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# ELEMENTAL EPIDEMIOLOGY

## The Complex Association Between Mineral Extraction and Health

MARTIN MCKEE

## Abstract

While much attention has, rightly, been devoted by the public health community to the unsustainability of our addiction to activities that involve burning the Earth's finite supplies of hydrocarbons, this is not the only way in which we are threatening the health of the world's population by depleting resources. The quest to control supplies of minerals, many of them present in small quantities, is having profound consequences for health. This chapter examines these consequences, including environmental contamination, conflicts and violence as warlords seek control of mineral-rich land, and the working conditions of those who mine these materials. These examples illustrate the importance of taking the broadest possible perspective on the determinants of health in a complex, interlinked world.

## Introduction

It has been suggested that the reason why humans have never been contacted by inhabitants from other planets is because, long before sentient beings reach the stage when they can travel across space, they have already destroyed their own planets. For several decades, Tony McMichael was warning us that we risked repeating this mistake (McMichael, 1993, 2001). Blending insights from epidemiology, climate science and behavioural sciences, he rendered visible what would otherwise have remained invisible (such as how seemingly unconnected events such as landslides and forest fires in geographically dispersed lands were linked through man-made climate change), confronting us with difficult, but essential, questions of whether we were asking our planet to bear a load that was unsustainable (McMichael, 2001, 2012). In particular, he held us to account for the stewardship of our carbon resources and, especially, our propensity to take complex hydrocarbons needed for many of the materials that made modern life so easy and simply burn them. In this chapter, I examine a related issue. How well have we performed in our stewardship of some of the Earth's other resources?

## An (Uneven) Abundance of Riches

The atomic composition of the universe is the result of a complex set of nuclear reactions, going back to the Big Bang, when much of the hydrogen and helium were created. However, the speed of this process left little time for the next largest elements to be formed, so that lithium, beryllium and boron remained relatively uncommon, even today, and there was no time to form carbon, with the next largest nuclei.

The process then moved to the stars. Alpha particles (helium nuclei) combined to form ever larger elements, explaining why those elements with even numbers of protons were more common than those with odd numbers, as well as why iron was so common (iron-56 is the largest stable nucleus that can be created by combining alpha particles, and so is the end of the line for this process). Other elements came about as a result of neutron capture and, to a lesser degree, fission of those nuclei that were unstable.

These processes gave rise to the overall composition of Earth, formed from the condensation of interstellar material. Initially, the slowly solidifying lump of molten rock was believed to be fairly homogeneous, but this changed over time as iron and those metals, such as nickel, that most easily formed alloys with it sank, while those elements that formed oxides remained on the crust. Flowing water dissolved and released many of these oxides, depending on the prevailing conditions of temperature and pressure arising from the constant volcanic activity (Fleischer, 1954). The consequence of this and other processes, such as those linked to tectonic movements (McDonald, 2005), meant that many elements were concentrated in particular places; for example, because they were leached out of rock formations or because they were left behind when other elements were leached out.

It is only because of these processes that it has been possible for humans to extract them from the Earth's surface. The concentration of elements in certain places made it possible to mine them commercially, especially as some related elements, such as silver, gold and platinum, were concentrated in the same places. Yet, not all elements were concentrated to the same extent. One group that largely escaped these processes is a set of 17 elements, all but two heavy elements, with atomic numbers between 57 and 71, making them relatively uncommon in the universe. However, they are also relatively dispersed on Earth, giving rise to their description as 'rare earths'. They are found in significant amounts in some places, such as the small Swedish mining town of Ytterby, which gave its name to no fewer than four elements, yttrium, erbium, terbium and ytterbium. Elsewhere, however, they are found only in very low concentrations.

The extraction of all but the most common and concentrated elements, such as iron or aluminium, can involve enormous effort. Thus, it can take one tonne of ore to extract one gram of gold. The ores with the highest yields of many elements are already depleted. Save some new discoveries in unexpected places, we are already exploiting ores with yields far below what would have been considered viable even a few decades ago. However, the extraction of these elements from ores where they have lain undisturbed for millennia begins a process of human-led dispersal, whereby they are distributed throughout the environment, in rubbish dumps or as litter, across the planet. In effect, we are speeding up the phenomenon known as entropy, whereby, over time, the universe will reach a cold, homogeneous, and dead state. While there will still be vast quantities of these elements in ocean water and sediment reserves, it will no longer be economically viable to extract them in useable quantities.

