Biodiversity restoration and conservation of inland water ecosystems for environmental and human well-being

BioReset

BiodivRestore-406

2020 - 2021 Joint Call
Joint COFUND Call on "Conservation and restoration of degraded ecosystems and their biodiversity, including a focus on aquatic systems"

Deliverables 2.4.1 + 2.4.3

Life Cycle Assessment of the technologies developed for EC and microplastic removal with the assessment of environmental impacts of biodiversity restoration and conservation

Lead Beneficiary	Work package	Delivery month
REQUIMTE	**1**	**13**

Catalyst Based Technologies

Target Contaminant: mono/bi contaminant

Sulfamethoxazole $\eta\ (\%) = 100\%$

Puga, A. et al. (2023). doi: 10.3390/catal13040679.

Sulfamethoxazole
Antypirine $\eta\ (\%) = 95\%$

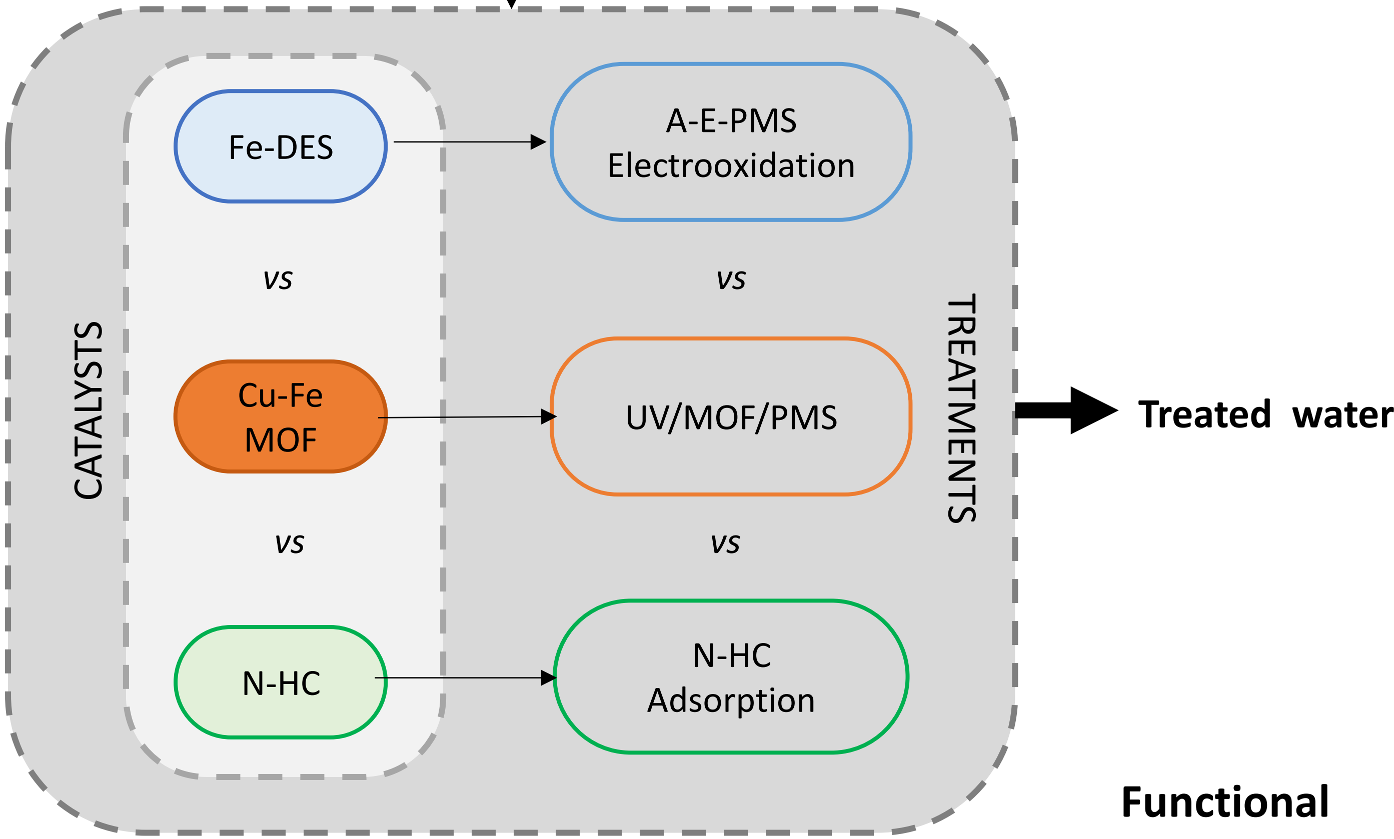
Fdez-Sanromán, et al.(2023). doi: 10.3390/catal13050820.

Cefazolin
Fluoxetine $\eta\ (\%) = \begin{matrix} 100\% \\ 66\% \end{matrix}$

Escudero-Curiel, et al.(2023). doi:10.1016/j.envpol.2023.121751.

