Trendalert

S E P T E D

Will Critical Raw Materials critically impact water?

Authors: Daniel J. Duarte, Thomas ter Laak

Summary

Socioeconomic dependence on technological advancements, especially in electronics, energy, and defense, has increased the demand for Critical Raw Materials (CRMs). These scarce elements are essential but pose largely unknown risks as potential water pollutants, recently highlighted in cases like lithium (batteries) and gadolinium (healthcare). Monitoring CRMs as contaminants of emerging concern is therefore required to guarantee the long-term protection of water quality and availability by CRMs, requiring proactive, sustainable water management.

Critical Raw Materials (CRMs) are essential for modern technologies and sustainability goals, yet may challenge water quality. (Image modified from DALL·E 3)

Consequences for you

	Low	Middle	High	Brief explanation
Impact				Pollution of water resources with unknown magnitude
Certainty				Increased demand with high inertia challenging water quality

S = sociaal E = economisch P = politiek T = technologisch E = ecologisch D = demografisch

S E P T E D

Background

In recent decades, there has been a significant surge in technological advancements, including the rise of digitalization, energy infrastructure and storage, advanced medical equipment, modern industrial processes, military and clean technology. As a result of these developments, society has become more reliant on essential natural materials that are scarce yet critical – entering *critical raw materials* (CRM).

Critical and Strategic Raw Materials

A 'raw material' is a substance in processed or unprocessed state used as an input for the manufacturing of intermediate or final products, excluding substances predominantly used as food, feed or combustion fuel. The identification of CRM is assessed based on a material's *criticality* using economic importance and *supply risk*. The first offers insight into a material's significance for end-use applications and its added value. The second indicates the potential risk of supply disruption from raw materials producing countries.

A metal element may not meet the CRM criteria thresholds but still be included in the CRM list due to strategic reasons (e.g., copper and nickel). In fact, raw materials of high strategic value, including in unprocessed form, at any stage of processing and when occurring as a byproduct of other extraction, processing or recycling processes – so called, *Strategic Raw Materials* – are considered to be critical raw materials [1].

The latest EU list of critical raw materials published in 2023, identified 34 CRM out of 70 candidate raw materials, 67 of which individual materials, and 3 material groups (10 heavy rare earth elements, 5 light rare earth elements, and 5 platinum group metals). In the latter assessment, four new materials were evaluated, namely neon, krypton, xenon and roundwood. Table 1 depicts current CRMs and SRMs.

A key challenge is that the environmental behavior and impacts of pollutants are often specific to their location, which complicates their accurate assessment using general fate-transport models. Additionally, there is a lack of data on the (eco)toxicological effects of many CRMs, leading to a limited understanding of how these materials and elements influence the aquatic environment and potentially affect our drinking water sources.

Critical Raw Materials in water

There is growing recognition that anthropogenic CRMs, elements that have been extracted and processed rather than occurring naturally, have entered the environment and wildlife [4]. The Dutch Ministry of Economic Affairs acknowledges that in addition to the socioeconomical aspects of critical materials, it is crucial to address the potential environmental impacts of mineral extraction and trade throughout the supply chain [5].

A study in the Belgian-Dutch transboundary Dommel River catchment found that lithium concentrations ranged from 1.55 to 39.20 µg/L, with an average concentration of 6.58 µg/L, exceeding the global average of 1.9 µg/L [6]. Lithium and lithium-ion batteries are a prime case of a crucial element and component for the green energy transition. By 2040, lithium demand is expected to increase nearly ninefold, driven by the rise in electric vehicle battery production, yet these are becoming a major source of waste by holding a service life of only 6 to 8 years [7, 8]. Another study, this time in the multi-transboundary river Rhine, gadolinium has exceeded the environmental European River Memorandum (ERM) target value of 0.1 µg/L at four key monitoring locations in 2023 [9]. The presence of higher concentrations of TCEs than natural background (Y, Rh, Ga, Ge, and Tl), has also been detected in groundwater, raising some concerns about the health risks for humans and wildlife [10].

Environmental presence of CRMs is often linked to their removal from wastewater, which remains poorly understood or insufficiently studied. For instance, lithium appears to pass through current treatment systems largely unchanged, with minimal removal. In contrast, elements like gadolinium may partially transform into potentially more harmful transformation products, which could pose a greater risk to the drinking water sources, particularly when UV end-of-pipe treatments are applied [11].

