SUBSTANCE EVALUATION CONCLUSION

as required by REACH Article 48
and
EVALUATION REPORT

for

Silver

EC No 231-131-3
CAS No 7440-22-4

Evaluating Member State(s): The Netherlands

Dated: 30 November 2018

Evaluating Member State Competent Authority

The Netherlands

Bureau REACH on behalf of the Ministry of Infrastructure and Water Management and the National Institute for Public Health and the Environment

P.O. Box 1

3720 BA Bilthoven

The Netherlands

Email: CA.REACH.NL@MINIENM.NL; bureau-reach@rivm.nl

Year of evaluation in CoRAP: 2014

Before concluding the substance evaluation a Decision to request further information was issued on: 6 July 2016

Further information on registered substances here:

http://echa.europa.eu/web/guest/information-on-chemicals/registered-substances

DISCLAIMER

This document has been prepared by the evaluating Member State as a part of the substance evaluation process under the REACH Regulation (EC) No 1907/2006. The information and views set out in this document are those of the author and do not necessarily reflect the position or opinion of the European Chemicals Agency or other Member States. The Agency does not guarantee the accuracy of the information included in the document. Neither the Agency nor the evaluating Member State nor any person acting on either of their behalves may be held liable for the use which may be made of the information contained therein. Statements made or information contained in the document are without prejudice to any further regulatory work that the Agency or Member States may initiate at a later stage.

Foreword

Substance evaluation is an evaluation process under REACH Regulation (EC) No. 1907/2006. Under this process the Member States perform the evaluation and ECHA secretariat coordinates the work. The Community rolling action plan (CoRAP) of substances subject to evaluation, is updated and published annually on the ECHA web site[1].

Substance evaluation is a concern driven process, which aims to clarify whether a substance constitutes a risk to human health or the environment. Member States evaluate assigned substances in the CoRAP with the objective to clarify the potential concern and, if necessary, to request further information from the Registrant(s) concerning the substance. If the evaluating Member State concludes that no further information needs to be requested, the substance evaluation is completed. If additional information is required, this is sought by the evaluating Member State. The evaluating Member State then draws conclusions on how to use the existing and obtained information for the safe use of the substance.

This Conclusion document, as required by Article 48 of the REACH Regulation, provides the final outcome of the Substance Evaluation carried out by the evaluating Member State. The document consists of two parts *i.e.* A) the conclusion and B) the evaluation report. In the conclusion part A, the evaluating Member State considers how the information on the substance can be used for the purposes of regulatory risk management such as identification of substances of very high concern (SVHC), restriction and/or classification and labelling. In the evaluation report part B the document provides explanation how the evaluating Member State assessed and drew the conclusions from the information available.

With this Conclusion document the substance evaluation process is finished and the Commission, the Registrant(s) of the substance and the Competent Authorities of the other Member States are informed of the considerations of the evaluating Member State. In case the evaluating Member State proposes further regulatory risk management measures, this document shall not be considered initiating those other measures or processes. Further analyses may need to be performed which may change the proposed regulatory measures in this document. Since this document only reflects the views of the evaluating Member State, it does not preclude other Member States or the European Commission from initiating regulatory risk management measures which they deem appropriate.

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[1] http://echa.europa.eu/regulations/reach/evaluation/substance-evaluation/community-rolling-action-plan

Contents

Part A. Conclusion

1. CONCERN(S) SUBJECT TO EVALUATION

Silver was originally selected for substance evaluation in order to clarify concerns about Nanoparticles/Ecotoxicity of different forms of the substance; Environmental fate; Exposure/Wide dispersive use; aggregated tonnage.

The scope of the substance evaluation was limited to the properties of and information on nanoforms of silver. Thus this evaluation did not include a full evaluation of all elements of the registration dossiers but was targeted to the characterisation of the substance, environmental fate properties, environmental hazard assessment and exposure assessment of the nanoforms of silver that are covered by the REACH registration dossier(s) submitted for silver.

During the evaluation no other concern was identified.

2. OVERVIEW OF OTHER PROCESSES / EU LEGISLATION

Silver (EC No. 231-131-3), including silver as a nanomaterial, is under review by Sweden in the Review Programme of the Biocidal Active Substances.

3. CONCLUSION OF SUBSTANCE EVALUATION

The evaluation of the available information on the substance has led the evaluating Member State to the following conclusions, as summarised in Table 1 below.

Table 1

CONCLUSION OF SUBSTANCE EVALUATION	
Conclusions	**Tick box**
Need for follow-up regulatory action at EU level	X
Harmonised Classification and Labelling	X
Identification as SVHC (authorisation)	
Restrictions	
Other EU-wide measures	
No need for regulatory follow-up action at EU level	

4. FOLLOW-UP AT EU LEVEL

4.1. Need for follow-up regulatory action at EU level

4.1.1. Harmonised Classification and Labelling

At present there is only a harmonised classification for silver nitrate (EC No. 231-853-9). According to Regulation (EC) No 1272/2008, Annex VI, silver nitrate is classified as Aquatic Acute 1 – H400 and Aquatic Chronic 1 – H410. No M-factors are yet included. In the registration dossier for silver nitrate M-factors for acute and chronic of 1000 and 100 are applied, respectively.

Based on the new data provided, there is no reason to classify the nanoforms of silver (EC No. 231-131-3) more stringently than silver nitrate. In the registration dossier for the nanoforms of silver the same classification and M-factors are applied as those indicated above for silver nitrate.

4.1.2. Identification as a substance of very high concern, SVHC (first step towards authorisation)

Not applicable.

4.1.3. Restriction

Not applicable.

4.1.4. Other EU-wide regulatory risk management measures

Not applicable.

