Univerza v Mariboru

FRAMEWORK PROGRAMME OF EARLY STAGE RESEARCHER TRAINING[1]

1. BASIC DATA

Mentor's name and surname	**Lidija Fras Zemljič**	Mentor's register number at ARIS (SICRIS):	**19753**
Mentor's e-mail:	lidija.fras@um.si	Mentor's tel. no.:	02 220 7909
Research programme (RP) leader's name and surname:	Lidija Fras Zemljič	RP leader's register number at ARIS (SICRIS):	19753
Title of research programme:	Textile Chemistry and Advanced Textile Materials	RP's Register number at ARIS (SICRIS):	P2-0118
Research organisation (RO) of University of Maribor, where training shall be conducted:	UM FS	RO Register number at ARIS (SICRIS):	0795
Research field according to ARIS classification:	2.14.02.Textile chemistry	Research field according to Ortelius classification (EURAXESS)	15.17 Materials engineering

2. DEFINITION OF RESEARCH PROBLEM AND GOALS OF DOCTORAL RESEARCH[2]

Starting point of research task of the early stage researcher and its position in the research programme, where the mentor is included, work hypothesis, research goals and foreseen result with emphasis on an original contribution to science:

Scientific background
Cultural heritage (CH) is invaluable historic legacy of humankind that must be passed on to future generations. Among them, **fibre-based CH such as textile and paper** (e.g., books, pictures, manuscripts, newspapers) **are of great value**. Textile accompanied societies though millennia during daily life, religious, diplomatic and political ceremonies and as functional materials, while paper-based writing supports still remain the most important medium to transfer ideas and concepts through generations *[Agbota H. et al, Sensors 2014, 14: 8779-8793]*.

[1] *Term early stage researcher (ESR) is written in male form and used as neutral for women and men.*

[2] *Research and study programme of training have to harmonise with contents of the research programme, where the mentor is a member.*

It is therefore extremely important to preserve our sensitive fibre-based cultural heritage as the most fragile CH materials as the basis of cultural identity and a shared resource that binds communities together.

It is well known, that **historic fibrous materials are particularly vulnerable:** with a high specific surface area, hydrophilic composition and numerous functional groups, **they are prone to rapid decay under several circumstances** *[Baty J.W. et al., BioResources, 2010, 5/3: 1955-2033]***.** Fibre-based objects thus require **stringently controlled storage conditions** to prevent decay, either chemical or biological. Degradation of **fibre based CH** objects can lead to loss of aesthetics or complete loss of mechanical properties *[Sterflinger K., Fungal biology reviews 2010, 24: 47-55; Bresee R. R., JAIC 1986, 25/1, 4: 39-48]*. Their structural **integrity is essential and sustainable preventive conservation solutions** are needed to point out these issues that address the **problem at source**, and damage functions, i.t. computational damage models enabling the evaluation of cost-benefits, also need to be developed for materials being **appropriate protected.**

Problem identification and motivation

Only a very small percentage of all **fibre based CH objects in museums are on display (less than 10%);** the vast **majority (≈90 % of the material) are normally in storage**, especially in small and medium sized museums. More specifically, between 45% and 80% of CH objects are generally **stored enclosed in packaging materials**, corresponding to millions of packaging materials and millions of cultural objects in the EU *[Smith A. W., Journal of the Society of Archivists, 1999, 20/1: 25-39; Smedemark S.H. et al., Building and Environment, 2020, 175: 106782]*. These are variation according to material type, but **fibre-based materials are most often stored in enclosures**.

