Due Diligence for Responsible Sand and Silicate Supply Chains

Due Diligence for Responsible Sand and Silicate Supply Chains

BETTER POLICIES FOR BETTER LIVES

Please cite this publication as:
OECD (2026), *Due Diligence for Responsible Sand and Silicate Supply Chains*, OECD Publishing, Paris, https://doi.org/10.1787/7be0093e-en.

ISBN 978-92-64-67869-9 (print)
ISBN 978-92-64-59583-5 (PDF)
ISBN 978-92-64-49904-1 (HTML)

Photo credits: Cover © mariusz_prusaczyk/Getty Images.

Corrigenda to OECD publications may be found at: https://www.oecd.org/en/publications/support/corrigenda.html.

Foreword

Efforts to source minerals and metals responsibly using risk-based due diligence have increased since the adoption of the OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas (OECD Minerals Guidance) in 2011. Market and regulatory expectations for companies to identify and mitigate risks in their supply chains based on OECD standards on responsible business conduct (RBC) cover 15 minerals and metals as of 2025[1].

> *The OECD Minerals Guidance provides practical, government-backed due diligence recommendations and helps companies avoid contributing to severe adverse impacts like serious human rights abuses, conflict and financial crime through their mineral purchasing decisions and practices. It serves as the leading international standard for minerals due diligence and applies to all minerals globally. The Guidance is embedded into a range of sustainability initiatives that companies participate to support and demonstrate due diligence in alignment with international standards. Other OECD standards including the Guidelines for Multinational Enterprises on Responsible Business Conduct, the Due Diligence Guidance for Responsible Business Conduct, the Handbook on Environmental Due Diligence in Mineral Supply Chains and the Due Diligence Guidance for Meaningful Stakeholder Engagement in the Extractive Sector address the full range of RBC risks related to people, planet and society.*

Sand and silicates are the most extracted resources after water and, considering their extraordinary production volumes, significant risks and adverse impacts are linked to their extraction and trade. To date, OECD due diligence recommendations have not been widely applied to sand and silicates, a family of minerals extracted in nearly every country. While some multi-stakeholder efforts have emerged to raise awareness about risks in the sector, understanding and action to address them remain limited. This report examines sand and silicate supply chains and analyses RBC risks in the sector based on the OECD Minerals Guidance, the OECD Handbook for Environmental Due Diligence in Mineral Supply Chains, and other OECD standards on RBC. It provides recommendations on how companies can adopt an integrated approach to assess and address risks spanning environmental impacts, human rights abuses, conflict finance, and financial crime in addition to other risks affecting workers and communities.

The report is global in scope and examines a range of sand and silicate materials. Minerals that are often extracted from sand but do not belong to the sand and silicates family are excluded from the report, for example titanium, zirconium and other precious minerals more commonly defined as sand minerals. The research is based on a comprehensive literature review of academic, industry and policymaker sources, complemented by input from a cross-sectoral dialogue and expert interviews. Annex A provides additional detail on the methodology and scope.

Acknowledgements

This report has been authored by Cäcilie Le Gallic, Benjamin Katz and Louis Maréchal under the direction of Hannah Koep-Andrieu and Allan Jorgensen from the OECD Centre for Responsible Business Conduct jointly with Louise Gallagher, Daniel Holm and Daniel M. Franks of the Global Centre for Mineral Security at the University of Queensland's Sustainable Minerals Institute. Members of the Coalition for Responsible Sand and Silicates provided support to the dialogue and research process, including Inter IKEA, Roca Group, Cary Group, Mota Ceramics Solutions Group (MSC Group), RiaStone, and World Wide Fund for Nature (WWF). In addition to the Coalition, the following organisations provided input: Alliance for Responsible Mining, Bernreuter Research, Alan Crawford Consulting LLC, Delve Exchange, Global Cement & Concrete Association, H&M, Holcim, Imerys, Intel, Industrial Minerals Association Europe (IMA-Europe), The Concrete Sustainability Council (CSC), Responsible Mica Initiative, Responsible Minerals Initiative (RMI), United Nations Development Programme (UNDP), United Nations Environment Programme (UNEP) and Quarzwerke.

Table of contents

FIGURES

TABLES

Executive summary

The economic significance of sand and silicates

Sand and silicates are **the two most extracted solid materials globally.** They are essential for **construction and infrastructure,** in addition to **semiconductors and energy**. **Trade dependencies** for silicate-based raw material inputs for solar and semiconductor supply chains fluctuate between OECD countries and the People's Republic of China (hereafter 'China'), switching direction multiple times along the supply chain.

China has achieved dominance over the solar supply chain, in addition to key segments of the semiconductor value chain, accounting for 85% of the world's silicon metal production, 95% of solar-grade polysilicon and 97% of solar-grade silicon wafer production. However, **China is dependent on the United States for high-purity quartz (HPQ),** a raw material that is vital for crucibles used to process silicon metal into polysilicon for both semiconductors and solar panels. A single US mine is responsible for 70% of the global supply of HPQ.

OECD countries like Germany, Japan, Korea and the United States play **leading roles in other parts of the semiconductor supply chain,** accounting for 65% of semiconductor-grade polysilicon and over 70% of semiconductor-grade silicon wafers. Beyond the interdependencies within each supply chain, semiconductor raw material and intermediate input producers also depend on demand from the solar industry due to its much larger scale of raw material use, and are therefore exposed to price and industry trends in the solar sector. In a context of growing economic security concerns, this strategic supply chain is an example of interdependency. **Parallel measures have ensued**, with several OECD countries listing silicon as a critical mineral and China listing HPQ as a strategic material, leading to the discovery of new deposits in China.

The construction sector is the largest user of sand and silicates and accounts for 13% of global GDP. With more than 50 billion tonnes of annual consumption, sand and silicate extraction is taking place in almost every country. Only **1-2% of global sand and silicate output is traded** internationally, but trade volumes surpass many high-value minerals due to the sheer size of the sector. Global annual sand and silicate consumption amounts to 70 000 times the combined volumes for cobalt, lithium, gold, tantalum, tin and tungsten. The sand and silicate **market is estimated to amount to USD 600 billion** annually, making the sector more than **50% larger than the value of annual gold** production while being more than **a million times larger in volume**. The extraction and processing of these materials present unique opportunities for beneficiation, development and livelihoods.

Scale of risks and impacts

Freshwater and marine extraction of sand and silicates can have particularly **significant environmental impacts** since sand plays a direct role in the functioning of such ecosystems. Biodiversity loss, climate change risks, water depletion, and air, water and soil pollution are all linked to the sector. In some areas, extraction rates are unsustainable, with regional environmental and economic implications. In the Mekong River Delta, sand **extraction is ten times the replacement rate**, resulting in riverbed instability. From 2018 to 2022, up to **one-sixth of dredging occurred in marine protected areas,** which are sanctuaries for underwater life. Most conflict-affected and high-risk areas have some sand and silicates production. **Corruption, human rights abuses, financial crime and conflict finance** are reported across the supply chain, in addition to occupational health and safety concerns and adverse impacts on communities and Indigenous Peoples. While sand and silicates are crucial to global supply chains, governance of their production is fragmented, with regulations varying across local, national and international levels, especially in transboundary freshwater systems. A substantial share of extraction occurs informally, posing challenges for governance, regulatory oversight and illicit trade.

Building responsible sand and silicate supply chains

OECD standards on responsible business conduct (RBC) call on enterprises to undertake risk-based due diligence to identify, prevent, mitigate and account for how they address actual and potential adverse impacts in their own operations and supply chains. Implementation of RBC standards, including sustainability initiatives that facilitate or audit due diligence by companies, generally focusses on widely traded higher-value minerals, but are also an important basis for wider uptake of due diligence in sand and silicate supply chains.

Considerations for companies

The report identifies key actions companies producing and sourcing these materials can take to apply OECD standards and tailor their recommendations to the sector:

- Map material flows and extraction contexts: Identify where sand and silicates originate, transport routes, and overlap with high-risk areas.
- Screen for ecosystem-sensitive sourcing: Include checks for extraction from freshwater or marine environments and high-biodiversity zones.
- Adapt mitigation to supply chain structure: For short, localised chains, use community-based approaches; for transboundary chains, integrate sand and silicates into multi-tiered due diligence frameworks used for minerals due diligence.
- Leverage existing sustainability initiatives: Explore entry points such as lime use in smelting and refining to connect sand and silicate oversight with established sustainability initiatives and, where relevant, audit and certification programmes.
- Address cumulative and systemic environmental impacts at the extraction stage: Consider that risks can propagate beyond the immediate extraction site and accumulate over time; orient engagement with suppliers to ensure they address related environmental risks.
- Invest in circularity and resource efficiency: Where extraction and consumption rates are unsustainable, prioritize recycling, alternative materials, and efficiency measures.
- Collaborate on sector-specific initiatives: Share risk data, develop monitoring systems tailored to sand and silicates, and assess whether a “control point” model is feasible for these supply chains.

Considerations for governments

Given the use of sand and silicates in a range of strategic sectors and potentially unsustainable levels of extraction, there is a shared interest in pursuing global approaches for the responsible and sustainable use of these materials. Governments may consider the following policy measures in support of such aims:

- Infrastructure policy: Support the implementation of RBC provisions in public procurement, export credit agency-backed projects, infrastructure development frameworks, public-private partnerships, and risk management systems of development finance institutions while adopting a risk-based approach adapted to specific types of sand and silicates and varying risk profiles.
- Resilience: Building on existing efforts, consider shifting trade dependencies in the semiconductor supply chain in policies to enhance resilience for critical raw materials.
- Trade monitoring: Harmonise HS trade classifications for sand and silicates to improve trade data transparency for traded types of sand and silicates that cannot be easily tracked at present; progressively extend supply chain due diligence expectations to these materials; and strengthen customs and law enforcement co-operation to counter illicit flows where relevant.
- Environmental conventions and law enforcement: Integrate responsible sand and silicate supply chains into implementation programmes for international environmental agreements, including to foster circularity, recycling and resource efficiency, and ensure enforcement of relevant environmental regulations in line with international best practice, especially in areas where RBC risks are significant and sand and silicate extraction rates unsustainable.
- International collaboration: Pursue international co-operation to track sand and silicate extraction and consumption, especially for construction sand at regional level where extraction can become unsustainable, and foster multi-stakeholder collaboration to enable more sustainable sand and silicate production and consumption rates.

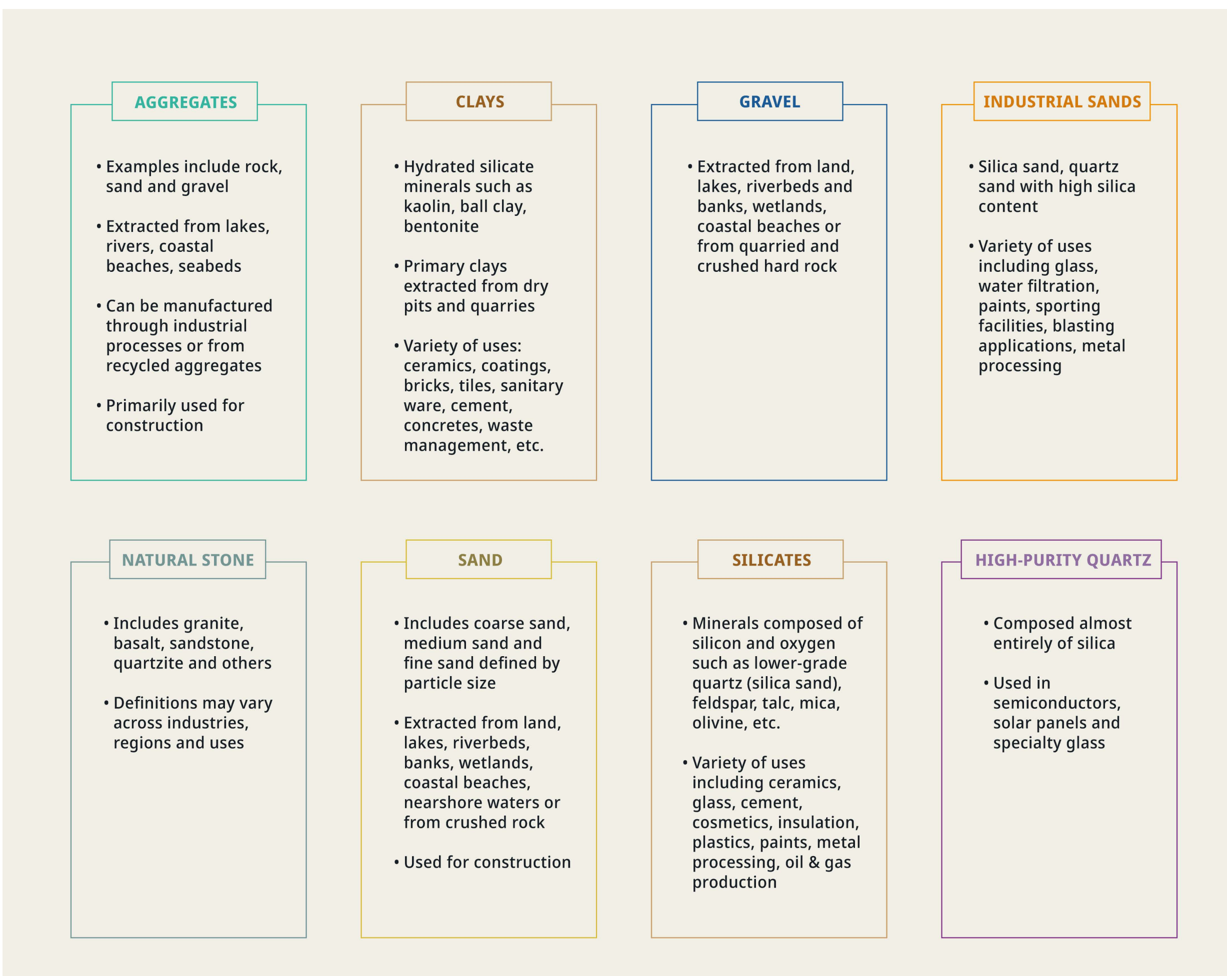
1 Overview of the sand and silicates sector

Sand and silicates are essential building blocks of modern life. They are used to build roads and housing and drive economic and industrial development across regions through vital inputs and goods delivery. Ceramics, glass, paint and concrete are all made of sand and silicates, serving as critical inputs to strategic sectors like electronics and renewable energy. Global demand for sand and silicates is only increasing and feeds material production in nearly every country in the world. Finite resources and production that exceeds replenishment rates, however, are unsustainable and pose significant economic resilience challenges.

Why are sand and silicates important?

Sand and silicates are the most widely used solid materials in the world and the second largest extracted resource after water. They serve as building blocks for economies and societies, providing the materials necessary for infrastructure, housing and a wide range of sector-specific products and services. Sand and silicates are vital for local, regional and international sustainable development in producing and consuming countries alike (Franks, 2020[1]). They support economic and energy security by serving as critical inputs for energy technologies (both renewable energy and for oil and gas fracking), electronics, and the automotive industry. Many industrial processes depend on sand and silicates, including metal processing and refining. Some materials such as clay and silica sand are often overlooked when they enter global supply chains as inputs in the form of glass, cement, plastic or paint. Silicon, on the other hand, derived from high-purity quartz - a member of the sand and silicates family - has received more attention as a high-profile material because of its geographical concentration at both mineral production and intermediary processing stages (see Section 2) and its criticality to the production of semiconductors and solar panels.

Figure 1.1. Overview of sand and silicates classification



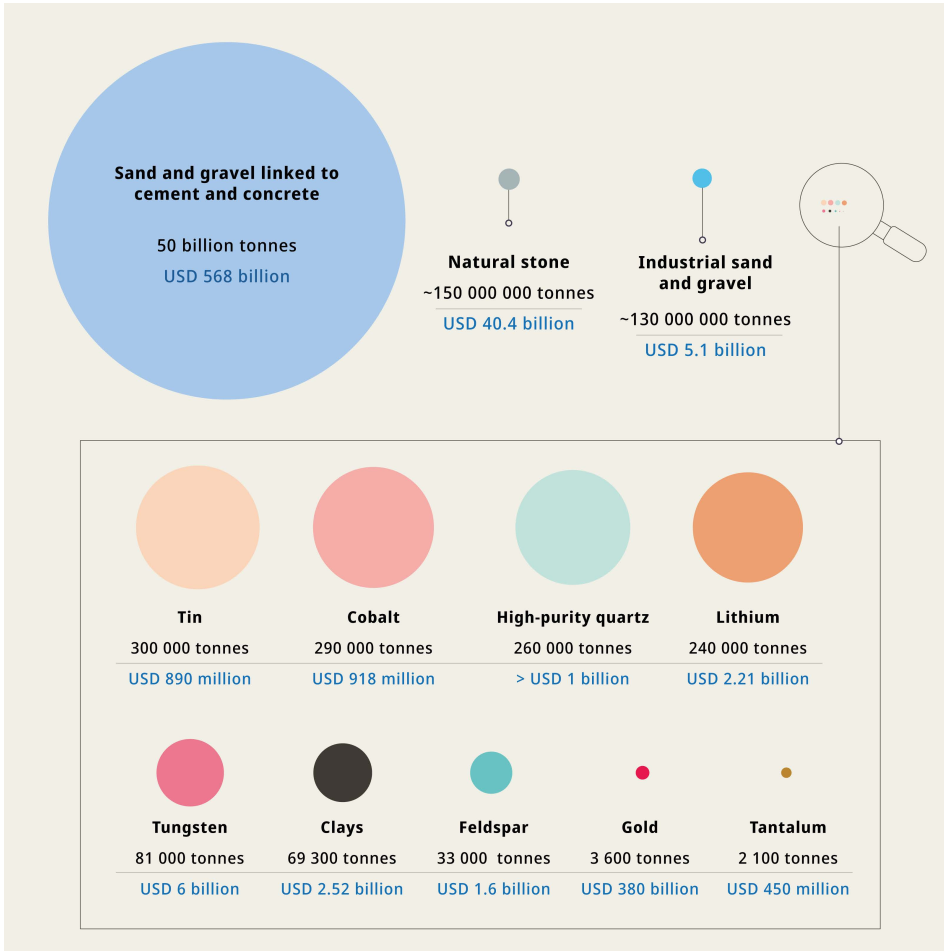
Defining sand and silicates

Sand and silicates refer to a diverse group of mineral materials containing silicon and oxygen. This group includes sand, gravel, stone, clays, quartz, and other silicate minerals that play indispensable roles in our societies and economies. Sand and silicates are abundant, stable, strong, and versatile materials with properties that make them useful for many applications.[2] Defining sand and silicates means considering key characteristics like form, grain size, shape, mineralogy and end uses. Taking account of the breadth and diversity of sand and silicates, this report classifies sand and silicates using the categories shown in Figure 1.1. Given the range of classifications and these commodities often consisting of aggregates of minerals, this report uses the term 'materials' rather than 'minerals'. The distinguish themselves from sand ores – such as zirconium and titanium – which are metal ores extracted from sand and resulting in the production of sand produced as a by-product.

Extraordinary consumption volumes

Extraction and use of sand and silicates have reached extraordinary volumes and take place in diverse natural environments within the earth’s crust - from terrestrial lands and mountains to freshwater lakes, rivers and the sea. Current estimates place global consumption at around 50 billion tonnes annually (UNEP, 2019[2]; 2022[3]) and demand is estimated to reach 86 billion tonnes in 2060 (OECD, 2019[4]). Sand and gravel used for cement, concrete and aggregates, account for most of this vast volume (see Figure 1.2). This compares to the combined annual consumption of high-value minerals such as gold, cobalt, lithium, tin, tantalum, and tungsten, which collectively amount to approximately 740 000 tonnes, or about 70 000 times less than global annual sand and silicate consumption. The value of these minerals is driven by the gold sector with a mined production of 3600 tonnes worth around USD 380 billion in 2024 (World Gold Council, 2025[5]). In comparison, the sand and silicate market may amount to USD 600 billion annually,[3] making the sector just over 1.5 times larger than the value of annual gold production while being more than a million times larger in volume.

Figure 1.2. Global annual sand and silicate consumption



Sources: USGS (2023[6]), Mineral Commodity Summaries 2023: GOLD, https://doi.org/10.3133/mcs2023; World Gold Council (2024[7]), Historical demand and supply, https://www.gold.org/goldhub/data/gold-demand-by-country; Statstica (2024[8]) Major countries in industrial sand and gravel production worldwide in 2023, https://www.statista.com/statistics/376665/industrial-sand-and-gravel-production-by-top-countries/; Cobalt Institute (2021[9]), State of the Cobalt Market, https://www.cobaltinstitute.org/wp-content/uploads/2025/02/Cobalt-Institute-State-of-the-Cobalt-Market-Report_2020.pdf; USGS (2024[10]), Cobalt Statistics and Information, https://www.usgs.gov/centers/national-minerals-information-center/cobalt-statistics-and-information; USGS (2022[11]), Mineral Commodities Summaries 2022: LITHIUM, https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-lithium.pdf; USGS (2024[12]), Mineral Commodity Summaries 2024 TIN, https//pubs.usgs.gov/periodicals/mcs2024/mcs2024-tin.pd; USGS (2020[13]), Mineral Commodity Summaries 2020 TANTALUM, https://pubs.usgs.gov/periodicals/mcs2020/mcs2020-tantalum.pdf; USGS (2022[14]), Mineral Commodity Summaries 2022 TUNGSTEN, https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-tungsten.pdf; Statistica (2024[15]), Distribution of tungsten consumption worldwide between 2012 and 2016, by country, https://www.statista.com/statistics/1009699/tungsten-consumption-distribution-worldwide-by-country/; UNEP (2019[2]), Sand and sustainability: Finding new solutions for environmental governance of global sand resources, https://unepgrid.ch/storage/app/media/documents/Sand_and_sustainability_UNEP_2019.pdf; UNEP (2022[3]), Sand and sustainability: 10 strategic recommendations to avert a crisis, https://www.unep.org/resources/report/sand-and-sustainability-10-strategic-recommendations-avert-crisis; USGS (2023[16]), Mineral Commodity Summaries 2023 SAND AND GRAVEL (INDUSTRIAL), https://pubs.usgs.gov/periodicals/mcs2023/mcs2023-sand-industrial.pdf; USGS (2024[17]), Minerals Commodity Summaries 2024: CLAYS, https://pubs.usgs.gov/periodicals/mcs2024/mcs2024-clays.pdf; USGS (2024[18]), Mineral Commodity Summaries 2024 QUARTZ (HIGH-PURITY AND INDUSTRIAL CULTURED CRYSTAL), https://pubs.usgs.gov/periodicals/mcs2024/mcs2024-quartz.pdf; USGS (2024[19]), FELDSPAR AND NEPHELINE SYENITE, https://pubs.usgs.gov/periodicals/mcs2024/mcs2024-feldspar.pdf; Research and Markets (2024[20]), Natural Stone Global Market Report 2024, https://www.researchandmarkets.com/reports/5766803/natural-stone-global-market-report.

