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Cross-infection effect of polymers of historic and heritage significance on the degradation of a cellulose reference test material☆

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ABSTRACT

The cross-infection effect of 105 polymer samples was studied, using cellulose as a reference test material. In total 14 polymer types were studied, comprising "modern materials" commonly found in historic and artistic collections including: cellulose acetate (CA), cellulose nitrate (CN), poly(vinyl chloride) (PVC), polyurethane (PUR) and a selection of specialised packaging materials used in art and heritage conservation. Polymer samples were placed in glass vials containing a piece of the cellulose reference and vials were sealed before being heated to 80 °C for 14 days. The cross-infection effect on the reference cellulose was measured using viscometry to calculate the degree of polymerisation relative to that of a control reference and a classification system of the cross-infection or preservation effect is proposed.

Solid phase micro-extraction (SPME)-GC/MS was used to detect and identify the emitted volatile organic compounds (VOCs) from a select number of polymer samples. CN was identified as the polymer with the most severe cross-infection effect while others e.g. polycarbonate (PC) had no effect or even a beneficial effect. Acetic acid was found to be the most characteristic emission detected from the most severely cross-infecting materials.

1. Introduction

Polymer degradation can be both infectious and cross-infectious, resulting in the spread of degradation within a sample and/or between samples composed of the same or different materials. Infections are spread via reactive species, such as radicals or volatile organic compounds (VOCs). For example, a pro-degradant cross-infection effect of degrading polypropylene (PP) on the degradation of both polypropylene (PP) and polybutadiene samples has been observed, although the reactive species were not identified [1,2]. Recent work has modelled infectious polymer degradation using stochastic methods, similar to those used for studying the spread of infectious diseases in human populations [3,4].

The phenomenon of cross-infectious material degradation is well-known within the heritage sector, having been observed as early as the 1890s [5]. The effect on cultural heritage collections of VOCs released during the degradation of materials used in display and storage is a particular area of concern and new materials are routinely tested to assess their potential hazards [6,7]. Historic objects themselves can display a cross-infection effect and it has recently been demonstrated that the degradation of historic paper can be accelerated by reactive species emitted from both iron gall inks and from the paper itself [8,9].

The cross-infection effect of "modern materials" has also been observed. Within a heritage context, "modern materials" refers to synthetic and semi-synthetic polymers produced from the mid-nineteenth century onwards, incorporating vulcanised rubber, Bakelite and cellulose derivatives in addition to more recent industrial materials such as poly(vinyl chloride) (PVC) or polyethylene (PE). A wide range of VOCs are known to be emitted from modern materials ([10,11], this issue) One well-documented cross-infection effect is "vinegar syndrome", whereby the release of acetic acid vapour from degrading cellulose acetate (CA) objects,

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Table 1
Plastic objects used in degradation experiments.

Entry	Sample no.	Object	VOCs analysed by SPME-GC/MS	Notes
Cellulose acetate and derivatives				
1	HS34	Transparent ResinKit	Yes	Cellulose Acetate Propionate
2	HS35	Transparent ResinKit	Yes	Cellulose Acetate Propionate
3	HS45	Transparent ResinKit	Yes	Cellulose Acetate Propionate
4	HS91	Ladybrush doll	Yes	Cellulose Acetate
5	HS166	Black spectacles frame	Yes	Cellulose Acetate Propionate
6	HS250[a]	Orange plastic sample	No	Cellulose Acetate Butyrate
7	HS251[a]	Transparent plastic sample	Yes	Cellulose Acetate
8	HS331	Imitation tortoiseshell sample	Yes	Cellulose Acetate (Rhodoid)
Cellulose nitrate				
9	HS2	Cream-coloured jewellery box	Yes	
10	HS3	Imitation tortoiseshell jewellery box	No	
11	HS104	Vanity set	Yes	
12	HS232	Cream-coloured box	Yes	
13	HS248[a]	Ruler	Yes	
14	HS249[a]	Ruler – degraded	Yes	
15	HS266	Brown box	Yes	
16	HS270	Comb	Yes	
17	HS271	Cigarette case	Yes	
Poly(vinyl chloride)				
18	HS5	Doll	No	
19	HS61	Transparent ResinKit	No	
20	HS62	Transparent ResinKit	No	
21	HS153[a]	White and grey tile	Yes	
22	HS157[a]	Transparent film	Yes	
23	HS321	White plastic sample	No	
Poly(vinyl chloride)/Poly(vinyl acetate)				
24	HS132	Vinyl record	Yes	
25	HS136	Vinyl record	Yes	
26	HS137	Vinyl record	Yes	
27	HS138	Vinyl record	Yes	
28	HS149[a]	Green plastic mould	Yes	
29	HS154[a]	Vinyl record	Yes	
Polyurethane				
30	HS69	Elastomeric ResinKit	No	
31	HS201[a]	Artificial leather	No	Thermoplastic Polyurethane (TPU) Elastomer
32	HS202[a]	Artificial leather	No	Thermoplastic Polyurethane (TPU) Elastomer
33	HS206[a]	Foam	No	Thermoplastic Polyurethane (TPU) Elastomer
34	HS244[a]	Yellow foam	Yes	Polyurethane Ether
35	HS245[a]	Black foam	Yes	Polyurethane Ester
36	HS316	White foam	No	Polyurethane Ether
37	HS317	Grey foam	No	Polyurethane Ester
38	HS328	Colourless transparent plastic sample	No	Thermoplastic Polyurethane Ester
39	HS329	Colourless transparent plastic sample	No	Thermoplastic Polyurethane Ether
Rubbers				
40	HS30	Red baking cup	Yes	Silicone Rubber
41	HS67	Elastomeric ResinKit	No	Acrylonitrile-Butadiene Styrene
42	HS92	White swimming cap	No	Polyisoprene Rubber
43	HS150[a]	Rubber cookie	No	Styrene-butadiene Rubber
44	HS214[a]	Degraded yellow rubber sample	No	Polyisoprene Rubber
45	HS216[a]	Soft yellow object	Yes	Polyisoprene Rubber
46	HS268	Pipette bulb	Yes	Polyisoprene Rubber
47	HS269	Brown doll's head	No	Polyisoprene Rubber
Styrene-Butadiene Copolymers				
48	HS43	Transparent ResinKit	No	
49	HS144[a]	White cup	No	
Polystyrene				
50	HS4	Pink box lid	No	
51	HS25	Transparent box	No	
52	HS32	White ball (foamed Polystyrene)	No	
53	HS36	Transparent ResinKit	No	
54	HS37	Transparent ResinKit	No	
55	HS38	White ResinKit	No	
56	HS145	Green plastic bowl	Yes	
57	HS168	Record duster	No	
58	HS300	Black plastic sample	Yes	High-impact Polystyrene
59	HS312	Extruded Foam	No	
60	HS322	Transparent, rigid plastic sample	No	
Polycarbonate				
61	HS12	Transparent sheet	No	
62	HS52	Transparent ResinKit	No	
63	HS143[a]	Green bottle	Yes	
Polyesters				
64	HS50	Transparent ResinKit	Yes	Polyethylene terephthalate Glycol-modified

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