Study into the Biodegradation and Ecotoxicity of Aquapak's Hydropol Apparel bag in Municipal effluent streams

Scope

Polyvinyl alcohol (PVOH) is a well-established polymer which is widely used as a solution-cast coating for dishwasher tablets and laundry detergent pods. PVOH is water soluble, inherently biodegradable and non-toxic – unique properties which are well suited to single dose detergent applications where the product solubilises during the wash cycle and is biodegraded within municipal biological effluent treatments as part of its intended use.

Hitherto, PVOH has not become a mainstream packaging substrate because it is difficult to thermally extrude using standard thermoplastic processing equipment. Aquapak has developed proprietary methods to convert PVOH flake into pellets which are compatible with standard thermoplastic processing equipment used to extrude polymer film onto paper or to make mono-film to replace non-soluble/non-biodegradable polyethylene.

The introduction of water soluble and biodegradable packaging film for apparel bags, for instance, potentially extends the biological waste management recovery options beyond home and industrial composting to use the same municipal biological effluent treatments which are currently harnessed to mineralise PVOH associated with single dose detergent products.

Since the solubilised bag material could be discharged into the environment for biological treatment as part of the intended use then the potential impacts need to be evaluated.

This document examines secondary information sources to assess the fate of Hydropol (PVOH) used as apparel bags following polymer dissolution and release into the sewer for biological treatment. Scenarios are developed to determine the potential increase in organic loading which municipal biological treatment plants might receive should this waste management practice be more widely adopted.

Background to the study

Hot water soluble Hydropol bags are designed to dissolve when exposed to water at temperatures above 65^{o}C. These temperatures could be achieved following discharge of 'washing-up' water or for instance recently boiled water which would otherwise go cold if unused. The dissolved Hydropol would be discharged for effluent treatment as part of its intended use, where it is mineralized (biodegraded) together with other biodegradable organics which are generated when crockery/cutlery is washed. Disposing of water-soluble biodegradable Hydropol apparel bags for municipal effluent treatment could provide a complimentary waste management practice to home or industrial composting. However, three important questions remain:

1. Once dissolved, is Hydropol biodegraded within activated sludge plants used by municipal biological treatment plant?
2. Are there any acute and chronic environmental impacts from the usage of Hydropol?

3. Will the use of dissolvable bags increase the organic loading received by the municipal effluent treatment plant?

Effluent treatability of HWS Hydropol within municipal effluents

Schonberger et al (1997)[i] compiled extensive laboratory test data which confirms the biodegradation of PVOH within activated sludge treatment plants which are commonly used in the treatment of municipal effluents. Of the 15 tests described, the extent of biodegradation was noted as follows:

- 7 tests (90% biodegradation or higher)
- 5 tests (80% biodegradation or higher)
- 2 tests (60-75% biodegradation)
- 1 test (29% biodegradation).

It was noted that an activated sludge which is acclimatized to PVOH together with effluent temperatures in excess of 15°C were required if high rates of biodegradation were to be achieved.

Assessment of acute and chronic effects

P&G first introduced its Tide Pod range of laundry detergent pods, with a soluble PVOH coating in 2012[ii]. Since then, soluble PVOH coatings have been widely adopted by many companies for the delivery of 'unit-dose' chemicals for domestic and commercial dishwashers and washing machines. Henkel carried out an in-depth environmental safety assessment of PVOH associated with its liquid laundry detergent[iii]. An extensive set of aquatic toxicological and biodegradation information was collated to develop scenarios on detergent use and to assess the risk associated with the raw material use in the respective scenarios. Dual tests which examined Total Organic Carbon and mineralization to CO_2 qualified PVOH as inherently biodegradable and that a significant proportion would be removed from sewage during biological treatment. The REACH regulations[iv] classify persistent substances as those that display a half-life of 60 days or more in aquatic environments. Since PVOH is inherently biodegradable it was concluded that PVOH is not persistent and does not accumulate in aquatic environments. Acute toxicity data against algae and *Daphnia magna* revealed low toxicity. When extrapolated, it was concluded that chronic effects would not be expected for a range of end-use scenarios. Henkel concluded for all scenarios addressed, that the use of PVOH with its liquid laundry detergent was safe.