Growing global demand is spurring production across the world

Sand and silicates are extracted in nearly every country in the world. Urbanisation, infrastructure development, large-scale industrial demand, and a growing focus on renewable energy technologies are driving demand for sand and silicate production. From construction and transport infrastructure on the African continent (AfCFTA, n.d.[21]) to ongoing construction booms in the Middle East - especially in the Gulf states (Oxford Economics, 2023[22]) to rapidly developing markets in Latin America or rising demand for high-purity silica sand for the fracking industry in the United States – growing demand is expected to spur global sand and silicate production which is estimated to double from 2020 levels by 2060 (Zhong et al., 2022[23]).

Reconciling high demand and finite resources

While natural reproduction processes and manufacturing can sustain long-term supply, not all sand and silicates can be easily or affordably accessed (Padmalal and Maya, 2014[24]). Localized shortages of sand and aggregates for construction have emerged in contexts of massive land reclamation, construction and beach nourishment in Africa, Asia and North America (Tychsen, Batista and Carvalho, 2022[25]; Ren et al., 2022[26]; IADC, 2023[27]; Franke, 2014[28]; UNDP, 2018[29]). Concerns regarding the availability of industrial sands and high-purity silica with certain characteristics in proximity to end users, also regularly arise (Blervacq, 2022[30]). The drivers of such shortages include limited sand deposits, extraction occurring at an unsustainable pace exceeding geological availability or natural replenishment rates, high fuel and energy costs and supply chain disruptions in the context of conflict. While being traded at significantly lower values compared to high-value minerals such as gold, sand and silicate prices have soared in some locations, including in OECD countries, in response to supply constraints (Schwing, 2024[31]; IADC, 2023[27]) progressively eroding the perception that these materials are abundant and inexpensive resources. High levels of concentration in the market of high-purity quartz (HPQ) and silicon metal, materials critical for global semiconductor manufacturing, provides only one example of how trade dependencies can emerge and amplify vulnerabilities of global sand and silicate supply chains (see Section 2).

2 The sand and silicate supply chain

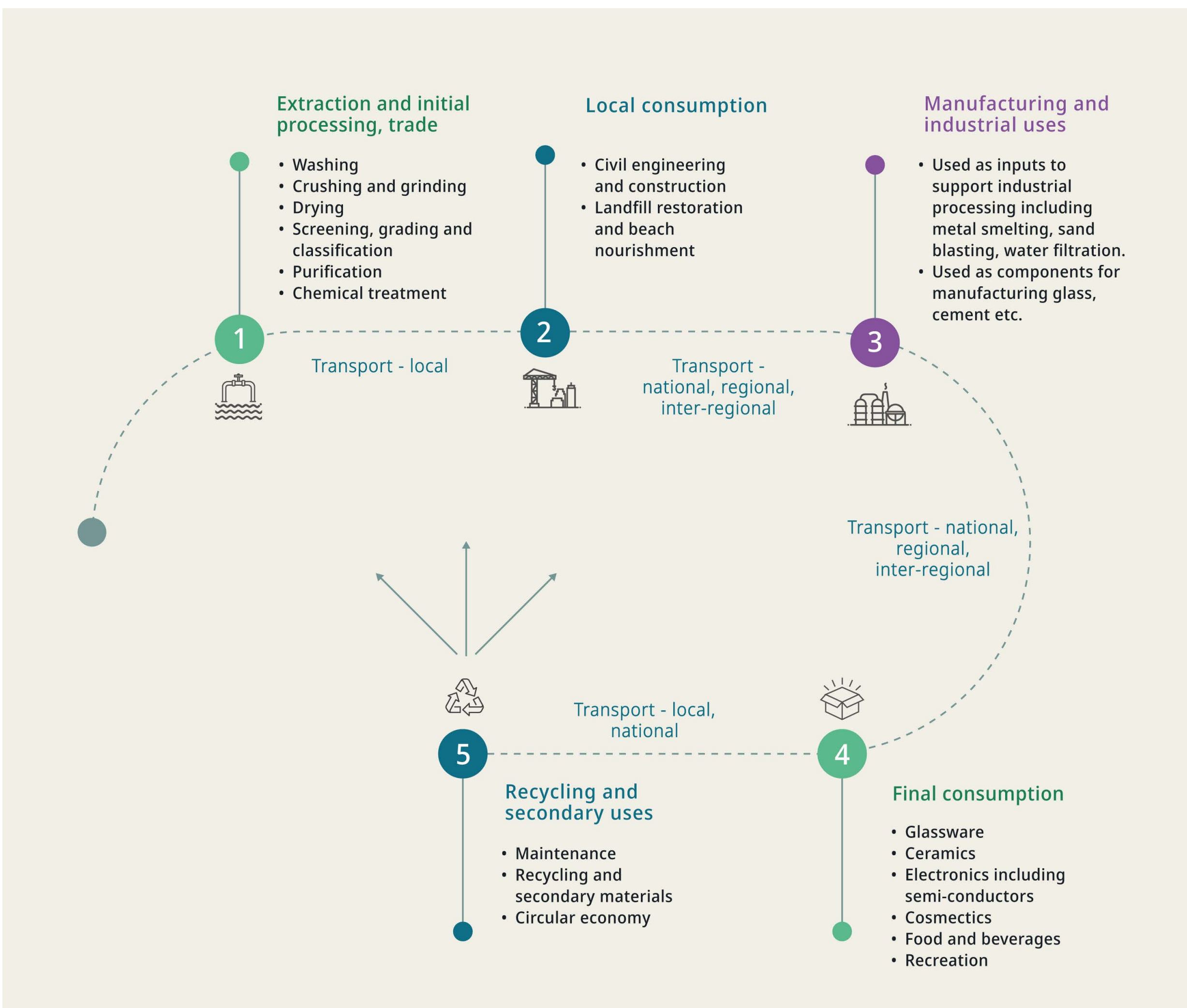
This chapter illustrates how sand and silicate extraction systems work, how they interact with each other and how they connect to mid- and downstream sectors. An analysis of international sand and silicate trade shows that the bulk of these materials is consumed locally. Overlapping production systems involving artisanal and small-scale as well as industrial mining operations lead to the blending of feedstocks, especially in local contexts. Some sand and silicate materials are traded internationally as often overlooked inputs in global supply chains. Despite the importance of locally contained production and trade systems in the sector, considering the sheer scale of their consumption, international trade in sand and silicates is significant.

An overview of sand and silicate supply chains

Developing an understanding of the structure and dynamics of sand and silicate supply chains is important for enabling scoping and risk identification and for developing appropriate measures to mitigate risks and address impacts. A key feature of sand and silicates is the heterogeneity of supply chain operators with the presence of few dominant players (Torres et al., 2021[32]; Holm, Gallagher and Franks, 2023[33]). This stems from the existence of diverse resource production systems involving many types of minerals, extraction practices, supply chains, governance structures and actors.

Figure provides an overview of sand and silicate supply chains from extraction to processing, transport, and end-use industries, as well as recycling. Some supply chains are short and straightforward, such as the local supply of construction aggregates, while others are longer and more complex, involving international trade and industrial transformation. This diagram, while schematic and simplified, provides a foundation for exploring the complexities and opportunities for risk mitigation within these supply chains.

Figure 2.1. Overview of the sand and silicate supply chain



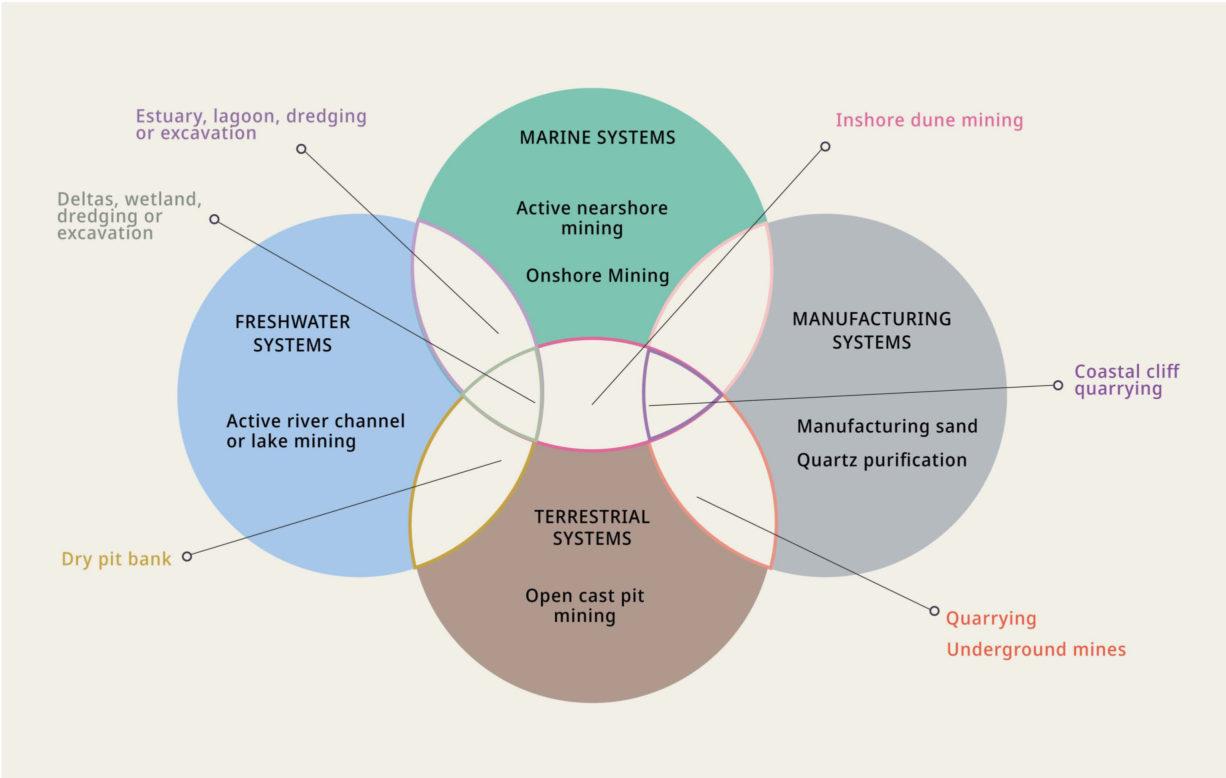
Sand and silicate extraction

A key point critical to understanding the risk landscape of sand and silicate supply chains is that, in contrast to many other minerals, sand and silicates are extracted from two types of sourcing environments: dynamic and static. In dynamic systems, sand, gravel and clay play important ecological functions that can be significantly impacted by their removal. Dynamic systems include *freshwater systems* whereby river currents shape, transport and deposit rocks and sediments in river channels, lakes, wetlands and estuaries, as well as marine systems where marine processes like erosion and deposition shape distinct silicate deposits on the seabed and along coastlines. While being shaped by water and rivers, sand and silicates are themselves essential to the functioning of freshwater and marine systems with aquatic life. Sand and silicates help maintain a balanced natural sediment structure and enable nutrient cycling on which aquatic life depends. Marine sand extraction from coastal ecosystems is estimated to account for 4-8 billion tonnes of sand and silicate consumption each year (UNEP, 2024[34]).

In static systems sand, gravel, clay and crushed stone are not typically fundamental to the functioning of the ecosystems above them, but extraction can still disturb these ecosystems. Static systems include terrestrial systems such as rocks, stones, sand, gravel, or other silicate materials which are typically extracted from the earth's surface in open pit mines or quarries and can result from industrial processes applied in manufacturing systems. A significant share of naturally sourced sand and silicates undergoes mechanical or manual processing within manufacturing systems, which are becoming increasingly important in global sand and silicate production (Bhatawdekar et al., 2021[35]). Most manufacturing systems transform natural materials like stones and quartz for uses further downstream. This transformation and processing comprise a multitude of steps which can result in a diverse range of subsequent material flows. Due to the complexity and variety of processing techniques, manufacturing systems are generally seen as a distinct source of supply in the sector[4]. An analogy to scrap and secondary sourcing in other mineral supply chains can be made where such materials tend to be treated as a distinct source of supply separate from primary or mined materials for due diligence purposes, even if the comparison with manufacturing systems of sand and silicates is not an exact equivalent.

Each of the four extraction systems – from freshwater, marine, terrestrial and manufacturing systems, produces sand and silicates with unique characteristics suited to different applications, yet they all share similar mineralogy. Importantly, sand and silicate extraction can also take place in areas where extraction systems co-exist (see Figure 2.2). For example, quarrying can take place in marine systems, through coastal quarrying, as well as in terrestrial systems by means of natural stone quarrying. Sand and silicates can also be engineered through manufacturing processes, sourced as secondary materials or recycled from non-sand mineral extraction which generate sand in the form of tailings. While material recycling and secondary sourcing does exist in the supply chain, the characteristics of secondary sand and silicate sourcing and related risks and impacts fall beyond the scope of this report.

Figure 2.2. Sources and extraction methods for sand and silicate production



The scale of extraction from artisanal to small-scale and industrial operations

Sand and silicates are extracted through a wide range of methods, from artisanal to large-scale and highly mechanised operations**.** Artisanal and small-scale mining (ASM) plays a crucial role in producing sands, clays, and stones used in construction in Asia, Africa and Latin America. In Sub-Saharan Africa, 90% of all sand mining is estimated to originate from ASM[5] which is broadly characterised by low levels of mechanisation. Extraction and initial processing support the livelihoods of millions of artisanal miners and their dependents. The artisanal production of industrial sands, albeit rare, also exists. Small to medium-sized enterprises (SMEs) and local businesses are equally important actors in sand and silicate supply chains. They tend to operate in local markets of sand and silicates or in the production of niche applications. Hydraulic pumping, mechanical excavators, and transporters can be used in small-scale operations. In the United States, in 2023, more than three thousand SMEs were observed to produce sand and silicates across all 50 States (USGS, 2024[36]). Large-scale mining (LSM) and quarrying enterprises are present in sand and silicate supply chains but, compared to other commodities, are less dominant. Sandstone, quartzite, basalt or other silica-rich materials can be extracted from large, formal quarries where capital-intensive, industrial operators engage in mining and preliminary processing at larger scale (MPA, n.d.[37])]). Similarly, industrial extraction can dominate in marine dredging and excavation as it requires relatively sophisticated equipment to remove sediment from the seabed (IADC, 2023[27]). LSM operations can also exist alongside informal and poorly regulated extraction activities (see Box 2.1).

Box 2.1. The relationship between artisanal mining and local livelihoods

ASM in sand and silicates often involves a higher proportion of local community members, including Indigenous People and supports the livelihoods of millions of people, as recognised in the 2018 Mosi-oa-Tunya Declaration on Artisanal and Small-scale Mining, Quarrying and Development, but there is limited analysis of the extent of artisanal sand extraction and trade. For example, in Morocco, aggregate quarries account for a measurable share of GDP due to their important role in the national construction sector. The artisanal production of construction aggregates is also a major source of local livelihoods and an important driver for local economic development in Southeast Asia. The large volumes extracted and the physical footprint of the sector, however, can disrupt economic activities and livelihoods that rely on the same ecosystems, a challenge made more pronounced by the unsustainable rates of removal of sand and silicates. For example, millions of people depend on the Mekong River for fisheries and agriculture. But these sectors that are put at risk by unsustainable levels of extraction with 35-55 million m_3 of sand being extracted each year exceeding replenishment rates by a factor of ten. The effects can involve significant health and environmental risks. Livelihoods of artisanal sand miners also tend to be threatened by the entry of more mechanised operations, for example in Colombia.

Sources: Agharroud et al. (2023[38]), Assessment of the sustainability of aggregate quarrying practices in northern Morocco: A case regarding the eastern provinces of the Tangier Peninsula, https://doi.org/10.1007/s10064-023-03252-x; Asare, Dawson and Hemmler (2023.[39]), A sand-security nexus: Insights from peri-urban Accra, Ghana, https://doi.org/10.1016/j.exis.2023.101322; Marschke and Rousseau (2022[40]), Sand ecologies, livelihoods and governance in Asia: A systematic scoping review, https://doi.org/10.1016/j.resourpol.2022.102671; Asif and Van Arragon (2023[41]), Precarious livelihoods at the intersection of fishing and sand mining in Cambodia, https://doi.org/10.1007/s13280-023-01963-9; WWF (2023[42]), SUMMARY REPORT: Sand Budget for Viet Nam Mekong Delta, https://www.sandbudget.net/the-viet-nam-mekong-delta-sand-budget.

Sand and silicates are extracted in different geographies, including in high-risk areas

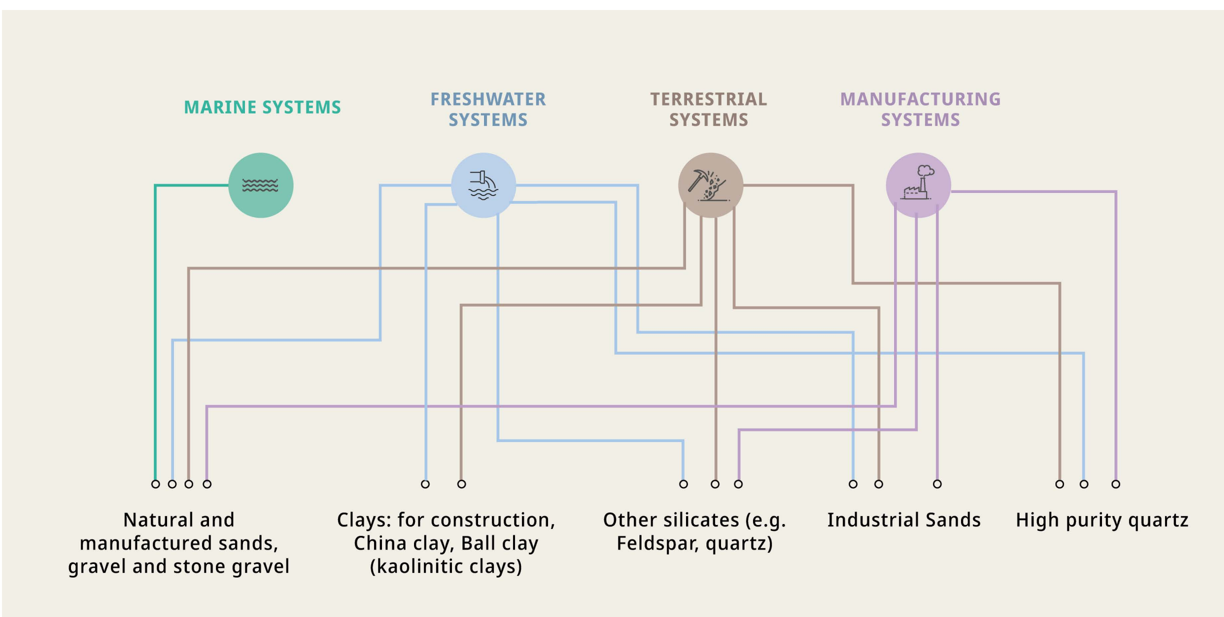
Due to the ubiquity of sand and silicates, most conflict-affected and high-risk areas (CAHRAs)[6] will have some relationship to sand and silicates which can interact with conflict in different ways. As with all other mining, the co-existence of artisanal with more mechanised mining operations can involve resource competition and fuel tensions in mining communities (see Box 2.1). The impacts of sand and silicate extraction on the availability and quality of natural resources such as clean water can also exacerbate community tensions leading to conflict (Bisht and Gerber, 2017[43]). As with any other RBC risk or impact, local tensions and community conflict in mining regions can materialise over time into sustained social unrest and opposition causing temporary suspension of mineral production or definite mine closure (OECD, 2023[44]). Inter-state conflict emergence and related state-imposed economic sanctions can, as in the case for Ukraine and the Russian Federation, demand exit by sand and silicate companies from specific markets or supply chains[7]. Conflict over sand and silicate resources can further emerge in the context of geo-political competition. Gravel, for example, has become a source of political and economic interest because of its use for climate-change adaptation measures. Where natural sand, earth and ice are eroding due to the effects of climate change, gravel and sand are used to replenish coasts and ice roads, as for example in the Arctic (Bendixen et al., 2019[45]; Bennett, 2023[46]). Sand and silicates also play an essential role in post-conflict and post-disaster reconstruction (Rogers, 2023[47]; Oxford Economics, 2023[48]). OECD standards on responsible business conduct recommend enhanced due diligence by companies when they source mineral materials from countries or transit hubs with specific location or supplier characteristics. Sourcing decisions involving CAHRAs or countries with known export-to-production discrepancies or suppliers that are connected to CAHRAs should trigger enhanced due diligence (see Section 3).

Interconnected supply chains

Significant overlap exists in where and how sand and silicate materials are produced. Sand and silicates can enter a variety of supply chains while originating from the same sources as is illustrated in Figure 2.3. Sand, gravel and stone are materials that can originate from all four extraction systems, including marine systems. Conversely, clays are predominantly produced in freshwater and terrestrial systems. Overall, terrestrial, manufacturing and freshwater systems are used to produce almost all types of sand and silicates while marine systems feed into sand, gravel and stone supply chains only. Sand and silicates that come from distinct deposits and locations can ultimately be blended when travelling down the supply chain. For example, sand and gravel production can be aggregated locally and traded in bulk to nearby larger firms, sometimes subject to further grading, cleaning, shaping and sizing (UNDP, 2019[49]). Aggregates extracted by a range of different actors from artisanal, small-scale and industrial sectors can ultimately find their way into local, national or international supply chains, for example for construction projects (Da and Le Billon, 2022[50]).

Complex sourcing and blending can result in materials linked to serious risks entering global supply chains, as outlined in Box 2.2. Governance challenges are widely discussed for aggregate production and trade, considering the scale of extraction of gravel, sand and stone, as well as the predominance of local, often informal, production and consumption circuits. However, similar governance challenges can characterise extraction and trade of other types of sand and silicate materials. 3 provides more contextual information.

Figure 2.3. Sand and silicate supply chains can have mixed and overlapping sources



The role of sand and silicates in international supply chains

Available data and statistics on international trade of sand and silicate materials are limited. In some cases, countries apply Harmonised System (HS) classifications to the import and export of different types of sand and silicates. For example, data for high-purity quartz is included in the Harmonised Tariff Schedule of the United States (HTS) but mixed with other types of sand and quartz which renders the tracking of these materials difficult (USGS, 2024[18]). Given available information, experts estimate that 1-2% of sand, gravel and quartz consumed worldwide by volume are traded internationally (Torres et al., 2021[32]). Despite the importance of local sourcing in these low-value supply chains, sand and silicate materials are traded internationally at significantly higher volumes than many other high-value minerals. Eight major industries are closely linked to the sand and silicates sector – construction, automotive, electronics, ceramics, glass, solar energy, oil and gas, and abrasives. However, the importance of sand and silicates as inputs for products or industrial processes is often overlooked. The sand and silicates market is estimated to amount to USD 600 billion annually in value, making the sector more than 50% larger than the value of annual mined gold production while being more than a million times larger in volume.

