

PCPC Global Science Plastic and Polymer Task Force (GSPPTF)

Technical Comparison of Plastic Microbeads and Synthetic Wax Alternatives

1. Introduction

The Taiwanese Environmental Protection Administration (TEPA) banned the production and import of cosmetic and personal care products (CPCPs) containing plastic microbeads, effective July 1st, 2018. The legislation passed by TEPA was consistent with US H.R. 1321; the Microbead-Free Waters Act of 2015. As a result, the CPCP industry has replaced exfoliating plastic microbeads in rinse-off CPCPs with non-plastic, biodegradable synthetic wax. However, TEPA is currently considering widening the scope of their plastic microbead ban to include non-plastic, biodegradable synthetic wax. The following technical summary outlines differences between plastic microbeads and non-plastic synthetic wax alternatives in terms of how they are characterized and manufactured. The report will also demonstrate that the analytical method used by TEPA to detect plastic microbeads cannot distinguish these materials from non-plastic synthetic wax alternatives. It will additionally be demonstrated that the biodegradability of these materials is widely different, which means synthetic wax is not persistent in the environment.

Based on the technical information outlined herein, the following can be concluded regarding plastic microbeads and synthetic wax:

- Synthetic wax is not considered to be polymeric nor plastic
- FTIR cannot distinguish between plastic polyethylene microbeads and synthetic wax, whereas alternative methods can
- Synthetic wax biodegrades, whereas plastic polyethylene does not, indicating that synthetic wax will not persist nor accumulate in the environment
- Because synthetic waxes are not plastic and are biodegradable, they should be considered outside the scope of legislation banning plastic microbeads in Taiwan

2. Microbead and Plastic and Polymer Definitions

TEPA and US H.R. 1321 define the term 'plastic microbead' as following:

Plastic microbead: Any solid plastic particle that is less than five millimeters in size and is intended to be used to exfoliate or cleanse the human body or any part thereof

Although the term 'plastic' was not defined by either law, other jurisdictions and organizations have. Three such examples are stated below:

PCPC GSPPTF: Synthetic water insoluble polymers that are molded, extruded or physically manipulated into various, solid forms which retain their defined shapes in their intended applications during their use and disposal

The Environmental Protection (Microbeads) (England) Regulations 2017: 'Plastic' means a synthetic polymeric substance that can be moulded, extruded or physically manipulated into various solid forms and that retains its final manufactured shape during use in its intended applications

The Plastic Industry Trade Association (SPI): Plastics are generally organic high polymers that are formed in a plastic state either during or after their transition from a small-molecule chemical to a solid material. Stated very simply, the large chainlike molecules are formed by hooking together short-chain molecules of chemicals (monomers: mono = one, mer = unit) in a reaction known as polymerization (poly = many). When units of a single monomer are hooked together, the resulting plastic is a homopolymer, such as polyethylene, which is made from the ethylene monomer

Considering available plastic definitions, plastic is defined as being:

- Polymeric
- Solid

With this in mind, the Organization for Economic Cooperation and Development (OECD) defines a polymer as follows:

Polymer: A substance consisting of molecules characterized by the sequence of one or more types of monomer units and comprising a simple weight majority of molecules containing at least three monomer units which are covalently bound to at least one other monomer unit or other reactant and consists of less than a simple weight majority of molecules of the same molecular weight. Such molecules must be distributed over a range of molecular weights wherein differences in the molecular weight are primarily attributable to differences in the number of monomer units. In the context of this definition a "monomer unit" means the reacted form of a monomer in a polymer

3. Polymeric and Synthetic Wax CPCP Ingredients

CPCPs are named according to INCI (International Nomenclature Cosmetic Ingredients). INCI names are systematic names internationally recognized to identify cosmetic ingredients. They are developed by the International Nomenclature Committee (INC) and published by the Personal Care Products Council (PCPC) in the International Cosmetic Ingredient Dictionary and Handbook.

The INCI system identifies names for ingredients on the basis of chemical composition

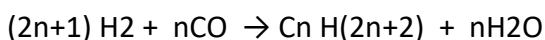
and production process. With this in mind, INCI categorizes ‘polymers’ and ‘natural and synthetic waxes’ separately. In the case of synthetic wax (produced by the Fischer-Tropsch process outlined below), this ingredient is not considered to be a polymer since it is not synthesized by processes such as those used to manufacture polymeric ingredients (e.g. copolymers and homopolymers).