5. CURRENTLY NO FOLLOW-UP FORESEEN AT EU LEVEL

5.1. No need for regulatory follow-up at EU level

Not applicable.

6. TENTATIVE PLAN FOR FOLLOW-UP ACTIONS (IF NECESSARY)

At present the biocidal use of different forms of silver (including nanocomposite forms) and silver salts is being assessed by Sweden. This will eventually result in CLH-proposals for each of these silver forms. Currently, Sweden is in the process of deciding on a Classification & Labelling proposal for elemental silver.

Table 2

FOLLOW-UP		
Follow-up action	**Date for intention**	**Actor**
Proposal for a harmonised classification according to article 37(1), CLP regulation.	To be determined	Sweden

Part B. Substance evaluation

7. EVALUATION REPORT

7.1. Overview of the substance evaluation performed

Silver was originally selected for substance evaluation in order to clarify concerns about Nanoparticles/Ecotoxicity of different forms of the substance; Environmental fate; Exposure/Wide dispersive use; aggregated tonnage.

The scope of the substance evaluation was limited to the properties of and information on nanoforms of silver. Thus this evaluation did not include a full evaluation of all elements of the registration dossiers but was targeted to the characterisation of the substance, environmental fate properties, environmental hazard assessment and exposure assessment of the nanoforms of silver that are covered by the REACH registration dossier(s) submitted for silver.

The Registrant(s) had proposed that the toxicity of ionic silver can be taken as a worst case for the hazard assessment of nanoforms of silver. The evaluating MSCA (eMSCA) had a concern that the environmental toxicity of nanoforms of silver may potentially be higher than that of silver nitrate (ionic silver) commonly used in risk assessment calculations.

Insufficient information was provided by the Registrant(s) in their original registration dossiers to judge to what extent the read-across of data from ionic silver to the nanoforms covered by the REACH registration was justified for environmental fate and ecotoxicity.

It was also unclear what the uses are of the individual nanoforms of silver covered by the registration dossier.

During the evaluation no other concern was identified.

With reference to the current Commission Recommendation on the definition of nanomaterial (EU, 2011), a nanoform of silver is defined as a form of silver that contains particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50% or more of the particles in the number size distribution, one or more external dimensions is in the size range 1 nm – 100 nm.

Nanomaterials are being engineered for their specific physico-chemical and biological characteristics, meaning that their reactivity and/or behaviour (such as their interaction with their environment) will depend on these characteristics. Although the toxicological profile of the chemical components of a given nanomaterial may be well known, there may be cases where its specific properties raise concerns about the specific potential to harm humans and the environment (SCENIHR, 2010).

In addition, nanomaterials may change during their life cycle. Parameters such as size, aggregation states, surface charge, coatings and other properties may change in different solvents, test media, and biological environments (SCCS, 2012; EC, 2013).

Therefore, the following information was requested (6 July 2016) in the Decision[2]:

Request 1: Information on ecotoxicity for the smallest nanoform of Silver with the highest specific surface area that is covered by the REACH registration dossier(s) submitted for Silver, *i.e.* information on toxicity to algae, aquatic invertebrates and soil microorganisms, according to OECD Test Guidelines No. 201, 211 and 216, respectively. For each of these tests, adaptations were requested concerning the composition of the test media, monitoring of the ratio between particulate and ionic silver throughout the tests, and including a control with exposure to silver nitrate. Furthermore, it was requested that the nanoform tested was sufficiently characterised (granulometry, specific surface area by volume, identification of surface treatment agent(s), dissolution rate, density and point of zero charge).

Request 2: Quantitative information on the fate of the nanoform of silver in soil pore water and the soil solid fraction. This information request only needs to be fulfilled in case the results of one of the ecotoxicity test as formulated under Request 1 indicate a higher toxicity of silver nanoparticles as compared to ionic silver.

Request 3: Information on the uses of each individual nanoform of silver that is registered.

On 5 July 2017 the Registrant(s) updated their dossier with information requested in Request 1 and Request 3. The tests were performed using the smallest nanoform with the highest specific surface area covered by the Silver REACH Registration dossier.

The results from the newly performed tests indicate that silver nitrate was either equally or more toxic as compared to silver nanoparticles. Therefore, the concern that silver nitrate (ionic silver) may not be a proper ‘worst case’ in the risk assessment regarding toxicity of the nanoforms of silver that are covered by the REACH registration dossier(s) submitted for silver is now removed. Furthermore, information Request 2 no longer needs to be fulfilled.

Annex 1 to the CSR was updated by the Registrant(s) with two specific exposure scenarios for the use of silver in nanoform. According to the information submitted, the use of silver in nanoform is limited to industrial use in sintering processes for production of electronics. Therefore, exposure scenarios for “Manufacture of nanosilver” and “Use of nanosilver in sintering processes for production of electronics” were specified and the use of silver in nanoforms was removed from the other exposure scenarios. For the newly specified scenarios risk characterisation ratios (RCRs) were derived that were (far) below those of other forms of silver, further limiting the concern that silver nitrate (ionic silver) may not be a proper ‘worst case’ in the risk assessment of the nanoforms of silver in the registration.

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[2] The Decision is publicly available at: https://echa.europa.eu/documents/10162/3f2ad1e1-0fe2-4802-bd58-252b0d84e10b

Table 3

EVALUATED ENDPOINTS	
Endpoint evaluated	**Outcome/conclusion**
Toxicity to algae	Test results indicate that silver nitrate (ionic silver) is more toxic than the nanoform of silver. Concern removed. No further action needed.
Long-term toxicity to aquatic invertebrates	Test results indicate that silver nitrate (ionic silver) is more toxic than the nanoform of silver. Concern removed. No further action needed.
Toxicity to soil microorganisms	Test results indicate that silver nitrate (ionic silver) is equally or more toxic than the nanoform of silver. Concern removed. No further action needed.
Fate of silver nanoparticles in soil and pore water	Information request expires due to outcome of above ecotoxicity tests. No further action needed.

