Depleting Resources, Ethics and Innovation


Susan L.S. Stipp

In this issue, we see how important phosphorus is in our lives. It is an essential ingredient of our bones and teeth, it is a limiting element for plant growth and it is the culprit in fouling our environment through eutrophication of lakes, but it can be our environmental saviour when used to immobilise heavy metals and radioactive species. Considering the importance of ATP (adenosine triphosphate) as the energy "currency" for metabolism in all life, I find Figure 7A in the article by Filippelli (page 94) particularly thought-provoking. Phosphorus pollution of the ocean is projected to stop only when we run out of phosphorus as fertiliser. Can the world's population justify over-fertilising, which both fouls the sea and depletes global resources? Certainly it does not make sense to dump an element that is critical for life, at the bottom of the world's oceans.

From time to time, we all see projections in the press about when this or that element will run out. Predictions vary dramatically, depending on the assumptions made to estimate "known reserves". A commodity is only a reserve if its selling price is higher than the cost to bring it to market. So reserves vary as supply and demand fluctuate. Although projections in the press vary, there is some consistency in forecasts for some of the rarer elements. For example, at current consumption rate, the global platinum supply could last about 80 years, but demand for catalytic converters and hydrogen fuel cells is expected to increase as Asia develops and non-fossil energy alternatives are adopted, shrinking stockpiles faster. Manufacture of LCD screens and mobile telephones is projected to exhaust supplies of tantalum in 25 years and indium in 10 years. A recent calculation puts the end of known phosphorus reserves before the end of this century. That is within the lifetime of some of the children now being born. Without fertiliser, the current world population is unsustainable. Of course, new estimates of doom are presented from time to time and spotlighted in the press, but so far, industry has found new resources, improved the technology for mining them or developed substitutes. The world has not come to an end, but there is reason for concern.

The thought of running out of resources raises three issues. The first is how to increase reserves. If we agree that a secure supply of metals and non-metals is critical for civilisation and that geologists and those in related disciplines are responsible for finding and producing them, our universities should be educating more mineralogy, petrology and geochemistry (MPG) students, not fewer. Innovative technology will allow us to exploit lower grade ores, to explore deeper, and to search on and under the sea floor and under continental ice sheets. The second issue is broader. How should priorities be set for resource use? How should that be monitored and who should do it? The third issue is the need for innovation in recycling that could lead us to complete sustainability. If 100% recyclability were achieved, we would not only ensure the supply of essential elements, we would simultaneously solve our pollution problems, because in principle, we call it pollution when the elements we want are in a place where we don't want them. This is also an issue where we in MPG ought to be able to help.

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The ethical issue of how we, as citizens in our global society, use our resources is unfortunately mostly an economic one. Driven by supply and demand, the cost of a scarce commodity promotes development of a replacement. Sometimes, ethical decisions affect our use of resources. The drop in popularity of diamonds a couple of years ago is one example where consumer conscience was the sole driving factor for altering buying patterns. Can squandering phosphate fertiliser to produce biofuel be justified when developing nations have too little food? Ethics probably should drive research on phosphate dosing methods to discourage the practice of over-fertilising, which results in run-off and eutrophication. Ethics should probably also discourage use of phosphates for immobilising heavy metals in sewage treatment. In some cases, health issues change resource-use patterns. World consumption of lead has fallen dramatically since limits were placed on its use in household products. However, one can imagine that as a resource comes into short supply or becomes substantially more expensive, government actions could have a dramatic effect. One doesn't have to think long to come up with an example of war waged over a resource. That puts resource supply squarely into the strategic arena, prompting politicians to speak of "defence issues", but too often, it is offensive action that results.

So how does resource supply look for the future? Is it an impossible dream to believe that essentially all resources could be economically recycled? It would require gathering elements that are dispersed in our waste products. We in MPG know that ore deposits are produced by accumulation of metals that are normally at very low concentrations. Such accumulation takes thousands if not hundreds of millions of years. To be economic, a deposit must have a certain quantity of the desired material per ton of rock. Economics is nearly always defined by the energy required to turn the ore into a saleable form and get it to market. Thermodynamics is not on our side when

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it comes to collecting elements to levels profitable as ore deposits. Entropy increases; random distribution is the lowest energy state.

But now, suppose we had some helpers. Countless species of bacteria exist. Some species have learned how to weather rock so they can harvest specific elements for their own use or for the use of a plant or animal with which they live in symbiosis. A colleague told me recently that half the world's biomass is below the Earth's surface, mainly as "extremophile" bacteria that can tolerate high pressure, high or low temperature and extremes in pH and redox conditions[1]. They get energy by catalysing redox reactions and they get nutrients by dissolving minerals in rocks or sediment. Think of the vast resources of organic compounds those bacteria know how to make!

Bioleaching is an old technology for extracting metals from low-grade ore, and bioremediation has been used for decades to degrade organic contaminants such as chlorinated solvents from groundwater aquifers. But releasing elements and degrading compounds is not specific or selective. It is crude work that one could equate with bringing in a bulldozer and moving the whole pile. But what about bringing in tweezers and separately picking out all the lead, all the tantalum, all the chromium and so on. It is not so wild to imagine that bacteria already exist that can specifically select for one element in preference to another. If we could find them, herds of bacteria could be set to work, like cows on grass, separating the elements. And they would not need to confine themselves to rock. Sediments from industrial harbours and soils long abused by industrial dumping could be bacteria pastures. The fly ash from coal, oil and municipal waste carries just about the whole periodic table. If bacteria could help us sort them out, the elements in our waste could be recycled. Not only solving the supply side of the equation, it would also reduce the environmental problems associated with waste disposal. In fact, microbiologists have already been working for at least a decade to improve the selectivity of organisms for some heavy metals and radionuclides. It is only a matter of time until the concept becomes reality.

Geomicrobiology and biogeochemistry are growing sub-disciplines. We in MPG, and our students, have a contribution to make. I have no doubt that innovation will eventually drive development of computer screens and mobile phones that do not need tantalum and indium. Hopefully, new technology will soon develop fertiliser dispersion systems that will minimise phosphate run-off to oceans and extend global reserves. And maybe by the end of this century, by the time my grandchildren's grandchildren are recycling all of their garbage, bacterial farms will harvest metals from sewage and waste dumps. Mankind will probably never achieve 100% sustainability, but as we strive toward that goal, we have a responsibility to see that some political and academic thought be given to the ethical use of resources, before serious shortages come to dominate national policy.

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1 Jørgensen BB, Boetius A (2007) Feast and famine – microbial life in the deep seabed. Nature Reviews Microbiology 5: 770-781

2 Susan Stipp was the principal editor in charge of this issue.

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