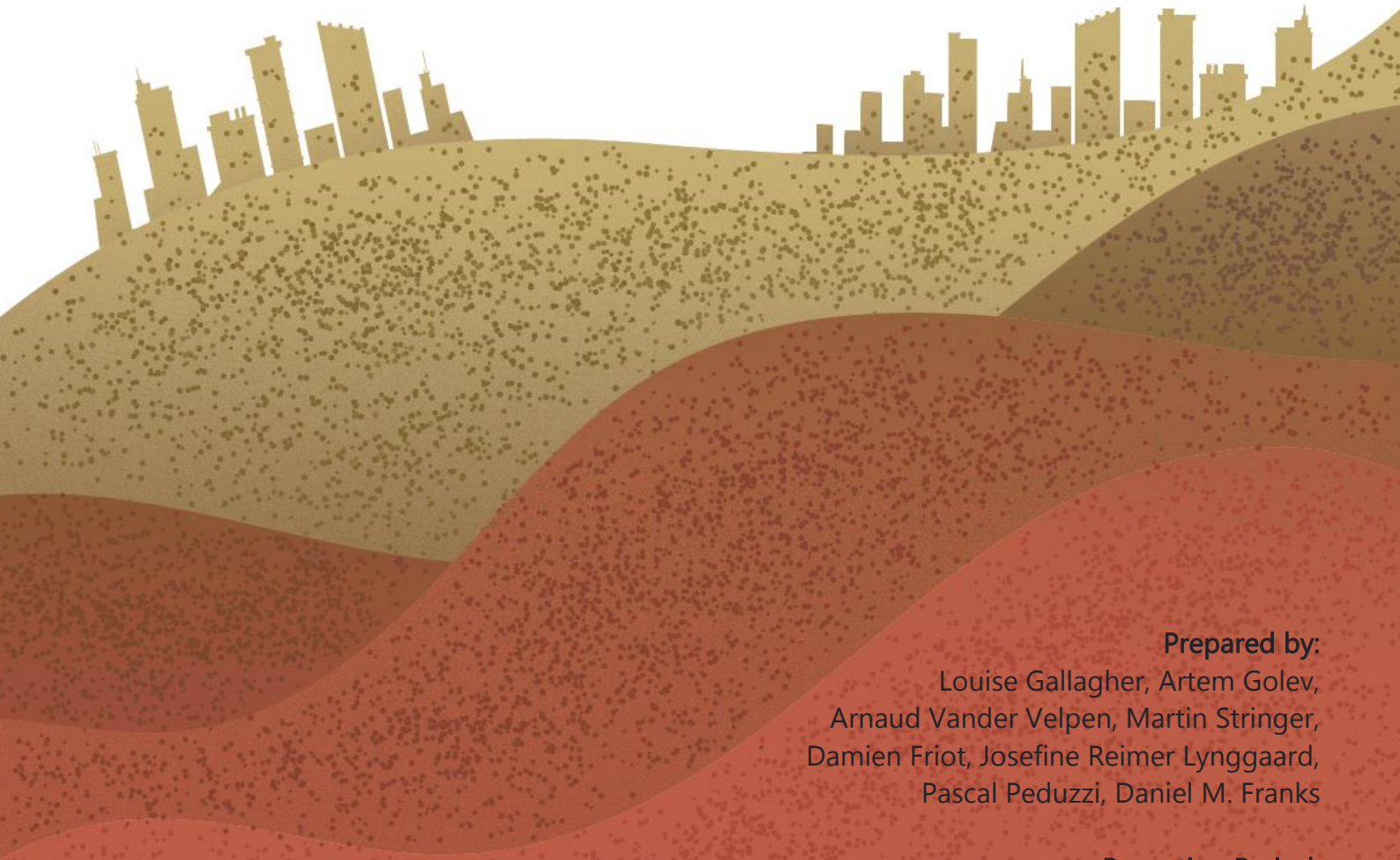
ALTERNATIVE SAND FROM MINERAL ORES:
A potential new solution to the global sand sustainability crisis

INTERIM REPORT (6 MONTHS)



Prepared by:
Louise Gallagher, Artem Golev,
Arnaud Vander Velpen, Martin Stringer,
Damien Friot, Josefine Reimer Lynggaard,
Pascal Peduzzi, Daniel M. Franks

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This report is dedicated to the families who have lost loved ones as a consequence of mine tailings storage facility failures worldwide, and the artisanal sand miners who work in circumstances of poverty and informality to mine the material that constructs our world.

