Rare metals getting rarer

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The supply of some natural resources is unlikely to keep pace with the increasing demands of a growing population. New technologies must be based on abundant materials if we are to achieve sustainable development.

The human population has grown exponentially over the past century and is expected to increase to nine or ten billion by the year 2050. This growth has been accompanied by an increasing rate of consumption of natural resources. Fossil fuels are arguably the most essential commodity that may become scarce during the coming decades[1], but rare minerals and metals — used, for example, in mobile phones — are also not in unlimited supply[2]. New technologies, such as transistors, pin-head capacitors, compound semiconductors, flat-screen liquid-crystal displays (LCDs) and thin-film solar cells therefore need to be developed according to the long-term availability of their key material ingredients.

LIMITS TO ACCESSIBILITY

Around 50 different metals are necessary to produce cars, computer chips, flat-screen TVs, DVD players, mobile-phone screens and cameras. For computer chips, this number has increased from around 10 different metals in 1980 to more than 40 today. The concentrated ore deposits of these metals that can be easily tapped through mining are finite, even if, overall, the metals are in sufficient supply in the Earth's crust. But are we running out of metals that lie at the heart of our technological society? At a recent international conference[3], experts from numerous geological surveys and mining companies claimed that many resources are yet to be mined, arguing that the key is to mine more deeply (up to 2 km) for lower-grade ores and to exploit the ocean floor (up to 7 km below sea level). But deeper mining and refining of lower-grade ores will require more energy[4,5] — another precious resource. Combining current knowledge of the reserves of some key metals, the locations of the ores, the technology they are used for and the degree of recycling (Table 1), it becomes apparent that many metals that we rely on are likely to become so scarce that they could be considered to 'run out' in the next 10–40 years.

MATERIAL CYCLES

Comprehensive life-cycle flow assessments are only available for very few substances. This is true in part because many of the mining companies closely guard their data, making world reserve figures uncertain[6]. However, some material-flow studies detailing a series of life stages are available. Mining and processing, fabrication, utilization and end-of-life data are documented for copper, zinc and lead[7–13], with less-detailed information available for platinum[14], tin, silver and nickel[12] and indium and gallium[2].

Table 1 Abundance data and main uses of metals discussed in the text.

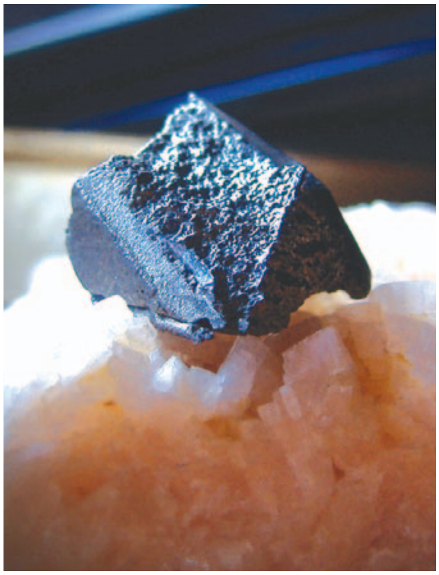
Metals	Reserve base[6] (metric tonnes)	Country of major reserves (>10% of world reserve base)	Main uses	Predicted availability (years)*		% of world use recycled
				Current rate	50% of US consumption	
Platinum/rhodium	80,000†	South Africa	Jewelry, catalysis, car fuel cells	360	40	0
Copper	940,000,000	Chile	Wire, coins, plumbing	60	40	30
Zinc	480,000,000	China, USA, Australia	Galvanizing, batteries, brass	45	35	25
Indium	16,000	Canada, China, USA	LCDs, new generation solar cells	15	5	0
Gallium	NA	China, Germany, Japan	LCDs, solar cells, lasers	NA	NA	0
Tin	11,000,000	China, Brazil, Malaysia	Cans, solder	40	15	25
Antimony	4,300,000	China	Drugs	30	15	NA
Tantalum	180,000‡	Australia, Brazil	Mobile phones, camera lenses, DVD players, computers	115	20	20
Lead	170,000,000	China, Australia, USA	Pipes, batteries	40	10	70
Aluminium	8,500,000,000§	Guinea, Australia	Transport, electrical, consumer durables	270	135	50

*Adapted from ref. 2. †Platinum and rhodium. ‡African reserves not available. §From bauxite reserves. NA, data not available.

