Aquapak Polymers Ltd

Hydropol™

A Circular Economy Plastic

Prepared by:

Dr J.R Williams CTO

www.aquapakpolymers.com
Introduction

Aquapak has a range of formulated plastic materials in thermo-processible pellet form marketed under the trade names Hydropol™ and Cytopol™. The base polymer for these products is polyvinyl alcohol, and by careful combination of different hydrolysis levels in a patented process, several products can be produced with specific functionality for end applications. However, the products are also formulated in such a way as to retain the inherent properties of the base polymer not only in terms of functionality but also solubility and end of life.

Aquapak’s patented technology changes the characteristics of the polyvinyl alcohol from those normally seen in the standard flake format of this material. The tensile and barrier properties of the subsequent processed pellets, when extruded into a blown film, for example, are markedly improved.

Polyvinyl alcohol was first synthesised in the early 1920s but despite its promising properties, it was rapidly overtaken by what are now conventional polymers such as PE, PP and PET. This is because it is very difficult to process into a usable form for what became standard plastic processing, for example, blown film extrusion, or injection moulding. There are several global manufacturers of the polymer, but a high percentage of the material is used as an intermediate to produce other polymers, such as PVB.

The polymer has a structure which has the typical long carbon chain of most polymers but with OH (hydroxyl units) fixed to the carbon chain. The number determines the degree of hydrolysis and therefore the degree of solubility. Typically, for the polymer to dissolve in cold water, the hydroxyl level is around 88% or less. The higher the hydrolysis the greater the resistance to solubility in water at ambient temperature but the greater the application potential and functionality. The relatively low percentage of polyvinyl alcohol which is currently used in single material applications is nearly all partially hydrolysed (cold water soluble) with some high hydrolysis material used in specialist applications only, like textile sizing.

The most usual method of manufacture of this polymer from the base resin is by dissolving it in water and then using the solution either directly or by producing a film via evaporation. This is complicated and expensive. Another complication is that, in processing, the higher the hydrolysis the less stable is the solution, as gelation occurs. As a result, fully hydrolysed solutions account for a low percentage of the polymer in circulation, and they cannot be stored for any length of time without degradation.

Aquapak has, after 10 years of R&D, perfected a method of thermally processing PVOH allowing the production of pellets, which is the standard form for secondary processing in the plastics industry. Aquapak’s global patent is a combination of process know-how and chemistry.
Aquapak’s products are in pelletised form at all hydrolysis levels, including high hydrolysis to maximise application potential. As they are available as standard plastic pellets, stability and storage is not an issue.

The availability of a stable pellet form enables the excellent functionality of the base polymer to be exploited more widely, namely:

- High tensile strength
- Water soluble
- Excellent puncture resistance (films)
- Heat sealable
- Excellent barrier to Oxygen, Nitrogen and Carbon Dioxide
- Highly resistant to oils, fats, grease, solvents
- Good Clarity (films)
- Natural electrostatic dissipation
- Natural uv resistance
- Readily printable without surface treatment
- Recyclable/Repulpable
- Biodegradable

However, the last two listed properties in combination with the primary functionality make a Hydropol a true circular economy material.

Aquapak’s products have the capability to manufacture finished products which are recyclable, recoverable and biodegradable.

**Circular Economy**

A major concentration of circular economy initiatives and pressure is to solve the problem generated in the packaging sector. There has been a major disconnect between the packaging providers, the government and the waste management industry, and hence the proliferation of Single Use Plastics with End of Life in landfill or incineration.

Packaging, whilst vital for modern living, is highly visible and often misunderstood by the consumer. The packaging manufacturers, users and retailers are seeing are being subjected to increasing media and consumer targeting by both official channels (global policy) and NGOs, and plastics is particularly under the spotlight.

Whilst there are a few examples of unnecessary packaging, which are easy targets for criticism, there are now some fundamental questions being asked about this market sector. **How, for example, do the manufacturers, brands and retailers continue to provide products which are convenient, safe and attractive but, at the same time, have a satisfactory answer to what happens to the package after its primary use?** Undoubtedly criticism will be aimed at other sectors, but packaging is at the forefront and therefore likely to set the benchmark for all circular economy initiatives.

Clearly the aim is to continue to provide/improve the functionality of the packaging but in addition have meaningful and economically feasible routes to dealing with it after its primary use.

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Recycling has been a theme and often a policy driver in many countries over the last 20 years and the obvious suspects, metal and glass, have largely been successfully dealt with, but plastics and materials with plastic content have proved to be a major issue. The principal characteristic that makes plastic such a dominant packaging material is its versatility, but this has been mostly achieved at the expense of making them complex. This complexity of material combinations inevitably leads to confusion for the consumer and to a high level of cost of handling to the waste industry.

In waste management, the development of more sophisticated identification and sorting is a great step forward but unfortunately (unless the penalty becomes very severe) adoption is at a relatively low level due to the lack of cost-effectiveness of recovering the different combinations of complex materials. There is therefore an increasing realisation that identification, sorting, and separation technology is not the entire answer, and that the key is to find a combination of new (less complex) packaging design and the introduction of new materials, which can offer multiple end of life options but retain/enhance functionality in primary use.

**Global Commitment to the New Plastics Economy**

Over the past four years, the Ellen MacArthur Foundation’s New Plastics Economy initiative has rallied businesses and governments behind a positive vision of a circular economy for plastics. Its 2016 and 2017 New Plastics Economy reports captured worldwide headlines, revealing the financial and environmental costs of waste plastic and pollution.

The initiative is supported by Wendy Schmidt as Lead Philanthropic Partner, the Global Environment Facility (GEF), MAVA Foundation, Oak Foundation, and players of People’s Postcode Lottery (GB) as Philanthropic Funders. Amcor, The Coca-Cola Company, Danone, L’Oréal, MARS, Incorporated, Novamont, PepsiCo, Unilever, and Veolia are the initiative’s Core Partners.

**Further information:** newplasticseconomy.org | @NewPlasticsEcon

Aquapak has signed up to the Global Commitment of the Ellen Mac Arthur Foundation to eliminate plastic pollution at source. It is one of the few raw material suppliers of polymers that has done this.

More details on all of the above can be found in Appendix 1.

**Aquapak Applications & Recyclability**

Aquapak’s products are undergoing technical and commercial trials in a range of applications (Film, Laminates, Extrusion coating, Thermoforming, Injection Moulding) where the packaging market have major challenges in delivering functionality and a true Circular Economy solution. Two key areas are discussed in more detail below:

1. **Replacing Barrier films and reducing layers in multi-laminates**
Ability to replace barrier and tensile layers in multiple layer laminates thereby minimising layers without functional penalty. Additionally, printing without pre-treatment and removal of tie layers adds another simplified dimension. A simple hot water wash system can then remove the Aquapak layer enabling the other materials to be cleanly separated. If sandwiched, then it allows the possibility of flaking the laminate and removing by hot wash.

Aquapak material has a unique IR signature allowing any more sophisticated plastic recovery process to identify and separate it. If hot wash is used, then the Aquapak solubilised polymer can be dealt with safely by 3 methods:

1. Biodegradation in standard waste water treatment
2. Biodegradation in any available anaerobic digestion system
3. If in enough concentration recovery of the virgin polymer from solution (Aquapak IP)

2. Replacing barrier layers in paper and board packaging systems.

Currently the plastics used to enhance the functionality of paper and paperboard are non-recoverable, non-recyclable. Whilst there are examples of brands putting in place collection of their specific product for material capture these are rare and often fraught with the problem of contamination.

Aquapak’s materials give the necessary functionality to the product but offer two direct recovery options:

(i) No requirement to separate from the paper/paperboard as the combination can be repulped in an industry standard paper recovery process. Aquapak product is entirely compatible and may also decrease the requirement for added paper strengthening chemicals in the process.

(ii) As in recycling the layer can be hot washed to remove it allowing clean paper/paperboard to be recycled. This is particularly relevant in more complex laminate combinations.

