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Recycling and resource efficiency: it is time for a change from quantity to quality

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Imagine a world where everything we use is eventually recycled. Sooner or later, this means also a world where everything we use contains recycled materials. Most natural environments work on this principle, via decomposition and assimilation. In a world full of products of human innovation, such as highly engineered materials, synthetic chemical compounds and complex products such as electrical and electronic equipment (EEE), and run at a fast forward pace, being inspired by natural environments remains paramount, but can also prove misleading. Recycling does have limits and is a means to higher level targets – not a goal in itself. The main benefit of recycling is environmental protection, decreasing the need to mine and produce virgin materials, and reducing energy requirements and large-scale emissions. In addition, the availability of resources is improved by recycling. Traditionally, modern solid waste management addressed public health and environmental protection and incidentally local resource scarcity, occurring for instance in war times or during the pre-industrial era. Recently, worldwide issues such as climate change and resource efficiency on a planet-wide scale have become increasingly the focus of the global waste management community. Here, we revisit the debate on recycling, resorting to fundamental arguments, sometimes forgotten in a one-dimensional drive towards material cycles. Does a high percentage of municipal solid waste (MSW) fractions collected for potential recycling translate into maximum sustainable resource efficiency?

Booming recycling numbers

Let us summarize the state-of-the-art for recycling of MSW. In affluent countries, we have managed to establish high recycling rates, starting from figures at < 10% wt. A gigantic effort over the last 30 years has led to prospering recycling numbers (composting included), with Eurostat reporting a 42% wt. average for the EU-27 in 2011, and numbers close to 70% wt. for the best countries; also rates close to 90% wt. for certain materials such as aluminium. Apparently, no high number is good enough: the sky (100%) is the limit for the recycling proponents, who may see in this a successful replication of a natural systems function. In many low-income countries the local industrial production is also fed by the informal sector, grass-roots and micro-enterprise recycling systems. These systems often achieve recycling rates of 20 to 30% wt. and, unlike Europe, are directly linked to the commodity value of recyclables as secondary raw materials. In a recent dynamic development in middle- and low-income countries, major industrial players are attempting to implement their environmental producer responsibility by connecting recyclables re-processors with the informal collectors, either augmenting or partly circumventing the traditional formal/municipal solid waste management systems.

The devil is always in the detail

It is beneficial to take a closer look at these achievements. Considerable amounts of materials considered ‘recycled’ in the EU are in fact shipped over to the ‘sink’ (as far as the EU is concerned) of the fast-growing Asian economies: this included close to 3.6 million tonnes of plastic wastes in 2012 (Eurostat data). However, by global waste trade we are essentially transferring risks. There, fate is unclear because of cases of lack of adequate regulations, poor law enforcement and insufficient product quality control. Indeed, there are concerns that waste plastics and polymers exported are used also for products of lower quality, containing environmentally problematic substances, such as brominated flame retardants or heavy metals. Moreover, transparent and reliable information about the pathways and end destinations of many substances are often missing. Examples demonstrate that the umbrella term ‘recycled’ can be misleading. The power of a single indicator (namely the % wt. collected for recycling) is insufficient to measure, in a meaningful and effective way, the contribution of recycling to sustainable resource management. Weight of material mixtures conceals density and utility differences. Therefore, with a view to the increased popularity of the notions of circular economy and resource efficiency, the quantitative goals of recycling have to be supplemented with qualitative goals. What kind of cycles do we want; what must be done with hazardous substances that potentially may enter recycling schemes; where are the final destinations for these substances that cannot be recycled? A ‘clean cycles’ and ‘safe final sink’ strategy must be developed, and a metric is required that allows the measurement of progress towards these goals.

‘If you can’t measure it, you can’t manage it’

There is an urgent need to measure recycling on a more sustainable basis. A recycling metric must be based on clear definitions of inputs and outputs, considering the time axis and material stocks along this time axis. Furthermore, the different qualities and constituents of materials must be taken into account. Plastics and metals are composed of numerous additives and alloying metals. When recycling targets are defined, these mixtures require individual attention in order to yield an optimum and balanced solution regarding economic, environmental and resource aspects. Furthermore, the need for safe energy recovery from non-recyclables (or final storage) has to be taken into account.

