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Moving beyond the Evident: A Case Study of Manganese Mining from Keonjhar District, India

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Abstract

The mining and metallurgical sector is essential for the development and economic growth of a developing country like India. It is evident that social responsibility has moved up the agendas of mining companies, with increased pressure on industries to be more responsive to meeting the needs of local people. It has become a common practice to scrutinize the mining projects for assessing the social and environmental risks, prior to decisions being made regarding project finance, and even for setting up pilot projects. Dubna manganese mines of Keonjhar district of Odisha is one of the important manganese ore-producing regions of India, which forms a part of [Precambrian](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/precambrian) sedimentary formation known as the [Iron Ore](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/iron-ore) Series developed in Singhbhum–Keonjhar–Bonai area. The present study is an attempt to evaluate the impact of mining on environment with special reference to impact of manganese on the health of mine workers. The study indicates that the existing legislations have not provided justice to communities suffering from health problems due to mining, there are no laws that specifically protect the rights of women’s health in mining, either as communities or as workers.

Chapter 30 - Mining in Indigenous Regions: The Case of Tampakan, Philippines

Author links open overlay panelDaniel Hostettler

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Abstract

The neoliberal globalization of trade and investment allows capital and products to flow with almost no restrictions between countries and markets. At the same time, global demand for natural resources soared. The high turnover in the raw material sector makes it profitable to invest in remote and inaccessible regions. Often, the people affected by business intervention in these areas are indigenous communities. The international human rights framework recognizes a series of specific rights for indigenous people. Indigenous people are entitled to set their own priorities for the development of their communities. If measures coming from outside affect their specific values and way of life, indigenous peoples must be consulted in order to obtain their free, prior, and informed consent. Thus, the appropriate way of trying to reconcile the often diverging interests of business and indigenous peoples would be to engage in such a consultation process, allowing indigenous peoples to know the risks and opportunities of a project from the very beginning. Recent case studies on conflicts concerning raw material projects in indigenous territories show that due consultation processes with indigenous peoples did not take place or were not in compliance with international human rights standards. A Human Rights Impact Assessment carried out in 2013 suggests that this may also be the case for the Tampakan Copper–Gold Project of Swiss-based Glencore Xstrata, in Mindanao, Philippines (INEF, 2013). The initial consultation processes with the local indigenous people may not have met international standards. Today the context of the mining project is so violent that the conditions for a correctly carried out consultation process are not given, according to the above-mentioned assessment. It follows that without an adequate de-escalation strategy and an implementation of due consultation processes with the local indigenous people, the violence threatens to grow.

Chapter 32 - Ethics and Mining—Moving beyond the Evident: A Case Study of Manganese Mining from Keonjhar District, India

Author links open overlay panelMadhumita Das

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Abstract

The mining and metallurgical sector is essential for the development and economic growth of a developing country like India. It is evident that social responsibility has moved up the agendas of mining companies, with increased pressure on industries to be more responsive to meeting the needs of local people. It has become a common practice to scrutinize the mining projects for assessing the social and environmental risks, prior to decisions being made regarding project finance, and even for setting up pilot projects. Dubna manganese mines of Keonjhar district of Odisha is one of the important manganese ore-producing regions of India, which forms a part of [Precambrian](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/precambrian) sedimentary formation known as the [Iron Ore](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/iron-ore) Series developed in Singhbhum–Keonjhar–Bonai area. The present study is an attempt to evaluate the impact of mining on environment with special reference to impact of manganese on the health of mine workers. The study indicates that the existing legislations have not provided justice to communities suffering from health problems due to mining, there are no laws that specifically protect the rights of women’s health in mining, either as communities or as workers.