Repulpability - Aquapak has successfully developed intermediate hydrolysis grades which demonstrate excellent adhesion to paper and paperboard with enhanced barrier properties. The Hydropol 33 series grades have been independently tested for repulpability (mimicking a standard paper recycling mill typically at a repulping temperature of 40°C) and have all passed the testing protocols.

Summary of findings:

- Hydropol 33100 (33100 represents the same chemistry as the 33 series) coated paper disintegrates with complete dispersion of fibres when repulped at 40°C and above (coating is almost non-detectable when repulped at 20°C) -meets criteria outlined in ISO 5263-1 Laboratory Disintegration of chemical pulps

- No evidence of Hydropol coating on mesh 8 with Bauer McNett fractionation-indicates complete polymer dissolution and fibre dispersion

- Solubilised Hydropol at high loading rates appears to have no effect on paper

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sheet properties in the case of recycled grey board furnish. For virgin copier paper furnish, no effects were noted for bulk, roughness (bottom), tear index, drainage and Schopper. Slight changes were noted for porosity, roughness (top), burst index, tensile index and freeness.

- Hydropol coated paper would repulp and release valuable fibre for paper and board manufacturing
- Hydropol coating would dissolve and would NOT form part of ‘mill rejects stream’ (Note: valuable fibre is entrained and lost with mill rejects (yield loss); rejects are costly to dispose for mills without waste to energy systems).
- Hydropol coating appears not to be substantive to fibre and unlikely to contribute either positively or negatively to paper sheet properties
- Hydropol coated paper could be recycled with Mixed Paper or OCC at packaging mills
- Segregated Hydropol coated paper e.g. coated white food board could be recycled at virgin-fibre based mills
- Effluent from Grey board+ Hydropol coated paper (20%) did not inhibit activated sludge bacterial respiration rates (i.e. no acute toxicity)
- Treatability of Hydropol by mill effluent treatment systems (DAF, AD and activated sludge).

Full Report is available in Appendix 4.

Aquapak is working in several projects with global brands, major converters and waste and recyclers to demonstrate the above recycling and recovery solutions at scale. Whilst many of these projects are commercially sensitive Aquapak will provide information and results where possible.

Biodegradation

Plastics can degrade via different mechanisms: thermal, chemical, photo and biological degradation. The degradation of plastics is a physical or chemical change in polymers that occurs as a result of environmental factors, like light, heat, moisture, chemical conditions or biological activity. Biodegradation is a bio-chemical process that refers to the degradation and assimilation of polymers by living microorganisms, to produce degradation products.

Biodegradation is defined as any physical or chemical change in a material caused by biological activity. Microorganisms such as bacteria, fungi and actinomycetes are involved in the degradation of both natural and synthetic plastics. Plastics are usually biodegraded aerobically in nature (including marine), anaerobically in sediments and landfills and partly aerobically in compost and soil. Carbon dioxide and water are produced during aerobic biodegradation, while anaerobic biodegradation produces carbon dioxide, water and methane.

Aerobic Biodegradation

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Also known as aerobic respiration, aerobic biodegradation is an important part of the natural breakdown of complex materials. Aerobic microbes use oxygen and break down organic chemicals into smaller organic compounds. CO\(_2\) and water are the by-products of this process.

\[ \text{C plastic} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{C residual} + \text{Biomass} \]

**Anaerobic Biodegradation**

Anaerobic biodegradation is the breakdown of organic contaminants by microorganisms when oxygen is not present. Some anaerobic bacteria use nitrate, sulphate, iron, manganese and carbon dioxide to break down organic chemicals into smaller compounds.

\[ \text{C plastic} \rightarrow \text{CH}_4 + \text{CO}_2 + \text{H}_2\text{O} + \text{C residual} + \text{Biomass} \]

In order to use such materials as a carbon and energy source, microbes developed a strategy in which they excrete extracellular enzymes that depolymerize the polymers outside the cells. A hydrophilic (water-liking) polymer like Hydropol reacts fastest. Extracellular and intracellular depolymerize enzymes are actively involved in biological degradation of polymers. During degradation, microbial exoenzymes break down complex polymers, yielding short chains or smaller molecules like oligomers, dimers and monomers. These molecules are small enough to be water-soluble and can pass through the semi-permeable outer bacterial membranes to be used as carbon and energy sources. This initial process of breaking down polymers is called depolymerization; and when the end products are inorganic species (e.g., CO\(_2\), H\(_2\)O, or CH\(_4\)), the degradation is called mineralization.

**Mechanism of Biodegradation**

Biodegradation of polymers involves following steps:

1. Attachment of the microorganism to the surface of the polymer.
2. Growth of the microorganism, using the polymer as a carbon source.
3. Ultimate degradation of the polymer.

Microorganisms are able attach to a polymer’s surface, if the latter is hydrophilic. Once the organism is attached to the surface, it can grow using the polymer as its carbon source. In the primary degradation stage, the extracellular enzymes secreted by the organism cause the main chain to cleave, leading to the formation of low-molecular weight fragments, like oligomers, dimers or monomers. These low molecular weight compounds are further used by the microbes as carbon and energy sources. Small oligomers may also diffuse into the organism and get assimilated in its internal environment. These reaction pathways are illustrated below:
Factors Affecting the Biodegradation of Plastics

The biodegradability of a polymer is essentially determined by the following physical and chemical characteristics:

1. The availability of functional groups that increase hydrophobicity (hydrophilic degradation is faster than hydrophobic). Hydropol is hydrophilic.

2. The molecular weight and density of the polymer (lower degrades faster than higher).

3. The morphology: amount of crystalline and amorphous regions (amorphous degrades faster than crystalline).

4. Structural complexity such as linearity or the presence of branching in the polymer.

5. Presence of easily breakable bonds such as ester or amide bonds.


7. The nature and physical form of the polymer (e.g., films, pellets, powder or fibres).

8. Hardness (Tg) (soft polymers degrade faster than hard ones)

Aquapak’s materials, being based on PVOH a hydrophilic and water-soluble polymer, are inherently biodegradable, that is, given the right balance of environment and microbial presence it will biodegrade to carbon dioxide, water and mineralised natural biomass.

This is a complicated area and some caution is required to ensure the correct paths are chosen. For the purpose of this paper it will be divided into two parts, firstly captured and controlled biodegradation and secondly uncontrolled, environmental release.

(a) Composting.

Aquapak material in thin film form will compost. Tests have been undertaken with third party test houses (OWS and TUV Vincotte) on fully hydrolysed 30 series films only at 3 different gauges (15, 25 and 35 micron). The testing protocol was carried out according to EN13432 criteria.

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The average disintegration percentage of test material 30124 (15 µm) is 92.9%. The 90% pass level as required by the standards was reached. The 25- and 35-micron film samples did not achieve the disintegration in the time designated by the Standard. However, a 15-micron Aquapak film is 2-3 x stronger than a PE or Biobag of the same gauge.

It should be noted that Aquapak has not moved to certify the film as the samples were internally produced on our pilot equipment for indicative purposes only. The test was undertaken to establish the compostability of the film. It is normal commercial practice that the product actually entering the market from the producer requires certification to substantiate a claim.

Aquapak is undertaking more work on other grades in the coming months and updates will be included here.

(b) Anaerobic Digestion (AD)

AD is commonly used as treatment for organic waste in waste water systems, silage production and food waste.

There are two AD processes in commercial systems:

1. Thermophilic (operating at a temperature of 55-60°C)
2. Mesophilic (operating at a temperature of 33-37°C)

Thermophilic is the more aggressive and breaks down organic matter faster and without Agitation. Typically used for food waste and particularly that containing animal by-products.

Unusually, as most plastics are not, Aquapak films are compatible in AD systems. Clearly the gauge of the film, hydrolysis of the product and the type of AD system are critical. Thicker gauges (30-35 micron) of both fully and partially hydrolysed film will breakdown in thermophilic units within the normal operating dwell time. The thicker gauges of fully hydrolysed film do not meet the requirements of a mesophilic unit.

