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Biodegradability of Polyvinyl Alcohol Based Film Used for Liquid Detergent Capsules

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The unintentional release of microplastic into the aquatic environment (marine as well as freshwater) is of concern for human health and the ecosystem. Although our understanding of microplastics is changing, California's proposed definition refers to particles that are solid (i.e. not water soluble) polymeric materials that have at least two dimensions greater than 1 but less than 5,000 micrometers (µm).Such plastics may be intentionally added (such as microbeads), or result from progressive physical fragmentation into smaller and smaller particles can take place in the environment. Such particles can be ingested and potentially transfer within food chains. Further, microplastics are practically impossible to remove from the environment after release.

Detergent packs contain highly concentrated cleaning formulas encased in water-soluble films which are made in part from PVOH. To avoid spillage and to ensure consumer safety, the soluble film is designed not to dissolve and rupture prematurely (i.e., when touched with wet hands, or when put into the mouth); to resist compression (i.e., when squeezed by a child); and to trigger an aversive reaction in case of oral contact. The packs are designed to dissolve after contact with water (including cold water (approximately 60-80 ◦F)) inside the washing machine or dishwasher, and then release the detergent. This way, consumers can easily dose the correct amount of product without the need to measure, and without spills that may occur when dispensing a traditional free-flowing detergent product. In addition, the high level of concentration leads to decreased materials volume for shipping and packaging which have great sustainability benefits when it comes to reducing emissions and waste associated with transportation and materials use.

The water-soluble film used for detergent packs is not a microplastic. This is because the film is both water-soluble and biodegradable. Nevertheless, misperceptions do exist. For example, some publications incorrectly implied that polyvinyl alcohol (PVOH) from laundry detergent pods would be a common component in microplastic debris found in the environment. This misconception was based on earlier studies in which PVOH was identified among sorted microplastic debris. However, the considered studies all predate the market entry of liquid laundry detergent capsules - which mainly occurred after 2010. In these earlier environmental studies PVOH was identified in fibers, but these most likely originated from fishing lines. It is critical to note that the PVOH used in fishing lines is different from the PVOH used in detergent films. The type of PVOH used in fishing lines is more hydrolyzed and therefore much less water-soluble and may persist for years in the environment before biodegrading.

PVOH has various applications for use including food packaging, construction, electronics, coatings, printing, textile, cosmetics, and paper. The overarching nomenclature of PVOH covers a broad variety of polymer designs - several of which do not exhibit the same water solubility and biodegradability as the PVOH grades used for detergent film applications. Thus, it is not surprising that such materials may indeed persist sufficiently long in the environment to be detectable. Only a specific range of PVOH meets the performance requirements to be usable for detergent soluble film applications, including dissolution in water.

For the purpose of the current analysis, data on 6 different films used in liquid laundry detergent packs were available for review. These studies were conducted between 2010 and 2018. Because of confidentiality and competition law considerations between manufacturers, no information about the individual studies (neither on the test materials and their characteristics, nor on the individual results) can be publicly disclosed. Instead, the data were compiled confidentially by the International Association for Soaps Detergents and Maintenance Products (A.I.S.E.) and were anonymized. In this paper an aggregation is provided of the different studies that were made available. Consequently, the data presented in this paper reflect the holistic biodegradability profile of technical PVOH films (i. e. technical mixtures) as used for detergent film applications, rather than the biodegradability of pure PVOH in isolation.

The extent of biodegradation after 28 days was 60.4% on average across the six materials. Across the studies, the 28 days value ranged quite broadly, from 38% up to 86%. As outlined above, different study protocols had been used, that are fundamentally equivalent but that nevertheless could result in a different duration of the lag phase or different kinetics. As such, the relevant result to be compared across the studies is the eventual biodegradation percentage, rather than what happens during the first weeks of the study. For 2 out of the 6 materials, the 60% threshold was not reached within 28 days. However, for these specific film materials, the enhanced OECD 301B protocol had been applied with measurements continuing up to 60 days. This showed a biodegradation extent well above the 60% threshold in both cases, demonstrating that the result below 60% on day 28 did not imply a lack of biodegradability. Furthermore, modelling determined that all films would be fully biodegraded in 90 days.

The presented data confirm that the PVOH material used in detergent capsule film materials is biodegradable. As this was shown by means of the stringent OECD ready biodegradability screening tests, due to the conservative design of the studies, these positive results unequivocally indicate rapid and ultimate biodegradation in most environments. These findings are in line with what is reported in the literature on PVOH and on PVOH based detergent films.

Due to its structural similarity to natural biological materials such as cellulose and carbohydrates, PVOH has the potential for complete biodegradation, especially PVOH grades that are highly water-soluble. The structure of PVOH share a common feature with materials like carbohydrates and cellulose which are predominately degraded by microorganisms. Degradation mechanisms have been proposed by which enzymes from microorganisms found in WWTPs (Wastewater Treatment Plants) can biodegrade PVOH. Laundry PVOH biodegradation products are further metabolized by classical B-oxidation pathways and the Krebs cycle, common metabolic pathways employed by microorganisms. That is, the biodegradation is via common pathways found in nature to breakdown paper (cellulose) and vegetable scraps (carbohydrates).

In conclusion, PVOH used in liquid detergent capsule films does not meet any of the definitions of microplastic: it is not micro- or nano-sized; (2) it is highly water-soluble; and (3) it is biodegradable in the environmental conditions where it is discharged. Rather, it is ultimately biodegradable via common pathways found in nature.

Key messages:

- Liquid laundry detergent packs are encased in a film which in part is composed of PVOH.
- The film of these detergents is highly water soluble, also in cold water, as it must fully dissolve during every type of washing process.
- Water-soluble grades of polyvinyl alcohol, the most commonly used detergent capsule film material, are recognized in peer-reviewed literature to be biodegradable.
- The biodegradation of PVOH has been well studied over the last 20 years as evidenced by the many references cited within the recent publication by Byrne et al., 2021.
- The structure of PVOH share a common feature with materials like carbohydrates and cellulose which are predominately degraded by microorganisms. Degradation mechanism have been proposed by which enzymes from microorganisms found in WWTPs (Wastewater Treatment Plants) can biodegrade PVOH. Laundry PVOH biodegradation products are further metabolized by metabolic pathways employed by microorganisms.
- In the current paper, biodegradability is confirmed by means of internationally accepted, stringent ready biodegradation screening tests, across a range of PVOH detergent grade films. These tests can be routinely performed in laboratories and utilize activated sludge (containing microorganisms) from municipal wastewater treatment plants to mimic real-world conditions.
- Because PVOH laundry detergent films are highly soluble in water and biodegradable, they are not microplastics, even as defined by California's proposed definition.
- Furthermore, their biodegradability ensures there is no concern for persistence or accumulation of PVOH from laundry detergent films in the environment. These findings are in line with what has previously been reported in the literature.