This is becoming increasingly problematic as we find new uses for many elements that were previously little more than chemical curiosities. Tantalum, for example, is an essential component of mobile phones. Neodymium and lanthanum are necessary for the production of hybrid cars. Iridium is used to make crucibles in which large, high-quality single crystals used in the electronics industry are grown. Neodymium, dysprosium and samarium are used in high-strength magnets. Promethium is used in nuclear batteries, and scandium is used in aerospace components. A number of others, such as yttrium, holmium and erbium, are used in specialist lasers. There is, however, a finite amount of these elements on Earth, unless at some stage in the future we discover how to create controlled, large-scale nuclear fusion, at best a distant prospect.

The growing demand for these elements has important implications for those countries that, by an accident of geology, have deposits of these substances. Some will find themselves in an economically extremely powerful position. Others, especially if their governments are too weak to safeguard their resources, may become victims of conflict, as warlords seek to control the resources. All these scenarios have consequences for human health.

## Taking Control of Earth

Those who control a finite resource have power over those who need it. It is possible to view much of human history as a struggle for control over scarce resources, whether it was the expansion of the Roman Empire as it sought to maintain its supplies of maize from North Africa, the Spanish conquest of South America in pursuit of silver, or the colonisation of Asia by European powers in search of spices. More recently, few believe those politicians who deny that at least some of the causes of conflict in the Middle East lie in the quest for control of oil.

At the beginning of the 20th century, the struggle is no longer for control of spices but of those minerals that are increasingly in demand. One country, China, now dominates the global debate of access to many of these resources. In particular, it has developed a near monopoly on the production of the rare earths. It has used the power that comes with this monopoly position.

Since 2005, China has reduced the amount of rare earths it exports, from just under 60,000 tonnes per year to just over 30,000 tonnes in 2011. This led to a steep increase in world prices. However, it also stimulated a number of responses in other countries, including a referral to the World Trade Organization on the basis that its export quotas were illegal, the relocation of companies that used them in manufacturing (especially Japanese companies) to China and the opening up of production in other parts of the world, such as the USA and Australia, where it had previously been economically non-viable. As a consequence, prices have fallen back somewhat. However, while the widespread dispersion of rare earths means that there are alternative sources, China's actions serve as a warning. European powers once colonised large parts of the world to ensure control of natural resources. Nowadays, the process is different. Wealthy countries are not seeking to govern other countries. Instead, sovereign wealth funds and similar entities are taking advantage of international settlement procedures that enable them to enforce property rights to buy up large tracts of land. So far, this has been mainly for agricultural production, but, increasingly, it is likely that it will be to secure control over strategic stocks of minerals. The likely price rises may place in peril the affordability of many of the new technologies on which the world depends for clean energy, with negative implications for our planet.

A related issue is the health consequences of extraction. In China, activity centres on the mines at Bayan Obo in the north of Inner Mongolia (Bontron, 2012). The ores are brought 120 km south to the town of Batou, where two-thirds of Chinese production is processed. Because these elements are in such low concentrations, they can be extracted and purified only with great difficulty. The processes used involve strong acids (now deemed by the International

Agency for Research on Cancer as a Group 1 carcinogen; International Agency for Research on Cancer, 2012) and give rise to large amounts of waste that is corrosive and contains many toxic chemicals. The waste is also radioactive as a result of the thorium that is extracted at the same time. The inevitable result is that the land around Batou, which once supported agricultural production, is now unusable. Moreover, the air is heavily polluted with sulphuric acid mists and pollutants from the coal-fired electricity generators used to power the local industry.

Despite growing awareness of the hazards, and in some cases extensive programmes to clean up polluted areas in countries such as China and Malaysia, similar stories can still be told in many other parts of the world. For example, the extraction of gold, silver and platinum involves the extensive use of cyanide, which too often has leaked into watercourses, destroying wildlife.

## Conflict Commodities

The song, 'Oh my darling Clementine', serves as a reminder that the 1848–55 California gold rush was accompanied by many individual tragedies, although the fate of the indigenous inhabitants of the land on which the gold was found has often received less attention. Today, there are many similar land grabs going on, some for gold, but more often for other substances. Perhaps the best known are 'blood diamonds', made famous by a movie of the same name and now subject to a raft of international measures, of varying degrees of success, to control the trade. Blood diamonds played a key role in the civil war in Sierra Leone, leading to the death and maiming of thousands of people, illustrated horrifically by the pictures of young children with both hands severed by machetes. However, there are many others.

