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Disruption of nutrient cycles[1]

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In natural ecosystems the nutrient elements that are part and parcel of every living organism are recycled within the system – through the soil and atmosphere in the case of terrestrial ecosystems, and through water and the atmosphere in the case of aquatic ecosystems. In both types of environment, however, the major pathways involve uptake from solution by plants followed by consumption and redistribution by animals, with micro-organisms playing a crucial role at various levels along the way.

Some elements, most notably oxygen, hydrogen, nitrogen and carbon, make significant use of the atmosphere as one of their cycling options. With the exception of sulphur, most of the other essential elements, including phosphorus, have very limited access to the atmosphere as a means of transport. The point to emphasise here is that the recycling of elements within an ecosystem is an essential part of that system; without it the biota would eventually exhaust their supplies of some elements and cease to exist. Human activities, however, have disrupted nutrient cycles, with profound implications for the global environment and the human population.

Agriculture appeared on the scene about 10,000 years ago. At first it had very little, if any, significant effect on the cycling of nutrient elements. There were several reasons for this. For example, the human population was small and much of the farming was 'swiddening' in which an area was cropped for a short period and then left to recover. In any case, under such conditions it would have been virtually inevitable that the farmers, intentionally or otherwise, returned their food wastes and excrement to the farmland. Similar comments apply to the early days of fixed field farming.

Eventually, however, the positive feedback between the food supply and the population forced change. An increasing food supply enabled some of the farming population to leave the farm, go and live somewhere else and do something else for a living. That 'something else' embraced a range of activities, including making tools which, among other things, improved the 'efficiency' of farming, accelerated population growth, enabled and eventually obliged even more people to live in towns. Thus another positive feedback loop was formed and, in the process, an increasing proportion of farm produce was consumed away from the farm. This meant that if the non-volatile nutrient elements in the food eaten by the urban population were to be recycled, then recycling could no longer be left to chance. It had to be done deliberately.

The process of population growth and urbanisation has continued to the present, with some major setbacks along the way associated with appalling hygiene and sanitation. Throughout that time there have been deliberate efforts to return some sewage and food wastes from cities to farms, but there is little doubt that an important reason for many of these attempts lay in concerns about urban sanitation and its implications for public health. Inevitably, as the urban population grew, the logistics of recycling became more difficult and the proportion of nutrients recycled declined. Currently the human population is about 6 billion with the 'urban' component ranging from 39% in Africa to 85% in Australia and 87% in New Zealand.[2]

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His research has been in microbiology in the CSIRO Divisions of Food Preservation and Transport, and Fisheries and Oceanography (as they were called in those days) and subsequently in the Department of Microbiology at the University of N.S.W. In 1975 he was appointed to the Foundation Chair of Biology (now Biological Sciences) at the University of Wollongong. While in Wollongong an earlier interest in environmental matters grew significantly. After retirement that interest led to the publication of his book, *Feed or Feedback.*

In the remainder of this article we will consider, albeit briefly, the present and future implications of the current state of human population dynamics for two elements central to the existence of all living organisms, nitrogen and phosphorus.

Nitrogen

Towns and cities are the major sources of all types of man-made pollution. Much of that pollution is air-borne and it makes a significant contribution to the geographical movement of bound nitrogen, predominantly as ammonia and nitrogen oxides. Bound nitrogen is also released to the atmosphere by the application to soil of nitrogenous fertilisers. Recent estimates indicate that human activities annually discharge to the atmosphere some 210 million tonnes of bound nitrogen compared with 140 million tonnes from natural sources.[3]

Bound atmospheric nitrogen is a potential threat to public health. Estimates for 1995 give mean annual concentrations of nitrogen dioxide (NO_2, $\mu g/m^3$) of 76 for Canberra and 30 for Melbourne. The Canberra figure exceeds the 'acceptable' concentration listed in WHO guidelines.