The mechanism looks like it is associated with the material dissolving or starting to dissolve allowing the residence activity of the microbes to have time to break the material down. Laboratory tests have been conducted both at the Open University and OWS defining breakdown times and looking in detail at fragmentation mechanisms. A trial was undertaken at a UK waste facility which successfully processed 30-micron Aquapak film through its AD system and post analysis showed no fragments in the bio digestate or residence in the digester.

Further work is ongoing to capture more data including working with third party accredited test laboratories test methods and scale trials at both waste facilities and Paper Mills.
A literature review is shown in Appendix 2 referencing several papers on the biodegradation of polyvinyl alcohol. There is clear evidence that polymer entering the waste water stream, for example, is successfully acclimated in the process yielding harmless by-products.

There appears to be a link to acclimated microbes and the historical use of polyvinyl alcohol, particularly in textile operations and subsequently in detergent tablets, which has “taught” the microbes in waste water treatment to process it efficiently. Further work will be undertaken to confirm that viable product types using Aquapak material are fully processed, which includes continuing work with UK water companies to both demonstrate and model the material flows. A project is currently being scoped to work with the Water Research Council (UK) and Southern Water to confirm the safe disposal and provide extra data for the behaviour of Hydropol in waste water systems.

The Environment and Uncontrolled Release

**Plastics are not designed to be disposed of in nature**

Unfortunately, materials of all types enter the environment in an uncontrolled way and plastics being a mass produced and visible substance inevitably attract the most attention. Nearly all plastics, and certainly the most used, are hydrophobic (water-hating) materials which not only take hundreds-thousands of years to break down but often produce toxic breakdown products as they do.

There are clear advantages to switching to plastics which have better environmental credentials such as hydrophilicity (water-liking) which promotes faster breakdown in soil, water, etc. Ideally such plastics should not cause any toxicological issues as they breakdown.

Aquatpak material meets this requirement whilst still delivering primary functionality.

(a) Marine/Ocean

A major concern given the amount of toxic plastic waste in the oceanic environment. Clearly no one wants to deliberately release plastics into the environment but unfortunately it is present and a major global concern. The main issues are the accretion of toxins into the plastics causing long term effects on marine flora and fauna which can then enter the food chain, and the longevity of the material causing direct macro pollution as seen in the many cases of marine mammals’ entanglement and digestive blockages.

All our commonly used plastics are hydrophobic (water hating) which necessarily means they resist the water they are in and attract other hydrophobic materials to them such as pesticides and other toxins. This allows for these plastics to concentrate toxins in combination with longevity – a perfect storm.

Aquatpak’s material is hydrophilic (water liking) and has no propensity to attract toxins or form toxic micro plastics and is itself non-toxic to marine fauna as defined by tests conducted by the Open University. This toxicity screening has been tested by OWS (Belgium) using the Daphnia test protocol for ASTM D6691 and OK Marine.
Aquapak 30 series products represented by Hydropol 30110, and 33 series products represented by Hydropol 33101 which represents a family of grades have successfully proven non-toxicity under the test protocol. From these results it can be concluded that the addition of 0.1% Hydropol 30110 HWS and 33101 WWS to a chemically defined (mineral) aqueous medium that was spiked with micro-organisms, does not exert a negative effect on the mobility of Daphnia magna after a 91 days incubation period at 30°C (±2°C). The environmental safety requirement of the OK biodegradable MARINE certification scheme of TÜV AUSTRIA Belgium was fulfilled for sample Hydropol 30110 HWS. (see Appendix 5 for test report).

Ocean conditions vary, and it is too early to say how quickly Aquapak material will break down but the fact it is non-toxic and safely digestible reduces the problem hugely. This is a major problem with old existing standards as they are now known to not accurately reflect the biodegradation and toxicity of plastics in marine conditions. Standards are now under review.

Hence Aquapak is undertaking a 2-year programme of research starting in September 2019 with Prof. Theodore Henry at Institute for Life and Earth Sciences at Heriot-Watt University (see profile below) to look at macro effects and eco-toxicity modelling. Testing and modelling will involve not only Aquapak material in various forms (monolayer film, coex constructions, laminates and extrusion coating) but a comparison with existing common plastics.

The observations, findings and results will be published, and updates as the research progresses will be included in further editions of this White Paper together with Aquapak’s website.

Prof. Henry profile: His research interests are focused on issues of environmental toxicology that impact aquatic ecosystems on a global scale and working with stakeholders to resolve these issues. He is particularly interested in warmwater environments and the environmental fate, bioavailability, and toxicology of pollutants.

He directs the Ecotoxicology and Pathophysiology of Aquatic Organisms Research Program which investigates organism responses and pathophysiology across levels of biological organization. His team are particularly interested in evaluating expression profiles of target gene transcripts that are involved in biological processes and evaluating how these profiles relate to activity of gene products and higher order responses at tissue (histopathology), organism (behaviour, reproduction), and population levels.

Manipulations include stressors such as toxicant exposure, particle exposure (engineered nanomaterials, microplastics), pathogen exposure, thermal stress, and alterations of water chemistry (e.g. acidification). Research organisms include mostly fresh and saltwater fishes but also various aquatic invertebrates. They are especially interested in contaminant issues that impact the ecological services of aquatic environments in vulnerable ecosystems and working with stake holders to manage these issues.

(b) Fresh water

There are current test methods and Standards for the biodegradation of polymers in
freshwater systems (ISO 14851). Some of this work has been covered in the original Open University work (under a UK government Department of Environment, Farming & Rural affairs programme) – see Appendix 3. Showing Aquapak material to be harmless. Further accredited tests are planned to look at the behaviour of the most likely Aquapak material to enter this environment, film and coated paper, in October 2019.

(c) Soil

Again, some aspects have been looked at already in the Open university work and the composting tests. It is expected that Aquapak film and thin extrusion coated products will not be a problem in this environment given the positive test results so far. There are two aspects to soil biodegradation.

1. The usage of plastic films in agricultural and land management which has accredited international standards. Aquapak will engage in official testing protocols in November 2019.

2. Littering of plastics. Aquapak is involved in working with BSI in supporting a test methodology (PAS) development for littering of plastics. This work will start in 2020. Clearly littering is a challenging environmental and social issue and any material deliberately littered has a disproportionate impact mainly because of visibility. It is likely given the nature of Aquapak materials that they will not dwell in the environment like standard plastics and do not have the toxic hydrophobic microplastic formation. Aquapak will continue to work with regulators and NGOs in this area.

(d) Landfill

Tests will be undertaken (ASTM D-5511) in early 2020 which determine biodegradation in high solids anaerobic conditions like that found in wet managed landfill. However, given the positive results for Aquapak products in controlled AD conditions it is not anticipated the material will cause an issue.

Standards & Test Methods

There are over 600 standards and test for plastics globally. Some are very similar in their methodology having been developed at the individual national level. Others have become adopted or are becoming adopted through ISO as internationally recognised standards.

Aquapak follows national and international protocols appropriate to the testing of our products and works closely with end users, converters, designers and NGO’s to ensure we are compliant.

In the assessment of the behaviour of plastics in the natural environment many test methods and Standards have been found to be unsuitable as they do not reflect the true behaviour of the plastic. An additional complication with Aquapak is that the hydrophilic nature of the material and the fact that in certain situations the material dissolves in water presents further challenges to the existing protocols.

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We will continue to test appropriately but also, as in the marine project, aim to add to the knowledge internationally and ensure a much more fact-based approach is adopted and plastics are assessed on their actual environmental behaviour and not a theoretical test model.

Test results will be included in White Paper updates and added to the latest versions of our technical data sheets.

Example of some of the more pertinent tests and Standards are listed below:

1. Determination of biobased content: CEN/TS 16137; ASTM D6866
2. Compostability: EN 14995; EN13432; ASTM D6400; ISO 17088; AS4736; ISO18606; ASTM D6868
3. Anaerobic Digestion: ISO 15985; ASTM D5511
4. Soil: ISO 17556
5. Freshwater: ISO 13975; EN14987
6. Landfill: ASTM D 5526
7. Aerobic wastewater & sewage sludge: EN14851; EN14852
8. Anaerobic wastewater: EN14853
9. Marine: ASTM D6691; OK Marine; ISO 18830 (floating); ISO 19679 (sediment)
10. Recycling: ISO 15270 Guidelines for the recovery and recycling of plastics waste
11. Plastic waste: EN15347

**Life Cycle Assessment & Environmental Product Declaration**

Aquapak is now a fully operating commercial producer operating in a purpose-built factory. It is now ready to undertake a full independent assessment (LCA & EPD) under ISO 14000 environmental management protocol.

