Feature Articles

Can Non-Recyclable Plastic Waste Be Made Environmentally Sustainable?

Luigi Campanella¹, Giuseppe B. Suffritti²

¹ Dipartimento Chimica, Sapienza, Università di Roma, Roma, Italy
² Dipartimento di Chimica e Farmacia, Università degli studi di Sassari, Sassari, Italy
E-mail: luigi.campanella@uniroma1.it; pino.suffritti@gmail.com

Abstract. After death the fraction of living matter which is not biodegraded (shells, bones, corals, carbonaceous deposits) becomes environmentally sustainable. This is not the case for plastics so that these wastes should be either recycled or made environmentally inert and stored in secure repositories as a resource for future generations. Chemistry has offered different solutions to this problem, and each brings about advantages and disadvantages when compared to other options. One further possible route could consist in the enrichment of the plastics waste in carbon content (“carbonization”), in analogy with the production of charcoal from wood, but we hope to stimulate a debate about all the other possible routes among scientists and engineers in the involved fields.

Keywords: plastics waste accumulation and dispersion, circular economy, carbonization of plastics waste.

1. INTRODUCTION

There is a growing concern about the accumulation and dispersion of plastics waste.¹ ⁴ Plastics have become indispensable for human life and for industry, but their high chemical stability makes most of them not completely degradable when dispersed in soil, fresh and sea water, and in air, unless it was properly designed to be biodegradable. Most plastics are obtained from fossil oil, up to about 10-12 % of the global production, according to an IEA report published in 2018.³ Even using the best plastic waste management practices,⁵-⁹ models predict that an important fraction of plastics waste (more than 22% in 2050) will accumulate,¹⁰ especially in surface water and oceans, reaching a mass of 500±100 Mt in 2050.³

In oceans these wastes are able to create true plastic islands, that reached in 2018 an overall surface of 1.6·10⁶ km², corresponding to about 6 times the surface of France, in the Pacific Ocean only.³ Plastics waste degradation is accelerated by irradiation from the UV component of sunlight and by some mechanical wearing, with the continuous production of smaller and smaller debris, maintaining a substantial chemical integrity.¹¹-¹⁷ Energy recovery as heat, steam, or electricity by burning plastics wastes, that in 2016 represented...
the fate of as much as 40% of plastics waste, is strongly
discouraged because of the production of greenhouse
gases and pollutants. As it will be better detailed
below, different strategies have been proposed for reus-
ing and recycling plastics waste, but its large fraction
that accumulates in landfills and, what is much more
dismaying, in surface waters and oceans, is generally
not adequately considered. Although we are not pure
specialists in the field, general common sense considera-
tions led us to give our little contribution to drive the
attention of the scientific community of chemists to this
important problem in order to be allowed to say “I do
my part of the job”

2. CIRCULAR ECONOMY AND PLASTICS WASTE

There are several different ways to define circu-
lar economy. According to the European Commission’s
Implementation of the Circular Economy Action Plan,
approved in 2019, Circular Economy is:

A system aimed at eliminating waste, circulating and
recycling products, and saving resources and the environ-
ment.

In a recent review focused on the plastics waste, it is
stated that:

[the] concept of “circular economy” (CE) commonly refers
to the “take-make-use-break-make” concept, where the
main goal is to create economic impetus from the waste.
It also enables the close-looping of product – waste –
building block cycle.

However, as remarked for instance by Kümmrer
et al., a complete recycling of plastics waste is practi-
cally impossible, unless plastics materials are purposely
designed, and in fact a huge amount of wasted plastic
residues is actually dispersed in the environment.

A closer look at natural living systems action to
maintain environmental sustainable cycles can give
some further insight in extending the concept of circu-
lar economy. Indeed, after completing their vital cycle,
the fate of living matter “waste”, besides a small quan-
tity of volatile compounds, which are dispersed in the
atmosphere, water or in soil, is mostly bio-recycled. Only
a negligible fraction of it is burned as a consequence of
natural events, such as fires caused by lightning, or by
volcanic eruptions. However, a more or less important
fraction of living matter waste is made of mineralized
remnants. For instance, bones buried in soil last nearly
unchanged for centuries, shells of aquatic animals are
accumulated in lakes, seas, oceans floors and eventually
become rocks, and coral colonies are able to build up
entire islands. Finally, fossil carbonaceous deposits (coal,
oil and natural gas) were originated by large amounts of
living matter deeply sunk in soil. All these long-lasting
living matter wastes share the important property to be
environmentally sustainable, or inert. In conclusion, the
natural ecology is not strictly circular, but the produced
“waste”, which is not recyclable is environmentally sus-
tainable. Therefore, it is reasonable to ask ourselves why
we cannot follow a similar route for the management of
plastics waste, by proposing that all what cannot be bio-
degraded or used as feedstock for recycling shall be
treated to become environmentally inert and stocked in
secure repositories, for future use as matter and energy
resource.

3. OVERALL MANAGEMENT OF THE PLASTICS
   WASTE

Plastics often consist in one or more co-polymers
along with several additives such as plasticizers, flame
 retardants, coloured agents, ultraviolet-light stabilizers,
antioxidants that are difficult to separate during the recy-
cle process leading to waste of time, money and material.
The bottleneck of recycling is the preliminary separation
and fractionation of the present compounds. Therefore
recycling is often considered only at the atomic or molec-
ular level with possible loss of the intrinsic properties of
the products compared to those of the same products in
the original waste. In January 2018 the European Com-
mision announced a vision for Europe’s new plastics
economy substantially based on a new model of econo-
my: from linear to circular economy. So the following
commitments are considered to be implemented:
– all plastic packaging used in Europe must be reused
   or recycled by 2030;
– more than half of the plastic wastes must be recy-
   cled;
– plastic sorting and recycling capacity must be
   extended fourfold by 2030;
– some 10 million tons of recycled plastics are to be
   used for new products by 2025.