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Authors: Louise Gallagher, Artem Golev, Arnaud Vander Velpen, Martin Stringer, Damien Friot, Josefine Reimer Lynggaard, Pascal Peduzzi, Daniel Franks.

UQ Team: Daniel Franks (Project Leader), Artem Golev (Project Manager), Martin Stringer, Diana Arbelaez-Ruiz; Sustainable Minerals Institute, The University of Queensland, Australia.

UNIGE Team: Pascal Peduzzi, Louise Gallagher, Arnaud Vander Velpen, Damien Friot, Josefine Reimer Lynggaard, Stephanie Chuah; The University of Geneva, Switzerland.

UFMG Team: Douglas Mazzinghy, Luanna Moura; Federal University of Minas Gerais, Brazil.

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Executive summary

After water, aggregates (sand, gravel, and crushed rock) are the second most exploited natural resource in the world. Their use has tripled over the last two decades to reach an estimated 50 billion metric tons per year, and the demand is growing exponentially around the world with urbanisation, development, population growth and sea-level rise. Yet, their extraction from rivers and the nearshore environment is already a global environmental and resource problem. Despite increased recognition of sand (and aggregates broadly) as a strategic resource for sustainable development, the issue remains largely unaddressed and unresolved in many places around the world. With infrastructure and construction a major feature of post-COVID recovery plans and aggregates the largest input demanded by this sector, the sustainability of aggregate production requires urgent global attention.

In 2019, the United Nations Environment Programme released the report 'Sand and Sustainability: Finding New Solutions for Environmental Governance of Global Sand Resources.' In the same year, United Nations Members States adopted the United Nations Environment Assembly (UNEA-4) Resolution of Mineral Resource Governance, which explicitly called for solutions to the challenges of global sand sustainability.

Awareness of sand sustainability is generating clear calls for alternatives at scale. Among secondary sources, one stands out globally – mineral ores. Currently large volumes of sand- and aggregate-like materials are produced by crushing mineral ores for the extraction of metals (and other commodities), which are then discarded as part of mine waste rock and tailings. Currently, it is estimated that 30 to 60 billion tonnes of mine waste are generated per year, making it the largest waste stream on the planet, an order of magnitude higher than all urban waste.

Attempts to give mining residues a second life have been made in the past, and suitability for certain applications has been proven. However, serious uptake has been impeded because: 1) these residues must be technically and economically competitive with conventional materials and 2) they were residues, rather than by-products or co-products[1] that required their own optimisation to achieve specific properties during mineral processing. In this report we introduce the term ore-sand (o-sand) to signify this distinction and to differentiate sand produced as a by-product or co-product of the processing of mineral ores.

[1] The traditional distinction between terms co-product and by-product is strictly a function of mineral economics related to the revenue and/or profit from a given mining operation. A situation when a collective extraction of several minerals is required for a feasible operation represents the case of co-products. In contrast, by-products are rather incidental products that may or may not be recovered. With an increased recognition of environmental impacts and expected transition towards zero waste management, including affecting the permitting for mining in the first place, potential by-products from mine residues are in some cases becoming co-products. This highlights their equal importance in the design of mining operations and for the assessment of company's sustainability performance. In this report, we use both terms interchangeably, although by-product is the preferred term for known case-studies, while co-product refers to the (full) potential of alternative sand from mineral ores.

After a series of catastrophic failures of mine tailings storage facilities in recent years that left severe environmental, social, economic, and human costs, The United Nations Environment Programme, International Council on Mining and Metals and the Principles for Responsible Investment introduced a new Global Industry Standard on Tailings Management. This and other recent reforms of mining, environmental and waste policy mean that large volumes of mine waste, in particular tailings, now need to be managed differently in many places in the world. The rising value of sand, the costs of storing mining residues, and the possibility of optimising mineral processing circuits for both the primary commodities and sand co-products may give new impetus to a circular economy synergy with the potential for a strong contribution to sustainable development.

This 12-month (pilot) project aims to investigate whether co-products of mineral ores, with favourable mineralogical and physicochemical characteristics, can be a viable and sustainable source of substitute aggregate material for construction and other industries, and reduce the rising demand for sand extracted from the natural environment. Focusing on promising real-life examples, our research explores whether co-products of iron ore can provide a suitable, responsible and just alternative source of sand, and a solution to be considered as part of the UNEA-4 Resolution on Mineral Resource Governance.