**China, the Democratic Republic of the Congo, and artisanal cobalt mining from 2000 through 2020**

June 20, 2023

From 2000 through 2020, demand for cobalt to manufacture batteries grew 26-fold. Eighty-two percent of this growth occurred in China and China’s cobalt refinery production increased 78-fold. Diminished industrial cobalt mine production in the early-to-mid 2000s led many Chinese companies to purchase ores from artisanal cobalt miners in the Democratic Republic of the Congo (DRC), many of whom have been found to be children. Despite extensive research on artisanal cobalt mining, fundamental questions about its production remain unanswered. This gap is addressed here by estimating artisanal cobalt production, processing, and trade. The results show that, while total DRC cobalt mine production grew from 11,000 metric tons (t) in 2000 to 98,000 t in 2020, artisanal production only grew from 1,000 to 2,000 t in 2000 to 9,000 to 11,000 t in 2020 (with a peak of 17,000 to 21,000 t in 2018). Artisanal production’s share of world and DRC cobalt mine production peaked around 2008 at 18 to 23% and 40 to 53%, respectively, before trending down to 6 to 8% and 9 to 11% in 2020, respectively. Artisanal production was chiefly exported to China or processed within the DRC by Chinese firms. An average of 72 to 79% of artisanal production was processed at facilities within the DRC from 2016 through 2020. As such, these facilities may be potential monitoring points for artisanal production and its downstream consumers. This finding may help to support responsible sourcing initiatives and better address abuses related to artisanal cobalt mining by focusing local efforts at the artisanal processing facilities through which most artisanal cobalt production flows.

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Mining Product

Mining products are vital and indispensable to our modern society and contribute significantly to our wealth, being a major economic activity.

From: [Encyclopedia of Environmental Health (Second Edition), 2019](https://www.sciencedirect.com/science/article/pii/B9780124095489110565)

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[Uranium](https://www.sciencedirect.com/science/article/pii/B0122274105008024)

William L. Chenoweth, Thomas C. Pool, in [Encyclopedia of Physical Science and Technology (Third Edition)](https://www.sciencedirect.com/referencework/9780122274107/encyclopedia-of-physical-science-and-technology), 2003

IV.D Nuclear Fuel

Most nuclear fuel is produced from uranium by a series of processes including: conversion, enrichment, and fabrication. Yellowcake from the conventional mills, solution mining, and by- product operations is shipped to conversion facilities where is converted to [uranium hexafluoride](https://www.sciencedirect.com/topics/chemistry/uranium-hexafluoride) (UF6).

[Uranium hexafluoride](https://www.sciencedirect.com/topics/chemistry/uranium-hexafluoride) is a solid at [room temperature](https://www.sciencedirect.com/topics/chemistry/ambient-reaction-temperature) but forms a gas when heated. In gaseous form, the concentration of the fissionable isotope 235U, can be increased from the natural level of 0.711% to nuclear fuel levels of 3.0–5.0% by either a diffusion or centrifuge process. In the United States by process of diffusion, gaseous UF6 is passed through a series—or cascade—of porous [membrane filters](https://www.sciencedirect.com/topics/engineering/membrane-filter). Because UF6 molecules containing the U-235 isotope diffuse through the filters more readily than those containing the U-238 isotope, the [diffusion process](https://www.sciencedirect.com/topics/engineering/diffusion-process) eventually results in two product streams of UF6. Compared to the original feed material, one product stream is relatively enriched in the isotope U-235, and the other is relatively depleted in U-235.

Enrichment of the 235U isotope is necessary because the amount of fissile U-235 in [natural uranium](https://www.sciencedirect.com/topics/engineering/natural-uranium) is too low to sustain a nuclear chain reaction in light-water reactors. By contrast the 235U content of nuclear weapons is typically in excess of 90%.

At the fuel fabrication plant, the enriched UF6 is converted to uranium dixoide (UO2). The uranium dioxide is compressed into solid, cylinder-shaped pellets, which are placed in hollow [rods](https://www.sciencedirect.com/topics/materials-science/rod) made of a [zirconium](https://www.sciencedirect.com/topics/engineering/zirconium) [stainless steel alloy](https://www.sciencedirect.com/topics/engineering/stainless-steel-alloy). These rods, which are grouped into fuel rod assemblies, are shipped to [nuclear power plants](https://www.sciencedirect.com/topics/engineering/nuclear-power-plant) for use as nuclear reactor fuel. One pound of natural uranium can produce as much energy as about 14,000 lb of coal.

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[Mining in Indigenous Regions](https://www.sciencedirect.com/science/article/pii/B9780127999357000307)

Daniel Hostettler, in [Geoethics](https://www.sciencedirect.com/book/9780127999357/geoethics), 2014

Increasing Demand for Natural Resources

Global economic development in the last two decades has created a huge demand for natural resources. In emerging economies such as China, India, and Brazil, the need for raw materials increased sharply. According to the WTO, worldwide imports of fuels and mining products rose from around USD 500 billion (1990) to more than USD 4 trillion (2012)1, which represents an increase by a factor of 8. At the same time, neoliberal globalization, with its deregulating trends, led to the gradual removal of national legal barriers, such as import duties, opening up markets to unprotected competition. Today, the flow of both capital and goods between countries and markets is largely unrestricted. The consistently strong demand and unimpeded access have, in recent years, encouraged a price trend that made raw material extraction profitable even in the most remote and inaccessible terrains. The consequences are investment in ever more fragile environments and socially sensitive regions. Many of these regions, which are mostly in developing countries, are inhabited by indigenous communities.