The main problem is that most museums, especially small and medium sized, are located in historical buildings with storage rooms of insufficient or non-existing climate control, **often with (excessive) humidity and temperature variations.** Therefore, the stored objects are exposed to diurnal and seasonal temperature and humidity fluctuations. It is known that for CH objects humidity variations should be small and gradual. **Too high or too low humidity can affect the object shape and size, trigger chemical degradation and biodegradation, and causes mould growth and bacterial infections** *[Zhanga X e tal., Journal of Cultural Heritage 2011, 12: 408–411; Lech T., Tex Res J, 2017, 87/17: 2076–2088; Kavkler K. et al., International Biodeterioration & Biodegradation 2015, 97: 51-59; Ozturk B. e tal., LWT 2021, 138: 110639; Serrano A. et al., Journal of Cultural Heritage 2020, 44: 91–100; Quye A., Polymer Degradation and Stability 2014, 107: 210-218; Chelazzi D. et al., Journal of Colloid and Interface Science 2020, 576: 230–240; Bertolin C., Geosciences, 2019,9: 250; Atkinson J.K., Studies in Conservation, 2014, 59/4: 205-212; Odlyha M. Journal of Thermal Analysis and Calorimetry, 2011, 104: 399–403; Havlínová B. et al., Journal of Cultural Heritage, 2009, 10/2: 222-231]***.**

Most fibre-**based CH objects are hygroscopic materials** as readily attracts water from their surroundings. **Silk is one of the most delicate and vulnerable historical materials.** Most of these materials are so-called "weighted" silks, meaning they have been treated with inorganic salts of aluminium, iron, lead, tin, etc. to increase their basis weight, and **these degrade even faster** (Smith et al 1999, Serrano 2020, Zhang 2011). On other hand, libraries and archives store invaluable collections **of paper,** the basic component of which is cellulose, **which strongly interacts with water** *[Serrano A. et al., Journal of Cultural Heritage 2020, 44: 91–100; Mallo A.C., INT J CONSERV SCI 2017,8/3: 537-544]*. High **hydrophilicity of fibre-based materials** cause quick responses to relative humidity, as they rapidly absorb and release moisture, **which lead to expansion and contraction, leading to creep as well as cracking, peeling, delamination and wrinkling** *[Quye A., Polymer Degradation and Stability 2014, 107: 210-218; , Smith A.W., Journal of the Society of Archivists, 1999, 20/1: 25-39]*. Low humidity (below 30%) causes brittleness and mechanical damage, and high humidity leads to hydrolytic reactions of **fibres** *[Lech T., Tex Res J, 2017, 87/17: 2076–2088; Smith A.W., Journal of the Society of Archivists, 1999, 20/1: 25-39]*. For example, a long period of storage below 25% could cause mechanical stress and cross-linking of **cellulosic materials** *[Quye A., Polymer Degradation and Stability 2014, 107: 210-218; Smith A.W., Journal of the Society of Archivists, 1999, 20/1: 25-39]*. Materials made of leather **and silk** CH should not have moisture levels below 35% as they become brittle and mouldy above 65%. In addition, relative humidity (RH) above 70% leads to germination and growth of fungi, which is particularly **problematic in natural fibre materials** which are ideal for their **growth** *[Chelazzi D. et al., Journal of Colloid and Interface Science 2020, 576: 230–240; Sterflinger K., Fungal biology reviews 2010, 24: 47-55]*. It became clear that the most suitable conditions for fungal growth **are room temperature and high humidity**, with **high humidity playing a significant role** *[Kavkler K. et al., International Biodeterioration & Biodegradation 2015, 97: 51-59]*. On the other hand, the **big problem is transport** where, temperatures could fluctuate significantly and its decrease for about 10 degrees would increase RH in an airtight enclosure to 90%. At even cooler temperatures, condensation on the artefact surface could **lead to catastrophic damage**. This significant problem with relative humidity is connected **to temperature fluctuations**, especially for objects where internal stresses develop due to differences in expansion coefficients. CH materials **of organic and fibre based origin:** wood, paper, textiles (cellulose, silk, etc.) are under **uncontrolled conditions** readily attacked by **biodeteriorants: fungi, bacteria**, etc.

Biodeteriorants cause consequences for fibre based CH objects as: discoloration, loss of strength and elongation, partial destruction of the material with underlying chemical changes in hand: oxidation state, degree of polymerization, degradation of molecular structure, etc.