Box 2.2. Governance challenges and informal trade in global construction aggregate supply chains

Sand and silicate extraction is often poorly regulated with little oversight by government agencies, making informality common. Legal frameworks often do not assign responsibility for regulating the sector, either at national or sub-national levels. In some regions, the existence of dual systems of formal and informal extraction involving industrial and smaller-scale or artisanal operators can pose additional governance challenges. Weak enforcement mechanisms, coupled with soaring demand for construction materials and industrial minerals, can undermine attempts to regulate informal mining, and attempts to do so are further complicated by a lack of comprehensive data on extraction rates, trade, and consumption.

Aggregates are typically sourced from coastal areas, riverbeds, and terrestrial quarries. Formal extraction is regulated in some places, though enforcement challenges remain in many jurisdictions. Meanwhile, informal extraction - particularly from beaches - has raised environmental concerns, including significant coastal erosion and loss of natural habitats. While riverbed and quarry extraction tend to be more regulated, informal mining activities persist. The complexity of these supply chains, coupled with high demand, continues to drive both formal and informal trade in construction aggregates.

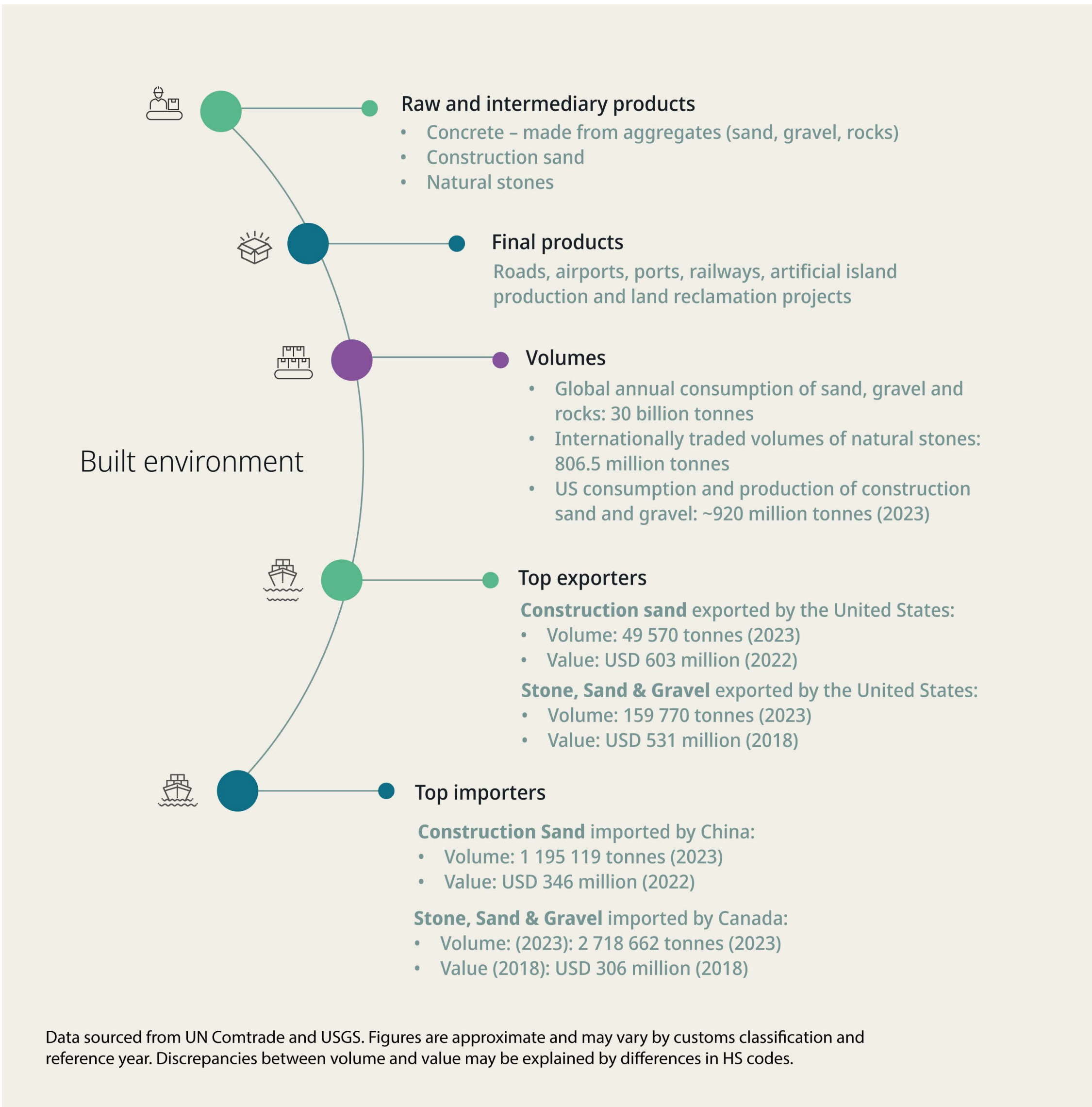
While most domestically extracted aggregates are consumed by nearby urban centres, international trade in sand and gravel does exist and concerns have been raised about informal construction sand and gravel trade across borders in regions like North and sub-Saharan Africa, and Southern Europe.

Source: UNEP (2019[2]), Sand and sustainability: Finding new solutions for environmental governance of global sand resources, https://unepgrid.ch/storage/app/media/documents/Sand_and_sustainability_UNEP_2019.pdf; Padmalal and Maya (Padmalal and Maya, 2014[24]), Sand Mining: Environmental Impacts and Selected Case Studies, https://link.springer.com/book/10.1007/978-94-017-9144-1; Pilkey et al. (2022[51]), Vanishing sands: Losing beaches to mining, https://doi.org/10.1215/9781478023432; Abderrahmane (2022[52]), Extracting and Trafficking Morocco's Coastal Sand, https://enactafrica.org/research/research-papers/extracting-and-trafficking-moroccos-coastal-sand; Ameziane and Suykens (2023[53]), Political Settlements and the Historical Development of Sand Governance in Morocco, https://doi.org/10.1016/j.exis.2023.101245.

Sand, gravel and stones are sourced, often locally, in extraordinary volumes for construction

Construction – or the built environment - is the largest sand and silicates consuming sector. Annually, 30 billion tonnes of sand, gravel and rocks are consumed for residential and non-residential construction, infrastructure including roads, airports, ports, and railways, and artificial islands and land reclamations projects. Natural sand of all kinds as well as natural stone, gravel, rocks, other aggregates as well as limestone and clay are all used to produce concrete, bricks, cement, float glass and other inputs to the built environment. Representing approximately 13% of global GDP (World Economic Forum, 2025[54]), the construction sector accounts for by far the largest volume of sand and silicate materials use and is a main driver of global demand (UNEP, 2024[55]). The global demand for buildings and infrastructure in the last thirty years has led to a fourfold increase in concrete production, reaching approximately 26 gigatonnes per year by 2020. The yearly need for virgin concrete aggregates recently surpassed the extraction of all fossil fuels in terms of annual extraction volumes (Watari et al., 2023[56]).

Figure 2.4. An overview of consumption and internationally traded sand and silicate materials for the built environment



Sources: UNEP (2019[2]), Sand and sustainability: Finding new solutions for environmental governance of global sand resources, https://unepgrid.ch/storage/app/media/documents/Sand_and_sustainability_UNEP_2019.pdf; Research and Markets (2024[20]), Natural Stone Global Market Report 2024, https://www.researchandmarkets.com/reports/5766803/natural-stone-global-market-report; USGS (2024[36]), Mineral Commodity Summaries 2024 SAND AND GRAVEL (CONSTRUCTION), https://pubs.usgs.gov/periodicals/mcs2024/mcs2024-sand-gravel.pdf; OEC (2022[57]), Sand, https://oec.world/en/profile/hs/sand; OEC (OEC - Stone, sand and gravel, 2018[58]), Stone, sand and gravel, https://oec.world/en/profile/sitc/stone-sand-and-gravel.

Sand and silicates for the construction sector often come from local sources and are used without crossing any borders. For example, in 2023, an estimated 920 million tonnes of construction sand and gravel were produced and consumed in the United States (USGS, 2024[36]). However, access, affordability and governance challenges have led to a growing trend of countries importing sand and silicates to meet their construction needs. For example, Pacific islands host a limited range of geological materials and rely on long-distance intra-regional trade in aggregates. Even where there are abundant resources, the necessary infrastructure and capacity to extract these resources may be limited. With demand outstripping local production capacity, more countries are resorting to sand and silicate imports. The fastest growing import markets in gravel and crushed stone for Pacific countries are the People's Republic of China (China), New Zealand and Japan (Rogers, 2023[47]). In 2022, China was the largest importer of construction sand, while the United States was the largest exporter for the same year (see Figure 2.4).

Quartz and silicon: critical raw materials for semiconductors and solar energy

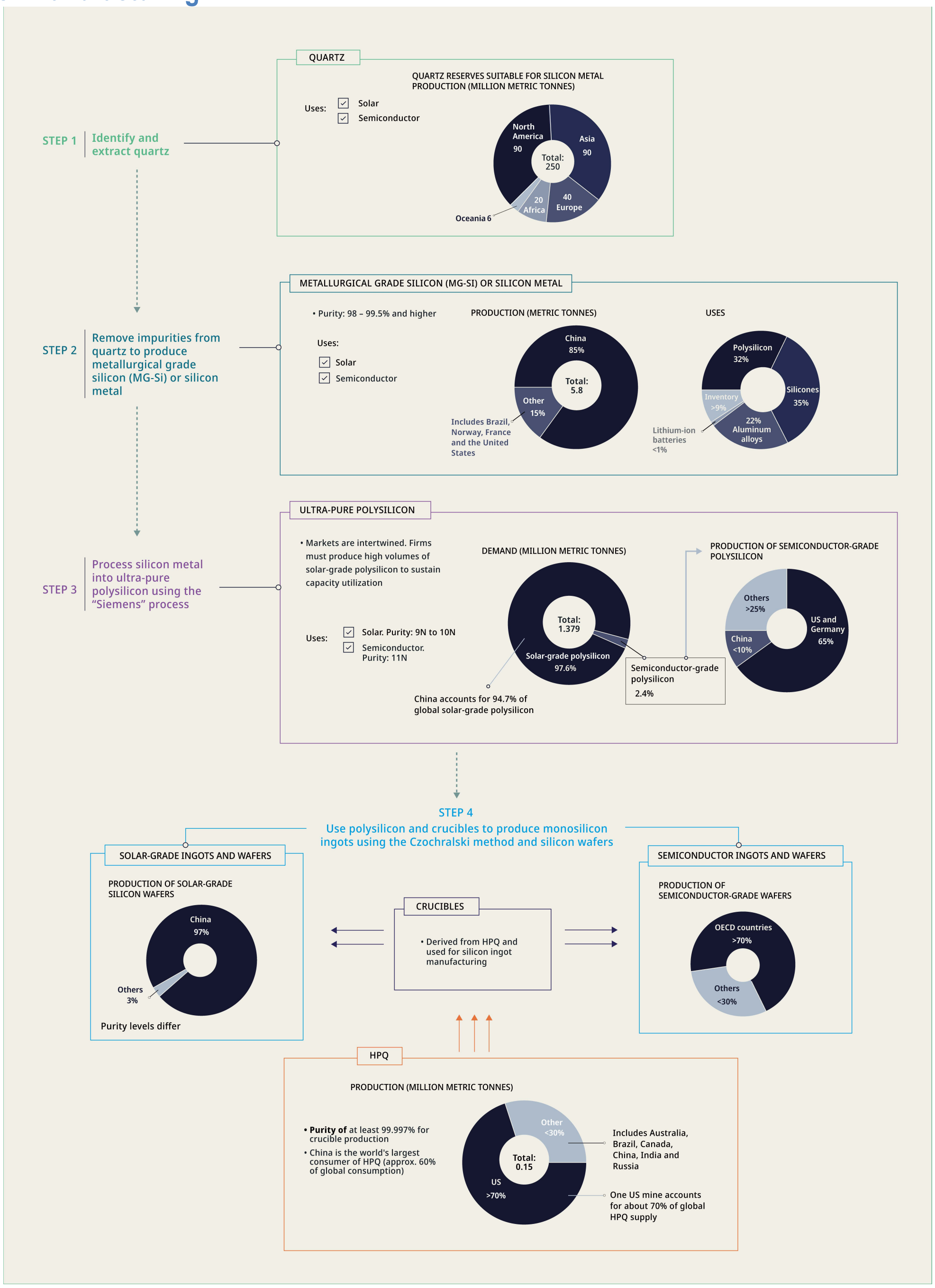
Sand and silicates comprise the raw materials for semiconductors and solar panels, in addition to the crucibles used to manufacture silicon wafers for these products. This starts with **quartz**, in the form of gravel from riverbeds or rock extracted from the earth, which is used to produce metallurgical silicon (MG-Si) or silicon metal. Quartz is one of the most common materials in the world and available in many regions (Kalyani Mohanty, 2025[59]), but deposits vary in purity and strength. A purity of 99.4%-99.8% silicon dioxide (SiO_2) is needed for quartz used in silicon metal production. In addition, quartz feeding into silicon metal production needs to be sufficiently heat-resistant during smelting. Geological sources of quartz suitable for silicon metal production can be found across all five continents, pointing to a relatively high level of diversification at the raw material production stage. However, significant bottlenecks emerge when moving down the supply chain.

Following quartz extraction and processing into silicon metal, the metal is used to produce polycrystalline silicon rods or polysilicon. Polysilicon can be produced at different grades of Si content, but very high purities can be used for the manufacturing of semiconductor ingots and wafers, at 99.999999999% (11 nines, or 11 N) while polysilicon used in the solar industry is of a lesser grade, requiring purity of 9-10N, though this gap is closing due to recent technological shifts in the solar industry requiring higher purity (Bernreuter, 2025[60]). Figure 2.5 provides an overview of how quartz is transformed into silicon metal and polysilicon for the purpose of silicon wafer manufacturing in both solar and semiconductor supply chains.

Over the past twenty years, China has achieved dominance over global polysilicon production by expanding its market share from negligible production in 2005 to almost 95% of global production in 2025, of which around 98% is solar-grade polysilicon with a purity of 9 to 10N (Bernreuter, 2025[60]). One further step down the solar supply chain, China is also the leading solar-grade silicon ingots and wafer producer with a global market share of 95% and 97% respectively (IEA, 2022[61]; Bernreuter, 2019[62]). China has also become the leading global supplier of silicon metal, accounting for around 4.9 million metric tonnes or 85% global production of this material in 2024 (Shangai Metals Market, 2025[63]; CRU Group, 2025[64]). OECD countries like France, Norway and the United States, in addition to Brazil, are estimated to account for most of the remainder (Kalyani Mohanty, 2025[59]; BRGM, n.d.[65]). China is not only responsible for most of the world's global silicon metal output, but it also consumes approximately two thirds of this material to feed its domestic solar industry among other sectors in the country.

In response to dependency on China, some OECD countries have listed silicon metal as a critical material, particularly due to its use in the semiconductor industry (Australia, the United States, United Kingdom, Japan, Korea, the European Union). However, despite China's dominant role overall in silicon, solar-grade polysilicon, ingots and wafers, only a handful of companies, all of which are based in OECD countries, possess the technology and know-how to produce semiconductor-grade polysilicon with a purity of 11N. Germany and the United States are leading producers and account for approximately 65% of global market share while Japan and Korea also have significant semiconductor-grade polysilicon production capacities (Bernreuter, 2025[60]). By comparison, China's market share of semi-conductor grade polysilicon is estimated at less than 10% (Bernreuter, 2025[60]). OECD countries also dominate the semiconductor-grade silicon wafer market, which is again heavily concentrated. The largest semiconductor-grade silicon wafer producers are Germany, Japan, Korea, the United States, and Chinese Taipei, accounting together for around 85% of the global semiconductor-grade wafer market ((SIA), 2025[66]).

Figure 2.5. An overview of quartz and silicon metal consumption for solar- and semiconductor-grade wafer manufacturing



Sources: SIA (2025[66]), Notice of Request for Public Comments on Section 232 National Security Investigation, https://www.semiconductors.org/wp-content/uploads/2025/08/Semiconductor-Industry-Association-SIA-Comments-Polysilicon-Section-232-Investigation.pdf; Bernreuter (Bernreuter, 2025[60]), The Polysilicon Market Outlook 2029, https://www.bernreuter.com/polysilicon/industry-reports/polysilicon-market-outlook-2029/; Bernreuter (2019[62]), Bernreuter Research, https://www.bernreuter.com/solar-industry/value-chain/; Shanghai Metals Market (2025[63]), https://zhuanlan.zhihu.com/p/20308202564; Jennings (2023[67]), A review of high-purity quartz for silicon production in Australia, https://doi.org/10.1080/08120099.2024.2362296; USGS (2024[18]), Mineral Commodity Summaries 2024, https://pubs.usgs.gov/periodicals/mcs2024/mcs2024-quartz.pdf; Kalyani Mohanty (2025[59]), Perspectives for High-Purity Quartz from European Resources, https://doi.org/10.3390/min15101080; Yameng Ma (2025[68]), Characteristics of high-purity quartz raw materials for crucibles and exploration of key purification technologies, https://doi.org/10.1016/j.mineng.2025.109446; OECD (2025[69]), Mapping the Semiconductor Value Chain, https://www.oecd.org/content/dam/oecd/en/publications/reports/2025/06/mapping-the-semiconductor-value-chain_5ba52971/4154cdbf-en.pdf.

The interdependencies in the semiconductor value chain extend beyond China's dominance in silicon metal and OECD countries' leading roles in semiconductor-grade polysilicon and wafers. The small share of semiconductor-grade polysilicon of the global total, only 2.4% compared to the solar-grade polysilicon market share of 97%, will have implications for the resilience and economic sustainability of semiconductor-grade producers operating in OECD countries ((SIA), 2025[66]). To reach viable economies of scale, semiconductor-grade polysilicon producers tend to produce higher volumes of solar-grade polysilicon for which the market is larger and production costs are lower. The implication of this is that both markets are interconnected and operators involved in semiconductor-grade polysilicon production will not be immune to global price and industry trends in the solar sector ((SIA), 2025[66]).

Another dimension of the semiconductor value chain in which OECD countries excel is raw materials that, instead of being inputs for semiconductors or solar panels, are critical to manufacturing processes. Crucibles derived from high-purity quartz (HPQ) with a purity of at least 5N are tubes resistant to liquid silicon which are commonly used to grow monocrystalline silicon ingots and ultimately produce wafers[8]. Using the Czochralski process, polysilicon is melted in HPQ-crucibles at very high temperatures to produce monocrystalline silicon or monosilicon ingots. This method is commonly used for both solar and semiconductor ingot manufacturing and has expanded in recent years, being critical to nearly all semiconductor manufacturing.

HPQ demand has increased in response and is estimated to increase 40-fold by 2050 (Geoscience Australia, 2024[70]; Gabriela Kazimiera Warden, 2023[71]). China consumes 60% of global HPQ production. However, in contrast to lower-purity quartz, natural HPQ deposits are rare (Kalyani Mohanty, 2025[59]) and mined production is heavily concentrated in the United States. A single US mine is estimated to account for about 70% of global supply (Kalyani Mohanty, 2025[59]; Geoscience Australia, 2024[70]; Yameng Ma, 2025[68]) and few viable HPQ deposits are known to exist in other countries (USGS, 2024[18]). This level of concentration had disruptive effects on the supply chain in 2024 due to Hurricane Helene leading to a temporary suspension of production at the US mine (The Quartz Corp, 2024[72]). Some companies have started to manufacture HPQ from low-quality quartz through purification, but this method has not proven economically viable enough to scale up (USGS, 2024[18]).

China, while having achieved market dominance in many other critical mineral supply chains, is dependent on HPQ imports from the United States to feed domestic crucible production. To reduce import dependence, China has listed HPQ as a strategic material and national exploration efforts have started to bear fruit, resulting in the recent discovery of HPQ reserves in the country (Hart, 2025[73]). As in any supply chain, exploration and mine development can contribute to changing supply chain dependencies over time. While lead times from mineral discovery to production tend to vary by mineral, location and mine type, historic analysis shows that it takes on average 16 years to bring greenfield mines online (IEA, 2021[74]). China has also responded to bottlenecks in the semiconductor market through heavy investment in the production of higher-grade silicon wafers (Allen, 2023[75]).

Overall, the case of quartz and silicon use in solar and semiconductor supply chains illustrates how supply chain dependencies can take multiple forms and shift direction several times when moving down the supply chain or into strategically connected sectors, revealing both significant vulnerabilities and advantageous positions in the sector for OECD countries (see Figure 2.5). In a context of growing economic security concerns, this strategic supply chain is an example of interdependency, which can inform efforts by policy makers to enhance resilience. While trade dependencies in the silicon metal and downstream solar and semiconductor markets have received strong attention by policy makers in recent years, the raw materials required for polysilicon and monocrystal ingot production, HPQ, have received less attention despite the rest of the value chain depending on it.

Sand and silicates are indispensable but often hidden inputs in many industries and sectors

Silicon is only one intermediary product made from sand and silicates feeding into various mid-stream and downstream sectors. Approximately 40 million tonnes of **sand-based glass** are produced annually (Glass Alliance Europe, n.d.[76]) feeding into electronics, automotives, infrastructure and other sectors. Speciality glass, itself derived from silicon, can feed into semiconductor manufacturing as well as medical and other equipment and can also include other types of speciality glass such as borosilicate glass for laboratory use and fibre optic glass for light signal transmission. The most common type of industrial glass, float glass, is used for windows, mirrors, drinking glasses, glass packaging and decorative glassware. Sheet glass, thinner and lower cost, is used in residential windows and picture frames. Safety glass includes tempered glass, heat-treated for strength and resistance, and laminated glass, maintaining cohesion when shattered. Smartphones, which were the world's ninth most traded product in 2022 (OEC, 2022[77]) also use glass that is made from silica, which is sourced from industrial operations in Europe, the United States, China and other countries in Southeast Asia. The case of smartphones illustrates how sand and silicate use can sometimes be obscured by higher-profile materials in global mineral supply chains.

In the **automotive sector**, silica sand is not only a key ingredient in the production of safety glass used for windscreens and windows of vehicles. It is also used in the production of tyres to improve traction and performance while silica-based materials are essential in manufacturing vehicle composites, used in electronics systems, utilised in paints and coatings, and essential inputs for glass fibres woven into glass fibre fabrics which are utilised in automotives as well as electronics and others. Sand casting is further used to form various metal parts of a vehicle.

