REPORT

Life Cycle Assessment of Aurubis Raw Nickel Sulphate

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) for our raw nickel sulphate using data from 2022. This assessment is 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 in tracking the improvement progress and identifying opportunities for further improving our 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 nickel sulphate such as customers, investors, governmental authorities, non-governmental organizations.

This study was performed with the help of Sphera.

Scope

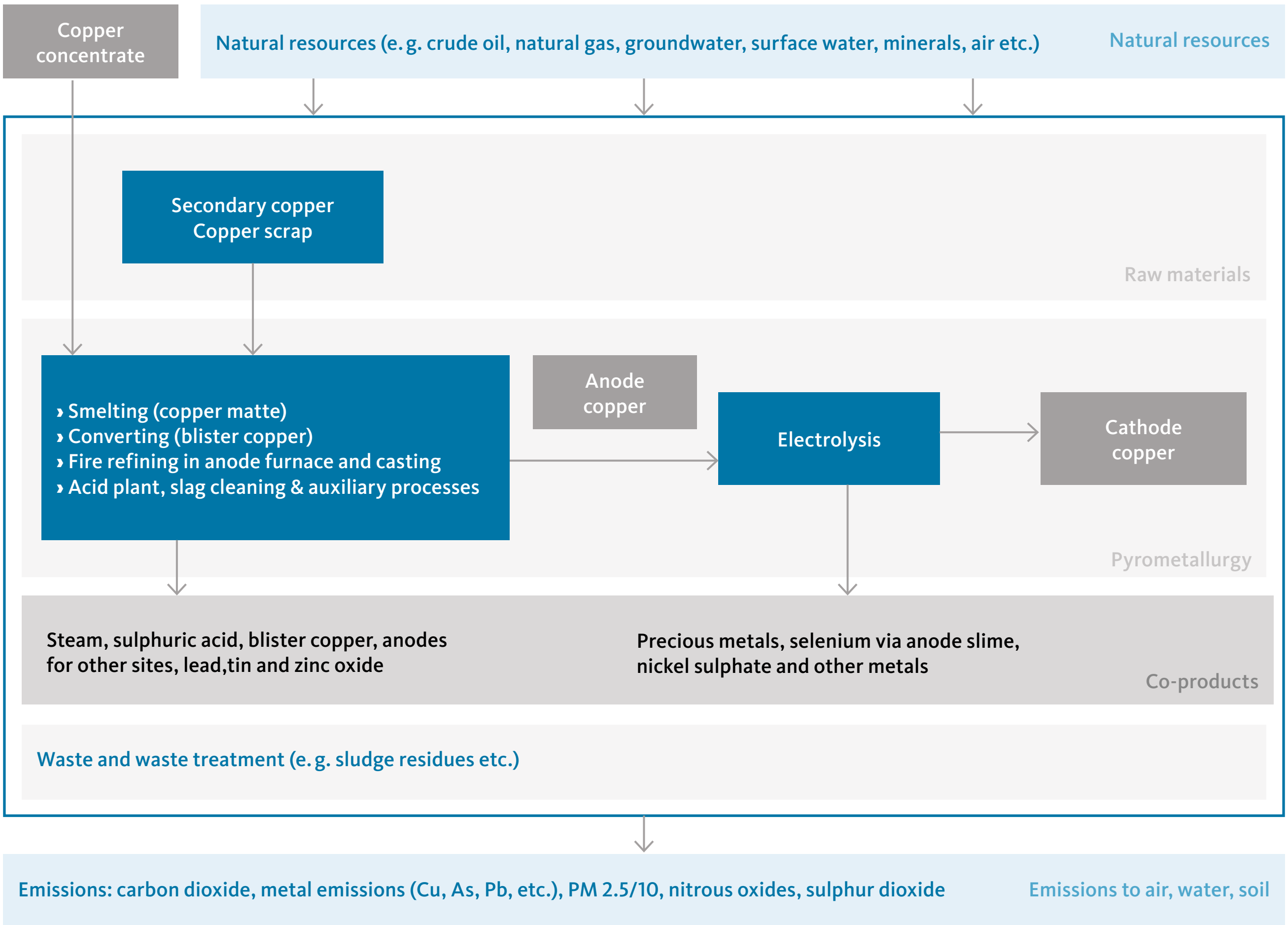
The study was conducted in conformance with the standards ISO 14040 (ISO 14040:2021 Environmental management — Life cycle assessment —Principles and framework) and ISO 14044 (ISO 14044:2021 Environmental management — Life cycle assessment —Requirements and guidelines) on LCA.

Product and declared unit	1 ton Nickel contained in Raw Nickel sulphate
Aurubis profile	The weighted average raw Nickel Sulphate produced at Hamburg, Pirdop and Luenen plants
Considered production system (system boundaries)	Cradle-to-gate, production of raw nickel sulphate
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 raw nickel sulphate. This LCA study is directly linked to the LCA study for the copper cathode where economic allocation has been applied to the nickel sulphate at the copper electrolysis.