Beside **humidity and temperature**, the concentration of **air pollutants is another major aspect** that defines the suitability of storage enclosures - display cases and archival boxes. **Pollutants have different sources**, namely, contemporary art with its abundance of new materials (especially fibre based) is very sensitive to air pollutants **like ozone and NOx** [*Pastorelli G. et al., Polym. Degrad. Stab 2014, 107: 198-209]*. Some of these pollutants enter fibrous structure and trigger various reactions depending on fibre type and condition *[Smith A.W., Journal of the Society of Archivists, 1999, 20/1: 25-39]*. Nitrogen oxides and ozone cause cellulosic and wool textiles to fade, while those of silk fabric become somewhat crisp and stiff *[Smith A.W., Journal of the Society of Archivists, 1999, 20/1: 25-39]*.

It is clear that by storage process of fibre based CH objects, humidity, temperature and air pollutants are parameters really need to be tightly controlled, which, however, is not guaranteed by today's storage facilities.

Fundamental challenges

Building a new air conditioning systems or clean storage rooms in historical buildings is a high technical and conservation challenge and often cannot **be financially justified, especially not by small and medium sized institutions.** The same problem **is facing Slovenia, where most museum storage conditions are not climate controlled** *[Kavkler K. et al., International Biodeterioration & Biodegradation 2015, 97: 51-59]*, **putting CH collections at serious risk.** Instead, moisture can be buffered by appropriately developed and optimized, **cost-effective novel packaging systems whose integrated active concept that lead to the expansion or introduction of additional protective functions of a package.** Currently, standard enclosures made of paper board (archival boxes), plastics (sleeves) or textile PE nonwoven sheets do not provide sufficient protection against humidity fluctuations e.g. caused by daily heating cycles but acts as **passive packaging providing mechanical protection only.** The transfer of oxygen and other gases (ozone, NOx), water vapour, or other elements into- or out of their packaging significantly affects fibre-based CH objects, so **the perfect packaging solution must provide barrier properties against moisture and airborne contaminants**. **Bioactivity** as an additional function against microorganisms (fungi, bacteria) that are **a consequence** of uncontrolled storage conditions **would be priceless**. And, of course, there is no need to stress the protection of fibrous packed CH materials **from water and fire.**

Objectives and aims of the proposed research

The main objective of this PhD is to make a step forward in the field of science of cultural heritage **protection by preparing innovative active multifunctional packaging** from passive packaging aimed for fibre-based cultural objects as the most sensitive class of these objects. Specifically packaging systems will be developed for **a long-term storage of cultural heritage objects** with the assistance **of computational damage models** which represents step forward in fundamental study of textile and paper stored materials.

Specific objectives are:

- √ Multifunctional colloidal formulations establishment (month M6) further used as coating and bulk fillers
- √ Chemical attachment of selected formulations as coatings onto CH protective packing materials such as: cardboard, plastic films and foils, and textile nonwovens PE sheets, using technologies as screen printing, soaking, and (electro) spraying (M20)
- √ Integration of formulations as fillers into bulk (pulp and plastics melt) to reinforce and functionalized material matrices (extrusion –plastics and pulping –paper pulp) (M18)

- √ Fundamental insights of interaction profiles among substrates/individual compounds in colloidal formulations themselves, colloidal formulations and packaging materials (adsorption/desorption kinetics and thermodynamics) and functional packaging materials physic- chemical characteristics (M22)
- √ Understanding the active packaging influence on the microbiological profile environment (M26
- √ Defined action of mode of specific active packaging material in contact with each selected fibre based CH facilities: paper and silk and defined active packaging influence on inhibition of decay of fibre based CH (M32)
- √ Establishing of computational damage models specifically for silk as a proteinaceous heritage material at risk in order to evaluate cost/benefit of the new packaging materials (M32)

Hypothesis: With such concepts **of active packaging** following priority functionalities on the packaging will be achieved:
Priority 1: NO_2, O_3, O_2, and H_2O (humidity/sorption properties) barrier functionality
Priority 2: Antifungal and antibacterial functionality
Priority 3: Protection against fire and running water (topical by the event of fires and floods)
This kind of packaging will help to ensure a longer lifetime for the fibre based CH objects with minimal damage or degradation.

