REPORT

Life Cycle Assessment of RETORTE Selenium Products

What is Life Cycle Assessment?

LCA is a decision-making tool used to identify environmental burdens and evaluate the potential environmental impacts of goods or services over their life cycle.

The benefit of using an LCA approach means that negative impacts can be identified and possibly minimized while avoiding the transfer of these impacts from one life cycle stage to another. When applied to product design, production processes and a decision-making aid, LCA is a meaningful tool for implementing effective sustainability strategies.

Goal

To evaluate our environmental performance and contribution to sustainable development, we carried out a life cycle assessment (LCA) of Selenium products produced at RETORTE using data from 2023. This assessment is partially linked to the study for our main product copper cathode and is consistent with the methodology adopted by the International Copper Association.

This study helps Aurubis in tracking the improvement progress and identifying opportunities for further improving Aurubis' environmental performance. The results are intended to be published and disclosed to the public. The target audience includes stakeholders interested in the life cycle environmental impacts of selenium such as customers, investors, governmental authorities, non-governmental organizations.

This study was performed with the help of Sphera.

Scope

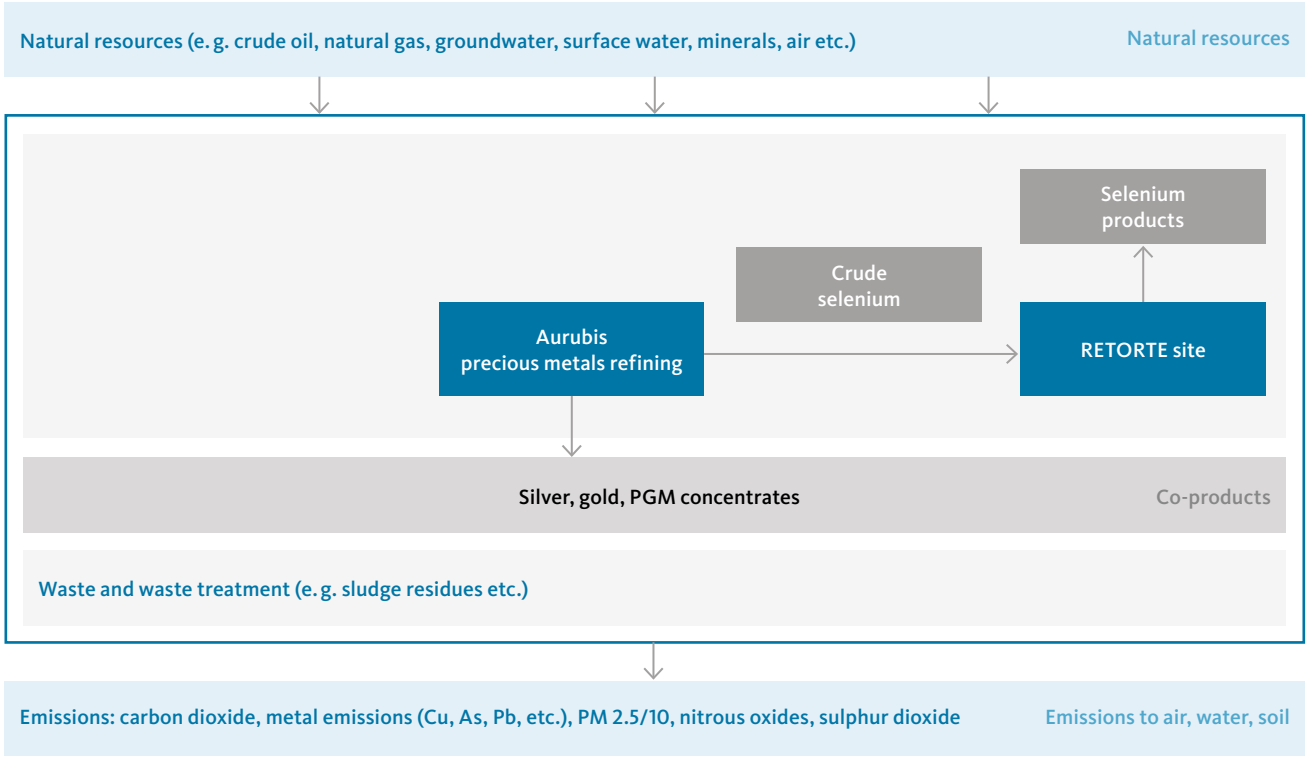
The study was conducted in conformance with the standards ISO 14040 (ISO 14040:2021 Environmental management — Life cycle assessment —Principles and framework) and ISO 14044 (ISO 14044:2021 Environmental management — Life cycle assessment —Requirements and guidelines) on LCA.