In this report we share the findings of our analysis of a preliminary sample of sand by-product that was supplied by Vale, from one of its largest iron ore processing sites in the state of Minas Gerais, Brazil. In our final report we will present analysis of additional independent samples recently collected by the research team. Since the devastating tailings facility failures that occurred at two iron ore mines owned or co-owned by Vale, the Córrego do Feijão and Germano mines, both in Minas Gerais, Brazil, Vale has accelerated its investment in the adoption of circular economy approaches to mine waste. In 2013, Vale initiated the Quartz Project to investigate whether sand by-products could drastically reduce the amount of tailings requiring storage at its mine sites, and a number of products are already undergoing market trials. These innovations are significant shift for the mining industry and an innovation response that has the potential to address two global sustainability issues simultaneously: the safe management of mine tailings and the large and growing demand for sand.

The recovery and supply of alternative aggregate materials, previously discarded as mine waste, can be viewed as a disruptive innovation that can challenge the existing norms and attitudes in the market. In this report, we also explore the sand market and different uses of sand; overview our approach to mapping and matching mine tailings generation with sand consumption in different parts of the world; and present current results from interviewing major stakeholders in the aggregate market across several countries and regions. The results from interviews outline the broad landscape within which the relative advantages, compatibility, complexity, trialability and observability of alternative sands from mineral ores would have to be demonstrated and communicated. While relative economic and technical advantages seem to be the most critical factors for the mainstream markets, it is also vital to find a niche and pass regional and national regulatory gateways, work closely with customers and "allies" who would support demonstration of the material in use, and have a sound sustainability agenda including a holistic assessment of the environmental and social impacts and risks.

This is an Interim Report for the project (6 months), which will be superseded by the Final Report (12 months). While the audience for this report is limited to our interim stakeholders – Vale SA, Vale International SA, and members of the Independent Scientific Committee – we have structured the report and written up preliminary findings with our final audiences in mind. The Final Report is intended to be published and disseminated widely to:

- Constituencies of the 5th United Nations Environment Assembly, scheduled for February 2022;
- Audiences and participants of the international conferences, webinars and other online events, where the findings from this project will be presented; and,
- The broader community related to current practices on sand and sustainability, and mine tailings management, in the research, private and civil society sectors.

Terms and definitions[2]

Aggregates is a term for granular material of natural, processed or recycled origin used essentially for construction purposes with an upper grain size limit of 75 mm. Segmenting into three aggregates subcategories is useful:

- **Primary aggregates** include rock, sand and gravels sourced from the natural environment. Crushed rock is extracted in hard rock quarries by blasting and crushing; and sand and gravels are extracted from pits by excavation, crushing, screening and washing (if required), dredged or pumped from lakes (lacustrine sand) and rivers (river sand), removed from coastal beaches, or dredged from the seabed (marine sand or marine aggregates).
- **Secondary or recycled aggregates** include crushed rock, sand and gravels produced by sorting, crushing and screening of construction and demolition waste materials.
- **Industrially-processed aggregates** – crushed rock and other sand and gravels substitutes produced through mechanical crushing of rock or an industrial process involving thermal or other modification.

Sand is a mineral granular material which does not stick together when wet and remoulded and where the combined weight of 50% of the particles is smaller than 4.75 mm. These materials are sourced from pits on land, hard rock which is mined and processed, from lakes, river beds and banks, wetlands, coastal beaches and nearshore waters. Additional qualifiers are needed for a precise and correct description of sand as a form of aggregates, for example a limit on the percentage of fines (material smaller than 75 µm) is often specified for concreting applications.

Gravel is a mineral granular material which does not stick together when wet and remoulded and where the combined weight of 50% of the particles is larger than 4.75 mm but smaller than 75 mm. These materials are sourced from pits on land, hard rock which is mined and processed, from lakes, river beds and banks, wetlands, coastal beaches and nearshore waters.

Manufactured sand (m-sand) is an artificially produced sand from a suitable source rock. The major production processes include crushing, screening and classifying to achieve the required properties for the use in concrete, asphalt, and other specific products.

Ore sand (o-sand) is a type of processed sand sourced as a co-product or by-product of mineral ores. Typically, it is a result of mechanical crushing and grinding, different physical and physico-chemical beneficiation processes for mineral concentrates recovery, including optimization of these processes and additional processing stages to achieve the required properties of sand.

[2] There are no universally accepted definitions for the terms sand, gravel and aggregates. The definitions in technical standards and guidelines may vary from industry to industry and from region to region with regards to the grain-size fraction boundaries, (mineral) composition and mechanical properties. The definitions in this report are based on the ISO 14688-1:2018, ASTM D2487:00, and 2020 UNEP/GRID-Geneva expert discussion 'What is sand?'. The term ore-sand is introduced in this report and defined by the present authors.