For many countries in the Global South, natural resource extraction is a key element in the State’s economic policy. The sale of natural resources and the accompanying investment of foreign capital lead to what is often considerable economic growth. However, paradoxically, a large proportion of the population continues to live in poverty in many of these countries. There is no correlation between increasing raw material exports and the fight against poverty. On the contrary, there seems to be a link between an abundance of natural resources and [underdevelopment](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/underdevelopment) given that, according to Revenue Watch, two-thirds of the world’s poorest people live in resource-rich countries (Revenue Watch Institute, 2010)—and indigenous peoples worldwide are among the poorest of the poor (World Bank, 2010)2 (e.g., Zúñiga et al., 2015).

Many countries in the Global South lack the means and the capacity, but also often the will, to effectively regulate and monitor the activities of transnational mining corporations. Weak State structures and deficiency of the rule of law, inadequate enforcement bodies, corruption (e.g., Bilham, 2014, 2015), as well as frequently a deep-seated cultural racism toward indigenous peoples are reasons why the interests of those directly affected are scarcely taken into account, despite relevant national legislation.

According to a survey carried out by the Special Rapporteur on the rights of indigenous peoples, James Anaya, the majority of consulted indigenous communities do not see any positive impact of mining operations within their territories whereas these operations are among the most significant sources of abuse of the rights of indigenous peoples worldwide (Anaya, 2011). There is indeed growing awareness among the public and politicians of the need for special protection of the rights of indigenous peoples, which has been enshrined in international agreements. However, numerous examples in recent years show that, in practice, these are being implemented rather tentatively (e.g., Indigenous Peoples Links, 2013).

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Carla Candeias, ... João P. Teixeira, in [Encyclopedia of Environmental Health (Second Edition)](https://www.sciencedirect.com/referencework/9780444639523/encyclopedia-of-environmental-health), 2019

Introduction

Natural resources are randomly distributed on the earth, being very important for the survival and development of humankind. Mining is one of the oldest and most important activities in the history of human civilization as it provides the raw ingredients to most of the materials available. Mining products are vital and indispensable to our modern society and contribute significantly to our wealth, being a major economic activity. The demand for ore comes from the beginning of the human existence and this activity plays a key role for human survival and development. The American mining industry, which predates the Revolutionary War, has played an essential role in the economic well-being and in the national security of the United States. Without mining, the development of the western United States as we currently know it would not have been possible. Europe has an unquestionable importance in the world economy and mineral extraction plays an important role in the supply and also in the consumption of all groups of explored minerals. Rich and complex [geologies](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/geology), with considerable mineral potential, normally contribute significantly to the gross domestic product (GDP) of their countries. The use of minerals by countries worldwide is extensive and includes electricity generation, production of cement, steel, agricultural lime, commercial and residential building materials, asphalt, and medicines, as well as countless household, electronic, and other manufactured products. Nevertheless the mining industry routinely modifies the surrounding landscape by exposing previously undisturbed earthen materials, whether in small or large scale. Ore exploitation, extraction and processing activities generate substantial amounts of solid and [liquid wastes](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/liquid-waste) that can have deleterious impacts both in the occupational and in environmental contexts. The environmental impact of past mine development was high, once the industrial mining activities were developed without the environmental concerns that currently prevail and severe negative environmental impacts still remain, inherited from ages and [cultures](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/culture) with different values as many early mine operators disregarded the damaging environmental consequences of their activities and for which remedial action is now imperative.

Mining operations are diverse and include abandoned radioactive tailings, mercury and other toxic heavy metals entering the [food chain](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/food-chain), [leakages](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/leakage) and failures of [tailings dams](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/tailings-dam), invasion and depletion of aquifers, acid [mine drainage](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/mine-drainage) affecting wide areas and abandoned mines requiring remediation. The extent of environmental damage caused by these mining operations was only understood after the shut down the mine, being the reason why serious environmental problems of the past are still currently affecting the health of the populations.

In a complex framework of interventions associated with the recovery operations of the degraded mining areas [environmental rehabilitation](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/environmental-rehabilitation) of abandoned mines is needed. Nevertheless the effects of environmental rehabilitation of abandoned mines are felt only in the medium and long term, thus requiring the adoption of concepts and perspectives different from those established and regulated for the present and future activities related to mine closures.