Spiked Wastewater Tertiary Effluent /Spiked Synthetic Solution

Spiked with 20-30 mg/L pharmaceuticals



System Boundaries

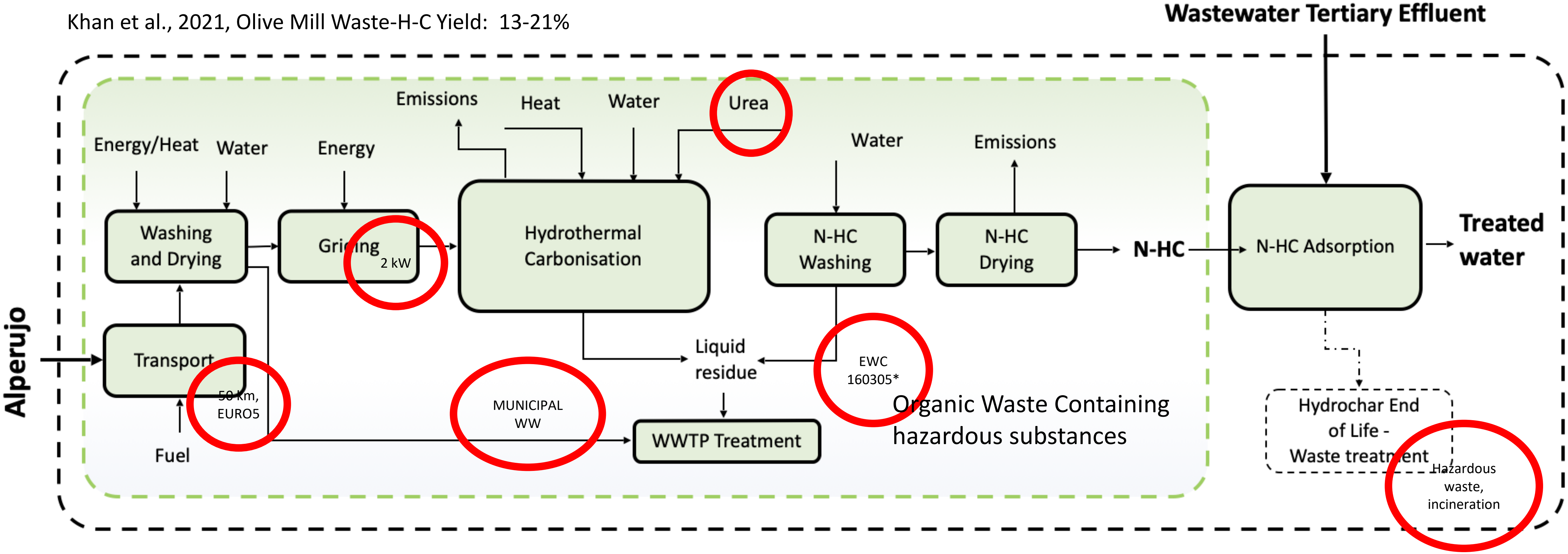
Functional Unit: 1L

Wastewater Tertiary Effluent

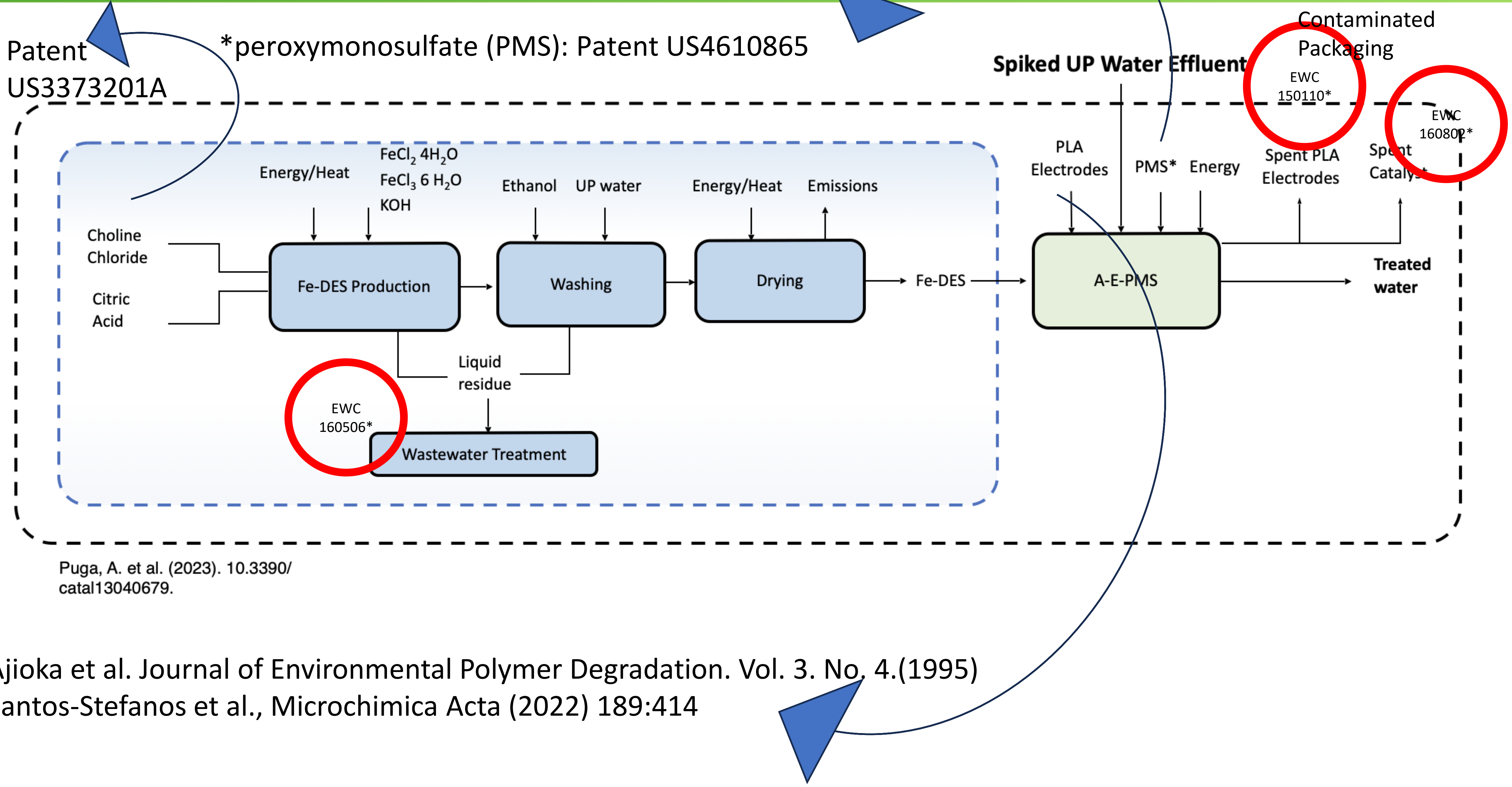
N-HC Adsorption Flowsheet

Energy and Mass Balance based on Bhatt et al., 2018 (normalized)
220 ℃, 2.5 h, yields: N-HC 14% w/w, Liquid 78% w/w, Gaseous Emissions 7% w/w

Khan et al., 2021, Olive Mill Waste-H-C Yield: 13-21%



A-E-PMS Electrooxidation Flowsheet

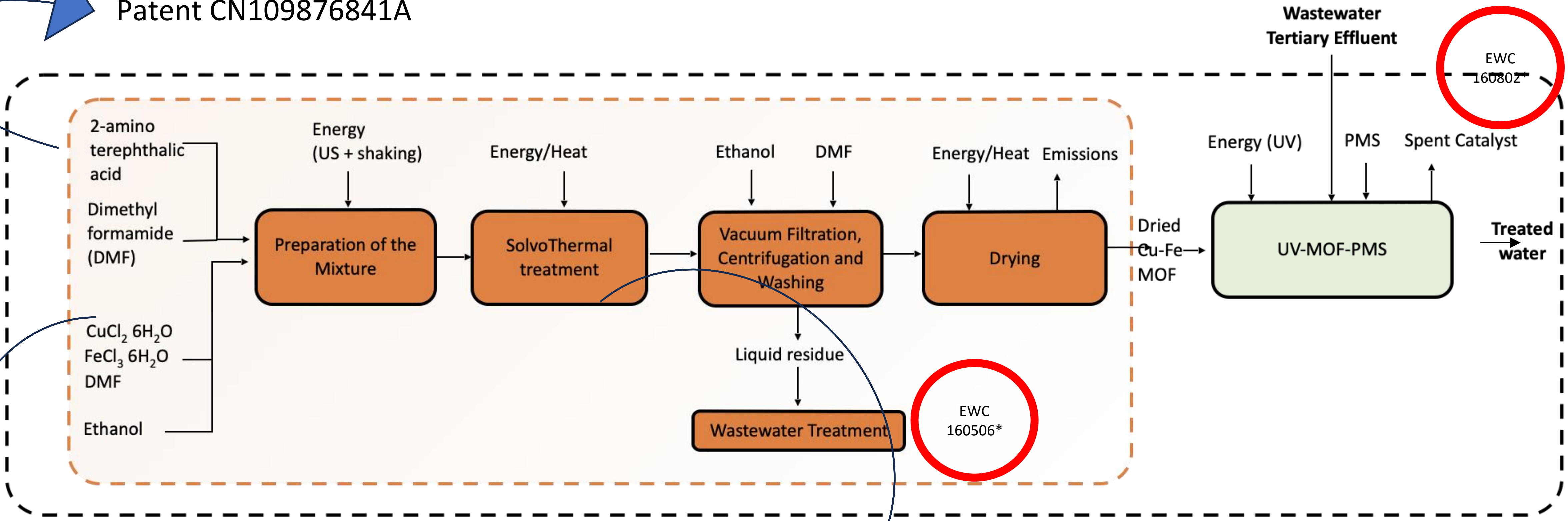


Puga, A. et al. (2023). 10.3390/catal13040679.

Ajioka et al. Journal of Environmental Polymer Degradation. Vol. 3. No. 4.(1995)
Santos-Stefanos et al., Microchimica Acta (2022) 189:414

UV/PMS/MOF Flowsheet

Patent CN109876841A



Fdez-Sanromán et al., 2023, 10.3390/catal13050820

$CuO_{(s)} + 2\,HCl_{(aq)} \rightarrow CuCl_{2(aq)} + H_2O_{(l)}$

5kW Thermal Treatment, 150 °C, 24 h

Methodology

ISO 14040 - 14044
Cradle-to-gate LCA
Software: SimaPRO v.9.5
Ecoinvent v.3.9
LCIA method: ReCiPe(H) (Endpoint, Single Score)