Currently this assessment is being scoped and the expected start date is January 2020.

John R Williams  
Dr John R Williams (Technical Director)  
Aquapak Polymers Limited

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Appendix 1

The New Plastics Economy and Global Commitment

At the heart of the Global Commitment is a vision of a circular economy for plastic, where plastics never become waste. Each signatory formally endorses the vision and the need to work towards achieving it.

It is defined by six key points:

- Elimination of problematic or unnecessary plastic packaging through redesign, innovation, and new delivery models is a priority
- Reuse models are applied where relevant, reducing the need for single-use packaging
- All plastic packaging is 100% reusable, recyclable, or compostable
- All plastic packaging is reused, recycled, or composted in practice
- The use of plastic is fully decoupled from the consumption of finite resources
- All plastic packaging is free of hazardous chemicals, and the health, safety, and rights of all people involved are respected

The Global Commitment aims to create ‘a new normal’ for plastic packaging, with signatories committing to:

- Eliminate problematic or unnecessary plastic packaging and move from single-use to reuse packaging models
- Innovate to ensure 100% of plastic packaging can be easily and safely reused, recycled, or composted by 2025
- Circulate the plastic produced, by significantly increasing the volumes of plastic reused or recycled into new packaging

By providing previously unpublished data and setting out commitments side by side, a report has been published to start the process of achieving a new level of transparency about today’s plastic system and efforts to stop plastic waste and pollution.

The decision by more than 30 companies to publicly disclose their annual plastic packaging volumes in the report is an important step towards greater transparency. We encourage all companies that make and use plastics to disclose their plastics footprint.

The report shows welcome progress in increasing the amount of recycled content in plastic packaging, and the phasing out of non-recyclable materials. The recycled content targets for plastic in packaging jointly represent 5 million tonnes by 2025. This is the biggest ever commitment to use recycled plastics in packaging and provides clear demand for increased investment in high-quality recycling and will result in a significant reduction in virgin plastics production.

However, while improving recycling is crucial, we cannot recycle our way out of the plastics issues we currently face. Elimination of problematic or unnecessary plastic packaging through redesign, innovation, and new delivery models is a priority. Reuse models need to be applied where relevant, reducing the need for single-use packaging. All of this is an explicit part of the
Global Commitment vision, endorsed by all 350+ signatories.

**New Plastics Economy lead Sander Defruyt** said: “The targets and action plans set out in this report are a significant step forward compared with the pace of change of past decades. However, they are still far from truly matching the scale of the problem, particularly when it comes to elimination of unnecessary items and innovation towards reuse models. Ambition levels must continue to rise to make real strides in addressing global plastic pollution by 2025 and moving from commitment to action is crucial. Major investments, innovations, and transformation programmes need to be started now, to realise the impact by 2025.”

**Lisa Svensson, UN Environment, Coordinator of the Marine and Coastal Ecosystems Branch,** said: “UN Environment is delighted to be working with the Ellen MacArthur Foundation to help turn the tide on plastic pollution. Within just a few months of the launch of the New Plastics Economy Global Commitment we have seen important progress. The Foundation’s work to create a circular economy for plastic aligns very well with our Clean Seas campaign, which has become the biggest global compact addressing marine plastic.”

Read entire vision here: [https://newplasticseconomy.org/assets/doc/npec-vision.pdf](https://newplasticseconomy.org/assets/doc/npec-vision.pdf)

More than 250 organisations, representing every part of the plastics system, signed the commitment when it was launched in collaboration with UN Environment in October 2018. Since then the number of signatories has risen to more than 350 and now includes Barilla, Tetra Pak, and L’OCCITANE en provence, as well as the Government of Rwanda and the cities of São Paulo (Brazil) and Ljubljana (Slovenia). Financial institutions with over USD 4 trillion in assets under management have endorsed the commitment.

Further details of the commitment are:

- First New Plastics Economy Global Commitment report reveals targets and initial steps by Global Commitment signatories to eliminate plastics waste and pollution

- Major companies including Carrefour, Colgate Palmolive, Danone, MARS, Incorporated, Nestlé, SCJohnson, The Coca-Cola Company, and Unilever publish data on their annual plastic packaging volumes, most of them for the first time

- Consumer goods companies and retailers commit to increase recycled content in their packaging to an average of 25% by 2025, compared with the current global average of just 2%

- Leading businesses and governments will end the use of problematic and unnecessary plastic including PVC and single-use plastic straws and carrier bags, many of them by the end of this year. 40 brands and retailers are piloting or expanding reuse and refill schemes

- The Ellen MacArthur Foundation welcomes these initial efforts, but calls for more action to eliminate problematic and unnecessary plastic packaging, and a greater shift to reuse delivery models that reduce the need for single-use packaging

- Number of Global Commitment signatories rises from 250 to more than 350. New Version 22 August 2019
signatories include Apple, Barilla, Tetra Pak, L’OCCITANE en provence, Government of Rwanda, and the cities of São Paulo (Brazil), and Ljubljana (Slovenia). Financial institutions with over USD 4 trillion in assets under management have endorsed the commitment.

National-level efforts to put the Global Commitment’s vision into practice include a growing network of Plastic Pacts. These collaborations between government, NGOs, and businesses focus on creating country-specific circular economy solutions to plastics waste. The UK launched the first Plastics Pact in April 2018 and the French pact was launched last month. The Chilean government has announced plans to do the same later this year. All countries are signatories to the Global Commitment.


The New Plastics Economy will publish a further report on signatory progress in Autumn 2019, and every year following.

This work builds on the Ellen MacArthur Foundation’s New Plastics Economy initiative, set out a few years ago in collaboration with UN Environment. This established a vision to stop plastic waste and pollution at source by applying circular economy principles.

The leading drivers behind current initiatives are:

**THE ELLEN MACARTHUR FOUNDATION**

The Ellen MacArthur Foundation was launched in 2010 to accelerate the transition to a circular economy. The Foundation works across key areas including insight and analysis, business and government, learning, systemic initiatives, and communications. With its Knowledge Partners (Arup, IDEO, McKinsey & Company and SYSTEMIQ), the Foundation works to quantify the economic opportunity of a more circular model and to develop approaches for capturing its value. The Foundation collaborates with its Global Partners (Danone, Google, H&M, Intesa Sanpaolo, NIKE Inc., Philips, Renault, SCJohnson, Solvay, Unilever), Core Philanthropic Funders (SUN, MAVA, players of People’s Postcode Lottery (GB)), and its CE100 network (businesses, universities, emerging innovators, governments, cities, affiliate organisations) to build capacity, explore collaboration opportunities, and to develop circular business initiatives.

**Further information:** ellenmacarthurfoundation.org | @circularconomy

**UN ENVIRONMENT**

UN Environment is the leading global voice on the global environment. It provides leadership and encourages partnership in caring for the environment by inspiring, informing, and enabling nations and peoples to improve their quality of life without compromising that of future generations. UN Environment works with governments, the private sector, civil society and with other UN entities and international organisations across the world.
GLOBAL PLASTICS ACTION PARTNERSHIP (GPAP)

GPAP is a global public-private platform for collaboration to help translate political and corporate commitment to address plastic pollution into tangible strategies and investible action plans. GPAP brings together governments, companies, civil societies and think-tanks to avert plastic pollution from source to sea by 2025, by fast-tracking circular economy solutions.

