Cycles, spirals and linear flows

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Earth science presents a fascinating picture of the development of our planet: Rising by an accretion of solar nebula 4.5 billion years ago, the globe subsequently cools down from a molten state to a solid crust, surrounded by hydrogen and helium, an 'atmosphere' radically different from that of today. One billion years later, the first primitive forms of life appear on this planet. It takes another 1.5 billion years for photosynthetic life to develop, resulting in a slow increase in atmospheric oxygen, and enabling finally the creation of higher organisms. Today, the biosphere is the most complex and sophisticated system that one can imagine.

Seen from a natural history point of view, the development of today's world was a linear process, with no cycles. Where then does the notion 'cycles of nature' come from? If smaller time scales are taken into account, regularly occurring phenomena can be observed: The daily cycles, the seasonal pattern during a year, the corresponding hydrological cycle, the cycling of carbon and nitrogen, and others. These cycles are important for nature as well as mankind. At a second examination, most of the natural cycles are not closed, they deviate from a cycle. During the beginning of the photosynthetic period, oxygen was a useless waste product that slowly increased the oxygen concentration in the atmosphere. It may be more appropriate to use the metaphor of a spiral: At first sight, it looks like a cycle, but when you come closer, you realize, that the natural system does not come back to exactly the same point. From a larger distance, the movement follows the form of a spiral, which – in contrast to a cycle – is headed towards a certain direction. While a cycle defines a static situation returning to the same state, a spiral allows progress, resulting in new developmental possibilities.

Cycles, spirals, or linear flows – what has all this got to do with waste management? The discussion about the direction of waste management has always been influenced by the underlying world views. In our times, the notion of a cycling economy is the predominant paradigm. There is no doubt that reuse and recycling conserve energy and resources, and that they contribute significantly to reduce pollution. But it is also a fact that waste management is a key element for controlling linear flows, too. Like natural systems, man-made systems produce residues of no further immediate use that cannot be recycled. Examples comprise materials with constituents that have been banned because of the hazard they pose, such as asbestos in construction material, heavy metals and flame retardants in plastic and wood waste, chlorofluorocarbons (CFCs) in coolants, or polychlorinated biphenyls (PCBs) in capacitors. These waste materials need to be disposed of in a safe place, a so-called 'sink' (as an antonym to 'source'). Appropriate sinks for organic materials are waste-to-energy plants. The conditions in a modern incinerator ensure that even persistent organic substances are mineralized and transformed into harmless products such as carbon dioxide (CO_2), water and inorganic salts. Storage sites that are able to exclude materials from the hydrological system represent suitable final sinks for immobilized inorganic wastes.

The hierarchy of recycling over disposal cannot be based on experiences with natural systems. In nature, both cycles and linear flows occur. The same is true for our man-made systems: Nearly all gold exploited from the Earth's crust is recovered with a very high recycling rate, but most of the zinc used is dissipated and lost; to recycle it would require immense amounts of energy and financial resources. To ask for a general and undifferentiated strategy of recycling for all substances neglects the differences in application, chemical speciation and biogeochemical behaviour of the tens of thousands substances that are in use today. Furthermore, the recycling industry increasingly feels the impact of modern products, namely the problem of producing 'pure' secondary resources from a highly complex and chemically mixed 'dirty' waste input. The reason is that technology constantly develops new and valuable functions for a range of substances that have never been used before. As a consequence, consumer as well as investment goods are containing a fast-growing number of different and new constituents. Thus, to produce valuable secondary products from waste materials, recycling requires separating individual elements and chemical compounds into fractions of uniform composition. Experience from primary mining, extraction and processing helps, but is not enough. The new anthropogenic mixtures pose new challenges. Due to the complexity of today's goods, tomorrow's recycling might turn out to be more difficult than anticipated.

A way out of the dilemma is to link production of goods and waste management in a much more systematic and comprehensive way than today. 'Design for recycling' must become a more important, maybe mandatory issue for future production. Whereas this is a straightforward task for short-living materials ('consumer goods' such as packaging), it is more challenging for long-living products ('investment goods') such as construction materials: Who knows what technologies will be available in 40 years when today's buildings and infrastructure become obsolete and turn into waste? How can the technical means for recycling in a distant future be anticipated today? What are the transaction costs for such long-term recycling strategies, in terms of information management for example? After all, concepts for and products of recycling must compete in a global economy with primary resources which are – despite some recent volatility – still reasonably priced.

'Zero waste' has been introduced as a strategy to overcome some of the problems discussed above. The best solution to the waste problem is of course to produce no waste. Often, prevention is seen as a key for zero waste. Without doubt, many waste materials can be reduced and sometimes have the potential to be totally prevented. But like natural systems, anthropogenic systems produce waste materials too. Higher organisms release faeces and urine, and exhale CO_2, in the same way as vehicles and heating systems end up in scrap metals and CO_2. A complete 'zero waste' strategy is not a realistic goal, first for thermodynamic and second for economic reasons. Without external input of energy, longstanding science has proven that the 'quality' of matter deteriorates, and losses occur inevitably. Due to the depreciation of materials with use, wear and age, the value of a material often falls below a point at which economic recovery is possible. Hence, waste materials will exist forever, even in a highly optimized society.

The two main goals of waste management are protection of humans and the environment, and conservation of resources such as materials, energy, and space. For sustainable waste management, a third goal is to manage waste materials in a way that does not leave any burden for neighbours and future generations ('no export of waste related problems in space and time'). This is intended to protect future consumers by removing hazardous substances from today's recycling streams, to release from waste treatment only low emissions that do not impair the environment, and to operate and close landfills that require minimal after-care. The concepts to reach the above goals are manifold, from prevention to recycling, composting, waste-to-energy and landfilling. This begs the question: Must all effective waste management systems be based on a waste hierarchy approach and/or zero waste concepts?

The drawbacks of the concepts 'waste hierarchy' and 'zero waste' are that they pretend that a society without waste is possible, that all waste can be prevented and recycled. Putting prevention and recycling on top of the hierarchy makes final disposal in sinks an inferior practice. The attitude 'cycles are good and linear flows are bad' is not beneficial for waste management, particularly considering the protection of human health as a key goal. In fact, in view of reaching the goals of waste management, both cycles and linear flows are equally important and necessary: Recycling of many waste materials certainly provides valuable products but also – and inevitably if the aim is 'clean cycles' – it produces recycling residues that are unsuitable for further use and that have to be disposed of in sinks. Thus, landfilling and incineration are as essential as prevention and recycling, and they depend upon each other to get the job done.

The main task of waste management is to reach the above-stated goals. How to reach these goals should not be a matter of world view, but should be left to the creativity and ingenuity of the waste management community and to economic considerations at the regional if not local levels. This is especially the case for emerging economies, in which relatively little financial resources are available for waste management. In such countries, application of the waste hierarchy is not appropriate because the first and most important step for reaching the protection goals is the complete collection and safe disposal of waste materials. What is needed is an open approach that is free of preconception: here are the goals, these are the means, and let us choose those means that reach the goals at least cost and affordable to the citizens served. Such an approach produces new ideas and creative solutions, and leads to true progress in waste management. Cycles, spirals, and linear advancements apply to solid waste management just as they do for Mother Earth.

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