7.2. Procedure

The procedure leading to the Decision on silver is summarised in that Decision and made publicly available on 6 July 2016[3].

On 24 November 2016 the Registrant(s) discussed with the evaluating MSCA (eMSCA) initial range finding results and the test set-up for definitive tests. On 22 May 2017 the Registrant(s) discussed with eMSCA the draft results of the definitive tests.

On 5 July 2017 the Registrant(s) complied with the information requests and updated the registration dossier accordingly.

Since July 2017 the updated registration dossier has been evaluated by the eMSCA.

The conclusion document was finalised on 30 November 2018.

7.3. Identity of the substance

Table 4

SUBSTANCE IDENTITY	
Public name:	Silver
EC number:	231-131-3
CAS number:	7440-22-4

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[3] The Decision is publicly available at: https://echa.europa.eu/documents/10162/3f2ad1e1-0fe2-4802-bd58-252b0d84e10b

SUBSTANCE IDENTITY	
Index number in Annex VI of the CLP Regulation:	–
Molecular formula:	Ag
Molecular weight range:	107.8682
Synonyms:	**Trade names:** Ag Granalien; ARGENTO; BRM001; BRM017; BRM073; Fine silver; Impure Silver Ingot; Silber Kristalle 5N; Silver; silver bullion; Silver granules; Silver Ingot; silver ingots; Silver powder; SrA-1; SrA-2; SrCH-1; SrCH-2; Syndox **IUPAC names:** Silver; silver(1+)

Type of substance ☒ Mono-constituent ☐ Multi-constituent ☐ UVCB

Structural formula:

Ag^+

7.4. Physico-chemical properties

Table 5

OVERVIEW OF PHYSICO-CHEMICAL PROPERTIES*	
Property	**Value**
Physical state at 20°C and 101.3 kPa	Solid
Melting point at 101.3 kPa	961.93 °C
Boiling point at 101.3 kPa	2187 °C
Vapour pressure	0.013 Pa at 840 °C
Water solubility	30 ng/L
Flammability	Non flammable
Explosive properties	Non-explosive
Oxidising properties	No

<table>
<tr><th colspan="2">OVERVIEW OF PHYSICO-CHEMICAL PROPERTIES*</th></tr>
<tr><th>Property</th><th>Value</th></tr>
<tr><td>Granulometry</td><td>
<p>Silver is produced in various forms: powders (non-nano and nano-size) and massives (ingots, wires...). Powders are produced with variable specifications, including various particle size distributions.</p>
<p>Particle size data have been generated for the nanoforms of silver covered by the REACH registration dossier (Nano sample 1 and 2).</p>
<p>Nanosilver is usually marketed in suspension/wet powder form. The table below gives an overview of registered nanosilver products. For confidentiality reasons, the information on coatings and solvents has been omitted from the summary table below. The morphology was determined by visual inspection of Transmission Electron Microscopy (TEM) images. Quantitative analysis was done by TEM combined with ParticleSizer software. The volume specific surface area was calculated from the particle size (mean diameter).</p>
<table>
<tr><th>Nano sample</th><th>Type</th><th>Size of primary particles*</th><th>Morphology</th><th>Volume Specific Surface Area</th></tr>
<tr><td>1</td><td>suspension/ wetted powder</td><td>Min: 5 nm
D25: 7 nm
D50: 8 nm
D75: 9 nm
Max: 61 nm</td><td>spherical</td><td>714 m^2/cm^3</td></tr>
<tr><td>2</td><td>suspension/ wetted powder</td><td>Min: 11 nm
D25: 25 nm
D50: 34 nm
D75: 48 nm
Max: 161 nm</td><td>spherical</td><td>150 m^2/cm^3</td></tr>
</table>
<p>* Determined by TEM (Min. Feret diameter)</p>
</td></tr>
</table>

** This information refers to silver in general, unless indicated otherwise.*

In addition, the following physico-chemical properties of the nanoforms of silver were measured: agglomeration / aggregation, specific surface area, zeta potential, pour density. The results are presented in Table 6. For confidentiality reasons, the information on identification of surface treatment agents is not reported here.

The results show that of the two nanoforms that are covered by the Silver REACH Registration dossier, Nano sample 1 is the smallest nanoform with the highest specific surface area. Furthermore, the physico-chemical properties of the nanoforms of silver indicate that the nanoparticles have a tendency to aggregate, which influences their behaviour in the environment and ecotoxicological tests (see also Section 7.7 and Section 7.8).