Further information: weforum.org | @wef
Appendix 2

References on behaviour of PVOH in the environment particularly in waste water


Schonberger, H. Baumann,A. Keller,W. “Study of Microbial Degradation of Polyvinyl Alcohol (PVA) in Wastewater Treatment Plants”, American Dyestuff Reporter, August 1997


DuPont (a), Technical Bulletin, Biodegradation of Elvanol polyvinyl alcohol (publication date unknown)

DuPont (b), Technical Bulletin, PVOH recovery in textile industry; separation systems (publication date not known)


Suzuki T and Tsuchii, A (1983), Process Biochem, 18 (December), 13-16


Wheatley, Q D, Baines, F C, (1976) Textile Chemistry & Colorists, 8(2), 28

1 Executive Summary

This project addressed the Department for Environment, Food and Rural Affairs (DEFRA) desire for a biodegradable single-use carrier bag that breaks down into harmless by-products in a variety of different organic waste treatment processes (composting and anaerobic digestion) and in various natural environments (marine and terrestrial). In response to this, this project investigated whether a polyvinyl alcohol (PVOH) based carrier bag would satisfy these criteria. Moreover, because unfortunately not all plastic based products are captured at the end of their life by recycling and/or waste treatment processes, this project examined any risk that a hydrophilic polymer-based product may pose to marine life and the aquatic food web. At the request of the DEFRA, the project was not
designed to be an in-depth study of one environmental compartment, rather than a broad indication of biodegradation and ecotoxicity in many different environments. To achieve these aims the project was split into four work packages:

- Biodegradation under simulated waste treatment environments
- Microbial optimisation and acclimation of simulated waste treatment processes
- Biodegradation in the natural environment
- Aquatic food web impact

The following outlines the methods and research findings in each of these work packages:

**Biodegradation under simulated waste treatment environments**

This package investigated the biodegradability of PVOH filmic material under simulated industrial composting and anaerobic digestion conditions. To determine the aerobic (with oxygen) compostability of a PVOH filmic material the following assessments were undertaken: product environmental impact (characterisation of heavy metal component), biodegradability, disintegration & compost quality. In summary, the PVOH material provided by Aquapak Polymers Limited contained only trace levels of metals that were well within environmental acceptable limits. The material was not biodegradable under simulated idealised composting conditions (BS EN ISO 14855-1:2012 methodology; analysis by evolved CO₂) using a stabilised (composted) green waste or within fresh food waste. Biodegradability in these experiments required 90% of the total carbon within the test material to be transformed into biomass, water and gas. The PVOH material achieved 7%, a figure that is likely to correlate with the glycerol content of the film. The PVOH film did pass acceptable levels of disintegration over a 12-week simulated test; likely due to the hydrophilic (water absorbing) properties and mechanical sheering forces induced when turning the experimental vessels.

Anaerobic biodegradability experiments were undertaken following BS ISO 14853 methodology, at 35 °C and 60 °C in anaerobic sewage sludge and food waste. In both food inoculum (substance used to inoculate, in this case, the microbiology associated with industrial anaerobic digestion) and sewage sludge, total anaerobic degradation was highest in the 35 °C conditions. In all conditions, PVOH showed both the highest biogas generation and percentage degradation when compared to other test plastics (low density polyethylene and a certified compostable biobased plastic (poly lactic acid)). At best, PVOH showed a 20% degradation in the 35 °C food waste inoculum, this however falls below the >70% required for a biodegradable label/certification in this type of environment. These results show that PVOH might be deemed ‘biocompatible’ as it contributes to biogas production above and beyond other types of plastic.
Biodegradation in the natural environment.

The biodegradability of PVOH in the marine and terrestrial environment was assessed in this work package. The ASTM method D6691-09 was used as the basis for the marine simulation experiment, where a natural sea water was used as the inoculum and respiration (evolution of CO$_2$) was used as the measure of degradation. Experiments were undertaken at 15 and 30 °C. The terrestrial experiments buried PVOH in five different soils types over the course of one year, with samples analysed at time zero, six and 12 months for changes in in polymer structure using Fourier transformed infra-red spectrometry (FT-IR). In all soil types, changes in ratio of focal peaks were apparent after two months exposure, indicating differing breakdown rates in the selected bonds. Comparison of the initial and final spectra of PVOH indicated the largest reduction in relative absorbance of the peak at 1088.59 cm$^{-1}$; however, when examined as a percentage decrease, 1418.93 cm$^{-1}$ showed the greatest reduction. This absorbance is likely identifying alcohol related bonds in the plastic and therefore suggestion that the early onset of microbial degradation is focused on alcohol groups.

Aquatic food web impact

It is well documented that plastic materials inadvertently enter the marine environment and the food chain/web. The aims and objective of this work package was to assess any environmental and/or ecological impact of PVOH filmic material in aquatic environments. Baseline assessments were made of the underlying chemical and microbial community alternations due the presence of PVOH in freshwater and marine waters. In closed experiments it was shown that the addition of PVOH added a selection pressure that changed the diversity of the microbial community, as well as the amount of organic and inorganic carbon, which were expected results. The ecotoxicology experiments examined the effects of PVOH on different species along the food web. The presence of PVOH film dissolved in freshwater at realistic contamination concentrations had no deleterious effect on growth rate of the algal species *Selenastrum capricornutum*. Moreover, at concentrations lower than 50 g L$^{-1}$ the presence of the polymer enhanced growth of the algae. Equally, there were no deleterious effect from dissolved PVOH on water fleas at 0.001, 0.01, 0.1, 1 &10 g L$^{-1}$ of PVOH in terms of loss of swimming and death rate. The ecotoxicological effects of PVOH on *Homarus gammarus* (European lobster) were examined by exposing them to pelleted food combined with ground microplastic films (<180 µm) for 6 hours per day over 30 days. To determine the effect of microplastic on growth, nutritional state, the carapace length, hepatosomatic index and hepatopancreas water content were determined. There were no significant differences between PVOH treatment and control after 30 days in all but one of the measures. Post hoc tests indicated that there was reduced growth in the PVOH condition.

The presence of PVOH in aquatic environments had no adverse impacts on key indicator species of algae and water flea.
Appendix 4

Repulpability assessments of Hydropol coated papers
Objectives

1. To confirm repulpability of Hydropol coated papers

2. To determine the impact of solubilised Hydropol coating on paper sheet properties (strength etc)

3. To assess the impacts of solubilised Hydropol coating on process water quality and secondary biological treatments which are currently used by papermills
Test samples
Control ‘base paper’ (L) – chemical pulp, 72gsm coated on one side with modified starch.

Hydropol 33100 (R)- 30µm coating applied on ‘base paper’ – sample cut to 10cm x5cm for repulping tests
1) Laboratory scale repulpability assessments

- ISO 5263-1 *Laboratory Disintegration of chemical pulps*
- Temperature 20°C, 40°C and 50°C (temperatures typical of ‘open’ and ‘closed’ pulper systems)
- pH 7.1
- Disintegrator revolutions 10,000 and 50,000
- Hydropol coated paper tested as 100% of fibre furnish
- Fibre dispersion - Y/N
• pH measured after pulping
Laboratory scale repulpability assessments
Laboratory disintegrator, temperature checks and charging pulper with test sample
Fractionation

• Samples fractionated using a Bauer McNett fractionator (Tappi T233 cm-06) equipped with 8/16/50 and 100 mesh screens (slot size- 2.5mm/1.5mm/0.31mm and 0.15mm)
  • Weight of fraction retained by each mesh measured
  • Examination for presence of Hydropol coating retained by each mesh
• Undisperssed fibre/coating is retained by mesh 8, while softwood and hard wood fibres are retained by mesh 50 and 100 respectively
• Material passing through 100 mesh would be lost to drain/effluent
Results – impact of temperature and repulping duration