The one that has given rise to most deaths is the quest to control coltan reserves in the Democratic Republic of Congo (DRC). Coltan is an abbreviation for columbite-tantalite, a compound containing the element tantalum, and the DRC is an increasingly important producer. When refined, it forms a heat-resistant powder that can hold a very high electric charge, leading to its widespread use in capacitors and energy storage cells in a wide range of portable electronic devices such as mobile phones and laptops. Unfortunately, the coltan that is mined in the DRC contributes little to the welfare of its people. Warlords from Rwanda, Uganda and Burundi have deployed militia forces in the DRC to achieve control of the trade in coltan and other natural resources. The resulting conflict has been characterised by widespread atrocities, while the money they have raised has contributed to instability and rapidly growing inequality in the neighbouring countries in which they are based (Montague, 2002).

## 'Oil and Democracy Do Not Mix'

This oft-cited quotation is from an op-ed in the *New York Times* in which Ottaway (2005) notes that only two of the world's top ten oil producers are fully democratic, with three more only partially so. However, this is not just an assertion. Ross (2001) conducted a pooled time-series using cross-national data from 113 countries between 1971 and 1997 and showed that oil exports were associated strongly with authoritarian rule but, crucially, that export of other types of minerals had a similar antidemocratic effect, while the other types of commodity exports studied (food and non-food agricultural products) did not. In subsequent analyses, he found some support for three possible explanations: a 'rentier effect', whereby resource-rich governments used patronage to dampen democratic pressures; a 'repression effect', whereby they used their resources to strengthen their internal security and thus repress popular movements; and a 'modernisation effect', whereby growth, driven by the export of oil and minerals, failed to bring about the social changes that produced democratic governments.

This interpretation is important because of the contribution of democratic governance to health, increasing the responsiveness of governments to the needs of their people, including their health needs, and encouraging representation of their poorest citizens (Mulligan et al., 2004). Greater democracy is associated with lower infant mortality (Lena and London, 1993; Navia and Zweifel, 2003). Children in Africa, born to the same mother before and after political changes, have different health outcomes; infant mortality falls when multi-party elections lead to a change of leader, but not where the incumbent wins or when the change of leadership is undemocratic (Kudamatsu, 2006). In these ways, dependence on extractive industries can act through political processes to undermine health.

## Mines and Health

Miners face increased risks of injuries and a large number of illnesses through physical exposures, including those from dust, such as silicosis, and those from toxic chemicals, such as mercury poisoning (Eisler, 2003). However, mineral miners are also at high risk of tuberculosis (TB) (Packard, 1987; Rees and Murray, 2007). Miners in sub-Saharan Africa have a higher incidence of TB than in any other working population in the world (Government of South Africa, 2007), reflecting both the intensity of exposure to infection in confined spaces, both in the mines and in accommodation blocks (Leon et al., 1995), and the effects of silica dust exposure, which increases the risk of pulmonary TB (Hnizdo and Murray, 1998; Churchyard et al., 2000; Rees and Murray, 2007). Miners are also at high risk of HIV infection because of the extent of sex work associated with mining facilities (Campbell, 1997). Miners in this region have three–four times the prevalence of HIV compared with non-miners, while partners of migrant miners have also been found to have a significantly greater prevalence of HIV (Lurie et al., 2003). However, mines are not only a risk to those who work in and around them. They act as incubators of infectious diseases, which then spread into the general population as miners circulate between the mines and their often distant homes (Basu et al., 2011). Thus, the intensity of mining is associated significantly with overall rates of TB in the countries of Africa (Stuckler et al., 2011).

## Conclusion

Tony McMichael changed the way we thought about the determinants of human health, looking far upstream for the answers to exploring some of the greatest challenges facing humanity. This necessitated a breadth of vision, as well as an ability to make connections across complex chains of causation. Fundamentally, he was concerned about how we interacted with our environment and the ecosystems in which we were embedded, and the scarce resources we inherited. In a small way, this chapter seeks to reinforce and, indeed, to bolster this tradition.

## References

Basu, S., Stuckler, D. & McKee, M. 2011. Addressing institutional amplifiers in the dynamics and control of tuberculosis epidemics. *American Journal of Tropical Medicine and Hygiene* 84, 30–7.