Life Cycle Inventory

Environmental Impacts

BASELINE: Hierarchist

EndPoint

18 Impact Categories in an aggregated value

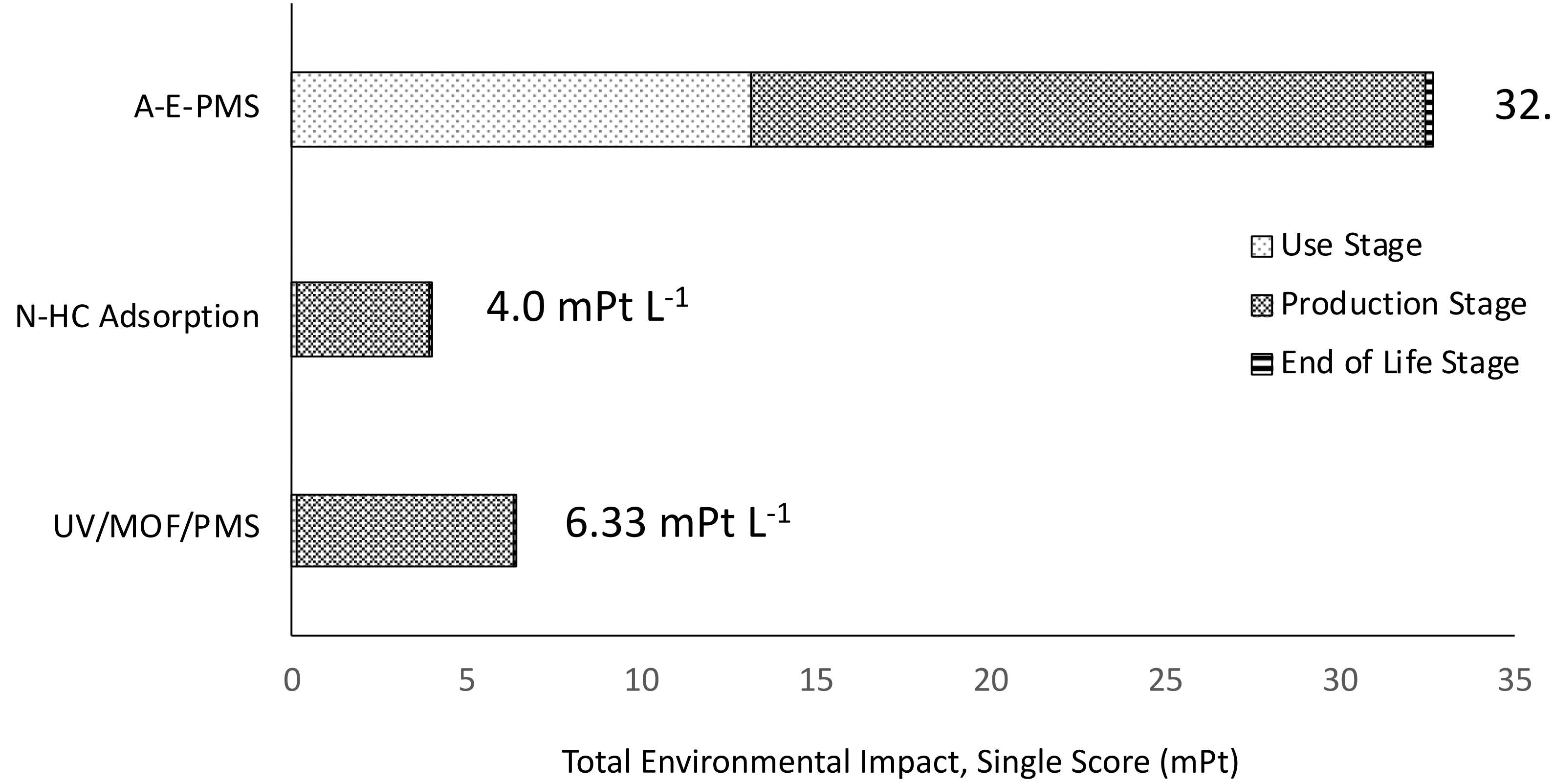
- Fine Particulate Matter Formation
- Ionizing Radiation
- Ozone Formation, human health
- Ozone Formation, Terr. Ecosystems
- Stratospheric Ozone depletion
- Human Toxicity (cancer)
- Human toxicity (non-cancer)
- Global Warning
- Water Consumption
- Freshwater Ecotoxicity
- Freshwater Eutrophication
- Marine Eutrophication
- Terrestrial Ecotoxicity
- Terrestrial Acidification
- Land Use
- Marine Ecotoxicity
- Mineral Resources Scarcity
- Fossil Resources Scarcity

Single score (mPt)

Some subjectivity associated, useful to preliminary assessments and comparison

In general, value choices made in the hierarchist version are scientifically and politically accepted.