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Disintegrator Revs.</th>
<th>pH (start)</th>
<th>pH (end)</th>
<th>Fractionation</th>
<th>Percent Retention</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C</td>
<td>K</td>
<td></td>
<td></td>
<td></td>
<td>8</td>
</tr>
<tr>
<td>Uncoated control</td>
<td>20</td>
<td>10</td>
<td>7.1</td>
<td>8.89</td>
<td>2.82</td>
</tr>
<tr>
<td>20</td>
<td>10</td>
<td>7.1</td>
<td>8.84</td>
<td>2.21</td>
<td>6.82</td>
</tr>
<tr>
<td>40</td>
<td>10</td>
<td>7.1</td>
<td>8.11</td>
<td>0.90</td>
<td>4.90</td>
</tr>
<tr>
<td>50</td>
<td>10</td>
<td>7.1</td>
<td>8.91</td>
<td>0.50</td>
<td>10.06</td>
</tr>
<tr>
<td>Hydropol coated</td>
<td>20</td>
<td>50</td>
<td>7.1</td>
<td>8.86</td>
<td>0.55</td>
</tr>
<tr>
<td>40</td>
<td>50</td>
<td>7.1</td>
<td>8.45</td>
<td>0.20</td>
<td>5.30</td>
</tr>
<tr>
<td>50</td>
<td>10</td>
<td>7.1</td>
<td>8.92</td>
<td>0.74</td>
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<tr>
<td>50</td>
<td>50</td>
<td>7.1</td>
<td>8.91</td>
<td>0.50</td>
<td>10.06</td>
</tr>
</tbody>
</table>

- Uncoated control – after 10,000 revolutions, 2.82% of control material was retained by mesh 8 indicating good fibre dispersion. 32% retained by mesh 100 suggesting high hardwood fibre content. pH increased to 8.89

- Hydropol coated samples - at 20°C and 50,000 revolutions only a small amount of Hydropol was detected on mesh 8 with complete fibre dispersion. At 40°C and 50°C and 10,000 or 50,000 revolutions, NO Hydropol was noted on mesh 8 with complete fibre dispersion.

- pH increases noted to be similar to uncoated control
Summary: Hydropol coating is repulpable with complete fibre dispersion at 40°C and above with complete solubilization of coating.
2) Impacts of Hydropol coating on paper sheet quality parameters

1. Could Hydropol-coated packaging papers be used in CCM and other packaging grades?

2. Does Hydropol impact on recycled paper sheet properties?

3. Could Hydropol serve as a ‘strength enhancer’ enabling mills to use lower quality recovered fibre?

4. Could Hydropol-coated papers be used in fine papers (if segregated) so that products can qualify ‘recycled fibre content’?

<table>
<thead>
<tr>
<th>1 Grey board</th>
<th>1 Virgin fibre</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Greyboard + uncoated control (20%)*</td>
<td>2 Virgin fibre + uncoated control (20%)</td>
</tr>
<tr>
<td>3 Greyboard + uncoated control (50%)</td>
<td>3 Virgin fibre + uncoated control (50%)</td>
</tr>
<tr>
<td>4 Greyboard + Hydropol coated paper (20%)*</td>
<td>4 Virgin fibre + Hydropol coated paper (20%)</td>
</tr>
<tr>
<td>5 Greyboard + Hydropol coated paper (50%)</td>
<td>5 Virgin fibre + Hydropol coated paper (50%)</td>
</tr>
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</table>
## Impacts of Hydropol-coated paper on greyboard

<table>
<thead>
<tr>
<th>Fibre type</th>
<th>Furnish</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
</tr>
<tr>
<td>Greyboard</td>
<td>Uncoated</td>
</tr>
<tr>
<td>Hydropol coated</td>
<td>20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Test</th>
<th>Units</th>
<th>1.966</th>
<th>1.908</th>
<th>1.911</th>
<th>1.810</th>
<th>1.881</th>
<th>Change-compared with inclusion of uncoated control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulk</td>
<td>cm³/g</td>
<td>1.966</td>
<td>1.908</td>
<td>1.911</td>
<td>1.810</td>
<td>1.881</td>
<td>No change</td>
</tr>
<tr>
<td>Porosity</td>
<td>mls/min</td>
<td>1109</td>
<td>1308</td>
<td>1277</td>
<td>1788</td>
<td>1792</td>
<td>No change</td>
</tr>
<tr>
<td>Roughness</td>
<td>Glazed top</td>
<td>µm</td>
<td>4.49</td>
<td>4.52</td>
<td>4.59</td>
<td>4.93</td>
<td>4.96</td>
</tr>
<tr>
<td></td>
<td>Bottom</td>
<td>µm</td>
<td>6.95</td>
<td>7.03</td>
<td>6.96</td>
<td>7.44</td>
<td>7.10</td>
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<tr>
<td>Burst Index</td>
<td>Kpa/g</td>
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<td>1.20</td>
<td>1.19</td>
<td>1.41</td>
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<tr>
<td>Tear Index</td>
<td>mNm²/g</td>
<td>4.83</td>
<td>4.93</td>
<td>4.70</td>
<td>5.17</td>
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<tr>
<td>Tensile Index</td>
<td>Nm/g</td>
<td>25.59</td>
<td>27.89</td>
<td>28.06</td>
<td>29.94</td>
<td>28.15</td>
<td>No change</td>
</tr>
<tr>
<td>Drainage</td>
<td>secs</td>
<td>8.29</td>
<td>8.06</td>
<td>8.36</td>
<td>6.17</td>
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</tr>
<tr>
<td>Freeness</td>
<td>CsF</td>
<td>337</td>
<td>318</td>
<td>340</td>
<td>337</td>
<td>332</td>
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</table>
Inclusion of either the uncoated control or Hydropol coated papers @20 or 50% w/w imparted the same changes to the paper sheet properties.
<table>
<thead>
<tr>
<th>Fibre type</th>
<th>Furnish</th>
<th>Units</th>
<th>Change-compared with inclusion of uncoated control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virgin copier paper</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uncoated</td>
<td></td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>Hydropol coated</td>
<td></td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>Test</td>
<td>Units</td>
<td>Change</td>
<td></td>
</tr>
<tr>
<td>Bulk</td>
<td>cm³/g</td>
<td>1.888</td>
<td>1.815</td>
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<td>1.872</td>
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<td></td>
<td>1.829</td>
<td>1.773</td>
</tr>
<tr>
<td></td>
<td></td>
<td>No change</td>
<td></td>
</tr>
<tr>
<td>Porosity</td>
<td>mls/min</td>
<td>3405</td>
<td>3487</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4376</td>
<td>4397</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4372</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slight increase in porosity</td>
<td></td>
</tr>
<tr>
<td>Roughness</td>
<td>Glazed top</td>
<td>µm</td>
<td>5.03</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.30</td>
<td>5.07</td>
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<td></td>
<td>5.27</td>
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<td>Slight increase in roughness</td>
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<td>Bottom</td>
<td>µm</td>
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<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Burst Index</td>
<td>Kpa/g</td>
<td>1.34</td>
<td>1.65</td>
</tr>
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<td></td>
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<td>1.35</td>
<td>1.51</td>
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<td></td>
<td></td>
<td>1.38</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>Slight strength decrease</td>
<td></td>
</tr>
<tr>
<td>Tear Index</td>
<td>mNm²/g</td>
<td>4.53</td>
<td>5.57</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4.70</td>
<td>5.07</td>
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<td></td>
<td></td>
<td>No change</td>
<td></td>
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<tr>
<td>Tensile Index</td>
<td>Nm/g</td>
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<td></td>
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<td></td>
<td></td>
<td>29.51</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Slight reduction in tensile index</td>
<td></td>
</tr>
<tr>
<td>Drainage</td>
<td>secs</td>
<td>5.26</td>
<td>4.87</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5.09</td>
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<td>5.04</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>No change</td>
<td></td>
</tr>
</tbody>
</table>

Impacts of Hydropol-coated paper on virgin copier paper
**Increased freeness**

<table>
<thead>
<tr>
<th>Freeness</th>
<th>Csf</th>
<th>392</th>
<th>407</th>
<th>428</th>
<th>392</th>
<th>443</th>
<th>Increased freeness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schopper</td>
<td>°SR</td>
<td>32</td>
<td>31</td>
<td>30</td>
<td>32</td>
<td>29</td>
<td>No change</td>
</tr>
</tbody>
</table>