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[Resource Industries](https://www.sciencedirect.com/science/article/pii/B9780080449104002248)

R. Hayter, in [International Encyclopedia of Human Geography](https://www.sciencedirect.com/referencework/9780080449104/international-encyclopedia-of-human-geography), 2009

International Trade

Large-scale resource production of all kinds is organized to meet domestic needs within highly localized production chains. With the expansion of civilization and urbanization, however, resources always have been significant components of interregional and international trade; motives for [imperialism](https://www.sciencedirect.com/topics/social-sciences/imperialism), [colonialism](https://www.sciencedirect.com/topics/social-sciences/colonialism), and geopolitics; as well as for economic development. Resources remain a big component of international trade. Thus according to the [World Trade Organization](https://www.sciencedirect.com/topics/social-sciences/world-trade-organization) (WTO), total trade in ‘visible’ goods (all raw materials and manufactured goods) amounted to almost $6 trillion in 2001 (while ‘nonvisible’ (service) trade was worth $1.5 trillion). Agricultural and mining products, the WTO’s definition of the resource sector, accounted for 22.3% of the value of visible trade, and the contributions of primary manufacturing such as forest products and iron and steel would further increase this share. Oil dominates resource exports; in 2002 its export values were four and six times higher than natural gas and aluminum, the second and third export categories.

Generally speaking, rich countries are the world’s major resource consumers and importers, although recently Asian industrialization has led to significant shifts in global trade in many resources notably toward China and increasingly India. Within these rapidly changing trade dynamics, poor countries are the most export dependent on resources. However, the extent to which poor countries can exploit the resource strengths is limited because rich countries produce and consume vast amounts of resources domestically and are often major resource exporters themselves. The US, for example, in 2002 was among the top three global exporters of wheat, rice, fruit and nuts, cotton, oil seeds, wood, fish and coal, and an important supplier in many others. In contrast, in poverty stricken Angola and Gambia, just three commodities provide almost 100% and 79% of national exports, and domestic markets are small. The resource exports of poor countries are extremely dependent on rich markets that enjoy much discretion regarding sources of supply. The market power of rich countries is further reflected in organizational arrangements (Table 1).

Table 1. Share of three leading commodities in total exports of selected countries and country groups (in %)

| **Country or group** | **1965** | **1980** | **1995** | **2000** |
| --- | --- | --- | --- | --- |
| *Developing countries* | 11.9 | 61.2 | 17.7 | 21.8 |
| Brazil | 56.7 | 27.6 | 14.1 | 12.5 |
| China | 5.7 | 28.8 | 6.8 | 5.2 |
| India | 23.9 | 14.5 | 10.4 | 6.0 |
|  |  |  |  |  |
| *Least developed countries* | 29.1 | 42.0 | 34.1 | 45.7 |
| Angola (fuels, diamonds, fishery commodities\*) | 56.4 | 87.1 | 94.3 | 99.8 |
| Burundi (coffee, tea and mate, hides and skins\*) | 97.5 | 94.3 | 87.8 | 73.6 |
| Gambia (sugar, fishery commodities, groundnuts\*) | 75.2 | 89.2 | 70.0 | 79.1 |
| Mauritania (iron ore and concentrates, live animals, fishery commodities\*) | 95.2 | 89.9 | 58.5 | 59.3 |
| Somalia (live animals, ananas, fishery commodities\*) | 65.1 | 89.9 | 63.8 | 56.8 |
| *Developed countries* | 4.9 | 9.5 | 4.7 | 6.0 |

Source: UNCTAD (2005). *UNCTAD Handbook of statistics 2005*. New York: United Nations Publications.

\*

Three leading commodities in 2000.

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[The use of zeolites as an addition to fertilisers – A review](https://www.sciencedirect.com/science/article/pii/S0341816222001114)

Renata Jarosz, ... Monika Mierzwa-Hersztek, in [CATENA](https://www.sciencedirect.com/journal/catena), 2022

10 Ability of zeolites to trace elements

The presence of [heavy metals](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/heavy-metal) in soils can have natural and [anthropogenic sources](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/anthropogenic-source). Anthropogenic sources include: municipal and household wastes, industry, agricultural and military activities, mining, and [petroleum products](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/petroleum-hydrocarbon). Heavy metals occur naturally in soils, where they are a source of micronutrients essential for plants. However, when the content of heavy metals in soil is too high, they show toxic effects on plants (Belviso, 2020; Solanki et al., 2010; Wang et al., 2001; Zhang et al., 2014).