Beyond **renewable energy technologies**, other types of energy production processes make extensive use of sand and silicate materials. For example, hydropower dams are constructed across rivers or streams to store or divert water for energy production. While sand and silicates (such as silica sand) are not used to hold back and control water directly, they are used as construction materials, primarily as aggregates in concrete and other structural components of hydropower dams. Silica sand is further used in the role of proppant, which is used for fracturing in geothermal development and sand batteries are being explored as a larger-scale solution for storing thermal energy from wind and solar technologies since high-silicon anode material can increase the energy density of batteries. In the oil and gas sector, silica sand contributes to hydraulic fracturing, where it is injected with water and chemicals into rock formations at high pressure, allowing oil and gas to flow more freely.

Tourism and leisure are additional sectors with high dependence on sand and silicate supply. As just one example of tourism's dependence on sand, coastal and marine tourism accounts for roughly 50% of global tourism or 5.2% of the global GDP. This sector is particularly crucial for the economies of small islands and coastal communities (Northrop et al., 2022[78]). Sand is a major component of building and maintaining golf courses and integral to equestrian sport. Equestrian arenas predominantly use sand as a footing material, with silica sand enhancing shock absorption and stability (Zorn, 2018[79]).

Sand and silicates are additional key ingredients in **home- and sanitaryware**. Concrete or engineered quartz made from lower-grade natural quartz are used for equipping kitchens while silicate ceramics are commonly used for flooring and equipping interior spaces. Porcelain, made from kaolin clay and feldspar, is a type of ceramic widely used while ceramic toilets and sinks made from silicate-based clay. In **cosmetics**, sand and silicates like mica and talc are commonly used while hydrated silica acts as a powerful abrasive in toothpaste.

Ultimately, sand and silicates contribute to various components and manufacturing processes. **Metal processing**, including smelting and refining processes, rely on sand and silicates such as high-quality silica. Here again, HPQ is processed into silicon metal which helps to remove unwanted oxygen during steel production. **Water filtration**, where layers of sand are used to capture suspended solids, sediment, and contaminants as water passes through, is widely implemented in various sectors.

A range of consumer products and services cannot be manufactured without the supply of sand and silicates which serve as critical - and often hidden inputs - in a panoply of industrial processes and sectors spanning automotives, electronics, food and beverages, textiles, medical equipment, cosmetics, homeware and many more. Annex B provides an exhaustive list of applications.

Key takeaways about sand and silicate supply chains

The following points are critical for understanding the structure of sand and silicate supply chains, their functioning and the underlying dynamics of consumption and production:

- **Sand and silicates are extracted from both dynamic and static sourcing environments.** In dynamic systems, sand, gravel and clay play important roles in the functioning of ecosystems which can be significantly impacted by their removal, notably when volume and pace of extraction exceeds sustainable thresholds or their rate of replenishment.
- As sand and silicates are extracted across the globe through artisanal, small-scale or industrial operations, **most sand and silicate production and trade processes will in some way relate to CAHRAs.**
- Sand and silicate supply chains can have mixed and overlapping sources for material flows that feed a wide range of applications and downstream uses. **Their interconnectedness, and sometimes deep integration in international supply chains, can render these materials - and their associated risks - invisible.**
- **Sand and silicates can serve as critical materials in supply chains of strategic importance** to electronics, renewable energy and automotives.
- **Important but widely overlooked upstream segments of some sand and silicate supply chains are concentrated in OECD countries** with the United States emerging as a dominant supplier of construction sand and high-purity quartz used in semiconductor manufacturing.

3 RBC risks and impacts in sand and silicate supply chains

This chapter provides an overview of significant RBC risks and impacts in sand and silicate supply chains. Each step of the sand and silicate supply chain - from extraction to manufacturing, local or international trade and use, in addition to transport, can be associated with RBC risks. Environmental risks are widespread and widely documented. Risks spanning conflict, human rights abuses and financial crime pertain mainly to upstream segments of sand and silicate supply chains.

Risks in sand and silicate supply chains across sectors and regions

Media, civil society reports and academic research highlighting adverse impacts of sand and silicate extraction have increased in recent years (UNEP, 2019[2]). Heightened awareness of the impacts and risks in sand and silicate supply chains has sparked action by governments in some countries. Belgium, China, the Netherlands, Malaysia, Singapore, Switzerland and Vietnam have taken separate actions to improve governance of sand and silicate production and trade. In the European Union, efforts to foster due diligence and circular economy – including for construction materials and glass products – are gaining momentum. Globally, as demand for sand and silicates is soaring governments are faced with heightened pressure to promote a responsible supply of sand and silicates.

Understanding supply chain risks

Businesses can be linked to adverse impacts through their own operations, their supply chains and business relationships. The term 'risk' in OECD standards on responsible business conduct refers to the likely existence of adverse impacts (to which a business could be linked) or the potential of adverse impacts occurring in the future. In the sand and silicates sector, there is a potential for adverse impacts across the extraction, trading, handling, export and end use stages of the supply chain, and companies should use a risk-based approach, prioritising the most significant risks based on their severity and likelihood, to inform the order in which they assess their relationship to actual and potential adverse impacts and respond to them.

The OECD Minerals Guidance serves as a tool for prioritisation to address the most severe risks in mineral supply chains relating to conflict, human rights abuses and financial crime set out in Annex II of the Guidance (OECD, 2016[80]). The *OECD Handbook on Environmental Due Diligence in Mineral Supply Chains* contextualises other OECD recommendations on RBC for this set of risks in the minerals sector (OECD, 2023[81]). Broader risks related to labour, communities, and corruption are addressed in cross-sectoral RBC standards such as the *OECD Guidelines for Multinational Enterprises on Responsible Business Conduct* and the *OECD Due Diligence Guidance for Responsible Business Conduct* (OECD, 2018[82]; 2023[83]). The OECD Due Diligence Guidance for Meaningful Stakeholder Engagement in the Extractive Sector is also relevant to ensuring fair benefits to mining communities and managing the interface with the informal sector and adjacent or overlapping livelihood activities (OECD, 2017[84]).

Indicative risks and impacts across sectors and regions

Please note that this section provides examples of risks and adverse impacts in sand and silicate supply chains across sectors and regions. Risks and impacts are mapped against the OECD Minerals Guidance and the *OECD Handbook on Environmental Due Diligence in Mineral Supply Chains*. All examples provided are indicative and non-exhaustive. They are intended to point the reader to the types of risks and impacts that can potentially materialise in sand and silicate supply chains. Considering the extent and diversity of these supply chains with extraction, trading, processing and handling taking place in nearly every country in the world, risks and adverse impacts linked to the sector likely exceed the examples cited in this section. Upstream risks are more widely discussed in the literature and are therefore more strongly reflected in this section which does not preclude the existence RBC risks in relevant mid- and downstream sectors. The diversity of the sector also means that risk profiles can vary significantly from one commodity to another. Companies should always take a risk-based approach to their due diligence. This means that the measures that an enterprise takes to conduct due diligence should be commensurate to the severity and likelihood of the adverse impact. When the likelihood and severity of an adverse impact is high, then due diligence should be more extensive.

Risks related to serious human rights abuses, conflict financing and financial crimes

Serious associated with the extraction, transport or trade of minerals

The risk of **forced l**abus**labour** can exist in relation to mineral production and initial processing of construction materials (clay, bricks) (Dodd, Guthrie and Dumay, 2023[85]), as well as in international supply chains from automotives to dimension stones and solar panels, including in the manufacturing stages of specific products. The literature points to relevant risks in countries such as India, Indonesia, China, Bangladesh, Iran and Oman (Mercedes-Benz Group, November 2023[86]; American Bar Association, 2020[87]; Murphy and Elimä, 2021[88]) involving local or migrant labour. For example, in the sandstone industry in India, bonded labour obligations may be transferred from quarry workers to their spouses after workers deceased because they had contracted silicosis (American Bar Association, 2020[87]). The large footprint of solar-grade polysilicon production facilities in regions with risks of forced labour has been highlighted and makes the solar supply chain particularly vulnerable to this type of risk (U.S. Department of Labor, 2020[89]).

Cases involving **child labour** in sand and silicate supply chains may exist in relation to sand and silicate extraction for local use, in sand, clay and stone materials, as well as brick making. Available reports point to examples in countries like Morocco (Abderrahmane, 2022[52]), Indonesia (Arrozy and Edytya, 2022[90]) and India (American Bar Association, 2020[87]) as well as countries in Sub-Saharan Africa (Charles and Tychsen, 2023[91]). Child labour has also been identified as a potential risk in the automotive glass supply chain (Mercedes-Benz Group, November 2023[86]). It is important to note that children can sometimes be present on sand and silicate extraction sites in the company of their working parents and while not working themselves. In this context, children can nevertheless be exposed to prevailing risks and impacts (UNDP, 2018[29]). In some cases, children may directly participate in sand and silicate production including in the transportation of material, when guarding site entrances or trading materials in the pursuit of better livelihood opportunities (Tychsen, 2023[92]; American Bar Association, 2020[87]).

Further research is needed to assess whether reported incidents of child labour in sand and silicate supply chains meet the definition of **worst forms of child labour**. The latter comprises all forms of slavery or practices similar to slavery including forced labour, child prostitution, the use of children for illicit activities and work likely to harm the health, safety or morals of children (International Labour Organisation, 1999[93]). OECD standards and accompanying publications like the *Practical actions for companies to identify and address the worst forms of child labour in mineral supply chains* call on companies to suspend or discontinue engagement with suppliers if they are linked to worst forms of child labour and do not immediately end the use of child labour in their supply chains (OECD, 2017[94]). Measures to address child labour will seek to prevent the child from being pushed into a more precarious situation and avoid situations where the child is further penalised.

The literature illustrates how murders and assassinations may materialise in sand mining, pointing to examples in Asia (Bangladesh, India, Sri Lanka) and Africa (Kenya, Morocco), among other regions. These cases can involve police officers, local journalists and environmental defenders and more research is needed to understand whether these types of violent or criminal behaviour can amount to **incidents of cruel, inhuman and degrading treatment** in sand and silicate supply chains. Sometimes, violence in sand and silicate extraction and trade can be explicitly linked to illegal extraction as cases in Africa (Algeria, Ghana, Kenya, Morocco, Nigeria, The Gambia) and Asia (India) illustrate (Rege and Lavorgna, 2017[95]; Jeyaranjan, 2019[96]; Ameziane and Suykens, 2023[97]; Charles and Tychsen, 2023[91]). However, not all illegal sand and silicate production and trade is necessarily associated with violence and may be more related to informality than criminality.

Box 3.1. The 'sand mafia'

Illegal sand and silicate extraction and trade can occur in all regions including those with strong governance. While the majority of illegal sand and silicate extraction seems to be local, some cases involve external or foreign actors – at times working alongside local residents, at others having a coercive relationship with local communities – in illegal extraction and trade. The term 'sand mafia', while often used to highlight sand extraction with links to criminal networks has commonly been used to refer to instances of informal extraction that are not necessarily linked to organised crime. Disentangling criminality from informal mining and trade is challenging but important. Conflating them can oversimplify a multifaceted subject and has the potential to stigmatise informal miners who are typically not in positions of power and may not otherwise be associated with risks or criminality.

Sources: Rege and Lavorgna (2017[95]), Organization, operations, and success of environmental organized crime in Italy and India: A comparative analysis, https://doi.org/10.1177/147737081664962; Daghar (2022[98]), Kenya's sand cartels: Ecosystems, lives and livelihoods lost, https://enact-africa.s3.amazonaws.com/site/uploads/2022-035-03-sand-research-paper-26.pdf; Charles and Tychsen (2023[91]), La mine artisanale en Afrique Centrale, du Nord et de l'Est francophones: Guide pratique.

Violence at work (Lamb, Marschke and Rigg, 2019[99]; Charles and Tychsen, 2023[91]) and risks relating to **sexual and gender-based violence (SGBV)** may exist in the context of artisanal sand and silicate mining sites or in the construction sector. The literature provides relevant examples for Latin America, Asia, and Sub-Saharan Africa (EBRD, CDC and IFC, 2020[100]; Asegu et al., 2023[101]). Gender-based discrimination can also exist in sand and silicate supply chains. Available reports point to examples in Nigeria where women may face barriers to participation in aggregate production (Bendixen et al., 2023[102]) or to Mexico and Central Africa where discrimination can disadvantage women and limit their access to equal pay in the sand and silicate sector (Kauffer and Torres, 2023[103]; Charles and Tychsen, 2023[91]; UNDP, 2019[49]).

Direct or indirect support to non-state armed groups

Non-state armed groups, especially where they control or have influence over economic activities, can be involved in the extraction and use of sand and silicates.[9] Multiple reports illustrate how organised crime networks – some of whom operate in ways similar to non-state armed groups – can be involved in and benefit from sand and silicate extraction, processing, transportation or trade in India (Mahadevan, 2019[104]), Italy (Rege and Lavorgna, 2017[95]), Morocco (Abderrahmane, 2022[52]), Nepal (Hoffmann, 2021[105]) and Kenya (Daghar, 2022[98]). Furthermore, the case of the French construction materials company Lafarge providing financial support to ISIS and the Al Nusra Front during the Syrian civil war suggests that the relationship between sand and silicate extraction and support for non-state armed groups or serious human rights violations, particularly relating to construction in conflict zones, calls for ongoing monitoring and further exploration (Holcim, 2022[106]; European Center for Constitutional and Human Rights (ECCHRR), 2024[107]; Office of Public Affairs, US Department of Justice, 2018[108]).

Risks related to public or private security forces

Risks related to public or private security forces may exist in multiple sand and silicate supply chains. Available reports point to the use of excessive force by private and public security forces, for example in Kenya, Morocco and India. Organised crime actors can also be involved in large-scale extraction as illustrated in one case study on protection provided by state police officers in sand mining in Kenya (Daghar, 2022[98]).

Bribery and smuggling

Bribery and corruption can be widespread practice for sand production. Local political actors responsible for permitting can be compromised through corruption linked to sand and stone extraction and trade, for example in India (Jeyaranjan, 2019[96]). Generally, unsustainable sand and silicate mining practices can emerge when supply chain operators bribe officials to overlook local regulations or weaken law enforcement. Sometimes, bribery causing unsustainable sand and silicate production can involve criminal actors and organised crime groups (World Wildlife Fund, 2021[109]). Over-exploitation – leading to environmental impacts discussed below – can also occur where permits provide revenue for under-resourced municipal governments and are not necessarily directly linked to corruption but are issued liberally with little apparent scrutiny (i.e. Sierra Leone) (Lynggaard Reimer and Gallagher, 2023[110]). Multiple reports and expert interviews suggest bribery is of widespread concern and may be associated with sand and silicate supply chains in a range of regions and countries. Further research is needed to assess the magnitude of this risk, including in midstream and downstream segments of the supply chain.

Aggregates imported into Europe from North Africa, or construction materials used in domestic markets in India and Indonesia, can sometimes be associated with fraudulent misrepresentation of origin. In particular, the literature illustrates how extraction and export bans of river sand in China and Cambodia, and marine sand in Nigeria, Malaysia and Indonesia can lead to increased attempts to bypass such restrictions (Abraham et al., 2021[111]; van Arragon, 2021[112]). More research is warranted to assess the scale and exact contours of these risks, as well as their presence in other types of sand and silicate materials.

Money laundering and non-payment of taxes, fees and royalties due to governments

Money laundering is poorly documented for sand and silicate supply chains while understood to occur widely in contexts with weak institutions. Money laundering in sand and silicate supply chains can occur when illicit funds are integrated into the legitimate economy by purchasing, transporting, and selling these commodities. Several resources discuss the risk of money laundering in the construction industry worldwide (RICS, 2021[113]; John, 2021[114]) and sometimes refer to this phenomenon in relation to possible risks of organised crime and political corruption in India (Jeyaranjan, 2019[115]), Morocco (Abderrahmane, 2022[52]) and Sierra Leone (Lynggard and Gallagher, 2023[116]). It is unclear how prevalent this issue is. Non-payment of taxes, fees, and royalties due to governments[10] is reported as a concern in some countries, for example where ASM or illegal sand and silicate extraction occurs.

Table 3.1. Overview of risks related to serious human rights abuses, conflict financing and financial crimes in sand and silicate supply chains

RISK CATEGORY	SUBCATEGORY	POTENTIAL RISK IN THE SUPPLY CHAIN							
		1 Extraction and initial processing, trade				2 Localised uses	3 Manufacturing and industrial uses	4 Final uses and products	5 Transport
		Terrestrial	Manufactured	Freshwater	Marine				
Annex II risks									
Serious human right abuses	Torture, cruel, inhuman, and degrading treatment	(!)	(!)	(!)	(!)	(!)			
	Forced or compulsory labour			(!)		(!)	(!)	(!)	
	Worst forms of child labour	(!)	(!)			(!)	(!)	(!)	(!)
	Other gross human rights violations and abuses	(!)	(!)					(!)	
	War crimes or other serious violations of international humanitarian law								
Direct or indirect support to non-state armed groups		(!)	(!)	(!)	(!)	(!)			(!)
Direct or indirect support to public or private security forces		(!)							(!)
Money laundering		(!)	(!)	(!)	(!)	(!)			(!)
Bribery, corruption and fraud		(!)	(!)	(!)	(!)	(!)			(!)
Non-payment of taxes, fees and royalties		(!)	(!)	(!)	(!)	(!)			(!)

Environmental risks

Biodiversity loss

The literature points to risks of biodiversity loss[11] in sand and silicate supply chains, mainly resulting from materials extraction, processing and transport. Land-use changes with impacts on biodiversity and natural ecosystems tend to materialise in mining in general and can be expected to prevail in sand and silicates considering the sheer volumes associated with the extraction of these materials (OECD, 2025[117]).

Biophysical disruption, relating to the altered structure and quality of biodiversity and ecosystems*,* can be caused by terrestrial, freshwater and marine extraction alike. Terrestrial extraction of sand and silicates in pit mining and quarries, by means of land cover removal, deforestation and soil degradation, may cause direct biodiversity habitat loss and the degradation of flora and fauna across countries and continents, from historical examples in North America (Mac Lellan, 1984[118]) to more recent cases in Nigeria and across Sub-Saharan Africa (Adedeji, Adebayo and Sotayo, 2014[119]; UNDP, 2018[29]), Asia (Bisht and Gerber, 2017[43]; Gandri et al., 2023[120]) and Latin America (Zanon et al., 2021[121]). Likewise, freshwater extraction of sand, gravel and clay can take place within and close to significant ecosystems (Moroșanu and Ioana-Toroimac, 2022[122]; Padmalal and Maya, 2014[24]) with adverse effects on threatened freshwater species and bird life in many countries[12] (Arjun, Panda and Arun, 2023[123]; Kanehl and Lyons, 1992[124]). Marine extraction of sand and silicates, sometimes in Marine Protected Areas (MPAs)[13], can affect coastal and marine biodiversity (Rangel-Buitrago et al., 2023[125]) around the world. Between 2018 and 2022, up to one-sixth of dredging occurred in marine protected areas, zones that are supposed to be sanctuaries for underwater life (UNEP, 2024[34]). In both freshwater and marine ecosystems, rehabilitation and restoration are considered difficult to achieve (Alvarado-Villalon, Harrison and Steadman, 2003[126]) highlighting the importance of preventing disturbances in the first place, especially for protected areas. This is an example of a potential adverse impact of irremediable character, which is a component of severity in RBC standards. When adverse impacts are irremediable, disengagement from a business relationship may be appropriate as a last resort (OECD, 2018[82]).

Ecological changes affecting the ability of an ecosystem to sustain essential processes can materialise in both dynamic and static systems. In *dynamic systems*, sand extraction can disrupt sediments and deposition processes, fundamentally altering river channels and lakes with adverse effects on species reproduction and distribution dynamics. The literature highlights changes in sunlight penetration and nutrient cycling, with direct consequences for aquatic life and the potential of leading to long-term ecological imbalances (Rentier and Cammeraat, 2022[127]; Padmalal and Maya, 2014[24]; Gavriletea, 2017[128]). Disruptions to fish reproduction cycles and altered aquatic food chains can directly result from changes in the sediment structure and balance and nutrient cycling in freshwater and marine environments (Zhang, 2023[129]). In static systems, topsoil and vegetation removal from sand and silicate extraction can decrease the ability of land to support plant growth, reducing overall biomass. In addition, sand mining-related dust deposition on plant surfaces can reduce photosynthesis by blocking sunlight and damaging leaf tissue. Sand extraction in static systems can reduce water infiltration as illustrated by cases in Nigeria (Ako et al., 2014[130]) and Brazil (da Silva et al., 2020[131]). The resulting overall decline in biomass can affect the entire food chain, potentially putting at risk local food and water security.

Greenhouse gas (GHG) emissions

GHG emissions can materialise across sand and silicate supply chains with strong potential to contribute to carbon dioxide (CO_2) and methane emissions if energy systems are fossil fuel-based. Sand and silicate extraction, transport, processing and equipment manufacturing, when resorting to heavy machinery and energy-intensive techniques, can involve considerable amounts of GHG emissions (Alqadi et al., 2023[132]).

For example, silica sand undergoes considerable processing (Gerbinet, Belboom and Léonard, 2014[133]), clay is generally processed through energy-intensive techniques and cement, glass and ceramics production all involve high-temperature processes, as well as manufacturing for other end uses. In the same vein, sand and silicate extraction can damage the natural processes that regulate carbon within ecological systems through altered sediment structures. This impact is underexamined but has been shown to be a considerable effect in China where sand mining activities have impacted riparian areas - which connect land and river streams - by reducing the carbon sequestration potential of the soil. For example, sand mining can reduce carbon dioxide-fixed bacteria in riparian zones, a situation which can increase the risk of excessive water enrichment (Qin et al., 2020[134]).

Climate change

Sand and gravel can play a critical role in climate adaptation. They act as natural buffers against storms, floods, sea-level rise, and associated impacts such as coastal erosion and landslides. Extracting sand and gravel in vulnerable areas can undermine adaptation efforts even if this is done to build defensive infrastructure. By removing natural protective systems such as beaches, dunes, and sediment-rich coastal or riverine environments extraction can increase vulnerability to climate change. This is particularly true in regions where climate change is expected to increase the severity and frequency of floods and storms, or lead to higher sea levels. Pacific Small Island Developing States (SIDS) face high exposure to sea-level rise, storm surge, and coastal flooding. In these contexts, sand removal can erode natural buffers, limiting the islands' ability to adapt to these hazards (Mycoo, 2022[135]).

