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CRITICAL RESOURCES:

A Driving Force for Technological Advancement but a Growing Security Concern

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Introduction

In today's modern world, technology has been advancing at a rapid pace with research and development efforts increasing day by day to create a better and more comfortable living experience for the human race. Today's civilization uses more elements than at any previous time in history, both in terms of quantity and number. There is a plethora of elements in everything from home lights to personal computers, a hospital's medical equipment, and even the planes that let us travel the world. Compared to the materials that were used a century ago, there are a lot more materials accessible now. Even the elements found in our devices are crucial for enabling our modern lifestyle and the technologies we rely on every day. The utilization of a wide range of elements has become increasingly common in modern technologies. It is worth noting that this was not always the case.

Elements such as uranium, gallium, germanium, rhenium, rare-earth elements, and many others were not even discovered before 1932. However, these elements have now become integral to numerous industrial applications, and all naturally occurring elements have multiple uses in various industries.[1] Minerals and raw materials, that stand as the pillars of these developmental efforts, are found in alloys, magnets, batteries, catalysts, phosphors, and polishing compounds, which are subsequently used in a variety of products such as aeroplanes, communication systems, electric vehicles, lasers, naval vessels, and various consumer gadgets and lights. Several of these minerals, however, are in low supply, and extraction techniques have serious environmental and economic ramifications. Given their importance in a wide range of technological applications and a lack of substitutes thereof, there is worry over whether supply will be sufficient to fulfil the economy's ever-increasing demands in the future. Hence, owing to specific dimensions and factors,

[1] Supanchaiyamat, N., & Hunt, A. J. (2019, January 2). Conservation of Critical Elements of the Periodic Table. *ChemSusChem, 12*(2), 397-403.

these materials can be classified as critical. Material criticality can be measured in terms of supply risk, sensitivity to supply constraints, and environmental consequences.[2]

What are Critical Materials?

Critical materials, also known as critical minerals, are a class of naturally occurring elements and raw materials that are necessary for a wide range of technological uses but are in short supply. These materials have distinct qualities that make them indispensable in areas such as electronics, renewable energy, defence, and healthcare.[3] These substances are majorly used in the application of technology and related purposes, and they lack a proper or easy substitute, as a result of which, they are extremely valuable. Due to high economic demands for these materials, the extent of their mining from the earth's crust has been steadily heightening to a point at which the earth might find it difficult to replenish these materials in the amount of time that they are being consumed.

The dependence of the world economy upon specific raw materials and resources has become so increasingly influential and strategically important, that some of these materials have been termed to be critical when they are classified to be economically significant, yet in danger of running out. Despite their scarcity, these elements are not always regarded as vital since other variables are also taken into account including the availability of suitable alternatives, if the materials exhibit unique qualities upon usage, and the risk connected with the supply of the materials, for instance, owing to political turmoil in the producing nations.

The growing demand for larger quantities of limited raw materials, combined with concerns about their availability, has raised apprehensions regarding the future security of critical-element supply. Numerous elements utilized in various industries are considered "critical" due to their importance

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[2] Center for Sustainable Systems. (2022). *Critical Materials Factsheet*. Retrieved from University of Michigan: https://css.umich.edu/publications/factsheets/material-resources/critical-materials-factsheet

[3] Ministry of Mines. (2023). *Critical Minerals for India: Report of the Committee on Identification of Critical Minerals.* Indian Ministry of Mines.

for industry, national/regional economies, or national defence. The exact definition of a "critical element" may differ based on assessment goals and the evaluating organization's requirements. However, critical elements often involve supply risks and hold strategic significance. Consequently, if the supply of these elements were to be constrained, it would have a substantial impact on an economy or business.[4]

The materials that are presently considered critical include antimony, baryte, bauxite, beryllium, bismuth, borate, cobalt, coking coal, fluorspar, gallium, germanium, hafnium.[5] These also include rare earth elements (REE), which is a group of important minerals that although abundant within the earth's crust, their distribution is diffused and as a result, they are difficult to extract in large quantities. Additionally, more critical minerals include indium, lithium which is increasingly growing in significance due to its widespread use in batteries for laptops and mobiles, magnesium, natural graphite, natural rubber, niobium, phosphate rock, and phosphorus.[6] Furthermore, platinum group metals (PGM) which function as integral components of fuel cells and have other potential uses for advanced vehicle uses are also classified as critical along with scandium, silicon metal, strontium, tantalum, titanium, tungsten and vanadium.[7]

Why are Countries Hunting for Critical Materials?

The foremost reason that drives the international hunt for critical raw materials is that they are required for a wide range of technological breakthroughs and innovations. The demand for these

[4] Supanchaiyamat, N., & Hunt, A. J. (2019, January 2). Conservation of Critical Elements of the Periodic Table. *ChemSusChem, 12*(2), 397-403.

[5] Geological Survey of Sweden. (2021). *Critical raw materials*. Retrieved from Geological Survey of Sweden: https://www.sgu.se/en/mineral-resources/critical-raw-materials

[6] Ibid.

[7] Ibid.

materials has expanded dramatically as sectors such as electronics, renewable energy, electric cars, and telecommunications continue to grow. They are essential components of manufacturing processes and products, allowing for the advancement of new technology. And since numerous vital elements have limited geological occurrence and are concentrated in specific regions, countries try to maximise the amounts of resources that they can attain. The fact that critical materials production is concentrated in a small number of countries has generated concerns regarding geopolitical dependencies and the possibility of trade limitations. Countries have recognized the strategic significance of ensuring their access to these materials to protect their economic development, national security, and technological autonomy.