The ion-exchange properties of zeolites mean that they can selectively adsorb certain harmful or unwanted elements from soil, water and air. In addition, zeolites show a strong affinity for some heavy metals such as lead, chromium, nickel, and zinc (Pleśniak and Trzop, 2016).

Synthetic zeolites have very good [sorption](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/sorption) capacity for Cu (II) ions from water and wastewater. The affinity of Cu(II) ions for synthetic zeolites was much higher than for natural [clinoptilolite](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/clinoptilolite). The maximum sorption capacity of the synthetic zeolites was 256 mg g−1 Na-P1 and 141 mg g−1 Na-X. This was 10.6 and 6 times, respectively, higher than the sorption capacity of clinoptilolite (24 mg g−1) (Kyzioł-Komosińska et al., 2015).

Luo et al. (2018) showed that the adsorption capacity of hydrothermally modified zeolite towards Cu (II) and Pb (II) from aqueous solutions increased almost 20-fold to 431.0 mg g−1 for Cu (II) and 337.8 mg g−1 for Pb (II). The authors reported that zeolites synthesised from natural metakaolin have a high potential for use in the removal of heavy metals and organic pollutants.

Based on an experiment using a Na-P1-type zeolite, Adamczyk et al. (2011) found that synthetic Na-P1-type zeolites have the ability to absorb heavy metals from aqueous solutions. The percentage reduction of Zn, Pb and Mn concentrations in the solution amended with Na-P1 zeolite was very high and usually above 97%, while the reduction of Ni concentrations ranged from 71 to 95%.

The soil application of zeolites immobilises heavy metals in contaminated soils due to the high sorption capacity of these materials and their affinity for cations and anions. The literature is rich in results indicating the high ability of zeolites to sorb cadmium and lead (Chao and Chen, 2012; Panuccio et al., 2009).

Abbaspour and Golchin (2011) conducted an incubation experiment (6 months) on soil with elevated [heavy metal](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/heavy-metal) content, taken from the vicinity of a zinc and lead mine in Iran. Based on the results, the authors concluded that the application of natural zeolite had little effect on the transformation and mobility of heavy metals, such as lead, cadmium, zinc, and copper, in the soil.

Due to their specific structure, zeolites are capable of retaining zinc and releasing it slowly into the soil solution. With this property, zeolites can be used as a slow-release [zinc fertiliser](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/zinc-fertilizers), able to improve the efficiency of zinc utilisation by crops (Yuvaraj and Subramanian, 2018). Jakkula and Wani (2018) and Kalita et al. (2020) indicated that zeolite characteristics, such as ion exchange capacity and porosity, are very important for agronomy and soil science, as they benefit plant growth. These authors also emphasised the usefulness of zeolites for removing heavy metal cations (Pb, Hg, Cd, Co, Zn, Cu, Ag, Mg, Fe, Al, Cr, etc.) from wastewater, using zeolites property of ion exchange [selectivity](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/selectivity).

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[Valuing recreational services: A review of methods with application to New South Wales National Parks](https://www.sciencedirect.com/science/article/pii/S2212041621000735)

Marie-Chantale Pelletier, ... Mladen Kovač, in [Ecosystem Services](https://www.sciencedirect.com/journal/ecosystem-services), 2021

3.3.5 Resource Rent Method

Resource rent is described in the SEEA Central Framework as a means of measuring returns from extractive uses of [environmental assets](https://www.sciencedirect.com/topics/social-sciences/environmental-assets). It is used to derive an estimated value for the contribution of the environment to the market value of fishing, mining or agricultural products. In SEEA-EEA it is proposed as a suitable method for valuing provisioning as well as recreation cultural services (United Nations, 2014b). The method has been used previously in the Netherlands and for the Great [Barrier Reef](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/barrier-reef) region (Australian Bureau of Statistics, 2017; Remme et al., 2015).

The resource rent can be calculated using the ‘residual value method’ by “deducting user costs of produced assets from gross operating surplus after adjusting for any specific subsidies and taxes” (UN 2014a, 5.122). We used the broad definition of $7.0 billion in travel expenditure described in Section 3.3.1. We calculate a resource rent for the [economic sectors](https://www.sciencedirect.com/topics/social-sciences/economic-sector) that support visitor access to national parks. These include accommodation, food, transport, retail, sports and recreation services, etc.

