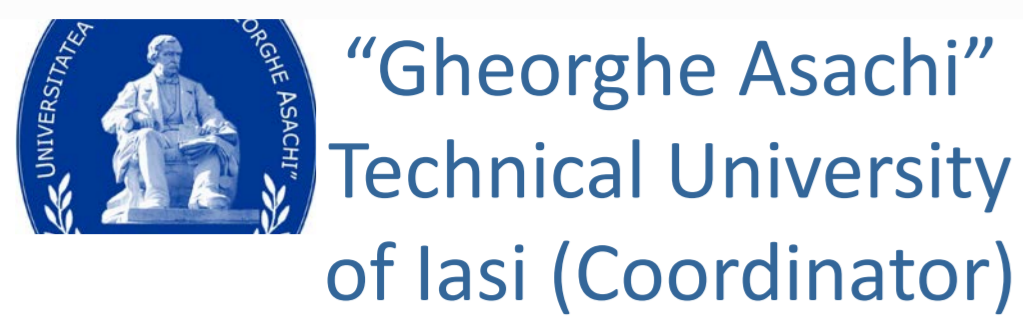




# Developing Non-conventional Material and Plasma Technique for Sustainable Solutions in Paper Heritage Conservation - Paphercon Project



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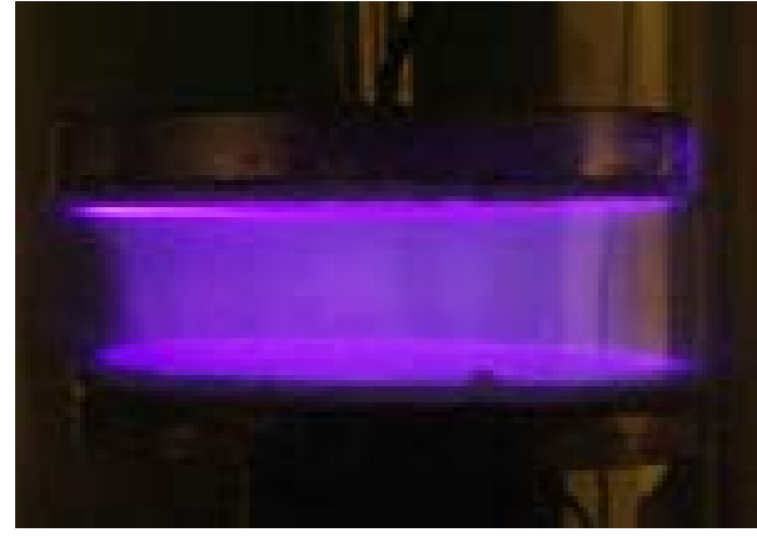
(Partner 3)  
COMPLEXUL MUZEAL NATIONAL "MOLDOVA"



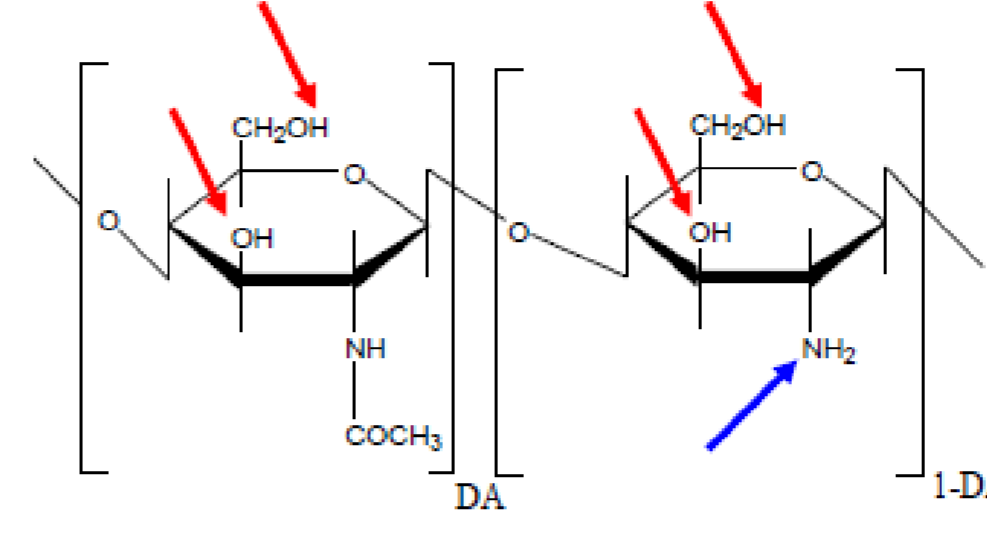
S.C. IMPEX ROMCATEL Cercetare – Proiectare S.A (Partner 4)