Table 6

<table>
<tr><th colspan="3">ADDITIONAL PHYSICOCHEMICAL PROPERTIES OF THE SILVER NANOFORMS</th></tr>
<tr><th>Property</th><th>Description</th><th>Value</th></tr>
<tr><td>Agglomeration / aggregation</td><td>Particle size data of the agglomerates have been generated for the nanosilver forms covered by the REACH registration dossier (Nano sample 1 and 2).
Mean size of agglomerates vary between 8.5 and 50 nm.</td><td>Nanosilver is usually marketed in suspension/wet powder form. The table below gives an overview of registered nanosilver products and their agglomerate size.
<table>
<tr><th>Code</th><th>Type</th><th>Size of agglomerates*</th></tr>
<tr><td>1</td><td>suspension/wetted powder</td><td>Min: 0 nm
D25: 7 nm
D50: 8 nm
D75: 9 nm
Max: 62 nm</td></tr>
<tr><td>2</td><td>suspension/wetted powder</td><td>Min: 0.6 nm
D25: 26 nm
D50: 36 nm
D75: 57 nm
Max: 370 nm</td></tr>
</table>
* Determined by TEM (Min. Feret diameter)</td></tr>
<tr><td>Specific surface area</td><td>The Volume Specific Surface Area (VSSA) has been calculated for the nanosilver forms covered by the REACH registration dossier (Nano sample 1 and 2).
Results vary between 150 and 714 m^2/cm^3</td><td>Nanosilver is usually marketed in suspension/wet powder form. The table below gives an overview of registered nanosilver products and their Volume Specific Surface Area (VSSA).
<table>
<tr><th>Code</th><th>Type</th><th>VSSA (m^2/cm^3)</th><th>SSA (m^2/g)</th></tr>
<tr><td>1</td><td>suspension/wetted powder</td><td>714</td><td>133</td></tr>
<tr><td>2</td><td>suspension/wetted powder</td><td>150</td><td>28.2</td></tr>
</table></td></tr>
<tr><td>Zeta potential</td><td>Zeta potential and isoelectric point (IEP) have been determined for the nanosilver forms covered by the REACH registration dossier (Nano sample 1 and 2).
The zeta potential varies between -23.3 and -33.5 mV and the IEP is for both samples <pH 1.</td><td>Nanosilver is usually marketed in suspension/wet powder form. The table below gives an overview of registered nanosilver products and their zeta potential an isoelectric point.
<table>
<tr><th>Code</th><th>Type</th><th>Zeta potential</th><th>Isoelectric point</th></tr>
<tr><td>1</td><td>suspension/wetted powder</td><td>-33.5 mV (pH = 5.5)</td><td>< pH 0.2</td></tr>
<tr><td>2</td><td>suspension/wetted powder</td><td>-23.3 mV (pH = 5.5)</td><td>< pH 1</td></tr>
</table></td></tr>
</table>

<table>
<tr><th colspan="3">ADDITIONAL PHYSICOCHEMICAL PROPERTIES OF THE SILVER NANOFORMS</th></tr>
<tr><th>Property</th><th>Description</th><th>Value</th></tr>
<tr><td>Pour density</td><td>Bulk density has been determined by helium pycnometry analysis for the nanosilver forms covered by the REACH registration dossier (Nano sample 1 and 2).
Results vary between 5.34 and 5.38 g/cm³.</td><td>Nanosilver is usually marketed in suspension/wet powder form. The table below gives an overview of registered nanosilver products and their bulk density.
<table>
<tr><th>Code</th><th>Type</th><th>Bulk density (g/cm³)</th></tr>
<tr><td>1</td><td>suspension/wetted powder</td><td>5.38</td></tr>
<tr><td>2</td><td>suspension/wetted powder</td><td>5.34</td></tr>
</table></td></tr>
</table>

7.4.1. Transformation/dissolution studies

The transformation/dissolution of the nanosilver test sample (Nano sample 1: median particle size 8 nm) was determined in the test media used for the Daphnia and algae testing, following OECD guidance 29. Three silver fractions in the media were measured: total silver, conventional dissolved silver (< 0.45 µm; *i.e.* ionic silver + silver particles with diameter < 450 nm) and truly dissolved silver (< 1 kDa; *i.e.* ionic silver).

In the Daphnia medium, there is an initial loss of total silver (from an initial 1153 µg/L to 254 µg/L after 7 days). This loss is partially transient reaching a plateau level of 473 µg/L after 28 days. The same steep fall in concentration of conventional dissolved silver is seen during the first days (from an initial 1074 µg/L to 99 µg/L after 7 days), after which the concentration becomes stable at levels around 120 µg/L (127 µg/L after 28 days). The truly dissolved silver concentration is very low at the start of the test (9 µg/L after 2 hrs), then slightly increases to about the same level as the conventional dissolved silver concentration (88 µg/L after 7 days and 146 µg/L after 28 days).

In the algae medium, the transformation/dissolution behaviour is very different from the one described above for Daphnia medium. The total and conventional dissolved silver concentrations in this medium decrease slightly over time but fluctuate around 1000 µg/L over the whole test period (total silver concentration is 1006 µg/L after 7 days and 957 µg/L after 28 days; conventional dissolved silver concentration is 974 µg/L after 7 days and 912 µg/L after 28 days). The truly dissolved silver concentration is very low at the start of the test (18 µg/L), then slowly increases during the test (125 µg/L after 7 days and 214 µg/L after 28 days).

These results show that this nanoform of silver only slowly dissolves in algae and Daphnia media. Assuming that only dissolved silver ions are causing toxicity (as argued by the Registrant(s)), this would suggest that longer periods of time are needed for nanosilver to induce an effect that is comparable to that of silver nitrate (ionic silver).

For the terrestrial compartment, a transformation/dissolution experiment was set up to determine the rate and extent to which the tested silver nanoform dissolved in soil pore water compared with silver nitrate. The total and truly dissolved silver (< 1 kDa) concentration was measured in the pore water of three agricultural soils (Rots, Lufa 2.2, and Poelkapelle, details on the soils are provide in Table 11) spiked with either silver nitrate or Nano sample 1.