Life Cycle Assessment of CATALYST-based Treatments

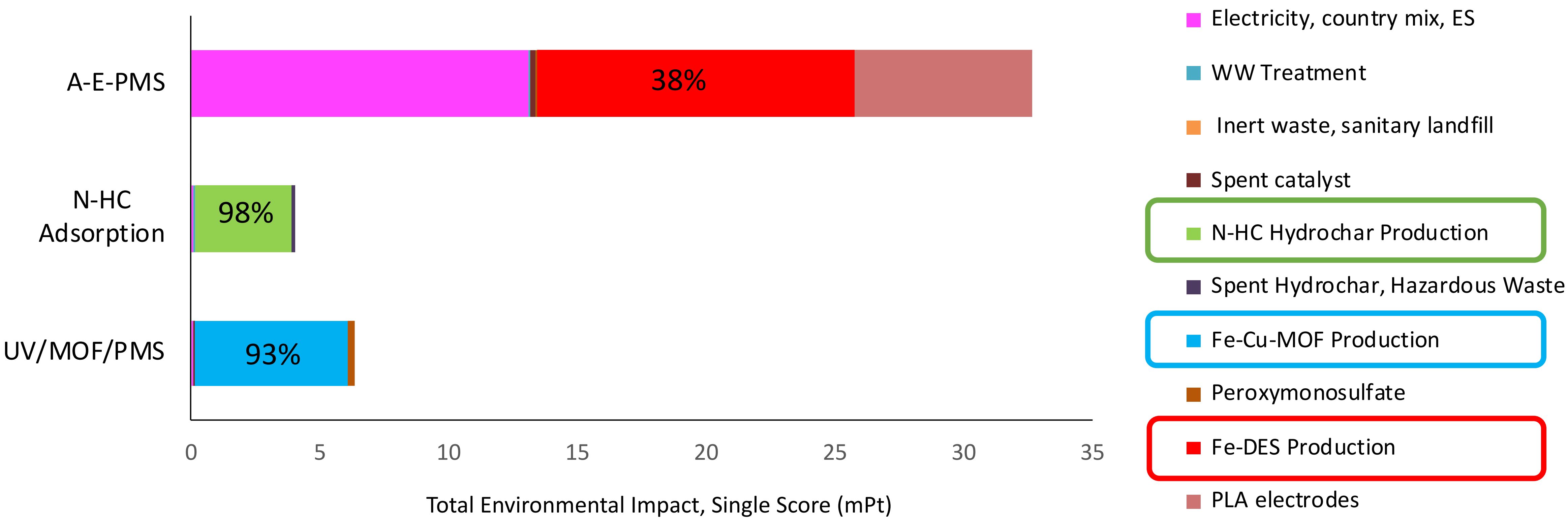


Production Stage: Chemicals, Reagents, Catalysts

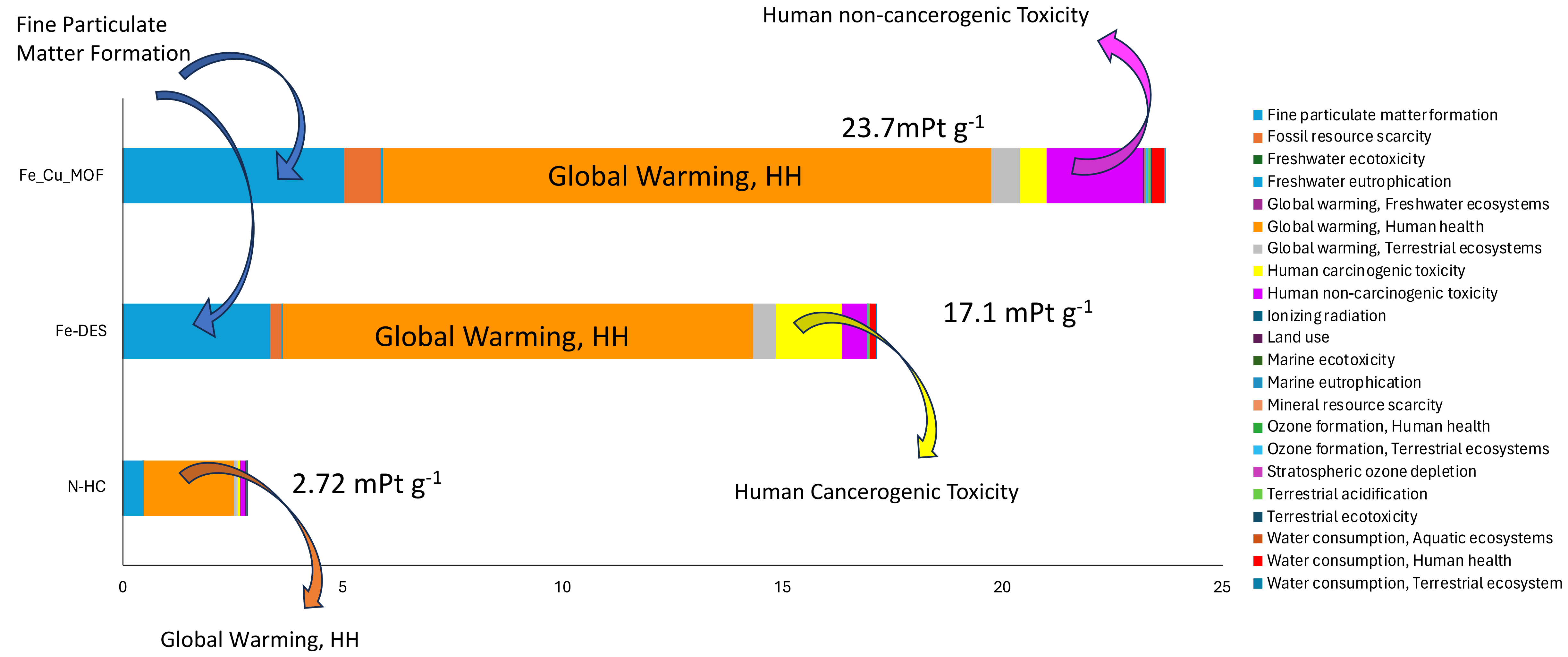
Use Stage (Operation): Electric energy, Spare Parts, WW emissions

End of Life Stage: Waste Management

Life Cycle Assessment of CATALYST-based Treatments

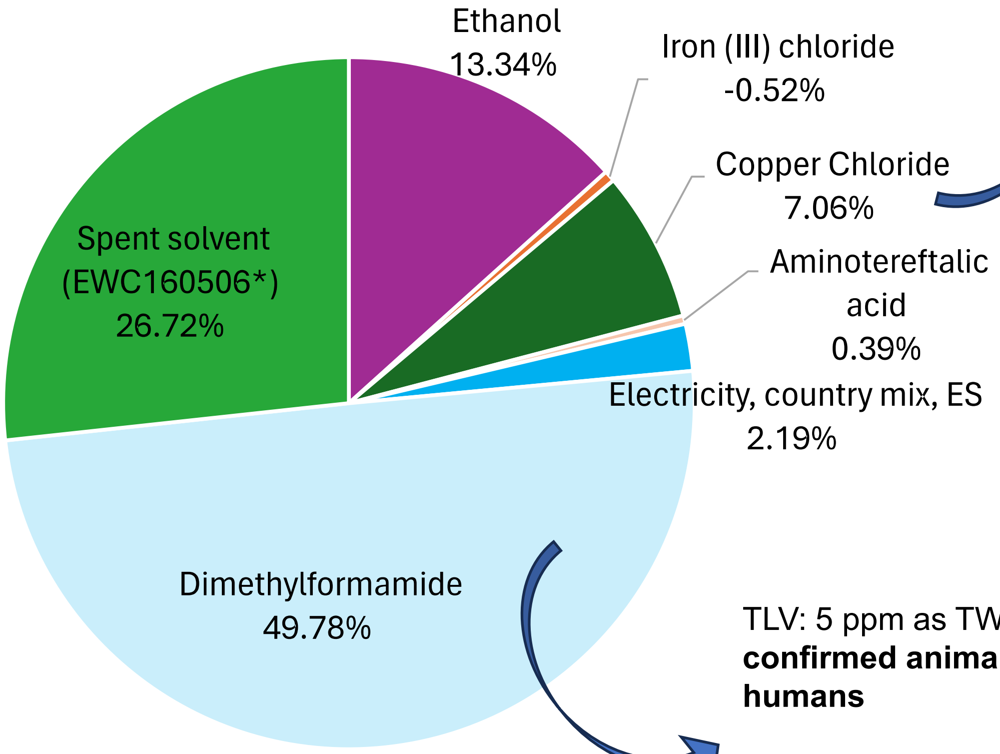


Catalyst Life Cycle Assessment, EndPoint(H), Single Score



Fe-Cu-MOF Production

TLV :4 mg/m³ as TWA, Acute toxicity, Skin Corrosion, **Very Toxic to aquatic life**



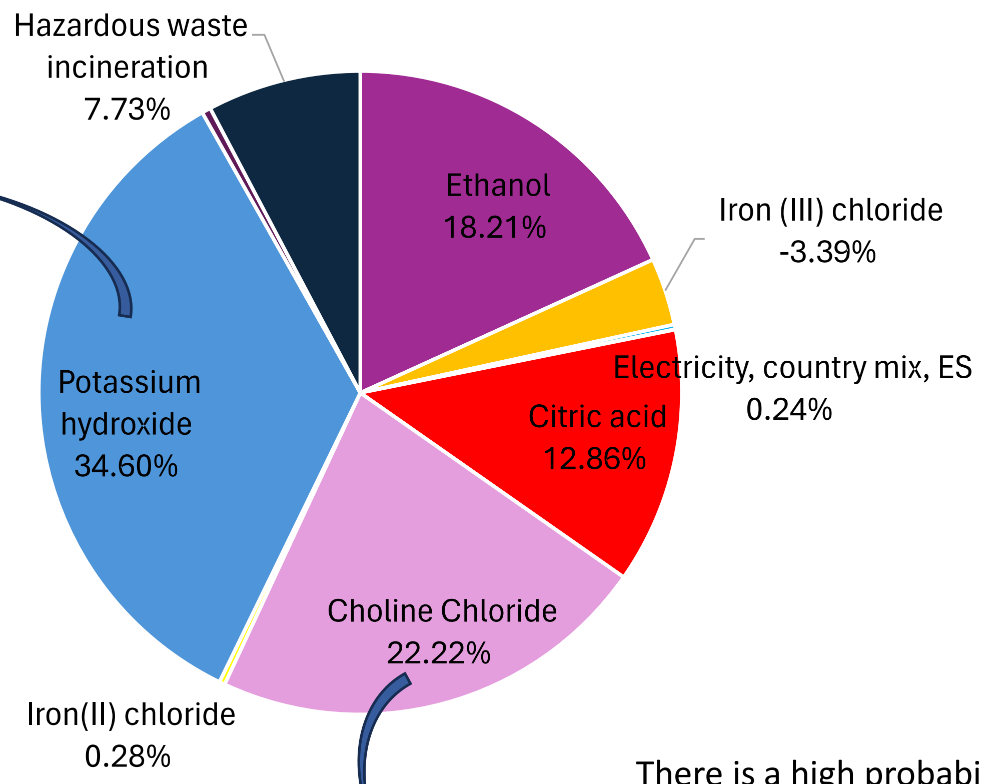
TLV: 5 ppm as TWA
confirmed animal carcinogen with unknown relevance to humans

WHO: **Environmental TOXICITY** effects of the substance have been adequately investigated and **appears to be LOW**. EC50 Algae 7500 mg/L, 96h; LC50 Fish (*Lepomis macrochirus*) 6.3 g/L, 96h

Total Impact (ReciPe(H)EndPoint, Single Score):