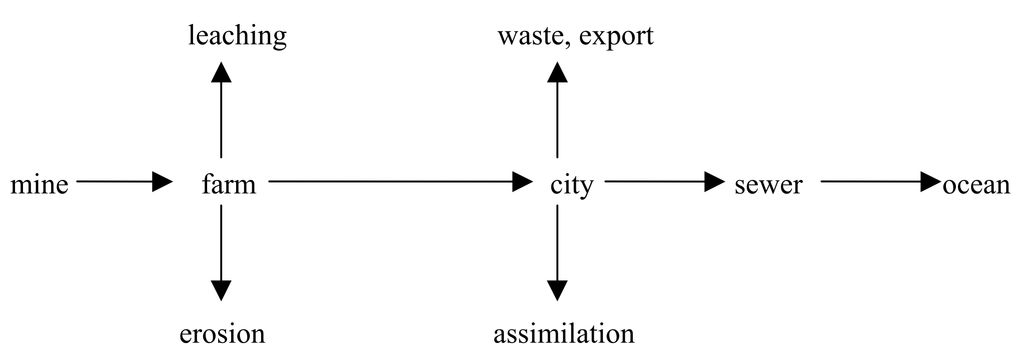
Eventually, however, much of that bound nitrogen is deposited on land, where it can be a blessing or a scourge depending on the circumstances, or in water, where it is more likely to be an unwelcome pollutant than a benefit. Estimates for rates of deposition of nitrogen compounds (kg N/ha/y) for the latter half of the 20th century range from 0.3 to 3 (Australia) to 21 to 83 (New Jersey).

From a global perspective, the environmental situation with nitrogen can be summarised as follows. There is no possibility of exhausting nitrogen ‘resources’. Some farmland will suffer from nitrogen deficiency when circumstances prevent or inhibit its biological fixation and/or when insufficient fertiliser is applied. Other areas will be exposed to excess deposition from the atmosphere and/ or to high levels of applied fertiliser. In those cases there is a real potential for polluting nearby waterways and thus contributing to their eutrophication. And, of course, nitrogen compounds are a substantial component of sewage and will become a pollutant of any body of water into which sewage may be discharged.

Phosphorus

Elements that are not volatile or that do not, under natural conditions, form substantial quantities of volatile compounds, do not cycle to any significant extent through the atmosphere. Under the present system of commercial agriculture, much of it involving international trade, if essential non-volatile nutrient elements are to be used ‘sustainably’, they must be recycled to farmland, and that recycling must be deliberate. Some recycling of food wastes and treated sewage is attempted in various parts of the world but the proportion so treated is a drop in the ocean – so to speak. Consequently, a number of essential nutrient elements are being used in a manner that, for all practical purposes, is irreversible. Supplies of such elements are, at least in theory, susceptible to exhaustion.

The most immediately vulnerable of such elements is phosphorus. A simple flow chart of this element in the current system of commercial agriculture is something along the following lines:



In this diagram, ‘waste’ refers to food wastes, much of which goes to garbage tips; ‘assimilation’ refers to uptake by a growing human population, much of which goes eventually to cemeteries. Quantifying rates of these various processes inevitably has a number of uncertainties; but, if this is acknowledged, the exercise can give some understanding of what is going on and its implications.

A 'balance sheet' for Australia indicates that, in an ‘average’ year, all primary produce contains 107 488 tonnes of elemental phosphorus of which 58% is exported, 9% is contained in sugar cane, 8% goes to food waste, 19% to sewage and 0.1% is assimilated by the population.[4]

Globally, the application of phosphate fertiliser peaked in the late 1980s. Then, after a sharp decline, it began increasing again in the mid 1990s. The reason for these changes was a drop in the rate of consumption by the ‘developed’ world and a continuous increase in consumption by the ‘developing’ world (Figure 1).

Figure 1 can be usefully extrapolated only with the help of a number of assumptions. With that qualification in mind, let me say that my own extrapolation indicates that, if current trends continue, known phosphate reserves will be exhausted within 85 to 190 years.

Figure 1

A question that must be asked here is why phosphorus which is discharged into the sea cannot be recovered. The answer to that question is complex. But, briefly, it would require pumping and treating sea water at rates about 70 times the current global consumption of fresh water, it would require enormous amounts of energy and it would effectively destroy the global marine ecosystem.

This is one of a number of serious threats to the future of civilisation and, indeed the species *Homo sapiens*. An effective response to it will not be simple. The most fundamental component of any response, however, must be the breaking of the positive feedback loop between the human population and its food supply. Unless that is done, all other efforts at conservation will ultimately have the significance of a pie in the sky.

[1] This subject is discussed in more detail in:
Brown, A.D. 2003. *Feed or feedback*. International Books. Utrecht.

[2] World Resources, 1988-99 Oxford University Press. New York

[3] Vitousek et al. 1997. cited in ref.2 (above)

[4] See ref. 1 above.