Climate change risks relate to sand and silicate supply chains in multiple ways. Climate resilience risks can directly result from unsustainable sand extraction when critical materials are depleted from dynamic systems, diminishing the natural ability to mitigate extreme weather events (Jouffray et al., 2023[136]; Rangel-Buitrago et al., 2023[125]). Sand-related degradation of ecosystems can also intensify climate-induced disasters and impact forests, agriculture, and fishing, thereby eroding socio-economic livelihoods and resilience to climate change (Ratter, Petzold and Sinane, 2016[137]). SIDS in the Pacific and Indian Ocean region are among the most vulnerable to climate change and particularly exposed to unsustainable sand and silicate extraction. Paradoxically, climate adaptation investments simultaneously warrant access to ore sand and silicate materials like aggregates which are used for the purposes of construction, natural beach preservation and coastal replenishment (Rogers et al., 2024[138]; Ratter, Petzold and Sinane, 2016[137]; Pilkey et al., 2022[51]). A similar phenomenon can be observed in the Arctic, where sand and gravel play an essential role in infrastructure investments to prevent effects induced by climate change, such as coastal erosion where gravel is increasingly used to replace eroding ice roads (Kuklina et al., 2023[139]; Bendixen et al., 2019[45]; Bennett, 2023[46]).

The improper use and disposal of hazardous chemicals

The improper use and disposal of hazardous chemicals such as oily ballast and bilge water is a significant risk in sand and silicate supply chains. Available reports point to the risk of oil spills and leakage in the phases of extraction, initial processing and transport in riverine and marine environments, often in relation to semi-mechanised extraction, for example in India and Malaysia (Pandey et al., 2023[140]; Hanti, 2022[141]; Ashraf, 2011[142]; Jouffray et al., 2023[136]).

Noise and vibration

Noise and vibration can arise as risks in a wide variety of sand and silicate extraction and processing contexts, impacting people and terrestrial and aquatic species in surrounding areas in countries like Morocco (Agharroud et al., 2023[38]), Nigeria (Aliu, Akoteyon and Soladoye, 2022[143]); Estonia (Orru et al., 2013[144])] and China (Deng et al., 2022[145]).

Physical instability, soil erosion and land degradation

Physical instability, soil erosion and land degradation can result from sand and silicate extraction across all extraction forms and geographies and undermine climate adaptation efforts. Landslides and land degradation may arise during pit mining and quarrying of natural stone, sand, and clay, and where sound management practices are not implemented or where activities take place in conditions that make mass soil movement likely. Examples include potential land degradation risks in Sub-Saharan Africa (Bendixen et al., 2023[102]), and landslides in South America (Asabonga et al., 2017[146]) and Indonesia (Dewi et al., 2019[147]). Excessive sand mining from riverbeds, exceeding replenishment rates, and subsequent risks of riverbed erosion, can emerge in the context of the Mekong River in Cambodia and Vietnam (Hackney et al., 2020[148]; Ngoc Anh et al., 2022[149]; Schmitt, Rubin and Kondolf, 2017[150]). Furthermore, marine sand dredging and beach sand mining may directly cause coastal erosion with examples from all regions, from Europe, Oceania and South America, (Anthony, 2016[151]), Africa (Aliu, Akoteyon and Soladoye, 2022[143]; Jonah et al., 2015[152]), and Asia (Choi, 2023[153]).

Dust particulate release and other types of pollution

The release of dust particulates in the air from extracting, crushing, sorting, transporting and using sand and silicate materials arises in the context of industrial sand mining and processing in the United States (Pierce et al., 2019[154]) in addition to some derivative products like engineered stone (Safe Work Australia, n.d.[155]). Respirable crystalline silica, a component of silica dust, can be particularly harmful when inhaled, as it can penetrate deep into the lungs and cause diseases such as silicosis, lung cancer, and other pulmonary conditions. Exposure can occur along several steps of the supply chain in mining, construction, hydraulic fracturing, and artificial stone industries. Evidence from Egypt (Zawilla, Taha and Ibrahim, 2014[156]), South Africa (Brickhill, 2021[157]), the United States, India, Canada, Australia, New Zealand (Hoy et al., 2022[158]), Romania and China (Popescu, Stoia and Morariu, 2023[159]) shows how widespread these impacts are, often causing irreparable harm to human health.

Box 3.2. Silicosis risks

Silicosis is an incurable lung disease caused by inhaling respirable crystalline silica dust, leading to lung inflammation, scarring, and severe respiratory impairment. Despite being preventable, it can be a major occupational hazard, particularly in mining, quarrying, construction, and manufacturing. Workers are most at risk during activities such as drilling, crushing, cutting, grinding and loading silica-containing materials – anywhere fine dust particles become airborne and easily inhaled. This can include upstream extractive activities, in loading and transporting and in intermediate processing. Workers with precarious or insecure employment status, immigrants, and those employed in small businesses can face a heightened exposure risk according to global incidence data available. While research and prevention efforts have largely focused on the mining sector, hazardous exposure may occur across many industries, particularly construction.

To mitigate exposure, operators can implement engineering controls like water suppression, ventilation, and enclosed processing systems. Behavioural measures, including safe work practices, training, and health monitoring, further reduce risks. Where necessary, personal protective equipment (PPE) such as respirators can be used.

Governments have introduced strict regulations to protect workers. Australia has introduced stringent workplace exposure limits and has recently moved toward banning engineered stone due to its high silica content and the alarming rise in cases of silicosis among workers. The United States enforces strict exposure limits through Occupational Safety and Health Administration (OSHA) regulations, while the EU Carcinogens and Mutagens Directive requires companies to implement preventive measures, conduct exposure assessments, and ensure worker protection through a combination of engineering controls and behavioural measures. Effective enforcement and industry compliance remain crucial in preventing this entirely avoidable but life-threatening disease.

Sources: IMA Europe (2018[160]),SafeSilica, www.safesilica.eu; Hoy et al. (2022[158]) Current global perspectives on silicosis—Convergence of old and newly emergent hazards, https://doi.org/10.1111/resp.14242; Safe Work Australia, (n.d.[155]), Engineered stone ban, https://www.safeworkaustralia.gov.au/esban.

Other types of pollution may stem from sediment particle release from quarrying and sand manufacturing in surface water and groundwater (Rentier and Cammeraat, 2022[127]) causing water contamination with altered chemical composition as for example observed in India (Bhattacharya, Das Chatterjee and Dolui, 2019[161]). Salt intrusion may also occur when sand extraction changes natural groundwater hydrology and allows saltwater to encroach into adjacent land and freshwater aquifers, potentially degrading water quality and harming agricultural productivity and local food security. Available reports illustrate how the problem can present acute risks in certain regions of India (Bhattacharya, Das Chatterjee and Dolui, 2019[161]), Ghana (Bendixen et al., 2023[102]), China (Best, 2019[162]); and Sierra Leone (Lynggaard Reimer and Gallagher, 2023[110]). Acidic conditions from industrial silica sand mining can also emerge (Pandey et al., 2023[140]).

Water depletion

The sand and silicates sector can exacerbate water depletion in three distinct ways. First, freshwater sand extraction can significantly reduce water retention in surface and groundwater sources (Saviour, 2012[163]; Mohanty, Kotadia and Sengupta, 2021[164]), affecting drinking water availability and agricultural irrigation systems (Asare, Dawson and Hemmler, 2023.[39]). Second, sand and silicate extraction and processing consume significant volumes of water for washing, sorting and dust management, for example in gravel, marine sand, silica sand and kaolin used for porcelain production (Kanehl and Lyons, 1992[124]; Ashraf, 2011[142]; Pilkey et al., 2022[51]; Grbeš, 2015[165]). Third, sand and silicate extraction can reduce the quality of freshwater through increased siltation in municipal or industrial water intake structures.

Waste mismanagement

Waste rock and associated dust can emerge as a serious issue for aggregates quarries, manufactured sands and river-bed mining, especially when waste rock and overburden is poorly managed or abandoned as part of dry tailings (Abdulazeez, 2016[166]). Waste mismanagement is a potential risk in quarrying, sand manufacturing and freshwater extraction. Unrehabilitated pits can sometimes be used for informal waste disposal, with associated odour nuisances and local pollution risks, as observed in Nigeria (Adedeji, Adebayo and Sotayo, 2014[119]). The literature further illustrates how informal sand mining sites in countries in Sub-Saharan Africa can involve improperly disposed plastic waste (Ali, 2020[167]). The amount of waste produced in sand and silicate production is likely to vary depending on processing methods. For example, the literature points to significant amounts of waste in clay processing for industrial uses (KaBCA, n.d.[168]).

Damage to aesthetics and cultural heritage sites

Damage to aesthetics and cultural heritage sites and protected areas with cultural value can arise, for example, in the context of sand extraction in sacred forests in São Tomé and Principe (Tychsen, Batista and Carvalho, 2022[25]), in proximity to cultural and sacred sites in Madagascar and Australia (Jouffray et al., 2023[136]), volcanic sands extraction from the sacred Mount Merapi in Indonesia (Miller, 2022[169]) and erosion threats to religious temples in China (Zhu, 2020[170]). In Australia, several World Heritage sites contain dune systems and landforms which are sensitive environments. The potential impact of sand mining on sacred sites in Australia has been discussed in the literature (Shannon Kilmartin-Lynch, 2025[171]). As with any other impact, immediate adverse impacts of sand and silicate extraction can accumulate and have larger-scale effects over time, for example when hydrogeological structures are affected by mining and act as a multiplier of the impact with reach beyond the immediate footprint of extraction activities.

Table 3.2. Overview of environmental risks in sand and silicate supply chains

RISK CATEGORIES IN OECD HANDBOOK ON ENVIRONMENTAL DUE DILIGENCE	RISKS OBSERVED IN THE SECTOR				
	1 Extraction and initial processing, trade (Terrestrial, Manufactured, Freshwater, Marine)	2 Localised uses	3 Manufacturing and industrial uses	4 Final uses and products	5 Transport
Biodiversity loss	(!)	(!)	(!)	(!)	(!)
Greenhouse gas emissions	(!)	(!)	(!)	(!)	(!)
Improper use or disposal of hazardous materials	(!)	(!)			(!)
Noise and vibration	(!)	(!)			(!)
Physical instability, soil erosion and land	(!)				
Pollution	(!)	(!)	(!)	(!)	(!)
Damage to aesthetics and cultural heritage sites	(!)	(!)			
Mismanagement of waste	(!)	(!)	(!)	(!)	
Water depletion	(!)	(!)	(!)	(!)	(!)

Social and community risks, including other human rights abuses

Occupational health and safety

Occupational health and safety risks can arise in the context of sand and silicate supply chains when workers at extraction or processing sites are exposed to dust and subsequent diseases including silicosis or tuberculosis (Brickhill, 2021[157]; Hoy et al., 2022[158]). Several reports point to potential accidents related to the use of machinery, drownings, and fire risks which can emerge as health and safety hazards (UNDP, 2018[29]; Kauffer and Torres, 2023[103]). Work-related risks and accidents, sometimes fatal, are less documented in the artisanal sector but can be assumed to prevail considering the high degree of informality in this sector (Pilkey et al., 2022[51]). Miners also can experience health impacts such as musculoskeletal pain and discomfort, skin and eye problems, excessive sunlight and heat exposure, direct contact with heavy metals and waterborne disease exposure burdens, for example in natural stone production in India (American Bar Association, 2020[87]). One case exploring clay quarrying in Egypt shows how natural radiation can exist in ceramic building materials, with serious health implications (Aboelkhair, Ibrahim and Saad, 2012[172]).

Adverse impacts on communities and Peoples

Additional adverse impacts on communities and Indigenous Peoples stemming from sand and silicate production and trade can include:

- Accidental loss of life through drownings of nearby residents and livestock when freshwater extraction changes the velocity and flow of rivers that were previously safe to swim in (Rentier and Cammeraat, 2022[127]) or through terrestrial pit mining where pits are abandoned due to poor mining rehabilitation (Nguru, 2007[173]). Road accidents, of which some can be fatal, due to heavy truck traffic transporting materials can arise locally (Pandey et al., 2023[140]).
- Adverse community health impacts and communicable disease can increase related to water pooling in unrehabilitated dry pits, leading to mosquito breeding and higher instances of malaria and cholera for example in Nigeria (Adedeji, Adebayo and Sotayo, 2014[119]) and Ghana (Asare, Dawson and Hemmler, 2023.[39]).
- Harm to food security from land degradation, agricultural productivity decreases due to dust, land loss through erosion or storage-related displacement of farmland and compromised fish reproduction (Aromolaran Adetayo, 2012[174]).
- Adverse quality of life and security impacts**,** including environmental amenity loss and environmental risks with implications for human rights. The literature illustrates how in Ghana, for example, sand mining can cause loss of community landholdings while reducing crop diversity and yields, hence affecting the food and livelihood security of households (Asare, Dawson and Hemmler, 2023.[39])
- Sand and silicates extraction can take place in landscapes with profound cultural meaning and natural importance to Indigenous communities, with hydrological changes from mining compounding over time, causing adverse impacts on ancestral waters (Shannon Kilmartin-Lynch, 2025[171])

These adverse impacts and risks provide some examples of the multiple ways in which sand and silicates may impact Indigenous Peoples and communities in areas of material extraction, transit and trade. More research is needed to determine how other factors, including circumstances related to conflict, natural resource use and land rights may compound adverse impacts through their interaction with sand and silicate extraction and trade.

4 Considerations for enhancing responsible sourcing of sand and silicates

This chapter explores how companies operating in sand and silicate supply chains can implement due diligence based on OECD standards. Considering their strategic uses, widespread adverse impacts and increasing, potentially unsustainable demand, there is a shared interest in collaborative measures by companies to more responsibly produce and source sand and silicates. Governments can support an enabling environment for responsible business conduct, including by setting an example through responsible public procurement and development finance for infrastructure.

Considerations for companies

Downstream uses of sand and silicates span a range of diverse sectors, some with significantly more experience with expectations for responsible business conduct. The following considerations can help companies with varying levels of experience apply OECD standards and their due diligence framework to the sand and silicates sector.

Considerations for all companies, including those with less experience in due diligence:

- Carry out a **scoping exercise to identify risks** across operations and business relationships, with special attention to high-risk areas and business models that may influence the nature of risks and the context of extraction and processing.
- **Identify and assess actual and potential adverse impacts** based on severity and likelihood. This includes reviewing credible, publicly available reports and engaging with suppliers, governments, civil society and relevant experts (OECD, 2018[82]).
- Engage with peer and partner companies to **learn about joint action** underway and explore **pre-competitive collaboration to build leverage and pool resources** for improving due diligence.
- Some sectors like **construction** consume large volumes of sand and silicates but tend not to disclose extensive information on their due diligence. **Greater uptake of due diligence** by this sector would make a significant contribution to enhancing responsible production and sourcing of sand and silicates.

Considerations for companies already conducting due diligence to integrate into existing systems and practices:

- Identify material locations and transport routes as part of the scoping exercise while being mindful of the participation of multiple, often small operators in supply chains of variable length and **multidimensional exposure to risks and impacts**.
- Identify dominant extraction systems as part of the risk scoping exercise to understand whether sourcing from **freshwater and marine ecosystems** is taking place. **High-value biodiversity areas** or ecosystems with unique biophysical characteristics can serve as additional screening factors for risk identification in sand and silicate production.

Adapt risk mitigation to the characteristics of the supply chain; where sand and silicates are produced and consumed within **short value chains, identify localised approaches to risk mitigation**. Where sand and silicate supply chains are transboundary, explore integration of sand and silicates into multi-tiered due diligence approaches for base and precious metals like those in Figure 1.1Figure 1.2. The use of l**ime in the smelting and refining of non-ferrous metals can be a good entry point** for applying existing due diligence verification initiatives to the sand and silicates supply chain.

- Considering the interconnectedness of RBC risks in sand and silicates, adopt a holistic approach to risk mitigation. For example, in dynamic ecosystems, **risks from sand and silicate extraction can propagate beyond the immediate extraction site** and accumulate over time. OECD standards for RBC provide guidance on how to assess a **company's involvement with the actual or potential adverse impacts** and how this influences expectations for risk mitigation (see Box 4.1) (OECD, 2018[82]).
- **Investment in circularity measures** and resource efficiency are relevant to addressing unsustainable extraction and consumption rates for sand and silicates and can help companies prevent environmental impacts (OECD, 2025[117]).
- **Pursue an engagement strategy** that meets the legitimate expectations of Indigenous Peoples, particularly with regard for domestic legal requirements to obtain free, prior and informed consent (FPIC) in order for projects to proceed. In countries where FPIC is not legally mandated, enterprises

should consider local expectations, the risks posed to Indigenous Peoples and to the operations as result of local opposition (OECD, 2017[84]).

Any company producing or sourcing sand and silicate materials can engage in collaborative efforts to:

- Generate and share more information on supply chain risks in the sector.
- **Establish upstream risk monitoring systems** adapted to sand and silicate supply chains that companies can use to inform their responses to identified risks.
- Help generate more information on **whether a control point[14] approach is fit for purpose** for sand and silicates and, where relevant, identify the most suitable control point.
- Explore the extent to which existing due diligence facilitation and verification initiatives (including audit and certification programmes) can adopt due diligence considerations for sand and silicates. Explore whether new approaches are needed while learning from, and building on, existing initiatives.
- Engage with other relevant stakeholders to support formalisation efforts and enhance market access for legitimate ASM in line with the OECD Minerals Guidance (OECD, 2016[80]) and building on international efforts and principles for ASM formalisation like those set out in Mosi-ao-Tunya Declaration (Mining, 2018[175]).

Box 4.1. OECD standards on responsible business conduct

The OECD Guidelines for Multinational Enterprises on Responsible Business Conduct call on enterprises to undertake risk-based due diligence to identify, prevent, mitigate and account for how they address actual and potential adverse impacts in their own operations and supply chains. OECD standards on responsible business conduct address risks spanning human rights, labour, environment, corruption among others affecting people, planet and society. The OECD Due Diligence Guidance for Responsible Business Conduct (RBC Guidance) and the OECD Minerals Guidance set out a step-by-step due diligence framework with specific recommendations for all companies sourcing minerals.

The OECD Handbook on Environmental Due Diligence in Mineral Supply Chains helps companies apply OECD standards on responsible business conduct to address environmental risks spanning biodiversity loss, air, water and soil pollution, water depletion and climate change. Together, the Handbook and the Minerals Guidance delineate responsibilities of companies based on their position in the minerals supply chain and their proximity to adverse impacts, from miners and traders to smelters and recyclers. While the sand and silicates sector is exceedingly varied, with a range of processing and value chain configurations, the recommendations and concepts in the RBC Guidance, Minerals Guidance and Environmental Handbook are fit to apply to sand and silicates.

Due diligence applies across the supply chain and should be proportionate to the nature, severity, and likelihood of impacts. Where it is not feasible to address all identified impacts at once, businesses should prioritise the most severe and likely impacts and allocate resources accordingly. Enterprises' relationship to adverse impacts determine how they should respond to them: where an enterprise causes an impact, it should cease, prevent or remedy it; where it contributes, it should mitigate or cooperate in remedy; and where it is directly linked, it should seek to influence partners to prevent or address the impact. The process applies across the entire supply chain, beyond first-tier relationships, and recognizes the role of "control points" such as smelters and refiners in mineral supply chains.

While contextual factors like leverage, size and resources influence how due diligence is carried out, they do not remove responsibility. The goal is meaningful progress on significant risks, using credible prioritisation and time-bound targets, without expecting risk-free supply chains.

Sources: OECD (2023[83]), OECD Guidelines for Multinational Enterprises on Responsible Business Conduct, https://doi.org/10.1787/81f92357-en; OECD (2018[82]), Due Diligence Guidance for Responsible Business Conduct, https://doi.org/10.1787/15f5f4b3-en; OECD (2016[80]), OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas: Third Edition, https://doi.org/10.1787/9789264252479-en; OECD (2023[81]), Handbook on Environmental Due Diligence in Mineral Supply Chains, https://doi.org/10.1787/cef843bf-en

Considerations for governments

Given the use of sand and silicates in a range of strategic sectors, spanning high-volume sectors like infrastructure as well as niche applications like semiconductors and specialty glass, widespread impacts and increasing, potentially unsustainable levels of extraction, there is a shared interest in setting global approaches and rules for the responsible, sustainable use of sand and silicates. Governments can take action by considering the following policy measures:

- In a context of growing economic security concerns, and building on existing efforts**, consider shifting trade dependencies in the semiconductor supply chain in policies to enhance resilience** for critical raw materials.
- Improve **harmonisation and precision of national trade nomenclatures** using the HS trade classification system for sand and silicates to enhance transparency of some of these materials.
- **Progressively extend existing supply chain due diligence expectations** to sand and silicates.
- Engage in customs and law enforcement cooperation to counter illicit flows of sands and silicates.
- Using a risk-based approach that is mindful of varying risk profiles across supply chains and commodities within the sand and silicates sector,, support the implementation of RBC provisions in public infrastructure policies spanning **export credit agencies, quality infrastructure frameworks and certification programmes**, and risk management frameworks applied by international development finance institutions (OECD, 2022[176]; OECD, 2022[177]). For example, governments can include certain criteria in public tenders to enhance responsible sourcing of sand and silicates (OECD, 2024[178]).
- Ensure enforcement of relevant environmental regulations in alignment with international best practice and integrate responsible sand and silicate supply chains into implementation programmes for international environmental conventions related to mining and quarrying, for example to help **give effect to the United Nations Environment Assembly (UNEA) Resolution 6/5** on environmental aspects of minerals and metals (UNEP, 2024[179]).
- Pursue international co-operation to track sand and silicate extraction and consumption, especially for **construction sand at regional level** where extraction can become unsustainable, and foster multi-stakeholder collaboration to enable more **sustainable sand and silicate production and consumption rates.**

Considerations for other stakeholders

Civil society organisations and academia can help support due diligence by companies in sand and silicate supply chains by enhancing knowledge in five key areas for improvement if properly consulted and resourced:

- Whole-of-supply chain research on RBC impacts in sand and silicate supply chains is rare, and existing life cycle assessments tend to focus on energy consumption and carbon emissions alone, often overlooking broader environmental impacts. There is scope to enhance available evidence on RBC across supply chain segments
- Available evidence largely relates to risks and impacts that can be associated with construction aggregates sourcing. Industrial sands, clays, high-purity quartz, and other silicate minerals are less explored, indicating a need for future research and guidance.
- Many existing studies address isolated sets of impacts bounded by each extraction system (terrestrial, manufacturing, freshwater, marine). More comprehensive, integrated assessments of sand and silicate trade flows and risks through global and interconnected supply chains are needed.
- Existing research often discusses 'illegal' sand and silicate extraction with insufficient attention to the underlying causes of informal mining, processing and trading. More analytical research on gaps in applicable legal frameworks, governance systems and transparency can help generate a more nuanced understanding of these root causes and provide the contextual information needed to conceive meaningful solutions for formalisation in the concerned regions and supply chains.