Resource Rent = Output (sales from sectors supplying park visitors)

*less* Tourism sectors operating costs (intermediate consumption, compensation of employees, net taxes)

*equals* Gross Operating Surplus

*less* User costs of produced assets (consumption of fixed capital plus return on produced assets)

*less* National Parks operating costs (6)

Resource Rent = $7,027M – $5,759M – $93M – $351M= $824M per annum

We consider the depreciation costs of national park ecosystem and infrastructure to be internalised in the management costs, as the expenses incurred include the maintenance and replacement of [capital assets](https://www.sciencedirect.com/topics/social-sciences/capital-assets). Operating costs for tourism sectors were calculated from tourism consumption figures published by Tourism Research Australia in State Tourism [Satellite Account](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/satellite-account) 2017-18 and Australia’s [National Accounts](https://www.sciencedirect.com/topics/economics-econometrics-and-finance/national-accounts) 2017-18 (Australian Bureau of Statistics, 2019; Tourism Research Australia, 2019). Consumption of fixed capital (5.39%) for NSW tourism sectors was calculated from the National Accounts: State Accounts, 2017-18 (Australian Bureau of Statistics, 2019). The return on produced assets was calculated using the Reserve Bank of Australia’s large business lending rate in June 2018 (3.86%).

The resource rent method clearly accounts for all three contributions (ecosystem, infrastructure and travel services), but it attempts to apportion value from transactions relating to services that received free environmental inputs in their production (Horlings et al., 2019b). It assumes an extension of the physical boundary of the economy by including the ecosystem contribution to the recreation service, without extending the income boundary, resulting in relatively contrived (residual) values. An additional limitation of this method is that changes in value of the ecosystem service are closely linked to changes in gross operating surplus (GOS) rather than change in ecosystem extent or condition, GOS in turn being a function of economic considerations such as input and [labour costs](https://www.sciencedirect.com/topics/social-sciences/labor-costs), or supply and demand conditions. This problem could even lead to negative values in years where investment may be high and visitation levels low.

[View article](https://www.sciencedirect.com/science/article/pii/S2212041621000735)

[Review on bromine in solid fuels. Part 1: Natural occurrence](https://www.sciencedirect.com/science/article/pii/S0016236111007824)

Pasi Vainikka, Mikko Hupa, in [Fuel](https://www.sciencedirect.com/journal/fuel), 2012

4.3 Shales

Coals, coaly shales and partings were analysed for Br by Eskenazy and Vassilev [86]. This data can be used in two different dimensions: firstly, in assessing the affinity of Br to organic matter (coal) in one deposit, and secondly, in evaluating the Br content in different mining ‘products’ from several mines as a function of ash content. Fig. 5 shows the bromine content in coal, coal shales and partings as a function of ash content. From the chart on the left it can be seen that in one deposit there seems to be a negative correlation between the ash and Br content of the ‘coal’. This supports the findings on the organic affinity of bromine in coals.

On the right in Fig. 5 the correlations between different mining products collected from seven different mines in Bulgaria are shown. This plot divides the ‘products’ into three classifications, where the coals with mean 20 wt% ash content have the highest bromine content. The next class is the shales, and the third partings. In one deposit (D1 or D2) the bromine content is always higher in the coal than in the shales or partings from the same deposit.

In addition to the coal in Fig. 5 (left) the bromine content in the coal samples calculated on ash free basis is plotted. The finding is that the bromine content is in the proximity of 30–35 mg kg−1 in the macerals, whereas from the chart on the right it is evident that the bulk of shales contain some 8 mg kg−1 Br. In Canadian oil sands a similar pattern can be observed where the raw bitumen separated from the sand is enriched in Br in comparison to the oil sand [103].

[View article](https://www.sciencedirect.com/science/article/pii/S0016236111007824)

[Naturally occurring asbestos—A recurring public policy challenge](https://www.sciencedirect.com/science/article/pii/S0304389407016846)

R.J. Lee, ... D.R. Van Orden, in [Journal of Hazardous Materials](https://www.sciencedirect.com/journal/journal-of-hazardous-materials), 2008

Ilgren reviewed studies involving a variety of mining communities, including taconite, talc, gold, dolomite limestone, [vermiculite](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/vermiculite), and copper mines, where workers and nearby residents may have been exposed to trace levels of [amphibole](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/amphibole) cleavage fragments that were present as impurities within the main mining product of interest [24]. These studies included taconite mining towns in Minnesota where the taconite (a low grade iron ore) typically had elevated levels of grunerite cleavage fragments and various talc mines in New York, Vermont, Italy, and Norway where the talc contained substantial levels of [tremolite](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/tremolite) cleavage fragments. The taconite and various talc mining studies concluded that the permeation of the residential areas near the mines by non-fibrous amphibole cleavage fragments did not result in a pandemic of asbestos-related disease among workers or residents. These studies also demonstrated that not all occurrences of amphibole minerals are necessarily a public health hazard.

