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Editorial corner – a personal view

Reconsidering plastics recycling and bio-plastics

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The environmental harm of plastics waste (especially litter) is known all too well. Yet, the consumer society could not survive for a month if all plastics disappeared in a moment. Even a reduction or more intelligent use of plastics requires protracted efforts on the part of governments, social media, industrialists, and scientists. Not investigating the possibilities of changing consumer attitudes (which would have the most significant effect, but is the most challenging problem and belongs to social sciences rather than to engineering), I would like to list briefly some goals which are usually pursued separately and rarely handled together as an interdependent system. These are as follows:

1. More efficient collection and compaction of plastics waste from the environment (there are promising initiatives to improve the 'harvesting' of sea- and river-borne plastic waste). It is more complicated to collect the land-based plastic waste once it is spread in the natural environment. The hazards of microplastics, which are partly the results of a misconception of accelerated photodegradation by pro-oxidant additives, have not yet been sufficiently understood. The hope that microplastics can eventually be degraded by microbes proved to be ill-founded, despite the increased specific surface.
2. Not all plastic packaging materials can be cleaned from biodegradable contamination (*e.g.*, food packaging), so they cannot be collected together with relatively clean plastic waste. More effective separation of plastics from communal waste is required, followed by proper cleaning but without producing too much sewage, which also spoils the aquatic environment. Despite increased efforts for selective waste collection (glass/metal/plastic/paper and the rest), still, large amounts of plastic waste end up in landfills.
3. Regarding thermoplastics, most attention has been devoted to direct recycling of selectively collected waste, and there are remarkable results in the field of compatibilization of mixed plastics and 'rehabilitation' of partly degraded plastic waste by post-stabilization or by chain-extension of slightly degraded condensation polymers (*e.g.*, PET). On the other end of the spectrum full decomposition of thermoplastics into low molecular gases and liquids has been practiced for a while, but it requires considerable energy and post-processing by the standard techniques of the petrochemical industry. Relatively less attention has been paid to the middle molecular weight range, although the cross-alkane metathesis reactions provide less energy-consuming routes to obtain various kinds of waxes and other products (https://doi.org/10.1126/sciadv.1501591; (https://doi.org/10.1016/j.chempr.2016.11.003) that could be functionalized and used as building blocks to produce new types of polymers.
4. In the field of thermosets, there is a need to gradually replace at least a part of the permanently crosslinked rubbers and resins by covalent adaptive networks (CANs, reprocessable thermosets, see, *e.g.*, (https://doi.org/10.1039/C5SC02223A, including biobased resins (https://doi.org/10.3390/polym12112645). They can be broadly classified

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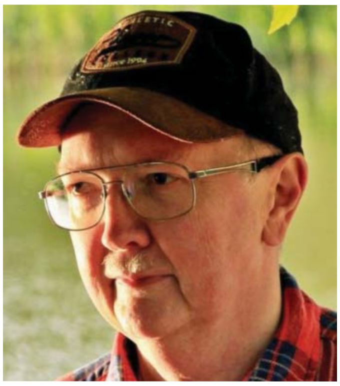
into two groups: dissociative CANs that break down into monomers and can be re-polymerized again, while associative CANs (also called vitrimers), just reorganize their crosslinked structure, which allows a kind of rejuvenation and thermoplastic-like reprocessing. Besides thermally reversible crosslinking, there is a growing tendency to move away from Bisphenol-A and other synthetic building blocks and use bio-based epoxies and other thermosets (https://doi.org/10.1016/j.crci.2017.10.005). There is a long way to go, but the process has already started.

5. Last but not least: bio-degradable polymers, which seemed to be THE solution for removing the threats of synthetic plastics to the environment, and society did not live up to the expectations – despite enormous efforts to the contrary. A part of the problems is technical (*e.g.*, the rigidity of poly(lactic acid) (PLA), the most widely used biodegradable polymer, or the slow biodegradation process in the soil), another is that if biodegradable waste is mixed with the synthetic polymer waste, it spoils the traditional recycling of the latter. The worst problem is that if the biodegradables are made from vegetables or crops that can be used for alimentary purposes, people will starve. That's why polyethylene made from bio-ethanol is hardly human-friendly. Great efforts must be taken to produce bio-based monomers or plastics from agricultural waste and to develop biotechnologies that can be operated in reactors that do not reduce arable land. Even this helps only if the effluents (gases, sewage water, and sludge) can be handled in an environmentally benign way.
6. In addition to the technical problems mentioned above, I believe that the LCA (Life Cycle Assessment) methodology needs improvements, specifically the inclusion of further factors to the well-known impact factors as ozone depletion, global warming, acidification, eutrophication, and various kinds of toxic effects. Somehow the ease of recyclability, the negative or positive impacts of recycling, and the reusability of the recycled products should be taken into account to motivate the manufacturing companies to design products that can be easily recycled into useful products without too much harm to the environment.
7. I am also convinced that above a certain complexity, the manufacturing firms should be obliged to take back their products and to perform at least the dissembling steps themselves and to give semifinished products to the large-scale recycling industry. Again, it would be a strong incentive to design products that can be easily dissembled (avoiding the use of multilayer systems that cannot be separated or consisting of incompatible components). It may also result in less complicated, 'eye-catching', but impractical featured designed into the products just for marketing reasons. If the manufacturer is supposed to pay the price of these tricks, he will look for trade-offs between profit and ecological requirements. Similar to banks or insurance companies, manufacturers should be obliged to collect funds that could be used for repairing environmental harms and meet legal duties (*e.g.*, recycling duties) if they go bankrupt. That may slow down the expansion of industrial activity but would reduce environmental injuries and evasion of legal responsibilities.

As anyone can see, these points are highly interrelated, and both industrial and governmental stakeholders should harmonize their efforts to solve them as a part of a single problem.



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