This study directly takes the allocated profile of raw nickel sulphate. There are not further refining steps for the production of raw nickel sulphate.

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



Process description

Raw nickel sulphate is produced as a result of the treatment and purification of the spent electrolyte from copper electrolytic refining. Copper is recovered as copper sulphate and further recovered by electrowinning. Nickel is recovered as nickel sulphate by evaporation and crystallization. The remaining sulphuric acid is returned back to the copper refinery.

The spent electrolyte treatment involves several steps:

- Evaporation and crystallization of copper sulphate in closed vessels. At the first step an evaporation takes place at a temperature about 65 C, than the temperature is reduced down to 25C for crystallization of copper sulphate.
- Deeper de-copperization in electro-wining cells using insoluble lead anodes. The electrolyte is pumped to tanks in closed circulation.
- Evaporation and crystallization of nickel sulphate. Nickel sulphate precipitates. Process takes place in closed evaporators under pressure (100 bar) and temperature 65 C. The precipitate is filtered on vacuum-belt filter or centrifuged giving crude nickel sulphate.
- Further processing: part of the product is washed to remove sulphuric acid. This part of nickel sulphate is dissolved in water and sold as nickel sulphate solution.The crude nickel sulphate from band-pass filter or centrifuge is directly put in big bags.

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 raw nickel sulphate as a result of the treatment of spent electrolyte from copper electrolytic refining in Hamburg, Luenen and Pirdop. The spent electrolyte (bleed) from the copper refinery in Olen is treated in Luenen.

The raw nickel sulphate (crystals) has a nickel content in the range of 23-29%. The nickel sulphate solution has a nickel content 9%.

Specific primary data were collected for the relevant Aurubis production sites. The data collection covered representative annual data for the calendar year 2023.

All relevant processes associated with spent electrolyte treatment were already included in copper cathode assessment. (See Report LCA Copper cathode ref. year 2023)

The specific allocated profile of nickel sulphate from the copper electrolysis was obtained for the sites of Hamburg, Luenen and Pirdop for the reference year 2023. The profile of the weighted average raw nickel sulphate was expressed per nickel contained and considered the actual share of raw nickel sulphate and actual content from the different Aurubis sites.

The allocation between different streams in the electrolysis and spent electrolyte treatment was improved in 2023. To be consistent, the results for 2022 were recalculated in the same way.

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

Treatment of CO products

The objective of the study is to quantify the inputs and outputs associated specifically with raw nickel production. Raw nickel sulphate is considered as a co-product in the copper cathode production.

The copper electrolytic refining processes result in the recovery of several coproducts.

Economic allocation was applied in the life cycle inventory of copper cathode in the electrolytic refining to account for the nickel sulphate.

Table 1: Summary of co-product treatment methods

Process	Co-products	Treatment method
Electrolytic refining	Precious metals, Selenium, Tellurium (via anode slime) Nickel sulphate	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 is the most advanced impact assessment method adopted by the European Commission. The Environmental Footprint impact assessment method (3.0) is applied to ensure consistency and comparability with the previous studies and upstream 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 Aurubis Raw Nickel sulphate (per 1 ton of Ni contained) for the reference year 2022 and 2023 are presented below.

Figure 1: Results for 1 ton of Ni contained in Aurubis $NiSO_4$ (2022) and (2023) , (Environmental footprint EF 3.0)

The results for all impact categories per ton of nickel contained in raw nickel sulphate for the reference year 2023 are shown below.

Table 3: Results for 1 ton of nickel contained in Aurubis raw nickel sulphate (2023), (Environmental footprint EF 3.0)

