SUSTAINABLE SOLUTIONS FOR MITIGATION OF PLASTIC WASTE

Rahul Raj M, Student, B.Sc Zoology (Hons), Ramjas College
Dr. Renu Gupta*, Associate Professor, Department of Zoology, Ramjas College

ABSTRACT

At present, the world is in the grip of a pandemic we never foresaw. But, plastic pollution is an ongoing anthropogenic pandemic to which most of the general public and big conglomerates are staying oblivious. Even when the global economy nearly came to a standstill, 367 million metric tons of plastics were produced globally in 2020 alone. Due to their biochemically inert structure, plastics take hundreds of years to decompose in nature. Therefore, plastics have even been considered stratigraphic indicators of the anthropocene.

No modern technology is effective at removing the toxicity of plastics completely. In this review poster, we try to understand certain microorganisms whose potential is being explored by the scientific community to solve the issue of plastic pollution.

From the deepest trench to the highest peak, plastic became ubiquitous and microbial communities started creating ecosystems on plastic debris, and the term "plastisphere" was coined to describe such ecosystems. The plastisphere biota may prove to be the miracle solution for tackling the problem of plastic pollution.

Biology alone may not stand a chance against these synthetic polymers, but it could well provide plausible solutions that can be integrated with existing and new technologies. Multidisciplinary research areas like synthetic biology are doing this by redesigning the naturally occurring plastic-degrading microbes and enzymes. Scientists have discovered more than 30,000 enzyme homologues with plastic-degrading potential. Also, biodegradable plastics that serve as a sustainable alternative to synthetic plastics are being invented across the world.

Plastic pollution can only be curbed if science and society work together. So, as a global society, we should make certain subtle changes in our lifestyle to reduce the impact of this problem.

PLASTICS- THE PROBLEM

Plastics are a class of materials formed by natural (from cellulose) or synthetic (from fossil fuels) organic polymers of high molecular weight that can be irreversibly molded by applying force (a property called plasticity). They are easy and cheap to produce, light in weight, and very flexible. All this has made them very common. But they have proved to be more harmful when left untreated. Also, their entire life cycle is toxic right from their manufacturing, which releases toxic gases like HCN.

Impact on human health:

- Hormonal changes
- Reproductive abnormalities
- Developmental disorders
- Cancer

Impact on wildlife:

- Changes in gene and protein expression
- Disruption of feeding behavior
- Stunted growth
- Changes in brain development
- Reduced respiration rates

Thereby, they indirectly affect global economy and also add to the causes of climate change.

Even current disposal methods are very dangerous to the environment and human health. Incineration releases toxic gases (like furans, dioxins, mercury, polychlorinated biphenyls (PCBs), etc.) and carbon soot, while landfilling causes danger by leaching chemicals into water bodies and soil. Thus, it is quintessential that we move on to alternate sustainable ways of dealing with plastics.

PLASTISPHERE

The term 'plastisphere' was coined by a marine microbiologist, Linda Amaral-Zettler, of the Royal Netherlands Institute for Sea Research in 2010. It refers to the ecosystem of microbiota that develops on plastic litter in the seas and elsewhere. In their investigations, her team saw cracks and pits in the plastic in which microbes were thriving. It hints at the biodegradation of plastics by the plastisphere microbiota.

Plastisphere thus is a stage of intense metabolism owing to the substrate the microbes are surviving upon. It shows us how microbes have evolved in response to plastics as well as how plastics are shaping new ecosystem dynamics. Though this looks hopeful from a biodegradation point of view, such ecosystems pose the threat of alien species invasion as plastics could easily reach anywhere via the oceans transporting these microbes.