The case of lithium

In recent years, the extraction of lithium has risen sharply due to the growing demand for CRMs used in products like mobile phones, batteries, and in the glass and ceramics industries [16]. Throughout the extraction process, product manufacturing, and waste management, lithium can be released into the environment, including surface water, groundwater, and potentially drinking water sources. In 2020, RIWA raised concerns about the levels of lithium in surface water, including the Meuse and Rhine Rivers. In its 2022 annual report, RIWA-Rijn alerted that lithium concentrations in the Rhine consistently exceeded the indicative guidance value for drinking water (7.5 µg/L) and surface water (11 µg/L), potentially due to lithium extraction from geothermal sources in the Rhine river basin [9, 16, 17]. While there have been a few exceedances, there are

Table 1. Critical and strategic raw materials [1]. CRM, Critical Raw Materials. SRM, Strategic Raw Materials.

Material	CRM	SRM
Bauxite	X	X
Antimony	X	
Arsenic	X	
Baryte	X	
Beryllium	X	
Bismuth	X	X
Boron/Borate	X	X
Cobalt	X	X
Coking Coal	X	
Copper	X	X
Feldspar	X	
Fluorspar	X	
Gallium	X	
Germanium	X	
Hafnium	X	
Helium	X	
Heavy rare earth elements	X	

Material	CRM	SRM
Lithium	X	
Light rare earth elements	X	
Magnesium	X	
Manganese	X	
Natural Graphite	X	
Niobium	X	
Platinum group metals	X	
Rare earth elements for permanent magnets		X
Phosphate Rock	X	
Phosphorus	X	
Scandium	X	
Silicon metal	X	
Strontium	X	
Tantalum	X	
Titanium metal	X	
Tungsten	X	
Vanadium	X	

ongoing uncertainties about mid- to long-term trends due to the green energy transition or natural phenomena [18]. Currently, like most other CRMs, little is known about the removal of lithium during drinking water treatment and its long-term public health impacts. If upstream activities such as lithium extraction, waste processing, or improper disposal continue, it is likely that lithium concentrations in the Rhine will keep rising [17]. On the other hand, it remains unclear whether lithium levels in the Meuse or Rhine are linked to groundwater through natural or human-induced activities. Additionally, unpublished data from the drinking water sector suggests that lithium is not effectively removed in current purification processes.

Future demand and emissions

Materials and elements, as illustrated by the case of lithium, which are critical for emerging technologies, are driving a rapid increase in demand and usage.

Many efforts have been made to recover critical raw materials (CRMs) from primary resources or waste streams from pyrometallurgical industry. More recently, however, modern techniques have been developed to recover these elements from end-of-life products, including optical fibers, photovoltaics, light emitting diodes and liquid crystal displays [27]. In this regard, the CRM regulation, emphasizes the importance of long-term recycling and resource recovery strategies as key contributors to securing Europe's supply and reducing dependency on external parties. This may be of particular importance to the Netherlands, which is one of the top importers.

Implications for water quality management

Due to the growth in use of CRMs, monitoring programs need to include these elements, in order to follow trends and to help address current concerns about CRM pollution of water sources. The Ministry of Infrastructure and Water Management and Rijkswaterstaat are currently taking steps to better understand sources, exposure and impact of CRMs and commissioned research (by KWR), and a report is expected early 2025. It is expected that this research will inform water managers on how to monitoring CRMs in downstream transboundary surface waters potentially impacted by CRM-emitting industries and activities (e.g., extraction, waste processing, recycling), such as the Rhine and Meuse Rivers.

The drinking water sector ought to closely follow these developments, monitor and understand the potential impacts of CRMs in the provision of wholesome and clean drinking water. Ultimately, an inventarisation of the most relevant CRMs to European and Dutch water quality should be performed.

More information

1. EU, *Regulation (EU) 2024/1252 of the European Parliament and of the Council of 11 April 2024 establishing a framework for ensuring a secure and sustainable supply of critical raw materials and amending Regulations (EU) No 168/2013, (EU) 2018/858, (EU) 2018/1724 and (EU) 2019/1020 (Text with EEA relevance).* Official Journal of the European Union, 2024.
2. Mertens, J., et al., *From emissions to resources: mitigating the critical raw material supply chain vulnerability of renewable energy technologies.* Mineral Economics, 2024. **37**(3): p. 669-676.
3. Haegel, N.M., et al., *Photovoltaics at multi-terawatt scale: Waiting is not an option.* Science, 2023. **380**(6640): p. 39-42.
4. Wosnick, N., et al., *From screens to seas: Tech contaminants in tiger sharks.* Environmental Pollution, 2024. **360**: p. 124690.
5. NL, *NL non-paper on the Action Plan on Critical Raw Materials and the Critical Raw Materials Act*, M.o.E. Affairs, Editor. 2023.
6. Négrel, P., et al., *Li and δ7Li as proxies for weathering and anthropogenic activities: Application to the Dommel River (meuse basin).* Applied Geochemistry, 2020. **120**: p. 104674.
7. JRC. *Future Demand for Raw Materials in Emerging Technologies – A Global Perspective*. [cited 2024; Available from: https://rmis.jrc.ec.europa.eu/futuredemand.

