Bioplastics and polymers

Anthropocene

- More plastic than steel is produced every year.
- Range of uses from textiles to machines
- Almost all plastics are currently made from non-renewable resources oil, coal or natural gas,
- Plastics waste is increasing, adding to the already burdensome problems of waste management.
- How can we balance convenient living with concern for ecology?

A Brief History of plastics

Early History: Natural resins-like amber, shellac, gutta percha, and casein

The 1800's - nitrocellulose

- Ascanio Sobrero (Turin): nitrocellulose based on nitration of paper and cardboard as an explosive (Sobrero studied with Alfred Nobel under Prof Pelouze in Paris)
- Johan Schoenbein: cotton treated in the same way and carefully dried gave guncotton.
- John Wesley Hyatt, Jr 1869 patented a stable solid nitrocellulose derivative as a synthetic replacement for ivory in making billiard balls and is considered the first industrial plastic.
- Celluloid developed - widely known for its use in photographic and movie film and also extremely unstable.

The 1900's - petroleum

- Petroleum emerged as a source of fuel and of chemicals displacing any development of bioplastics – linked with the development of the automobile and the integration of the petrol industry supply chain (how Rockefeller made his fortune)
- Later on World War II further stimulated demand for oil and synthetic polymers

The 1920's

- Ford looked for ways of using agricultural surpluses in car manufacture and included the use of plastic automobile parts made from soya bean surpluses - steering wheels, interior trim, and dashboard panels. There was also the famous “hemp car” (look it up!)

The 1930’s

- Wallace Carrothers working at DuPont invents nylon.
- Roy Plunkett accidentally discovers Teflon while working at DuPont

The 1950’s

- Ziegler and Natta – transition metal catalysed synthesis of regular syndiotactic and isotactic poly-olefins from simple olefinic feedstocks (ethene = polyethene, propylene = polypropylene etc). (Nobel prize 1963)

The 1960's

- *Cellophane* (acetylated cellulose) is the only well-established bioplastic that has survived the growth of the synthetic plastics industry
- Synthetic plastics derived from oil continue to dominate as their physical characteristics are developed further and they replace traditional materials such as steel, glass and stone.

The 2000's and beyond

- Demand for plastics is continually growing as is our understanding of real environmental impact and diminishing resources oil resources.
- Plastics are finding uses in all areas of life: throw-away medical equipment and devices, microbeads in cosmetics….

Reappraisal of bio-based plastics.

- how quickly can the plastic be re-integrated into the environment after it is no longer being used?
- how quickly are the ingredients that go into making the plastic created in the environment?
- how much pollution or waste is created during the process of actually making the plastic?
- *Traditional plastics fail on all three of these points.*

“Green” Plastics

- An emerging industry focused on making convenient living consistent with environmental sustainability using polymers from abundant renewable natural resources such as agricultural and marine feedstocks.
- Provides additional demand for currently underutilized biomass commodities.

- Biodegradability – a key property for environmental impact

Problems

1. **Competition**

- They are in direct competition with vast range of current plastics from non-renewable sources
- They must have adequate physical properties for intended use managed and controlled with technology for the development of adequate formulations and processing.

2. **Economics**

- Have to be cost-competitive.
    - Currently available biopolymers are significantly more expensive than synthetic polymers
    - Only *starch* competes with synthetic polymers in terms of cost.
- Niche uses – where they have significant advantages (e.g. cellophane)
- Must consider the *whole product life-cycle*. Economists talk about externalisation of costs – for example the cost of manufacture is easy to calculate and which is borne by the producer, but there are also costs associated with pollution, collecting, recycling, which are usually ignored until things get bad and which are almost always borne by society as a whole.

3. **Legislation**

- E.g. banning plastic bags, labelling changes to favour use
- Incentives and disincentives
    - government policy to promote investment and innovation in new industrial processes and behaviour change in producers and consumers.
    - Interest in the development of bioplastics will grow largely to the extent that there is real interest in and concern over the environment.
- New legislation will likely contain restrictions aimed at materials that are neither recyclable nor biodegradable.
- Labelling legislation may lead to an "ecolabel," based on a product's raw material usage, energy consumption, emissions from manufacture and use, and waste disposal impact.

Biodegradation

- Process of breaking a complex molecule down into simpler compounds through the action of microorganisms (bacteria, fungi, or algae)
- Most biodegradable materials *become* biodegradable after the action of another kind of degradation:
    - **Hydro-biodegradable** materials are first broken down by hydrolysis
    - **Photo-biodegradable** materials are first broken down by photolysis by sunlight

Oxo-degradable

- Some companies claim to have an additive which makes oil-based plastics “biodegradable”.
- The additive increases hydrolysis rates to give pieces which are small enough to be accidentally ingested by microbes, however they are not degraded further….
- See article about emerging problems with micro and nano sized plastic particles

Bioplastics

- Typically made by modifying an existing natural polymer + plasticizer + additives
- Processed using extrusion, thermosetting or electrospinning (e.g. nano-cellulose)

What makes green plastics:

- Biodegradable
- From renewable ingredients
- Evironmentally friendly processing

References

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- Fascinating story of the discovery of Teflon: https://www.chemheritage.org/historical-profile/roy-j-plunkett
- Some notes on green plastics that can be made at home: http://greenplastics.net