Impacts of HWS Hydropol bags on municipal biological treatment effluents

Per capita organic loading (as measured by Chemical Oxygen Demand) received by municipal biological treatment plants were reported to be 49.25[v] and 120g/capita/day[vi]. These values were obtained from municipal plants treating effluent from 7.5 and 9.0 million inhabitants respectively.

What would the increase in organic load be If each inhabitant receives one item/week in a Hydropol bag weighing 20g and choses to solubilise/dispose of the bag with their domestic wastewater?

Daily Hydropol consumption per capita amounts to 3g/day (COD equivalent 5.46g/capita/day). If each person disposes of their Hydropol bag via the municipal sewer then the percentage increase in organic load received by the municipal effluent plant is estimated at 4 and 10% (Table 1).

Table 1 Estimated organic loadings arising from solubilised Hydropol bags

	Population 1	Population 2
COD loadings per capita received by municipal treatment plants (g/capita/day)	120	49.25
COD arising from solubilisation and disposal of Hydropol bag (g/capita/day)	5.46	5.46
% increase in COD arising from solubilisation and disposal of Hydropol bag	4.35	9.98

Conclusions

The scenarios described in this document indicates that PVOH used to make the Hydropol bags could increase the organic load received by a municipal biological treatment plant by between 4 and 10%. These organic loading rate increases would arise only if 7.5 and 9 million people within the two populations examined each received a Hydropol bag weighing 20g and that every person disposed of their Hydropol bag by solubilisation with their domestic wastewater in the same week. The probability of such an event to occur is highly unlikely. Additionally, consumers would also use the range of biological treatments available to them including home and industrial composting as well as solubilisation and disposal with their domestic wastewater.

Summary of findings

In summary:

4. Effluent treatability studies confirm high rates of PVOH biodegradation within acclimatized activated sludge biological treatment processes which are operated at 15°C and above. PVOH is inherently biodegradable and does not persist in the environment
5. Absence of acute and chronic toxicity effects. Acute toxicity data and its extrapolation to evaluate chronic effects indicate low ecotoxicity.

The potential contribution from soluble Hydropol apparel bags to effluent organic strength (as measured by Chemical Oxygen Demand - COD) is considered. Estimates suggest percent COD increases of between 4 and 10%. Whilst these increases in organic load are relatively small yet significant, they would arise only if 7.5 and 9 million people within the two populations examined each received a Hydropol bag weighing 20g and that every person disposed of their Hydropol bag by solubilisation within the same week. The probability of such an event to occur is highly unlikely.

[i] Schonberger, H; Baumann A and Keller W (1997). Study of Microbial Degradation of Polyvinyl Alcohol (PVA) in Wastewater Treatment Plants. American Dyestuff Reporter

[ii] https://www.freedoniagroup.com/Content/Blog/2017/08/03/Water-Soluble-PVOH-The-Material-Behind-the-Booming-Detergent-Pod-Market

[iii] Meier F, Stelter N, Zeese NJ and Tolls J (2013). Raw material supplier and detergent manufacturer cooperate in Environmental Safety Assessment of a new detergent raw material – a case study

[iv] EC (2004) Regulation (EC) No 648/2004 of the European Parliament and of the Council of 31 March 2004 on detergents, Offic. J EU. L104,1

[v] Mesdaghinia *et al* (2015). The estimation of per capita loadings of domestic wastewater in Tehran. J Env. Sci. Eng. 15:25

[vi] Vaccari M; Foladori P, Nembrini S and Vitali F (2018). Benchmarking of energy consumption in municipal wastewater treatment plants – a survey of over 200 plants in Italy. Water Sci Technol (2018) 77 (9): 2242–2252