The difference between the Fischer-Tropsch Reaction process used to manufacture a synthetic wax and the polymerization process used to manufacture a plastic such as high-density polyethylene is explained in the next section.

Contrasting a Fischer-Tropsch Reaction Product (Synthetic Wax) to a Polymerization Product (Polyethylene Plastic)

a. Overview of Fischer-Tropsch Synthesis

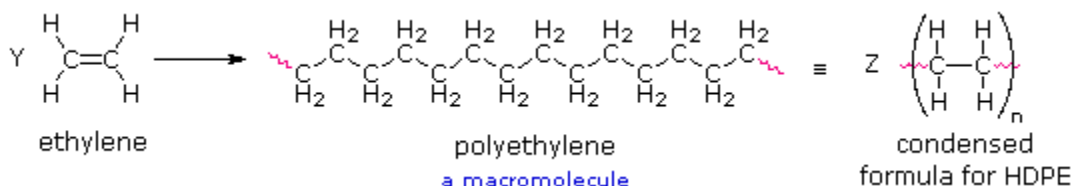
The Fischer-Tropsch process is a catalytic chemical reaction in which carbon monoxide (CO) and hydrogen (H₂) in the syngas are converted into hydrocarbons of various molecular weights according to the following equation:



Fischer-Tropsch process conditions are usually chosen to maximize the formation of higher molecular weight hydrocarbon liquid fuels, which are higher value products. Depending on the catalyst, temperature, and type of process employed, hydrocarbons ranging from methane to higher molecular paraffins and olefins can be obtained. One specific material that can be isolated from the reaction product is synthetic wax.

b. Overview of Polymer Synthesis

The repeating structural unit of most simple polymers not only reflects the monomer(s) from which the polymers are constructed, but also provides a concise means for drawing structures to represent these macromolecules. For polyethylene, arguably the simplest polymer, this is demonstrated by the following equation. Here ethylene (ethene) is the monomer, and the corresponding linear polymer is called high-density polyethylene (HDPE):



c. Contrasting Production of a Synthetic Wax to a Plastic Polymerization Product (e.g. Plastic Microbeads)

There are key differences to the production processes of synthetic wax and a polymerization product, such as plastic polyethylene. These differences are critical when distinguishing between plastic microbeads and non-plastic synthetic wax alternatives.

Fischer-Tropsch process:

- The Fischer-Tropsch process creates hydrocarbons having a wide range of chain lengths
- The Fischer-Tropsch process reacts hydrogen with carbon monoxide
- Neither substance can be considered a monomer since the final product is not a linked chain of either starting substance but rather a new chemical substance (hydrocarbon chain)
- The Fischer-Tropsch process requires secondary processing steps to isolate specific chain length fractions of the reaction product depending on the end material desired (oil, petrolatum, wax, etc.)
- Synthetic wax is one of many substances created by the Fischer-Tropsch process
- Hydrocarbons are not polymers; they are macromolecules
- Synthetic wax manufactured by the Fischer-Tropsch process has a low molecular weight (< 1000)

Polymerization process:

- The polymerization process begins with one or more monomers reacting to form a polymer
- The starting monomer(s) can be seen in the polymer structure as being linked to each other to form the polymer chain
- The polymerization process is a one-step reaction that creates a polymer; no secondary processing or separation steps are required to isolate the polymer
- Plastic polyethylene manufactured by polymerization has a high molecular weight (200000 – 2000000)

4. Regulatory Distinction between a Polymer and a Substance in the European Union and the United States

Synthetic wax is classified by the European Union under the European Chemicals Agency's (ECHA) REACH (Registration, Evaluation, Authorisation and Restriction of Chemicals) regulation as a substance, and not as a polymer. In contrast, plastic polymers such as polyethylene and polypropylene, are registered under REACH by the monomer (substance) that is used to make the polymer:

EC name	CAS #	EC #
Ethylene	74-85-1	200-815-3
Propene	115-07-1	204-062-1
Paraffin and Hydrocarbon waxes	8002-74-2	232-315-6

In the United States, the EPA (Environmental Protection Agency) lists these materials on the TSCA (Toxic Substance Control Act) inventory as follows:

EPA Registry Name	Systematic Name	CAS #
Polyethylene	Ethene, homopolymer	9002-88-4
Polypropylene	1-Propene, homopolymer	9003-07-0
Paraffin waxes and Hydrocarbon	Paraffin waxes and Hydrocarbon	8002-74-2

Regulatory authorities in the United States and the European Union agree and confirm that synthetic wax is a substance and not a polymer. It is not possible to describe synthetic wax as a reaction product of a monomer. Synthetic wax should therefore be classified as a substance and not a polymer.