For all of the three soils, both the total concentration and the concentration of truly dissolved silver in the pore water decreased with time, possibly due to ageing, when spiked with silver nitrate. When these soils were spiked with the nanoform, at the outset (during the first 7 – 14 days, depending on the soil) an increase was observed in both concentrations (total and truly dissolved), possible caused by dissolution of the nanoparticles, followed (from days 7 – 14 onwards, depending on the soil) by a decrease due to ageing. For all of the three soils the concentrations of silver in the pore water (total or truly dissolved) after the 97 days test period were equal or lower in the nanoform spiked soil than in those spiked with silver nitrate. In the Poelkapelle soil the concentration of truly dissolved silver in the pore water was during the whole experiment much lower in the nanoform spiked soil (generally below limit of quantification, *i.e.* < 3 µg/L) than in the silver nitrate spiked soil (decreasing from ~180 µg/L to ~4 µg/L). At 3 months after spiking none of the three soils showed a significant difference in solid:liquid distribution of total silver, of ionic silver, or of particulate silver between spiking with nanoform or silver nitrate. This shows that over time both the nanoform and the silver salt will lead to similar concentrations in the soil pore water.

7.5. Manufacture and uses

7.5.1. Quantities

Table 7

AGGREGATED TONNAGE (PER YEAR)				
☐ 1 – 10 t	☐ 10 – 100 t	☐ 100 – 1000 t	☐ 1000 – 10,000 t	☐ 10,000 – 50,000 t
☐ 50,000 – 100,000 t	☒ 100,000 – 1000,000 t	☐ > 1000,000 t	☐ Confidential	

Note that only a small fraction of this aggregated tonnage relates to nanoforms of silver.

7.5.2. Overview of uses

This substance is used in articles, by professional workers (widespread uses), in formulation or re-packing, at industrial sites and in manufacturing.

In line with the scope of this substance evaluation, only uses of the nanoforms of silver are listed here, and only environmental release categories are indicated.

Table 8

USES	
	Use(s)
Manufacture	Release to the environment of this nanosilver is likely to occur from industrial use: manufacturing of the substance.
Uses at industrial sites	Use of nanosilver in sintering processes for production of electronics Release to the environment of this substance is likely to occur from industrial use: Use at industrial site leading to inclusion into/onto article.

7.6. Classification and Labelling

7.6.1. Harmonised Classification (Annex VI of CLP)

The different forms of silver (EC no. 231-131-3) have no harmonised classification.

7.6.2. Self-classification

The following self-classifications are reported for the nanoforms of silver: Aquatic Acute 1; H400: very toxic to aquatic life; Aquatic Chronic 1; H410: very toxic to aquatic life with long lasting effects. The M-factors are 1000 and 100 for acute and chronic, respectively. These classifications for environmental hazards of the nanoforms of silver are the same as the self-classifications of silver nitrate.

Based on the new data provided, there is indeed no reason to classify the nanoforms of silver (EC no. 231-131-3) more stringently than silver nitrate (EC No. 231-853-9).

7.7. Environmental fate properties

7.7.1. Degradation

Not part of the requests of the substance evaluation as such and thus not evaluated.

7.7.2. Environmental distribution

In the aquatic environment, information on the fate of nanosilver appears mainly related to dissolution rate. Furthermore, some additional information is available from several studies (*e.g.* Johnson et al., 2011; Angel et al., 2013), indicating the influence of stabilising environmental factors, *e.g.* presence of natural organic matter.

The new studies on transformation/dissolution show that the nanoform of silver tested only slowly dissolves in algal and Daphnia media. In particular in algal medium stabilising factors appear to lead to higher stability leading to higher concentrations of larger particles (> 1 kDa) in the water column (see Section 7.4.1).

In contrast, information on the fate of nanosilver in soil is grossly lacking. The available data show that environmental fate of nanoforms of silver is different from that of ionic silver (*e.g.* Cornelis et al., 2010; Navarro et al., 2014).

The new studies on transformation/dissolution and agglomeration/aggregation in response to the request in this substance evaluation show that initially silver from the nanoform becomes more available in the pore water, as a result of dissolution processes. After 3 months, however, when effects of aging become more dominant, the differences in availability compared to silver nitrate have disappeared (see Section 7.4.1).

The newly submitted data in answer to requested toxicity tests indicate no higher toxicity for the nanoform than for silver nitrate (ionic silver) (see section 7.8), and in particular the results for Poelkapelle (see Section 7.8.2) suggest that silver ions are responsible for the toxicity for soil microorganisms observed.

As a result, the eMSCA concludes that silver nitrate may be considered a proper 'worst case' in regarding toxicity in soil for the nanoforms of silver that are covered by the REACH registration dossier(s) submitted for Silver. Therefore, further quantitative information on the fate of nanoparticles of silver following their introduction in soil as requested in Request 2 of the Decision on silver (see Section 7.1), no longer needs to be provided.

7.7.3. Bioaccumulation

Not part of the requests of the substance evaluation and thus not evaluated.

7.8. Environmental hazard assessment

The ecotoxicity tests performed in response to the request were accompanied by a transformation and dissolution test of the silver nanomaterial in algal and Daphnia media, dissolution rates in the three soils used for the microorganism toxicity test, and physico-chemical characterisation of the silver nanomaterial as requested. The nanoform tested (Nano sample 1) is the smallest nanoform with the highest specific surface area covered by the REACH Registration dossier for Silver.

7.8.1. Aquatic compartment (including sediment)

7.8.1.1. Fish

Not part of the requests of the substance evaluation and thus not further evaluated.

7.8.1.2. Aquatic invertebrates

In response to Request 1 in the Decision on Silver (see Section 7.1), the Registrant(s) updated their registration on 5 July 2017 with results from a long-term toxicity study to aquatic invertebrates.