8. Wang, M., et al., *Integrated assessment of deep eutectic solvents questions solvometallurgy as a sustainable recycling approach for lithium-ion batteries.* One Earth, 2023. **6**(10): p. 1400-1413.
9. Neefjes, R.E.M., et al., *Jaarrapport 2022 De Rijn*. 2023, RIWA-Rijn.
10. Amiel, N., et al., *Selected technology-critical elements as indicators of anthropogenic groundwater contamination.* Environmental Pollution, 2021. **284**: p. 117156.
11. Brünjes, R. and T. Hofmann, *Anthropogenic gadolinium in freshwater and drinking water systems.* Water Research, 2020. **182**: p. 115966.
12. Rodushkin, I., et al., *Application of double-focusing sector field ICP-MS for determination of ultratrace constituents in samples characterized by complex composition of the matrix.* Science of The Total Environment, 2018. **622-623**: p. 203-213.
13. Schmidt, K., et al., *Anthropogenic gadolinium in tap water and in tap water-based beverages from fast-food franchises in six major cities in Germany.* Science of The Total Environment, 2019. **687**: p. 1401-1408.
14. Bau, M. and P. Dulski, *Anthropogenic origin of positive gadolinium anomalies in river waters.* Earth and Planetary Science Letters, 1996. **143**(1): p. 245-255.
15. Schwesig, D. and A. Bergmann, *Use of anthropogenic gadolinium as a tracer for bank filtrate in drinking water wells.* Water Supply, 2011. **11**(6): p. 654-658.
16. Faber, M. and C. Smit, *Indicatieve milieurisicogrenzen voor lithium in oppervlaktewater*, in *Indicative environmental risk limits for lithium in surface water*. 2023, Rijksinstituut voor Volksgezondheid en Milieu RIVM.
17. Reus, A.A.H.-C., C.H.M.; Zwartsen, A. , *Toxiciteit Lithium.* KWR Water Research Institute, 2021. KWR 2021.046.
18. de Jonge, J.A., et al., *Jaarrapport 2023 De Rijn*. 2024, RIWA-Rijn.
19. Consilium. *An EU critical raw materials act for the future of EU supply chains*. 2024 12 September 2024 [cited 2024; Available from: https://www.consilium.europa.eu/en/infographics/critical-raw-materials/.
20. Cobelo-García, A., J. Schäfer, and I. Dror, *VSI: Environmental concentrations, cycling and modeling of technology critical elements.* Science of The Total Environment, 2018. **630**: p. 32.
21. Bohn, T.N., Tom; Ramaekers, Pascal; Fung Wong, Khee. *Kritieke materialen in de Nederlandse toeleveringsketen*. 2023 [cited 2024; Available from: https://www.cbs.nl/nl-nl/longread/rapportages/2023/kritieke-materialen-in-de-nederlandse-toeleveringsketen.
22. EU, *Regulation (EU) 2023/1542 of the European Parliament and of the Council of 12 July 2023 concerning batteries and waste batteries, amending Directive 2008/98/EC and Regulation (EU) 2019/1020 and repealing Directive 2006/66/EC (Text with EEA relevance).* Official Journal of the European Union, 2023.
23. Hans Peter H. Arp, S.E.H., Ulrich Borchers, Vassil Valkov, Laura Wiegand, Daniel Zahn, Isabelle Neuwald, Karsten Nödler, Marco Scheurer, *A prioritization framework for PMT/vPvM Substances under REACH for registrants, regulators, researchers and the water sector.* Umweltbundesamt, 2023(Texte | 22/2023): p. 238.
24. Romero-Freire, A., et al., *Assessment of baseline ecotoxicity of sediments from a prospective mining area enriched in light rare earth elements.* Science of The Total Environment, 2018. **612**: p. 831-839.
25. Duarte, D.J., et al., *Making waves: Xanthates on the radar – Environmental risks and water quality impact.* Water Research X, 2024. **24**: p. 100232.
26. Desrousseaux, A., et al., *A shared socio-economic pathway based framework for characterising future emissions of chemicals to the natural environment.* Futures, 2022. **144**: p. 103040.
27. Zheng, K., M.F. Benedetti, and E.D. van Hullebusch, *Recovery technologies for indium, gallium, and germanium from end-of-life products (electronic waste) – A review.* Journal of Environmental Management, 2023. **347**: p. 119043.

Keywords
critical raw material, strategic raw material, water quality

Authors: Daniel J. Duarte, Thomas ter Laak

Thematic Trendalert: Chemical Safety
Project number: 404300 - BTO 2024-2029