5. Analysis of Synthetic Wax and Plastic Polyethylene

FTIR (Fourier-transform infrared spectroscopy) is an analytical method that identifies functional groups of a substance. The method is used by TEPA to detect plastic microbeads in CPCPs. However, FTIR cannot distinguish between plastic polyethylene microbeads and synthetic wax. Consider the FTIR spectrum for polyethylene, for example (Appendix 1). The major absorbances of polyethylene (2915/2848, 1471/1463, 729/719) are all due to the –CH₂- structural element of polyethylene. However, other substances with a similar structure will show a similar FTIR spectrum. This can be seen by comparing FTIR spectra in Appendix 1 (polyethylene) with an FTIR spectrum for synthetic wax (Appendix 2). The same predominant absorbances for –CH₂- are present since both materials have a hydrocarbon chain structure (-CH₂-CH₂-CH₂-). It can therefore be concluded that FTIR cannot differentiate between plastic microbeads and synthetic wax.

One way to discern between two materials that have similar FTIR spectra is Differential Scanning Calorimetry (DSC). A DSC spectra comparing high density polyethylene plastic and synthetic wax is included in appendix 3. It can be seen that the spectra are very different.

It can therefore be concluded that current analytical methods used by TEPA to detect plastic polyethylene microbeads result in a false-positive when using this method to detect non-plastic synthetic wax.

6. Differentiating Synthetic Wax and Plastic Polyethylene by their Environmental Fate Properties

Plastic microbeads and synthetic wax can also be differentiated by their biodegradability. Specifically, synthetic wax is biodegradable, whereas plastic microbeads are not. Differences in biodegradability of these materials can be explained largely by the low molecular weight of synthetic wax compared to plastic microbeads.

Hanstveit (1992) demonstrated that synthetic wax was biodegraded within 28 days by microbes present in soil. The same study additionally showed that the biodegradability of synthetic wax was comparable to natural beeswax. The study therefore showed that

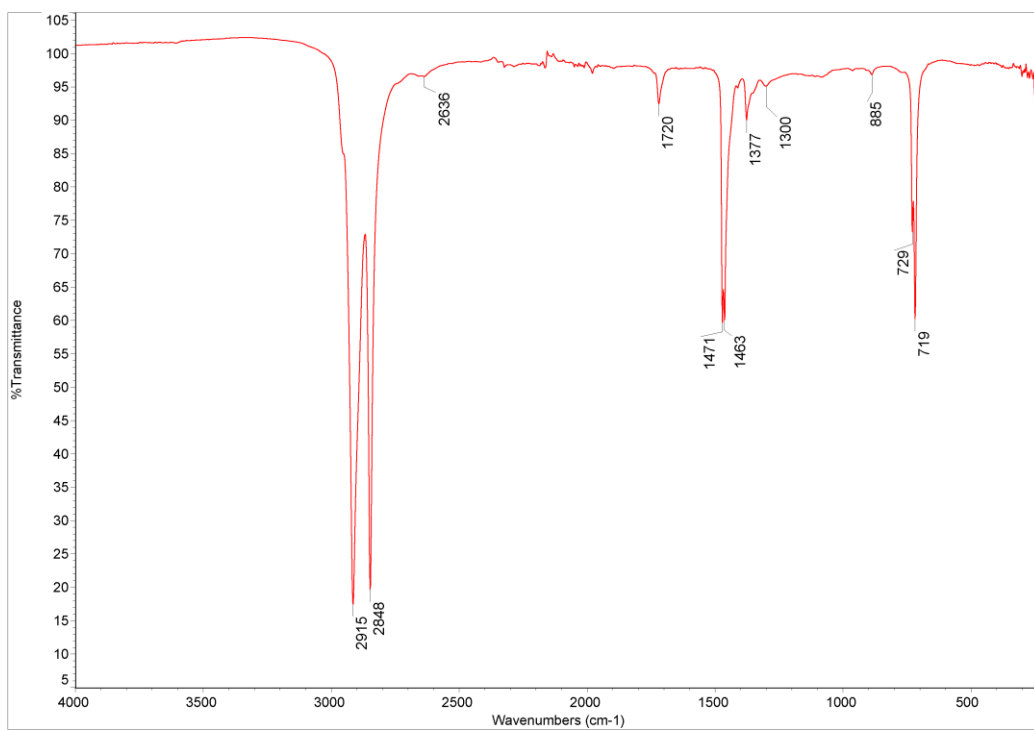
both synthetic and natural waxes are biodegradable and do not persist in the environment.