The sporadic distribution of the materials raises the risk of supply disruptions, particularly when manufacturing heavily depends on a few countries. In order to tackle that vulnerability, there has been a pursuit of alternative sources and the diversification of supply chains to ensure continuous and reliable availability. Moreover, supply chain resilience has become a top focus for governments and enterprises. The search for critical resources tries to limit reliance on a single supplier or location, therefore lowering the risks associated with supply interruptions and geopolitical uncertainty. Diversifying supply sources and encouraging indigenous manufacturing are crucial methods for improving supply chain resilience.

Most importantly, critical raw materials play a pivotal role in the transition to clean and sustainable energy and the decarbonisation of the environment. However, a clean energy-powered energy system is fundamentally distinct from one that relies on traditional hydrocarbon resources. The construction of solar photovoltaic plants, wind farms, and electric vehicles typically necessitates a greater quantity of minerals compared to their fossil fuel-based counterparts. To provide a comparison, the mineral inputs for manufacturing a typical electric car are six times higher than those required for a conventional car. Similarly, the construction of an onshore wind plant requires nine times more mineral resources than a gas-fired plant.[8]

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

Different clean energy technologies rely on various mineral resources. Lithium, cobalt, and nickel are crucial for enhancing the performance, longevity, and energy density of batteries. Rare earth elements are utilized in the production of powerful magnets, essential for wind turbines and electric vehicles. Copper and aluminium are extensively required for electricity networks. Hydrogen electrolysers and fuel cells rely on nickel or platinum group metals, depending on the specific technology. Copper is an essential element in nearly all electricity-related technologies.[9] These characteristics of a clean energy system imply a substantial increase in mineral demand as more batteries, solar panels, wind turbines, and networks are deployed. Consequently, the energy sector is poised to become a significant driver of mineral demand growth, underscoring the interconnections between minerals and clean energy technologies.

Security Implications

Minerals such as cobalt and lithium find their strategic value in their unique properties that increase efficiency. Lithium-ion batteries store a significant amount of energy in a short and compact size. Utilizing this key facet, lithium batteries allow for longer operation times for portable electronics and drones. Furthermore, lithium batteries recharge quickly, allowing them to be an integral part of rapid deployment procedures. Due to their inherent light weight, they are also employed in a variety of portable military devices such as unmanned aerial vehicles (UAVs). Lithium can also be employed as a high-energy additive to rocket propellants, giving it the potential to revolutionize the modern military. It can further be employed as a convertor to tritium which is widely known for its usage as a raw material for thermonuclear fusion reactions.[10] Cobalt commands strategic importance due to its unique ability to withstand corrosion and retain its hardness within alloys at

[9] Ibid.

[10] Sharma, R. (2023, February 21). *Lithium Reserves in India: Strategic Significance and Concerns – Explained, pointwise*. Retrieved from ForumIAS: https://forumias.com/blog/lithium-reserves-in-india-strategic-significance-and-concerns-explained-pointwise/#gsc.tab=0

high temperatures. As a result, cobalt is thoroughly employed as a super alloy for industrial and aircraft engines.[11]

The pure usability and functionality of these minerals create an immense demand for their procurement, often leading nations to resort to stockpiling and securing their own technological edge over other nations. Technologically advanced nations such as China, Japan, and the USA, which heavily rely on these minerals for their technological development, have chances of being embroiled in rising competition for mining these deep-sea reserves. As demand for these critical minerals outpaces their supply, competition between major powers for access and control could potentially heighten. This may lead countries to turn towards unethical tactics such as utilizing their own economic clout to pressurise resource-rich nations to grant them favourable access to the minerals. Unhealthy competition between developed nations can also lead to proxy conflicts within the resource-rich nations and eventually lead to military interventions to secure access to critical resources. The importance of critical minerals can also be outlined in the global process of transitioning to low carbon emissions and developing renewable energy technologies that are essential for countries all across the world in meeting their specific "Net Zero" commitments.[12]

Conclusion

Critical materials have an invaluable role in driving technological advancement. These materials are essential in the transition to a sustainable and low-carbon future, from rare earth elements that power wind turbines and electric vehicles to lithium-ion batteries that enable energy storage. However, their scarcity, concentration in certain places, and complicated supply networks have required a global search for alternate sources and supply chain diversification. The desire to control

[11] Indian Bureau of Minerals. (2020). *National Mineral Inventory - An Overview.* Indian Bureau of Minerals.

[12] Ministry of Mines. (2023). *Critical Minerals for India: Report of the Committee on Identification of Critical Minerals.* Indian Ministry of Mines

access, limit supply risks, and decrease geopolitical reliance drives the search for these key commodities and provides incentives for countries to reduce geopolitical dependencies.

The worldwide search for critical resources emphasises the interaction of economic, geopolitical, and environmental variables. It underscores the importance of developing long-term policies to maintain a robust and steady supply of these resources. Furthermore, the demand for critical materials continues to increase as the energy industry advances and renewable energy solutions become more widely available. Their importance in renewable energy generation, energy storage, electric mobility, and energy-efficient technologies continues to grow. The growing connections between minerals and clean energy technologies underline the need of ensuring a steady supply of vital materials to support ongoing innovation, economic progress, and environmental sustainability. The worldwide shift to renewable energy is quickening, propelled by the need to tackle climate change and reduce reliance on fossil fuels. This change, however, is strongly reliant on the availability and accessibility of critical resources.