Between July 2016 and June 2017, the Registrant(s) performed a *Daphnia magna* Reproduction Test under GLP and according to OECD Test Guideline No. 211. In accordance with the Request in the Decision, the amount of $Na_2EDTA \bullet 2(H_2O)$ was minimised and chloride salts were replaced by nitrate salts. The pH was set to the pH at which the medium equilibrates with air (in the final tests the pH was 7.94 – 9.37 and 8.25 – 9.40 for silver nitrate and silver nanoparticles, respectively) and temperature was 20.6 – 21.9 °C.

Daphnids (one daphnid per test container; 10 replicates per treatment group) were exposed to nominal concentrations of 0, 3.16, 10.0, 31.6, 100 and 316 µg Ag/L as silver nanoparticles (Nano sample 1) for 21 days under semi-static exposure conditions with renewal of test dispersions three times a week. Concentrations of total silver, ionic silver (< 3 kDa) and silver nanoparticles (up to 450 nm) were monitored throughout the study and results were based on the arithmetic means of these concentrations.

In parallel, the same test set-up as described above was used with silver nitrate instead of silver nanoparticles as the test substance. In this study, the daphnids were exposed to nominal concentrations of 0, 1.5, 3.0, 6.0, 12.0 and 24.0 µg Ag/L. Again, results were based on the arithmetic means of the concentrations of total silver, ionic silver (< 3 kDa) and silver nanoparticles (up to 450 nm).

Comparison of the results from the silver nanoparticles and the silver nitrate tests shows that EC_{10}, EC_{20}, and EC_{50} values for all endpoints (immobility, reproduction, age of first reproduction, length, intrinsic rate and development rate) were lower for silver nitrate (ionic silver) than for silver nanoparticles.

EC_{10} and EC_{50} values for reproduction of *Daphnia magna* are summarised in Table 9.

Table 9

RESULTS OF DAPHNIA REPRODUCTION TEST *			
Measured fraction	**Test substance**	**Reproduction EC$_{10}$ (µg Ag/L)**	**Reproduction EC$_{50}$ (µg Ag/L)**
Total silver	Silver nitrate Nanosilver	5.371 (2.888 – 7.119) 50.68 (26.07 – 67.88)	12.01 (9.793 – 14.95) 106.51 (83.54 – 139.08)
0.45 µm membrane filtered (silver nanoparticles)	Silver nitrate Nanosilver	3.494 (1.981 – 4.485) 33.39 (18.40 – 43.06)	6.97 (5.808 – 8.437) 62.54 (50.39 – 79.44)
3 kDa centrifuge filtered (ionic silver)	Silver nitrate Nanosilver	0.059 (0.022 – 0.088) 0.292 (0.143 – 0.396)	0.195 (0.151 – 0.266) 0.616 (0.475 – 0.821)

** Based on arithmetic mean measured silver concentrations (with 95% confidence limits)*

These results indicate that silver nanoparticles are less toxic to *Daphnia magna* than silver nitrate in a long-term exposure test. Consequently, the concern that silver nitrate may not be a proper 'worst case' in the risk assessment regarding toxicity of silver nanoparticles to aquatic invertebrates is removed for the nanoforms of silver that are covered by the REACH registration dossier(s) submitted for Silver.

7.8.1.3. Algae and aquatic plants

In response to Request 1 in the Decision on Silver (see Section 7.1), the Registrant(s) updated their registration on 5 July 2017 with results from a toxicity study to algae. Between July 2016 and June 2017, the Registrant(s) performed a Freshwater Alga, growth inhibition test in *Raphidocelis subcapitata* under GLP and according to the OECD Test Guideline No. 201. In accordance with the Request in the Decision, the amount of $Na_2EDTA \bullet 2(H_2O)$ was minimised and chloride salts were replaced by nitrate salts. The pH was set to the pH at which the medium equilibrates with air (in the final tests the pH was 7.25 – 8.47 and 7.36 – 8.59 for silver nitrate and silver nanoparticles, respectively) and temperature was 21.5 – 22 °C.

Exponentially growing cultures of the unicellular freshwater green alga species *Raphidocelis subcapitata* were exposed to nominal concentrations of 0, 1.00, 3.16, 10.0, 31.6, 100 and 316 µg Ag/L as silver nanoparticles (Nano sample 1) for 72 hours. Concentrations of total silver, ionic silver (< 3 kDa) and silver nanoparticles (up to 450 nm) were monitored throughout the study. EC$_{10}$, EC$_{20}$, and EC$_{50}$ values were calculated for growth rate and for yield, based on the total silver, silver nanoparticles and ionic silver geometric mean concentrations.

The same test set-up as described above was used with the test substance silver nitrate instead of silver nanoparticles using nominal concentrations of 0.316, 1.00, 3.16, 10.0 and 31.6 µg Ag/L.

Comparison of the results from the silver nanoparticles and the silver nitrate tests shows that the EC$_{10}$, EC$_{20}$, and EC$_{50}$ values for algal growth rate response were lower for silver nitrate than for silver nanoparticles (see Table 10).

Table 10

RESULTS OF ALGAL TOXICITY TEST*			
Measured fraction	**Test substance**	**Growth rate EC_{10} (µg Ag/L)**	**Growth rate EC_{50} (µg Ag/L)**
Total silver	Silver nitrate Nanosilver	0.46 (0.31 – 0.62) 1.92 (1.2 – 2.54)	2.52 (2.13 – 2.98) 5.36 (4.57 – 6.17)
0.45 µm membrane filtered (silver nanoparticles)	Silver nitrate Nanosilver	0.1 (0.05 – 0.16) 0.37 (0.21 – 0.54)	0.96 (0.72 – 1.32) 2.13 (1.69 – 2.68)
3 kDa centrifuge filtered (ionic silver)	Silver nitrate Nanosilver	0.005 (0.003 – 0.008) 0.17 (0.06 – 0.3)	0.285 (0.219 – 0.365) 0.89 (0.55 – 1.28)

* *Based on geometric mean measured silver concentrations (with 95% confidence limits)*

Consequently, the concern that silver nitrate may not be a proper ‘worst case’ in the risk assessment regarding toxicity of silver nanoparticles to algae is removed for the nanoforms of silver that are covered by the REACH registration dossier(s) submitted for Silver.