[View article](https://www.sciencedirect.com/science/article/pii/S0304389407016846)

[Multiproduct biorefinery from Arthrospira spp. towards zero waste: Current status and future trends](https://www.sciencedirect.com/science/article/pii/S0960852419311587)

Madhusree Mitra, Sandhya Mishra, in [Bioresource Technology](https://www.sciencedirect.com/journal/bioresource-technology), 2019

4.2 Maximize utilization of multiple products to maintain bioeconomy

Over the years, research studies have emphasized physicochemical stressors-based amelioration of the desired product in [microalgae](https://www.sciencedirect.com/topics/biochemistry-genetics-and-molecular-biology/microalga), including [*Arthrospira*](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/arthrospira). Much like any other [biorefinery](https://www.sciencedirect.com/topics/engineering/biorefineries), the whole range of products from *Arthrospira* spp. are divided into high-, mid-, and low-value products. Amelioration of these products in *Arthrospira* promotes maximum recovery of them from the cell biomass. Based on the market value and market share of an individual product, it is advisable to extract the main product first. For *Arthrospira*, high-value products like C-PC, GLA, and β-carotene hold a significant share in the [nutraceutical](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/nutraceutical), pharmaceutical, and cosmeceutical market; and since C-PC is the primary product, mining of C-PC followed by the valorization of the other high-, mid-, and low-value products deemed suitable for a zero-waste biorefinery. Howbeit, extracting C-PC first, could lead to a substantial decrease in the yield of other value-added products. Because, with reference to the algal [stress physiology](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/physiological-effect), amelioration of one desired product as a consequence of metabolic impairment brought forth a reduction in the [biosynthesis](https://www.sciencedirect.com/topics/biochemistry-genetics-and-molecular-biology/anabolism) of other co-products. Hence, it is evident that the accumulation of all the products at the same growth phase and or same cultivation condition is not conceivable. Therefore, to maximize the chance of multiple product co-recovery, the growth parameter optimization for multiple products strategy should be followed. During C-PC extraction, the filtrate can be utilized as biofertilizer/biostimulant owing to its rich profile of plant growth, promoting hormones and [nutrients](https://www.sciencedirect.com/topics/food-science/nutrient). Also, to improve the downstream process economics, chlorophyll can be extracted from the biomass residue left after the extraction of C-PC as proposed by Tavanandi and Raghavarao, 2019.

Moreover, to valorize *Arthrospira* for its [carotenoid](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/carotenoid) and GLA content, the [stationary phase](https://www.sciencedirect.com/topics/engineering/stationary-phase) [culture](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/culture) could lead to the co-recovery of β-carotene, GLA, and [polysaccharides](https://www.sciencedirect.com/topics/engineering/polysaccharides) (2–10 € Kg−1, [food](https://www.sciencedirect.com/topics/food-science/food-product) and feed market) (Minhas et al., 2016). Apart from these high-value products, *Arthrospira* is also being exploited for its potential as a biofuel [feedstock](https://www.sciencedirect.com/topics/engineering/feedstock). Howbeit, since bio-fuel is a relatively low-cost product (0.2–0.5 € kg−1) (Ketzer et al., 2018), higher profits can be made by co-utilization of mid- and low-value products (Ansari et al., 2017). Aside from these known products of *Arthrospira*, it can be utilized for the production of biopeptides (Montalvo et al., 2019), [polyhydroxyalkanoate](https://www.sciencedirect.com/topics/engineering/polyhydroxyalkanoate) (PHA) (Shrivastav et al., 2010), [biocrude](https://www.sciencedirect.com/topics/engineering/bio-oil) oil via [hydrothermal liquefaction](https://www.sciencedirect.com/topics/engineering/hydrothermal-liquefaction) (Zhang et al., 2018), biostimulants (Plaza et al., 2018), and [animal feed](https://www.sciencedirect.com/topics/agricultural-and-biological-sciences/animal-feed) (Holman and Malau-Aduli, 2013). Advantage, disadvantage, and cost analysis of different upstream strategies for sustainable biorefinery is shown in Table 2.