$23.7\ mPt\ g^{-1}$

Fe – DES Production



Hazardous for the aquatic environment

Corrosive, severe skin burns and eyes damages

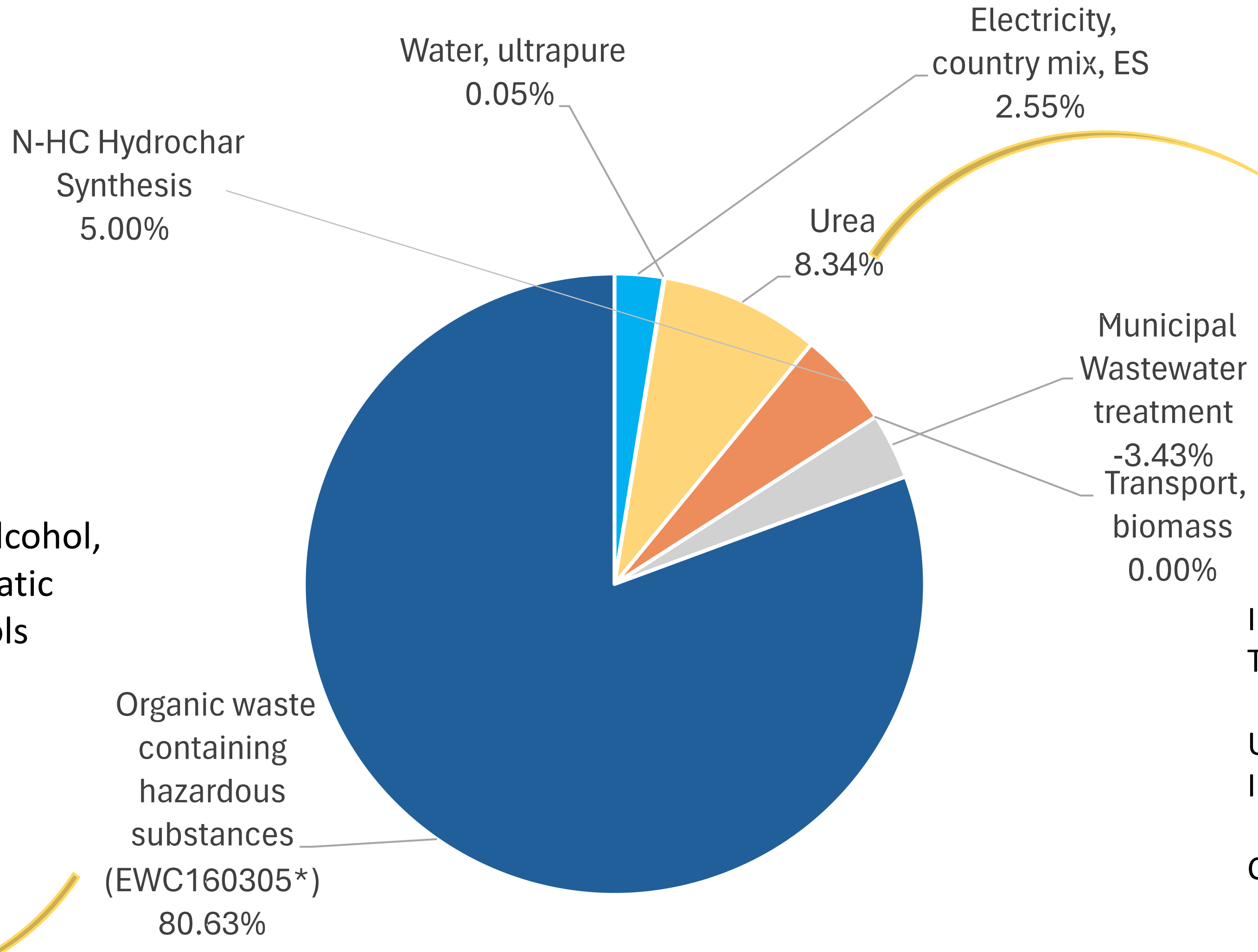
There is a high probability that the product is **not acutely harmful to aquatic organisms**

Skin and eye irritation, PPE required

Total Impact (ReciPe(H)EndPoint, Single Score):

17.1 mPt g^{-1}

N-HC Production



Liquid Phase N-HC: alcohol, aldehydes, polyaromatic hydrocarbons, phenols

Irritant for eyes, skin, respiratory tract,
TLV: 10 mg/m^3, 8-hour TWA

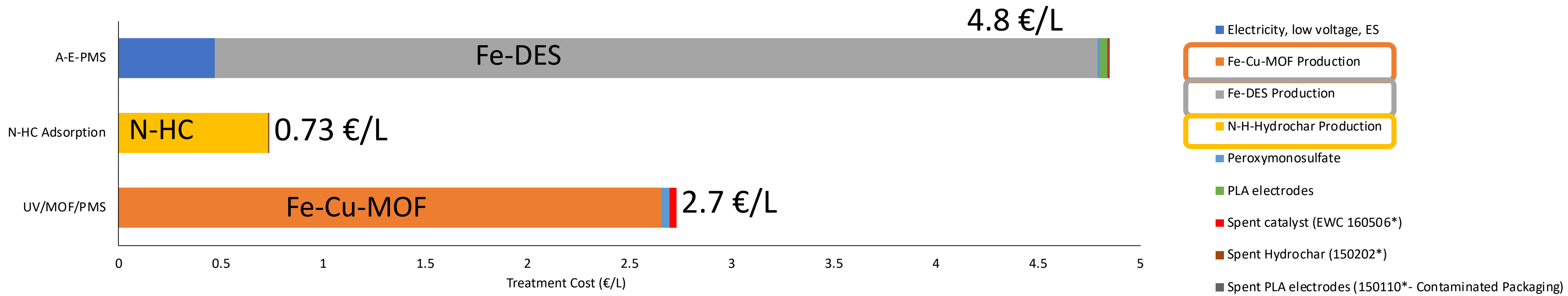
Urea has generally **low ecotoxicity**
Influence on eutrophication

Classified as **Not Hazardous Substance** (REACH)

Total Impact (ReciPe(H)EndPoint, Single Score):

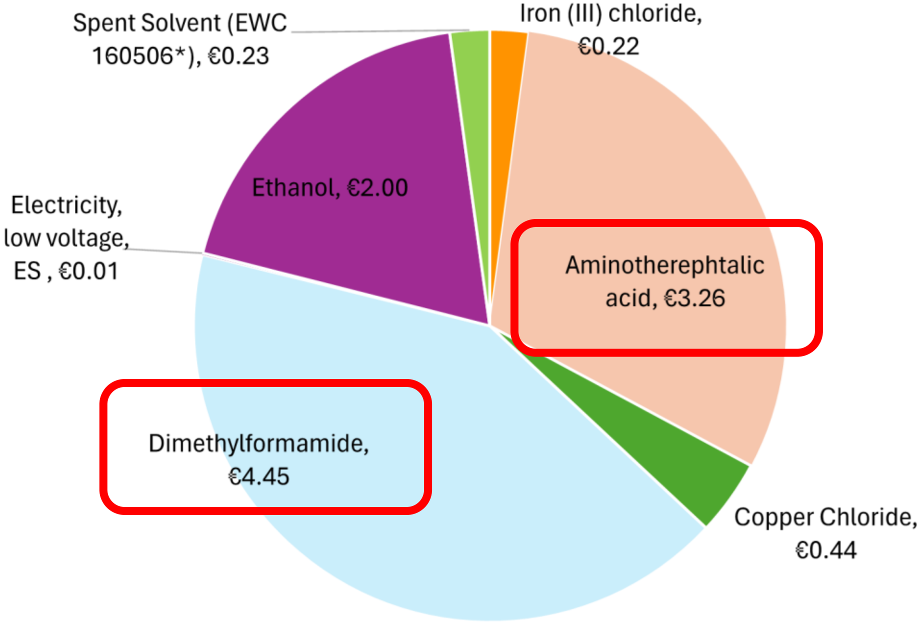
2.72 mPt g^{-1}

Catalysts- Based Treatments: Costs Assessments



Catalysts Costs Assessments

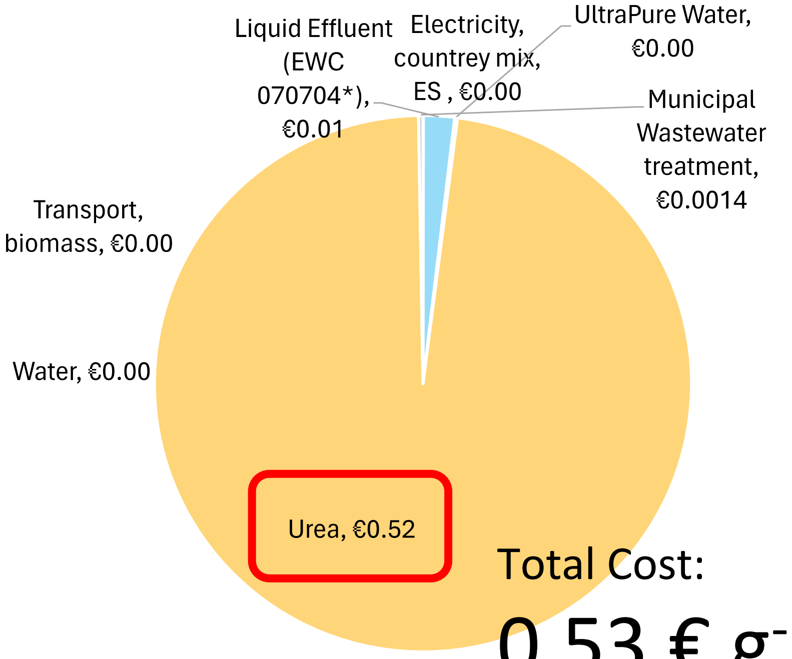
Fe- Cu-MOF



Total Cost:

10.6 € g^{-1}

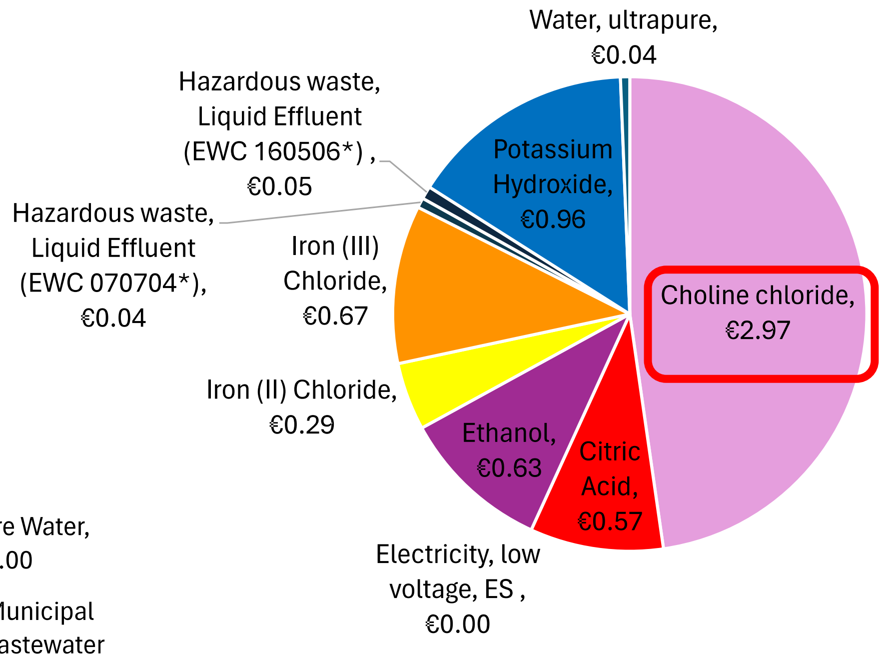
N-HC



Total Cost:

0.53 € g^{-1}

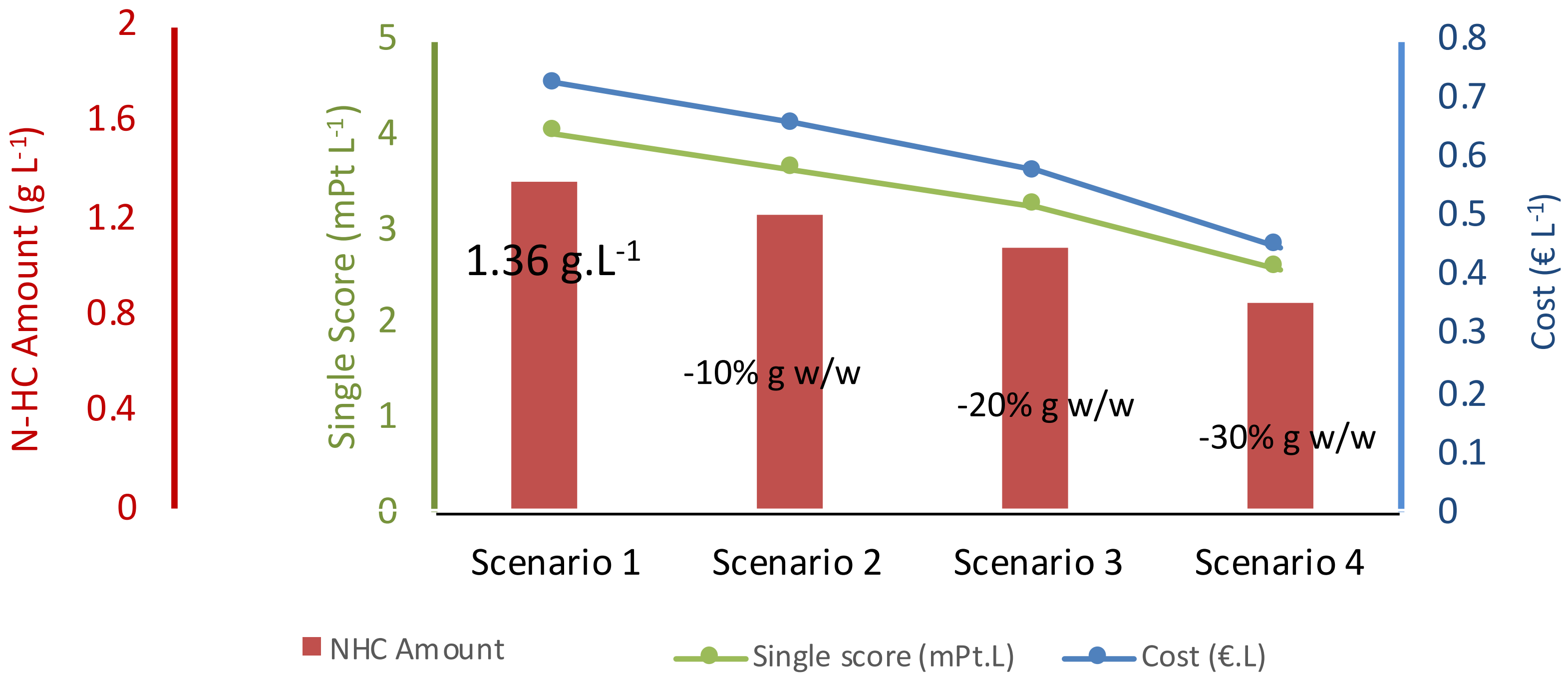
Fe-DES



Total Cost:

6.2 € g^{-1}

N-HC Adsorption Environmental and Costs Sensitivity Analysis

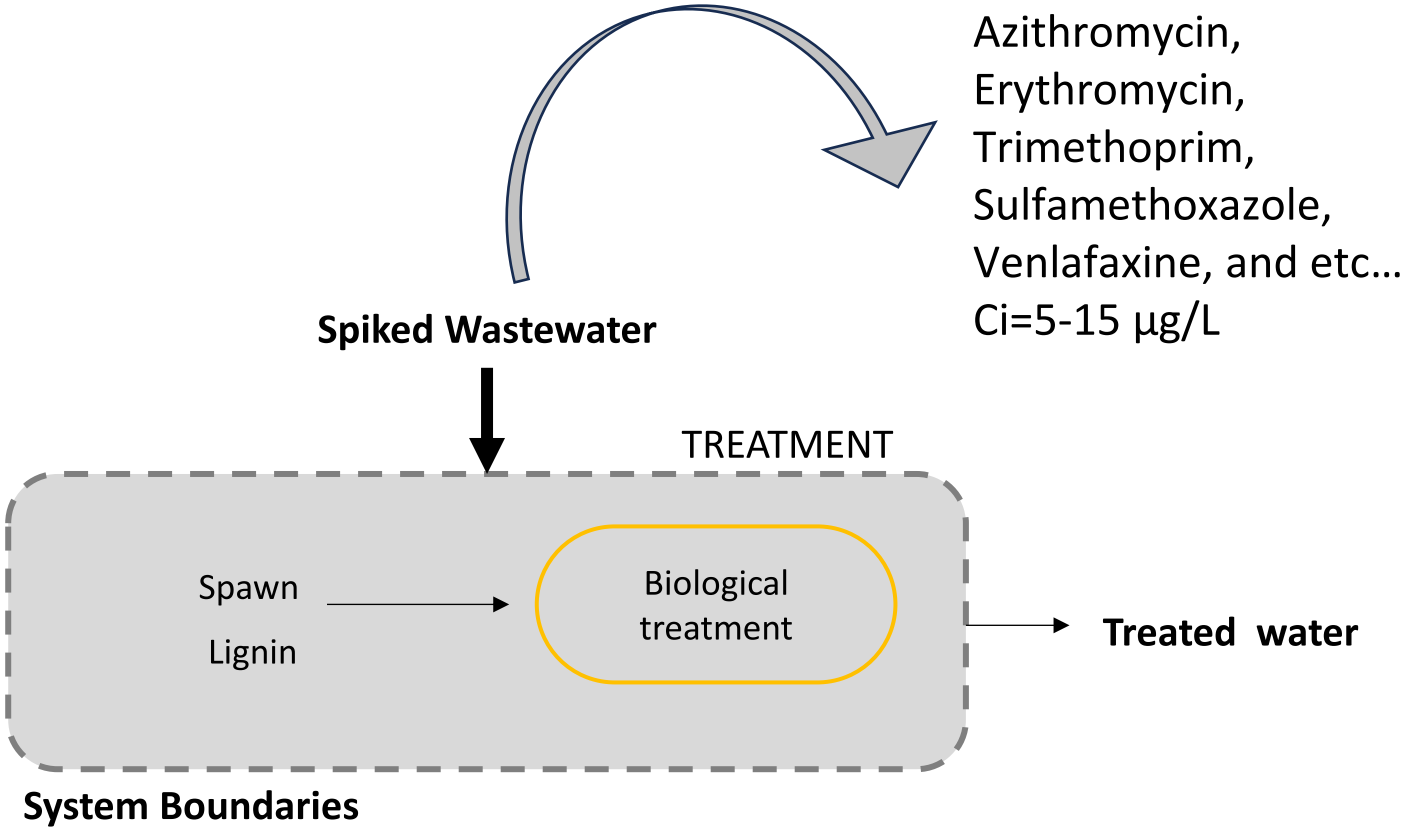


Preliminary Environmental and Costs Analysis of Biological treatment for Pharmaceuticals Removal

Target Contaminants

Sulfamethoxazole $\eta\ (\%) = 86\%$

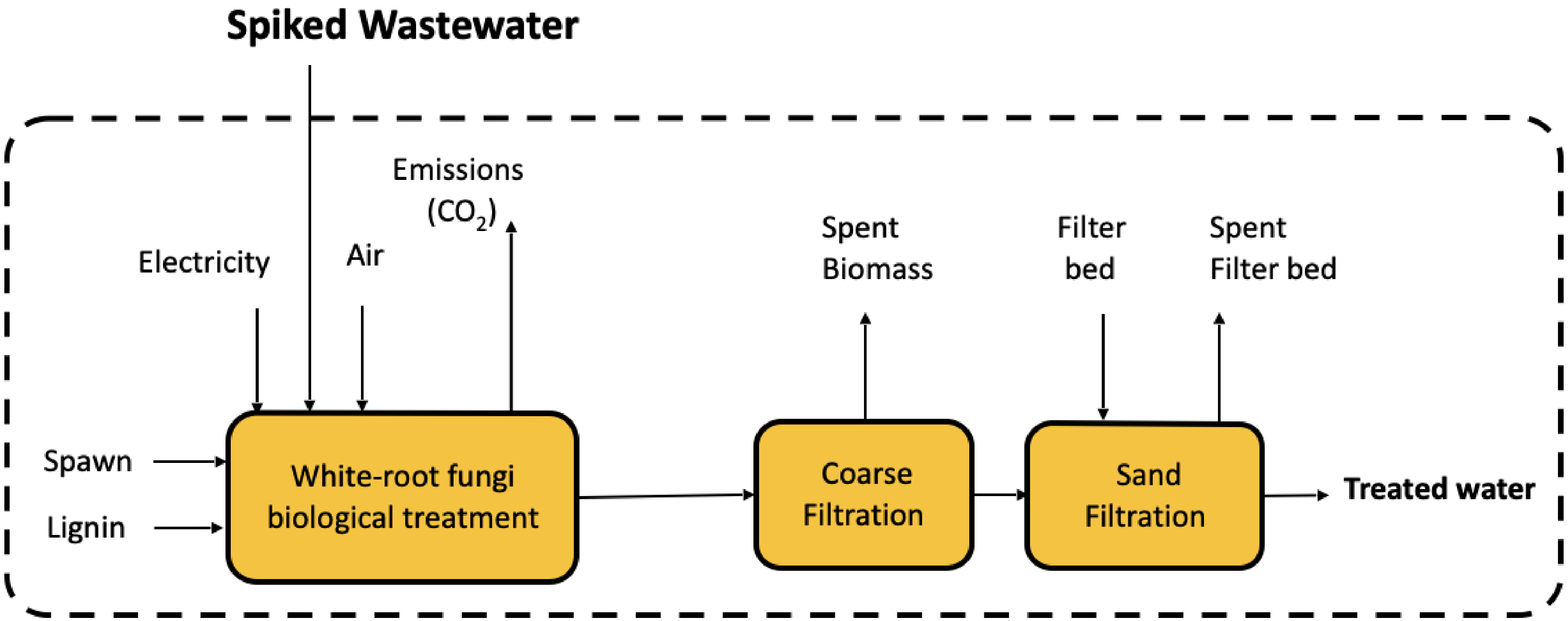
Silva, A.D.M et al. (2022). doi: 10.3390/ijerph19052672