Inclusion of uncoated control or Hydropol coated papers @20 or 50% w/w imparted the same changes to bulk, roughness (bottom), tear index, drainage and Schopper. Slight changes were noted for porosity, roughness (top), burst index, tensile index, and freeness.
Impacts on paper sheet quality parameters

1. Could Hydropol-coated packaging papers be recycled into CCM and other packaging grades? **YES.** *Uncoated control and Hydropol coated papers imparted the same paper sheet properties to greyboard*

2. Does solubilized Hydropol impact on recycled paper sheet properties? **NO.** *Uncoated control and Hydropol coated papers imparted the same paper sheet properties*

3. Could solubilized Hydropol impart strength to fibre/sheet properties enabling mills to use lower quality recovered fibre? **NO**

4. Could Hydropol-coated papers be used in fine papers (if segregated) so that products can qualify ‘recycled fibre content’? **YES**
3) Impacts of solubilized Hydropol on mill process waters and etp systems

Generic example:
Test liner manufacturer (Furnish – OCC and selected Mixed Papers)

1 Primary treatment – Dissolved Air Flotation – recovers fibre, cellulose fines and ash back to the mill

2 Secondary biological treatment - mineralises dissolved organic load:
   i. anaerobic digestion (AD)
   ii. aerobic activated sludge (AS)
   iii. sludge settlement (SS)
   iv. Treated effluent discharged to river
3) Impacts of solubilised Hydropol coating on process water quality and secondary biological treatments which are currently used by papermills – Final results expected October 2019

Test Tech:

- conductivity, charge demand and pH (ensure no changes above those observed with uncoated control)

AquaEnviro:

1. COD fractionation
   - OECD 301B BCOD Test (Zahn Wellens) – quantify the biodegradability of soluble organic material within effluent. Measures percentage mineralization of COD in aerated activated sludge over time

2. Carbonaceous and nitrification inhibition test – provides a measure of the treatability of the effluent samples and if is inhibitory to aerobic activated sludge bacterial respiration – **NO INHIBITION OF BACTERIAL RESPIRATION RATE** (ie no acute toxicity)

3. Biochemical methane potential testing – determines treatability by anaerobic digestion
Summary

- Hydropol 33100 coated paper disintegrates with complete dispersion of fibres when repulped at 40°C and above (coating is almost non-detectable when repulped at 20°C) - meets criteria outlined in ISO 5263-1 Laboratory Disintegration of chemical pulps

- No evidence of Hydropol coating on mesh 8 with Bauer McNett fractionation - indicates complete polymer dissolution and fibre dispersion

- Solubilised Hydropol at high loading rates appears to have no effect on paper sheet properties in the case of recycled grey board furnish. For virgin copier paper furnish, no effects were noted for bulk, roughness (bottom), tear index, drainage and Schopper. Slight changes were noted for porosity, roughness (top), burst index, tensile index and freeness.
At a mill:

1. Hydropol coated paper would repulp and release valuable fibre for paper and board manufacturing

2. Hydropol coating would dissolve and would NOT form part of ‘mill rejects stream’ (Note: valuable fibre is entrained and lost with mill rejects (yield loss); rejects are costly to dispose for mills without wte)

3. Hydropol coating appears not to be substantive to fibre and unlikely to contribute either positively or negatively to paper sheet properties

4. Hydropol coated paper could be recycled with Mixed Paper or OCC at packaging mills

5. Segregated Hydropol coated paper eg coated white food board could be recycled at virgin-fibre based mills

6. Effluent from Greyboard + Hydropol coated paper (20%) did not inhibit activated sludge bacterial respiration rates (ie no acute toxicity)

7. Treatability of Hydropol by mill effluent treatment systems (DAF, AD and activated sludge)-final results expected October 2019
Appendix 5

Marine Test Toxicity ASTM D-6691 OK Marine

FINAL REPORT
JRW-1/3

Aquatic invertebrate acute toxicity test with *Daphnia magna* on
Hydropol 30110 HWS

Author: Inez Monteny
Sponsor: Aquapak Polymers Ltd.
Hollymoor Point
Hollymoor Way
Rubery
Birmingham, B31 5HE
UNITED KINGDOM
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Identification of the test

General information

Project number

JRW-1/3

Sponsor
Aquapak Polymers Ltd.
Hollymoor Point
Hollymoor Way
Rubery
Birmingham, B31 5HE
UNITED KINGDOM

Sponsor contact

Version 22 August 2019
Before the actual start-up of the toxicity test with *Daphnia magna* (a freshwater species), the test item was added in a specific concentration to a chemically defined (mineral) aqueous medium that was spiked with micro-organisms. This mixture was incubated at a temperature of 30°C (± 2°C) in the dark during 91 days. For internal purposes of organization, the stabilisation process gets the code JRW-1/2. 

**Study schedule**

- **Study initiation date**: October 9th, 2018
- **Experimental starting date**: October 10th, 2018
- **Starting date of incubation period**: October 15th, 2018
- **Completion date of incubation period**: January 14th, 2019
- **Duration of incubation period**: 91 days
- **Starting date of toxicity test**: January 14th, 2019
- **Completion date of toxicity test**: January 16th, 2019
- **Duration of incubation**: 2 days
- **Experimental completion date**: January 17th, 2019
- **Study completion date**: January 28th, 2019

**Archiving**

All raw data and records necessary to reconstruct the study and demonstrate adherence to the study plan will be maintained in the archives of OWS nv. These records include notebooks, study plan, study report, samples of test item and specimens. They will be stored in a file coded:
The training records of personnel are stored in the maps ‘Organisation and Personnel’. These files are stored per person and administered by the Lab Quality Manager and the Assistant Lab Quality Manager.

After seven (7) years, all data and records will be destroyed or returned to the sponsor after agreement in writing by the involved Sponsor and the Study Director. In case no written agreement of the sponsor can be obtained after seven years, the data and records will be destroyed.

- **Confidentiality statement**

  The testing facility will treat strictly confidential all relevant information on the test item disclosed by the sponsor as well as all results obtained in executing the test.

  
  
  ![Signature]

  Bruno De Wilde
  Lab Manager

- **GLP compliance statement**

  The test was performed in accordance with the OECD principles of Good Laboratory Practices (GLP).

  
  
  ![Signature]

  Inez Monteny
  Study Director

**4 Quality assurance audit statement**

The results reported are in accordance with the study plan and raw data.

A quality control was executed on ……………

This quality control ensures that the final report is complete and accurately reflects the conduct and raw data of the study.

_____________________

Version 22 August 2019
5 Summary and conclusions

A toxicity test with *Daphnia magna* was performed on degradation residuals obtained after incubation of test item Hydropol 30110 HWS in a biological active aquatic environment.

The OK biodegradable MARINE certification scheme of TÜV AUSTRIA Belgium prescribes that the concentration of material to be tested must be 0.1% on dry mass basis.

The test item was added in a 0.1% concentration to a chemically defined (mineral) aqueous medium that was spiked with micro-organisms. The control series (= mineral aqueous medium spiked with micro-organisms) and the test series were incubated during 91 days at 30°C (±2°C). During this period biodegradation of the test material can occur.

The test was executed in line with OPPTS 850.1010 *Aquatic Invertebrae Acute Toxicity Test, Freshwater Daphnids* (1996) and OECD 202 *Daphnia sp., Acute Immobilia tion Test* (2004) taking into account the modifications on concentration and incubation as mentioned in the OK biodegradable MARINE certification scheme of TÜV AUSTRIA Belgium.

The OK biodegradable MARINE certification scheme of TÜV AUSTRIA Belgium prescribes that at least 90% of the tested organisms should remain mobile.

In the Hydropol 30110 HWS series mobility was observed for 100% of the *Daphnia magna* neonates after 24 hours and after 48 hours.

From these results it can be concluded that the addition of 0.1% Hydropol 30110 HWS to a chemically defined (mineral) aqueous medium that was spiked with micro-organisms, does not exert a negative effect on the mobility of *Daphnia magna* after a 91 days incubation period at 30°C (±2°C). The environmental safety requirement of the OK biodegradable MARINE certification scheme of TÜV AUSTRIA Belgium was fulfilled for sample Hydropol 30110 HWS.