Following the global strategies: Horizon Europe 2021-2027: **New Properties and Functionalization**: - Characterization, Quality Assurance; **S4 Smart Specialization Strategy SLO**: Networks for the Transition to Circular Economy and Development of Materials as Products. The project also responds to the **JPI Cultural Heritage Research Strategic Agenda**, specifically in relation to the need for sustainable management and the need for better understanding of the impact of climate change on cultural heritage. The project will also align with the **Research Strategy of the European Research Infrastructure for Heritage Science E-RIHS**. It should be noted that for these materials, there is currently **no specialized laboratory at the level of E-RIHS**, a gap which this consortium aims to fulfil. On the basis of the developed techniques, we will propose E-RIHS to include **UM's laboratory (FS UM) facility for textile research**, as part of its FIXLAB offer due to wide range of methods for fibre based CH characterization. In this way **textile chemistry** will be better integrated and promoted in E-RIHS.
Pointed novelties:

- Introduction of multifunctionality (see pointed out functional priorities) which is difficult to achieve in one hand and to be economically and fully efficient.
- Universal coating/fillers development as colloidal formulations developed acting for such a wide range of packaging materials (paper/cardboard, plastic films and textile nonwoven sheets).
- Interaction phenomena studied of colloidal formulations with these packaging materials fundamentally clarified and extensively characterized.
- Clarification of mode of action of these newly developed materials with fibre-based CH of different origins (cellulose based and protein-based) to serve as a platform for further cellulose- and protein-based CH objects and CH objects widely.

Such a complex study has not been done before and represents an innovation in textile chemistry towards fibre based cultural heritage preservation.

One pillar in the program group P2-0118 is devoted to cultural heritag science, especially in the filed of textile cultural heritage objects preservation. So, this research is in the frame of programme group aims and vision.

3. STUDY PROGRAMME

Foreseen study programme, to which early stage researcher shall be enrolled in academic year 2024/2025:

Doctoral school FS UM

4. DESCRIPTION OF WORK AND TASKS

Implementing projects of scientific research.
Taking part in the design of research programmes.
Cooperating with research sponsors.
Drawing up research and other reports.
Monitoring and coordinating research work according to the grant agreement.
Ensuring safety and health at work.
Organising and instructing employees and students on using personal safety equipment and other safety measures.
Performing other tasks at the behest of the superiors.
Participating in ad-hoc and permanent committees of university or faculty bodies.
Acting on behalf of colleagues and superiors during their absence (upon authorisation).
Participating in annual and other inventories.
Performing other related tasks delegated by superiors.

5. REQUESTED LEVEL OF EDUCATION

VII/2. tariff group

6. REQUESTED FIELD OF EDUCATION

Technical, Natural sciences

7. KLASIUS SRV

Seventh level: Second cycle of higher and similar education/Second cycle of higher and similar education

8. KLASIUS P

145 – Education of teachers of individual subjects
4 - Natural science, mathematics and computing
5 - Engineering, manufacturing and construction

9. REQUESTED KNOWLEDGE

Computer skills: MS Windows, Word, Excel, Internet, e-mail, e-commerce

10. REQUESTED SPECIAL REQUIREMENTS

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11. REQUESTED LANGUAGES

Active knowledge of one world language

12. REQUESTED WORK EXPERIENCE

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13. FORESEEN POSTDOCTORAL TRAINING

Integration into projects or programe group if free hours will be available

Mentor's signature:

Lidija Fras Zemljič

Digitally signed by Lidija Fras Zemljič
DN: C=SI, S=Slovenija, OU=individuals, G=Lidija + SN=Fras Zemljič + SERIALNUMBER=2469530912049 + CN=Lidija Fras Zemljič
Reason: I am the author of this document
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Date: 2024.02.23 15:53:07+01'00'
Foxit PDF Editor Version: 12.1.2

Research programme leader's signature:

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Name and surname of Dean or authorised person[3]:
red. prof. dr. Matej Vesenjak

Signature of dean or authorised person:

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Place and date:

Maribor, 23. 02. 2024

Stamp:

[3] The training program is signed by the dean of the member where the ESR's employment and training will take place.