References

(n.a.) (2025), *Bernreuter Research*. [203]

(SIA), S. (2025), *Notice of Request for Public Comments on Section 232 National Security Investigation*, https://www.semiconductors.org/wp-content/uploads/2025/08/Semiconductor-Industry-Association-SIA-Comments-Polysilicon-Section-232-Investigation.pdf. [66]

Abderrahmane, A. (2022), *Extracting and Trafficking Morocco's Coastal Sand.*, https://enactafrica.org/research/research-papers/extracting-and-trafficking-moroccos-coastal-sand (accessed on May 2024). [52]

Aboelkhair, H., T. Ibrahim and A. Saad (2012), "Gamma activity of stream sediment feldspars as ceramic raw materials and their environmental impact", *Radiation Protection Dosimetry*, doi:10.1093/rpd/ncr448, pp. 175– 182. [172]

Abraham, C. et al. (2021), "Towards effective monitoring of sand mining sites and post management techniques in sand dredged environment of Akwa Ibom State, Nigeria", *The Global Journal of Ecology*, https://dx.doi.org/10.17352/gje, pp. 092-099. [111]

Adedeji, O., H. Adebayo and E. Sotayo (2014), "Assessing environmental impacts of inland sand mining in parts of Ogun State, Nigeria", *Ethiopian Journal of Environmental Studies and Management*, 10.4314/ejesm.v7i5.2, p. 478. [119]

AfCFTA (n.d.), *African Continental Free Trade Area*, https://au-afcfta.org/ (accessed on August 2024). [21]

Afghan Witness (2024), *Afghanistan's mining sector under the Taliban*, https://www.afghanwitness.org/reports/afghanistan's-mining-sector-under-the-taliban (accessed on May 2024). [192]

Agharroud, K. et al. (2023), "Assessment of the sustainability of aggregate quarrying practices in northern Morocco: A case regarding the eastern provinces of the Tangier Peninsula.", *Bulletin of Engineering Geology and the Environment*, https://doi.org/10.1007/s10064-023-03252-x, p. 247. [38]

Ako, T. et al. (2014), "Environmental Effects of Sand and Gravel Mining on Land and Soil in Luku, Minna, Niger State, North Central Nigeria", *Journal of Geosciences and Geomatics*, 10.12691/jgg-2-2-1, pp. 42-49. [130]

Ali, A. (2020), *Socio-economic impacts of sand mining activities in Zanzibar*, The Open University of Tanzania. [167]

Aliu, I., I. Akoteyon and O. Soladoye (2022), *Sand Mining in African Coastal Regions: Exploring the Drivers, Impacts and Implications for Environmental Sustainability in Lagos Nigeria.*, Springer International Publishing. [143]

Allen, A. (2023), *Mapping the Semiconductor Supply Chain: The Critical Role of the Indo-Pacific Region*, https://csis-website-prod.s3.amazonaws.com/s3fs-public/2023- [75]

05/230530_Thadani_MappingSemiconductor_SupplyChain.pdf?VersionId=SK1wKUNf_.qSF3kzMF.aG8dwd.fFTURH (accessed on 28 November 2025).

Allied Market Research (2023), *https://www.alliedmarketresearch.com/abrasives-market*. [186]

Allied Market Research (2022), *Glassware Market Size, Share, Competitive Landscape and Trend Analysis*, https://www.alliedmarketresearch.com/glassware-market-A11874 (accessed on February 2024). [189]

Alqadi, S. et al. (2023), "A comparative life cycle energy and green house emissions of natural and artificial stone-manufacturing phase", *Results in Engineering*, 10.1016/j.rineng.2023.101055, p. 101055. [132]

Alvarado-Villalon, F., D. Harrison and E. Steadman (2003), *River Mining: Alluvial mining of aggregates in Costa Rica*, British Geological Survey. [126]

American Bar Association (2020), *Tainted Stones: Bonded Labor and Child Labor in the India-U.S. Sandstone Supply Chain: India*. [87]

Ameziane, L. and B. Suykens (2023), "Political settlements and the historical development of sand governance in Morocco", *The Extractive Industries and Society*, 10.1016/j.exis.2023.101245, p. 101245. [97]

Ameziane, L. and B. Suykens (2023), "Political Settlements and the Historical Development of Sand Governance in Morocco.", *The Extractive Industries and Society*, Vol. 14, pp. 101245 https://doi.org/10.1016/j.exis.2023.101245, https://doi.org/10.1016/j.exis.2023.101245. [53]

Anthony, E. (2016), *Impacts of sand mining on beaches in Suriname*. [151]

Arjun, M., B. Panda and P. Arun (2023), "Sand Mining as a Contemporary threat to Sandbar Nesting Birds: A Review.", *Contemporary Problems of Ecology*, https://doi.org/10.1134/S1995425523020038, pp. 189–204. [123]

Aromolaran Adetayo, K. (2012), "Effects Of Sand Mining Activities On Land In Agrarian Communities Of Ogun State, Nigeria", *Continental Journal of Agricultural Science*, 10.5281/ZENODO.844177, pp. 41-49. [174]

Arrozy, A. and F. Edytya (2022), "The Metaphor of Eros Civilization on Sand Mining Group In Kemalang Klaten Central Java.", *Hasanuddin Journal of Sociology (HJS)*, https://journal.unhas.ac.id/index.php/HJS/article/view/19564, pp. 2685–4333. [90]

Asabonga, M. et al. (2017), "The physical and environmental impacts of sand mining.", *Transactions of the Royal Society of South Africa*, https://doi.org/10.1080/0035919X.2016.1209701, pp. 1–5. [146]

Asare, K., K. Dawson and K. Hemmler (2023.), "A sand-security nexus: Insights from peri-urban Accra, Ghana.", *The Extractive Industries and Society*, https://doi.org/10.1016/j.exis.2023.101322, p. 101322. [39]

Asegu, K. et al. (2023), "Violence against women and associated factors among female construction workers in Addis Ababa, Ethiopia.", *BMC Psychiatry*, https://doi.org/10.1186/s12888-023-050, p. 547. [101]

Ashraf, M. (2011), "Sand mining effects, causes and concerns: A case study from Bestari [142]

Jaya, Selangor, Peninsular Malaysia", *Scientific Research and Essays*, Vol. 6/6, pp. 1216–1231.

Asif, F. and L. Van Arragon (2023), "Precarious livelihoods at the intersection of fishing and sand mining in Cambodia, https://doi.org/10.1007/s13280-023-01963-9", *Ambio*, pp. 565-578, https://doi.org/10.1007/s13280-023-01963-9. [41]

Athukorala, K. and C. Navaratne (2007), *Shifting Sands in Sri Lanka - Mobilizing and Networking for Collective Action by River Sand Mining affected Communities*, NetWwater. [201]

Bendixen, M. et al. (2023), "Drivers and effects of construction-sand mining in Sub-Saharan Africa.", *The Extractive Industries and Society*, https://doi.org/10.1016/j.exis.2023.101364, p. 101364. [102]

Bendixen, M. et al. (2019), "Promises and perils of sand exploitation in Greenland.", *Nature Sustainability*, https://doi.org/10.1038/s41893-018-0218-6, pp. 98–104. [45]

Bennett, M. (2023), "Gravel grabs: The rocky foundations of Indigenous geologic power in the Arctic.", *Ambio*, https://doi.org/10.1007/s13280-023-01862-z, pp. 1184–1197. [46]

Bernreuter, J. (2025), *The Polysilicon Market Outlook 2029*, https://www.bernreuter.com/polysilicon/industry-reports/polysilicon-market-outlook-2029/. [60]

Bernreuter, J. (2019), *Bernreuter Research*, https://www.bernreuter.com/solar-industry/value-chain/. [62]

Best, J. (2019), "Anthropogenic stresses on the world's big rivers.", *Nature Geoscience*, https://doi.org/10.1038/s41561-018-0262-x, pp. 7–21. [162]

Bhattacharya, R., N. Das Chatterjee and G. Dolui (2019), "Consequences of sand mining on water quality and instream biota in alluvial stream: A case-specific study in South Bengal River, India.", *Sustainable Water Resources Management*, https://doi.org/10.1007/s40899-019-00345-y, pp. 1815–1832. [161]

Bisht, A. and J. Gerber (2017), "Ecological distribution conflicts (EDCs) over mineral extraction in India: An overview", *The Extractive Industries and Society*, http://dx.doi.org/10.1016/j.exis.2017.03.008, pp. 548–563. [43]

Blervacq, C. (2022), *Sibelco and Responsible Sand Production*. [30]

Bravard, J., M. Goichot and S. Gaillot (2013), "Geography of Sand and Gravel Mining in the Lower Mekong River: First Survey and Impact Assessment.", *EchoGéo*, https://doi.org/10.4000/echogeo.13659. [196]

BRGM (n.d.), *https://www.mineralinfo.fr/fr*, https://www.mineralinfo.fr/sites/default/files/documents/2020-12/materialcriticalitysiliconmetal-public20191030.pdf. [65]

Brickhill, J. (2021), "A river of disease: Silicosis and the future of class actions in South Africa", *South African Journal on Human Rights*, 10.1080/02587203.2021.1963834, pp. 31-58. [157]

Bui, X., C. Lee and C. Drebenstedt (eds.) (2021), *River Sand Mining Vis a Vis Manufactured Sand for Sustainability.*, Springer International Publishing. [35]

Cement Concrete & Aggregates Australia (2008), *Guide to the Specification and Use of* [202]

Manufactured Sand in Concrete, https://www.ccaa.com.au/common/Uploaded%20files/CCAA/Publications/Technical%20Guides/CCAAGUIDE2009-T60-MANSAND-TBR.pdf.

Charles, N. and J. Tychsen (2023), *La mine artisanale en Afrique Centrale, du Nord et de l'Est francophones: Guide pratique*, Service géologique du Danemark et du Groenland (GEUS) et Service géologique de la France (BRGM), https://www.researchgate.net/profile/Nicolas-Charles-3/publication/370637119_La_mine_artisanale_en_Afrique_Centrale_du_Nord_et_de_l%27Est_francophones/links/64a6d9ea8de7ed28ba7e1160/La-mine-artisanale-en-Afrique-Centrale-du-Nord-et-de-lEst-francophones.pd. [91]

Choi, E. (2023), "Investigating the management of marine sand mining: A case of West Sea Exclusive Economic Zone in South Korea", *Regional Studies in Marine Science*, 10.1016/j.rsma.2023.103109, p. 103109. [153]

Cobalt Institute (2021), *State of the Cobalt Market*, https://www.cobaltinstitute.org/wp-content/uploads/2025/02/Cobalt-Institute-State-of-the-Cobalt-Market-Report_2020.pdf. [9]

CRU Group (2025), *Silicon*, https://www.crugroup.com/en/commodities/silicon/. [64]

Cusick, D. and E&E News (2024), *The U.S. Spends a Fortune on Beach Sand That Storms Just Wash Away*, pp. https://www.scientificamerican.com/article/the-u-s-spends-a-fortune-on-beach-sand-that-storms-just-wash-away/. [182]

da Silva, E. et al. (2020), "Environmental impacts of sand mining in the city of Santarém, Amazon region, Northern Brazil.", *Environment, Development and Sustainability*, https://doi.org/10.1007/s10668-018-0183-2, pp. 47-60. [131]

Daghar, M. (2022), *Kenya's sand cartels: Ecosystems, lives and livelihoods lost*, enact: Enhancing Africa's response to transnational organised crime, p. 23. [98]

Da, S. and P. Le Billon (2022), "Sand mining: Stopping the grind of unregulated supply chains", *The Extractive Industries and Society*, https://doi.org/10.1016/j.exis.2022.101070. [50]

Deng, M. et al. (2022), "Impacts of Sand Mining Activities on the Wetland Ecosystem of Poyang Lake (China).", *Land*, https://doi.org/10.3390/land11081364, p. 1364. [145]

Dethier, E. et al. (2023), "A global rise in alluvial mining increases sediment load in tropical rivers", *Nature*, https://doi.org/10.1038/s41586-023-06309-9, pp. 787–793. [194]

Dewi, I. et al. (2019), *Implementation of environmental management policies on the impact of illegal sand mining.*. [147]

Dodd, T., J. Guthrie and J. Dumay (2023), "Management controls and modern slavery risks in the building and construction industry: Lessons from an Australian social housing provider.", *The British Accounting Review*, https://doi.org/10.1016/j., p. 101098. [85]

EBRD, CDC and IFC (2020), *Addressing Gender-Based Violence and Harassment (GBVH) in the Construction Sector*, European Bank for Reconstruction and Development, CDC and International Finance Corporation. [100]

Eiko, N. et al. (2021), "A century of U.S. beach nourishment", *Ocean & Coastal Management*, 10.1016/j.ocecoaman.2020.105406, p. 105406. [181]

European Center for Constitutional and Human Rights (ECCHRR) (2024), *Lafarge in Syria: Accusations of complicity in grave human rights violations*, https://www.ecchr.eu/en/case/lafarge-in-syria-accusations-of-complicity-in-grave-human-rights-violations/ (accessed on January 2025). [107]

Fisher, R. and J. Hirschfeld (2022), *Why we are in 'the age of artificial islands'*, https://www.bbc.com/future/article/20220105-why-were-in-the-age-of-artificial-islands (accessed on April 2024). [180]

Franke, M. (2014), *When one country's land gain is another country's land loss...: The social, ecological and economic dimensions of sand extraction in the context of world-systems analysis exemplified by Singapore's sand imports*, https://hdl.handle.net/10419/97163. [28]

Franks, D. (2020), "Reclaiming the neglected minerals of development", *The Extractive Industries and Society*, https://doi.org/10.1016/j.exis.2020.02.002, pp. 453-460. [1]

Gandri, L. et al. (2023), "Analysis of the Biophysical Environmental Impact of Sand Mining in Mawasangka District, Central Buton Regency", *Journal of Soilscape and Agriculture*, http://journal.unej.ac.id/JSA, pp. 53-66. [120]

Gavriletea, M. (2017), "Environmental Impacts of Sand Exploitation. Analysis of Sand Market", *Sustainability*, 10.3390/su9071118, p. 1118. [128]

Geoscience Australia (2024), *New insights into Australia's unknown potential for high-purity quartz resources*, https://www.ga.gov.au/news/new-insights-into-australias-unknown-potential-for-high-purity-quartz-resources (accessed on 4 December 2025). [70]

Gerbinet, S., S. Belboom and A. Léonard (2014), "Life Cycle Analysis (LCA) of photovoltaic panels: A review", *Renewable and Sustainable Energy Reviews*, Vol. 38, pp. 747-753. [133]

Glass Alliance Europe (n.d.), , https://glassallianceeurope.eu/the-world-of-glass/ (accessed on May 2024). [76]

Grbeš, A. (2015), "A Life Cycle Assessment of Silica Sand: Comparing the Beneficiation Processes", *Sustainability*, https://doi.org/10.3390/su8010011, p. 11. [165]

Hackney, C. et al. (2020), "River bank instability from unsustainable sand mining in the lower Mekong River.", *Nature Sustainability*, 10.1038/s41893-019-0455-3, pp. 217–225. [148]

Hanti, H. (2022), *Assessment of Socio-economic and Environmental Impacts of Sand Mining: A case study of Dodoma City Council.*. [141]

Harriss-White, B. and L. Michelutti (eds.) (2019), *Sand and the politics of plunder in Tamil Nadu, India.*, UCL Press. [96]

Hart, E. (2025), "China Moves to Break Free from Its Last U.S. Dependencies with a €1.4 Billion High-Purity Quartz Discovery", *China Moves to Break Free from Its Last U.S. Dependencies with a €1.4 Billion High-Purity Quartz Discovery*, https://indiandefencereview.com/china-moves-to-break-free-from-its-last-u-s-dependencies-with-a-e1-4-billion-high-purity-quartz-discovery/ (accessed on 4 December 2025). [73]

Hoffmann, M. (2021), "Digging for sand after the revolution: mafia, labor, and shamanism in a Nepali sand mine", *Dialectical Anthropology*, https://doi.org/10.1007/s10624-020-09615-0, [105] pp. 117–133.

Holcim (2022), *Holcim Group Statement*, https://www.holcim.com/sites/holcim/files/2022-10/20221018_press_holcim_group_statement_en_5161029389.pdf. [106]

Holm, D., L. Gallagher and D. Franks (2023), *An invitation to explore responsible souricng of sand and silicates. Final report from a roundtable discussion at the OECD 2023 Forum on Responsible Mineral Supply Chains*, University of Queensland, https://smi.uq.edu.au/files/105494/OECD%20Forum%202023%20-%20Session%20summary.pdf. [33]

Hoy, R. et al. (2022), "Current global perspectives on silicosis—Convergence of old and newly emergent hazards", *Respirology*, 10.1111/resp.14242, pp. 387-398. [158]

Humbert, P. et al. (eds.) (2017), *Measuring Silica Nanoparticles in the Skin*, Springer International Publishing. [190]

IADC (2023), *Sand as a Resource: Best Practices to Conduct Responsible Dredging Projects*, Terra et Aqua. [27]

IEA (2022), *Special Report on Solar PV Global Supply Chains*, IEA, Paris, https://www.iea.org/reports/solar-pv-global-supply-chains. [61]

IEA (2021), *Net Zero by 2050: A Roadmap for the Global Energy Sector*, https://www.iea.org/news/hydropower-has-a-crucial-role-in-accelerating-clean-energy-transitions-to-achieve-countries-climate-ambitions-securely. [185]

IEA (2021), *The Role of Critical Minerals in Clean Energy Transitions*, https://www.iea.org/reports/the-role-of-critical-minerals-in-clean-energy-transitions. [74]

IMA Europe (2018), *SafeSilica*, https://safesilica.eu/ (accessed on January 2025). [160]

International Labour Organisation (1999), *Worst Forms of Child Labour Convention No. 182*, https://normlex.ilo.org/dyn/nrmlx_en/f?p=NORMLEXPUB:12100:0::NO::P12100_INSTRUMENT_ID:312327. [93]

Jennings, A. (2023), *A review of high-purity quartz for silicon production in Australia*, https://doi.org/10.1080/08120099.2024.2362296. [67]

Jeyaranjan (2019), *Sand and the politics of plunder in Tamil Nadu, India*, UCL Press, https://doi.org/10.2307/j.ctvfrxr41. [115]

John, R. (2021), "Sand geographies: Disentangling the material foundations of the built environment", *Geography Compass.*, https://doi.org/10.1111/gec3.12560. [114]

Johnson, A. (2017), *Golf Course Architecture 101, Part 5: Construction*, https://thefriedegg.com/golf-course-architecture-101-part-5-drainage-construction/ (accessed on May 2024). [191]

Jonah, F. et al. (2015), "Assessment of sand and stone mining along the coastline of Cape Coast, Ghana.", *Annals of GIS*, https://doi.org/10.1080/19475683.2015.1007894, pp. 223–231. [152]

Jouffray, J. et al. (2023), *Ocean sand: Putting sand on the Ocean Sustainability Agenda.*, Ocean Risk and Resilience Action Alliance (ORRAA) Report. [136]

KaBCA (n.d.), *What is Kaolin?*, https://kabca.org/what-is-kaolin.php (accessed on July 2024). [168]

Kalyani Mohanty, P. (2025), "Perspectives for High-Purity Quartz from European Resources", *Minerals*, Vol. 15(10)/Physicochemical Properties and Purification of Quartz Minerals, https://doi.org/10.3390/min15101080. [59]

Kanehl, P. and J. Lyons (1992), *Impacts of in-stream sand and gravel mining on stream habitat and fish communities, including a survey on the Big Rib River, Marathon County, Wisconsin. Report 155 [1992]*. [124]

Kauffer, E. and A. Torres (2023), "Gender and sand extraction in the Usumacinta River basin", *The Extractive Industries and Society*, 10.1016/j.exis.2023.101277, p. 101277. [103]

Kuklina, V. et al. (2023), "Dealing with sand in the Arctic city of Nadym.", *Ambio*, https://doi.org/10.1007/s13280-023-01868-7, pp. 1198–1210. [139]

La Notte, A. et al. (2017), "Ecosystem services classification: A systems ecology perspective of the cascade framework", *Ecological Indicators*, 10.1016/j.ecolind.2016.11.030, pp. 392-402. [193]

Lamb, V., M. Marschke and J. Rigg (2019), "Trading Sand, Undermining Lives: Omitted Livelihoods in the Global Trade in Sand", *Annals of the American Association of Geographers*, https://doi.org/10.1080/24694452.2018.1541401, pp. 1511-1528. [99]

Lynggaard Reimer, J. and L. Gallagher (2023), *Sand Policy Review 1: Sierra Leone*, https://archive-ouverte.unige.ch/unige:166547. [110]

Lynggard, J. and L. Gallagher (2023), *Sand Policy Review 1: Sierra Leone*, UNEP/GRID-Geneva. [116]

Mac Lellan, A. (1984), "Monitoring and modelling progressive rehabilitation in aggregate mining ... A decade of ontario experience and a look at the future", *Bulletin of the International Association of Engineering Geology*, 10.1007/BF02594419, pp. 279-283. [118]

Madhav, S., M. Kumar and S. Singh (eds.) (2023), *Assessment of Causes and Impacts of Sand Mining on River Ecosystem. In S. Madhav, V. B. Singh, M. Kumar, & S. Singh (Eds.), Hydrogeochemistry of Aquatic Ecosystems*, Wiley. [140]

Mahadevan, P. (2019), *Sand Mafias in India: Disorganized crime in a growing economy*, Global Initiative Against Transnational Organized Crime. [104]

Marschke, M. and J. Rousseau (2022), "Sand ecologies, livelihoods and governance in Asia: A systematic scoping review", *Resources Policy*, Vol. 102671, https://doi.org/10.1016/j.resourpol.2022.102671. [40]

Ma, Y. et al. (2022), "Spatial and Temporal Changes of Sand Mining in the Yangtze River Basin since the Establishment of the Three Gorges Dam. International", *Journal of Environmental Research and Public Health*, 10.3390/ijerph192416712, p. 167. [199]

Mercedes-Benz Group (November 2023), *Raw Material Report: Taking responsibility for raw material supply chains*, Mercedes-Benz Group AG. [86]

Miller, M. (2022), "A Transboundary Political Ecology of Volcanic Sand Mining.", *Annals of the American Association of Geographers*, https://doi.org/10.1080/24694452.2021.1914539, [169] pp. 78–96.