Product and declared unit	1 kg Selenium contained Selenium products (Zinc Selenite; Sodium Selenite; High Purity Selenium; Selenous Acid; Selenium Dioxide; Selenium granules/powder)
Aurubis profile	The weighted average of the Selenium products and compounds produced at RETORTE site.
Considered production system (system boundaries)	Cradle-to-gate, production of Selenium products
Time coverage	Reference calendar year 2023

The system boundary of the study included a cradle-to-gate life cycle inventory from the extraction of raw materials to the production of Selenium products. This LCA study is directly linked to the LCA study for the copper cathode where economic allocation has been applied to the anode slime from the copper electrolysis and lead bullion from the secondary smelter.

This study takes the allocated profile of anode slime and lead bullion into the precious metals refining, where another economic allocation distributes the impacts of its activity between its products Silver, Gold, PGM concentrate and crude Selenium. The study does also include further processing steps for the crude selenium to the Selenium Products of RETORTE.

It does not include the manufacture of downstream products, use, end-of-life, or secondary copper-containing materials recovery schemes.



Process description

The precious metal refinery is designed to refine both the precious metal-enriched anode slimes from copper production and the precious metal-enriched alloy from lead refining.

Pyrometallurgical lead refining consists of a series of kettles where the lead bullion is melted and given sequential treatments to remove specified impurities. In addition to refined lead, several coproducts are produced such as tin concentrate, tellurium concentrate, and silver-rich alloy. The anode slimes are a co-product of the electrochemical refining of copper anodes in the electrolysis plant. For these two intermediates, an allocation by economic value is performed as described in the treatment of co products chapter.

In the pyrometallurgical treatment of the input materials in a TBRC furnace at the precious metals plant, the selenium is volatilized, collected during gas scrubbing, and precipitated as crude selenium.

This crude selenium is shipped to RETORTE site where it is further processed to different Selenium products. This processing happens mainly in two pathways. The first one is the mechanical treatment of the input material to produce Selenium granules or Selenium powder. The second pathway is the production of high purity Selenium or Selenium compounds via oxidization to the intermediate of Selenous acid. These compounds include Zinc Selenite, Sodium Selenite, Selenium Dioxide as well as Selenous acid itself.

More information is available in the Environmental Report and EMAS Environmental Statement[1].

[1] www.aurubis.com/en/responsibility/reporting-kpis-and-esg-ratings

Life cycle inventory

Aurubis produces selenium products by processing crude Selenium as a co-product of Pyrometallurgical processes.

Specific primary data were collected for the Aurubis and RETORTE production sites. The data collection covered representative annual data for the calendar year 2023. The data covered all relevant processes associated with Selenium products:

- Internal processed for the production of raw materials (lead buillon, anode slime)
- Lead refining
- Precious metals refining plant processes including volatilization and recovery of Selenium
- Mechanical processing of crude selenium to Selenium granules or Selenium powder
- Production of high purity Selenium or Selenium compounds via oxidization to Selenous acid
- Selenium compound-specific production steps
- All related auxiliary processes: On-site wastewater treatment (treatment of process waters, direct cooling water, and surface runoff water), Gas cleaning systems (for primary and secondary off-gases), Waste Heat Boiler and Auxiliary Boilers

The Model includes all known inputs and outputs for the processes. Inputs are the use of energy (fuels, electricity, steam), water, primary and secondary raw materials, fluxes, reagents, etc. Outputs are the products, co-products, intermediates, emissions to air and water, and waste.

The upstream processes include:

- Production of purchased raw materials
- Production and supply of fuels
- Production and supply of electricity
- Production and supply of chemicals, auxiliaries
- Transport of raw materials

The Life cycle inventory is not included in the report for confidentiality reasons.

Treatment of Co Products

The objective of the study is to quantify the inputs and outputs associated specifically with the production of Selenium products.

The underlying processes result in the generation of several coproducts. To compile life cycle inventory data for a single product system (in this case crude Selenium for processing at RETORTE site), it is necessary to properly address this multi-functionality. As displayed below, economic allocation was applied to fairly account for the wide range of co-products.

Table 1: Summary of co-product treatment methods

Process	Co-products	Treatment method
Precious metals refining	Crude Selenium PGM concentrate Silver Gold	Economic allocation › 10-year average market value

The market value was based on the average metal price for the 10 years (2011 -2020) and fixed to reduce variability and influence on the results. The sources used to determine the reference price are:

- the London Metal Exchange (LME) listings: copper, tin, zinc, lead, nickel
- the European Central Bank listings: gold, silver, platinum group metals
- the Metal Bulletin and internal information: selenium, tellurium

Sensitivity

No sensitivity check was performed in the study.