Copper is currently in use as, for example, a heat conductor, an electrical conductor, a building material and a constituent of various metal alloys. But if the rate of its consumption continues to increase as it does today (without recycling), and if production is assumed to equal consumption, then copper will last no longer than another 60 years[2]. Moreover, if everyone on Earth consumed half the amount of copper that an average United States citizen does today, then available copper would run out even earlier (about 40 years). Zinc, which is an important ingredient of batteries, brass, architectural building material, and materials for corrosion protection, has even shorter respective timescales of 45 and 35 years (ref. 2). When these metals run out, we will lack galvanized metal (zinc) for everyday use as well as a good electrical conductor (copper) for the transfer of energy.

Platinum group elements are being used most notably in catalytic converters that make the burning of fossil fuels more efficient, also to catalyse a plethora of reactions in the chemical, petrochemical and pharmaceutical industries, and are at the core of future ceramic fuel cells. Platinum resources have been estimated to be of the order of 80 thousand tonnes (Table 1), of which about 29 thousand tonnes are effectively available after taking into account the efficiencies of the different mining, milling and smelting processes[14]. With petroleum becoming more scarce and expensive, fuel cells using platinum group elements as catalysts are seen as future sources of alternative energy. But the reserves of these elements will not fuel the world's cars long into this century — perhaps for only 15 years[2,12] if new technologies are adopted.

Tin, antimony, tantalum and lead are expected to become unavailable before the middle of this century. Tantalum is one of the metals that are currently used as pin-head capacitors in mobile phones and other electronic equipment. The rise in price of tantalum has not been as high as could have been expected based on the recent increase in its use; however, mining for this metal has exacted a heavy toll in terms of human lives. The People's Republic of Congo is among the suppliers of this metal, and mining there is carried out in dangerous conditions. Fighting over the right to mine deposits containing tin, antimony, tantalum and cobalt (the latter two referred to as coltan) is implicated in millions of deaths in that country[15].



GROVER SCHRAYER III

Figure 1 Yttrium on the rocks. Yttrium is one of the rare metals used in mobile phones.

RECYCLE AND REPLACE

In view of these findings, it is essential that we use copper and zinc, platinum group elements and tantalum as well as all other scarce resources in a sustainable manner. More efficient metal use through better product design and higher durability will also help. But there are limits to recycling; zinc, for example, is used in low concentrations for galvanizing, and is difficult to recycle once it is dissipated across metallic surfaces. Where possible, therefore, scarce resources need to be replaced by more common and easily accessible ones such as aluminium or silicon. A few such technologies are already being investigated. Pin-head capacitors in mobile phones that are currently made out of yttrium (Fig. 1), tantalum or hafnium could instead use aluminium[16]. Germanium and indium transistors can be made from silicon or silicon carbide[17] or carbon nanotubes[18]. And for car fuel cells, hydrogen could be produced in a cell made out of aluminium metal that is filled with water[19].

New-generation solar cells that are twice as efficient as silicon polyvinyl chlorides are made from the rare metals indium and gallium, along with arsenic. Table 1 shows that both indium and gallium are in short supply and are predicted to become practically unavailable in 5–15 years. It would therefore seem that research efforts should focus on making silicon cells more efficient, instead of chasing technological advances with metals that will be unavailable in the future.

It is not just price rises of metals on the world market that give an indication of scarcity: the Denver Post[20] reported in March 2008 that in mining companies, geologists are now receiving higher average starting salaries than those with MBA degrees. During the past century, industrial production around the world has increased 40-fold. Virgin stocks of several metals seem inadequate to provide the modern 'developed world' quality of life for all people on Earth under contemporary technology[12]. Of course, there will always be lower-grade metal to exploit, and we can also mine at deeper levels, leading some Earth scientists to reject this more pessimistic view[3]. But the price may well prove prohibitive in practice owing to the cost of energy.

It is therefore imperative that we start on a path towards sustainable development worldwide. Whether new technologies use components that will still be available in a few decades should be a key criterion for their development, not an afterthought.

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