Mining, I. (2018), *Declaration Mosi-ao-Tunya on the Develomment of Artisanal and Small-scale Mining*, https://developmentminerals.org/wp-content/uploads/2025/06/Mosi-oa-Tunya_Declaration_FR.pdf. [175]

Mohanty, S., N. Kotadia and D. Sengupta (2021), *Effect of Conventional Sand Mining Along Heavy Mineral Beach Placers and Its Environmental Impact.*, Springer International Publishing. [164]

Moroșanu, G. and G. Ioana-Toroimac (2022), "Evidence of hydromorphological alteration under present-day sand mining and management works. Case studies on Romanian rivers", *Graie Pôle Eau & Territoires*, https://www.graie.org/graie/graiedoc/doc_telech/isrivers2022/C5/C5_ISRivers22_1.pdf. [122]

MPA (n.d.), *Silica Sand*, https://mineralproducts.org/Mineral-Products/Silica-Sand.aspx (accessed on May 2024). [37]

Murphy, L. and N. Elimä (2021), *In Broad Daylight: Uyghur Forced Labour and Global Solar Supply Chains*. [88]

Mycoo, M. (2022), *Small Islands*, Cambridge University Press, https://doi.org/10.1017/9781009325844.017. [135]

Ndabula, C., G. K-Naisa Adamu and A. Yaro (eds.) (2016), "Literature review and conceptual framework submitted to the Department of Geography, Faculty of Social Sciences", in *A Review on the Impact of River and Inland Sand Mining on Nigerian River Basins.*, Federal University Dutsin-MA. [166]

Neti, N. (2021), *Assessment Report: Implementing An Integrated Landscape System Approach For Nature-Based Solutions In Asian Deltas*. [184]

Ngoc Anh, L. et al. (2022), "Drastic variations in estuarine morphodynamics in Southern Vietnam: Investigating riverbed sand mining impact through hydrodynamic modelling and field controls", *Journal of Hydrology*, 10.1016/j.jhydrol.2022.127572, p. 127572. [149]

Nguru, P. (2007), *Impacts of Sand Mining on the Environment in Mjanaheri- Ngomeni Areas of Magarini division, Kenya*. [173]

Northrop, E. et al. (2022), *OPPORTUNITIES FOR TRANSFORMING COASTAL AND MARINE TOURISM Towards Sustainability, Regeneration and Resilience*, The High Level Panel for a Sustainable Ocean Economy, https://oceanpanel.org/wp-content/uploads/2022/06/Sustainable-Tourism-Full-Report.pdf. [78]

OEC (2022), *Smartphones*, https://games.oec.world/en/profile/hs/smartphones (accessed on April 2024). [77]

OEC - Sand (2022), *Sand*, https://oec.world/en/profile/hs/sand. [57]

OEC - Stone, sand and gravel (2018), *Stone, sand and gravel*, https://oec.world/en/profile/sitc/stone-sand-and-gravel. [58]

OECD (2025), *Enhancing Regional Mining Ecosystems in the European Union: Securing the Green Transition and Supply of Mineral Raw Materials*, OECD Publishing, Paris, [117] https://doi.org/10.1787/97ba1224-en.

OECD (2024), *Harnessing Public Procurement for the Green Transition: Good Practices in OECD Countries*, OECD Publishing, Paris, https://doi.org/10.1787/e551f448-en. [178]

OECD (2023), *Handbook on Environmental Due Diligence in Mineral Supply Chains*, OECD Publishing, Paris, https://doi.org/10.1787/cef843bf-en. [81]

OECD (2023), *OECD Guidelines for Multinational Enterprises on Responsible Business Conduct*, OECD Publishing, Paris, https://doi.org/10.1787/81f92357-en. [83]

OECD (2023), *Responsible is reliable – How responsible sourcing can address disruption factors and geopolitical risks in the supply of transition minerals*, https://www.oecd.org/content/dam/oecd/en/topics/policy-sub-issues/due-diligence-guidance-for-responsible-business-conduct/Responsible_is_Reliable.pdf. [44]

OECD (2022), *Recommendation of the Council on the Role of Government in Promoting Responsible Business Conduct*, https://legalinstruments.oecd.org/en/instruments/OECD-LEGAL-0486. [176]

OECD (2022), "Responsible business conduct due diligence for project and asset finance transactions", *OECD Business and Finance Policy Papers*, No. 14, OECD Publishing, Paris, https://doi.org/10.1787/952805e9-en. [177]

OECD (2019), *Global Material Resources Outlook to 2060: Economic Drivers and Environmental Consequences*, OECD Publishing, Paris, https://doi.org/10.1787/9789264307452-en. [4]

OECD (2018), *OECD Due Diligence Guidance for Responsible Business Conduct*, OECD Publishing, Paris, https://doi.org/10.1787/15f5f4b3-en. [82]

OECD (2017), *OECD Due Diligence Guidance for Meaningful Stakeholder Engagement in the Extractive Sector*, OECD Publishing, Paris, https://doi.org/10.1787/9789264252462-en. [84]

OECD (2017), *Practical Actions for Companies to Identify and Address the Worst Forms of Child Labour in Mineral Supply Chains*, OECD Publishing, Paris, https://doi.org/10.1787/16863163-en. [94]

OECD (2016), *OECD Due Diligence Guidance for Responsible Supply Chains of Minerals from Conflict-Affected and High-Risk Areas: Third Edition*, OECD Publishing, Paris, https://doi.org/10.1787/9789264252479-en. [80]

Office of Public Affairs, US Department of Justice (2018), *Lafarge Pleads Guilty to Conspiring to Provide Material Support to Foreign Terrorist Organizations*. [108]

Open (ed.) (2023), *Recent developments on manufacturing and characterization of fused quartz crucibles for monocrystalline silicon for photovoltaic applications*, Open Ceramics, https://doi.org/10.1016/j.oceram.2022.100321. [71]

Orru, M. et al. (2013), *Possibilities for mitigating negative effects of noise and dust caused by extraction of sand, gravel and peat.*. [144]

Oxford Economics (2023), *Global Construction Futures*, Oxford Economics. [22]

Oxford Economics (2023), *OxfordEconomics.com*, [48] https://www.oxfordeconomics.com/resource/global-construction-futures/ (accessed on May 2024).

Padmalal, D. and K. Maya (2014), *Sand Mining: Environmental Impacts and Selected Case Studies, https://link.springer.com/book/10.1007/978-94-017-9144-1*, Springer. [24]

Pierce, C. et al. (2019), "Monitoring of airborne particulates near industrial silica sand mining and processing facilities.", *Archives of Environmental & Occupational Health*, 10.1080/19338244.2018.1436036, pp. 185-196. [154]

Pilkey, O. et al. (2022), *Vanishing sands: Losing beaches to mining, https://doi.org/10.1215/9781478023432*, Duke University Press., https://library.oapen.org/viewer/web/viewer.html?file=/bitstream/handle/20.500.12657/77076/external_content.pdf?sequence=1&isAllowed=y. [51]

Popescu, F., M. Stoia and S. Morariu (2023), "A cross-national perspective on silicosis: incidence, occupational settings, and trends", *Romanian Journal of Occupational Medicine*, 10.2478/rjom-2023-0001, pp. 6-11. [159]

Publishing, O. (ed.) (2025), *Mapping the semiconductor value working towards identifying dependencies and vulnerabilities*, https://doi.org/10.1787/4154cdbf-en. [69]

Qin, Y. et al. (2020), "Impact of sand mining on the carbon sequestration and nitrogen removal ability of soil in the riparian area of Lijiang River, China.", *Environmental Pollution*, Vol. 261, p. 114220., https://doi.org/10.1016/j.envpol.2020.114220. [134]

Rangel-Buitrago, N. et al. (2023), "The global impact of sand mining on beaches and dunes.", *Ocean & Coastal Management*, https://doi.org/10.1016/j.ocecoaman.2023.106492. [125]

Ratter, B., J. Petzold and K. Sinane (2016), "Considering the locals: Coastal construction and destruction in times of climate change on Anjouan, Comoros.", *Natural Resources Forum*, https://doi.org/10.1111/1477-8947.12102, pp. 112–126. [137]

Rege, A. and A. Lavorgna (2017), "Organization, operations, and success of environmental organized crime in Italy and India: A comparative analysis", *European Journal of Criminology*, https://doi.org/10.1177/147737081664962, pp. 160-182. [95]

Rentier, E. and L. Cammeraat (2022), "The environmental impacts of river sand mining.", *Science of The Total Environment*, https://doi.org/10.1016/j.scitotenv.2022.155877, p. 155877. [127]

Ren, Z. et al. (2022), "Stocks and flows of sand, gravel, and crushed stone in China (1978–2018): Evidence of the peaking and structural transformation of supply and demand", *Resources, Conservation & Recycling*, Vol. 180, p. 106173, https://doi.org/10.1016/j.resconrec.2022.106173. [26]

Research and Markets (2024), *Natural Stone Global Market Report 2024*, https://www.researchandmarkets.com/reports/5766803/natural-stone-global-market-report (accessed on May 2024). [20]

RICS (2021), *The cost of corruption in construction*, https://www.rics.org/news-insights/wbef/the-cost-of-corruption-in-construction (accessed on 2024 July). [113]

Rogers, P. (2023), *Low Carbon Concrete Options for Pacific Infrastructure*. [47]

Rogers, P. et al. (2024), *Responsable sourcing of aggregates in the Pacific*. [138]

Runeckles, H. et al. (2023), ""Local people want to keep their sand": Variations in community perceptions and everyday resistance to sand mining across the Red River, Vietnam.", *The Extractive Industries and Society*, 10.1016/j.exis.2023.101336, p. 101336. [197]

Safe Work Australia (n.d.), *Engineered stone ban*, https://www.safeworkaustralia.gov.au/esban (accessed on January 2025). [155]

Saviour, N. (2012), "Environmental impact of soil and sand mining: A review", *International Journal of Science, Environment and Technology*, https://www.academia.edu/14174645/ENVIRONMENTAL_IMPACT_OF_SOIL_AND_SAND_MINING_A_REVIEW, pp. 125-134. [163]

Schmitt, R., Z. Rubin and G. Kondolf (2017), "Losing ground—Scenarios of land loss as consequence of shifting sediment budgets in the Mekong Delta.", *Geomorphology*, https://doi.org/10.1016/j.geomorph.2017.04.029, pp. 58–69. [150]

Schwing, E. (2024), *Alaska is short on gravel and long on development projects*, https://www.hcn.org/articles/growth-sustainability-alaska-is-short-on-gravel-and-long-on-development-projects/. [31]

Sengupta, D. et al. (2023), "Mapping 21st Century Global Coastal Land Reclamation", *Earth's Future*, Vol. 11/2, p. e2022EF002927. [183]

Shangai Metals Market (2025), , https://zhuanlan.zhihu.com/p/20308202564. [63]

Shannon Kilmartin-Lynch, C. (2025), "Sand Sovereignty and environmental justice: Indigenous governance, sustainable aggregates, and the transformation of land use in Australia", https://doi.org/10.1016/j.envsci.2025.104264. [171]

Statistica (2024), *Distribution of tungsten consumption worldwide between 2012 and 2016, by country*, https://www.statista.com/statistics/1009699/tungsten-consumption-distribution-worldwide-by-country/ (accessed on May). [15]

Statistica (2024), *Global Silicon Production*, https://www.statista.com/statistics/573585/global-silicon-production/ (accessed on May 2024). [187]

Statistica (2024), *Major countries in industrial sand and gravel production worldwide in 2023*, https://www.statista.com/statistics/376665/industrial-sand-and-gravel-production-by-top-countries/ (accessed on May 2024). [8]

Statistica (2024), *World Silicon Production by Country*, https://www.statista.com/statistics/268108/world-silicon-production-by-country/ (accessed on May 2024). [188]

Tang, M., Z. Zhang and Y. Xing (2011), "Environment Monitoring of Offshore Sand Mining in Pearl River Estuary", *Procedia Environmental Sciences*, 10.1016/j.proenv.2011.09.225, pp. 1410-1415. [195]

The Quartz Corp (2024), *Impact of Hurricane Helene on The Quartz Corp in Spruce Pine*, https://www.thequartzcorp.com/articles/impact-of-hurricane-helene-on-the-quartz-corp-in-spruce-pine. [72]

Torres, A. et al. (2021), "Sustainability of the global sand system in the Anthropocene", *One Earth*, 10.1016/j.oneear.2021.04.011, pp. 639-650. [32]

Tychsen, C. (2023), *La mine artisanale en Afrique Centrale, du Nord et de l'Est francophones*, GEUS. [92]

Tychsen, J., M. Batista and J. Carvalho (2022), *Artisanal and Small-Scale Mining Handbook for Southern Africa Region*, Geological Survey of Denmark and Greenland, Copenhagen, Denmark and Geological Survey of Portugal, Lisbon, Portugal. [25]

U.S. Department of Labor (2020), *Traced to Forced Labor: Solar Supply Chains*, https://www.dol.gov/sites/dolgov/files/ILAB/images/storyboards/solar/Solar.pdf. [89]

UNDP (2019), *Baseline Assessment of Development Minerals in Fiji*. [49]

UNDP (2018), *Baseline Assessment of Development Minerals in Uganda*, UNDP. [29]

UNEP (2024), *Global Resources Outlook 2024: Bend the Trend – Pathways to a Liveable Planet as Resource Use Spikes*, UNEP. [55]

UNEP (2024), *Inside the high-tech effort to save the world's dwindling sand reserves*, https://www.unep.org/news-and-stories/story/inside-high-tech-effort-save-worlds-dwindling-sand-reserves (accessed on January 2025). [34]

UNEP (2024), "Resolution adopted by the United Nations Environment Assembly on 1 March 2024", https://docs.un.org/en/UNEP/EA.6/RES.5. [179]

UNEP (2022), *Sand and sustainability: 10 strategic recommendations to avert a crisis.*. [3]

UNEP (2019), *Sand and sustainability: Finding new solutions for environmental governance of global sand resources*, https://unepgrid.ch/storage/app/media/documents/Sand_and_sustainability_UNEP_2019.pdf. [2]

USGS (2024), *CLAYS*, https://pubs.usgs.gov/periodicals/mcs2024/mcs2024.pdf (accessed on May 2024). [17]

USGS (2024), *Cobalt Statistics and Information*, https://www.usgs.gov/centers/national-minerals-information-center/cobalt-statistics-and-information. [10]

USGS (2024), *FELDSPAR AND NEPHELINE SYENITE*, https://pubs.usgs.gov/periodicals/mcs2024/mcs2024-feldspar.pdf (accessed on May 2024). [19]

USGS (2024), *Mineral Commodity Summaries 2024 QUARTZ (HIGH-PURITY AND INDUSTRIAL CULTURED CRYSTAL)*, https://pubs.usgs.gov/periodicals/mcs2024/mcs2024-quartz.pdf (accessed on May 2024). [18]

USGS (2024), *Mineral Commodity Summaries 2024 SAND AND GRAVEL (CONSTRUCTION)*, U.S. Geological Survey. [36]

USGS (2024), *Mineral Commodity Summaries 2024 TIN*, https://pubs.usgs.gov/periodicals/mcs2024/mcs2024-tin.pdf (accessed on May 2024). [12]

USGS (2023), *Mineral Commodity Summaries 2023 SAND AND GRAVEL (INDUSTRIAL)*, [16] U.S. Geological Survey, https://pubs.usgs.gov/periodicals/mcs2023/mcs2023-sand-industrial.pdf (accessed on May 2024).

USGS (2023), *Mineral Commodity Summaries 2023: GOLD*, https://doi.org/10.3133/mcs2023. [6]

USGS (2022), *Mineral Commodities Summaries 2022: LITHIUM*, https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-lithium.pdf (accessed on May 2024). [11]

USGS (2022), *Mineral Commodity Summaries 2022 TUNGSTEN*, https://pubs.usgs.gov/periodicals/mcs2022/mcs2022-tungsten.pdf (accessed on May 2024). [14]

USGS (2020), *Mineral Commodity Summaries 2020 TANTALUM*, https://pubs.usgs.gov/periodicals/mcs2020/mcs2020-tantalum.pdf (accessed on May 2024). [13]

van Arragon, L. (2021), *Livelihoods Built On Sand: Exposing the Precarity of Labour in Cambodia's Sand Extraction Industry*, University of Ottawa. [112]

Watari, T. et al. (2023), "Growing role of concrete in sand and climate crises", *iScience*, Vol. 26/5, p. 106782, https://doi.org/10.1016/j.isci.2023.106782. [56]

Widzyk-Capehart, E. and A. Hekmat (eds.) (2019), *The Impact of Sand Mining on the Fluvial Environment: Case Study of Nzhelele River in Limpopo Province, South Africa. In E. Widzyk-Capehart, A. Hekmat, & R. Singhal (Eds.),*, Springer International Publishing. [198]

World Economic Forum (2025), *World Economic Forum*, https://www.weforum.org/communities/engineering-and-construction/#:~:text=The%20Engineering%20and%20Construction%20industry%20plays%20a%20vital%20role%20in,about%2013%25%20of%20global%20GDP. (accessed on 25 November 2025). [54]

World Gold Council (2025), *World Gold Council*, https://www.gold.org/goldhub/research/gold-demand-trends/gold-demand-trends-full-year-2024#:~:text=Demand%20in%20value%20terms%20reached%20previously%20unseen%20levels.&text=This%20took%202024%20over%20the,value%20of%20US%24382bn. [5]

World Gold Council (2024), *Historical demand and supply*, https://www.gold.org/goldhub/data/gold-demand-by-country (accessed on May 2024). [7]

World Wildlife Fund (2021), *Sand Mafias: Environmental Harm, Corruption and Economic Impacts*, https://www.worldwildlife.org/pages/tnrc-blog-sand-mafias-environmental-harm-corruption-and-economic-impacts. [109]

WWF (2023), *SUMMARY REPORT: Sand Budget for Viet Nam Mekong Delta*, https://www.sandbudget.net/the-viet-nam-mekong-delta-sand-budget (accessed on 26 January 2026). [42]

Yameng Ma, J. (2025), "Characteristics of high-purity quartz raw materials for crucibles and exploration of key purification technologies", *Minerals Engineering*, Vol. 231, https://doi.org/10.1016/j.mineng.2025.109446. [68]

Zanon, J. et al. (2021), "Impact of sand mining: A case study of initial growth of forest species for recovery of degraded areas", *BOSQUE*, 10.4067/S0717-92002021000100111, pp. 111- [121]

120.

Zawilla, N., F. Taha and Y. Ibrahim (2014), “Liver functions in silica-exposed workers in Egypt: possible role of matrix remodeling and immunological factors”, *International Journal of Occupational and Environmental Health*, https://doi.org/10.1179/2049396714Y.0000000061, pp. 146-156. [156]

Zhang, M. (2023), “Navigational safety at risk: The impact of sand Mining in a key waterway in China.”, *River Research and Applications*, https://doi.org/10.1002/rra.4156, pp. 1485–1496. [129]

Zheng, S. et al. (2022), “Sand mining impact on Poyang Lake: A case study based on high-resolution bathymetry and sub-bottom data.”, *Journal of Oceanology and Limnology*, 10.1007/s00343-021-1137-3, pp. 1404–141. [200]

Zhong, X. et al. (2022), “Increasing material efficiencies of buildings to address the global sand crisis”, *Nature Sustainability*, 10.1038/s41893-022-00857-0, pp. 389–392. [23]

Zhu, Q. (2020), *River Sand as a Disputed Resource: A Case of Illegal Sand Mining Near Zhuang Villages in Southwest China*, Universität zu Köln. [170]

Zorn, H. (2018), *Three Things to Understand About Sand*, https://premierequestrian.com/three-things-to-understand-about-sand/ (accessed on February 2024). [79]

Annex A. Methodology

The final dataset comprised of more than 450 documents provided data for risks and impacts associated with sand and silicate supply chains. Academic literature,[15] policy papers and reported prepared by industry and civil society published by 31 December 2023 were included and provided examples of risks and impacts for over 110 countries. Media articles were excluded from the dataset primarily due to their volume and often sensational nature. The information was organised into individual cases by region and country. Where a document treated multiple place-based case studies, that source was duplicated and coded with the relevant global region and country. This methodological approach resulted into 461 cases. Table A A.1 shows the breakdown of all cases by global region and Table A A.2 indicates the first ten countries associated with the greatest number of cases.

