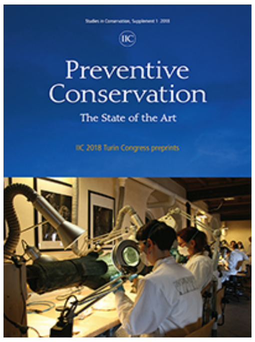

Studies in Conservation

ISSN: 0039-3630 (Print) 2047-0584 (Online) Journal homepage: http://www.tandfonline.com/loi/ysic20

A System Dynamics Approach to the Preventive Conservation of Modern Polymeric Materials in Collections

Katherine Curran

To cite this article: Katherine Curran (2018) A System Dynamics Approach to the Preventive Conservation of Modern Polymeric Materials in Collections, Studies in Conservation, 63:sup1, 342-344, DOI: 10.1080/00393630.2018.1476959

To link to this article: https://doi.org/10.1080/00393630.2018.1476959

Published online: 11 Sep 2018.

STUDIES IN CONSERVATION
2018, VOL. 63, NO. S1, S342–S344
https://doi.org/10.1080/00393630.2018.1476959

POSTER

OPEN ACCESS Check for updates

A System Dynamics Approach to the Preventive Conservation of Modern Polymeric Materials in Collections

Katherine Curran

UCL Institute for Sustainable Heritage, University College London, London, UK

ARTICLE HISTORY Received October 2017; Accepted April 2018
KEYWORDS Plastics; system dynamics; polymer degradation; modelling

Introduction

The preventive conservation of modern polymers such as plastics in museum collections presents a significant challenge. Despite substantial advances in recent years, there is much still to learn about degradation processes and appropriate environmental conditions for display and storage. A key problem in this area was articulated by Madden and Learner (2014) from the Getty Conservation Institute:

> … our understanding of plastics stability remains rudimentary. We have a menu of mechanisms that potentially explain degradation, but there is a tendency to default to them and recite them, rather than investigate skeptically what is actually going on …

Although many relevant degradation mechanisms, such as the deacetylation of cellulose acetate (CA) have been identified, there still exists a gap that prevents the translation of this knowledge into practical preventive conservation strategies. What is needed is an approach that builds on this existing knowledge, exploring interactions between physical and chemical processes within modern polymeric objects in order to better understand 'what is actually going on' and enable preventive conservators to make more evidence-based decisions about storage and display conditions.

In April 2017, a new five-year project was launched that aims to develop such an approach. *COMPLEX: The Degradation of Complex Modern Polymeric Objects in Heritage Collections: A System Dynamics Approach* will explore a new approach to understanding and modelling degradation within modern polymeric objects in museum collections. The team includes two postdoctoral researchers, two PhD students and the author, who is the principal investigator. This poster will present the concept and preliminary findings of *COMPLEX*.

COMPLEX: a system dynamics approach

System dynamics is a holistic method that seeks to understand the interactions between different processes on-going within a system. Coming from the work of Forrester in the 1950s, system dynamics was first used to apply principles of systems analysis from engineering to management and social systems (Forrester 1971, 2007, 2007). System dynamics takes as its fundamental assumption that the behaviour of a system is governed by its structure, enabling the internal mechanisms that drive the behaviour of a system to be understood and managed to avoid unwanted outcomes.

Our research will consider a modern polymeric object within its environment as a complex system and will model on-going degradation processes such as diffusion of plasticiser or moisture, or hydrolysis reactions, in order to predict and thus manage future material change. We will interrogate the structure of the system to deliver a new understanding of how real objects degrade over time and identify key 'leverage points' where the greatest impact on material degradation is observed, so that practical modifications such as temperature or control of relative humidity (RH) can be used to create beneficial change within the system and improve collections care.

Many of the processes relevant to the degradation of modern polymeric objects in heritage collections can be defined by known mathematical equations, such as Fick's laws of diffusion (1995) or equations describing the rates of chemical reactions. An outline causal loop diagram showing some of the processes relevant to the degradation of CA has been developed and is shown in Figure 1.

Using a combination of laboratory-based degradation studies, on-site analysis of plastic objects and mathematical modelling, *COMPLEX* will study multiple interactions within the same system to provide an understanding of the relationships between environmental parameters such as RH and temperature and material properties of interest such as discolouration or brittleness. It will model different scenarios e.g. different RH settings to understand how preventive conservation decisions will affect material properties over time.