Bontron, C. 2012. En Chine, les terres rares tuent des villages. *Le Monde*. Available at: www.lemonde.fr/asie-pacifique/article/2012/07/19/en-chine-les-terres-rares-tuent-des-villages_1735857_3216.html, accessed 5 February 2015.

Campbell, C. 1997. Migrancy, masculine identities and AIDS: the psychosocial context of HIV transmission on the South African gold mines. *Social Science & Medicine* 45, 273–81.

Churchyard, G.J., Kleinschmidt, I., Corbett, E.L., Murray, J., Smit, J. & De Cock, K.M. 2000. Factors associated with an increased case-fatality rate in HIV-infected and non-infected South African gold miners with pulmonary tuberculosis. *The International Journal of Tuberculosis and Lung Disease* 4, 705–12.

Eisler, R. 2003. Health risks of gold miners: a synoptic review. *Environmental Geochemistry and Health* 25, 325–45.

Fleischer, M. 1954. The abundance and distribution of the chemical elements in the earth's crust. *Journal of Chemical Education* 31, 446–51.

Government of South Africa 2007. *Tuberculosis Strategic Plan for South Africa, 2007–2011*. Ministry of Health, South Africa.

Hnizdo, E. & Murray, J. 1998. Risk of pulmonary tuberculosis relative to silicosis and exposure to silica dust in South African gold miners. *Journal of Occupational and Environmental Medicine* 55, 496–502.

International Agency for Research on Cancer. 2012. *Occupational Exposures to Mists and Vapours from Strong Inorganic Acids; and Other Industrial Chemicals*. IARC, Lyon, France.

Kudamatsu, M. 2006. Has democratization reduced infant mortality in sub-Saharan Africa? Evidence from micro data. ISER Discussion Paper No. 685. Institute of Social and Economic Research, Osaka, Japan.

Lena, H.F. & London, B. 1993. The political and economic determinants of health outcomes: a cross-national analysis. *International Journal of Health Services* 23, 585–602.

Leon, R., Davies, A., Salomon, M. & Davies, J. 1995. *Commission of Enquiry into Safety and Health in the Mining Industry*. Government Printers, Pretoria, South Africa.

Lurie, M.N., Williams, B.G., Zuma, K., Mkaya-Mwamburi, D., Garnet, G.P., Sturm, A., et al. 2003. The impact of migration on HIV-1 transmission in South Africa: a study of migrant and nonmigrant men and their partners. *Sexually Transmitted Diseases* 30, 149–56.

McDonald, I. 2005. *Mineral Deposits and Earth Evolution*. Geological Society, London, UK.

McMichael, A.J. 1993. *Planetary Overload: Global Environmental Change and the Health of the Human Species*. Cambridge University Press, Cambridge, UK.

McMichael, A.J. 2001. *Human Frontiers, Environments and Disease: Past Patterns, Uncertain Futures*. Cambridge University Press, Cambridge, UK.

McMichael, A.J. 2012. Insights from past millennia into climatic impacts on human health and survival. *Proceedings of the National Academy of Sciences (USA)* 109, 4730–7.

Montague, D. 2002. Stolen goods: coltan and conflict in the Democratic Republic of Congo. *SAIS Review* XXII, 103–18.

Mulligan, C., Gil, R. & Sala-i-Martin, X. 2004. Do democracies have different public policies than nondemocracies? *Journal of Economic Perspectives* 18, 51–74.

Navia, P. & Zweifel, T.D. 2003. Democracy, dictatorship and infant mortality revisited. *Journal of Democracy* 14, 90–104.

Ottaway, M. 2005. Tyranny's full tank. *New York Times*. Available at: www.nytimes.com/2005/03/31/opinion/31ottaway.html, accessed 5 February 2015.

Packard, R. 1987. *White Plague, Black Labor: Tuberculosis and the Political Economy of Health and Disease in South Africa*. University of California Press, Berkeley, California, USA.

Rees, D. & Murray, J. 2007. Silica, silicosis and tuberculosis. *The International Journal of Tuberculosis and Lung Disease* 11, 474–84.

Ross, M.L. 2001. Does oil hinder democracy? *World Politics* 53, 325–61.

Stuckler, D., Basu, S., McKee, M. & Lurie, M. 2011. Mining and risk of tuberculosis in sub-Saharan Africa. *American Journal of Public Health* 101, 524–30.

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