Table A A.1. Breakdown of cases by global region

Global regions	Cases per region
Arctic	3
Asia-Pacific & Oceania, including Japan, Australia, Pacific Islands	11
Central Asia	1
East Asia	44
Eastern Europe	13
Europe	6
Latin America and the Caribbean	24
Middle East and North Africa	21
North America	22
South Asia	55
Southeast Asia	76
Sub-Saharan Africa	158
Western Europe	32

Table A A.2. Top ten countries in the data set

Countries	Number of related texts
India	43
China	35
Indonesia	29
Nigeria	25
USA	20
Vietnam	18
Ghana	15
South Africa	14
Kenya	11
Cameroon	10

Annex B. End-use cases

Table A B.1. Sand and silicate use in the built environment

Use		Description
Construction materials and products for residential and non-residential buildings	Architectural concrete products	Architectural concrete products encompass a wide range of specialized concrete elements designed to enhance the aesthetic appeal and structural integrity of architectural projects, including decorative facades, countertops, and intricate paving elements.
	Bricks	Bricks are a fundamental building material known for their strength and durability. They are typically made from fired clay, a naturally occurring fine-grained soil. The clay is molded into individual units and then baked in a kiln at high temperatures. This process hardens the clay, transforming it into strong and weather-resistant building materials.
	Cement	A material used in construction that binds sets, hardens, and adheres to other materials to bind them together. It is fine powder typically produced by heating a mixture of limestone and clay (or similar materials) at high temperatures in a kiln.
	Concrete	A composite material made by mixing cement, aggregate (sand, gravel, rocks), and water. The cement hydrates (reacts with water) and binds the aggregate together to form a strong, durable material. There are many individual recipes for concrete, depending on different purposes.
	Engineered stone	A manufactured material combining crushed quartz or other stone with resin, offers a durable and stylish alternative to natural stone for countertops and flooring.
	Float glass	Float glass, the ubiquitous transparent material in windows and countless other applications, is a type of sheet glass. Sand, soda ash, and limestone, melted together at high temperatures to form the molten glass base.
	Plaster	Plaster is a versatile building material traditionally used for creating smooth surfaces on walls and ceilings. It is a mix of a binder, such as lime or gypsum, combined with sand and water. Once applied and dry, plaster hardens into a strong and fire-resistant surface.
	Natural stone	Valued for its beauty and durability, natural stone is used in various applications including countertops, flooring, wall cladding, and architectural elements.
	Structural, unbound materials	Materials used to create stable foundations or bases for various structures without the use of binders like cement or asphalt. These materials include aggregates such as gravel, crushed stone, or sand, which are compacted and layered to provide stability and support. Unlike bound materials, which rely on a binder to hold them together, structural, unbound materials rely on compaction and interlocking particles to achieve stability.
Buildings and infrastructure, including transport infrastructure	Disaster risk reduction / resilience investments	Before and during disaster events, sandbags are used to stabilise slopes prone to landslides. Silicate-based geotextiles reinforce riverbanks, preventing erosion during floods. Construction aggregates and other silicates are vital materials for interventions to reduce disaster risks and for building back after disaster events. In addition to the basic role they play in construction (see above), sand and silicates contribute to disaster-resilient construction whether as part of reinforced concrete and steel production, base isolation building techniques or replenishment of storm-affected beaches and dune systems (see below).
	Road network development	Sand and gravel are used to create robust foundations in road building. These are vital fill material, used to level the road surface and fill any gaps or cracks, ensuring a smooth and even roadway. Through compaction, it forms a sturdy base while also facilitating drainage around pipes, preventing water from pooling on the road surface. Tarmac or asphalt road surfacing sees these materials mixed with bitumen or tar to create a durable and smooth surface that can withstand the weight of vehicles and the rigors of everyday use.
	Airport and port infrastructure development and extensions	Reclamation for airport and port development is especially common in the Middle East, Southeast and East Asia, along with West Africa in line with significant infrastructure investments being undertaken in these regions (see Land Reclamation below). Kansai International Airport in Osaka, Japan is constructed on an approximately 11km^2-large artificial island.
	Railway ballast	Igneous and metamorphic rocks are preferred for railway ballast in view of their high strength and abrasion resistance. There is no need to meet specifications for polishing resistance, and so rocks which are unsuitable for road use might justifiably be quarried for railway ballast and be transported relatively long distances.
	Artificial Island construction	Artificial islands are intentionally constructed landmasses in bodies of water, created through methods like land reclamation or valley flooding. They can support entire communities with housing, amenities, and infrastructure, or serve industrial and commercial purposes such as offshore oil platforms, port facilities, or

Use		Description
		support for bridges and other structures. Notable examples include the Netherlands (970 km2) and Japan (Kansai International Airport: approximately 11 km^2), with a growing trend of island additions worldwide (Fisher and Hirschfeld, 2022[180]).
Land reclamation, flood management and coastal zone management	Beach nourishment	Beach nourishment, also known as replenishment, involves replacing lost sediment, typically sand, through human intervention due to longshore drift or erosion. It's a crucial part of coastal management, enhancing resilient shorelines amid rising sea levels. Sand is sourced from suitable offshore sites and transported to shore by pumping or shipping. While often considered environmentally friendly, the process can have significant short- and long-term effects due to the large volumes involved. Questions are arising over the cost-effectiveness and sustainability of this shore protection measure (Eiko et al., 2021[181]; Cusick and E&E News, 2024[182]).
	Coastal land reclamation	Land reclamation transforms submerged coastal areas into usable land for development. It's a longstanding practice in low-lying and space-constrained countries, with The Netherlands and Singapore frequently cited examples. However, large-scale reclamation is a more recent trend. A 2023 study reveals that 106 major coastal cities (population >1 million) have added 253,000 ha of land over the past 25 years, driven by urbanisation, global trade, and a desire for green spaces. Technological advancements also play a crucial role in enabling such large-scale projects (Sengupta et al., 2023[183]).*
	Flood management infrastructure	Floodplains undergo constant transformation, gradually accumulating sediment, such as sand, over time. This process serves as a natural mechanism to alleviate the effects of flooding on a broader geographical scale. Additionally, sandbags serve as a widely employed tool for flood control, functioning as prompt barriers adept at impeding the advance of floodwaters and safeguarding properties against potential harm.
	Natural delta and coastal replenishment	Rivers transport sediment to the coast, shaping deltas, beaches, dunes, and barrier islands along the way. Deltas like the Nile, Amazon, Mekong, and others are not only vital for natural processes but also serve as crucial agricultural hubs, population centers, and provide protection against coastal erosion (Neti, 2021[184]). On the seaward side, waves and tides shift sand along the coast to naturally replenish nearshore seabeds – important for wave attenuation and sea-life habitat, as well as carbon storage– as well as nourishing beaches, vital to coastal defense and tourism.
	Coastal climate resilience investments	Coastal erosion and disaster risk is exacerbated by climate change. Active built defenses go further by reducing wave force and expanding shorelines. Strategies include building artificial islands, reclaiming land, restoring dune systems, nourishing beaches. Built defenses like sea walls are typically made of reinforced concrete, armour stone, steel, or gabions, providing a solid barrier against waves. A shift towards sustainable approaches, including Nature-Based Solutions, which enhance resilience by harnessing natural processes like sediment flow from river systems is underway.

Note: *see MODUS 6 February 2024, 'Out of the deep: 10 massive land reclamation projects'. Available at: https://ww3.rics.org/uk/en/modus/natural-environment/land/out-of-the-deep--7-massive-land-reclamation-projects--.html, last accessed 29 April 2024.

Table A B.2. Sand and silicate uses in energy production and storage

Products	Description
Frac sand, uses in oil & gas production	Silica sand serves as a proppant in hydraulic fracturing, where it is injected with water and chemicals into deep rock formations at high pressure, creating fractures that release trapped oil and natural gas deposits, with the sand maintaining these fractures open for improved oil and gas extraction, allowing oil and gas to flow more freely.
Geothermal energy	Silica sand serves a function in geothermal energy production as a proppant. Injected into wells under high pressure, it fractures rock formations, enhancing permeability and facilitating the flow of water and steam, thus improving geothermal energy extraction efficiency. Additionally, silica sand is utilised in geothermal heat pump systems, where it acts as a thermal energy storage medium.
Hydropower energy	Dams are structures constructed across rivers or streams to hold back or divert water for energy production. According to the International Energy Agency (IEA), hydropower is crucial for accelerating clean energy transitions to meet countries' climate ambitions, producing large quantities of low-carbon electricity while offering flexibility and storage capabilities. (IEA, 2021[185]). Sand and silicates are vital for this infrastructure. While studies show a significant decline in the construction of large dams globally, construction is likely to continue, and maintenance and repair will be required until these structures are removed. Silica-based materials repair cracks, offering durability and chemical resistance. Silicate coatings protect concrete from water, chemicals, and weathering, while silica coatings enhance abrasion resistance for long-term maintenance. Silica sand aids in erosion control around dam spillways and embankments.
Solar energy	Solar panels are predominantly composed of silicon, derived from silica extracted from sand with a high silicon dioxide content heating it with a carbon material to produce metallurgical-grade silicon, which is then refined into high-purity silicon for solar cell manufacturing. The presence of silica sand significantly enhances the durability and longevity of solar panels, protecting the cells from environmental factors and reducing maintenance costs over time. Ultra-white embossed glass is used to protect solar panels, as well as increase the efficacy, insulation and resilience to agency. This glass primarily comprises raw materials

Products	Description
	such as quartz sand, soda ash, limestone, dolomite, sodium nitrate, mirabilite, sodium pyroantimonate, and aluminum hydroxide. Quartz sand serves as the main network-forming component, typically constituting over half of the glass composition.
Thermal Energy Storage	Heated silica sand provides a cost-effective method for storing thermal energy at temperatures as high as 1,200°C. This stored heat can be released from the silica sand and converted into electricity when there is a greater demand than supply, supporting electric power systems. Apart from its essential role in solar technology, silica sand is utilised in solar power plants to absorb and store solar energy as thermal energy during peak production. "Sand batteries" are also being explored as larger scale solution for heat storage. Low-grade sand is heated by cheap electricity from solar or wind and stored at temperatures of around 500°c for months on end.*
Transmission lines, energy grid	Ceramic and glass insulators, crafted from silica sand, are utilised in power transmission lines to bolster and insulate overhead cables, ensuring efficient transmission of electricity across extensive distances. Allied Market Research estimates that the global glass insulators market size was valued at USD345.8 million in 2021, and is projected to reach USD504.6 million by 2031.
Wind energy	Silica sand is widely used in the wind energy industry, particularly in the manufacture of wind turbine components. It is used as a molding material for casting metal parts such as turbine blades, bushings, and other critical components. The use of silica sand in the manufacture of wind turbines ensures high-quality, durable, and accurate parts that can withstand the harsh conditions and extreme forces experienced by wind turbines during operation. In addition to its use in the manufacture of components, silica sand is also used in the construction of wind turbine foundations.

Note: *Polar Night Energy is the Finnish company credited with the first, industrial-scale experimentation of this technology, aiming to provide reliable and affordable heat storage solutions for district heating and industrial applications. https://polarnightenergy.fi/.

Table A B.3. Sand and silicate uses in industrial production and products

Uses	Description
Automotive vehicle components	Sand and silicates contributing to various components and processes throughout the manufacturing process. Sand casting is used to form various metal parts of a vehicle, such as engine blocks and other componentshttps://www.iqsdirectory.com/articles/die-casting/sand-casting.html (see metal production). Silica sand is a key ingredient in the production of safety glass used for windscreens and windows. It is also used in the production of tyres to improve traction and performance, particularly on wet surfaces. Silica-based materials are essential in manufacturing lightweight and high-strength composites used in vehicle bodies and interiors. Silicates are also utilised in paints and coatings, electronics systems and even battery innovation. High-silicon anode material increases the energy density of batteries without compromising safety or other performance parameters.*
Abrasives	Abrasives, widely used in industries like transportation, metal fabrication, and electronics, facilitate processes such as grinding, cutting, and polishing through abrasion with silica sand a key component, particularly in abrasive blasting for smoothing surfaces. Sandblasting is a process used for cleaning, smoothing, or shaping surfaces by propelling abrasive material against them at high speeds using compressed air or steam. While the term "sandblasting" suggests the use of sand, various abrasive materials can be employed depending on factors such as the desired surface finish, the material being worked on, environmental considerations and health concerns. For example, the use of quartz as an abrasive in sandblasting operations has now been forbidden because of the attendant risk of silicosis, and olivine is used as a substitute. The global abrasives market, valued at USD42.6 billion in 2022, is expected to grow to USD67.0 billion by 2032, with a CAGR of 4.7% from 2023 to 2032 (Allied Market Research, 2023[186]).
Food and beverage production and processing	Sand plays a role in nutrient circulation, soil amendment, growing media, and groundwater management relevant for food production. Furthermore, sandy aquifer material provides water storage. They play various roles in food processing, serving as additives, desiccants, and stabilisers. As additives, they are used in powdered form to prevent caking and clumping in food products such as powdered sugar, spices, and seasoning blends. Additionally, silicates are employed as desiccants to absorb moisture and prevent spoilage in packaged foods, extending their shelf life. Moreover, silicates act as stabilisers in certain food products, helping to maintain texture, consistency, and quality over time. Furthermore, the food processing sector relies heavily on glass packaging
Glass production	Glass is primarily composed of sand that undergoes transformation through high-temperature melting and shaping, with additives used to alter its colour, strength, clarity, and other characteristics. Approximately 40 million tonnes of glass are produced annually globally (Glass Alliance Europe, n.d.[76]). The most common type of industrial production, float glass, used for windows, mirrors, and architectural applications, is produced by "floating" molten glass over molten tin, resulting in a continuous, high-quality ribbon. Sheet glass, thinner and lower cost, is used in residential windows and picture frames. Safety glass includes tempered glass, heat-treated for strength and shatter resistance, and laminated glass, maintaining cohesion when shattered. Specialty glass types include borosilicate glass for laboratory use, fiber optic glass for light signal transmission, and high-purity quartz glass for scientific instruments and semiconductor manufacturing.
Metal production	Foundry, or casting sand, is clean high-quality silica used in metal casting processes to create moulds for shaping both ferrous and non-ferrous metals. Treatments like moistening or heating, and adding binders, the sand maintains its shape. In modern foundry operations, sand is frequently recycled and reused across multiple production cycles. Maintaining sand quality is paramount as inferior sand can lead to casting defects. Consequently, foundries and sand producers dedicate significant

Uses	Description
	resources to quality control. Metallurgical silica, specifically processed for metal production, undergoes a purification process to achieve a high level of purity, typically around 98-99%. High-purity quartz is crushed and heated to extreme temperatures, approximately 1 500-2 000°C, in an electric arc furnace, often with a carbon source like coal or coke to reduce the silicon dioxide, eliminating oxygen and converting it to silicon metal. The resulting product, metallurgical-grade silicon aids in deoxidation during steel production, removing unwanted oxygen from molten steel. Additionally, it serves as an alloying agent, enhancing properties such as strength or corrosion resistance. Moreover, MGS can be employed as a raw material for the production of silicon carbide, a valuable abrasive material.
Textiles, footwear production	These materials are essential for making glass fibers woven into fabrics renowned for their strength, temperature resistance, and electrical insulation properties. These glass fiber textiles are utilised across industries like automotive and electronics. Silica sand contributes to textile treatment and finishing. For instance, sandblasting achieves a distressed denim appearance. They also aid in water purification processes within textile manufacturing. Moreover, silicates are integral to producing water-soluble sodium silicates, used as additives in textile printing paints and coatings, and in is used in some rubber shoe soles to enhance their durability and grip.
Water filtration, purification	In filtration systems, layers of sand are used to trap suspended solids, sediment, and contaminants as water passes through. Additionally, sand beds can also foster the growth of beneficial bacteria, aiding in the biological filtration of water. Sand filtration is widely implemented in various sectors, including municipal water treatment plants, swimming pool filtration, industrial water treatment, and groundwater remediation.
Other industrial applications	Sodium silicate, commonly referred to as water glass, is produced extensively for various applications, including detergents, chemical feedstocks, paper manufacturing, civil engineering, and adhesives. Silica aerogels, lightweight and insulating materials derived from silicates, can be used for storm-resistant windows and insulation. Silicate-based sealants enhance the durability of building materials, preventing water infiltration and wind damage.

Note:* Breakthroughs on silicon batteries can be explored at the following links, accessed in May 2024: https://group.mercedes-benz.com/company/news/mercedes-benz-and-sila.html; https://www.reuters.com/business/autos-transportation/new-silicon-anodes-could-help-ev-batteries-go-farther-charge-faster-2023-04-04/.

Table A B.4. Uses of sand and silicates in some major final consumer products and services

Products	Description
Cosmetics, personal care products	In makeup, minerals like mica and talc are commonly used for their shimmering properties, adding sparkle and gloss while also affecting the product's texture. When it comes to toothpaste, hydrated silica acts as a powerful abrasive, effectively removing stains, food particles, and plaque. Its compatibility with other toothpaste ingredients makes it a versatile choice. It is also being explored for skincare for its gentle exfoliating effect. Additionally, glass packaging (see Glass production) is a popular material for storing cosmetics and personal care items.
Electronics	Sand and silicates are indispensable in the production of consumer electronic goods, particularly in the semiconductor industry. Quartz sand (silica sand) is the primary source of silicon used in integrated circuits (ICs) and microchips. Silicon-based compounds derived from sand and silicates, including transparent conducting polymers, flame-resistant polymers, and liquid crystalline polymers, find applications in touchscreens, solar panels, flexible displays, and fire safety measures. Additionally, silicate glasses play vital roles in optical fibers, lenses, and camera sensors, exemplifying the broad impact of sand and silicates in modern electronics. In 2023, global silicon production amounted to an estimated total of nine million metric tonnes (Statistica, 2024[187]). This represents an increase from 2021, which saw the peak of silicon production during the period of consideration. China is the world's largest silicon producer, with a production volume estimated at 6.6 million metric tonnes in 2023 (Statistica, 2024[188]).
Glass consumer products	In addition to soda lime glass commonly used for everyday glass packaging, other glass products have common uses in everyday consumer products including ophthalmic lenses in eyewear, display glass for smartphones and tablets, technical glass in sensors and lighting, and precision-molded glasses for cameras. Glass ceramics, combining the properties of glass and ceramics, find applications in cookware, cooktops, and optical components. Crystal glass is prized in luxury items, jewelry, and decorative pieces. The global glassware market was valued at USD 15.2 billion in 2021. It is projected to reach USD 25.4 billion by 2031, growing at a CAGR of 5.2% from 2022 to 2031 (Allied Market Research, 2022[189]).
Medical, health industry	Medical instruments, and other precision devices rely on specialised glass. Some silicon-containing compounds are used in pharmacological products for wound healing and hair growth. Commercialisation is growing for silica nanoparticles as drug delivery and skin treatment systems, though studies are also underway on toxic side effects (Nafisi, Schäfer-Korting and Maibach, 2017[190]).
Homeware, tableware, sanitary ware	Sand and silicates are key ingredients in producing various homeware items, from kitchen countertops to sanitary ware. Engineered quartz countertops are popular due to their durability, low maintenance, and aesthetic appeal. These countertops are made by combining natural quartz crystals (silica) with resins and pigments. The result is a non-porous, heat-resistant surface that withstands daily wear and tear. Some concrete countertops use silicate-based binders to enhance strength and durability. Silicate-based glass is used for wardrobe doors, cabinet panels, and mirrors. Silicate ceramics are commonly used for flooring and wall cladding in wardrobes and other interior spaces. Porcelain, made from kaolin clay and feldspar, is a type of ceramic known for its delicate, white body and smooth texture. It is made from high-quality clays and fired at high temperatures. Silicate glass is the foundation for drinking glasses, wine goblets, and decorative glassware. Ceramic toilets and sinks are made from

Products	Description
	silicate-based clay fired at high temperatures. Their non-porous surface ensures easy cleaning and makes it resistant to bacteria growth, promoting hygiene. Enamel, or vitreous china, is the silicate-based glassy coating applied to porcelain products, but also bathtubs, for durability and shine.
Tourism & recreation (Golf courses, equestrian facilities)	As just one example of tourism's material dependence on sand, coastal and marine tourism accounts for roughly 50% of global tourism, equivalent to USD 4.6 trillion or 5.2% of the global GDP. This sector is particularly crucial for the economies of small islands and coastal communities. Of that, the global beach tourism market is projected to reach USD 152.3 billion by 2023, highlighting its substantial impact on the tourism industry as a whole (Northrop et al., 2022[78]). Sand is a major component of building and maintaining golf courses, particularly in creating bunkers and essential features for play as well as aesthetic benefits. Silica-rich sand, meeting required specifications for quality, particle size distribution, shape and colour, is applied on greens, tee boxes, and fairways. Additionally, sand is used for top-dressing, promoting turf health by improving surface smoothness, root growth, and soil aeration (Johnson, 2017[191]). Sand is integral to equestrian sport, especially in creating safe and functional riding surfaces. Equestrian arenas predominantly use sand as a footing material, with silica sand being a popular choice for its cushioning, shock absorption, and stability. The particle shape, particularly sub-angular grains, aids in creating a firm riding surface that supports horse movement. Properly graded sand ensures excellent drainage (Zorn, 2018[79]).

Notes

[1] Aluminium, cobalt, copper, gold, graphite, lead, lithium, molybdenum, nickel, palladium, platinum, tantalum, tin, tungsten and zinc.

[2] Silica is a mineral made up of oxygen and silicon, two of the most common elements on the planet (IMA Europe, 2018[160]).

[3] The market value of sand and silicates was estimated by means of an extrapolation of the annual value of sand and gravel production in 2023 in the United States to reflect annual global sand and gravel consumption of 50 billion tonnes. The resulting estimate also reflects other sand and silicate materials for which annual value estimates were available.

[4] One example is manufactured sand which is fine aggregate produced by crushing and shaping rock, then screening, cleaning, and blending the resulting fractions to achieve a consistent, specification-grade sand for construction use (Cement Concrete & Aggregates Australia, 2008[202])

[5] Gankhuang, U. (22 May 2024) Plenary panel intervention, ACP-EU Development Minerals Programme, implemented by UNDP: https://www.developmentminerals.org/index.php/en/ Responsible Sand and Silicates: Implications for Due Diligence. This figure was estimated by participants in the ACP-EU Development Minerals Programme country programmes. ASM participation in supply chains is difficult to validate.

[6] CAHRAs are defined by the presence of armed conflict, violence or other risks of harm to people. This includes high-risk areas prone to political instability, institutional weakness, insecurity, collapse in civil infrastructure and widespread violence, available at: (OECD, 2018[82])

[7] Roca Group and Holcim: experiences related to the emergence of the Ukraine war in 2022.

[8] Multi- instead of monocrystalline silicon ingots used to be commonly used for solar-grade silicon wafer production. However, the share of multicrystalline ingots in the solar industry has gone down from 74% in 2016 to to zero percent in 2024. Using the Czochralski process which relies on these HPQ-derived crucibles, monocrystalline silicon ingots are nowadays the preferred input for both semiconductor and solar-grade silicon wafer production while purity requirements differ ((n.a.), 2025[203])

[9] Reflection from expert interview with a social and environmental impact assessor working with large intergovernmental and public-private infrastructure projects across Asia and Africa, March 2024. Afghanistan: talc industry (Afghan Witness, 2024[192])

[10] Annex II, p24 (OECD, 2016[80])

[11] The organisation of biodiversity risks here follows the Cascade Framework for analysing biodiversity and ecosystem service change impacts (La Notte et al., 2017[193]), which discusses biophysical changes and

ecological process changes that lead to modifications in the benefits of healthy and intact biodiversity enjoyed in economies and societies.

[12] The baseline database contains cases from globally significant river basins like the Amazon River (South America) (da Silva et al., 2020[131]); the Mekong River (South East Asia) (Bravard, Goichot and Gaillot, 2013[196]); The Pearl (Zhujiang) and Yangtze Rivers (China) (Tang, Zhang and Xing, 2011[195]) (Ma et al., 2022[199]); the Red River (Vietnam) (Runeckles et al., 2023[197]) and across major river systems in countries like e.g. India (Pandey et al., 2023[140]), Nigeria (Abdulazeez, 2016[166]); Sri Lanka (Athukorala and Navaratne, 2007[201]), South Africa (Sengani and Zvarivadza, 2019[198]) – though in general the phenomenon of freshwater sand mining is poorly monitored (Dethier et al., 2023[194]):791. Poyang Lake in China is a seminal example of sand mining in lacustrine systems (Zheng et al., 2022[200]).

[13] https://wesr.unepgrid.ch/?project=MX-RZI-PB2-J4Z-3NM-H3E&language=en&theme=water_dark

[14] Control points are points in the supply chain where more market concentration and leverage prevail, there is high visibility over upstream risks yet relatively straightforward for downstream companies to map their supply chains to. These points are ideal for assessments and where relevant audits, and broader efforts to obtain risk information or track results of risk mitigation.

[15] Research abstracts were included in the dataset primarily because access to the full texts was not available. Despite this limitation, the abstracts often contained pertinent mentions of governance, social, and environmental risks related to sand and silicate materials. Including these abstracts was deemed valuable as they signal potential issues in specific countries or regions, thereby providing an indication of relevant concerns that might otherwise be overlooked. This approach ensures that even preliminary or limited information is considered, helping to build a more comprehensive understanding of the global landscape of risks associated with these materials.

Due Diligence for Responsible Sand and Silicate Supply Chains

Sand and silicate supply chains are the second most-extracted resource globally after water. Though sometimes overlooked in initiatives on critical minerals, sand and silicates are important to strategic uses spanning energy, infrastructure and technologies like semiconductors. This report provides an overview of significant risks related to responsible business conduct in this supply chain, and examines adverse impacts related to conflict, human rights, environmental damage and working conditions. It also includes considerations for companies and policymakers to use meaningful due diligence to address these risks and foster a supportive policy environment for enhanced resilience.

Co-funded by
the European Union

PRINT ISBN 978-92-64-67869-9
PDF ISBN 978-92-64-59583-5

9 789264 678699