Mechanical recycling consists in transforming the
plastic waste in raw material without any substantially
modification of its chemical structure. It is the largely
most adopted method in Europe but due to the pres-
ence of additives the process cannot recover more than
60-70% of the original wastes. The recycled materials
find the same application as the original plastic wastes,
in any sector of our today common life.
Institute of Biotechnology

The quite same properties of the original waste. With very promising results as the recycled material has leaves’ compost has opened a new way to recycle PET. The discovery made to be able to extract hydrogen from plastics. The main problem of this option is to have the prop-er catalyst able for the extraction of hydrogen and other elements similarly to what was obtained with the charcoal from the thermal treatment of wood. As recently reported, a catalyst based on mixed iron and aluminum oxides acting under a microwave field of 1000 W seems to be able to extract hydrogen from plastics.

Also biotechnological methods were successfully applied to the recycling of plastics. The discovery made by a group of researchers of Carbios and of the Toulouse Institute of Biotechnology of an enzyme present in the leaves’ compost has opened a new way to recycle PET with very promising results as the recycled material has the quite same properties of the original waste. In the 25th August 2020 issue of the Chemistry World weekly Kyra Welter reports that an International Group of research was successful in obtaining a polymer able to be recycled in principle for an infinite number of times, during which it was depolymerized and the obtained monomer was re-polymerized and so on. Contrary to mechanical recycling that changes the properties of the material after few cycles, monomerization can potentially bring to materials that can be recycled whenever needed without any limit and keeping the same properties of the raw starting material. The problem in this case is that monomerization, if not purposely designed for plastic materials is not an available chemical process.

The chemical modification of the existing hardly recyclable plastics can increase their lifetime and face three different problems: first, in general polymers easily decomposed do not present good properties; second, the obtained products behave better in many common applications; and, third, if one wants to have good mechanical properties for the new product it is necessary to control the stereochemistry of the polymerization. The integration of this option in the actual recycling systems could be difficult because of the multifarious variety of the plastic waste, increasing the number of the possible components. This point can only be solved by a very responsible behavior of citizens and of local Institutions.

In general, plastics waste treatment can entail a net cost, which is to be supported in view of the unbearable environmental damage of accumulation and dispersion of plastics waste. In line with a recent proposal about carbon taxes, this cost should be recovered from special ad hoc taxes “similar to a value added tax (VAT) […] such that end users pay the full costs.” Indeed general taxation usually is not equally charged and distributed among taxpayers. Note that actually many megatons per year of plastics waste are exported from Europe, Australia and North America to China and other countries, entailing transport costs that could be avoided if sustainable domestic treatments are properly implemented.

4. DISCUSSION AND CONCLUSIONS

In this paper we shortly outlined some dismay-ing problems connected with the management of plastics wastes, and particularly, of the large fraction of this waste which is accumulated untreated in landfills as well as in surface and sea waters, even if an increasing commitment is advanced to reuse and recycle plastics waste by the various available procedures. Any effort and strategy should be performed to avoid the dispersion of
plastics waste in air, waters and soil, by securing and controlling any phase of deposit, and especially in the long-lasting landfills.

As remarked, in view of the global warming problems, it should also avoided and restricted any treatment of plastics waste releasing CO₂ and other greenhouse gases into the atmosphere. In addition, the products of plastics waste recycling suitable as fuels should be preferably if not mandatorily used as feedstock for the chemical industry, so sparing mineral oil resources, or stored in secure repository.

A general strategy for the plastics waste management was proposed in the conclusions of a recent review about microplastics (tiny specks of plastics of micrometer size) by Hale et al.¹³

Most plastics are inexpensive to manufacture. Hence, there is little financial incentive to reuse them. To support a circular lifecycle, the upfront price of plastics must incorporate end of life costs. Currently, low volume plastic users and associated ecosystems bear a disproportionate burden (e.g., remote islands are now being littered with plastic debris). This environmental injustice echoes that of climate change and sea level rise. Landfills may be mined by future generations as resources become scarce and technologies improve. Optimization of such “dumps” into “repositories” is worthy of consideration. Political initiatives across borders should seek to accomplish these goals.

However, by considering the amounts and the rate of accumulation in landfills, in our opinion it is urgent to find also sustainable technical routes to transform the untreated or not recyclable plastics waste into “inert” matter which should be stored in secure repositories, such as exhausted mines of coal and other minerals, or impermeable quarries, as a resource for future generations. It could be objected that a large fraction of plastic waste is already environmentally “inert”, as it lasts almost unchanged for hundreds or even thousands of years,¹⁴ if properly saved. There are at least two reasons to propose a further treatment of plastic waste. First, the chemical nature of plastic materials makes their use as a feedstock in the future rather difficult and expensive, so that saving more homogenous materials would be preferable. The second reason is that the recovery of hydrogen, fluorine and other elements could help in reducing or even offset the cost of the treatment. In addition, the danger of a dispersion of degraded plastics in air and waters (especially as microplastics) would be contrasted, and the amount of the final waste could be reduced. All this can be obtained by the enrichment of the plastics waste in C content (“carbonization”). Examples of chemical processes that can achieve this result are discussed by Chen et al.²⁵

If this proposal is considered unpractical or too expensive, we wonder whether there are other ways to obtain environmentally sustainable materials from plastics waste.

In conclusion, on one hand, we urge scientists and engineers working in the field of plastics materials to think and propose practical solutions to this problem, and on the other hand we hope that a fruitful discussion about the ways to avoid accumulation and dispersion of plastics wastes will involve a larger scientific, technological, political and especially social public.

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