CONTACT Katherine Curran k.curran@ucl.ac.uk UCL Institute for Sustainable Heritage, University College London, Central House, 14 Upper Woburn Place, London WC1H 0NN, UK

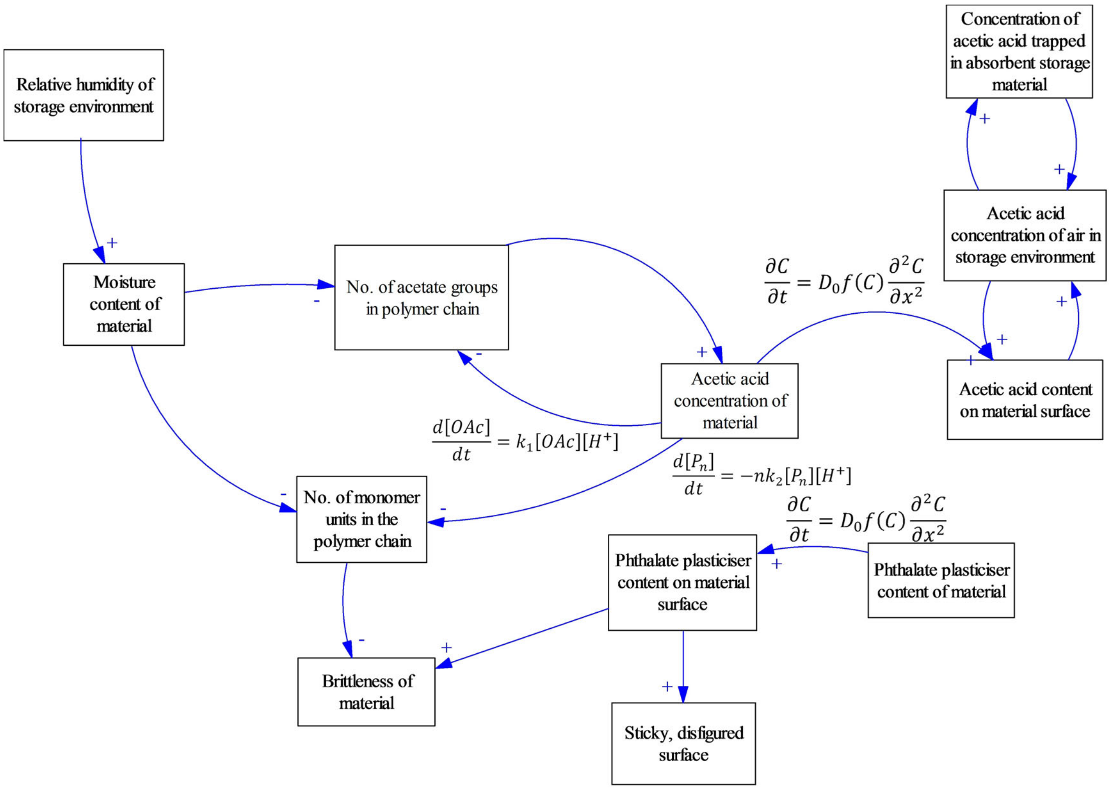

Figure 1. Outline causal loop diagram showing some of the processes relevant to the degradation of CA.

Results

A very basic model was built using equations defined by Knab, Little, and Parker (2015) for the degradation of polymeric drug delivery devices. These equations describe the rate of diffusion of moisture into a material and the hydrolytic degradation of the polymer and are thus very relevant in a museum context, as CA and cellulose nitrate and other relevant plastics components are known to degrade hydrolytically (Shashoua 2009a, 2009b). Using well-established mathematical methods, plots showing the change in moisture content and polymer molecular weight over time were developed. Variation in moisture content and molecular weight at different depths were also studied. This model was assessed under two scenarios, one referred to as 'Higher moisture' and the other as 'Lower moisture', with initial concentrations of moisture at the surface of the material used as inputs, representing an object existing in an environment with a higher or lower RH respectively. Figure 2 shows that the change in molecular weight at the surface proceeds at a greater rate under higher RH conditions, and shows the relative difference in the rates of change. This indicates that under the 'Higher moisture' scenario, an object would crack and/or become brittle more quickly.