Data quality

Data quality is judged by its completeness, reliability, consistency, and representativeness. To cover these requirements and to ensure reliable results, specific primary data in combination with consistent background LCA information from the MLC database 2024.1 were used.

Completeness: Data has been collected for all relevant processes. To ensure data consistency, all primary data were collected with the same level of detail. Each unit process was checked for mass balance and completeness of the emission inventory.

Reliability: All gate-to-gate data for the Aurubis production sites have been collected from verified sources and measured data such as emission declarations, and technical and metal balances. The environmental profile of global copper concentrate was obtained from the most recent and reliable dataset from the International Copper Association.

Representativeness: The primary data were collected for the 2023 calendar year. All secondary data come from the MLC database 2024.1 and are representative of the years 2020-2024. The data represented the technological and geographical location of the operations. All primary and secondary data were collected specifically for the countries or regions under study and were modelled to be specific to the technologies under study. Where country /region-specific or technology-specific data were unavailable, proxy data were used.

The LCA model was created using the LCA For Expert Software system for Life Cycle Assessment, developed by Sphera Solutions GmbH. The MLC database 2024.1 provides the life cycle inventory data for all background data including materials and energy/electricity.

Life Cycle Impact Assessment

The key environmental aspects were assessed with the Environmental Footprint impact assessment method (3.0) along 16 impact categories.

The Environmental footprint method (3.0) is the most advanced impact assessment method adopted by the European Commission. Using this method does also enable comparison with other publications as well as historic data.

The following key impact categories were selected because they represent a broad range of relevant environmental impacts and are each determined by a well-established scientific approach: Global warming potential, Acidification potential, Eutrophication potential, Photochemical Ozone creation potential, Resource use fossil, and Water use. Results for all 16 indicators are included in the report. However, it is important to note that “abiotic depletion potential” and “toxicity” impacts are not sufficiently robust and accurate to be used for metals.

Table 2: Key Life Cycle Assessment Impact Categories

Impact Category	Description
Global Warming Potential	A measure of greenhouse gas emissions, such as CO_2 and methane. These emissions are causing an increase in the absorption of radiation emitted by the earth, increasing the natural greenhouse effect. This may in turn have adverse impacts on ecosystem health, human health and material welfare.
Eutrophication Potential	Eutrophication covers all potential impacts of excessively high levels of macronutrients, the most important of which nitrogen (N) and phosphorus (P). Nutrient enrichment may cause an undesirable shift in species composition and elevated biomass production in both aquatic and terrestrial ecosystems. In aquatic ecosystems increased biomass production may lead to depressed oxygen levels, because of the additional consumption of oxygen in biomass decomposition.
Acidification Potential	A measure of emissions that cause acidifying effects to the environment. The acidification potential is a measure of a molecule’s capacity to increase the hydrogen ion (H+) concentration in the presence of water, thus decreasing the pH value. Potential effects include fish mortality, forest decline and the deterioration of building materials.
Photochemical Ozone Formation	A measure of emissions of precursors that contribute to ground level smog formation (mainly ozone O_3), produced by the reaction of VOC and carbon monoxide in the presence of nitrogen oxides under the influence of UV light. Ground level ozone may be injurious to human health and ecosystems and may also damage crops.
Ressource use, fossil	A measure of the total amount fossil resources non-renewable (e.g., petroleum, natural gas, etc.) extracted from the earth used for the primary energy production.
Water use	Deprivation water consumption.

Study Results

The life cycle impact results for the key impact categories for RETORTE Selenium Products (per 1 kg of Se contained) for the reference year 2023 are presented below.

Figure 1: Results for 1 kg of Se contained in RETORTE Selenium Products (2023), (Environmental footprint EF 3.0)

The results for all impact categories per kg of Se contained in RETORTE Selenium Products for the reference year 2023 are shown below.

Table 3: Results for 1 kg of Se contained in RETORTE Selenium Products (2023), (Environmental footprint EF 3.0)