Functional Unit: 1L

Wastewater Tertiary Effluent

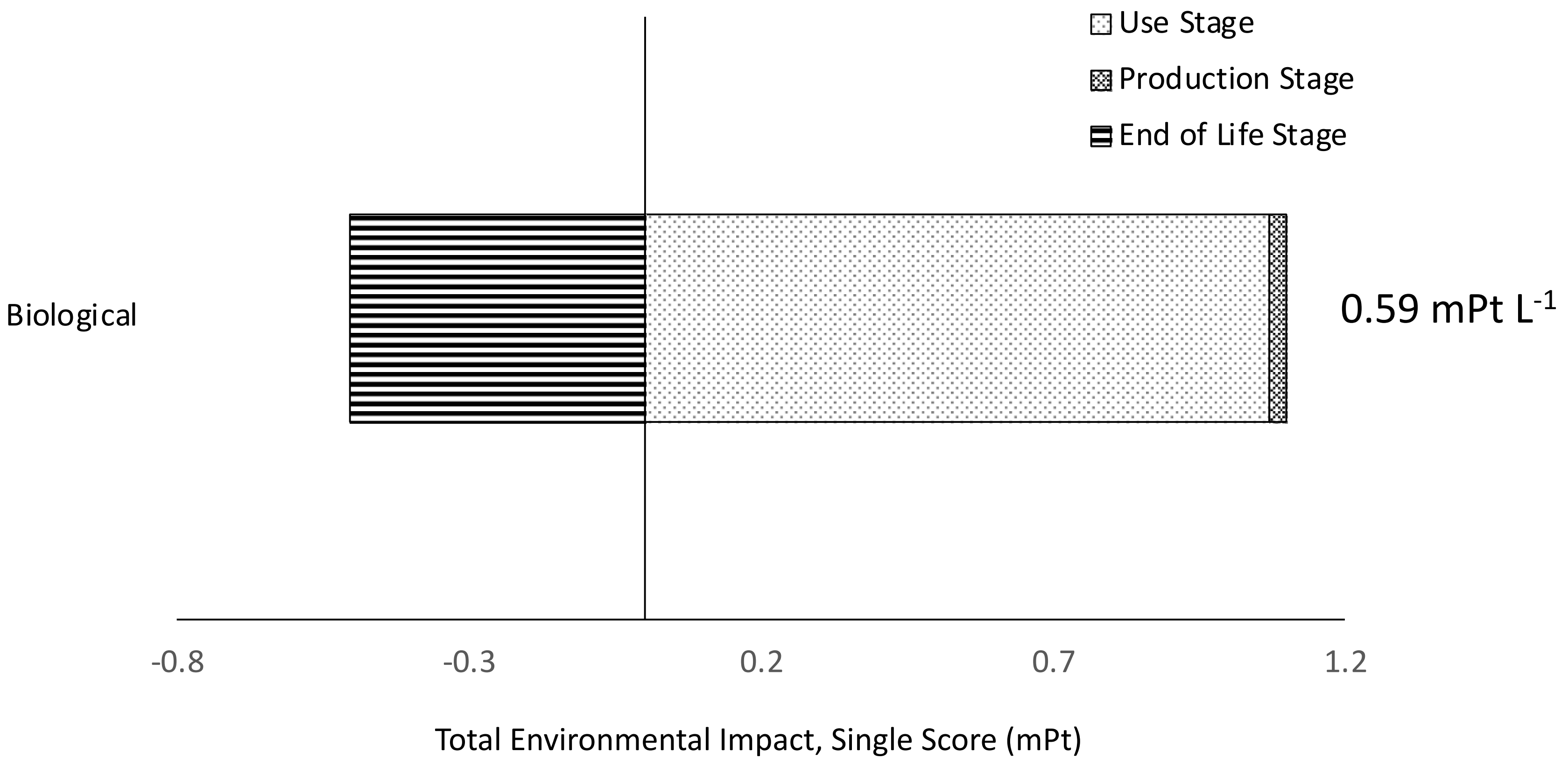
Flowsheet of Biological treatment



Silva, A.D.M et al. (2022), 10.3390/ijerph19052672 .

- O_2 consumption for WRF growth: 1.39-2.05 gO_2/g biomass.day, assumed 10 days growth
- O_2 consumption for WRF maintenance: 0.1 gO_2/g biomass.day, 24 h treatment
- Co_2 emission: 2 μmol/m^2.s^{-1}.

Life Cycle Assessment of Biological Treatment

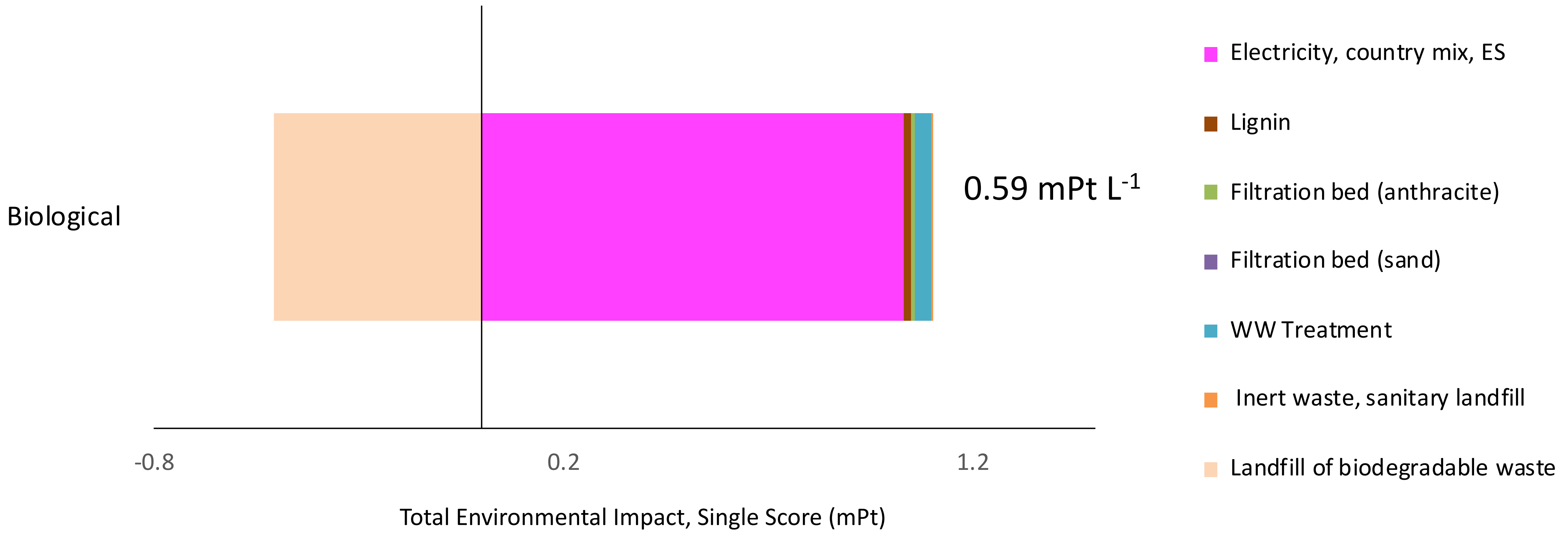


Production Stage: Raw Materials

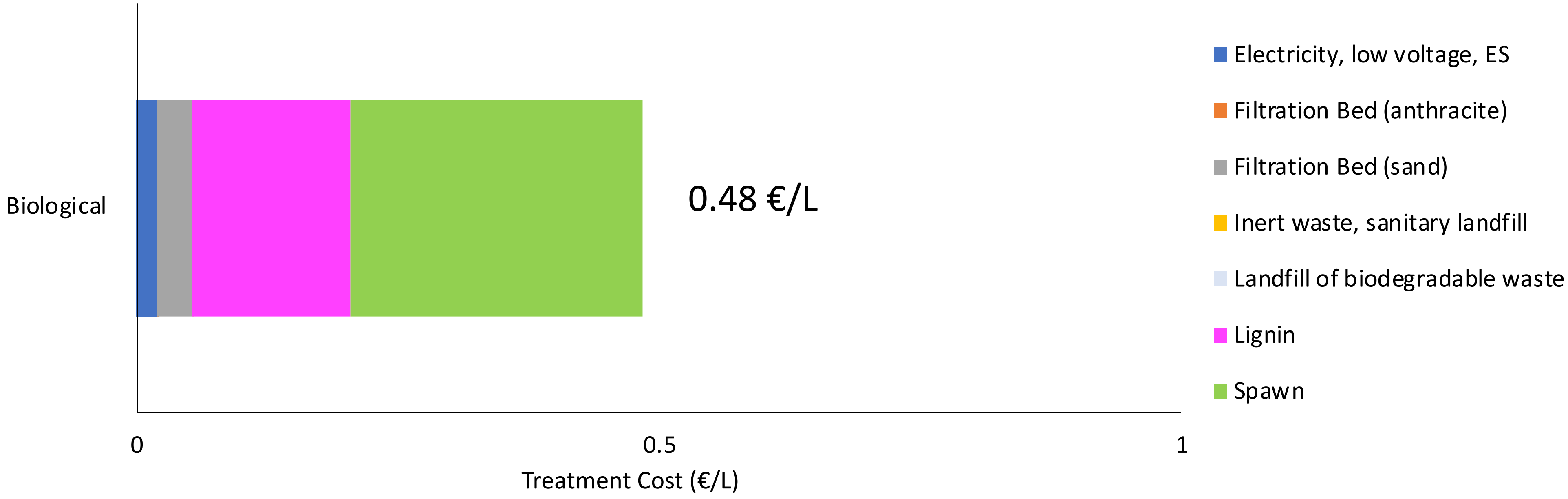
Use Stage (Operation): Electric energy, WW emissions

End of Life: Waste Management

Life Cycle Assessment of Biological Treatment



Costs Assessments



Conclusions

Catalyst based treatments: environmental and cost performance **N-HC Adsorption >** A-E-PMS**>**UV-MOF-PMS, being the catalyst the main contributor

The type and the **amount** of functionalizing agent for **N-HC** has key importance on the environmental and economic performance of N-HC quaternary treatment.

Further efforts are needed to optimize Fe-Cu-MOF and Fe-DES catalysts production

Alternative chemicals for dimethylformamide and copper chloride and a reduction of ethanol (Fe-Cu-MOF), as well as a reduction of the amount of choline chloride, ethanol and potassium hydroxide (Fe-DES) are of key importance to achieve environmental and cost viability of the associated treatments.

Biological treatment is an interesting alterative with good environmental and removal efficiency performances on selected pharmaceuticals (i.e. sulfamethoxazole).

Further efforts must be focused also on the optimization of the operational parameters of biological treatment, including reactor design and substrate selection to improve its efficiency.