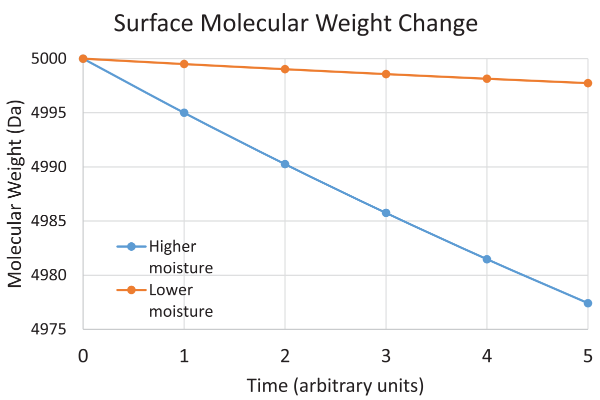

Figure 2. Results of a preliminary model showing change in molecular weight at the surface of a polymeric material with different initial moisture contents.

It should be pointed out that arbitrary values of the diffusion coefficient of water and rate constant of hydrolysis were used in this model and that the values shown in this plot can in no way be related to a real object yet. However, they illustrate the concept of the *COMPLEX* project and the method by which results will be produced. Using experimental results, values for key parameters can be identified and used as inputs for a model that consists of multiple degradation processes. Outputs like those shown in Figure 2 could then be used to understand the potential impact of preventive conservation decisions such as RH settings on the degradation of modern polymeric objects in collections.

Practical implications for preventive conservation practice

The results from the *COMPLEX* project are intended to inform future preventive conservation practice for the care of modern polymeric objects. This will be achieved in three ways:

- By understanding the relative impact of different system parameters such as environmental conditions or the presence of particular additives on degradation, key 'leverage points' within the object/environment system can be identified and used to inform conservation decisions
- By solving equations describing key degradation processes, models that describe the rates of change of material properties such as molecular weight, colour change or cracking under different environmental conditions can be developed, which will also inform decision-making
- By exploring the impact of different additives e.g. plasticisers on the degradation of modern polymeric objects, components that have a significant impact on material degradation can be identified. This will enable priorities for future analysis and research to be identified e.g. the results could provide evidence for the need to develop a screening tool for a particular additive.

Conclusions

COMPLEX represents a new approach to understanding the degradation of modern polymeric objects in museum collections. By using a system dynamics approach, relevant degradation processes such as diffusion and chemical reactions will be modelled using a system of partial differential equations. These can then be solved in order to understand the object/environment system in more detail and to use the model to make decisions. An initial, very basic model indicated a higher rate of molecular weight loss in environmental conditions corresponding to a higher RH – a result which makes sense intuitively. This approach will be further developed, using experimental results to provide realistic material parameters and to validate the models.

Acknowledgements

The author would like to acknowledge the support of partners in this project, the Museum of London, Tate, UCL Chemical Engineering, UCL Chemistry, Conservation by Design, Lacerta Technology and those working directly as part of *COMPLEX*: Ida Ahmad, Simoni da Ros, Isabella del Gaudio and Argyro Gkili.

Disclosure statement

No potential conflict of interest was reported by the author.

Funding

This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme under grant agreement No. 716390.

References

Fick, A. 1995. "On Liquid Diffusion." *Journal of Membrane Science* 100: 33–38.

Forrester, J. W. 1971. "Counterintuitive Behaviour of Social Systems." *Theory and Decision* 2: 109–140.

Forrester, J. W. 2007. "System Dynamics –a Personal View of the First Fifty Years." *System Dynamics Review* 23 (2): 345–358.

Knab, T. D., S. R. Little, and R. S. Parker. 2015. "A Systems Approach to Modeling Drug Release from Polymer Microspheres to Accelerate in vitro to in vivo Translation." *Journal of Controlled Release* 211: 74–84.

Madden, O., and T. Learner. 2014. "Preserving Plastics: An Evolving Material, a Maturing Profession." *Conservation Perspectives: The Getty Conservation Institute Newsletter* 211: 4–9.

Shashoua, Y. 2009a. "Degradation of Cellulose Acetate." In *Conservation of Plastics*, 180–184. Oxford: Elsevier.

Shashoua, Y. 2009b. "Degradation of Cellulose Nitrate." In *Conservation of Plastics*, 177–180. Oxford: Elsevier.