At present, the standard of regulation of different waste treatment and recycling systems varies. The most and probably best-regulated systems are waste-to-energy (WtE) plants (also known as energy from waste) in countries with strong institutions. In the EU, assessment of one aspect of a WtE plant performance has already being introduced: the Waste Framework Directive (WFD, 2008/98/EC), enables energy-efficient WtE plants to be classified as 'energy recovery' operations, if they meet the so-called 'R1' criterion. R1 has beneficially driven the sector towards higher value recovery from waste. If we want to be fair and maximize the benefits to society and the environment, recycling processes should be measured over the same yardstick as all other waste management and resource recovery means; so far, no evaluation of recycling applies.

What is the added value?

What is needed is an agreement on the types of added value and the contributions towards the higher level goals aspired to. The potential problematic side effects have to be taken into account, and contributions and side effects can be combined in an evaluation matrix. Clearly, such an evaluation is informed by our societal values, which vary by locale – so it may hard to reach a consensus. But in any case, an attempt is worthwhile, ending possibly in a plurality of or composite indicators.

Regarding added value, a secondary material can only be used for a finite number of cycles, whether by up-cycling or down-cycling, with financial and environmental consequences. The importance of substances in the bio-geo-chemospheric cycles should also be considered. Any definition and measurement of recycling should address the issue of suitable intermediate and final 'sinks'. Thermal waste treatment, such as properly designed and responsibly operated WtE plants and cement kilns, are the best available way to limit the dispersion of persistent organic pollutants. Long-term sequester sites, such as underground storage, may be necessary to dispose of hazardous inorganic waste materialss that cannot be recycled. If sink limitation is envisaged for a substance, product design should be adapted to eliminate the use of certain substances, as has happened with lead, cadmium, mercury and other heavy metals in EEE during the past decade.

The stage at which a material stops being a waste and becomes a commercially viable secondary raw material or product is the obvious point for certifying that recycling has been achieved. The EU WFD end-of-waste or voluntary quality management systems such as the UK Quality Protocols are potential routes to this end – but currently they are excessively complicated. The added value of recycling cannot be established without appraising the opportunity cost of alternative beneficial uses; for example, for the organic part of the waste as a source of nutrients and soil amendment vs a source of biogenic energy).

Methodologies

There has been considerable progress towards measuring environmental performance. Life-cycle assessment (LCA) is now recognized as capable of informing the hierarchy of the waste processing options, an approach built-in to the revised WFD. Sophisticated software tools recognizing the subtleties of environmental evaluation aspects are available. Material flow analysis (MFA) is instrumental for understanding the actual recycling and the fate of substances during recycling. A series of policy indicators have also been under development. Some metrics are still lacking: the fraction of a substance directed by waste management to an appropriate sink is not taken into account yet; neither is concentration or dilution of a substance (as a benefit or disadvantage). Externalities are not sufficiently considered. Despite the evaluation of critical resources being still in its infancy, materials criticality should be an integral part of the recycling evaluation. Multi-objective optimization will be needed to effectively synthesize all different considerations, delivering optimal solutions that are holistic and robust. A balance between regional and planetary added value should be sought.

Ensuring high quality and added value of recycling

Reliable data informs policy-makers towards setting workable targets. The main objective is a well balanced, optimized sustainable recycling scheme. Accurate measurement of recycling, possibly at multiple points in the re-processing system, and comparison against modelling reveals what is the current technically achievable level of recycling, and where innovation is most needed. New topics such as the management of complex composites, nanoparticles and multiple recycling loops will have to be assessed with transparent and credible metric systems. Sustainable recycling remains a moving target. Changes in values, as well as innovations, such as automated tagging and design for dismantling, will be continuously shifting the 'optimal level'. It seems timely to open up the discussion and to strive for a post-quantitative level of recycling with all three main goals, namely public health, environmental protection and resource conservation, in mind.

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