Table 2. Advantage, disadvantage, and cost analysis of different upstream strategies for sustainable biorefinery.

| Empty Cell | **Culture system** | | **Culture strategy** | |
| --- | --- | --- | --- | --- |
| Empty Cell | **Open raceway pond** | **Closed photobioreactor** | **Amelioration of desired high-value product** | **Co-accumulation of multiple products** |
| Advantages | Low-cost installation, ample amount of heat and sunlight for growth | Reduced chances of contamination, controlled growth conditions | Simplified recovery of the desired product | Recovery of multiple value-added products |
| Disadvantages | Contamination; drastic changes in the environmental conditions | Complex installation system, critical instrument handling, high maintenance, higher energy consumption | Low profit and higher waste generation | Complex extraction and fractionation process |
| Costs | Low-cost | High-cost | High-cost | Cost-effective |
| Future strategies |  | Installation of new photobioreactor system *viz.* thin cascade raceway, flat-panel PBR, building PBR |  |  |

[View article](https://www.sciencedirect.com/science/article/pii/S0960852419311587)

[Recycling mine tailings in chemically bonded ceramics – A review](https://www.sciencedirect.com/science/article/pii/S0959652617325854)

Paivo Kinnunen, ... Mirja Illikainen, in [Journal of Cleaner Production](https://www.sciencedirect.com/journal/journal-of-cleaner-production), 2018

5.3 Applicability of phosphate bonding to commonly available minerals in mine tailings

As is the case with alkali-activation, low reactivity of most silicate-based minerals is a challenge for utilizing them for phosphate bonding, though some exceptions (e.g. Wollastonite) exist. In general, mine tailings are less utilized for the phosphate bonding ceramics than for [alkali activation](https://www.sciencedirect.com/topics/engineering/alkali-activation). In fact, very little research exists on producing phosphate ceramics of any mining products, be it primary or secondary. Most silicates, while very useful in alkali activation processes, are a challenging group of materials for phosphate formation due to their extremely low solubility in [phosphoric acid](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/phosphoric-acid) (Wagh, 2004). [Quartz sand](https://www.sciencedirect.com/topics/engineering/quartz-sand) (SiO2) is commonly used either as inactive aggregate to lower the overall cost of phosphate bonded cements. The poor reactivity of quartz sand with magnesium phosphate was reported to have a negative effect on [compressive strength](https://www.sciencedirect.com/topics/engineering/compressive-strength) and ageing properties of a [phosphate cement](https://www.sciencedirect.com/topics/engineering/phosphate-cement) (Li et al., 2016). Examples of moderately reactive silicates include [Wollastonite](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/wollastonite) (CaSiO3) and [tricalcium silicate](https://www.sciencedirect.com/topics/engineering/tricalcium-silicate) (Ca3SiO5), the former being a potential raw material for structural applications (Colorado et al., 2011; Colorado et al., 2015) and the latter having added biofunctionality when mixed with magnesium phosphate to produce apatite-like structures (Liu et al., 2015).

Most frequently used raw materials encountered in publications regarding phosphate synthesis are either derivatives of commercially available mixtures of phosphate binders, or alternatively, soluble [acid phosphate](https://www.sciencedirect.com/topics/engineering/acid-phosphate) salts that are meticulously synthesized from high-grade hydroxides or carbonates through reacting them with hydrogen- or [ammonium phosphate](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/ammonium-phosphate) salts. Most novel structures with specific [stoichiometry](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/stoichiometry) are synthesized as coatings or particles in low quantities. On the other hand, in the field of [waste management](https://www.sciencedirect.com/topics/earth-and-planetary-sciences/waste-management) and structural composites, processing is conducted in very robust way and very little emphasis is put on purity of raw materials.

Even though the most widely used phosphate ceramic precursors are few, apatites and monopotassium phosphate (MKP) being the most common, a myriad of different mineral structures can be produced by phosphate forming reaction. This is due to the fact that phosphate formation can have several intermediary products before consolidating into a non-soluble ceramic. The final form of reaction products depends heavily on reaction kinetics and the chemical composition of solid raw materials. Table 4 presents a non-exhaustive collection of phosphate-based minerals found in different applications. Literature examples of precursors and formation processes for the certain applications are also included.