6 Introduction
6.1 Purpose and principle of test method

The purpose of the Aquatic Invertebrate Acute Toxicity Test (executed under static conditions with *Daphnia magna*) is to evaluate any toxic effect of the test item after an incubation in a biological active aquatic environment.

Before the start of the toxicity test, the test item is incubated at a temperature of 30°C (± 2°C) in the dark during 3 months under laboratory conditions. The incubation period can be shortened or extended till a maximum of 6 months in function of the results of the biodegradation test in seawater. The test material is brought into a chemically defined (mineral) aqueous medium and spiked with micro-organisms.

The immobilization (lack of movement) of *Daphnia magna* by biodegradation residuals of the test item and/or by the remaining parent compound is determined.

6.2 Standards followed

The test is based on:

- OPPTS 850.1010 *Aquatic Invertebrae Acute Toxicity Test, Freshwater Daphnids* (1996);

The modifications on concentration and incubation of the OK biodegradable MARINE certification scheme of TÜV AUSTRIA Belgium are taken into account.

7 Materials and methods

7.1 Test item

**Name:** Hydropol 30110 HWS  
**Colour:** Transparent  
**Description:** Film  
**Thickness:** 25 µm (As declared by the sponsor)  
**Sample preparation:** Cryogenic milling

7.2 General procedure

The toxicity test with *Daphnia magna* is performed in a polycarbonate multiwell test plate manufactured by MicroBioTests Inc. Each multiwell plate is provided with 4 test wells for the standard freshwater series and 4 test wells for the control series and for each test series. Additionally, the plates are provided on the left side with a column of rinsing wells. These rinsing wells serve to prevent dilution in the multiwell cups during the transfer of the test organisms from the hatching petri dish to the test plate.

The standard freshwater is “reconstituted” natural freshwater, which is prepared according to the procedure as prescribed in the standard operational procedure of the DAPHTOXKIT FTM MAGNA. The test is unacceptable if more than 10% of the control organisms are immobilized during the 48-h test period.
The test is performed in a static system. This means that the test solution and test organisms are placed in the test chamber and kept there for the duration of the test without renewal of the test solution.

The following procedure is used:

- **Filling of the test plate**
  - 10 ml of the different series (standard freshwater series, control series and test series) is added to the rinsing well and the 4 test wells.

- **Transfer of Daphnia neonates to the test vials**
  - At least 20 (actively swimming) neonates are transferred with the micropipet from the hatching petri dish into each rinsing well in the sequence: standard freshwater series, control series and test series.
  - Exactly 5 neonates are transferred from the rinsing well into the 4 wells of each row.

The multiwell plate is covered with a parafilm strip. The multiwell plate is incubated at a temperature of 20°C (± 2°C) in darkness during 48 hours.

After 24 and 48 hours the number of dead and immobilized (= the neonates which are not able to swim after gentle agitation of the liquid for 15 seconds are considered to be immobilized, even if they can still move their antennae) neonates is recorded.

More details on the procedure for the particular test reported, are given in the study plan.

### 7.3 Analytical methods

**pH**

The pH is measured directly on the aqueous sample with a pH meter after calibration with standard buffer solutions (pH = 4.0, pH = 7.0 and pH = 10.0), as described in ‘M_006. Determination of pH and electrical conductivity’.

**Salt content (electrical conductivity, EC)**

The salt content is measured with a conductivity meter after calibration in a 0.01 M KCl and 0.1 M KCl solution, as described in ‘M_006. Determination of pH and electrical conductivity’. Before inserting the electrode the sample is diluted with distilled water at a ratio of 5 to 1 (5 parts of distilled water versus 1 part of sample) and thoroughly mixed, as described in ‘M_012. Preparation of extracts and analysis solutions’. The results are given in µS/cm.

**Weight determination**

During the test a Sartorius AX6202 (max. 6200 g, d = 0.01 g) and an Acculab ATL-224 (max. 220 g; d = 0.1 mg) are used.
8 Results

8.1 Test conditions and set-up

Following series were tested:

- Standard freshwater
- Control series
- Hydropol 30110 HWS series (1000 mg/l - 0.1%)

The composition of the control series and the test series is given in Table 1. The inoculum consisted of a mixture of activated sludge from different sewage-treatment plants (Gent, Landegem and Destelbergen) treating domestic and/or industrial wastewater. After filtration over an 80 µm sieve, mixing in equal parts, decantation of the supernatant and replacement with mineral medium, the final sludge inoculum was obtained.

The OK biodegradable MARINE certification scheme of TÜV AUSTRIA Belgium prescribes that the concentration of material to be tested must be 0.1% on dry mass basis.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Mineral medium</th>
<th>Inoculum</th>
<th>Test item</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>490.02 g</td>
<td>10.00 g</td>
<td>-</td>
</tr>
<tr>
<td>Hydropol 30110 HWS - 1000 mg/l</td>
<td>490.03 g</td>
<td>10.02 g</td>
<td>500.1 mg</td>
</tr>
</tbody>
</table>

The standard freshwater, the control series and the test series were incubated during 91 days in the dark at 30°C (±2°C). During the incubation period the content of the reactors was stirred and moisture was added in case weight loss was detected. During the incubation period biodegradation of the test material can occur.

Four wells were used per series. In every well 5 Daphnia neonates are added. The used Daphnia species is *Daphnia magna*. The Ephippia (dormant stage) and the vials for the preparation of the standard freshwater are delivered by MicroBioTests Inc., Kleimoer 15, 9030 Mariakerke (Gent), Belgium.

8.2 Mobility

The test was stopped after 48 hours. The number of dead and immobilized neonates, versus that of the actively swimming test organisms was recorded after 24 hours and 48 hours. The results are shown in Figure 1. The average mobility and immobility of the Daphnia neonates after 24 hours and after 48 hours, together with the standard deviation, are given in Table 2.

The Daphnia neonates in the standard freshwater (SFW) showed an average mobility of 95% after both 24 hours and 48 hours, which means that the pass level of 90% mobility was reached. Moreover, in the control series, consisting of a chemically defined (mineral) aqueous medium that was spiked with micro-organisms, the Daphnia neonates showed an average mobility of 100% after 24 hours and 90% after 48 hours.

The OK biodegradable MARINE certification scheme of TÜV AUSTRIA Belgium prescribes that at least 90% of the tested organisms should remain mobile.

In the Hydropol 30110 HWS series mobility was observed for 100% of the Daphnia neonates after both 24 hours and 48 hours.

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From these results it can be concluded that the addition of 0.1% Hydropol 30110 HWS to a chemically defined (mineral) aqueous medium that was spiked with micro-organisms, does not exert a negative effect on the mobility of *Daphnia magna* after a 91 days incubation period at 30°C (±2°C). The environmental safety requirement of the OK biodegradable MARINE certification scheme of TÜV AUSTRIA Belgium was fulfilled for sample Hydropol 30110 HWS.

![Figure 1. Mobility of Daphnia neonates after 24 hours and 48 hours](image)

**Table 2. Mobility and immobility of Daphnia neonates after 24 hours and 48 hours**

<table>
<thead>
<tr>
<th>Test series</th>
<th>Mobility (%)</th>
<th>Immobility (%)</th>
<th>Mobility (%)</th>
<th>Immobility (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>24 hours</td>
<td>48 hours</td>
<td>24 hours</td>
<td>48 hours</td>
</tr>
<tr>
<td></td>
<td>AVG</td>
<td>SD</td>
<td>AVG</td>
<td>SD</td>
</tr>
<tr>
<td>SFW</td>
<td>95</td>
<td>10</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Hydropol 30110 HWS - 1000 mg/l</td>
<td>100</td>
<td>0</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>

With AVG = average, SD = standard deviation.

Figure 2 and Figure 3 show the pH and the electrical conductivity (EC), respectively, of the different series. The pH of the control series and the test series was somewhat lower when
compared to standard freshwater, while the EC of the control series and the test series was higher when compared to standard freshwater.
Figure 2. pH of the different series

Figure 3. Electrical conductivity of the different series