Acidification	Mole of H+ eq./kg Se	1,67E-01
Climate Change - total	kg CO_2 eq./kg Se	2,46E+01
Climate Change, biogenic	kg CO_2 eq./kg Se	8,19E-02
Climate Change, fossil	kg CO_2 eq./kg Se	2,44E+01
Climate Change, land use and land use change	kg CO_2 eq./kg Se	3,14E-01
Ecotoxicity, freshwater _ total	CTUe/kg Se	1,54E+03
Ecotoxicity, freshwater inorganics	CTUe/kg Se	1,46E+03
Ecotoxicity, freshwater metals	CTUe/kg Se	7,33E+01
Ecotoxicity, freshwater organics	CTUe/kg Se	2,25E+00
Eutrophication, freshwater	kg P eq./kg Se	2,17E-04
Eutrophication, marine	kg N eq./kg Se	3,95E-02
Eutrophication, terrestrial	Mole of N eq./kg Se	4,24E-01
Human toxicity, cancer - total	CTUh/kg Se	1,68E-08
Human toxicity, cancer inorganics	CTUh/kg Se	3,65E-19
Human toxicity, cancer metals	CTUh/kg Se	6,57E-09
Human toxicity, cancer organics	CTUh/kg Se	1,03E-08
Human toxicity, non-cancer - total	CTUh/kg Se	1,20E-05
Human toxicity, non-cancer inorganics	CTUh/kg Se	1,16E-05
Human toxicity, non-cancer metals	CTUh/kg Se	3,58E-07
Human toxicity, non-cancer organics	CTUh/kg Se	2,83E-09
Ionising radiation, human health	kBq U235 eq./kg Se	1,12E+00
Land Use	Pt/kg Se	7,23E+01
Ozone depletion	kg CFC-11 eq./kg Se	1,40E-10
Particulate matter	Disease incidences/kg Se	2,21E-06
Photochemical ozone formation, human health	kg NMVOC eq./kg Se	1,09E-01
Resource use, fossils	MJ/kg Se	3,35E+02
Resource use, mineral and metals	kg Sb eq./kg Se	1,19E-02
Water use	m^3 world equiv./kg Se	3,60E+01

Interpretation

The impact of the production of Selenium products is highly dominated by the impacts of the production of Crude Selenium serving as raw material for RETORTE site followed by a small contribution of the electricity supply at the production site. Auxiliary materials and direct emissions have a minor contribution of never more than 10% each. This distribution of the contribution of impacts supports the validity of the aggregation of various Selenium products in the functional unit.

Conclusion

The goal of the study was to evaluate the environmental profile of Selenium contained in Selenium Products to allow tracking of the progress and further improvement. The results show that the environmental impacts are closely related to the supply of crude Selenium. This upstream profile is again highly influenced by the sourced material of the Aurubis smelter sites, especially Hamburg as the main supplier for crude Selenium, linking it closely to the sustainability efforts of all Aurubis Group. We invested in energy-efficient and low-carbon technologies at all sites across Aurubis Group and implemented measures to save energy, facilitated the switch to renewable energy (e.g building of windmills, electricity production from waste heat, an electric steam boiler). More information on Aurubis' sustainability efforts can be found in our Environmental Report and EMAS Environmental Statement[2].

The Environmental profile of RETORTE Selenium Products will be updated on a regular basis.

[1] www.aurubis.com/en/responsibility/reporting-kpis-and-esg-ratings

CERTIFICATE OF VALIDITY

DIN EN ISO 14040:2021 / DIN EN ISO 14044:2021
(product-related life cycle assessment - LCA)

Evidence that the application conforms to the regulations was delivered, and is herewith certified according to the TÜV NORD CERT Prüf- und Umweltgutachtergesellschaft mbH - procedure for

Aurubis AG
Hovestraße 50
20539 Hamburg
Germany

Range of application

Life Cycle Assessment „Production of Selenium and Selenium compounds“

The requirements of the above-mentioned standards were evidently fulfilled by a critical review with regard to

- the scientifically justified and technically valid methods used in carrying out the LCA;
- the appropriateness of the data used in relation to the objective of the study;
- the consideration of the objective of the LCA and the identified limitations in the interpretations.

The LCA report (Ref: 35383293-9, 25.09.2024) is transparent and self-consistent.

This declaration of validity refers exclusively to the functional unit at point in time of the LCA report.

Report No. 3538 3293-9

TÜV NORD CERT Prüf- und Umweltgutachtergesellschaft mbH

Mr. Dr. Hirtz
Environmental verifier

Hannover, 2024-11-05

Alejandro Ibanez Cuesy
Environmental expert

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The impact of the production of Selenium products is highly dominated by the impacts of the production of Crude Selenium serving as raw material for RETORTE site followed by a small contribution of the electricity supply at the production site. Auxiliary materials and direct emissions have a minor contribution of never more than 10% each. This distribution of the contribution of impacts supports the validity of the aggregation of various Selenium products in the functional unit.

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Critical review

An independent, external auditor reviewed the methodology, data quality, and modelling aspects of the study.

Name and contact information of the auditor:

Dr. Winfried Hirtz
Alejandro Ibanez Cuesy

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The review was performed according to ISO 14040 (2021) and ISO 14044 (2021).

Note:
The Certificate of Validity can be found as an Annex to this document.

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