**Concept:** Integrating main steps of paper heritage conservation by integrating

**Cold HF plasma** as cleaning and decontamination technique



With **Chitosan derivatives** as multi-functional materials for durable and protective effects

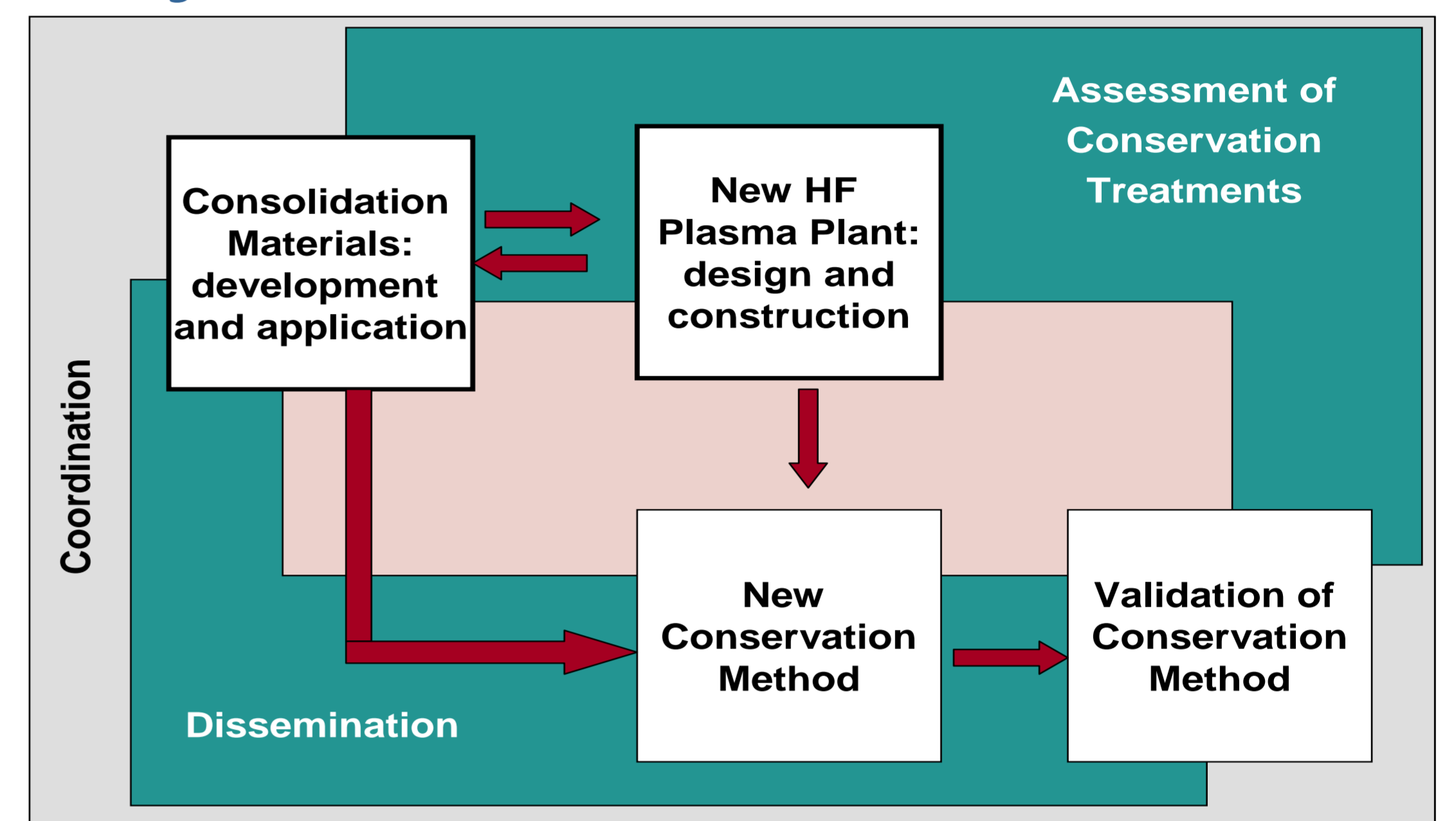


In **A sustainable method for conservation and protection**

## Objectives:

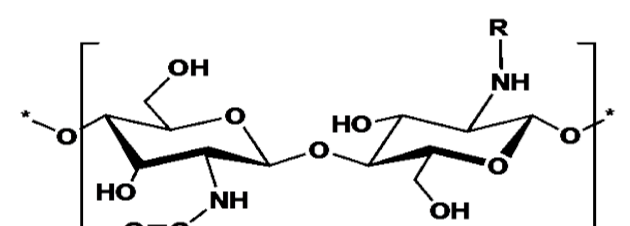
- To develop new bio-based materials with multiple functions in the conservation/restoration of paper heritage objects.
- To innovate the cold HF plasma plant and optimize application technique for ecological cleaning and microbial decontamination of paper heritage items.
- To elaborate and validate a sustainable method for conservation of paper heritage objects and a scientific method for the assessment of its effectiveness.