Synthetic wax has also been shown to biodegrade using the OECD 302C standard test guideline (a globally recognized guideline for demonstrating biodegradability of a substance). The data represented by the graph in Appendix 4 show that synthetic wax was biodegraded an average of 38.4% after 86 days (across 3 replicates). Based on testing following the OECD 302C guideline, synthetic wax is considered inherently biodegradable due to 'evidence of inherent, primary biodegradability for biodegradation'.

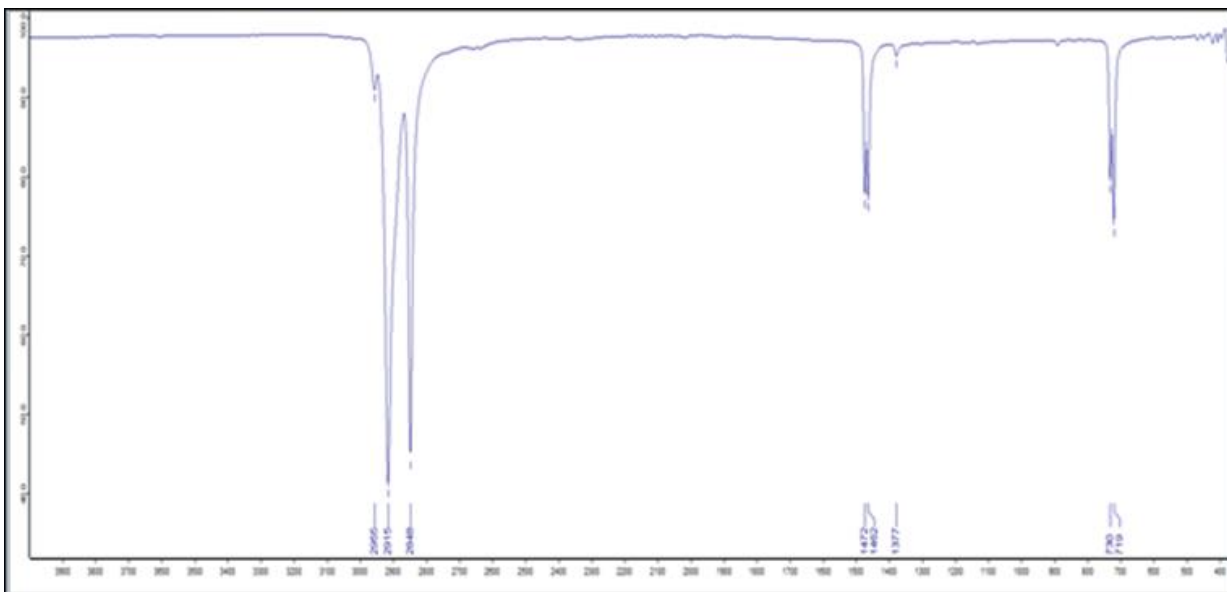
Overall, available data indicate that synthetic wax is biodegraded in the environment in a similar manner to naturally occurring waxes. By contrast, plastic microbeads are non-biodegradable and are therefore expected to persist in the environment.