Acidification	Mole of H+ eq./t Ni	3.31E+01
Climate Change - total	kg CO_2 eq. /t Ni	5.64E+03
Climate Change, biogenic	kg CO_2 eq./t Ni	4.88E+00
Climate Change, fossil	kg CO_2 eq./t Ni	5.63E+03
Climate Change, land use and land use change	kg CO_2 eq./t Ni	2.72E+01
Ecotoxicity, freshwater – total	CTUe/t Ni	2.08E+04
Ecotoxicity, freshwater inorganics	CTUe/t Ni	1.63E+04
Ecotoxicity, freshwater metals	CTUe/t Ni	4.24E+03
Ecotoxicity, freshwater organics	CTUe/t Ni	2.32E+02
Eutrophication, freshwater	kg P eq./t Ni	1.32E-02
Eutrophication, marine	kg N eq./t Ni	5.24E+00
Eutrophication, terrestrial	Mole of N eq. / t Ni	5.75E+01
Human toxicity, cancer - total	CTUh/t Ni	2.17E-06
Human toxicity, cancer inorganics	CTUh/t Ni	6.17E-18
Human toxicity, cancer metals	CTUh/t Ni	1.01E-06
Human toxicity, cancer organics	CTUh/t Ni	1.16E-06
Human toxicity, non-cancer - total	CTUh/t Ni	7.80E-05
Human toxicity, non-cancer inorganics	CTUh/t Ni	9.73E-06
Human toxicity, non-cancer metals	CTUh/t Ni	6.82E-05
Human toxicity, non-cancer organics	CTUh/t Ni	5.78E-07
Ionising radiation, human health	kBq U235 eq./t Ni	4.73E+01
Land Use	Pt/t Ni	7.63E+03
Ozone depletion	kg CFC-11 eq./t Ni	3.34E-09
Particulate matter	Disease incidences/t Ni	3.34E-04
Photochemical ozone formation, human health	kg NMVOC eq./t Ni	1.55E+01
Resource use, fossils	MJ/t Ni	6.09E+04
Resource use, mineral and metals	kg Sb eq./t Ni	8.77E-01
Water use	m^3 world eq./t Ni	1.54E+03

Interpretation

The impact of raw nickel sulphate is based on allocation from the copper cathode and thus directly linked to the copper cathode results.

The impact is dominated by the concentrate (mining and concentration) and purchased blister. Emissions associated with purchased electricity and grid mix also play an important role.

For the Carbon footprint/Global warming potential, the concentrate production and emissions from purchased electricity are the most significant contributor.

The Resource use, fossil included non-renewable energy resources for fuel production and electricity generation.

For the Acidification potential, results are mainly driven by the concentrate production, direct SO_2 emissions from smelting, as well as SO_2 emissions from purchased electricity.

Results for Eutrophication potential are driven by NO_x emissions associated with diesel combustion, during mining and transport of concentrates to the smelter. Purchased electricity contributes for country grids with a high coal power plant share.

Results for Photochemical Ozone creation potential are mainly driven by direct SO_2 emissions from smelting, as well as SO_2 emissions from purchased electricity.

Water use is mainly driven by the mining and concentrate production.

Conclusion

The goal of the study was to evaluate the environmental profile of raw nickel sulphate and allow tracking of the progress and further improvement.

The allocation between different streams in the electrolysis and spent electrolyte treatment was improved in 2023. To be consistent, the results for 2022 were recalculated in the same way. The results for 2023 can not compared with the 2021 results because of the different modelling.

Improvement in 2023 compared to 2022 is mainly related to lower contribution from concentrate in the copper cathode and subsequently lower allocated profile to nickel sulphate.

The carbon footprint of Aurubis $NiSO_4$ of 5,640 kg CO_2/t nickel content in nickel sulphate is significantly lower than the footprint of the global industry average of 18,200 kg CO_2/t nickel content in nickel sulphate.[2]

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).

The results for Resource use, fossil are higher for 2023, mainly related to the environmental impacts of the upstream natural gas energy carrier (impact related to flaring and venting during natural gas production).

The operations have taken continuous efforts for the reduction of direct emissions of pollutants such as dust, SO_2 as well as greenhouse gas emissions.

Our recycling as well as the efficiency of metal recovery has an important role in the results of our life cycle assessment.

The recycled content of nickel (contained in raw nickel sulphate) from the Aurubis Group for the calendar year 2023 was 60%. The recycled content has been verified by TUEV Nord Cert on the basis on ISO 14021 and regulation EC 1221/2009.

[2] Sources: Nickel Institute, Life cycle data, Jan 2023 / Aurubis, supported by Sphera, Report: Life Cycle Assessment of copper cathode, Sept. 2024

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
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Germany

Range of application

Life Cycle Assessment „Production of raw Nickel sulphate"

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: 35383293-6, 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 3293-6

TÜV NORD CERT Prüf- und Umweltgutachtergesellschaft mbH

Hannover, 2024-11-05

Mr. Dr. Hirtz
Environmental verifier

Alejandro Ibanez Cuesy
Environmental expert

VERIFICATION

of group-wide harmonised Recycling-Quota (RQ)
for input materials, metals and copper products

on the basis of
DIN EN ISO 14021:2021 and the
Regulation (EC) No 1221/2009 as amended on 25 November 2009

As result of the review on the basis of the Standard and the Regulation, we hereby confirm in respect of

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and
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as well as the associated locations to the annex

that

- **the data and the method of determination of Recycling-Quota in the „Report of the verification of group-wide harmonised Recycling-Quota (RQ) for input materials, metals and copper products" from August 22nd, 2024, reliably and credibly reflect the process relevant facts at the mentioned locations.**

Hamburg, 2024-11-21

Rainer Winter
Environmental Verifier
DE-V-0265

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.

Aurubis AG
Corporate Environmental Protection

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