7.8.1.4. Sediment organisms

Not part of the requests of the substance evaluation decision and thus not further evaluated.

7.8.1.5. Other aquatic organisms

Not part of the requests of the substance evaluation decision and thus not further evaluated.

7.8.2. Terrestrial compartment

In response to Request 1 of the Decision on Silver (see Section 7.1), the Registrant(s) updated their registration on 5 July 2017 with results from a toxicity study to soil microorganisms in three different soils.

In accordance with the Request in the Decision, between July 2016 and June 2017 the Registrant(s) performed a Soil Microorganisms, Nitrogen Transformation Test according to OECD TG No. 216. The test was conducted in three European soils that cover a wide range of soil properties expected to affect the fate of silver nanoparticles in soil, including pH, clay content and organic matter content and moisture content: Rots (France), Lufa 2.2 (Germany) and Poelkapelle (Belgium). Characteristics of the soil types are shown in Table 11. The study was performed with silver nanoparticles (Nano sample 1) and with silver nitrate as test substances.

The nominal concentrations (added silver) were as follows for each soil and silver material (mg Ag/kg soil):

Soil	Silver nitrate	Silver nanoparticles
Rots	4.6, 15, 47, 150, 480, 1536	7, 24, 75, 242, 773, 2474
Lufa 2.2	0.5, 1.5, 4.7, 15, 48, 154, 492	0.7, 2, 6, 20, 65, 209, 669
Poelkapelle	10, 32, 102, 328, 1049, 3355	14, 44, 139, 446, 1427, 4563

Table 11

CHARACTERISTICS OF THE SOILS AND THEIR POREWATERS						
Soil	**Country of origin**	**pH**	**% OC**	**% sand / silt /clay**	**CEC (cmol$_c$/kg)**	**Total Ag (mg Ag/kg)**
Rots	France	7.3	1.30	20/50/10	14.3	0.4
Lufa 2.2	Germany	5.4	1.61	76/17/8	9.7	0.4
Poelkapelle	Belgium	6.0	3.80	17/66/16	19.7	0.1
Soil	**Pore waters**		**DOC ** (mg C/L)**	**K ** (mM)**	**Ca ** (mM)**	**Fe ** (µM)**
Rots			20.9 (1.9)	0.85 (0.01)	10.16 (0.12)	0.15 (0.09)
Lufa 2.2			32.1 (7.3)	0.06 (0.01)	1.71 (0.38)	59 (1)
Poelkapelle			12.2 (3.3)	0.02 (0.01)	1.55 (0.10)	1.080 (0.64)

** Pore waters of the soils were sampled after 2 weeks of incubation.*

*** Values in brackets indicate standard deviation.*

The results showed that for the Rots and Lufa 2.2 soils, the observed EC_{10} or EC_{50} values for the measured endpoints Potential Nitrification Rate (PNR) and Substrate Induced Nitrification (SIN) were similar for the silver nanoparticles and silver nitrate test. In the Poelkapelle soil, EC_{10} and EC_{50} values were significantly lower after addition of silver nitrate as compared to silver nanoparticles (Table 12, Table 13). Furthermore, the transformation and dissolution test showed that only limited dissolution of silver nanoparticles occurred after addition to the Poelkapelle soil (see Section 7.4.1), which may explain the observed difference in toxicity between the silver nanoparticle and silver nitrate tests.

In conclusion, these results indicate that for the three different soil types, silver nitrate is equally or more toxic to soil microorganisms as compared to silver nanoparticles. Consequently, the concern that silver nitrate may not be a proper 'worst case' in the risk assessment regarding toxicity of silver nanoparticles to soil microorganisms is removed for the nanoforms of silver that are covered by the REACH registration dossier(s) submitted for Silver.

Table 12

EC_{10} AND EC_{50} VALUES FOR THE PNR OVER 14 DAYS (PNR 0 – 14) FOR THE THREE DIFFERENT SOILS*			
Soil	**Test substance**	**EC_{10} PNR 0 – 14 (mg Ag/kg)**	**EC_{50} PNR 0 – 14 (mg Ag/kg)**
Rots	Silver nitrate Nanosilver	4.8 (2.3 – 10) 9.0 (4.1 – 17)	49 (30 – 83) 68 (47 – 97)
Lufa 2.2	Silver nitrate Nanosilver	3.8 (1.2 – 11) 3.8 (0.0 – 14)	36 (8 – 143) 38 (23 – 62)
Poelkapelle	Silver nitrate Nanosilver	8.1 (4.1 – 15) 29 (13 – 59)	66 (34 – 128) 242 (165 – 356)

** Based on geometric mean measured total silver concentrations in soil (with 95% confidence limits)*

Table 13

EC_{10} AND EC_{50} VALUES FOR THE SIN FOR THE THREE DIFFERENT SOILS*			
Soil	**Test substance**	**EC_{10} SIN (mg Ag/kg)**	**EC_{50} SIN (mg Ag/kg)**
Rots	Silver nitrate Nanosilver	30 (22 – 41) 35 (22 – 54)	113 (91 – 146) 141 (112 – 177)
Lufa 2.2	Silver nitrate Nanosilver	42 (29 – 72) 37 (33 – 42)	100 (76 – 133) 107 (93 – 114)
Poelkapelle	Silver nitrate Nanosilver	45 (33 – 61) 132 (90 – 189)	134 (98 – 182) 397 (269 – 568)

** Based on geometric mean measured total silver concentrations in soil (with 95% confidence limits)*

7.8.3. Microbiological activity in sewage treatment systems

Not part of the requests of the substance evaluation and thus not evaluated.