7. References

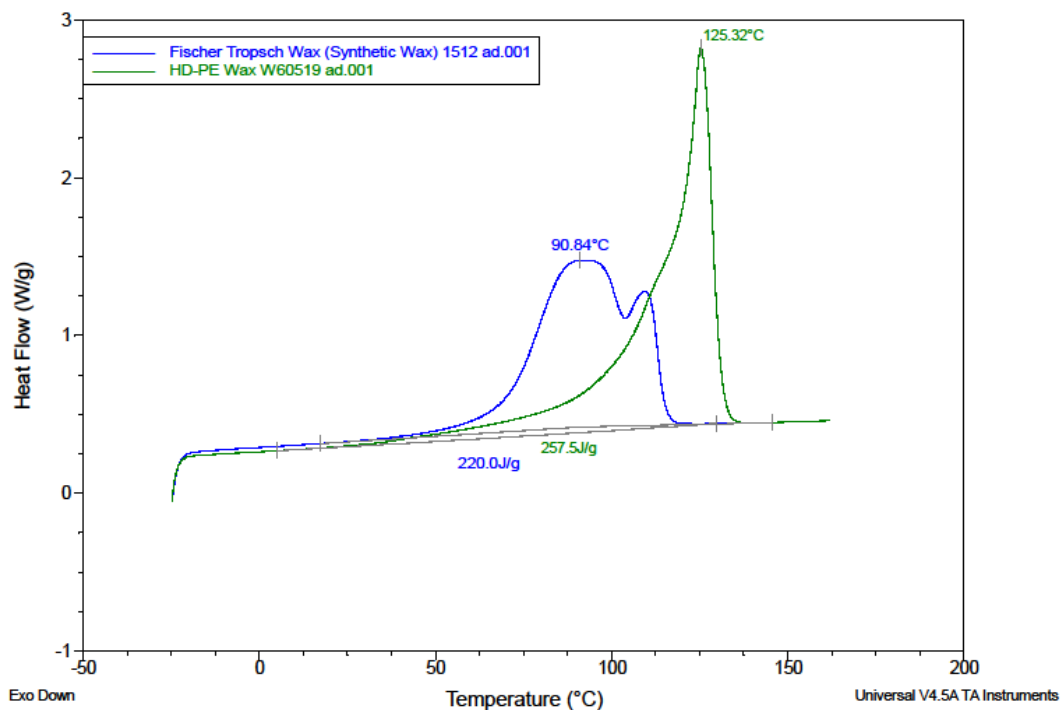
Hanstveit, A.O. 1992. Biodegradability of petroleum waxes and beeswax in an adapted CO₂ evolution test. *Chemosphere* 25(4): 605-620



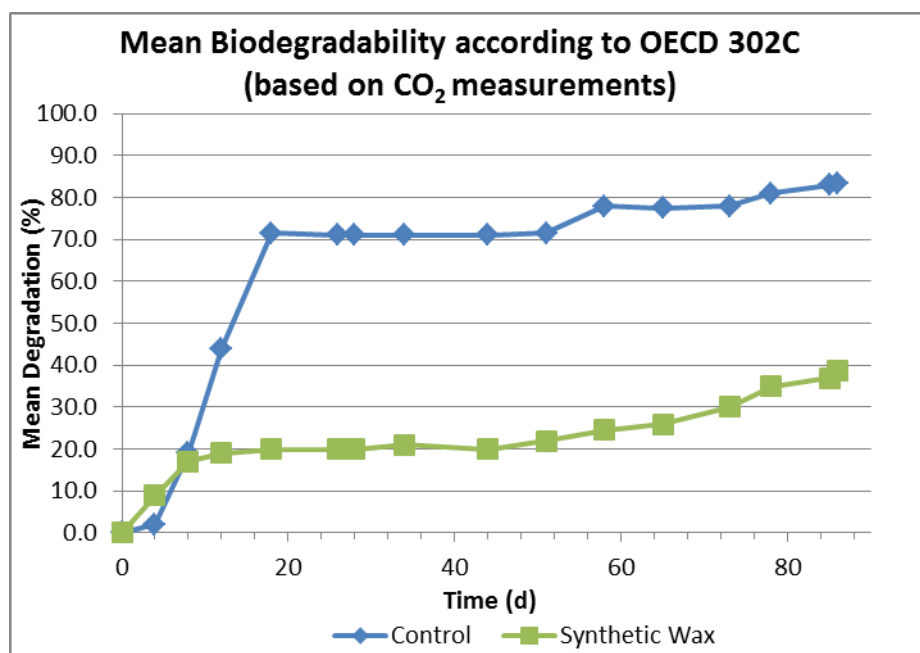
Appendix 1: FTIR spectrum of high density polyethylene



Appendix 2: FTIR spectrum of synthetic wax



Appendix 3: DSC spectra comparing high density polyethylene to low density synthetic wax



Appendix 4: Biodegradation of synthetic wax compared to a positive control (aniline) over an 86 day period using the OECD 302C test guideline