Intense abrasion due to an intentional or unintentional repetitive motion with significant friction	0	
	18. Separation of parts of the material due to strong abrasive or shear forces	0	
	19. Mechanical stress caused by a drill or drilling-like interaction	0	
	20. Strong abrasion due to repetitive impact of small, abrasive material, including intentional sandblasting or incidental exposure (e.g., wind-blown particles)	0	
	21. Shaking, bumping, bouncing or other mechanical stress due to movement	1	
Combustion	22. The material will be incinerated or exposed to flame, fire, or combustion during use	0	0
Chemical Reactivity	23. It will be exposed to chemical agents for cleaning	1	0.8
	24. It will be exposed to surfactants	1	
	25. The material can inadvertently come into contact with other chemical solutions (spills, splashes, sprays, accidental exposure, etc.)	0	
Corrosion	26. It will be subjected to corrosive cleaning agents	1	2.3
	27. The material will be subjected to redox in the environment	1	

Category	Question	Question Score	Total Release Score (90th Percentile)
	28. The material will be used in salt water environments	5	
Aging*	29. Given the product use characteristics and properties is material aging a concern	5*	5*

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