7.8.4. PNEC derivation and other hazard conclusions

The data that were provided showed silver nitrate to be equally or more toxic than the silver nanoparticles tested. As a result, PNECs derived for silver nitrate can be used as PNECs for the nanoforms of silver that are covered by the REACH registration dossier(s) submitted for Silver.

7.8.5. Conclusions for classification and labelling

Taking into account that silver nitrate can be seen as a ‘worst case’ in the risk assessment regarding toxicity of the nanoforms of silver that are covered by the REACH registration dossier(s) submitted for Silver (as shown in Section 7.8), the eMSCA can agree with the approach to use the harmonised classification for silver nitrate (and corresponding M-factors) to self-classify the nanoforms of silver.

7.9. Human Health hazard assessment

Human Health endpoints are beyond the scope of this Substance Evaluation.

7.10. Assessment of endocrine disrupting (ED) properties

Endocrine disrupting (ED) properties are beyond the scope of this Substance Evaluation.

7.11. PBT and VPVB assessment

PBT and VPVB assessment goes beyond the scope of this Substance Evaluation.

7.12. Exposure assessment

According to the information submitted, the use of silver in nanoform is limited to industrial use in sintering processes for production of electronics. Therefore, exposure scenarios for “Manufacture of nanosilver” and “Use of nanosilver in sintering processes for production of electronics" were specified and the use of silver in nanoforms was removed by the Registrant(s) from the other exposure scenarios.

In this Substance Evaluation the focus was on the use of silver in nanoforms and other uses were therefore not assessed.

7.12.1. Human health

Human health endpoints and exposure are beyond the scope of this Substance Evaluation.

7.12.2. Environment

Based on EUSES estimations provided by the Registrant(s), exposure concentrations to the environment for "Manufacture of nanosilver" and "Use of nanosilver in sintering processes for production of electronics" are estimated to be lower or equal for all compartments in comparison with other forms of silver.

7.13. Risk characterisation

The results from the requested tests with daphnids, algae and soil microorganisms indicate that silver nitrate (ionic silver) is equally or more toxic as compared to the silver nanoparticles tested. Consequently, the PNEC values derived from silver nitrate can also serve as PNEC values for the nanoforms of silver that are covered by the REACH registration dossier(s) submitted for Silver. Combined with the low environmental releases, this results in (much) lower risk characterisation ratio (RCR) values for the nanoforms of silver than those for silver in general. For silver in general the Registrant(s) indicate in their exposure scenarios that risk management measures (RMMs) should be implemented that ensure that the environmental release will not result in exceedance of the PNEC values (for which those for silver nitrate are used as 'worst case'). As such, in line with silver in general, safe use of nanoforms of silver relies on implementation of such RMMs.

7.14. References

Angel BM, Batley GE, Jarolimek CV and Rogers NJ, 2013. The impact of size on the fate and toxicity of nanoparticulate silver in aquatic systems. Chemosphere 93: 359-365.

Cornelis G, Kirby JK, Beak D, Chittleborough D and McLaughlin MJ, 2010. A method for determination of retention of silver and cerium oxide manufactured nanoparticles in soils. Environ. Chem. 7: 298-308.

EC, 2013. General Report on REACH - Report from the Commission to the European Parlement, the Council, the European Economic and Social Committee and the Committee of the Regions in accordance with Article 117(4) of REACH and Article 46(2) of CLP, and a review of certain elements of REACH in line with Articles 75(2), 138(2), 138(3) and 138(6) of REACH. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2013:0049:FIN:EN:PDF.

EU, 2011. Commission Recommendation of 18 October 2011 on the definition of nanomaterial (2011/696/EU). O. J. L 275: 38-40.

Johnson A, Cisowska I, Jürgens M, Keller V, Lawlor A and Williams R, 2011. Exposure assessment for engineered silver nanoparticles throughout the rivers of England and Wales (CB0433). Final report, Natural Environment Research Council, Centre for Ecology and Hydrology, Wallingford, UK.

Navarro DA, Kirby JK, McLaughlin MJ, Waddington L and Kookana RS, 2014. Remobilisation of silver and silver sulphide nanoparticles in soils. Environ. Pollut. 193: 102-110.

SCCS, 2012. Guidance on the safety assessment of nanomaterials in cosmetics SCCS/1484/12, Scientific Committee on Consumer Safety (SCCS), Brussels, Belgium.

SCENIHR, 2010. Opinion on the scientific basis for the definition of the term "nanomaterial", Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR), European Commission Brussels, Belgium. Available at: http://ec.europa.eu/health/scientific_committees/emerging/docs/scenihr_o_030.pdf.

7.15. Abbreviations

CSR: Chemical Safety Report.

EC_x: Concentration at which an x % effect is measured (*e.g.* EC_{10}, EC_{20}, and EC_{50}).

eMSCA: Evaluating Member State Competent Authority.

EUSES: The European Union System for the Evaluation of Substances.

GLP: Good laboratory practice.

PEC: Predicted environmental concentration.

PNEC: Predicted no effect concentration.

PNR: Potential nitrification rate.

RCR: Risk characterisation ratio, *i.e.* for the environment the ratio between a predicted environmental concentration (PEC) and a predicted no effect concentration (PNEC).

SIN: Substrate induced nitrification.

TEM: Transmission Electron Microscopy.