BIODEGRADABLE PLASTICS AND BIOPLASTICS

- Biodegradable plastics are petrochemical plastics treated with chemical additives, like compounds of iron, cobalt, nickel, etc., that allow microbes to naturally decompose them at a faster rate, while bioplastics are made from natural sources such as plants or microbes (hence renewable) and hence can be broken down on their own, by dissolving them in water, or exposing them to sunlight.
- While biodegradable plastics have been debunked by researchers as truly biodegradable, bioplastics are proven sustainable alternatives.
- Bioplastics are made from a wide variety of sources like corn starch, food waste, woodchips, plants like elephant grass and seaweed, vegetable oils and fats. They have natural biopolymers like cellulose, starch, gelatin, polylactic acid (PLA), etc. A striking example is that of 100% degradable bioplastics reported to be synthesized from chitin.
- While they're sourced from renewable resources and the emission of toxic gases is less, they may pose the problems of eutrophication and acidification compared to normal plastics. They're also costlier. But since new inventions on them happen as we read this, they still have the potential to be a part of our sustainable approach.

BIODEGRADATION BY MICROBES

Alternatives to plastics are coming up frequently. But to address the amount of plastic that we have already put out there, a whopping 8300 Mt, researchers have looked into microbes, extracted thousands of enzymes with the potential to degrade plastics from them, and tried to genetically engineer microbes to amplify this potential. Some studies are as follows:

1. Two fungi, *Aspergillus tubingensis* and *Pestalotiopsis microscpora*, were found to degrade 90% of polyurethane within 21 days and 16 days, respectively.
2. The bacterium, *Ideonella sakaiensis*, was reported to fully degrade PET within 6 weeks in 2016.
3. *Bacillus pseudofirmus* degraded 8.3 % of LDPE in the observed 90 days, while a microbial consortium of *B. pseudofirmus* and *B. agaradhaerans* supplemented with iron oxide nanoparticles, degraded 18.3 +/- 0.3% after 60 days of incubation.
4. Larvae of a mealworm species, *Tenebrio molitor*, were found to degrade polystyrene in their gut. *Enterobacter* sp. could degrade 12.4% of polystyrene in 30 days and 7.8% in 60 days by *Exuguobacterium* sp.
5. *Zalerion maritimum*, a marine fungus, was found to degrade 70 % of polyethylene in 70 days.
6. A crust fungi species, *Phanerochaete chrysosporium*, was found to degrade 5.4% of polycarbonate in 12 months. It could also degrade PVC and polypropylene; an 11% reduction was reported in 7 days for PVC and up to 19% in one year for PP when added with *Engyodontium album*.
7. Separate research has found that two bacteria, *Anoxybacillus rupiensis* and *Geobacillus thermocatenulatus,* and a fungus, *Trametes versicolor,* are able to naturally degrade nylon plastics.

It is right to infer that in most of the cited examples, the biodegradation potential is quite low, but scientists are trying to genetically modify these microbes to enhance their biodegradation potential. They are also extracting the responsible enzymes for biodegradation wherever possible and trying to produce them on a large scale and applying them on pre-treated plastics so as to enable quick degradation.

ROLE OF SOCIETY

Some steps that we can take to eradicate plastic pollution include:

- ❏ From carrying our own bags to shops and avoiding buying use-and-throw water bottles, an individual can do a lot, but as a society major legislation and collective incentives are needed to fight plastic.
- ❏ Impose strict Extended Producer Responsibility (EPR) so that manufacturers are motivated to deal with the plastic they produce.
- ❏ The 3R principle of Reduce, Reuse, and Recycle should be taken up by every individual so as to meaningfully fight against this problem.
- ❏ Policy making should include public information systems about plastic pollution and its effects. Creating awareness among the general public is very important in order to make informed choices.
- ❏ A circular economy can be devised for plastics wherein all the raw materials are never wasted and continuously reused in some manner.
- ❏ Single-use plastics are being banned in many countries. This can be adopted by more countries.

CONCLUSION

Plastics have become indispensable to humans. They were in the first line of defense against the COVID pandemic. Hence, it would be hypocritical to advocate for a ban on plastics. We must look closely for more ways by which their usage stops affecting human and environmental health. Alternatives should be given a chance, and research should be promoted to solve this problem. There is no single-stop solution; the only way ahead is an integrative approach that draws on ideas from different aspects of science, technology, and society. Compromising the sustainability factor will only worsen the plastic pandemic for present and future generations.

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