## Project structure:

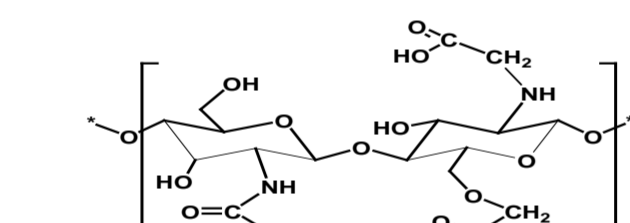


## Summary of results

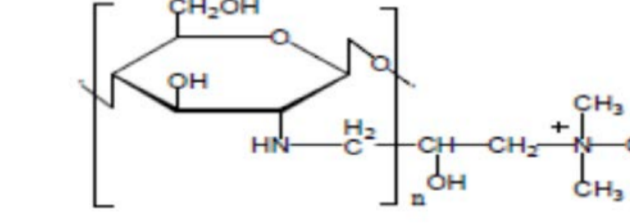
### Chitosan derivatives: synthesis and effectiveness assessment



Hydrophobic (HCh)

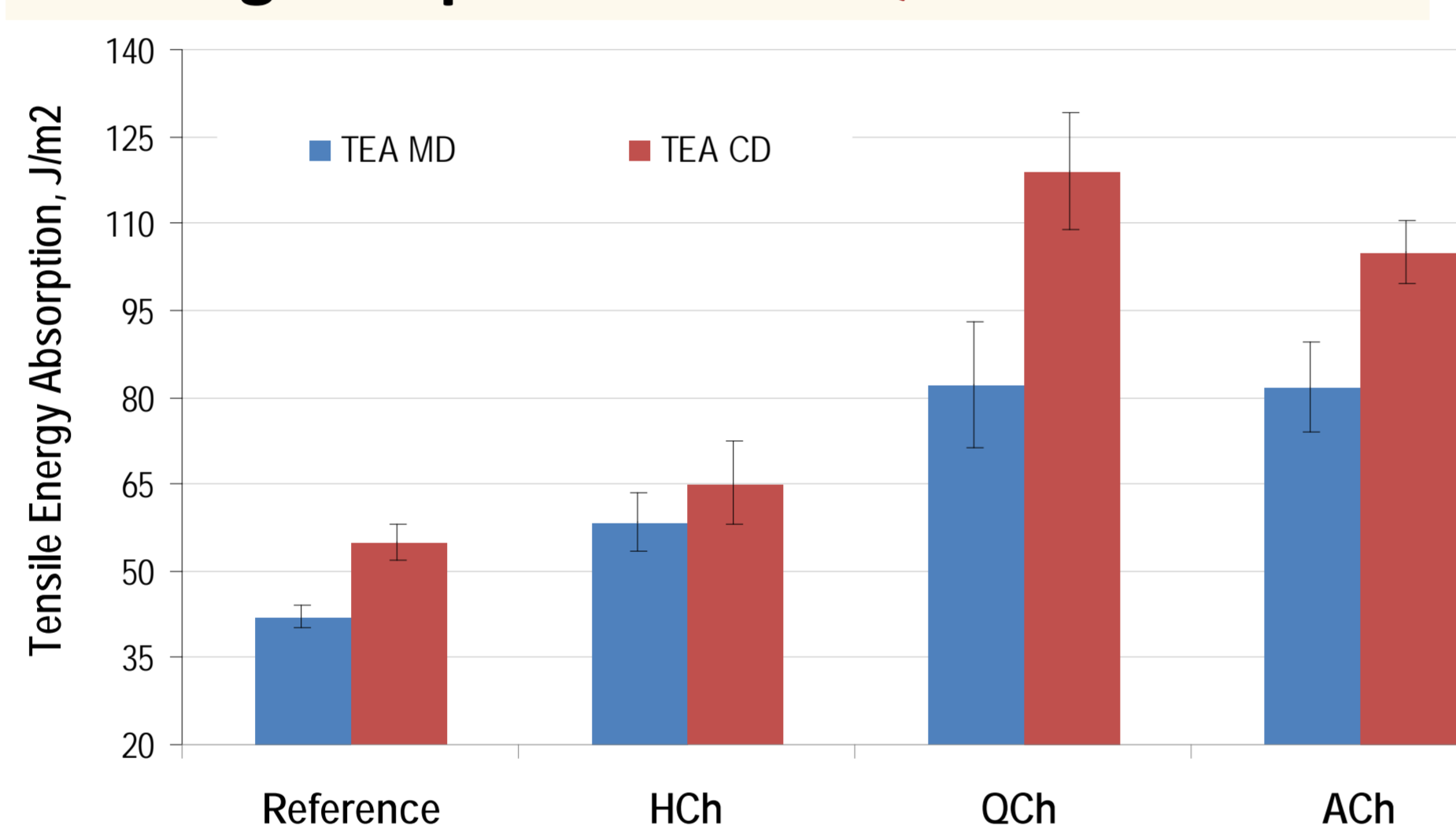


Amphoteric (ACh)

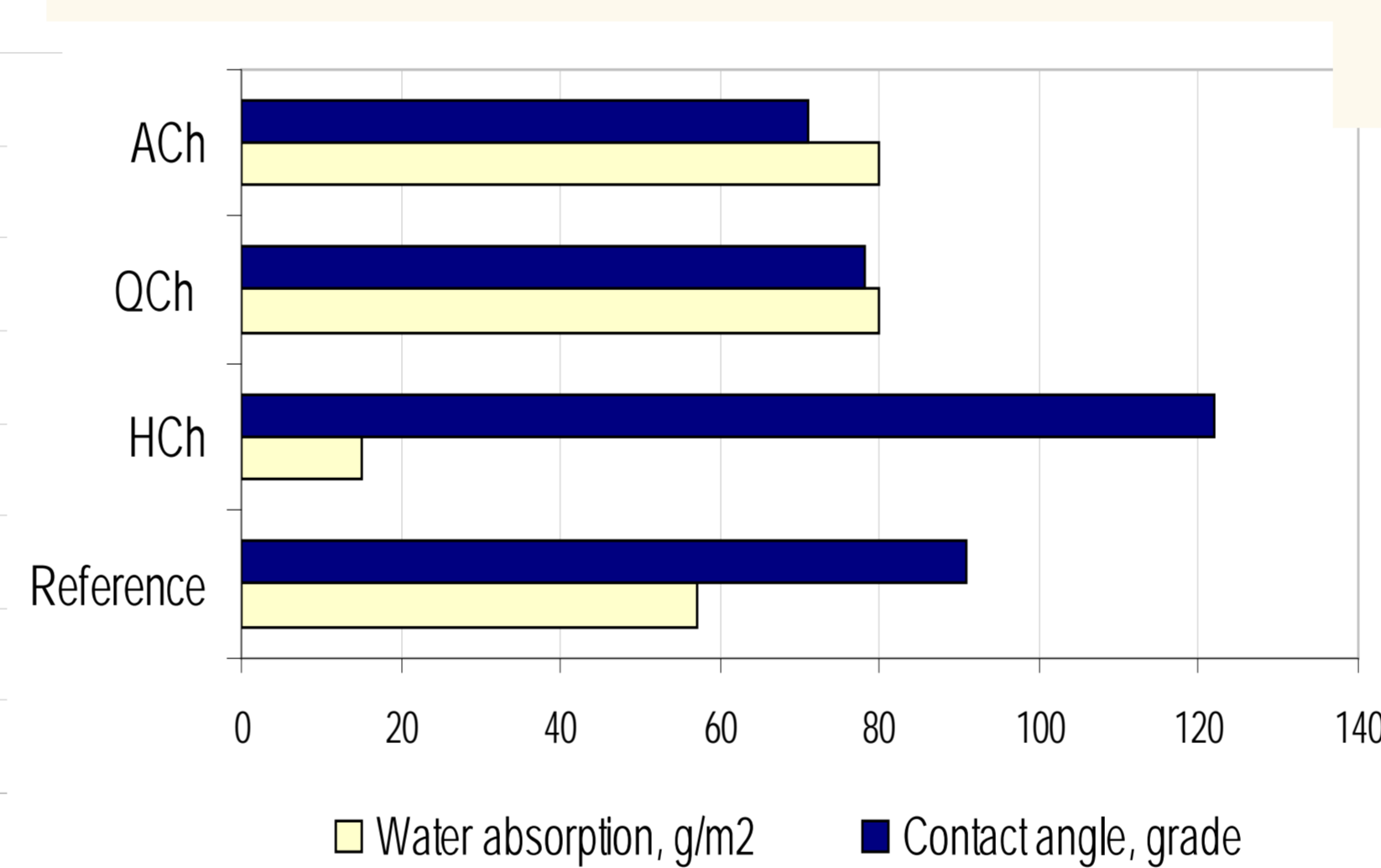


Quaternary (QCh)

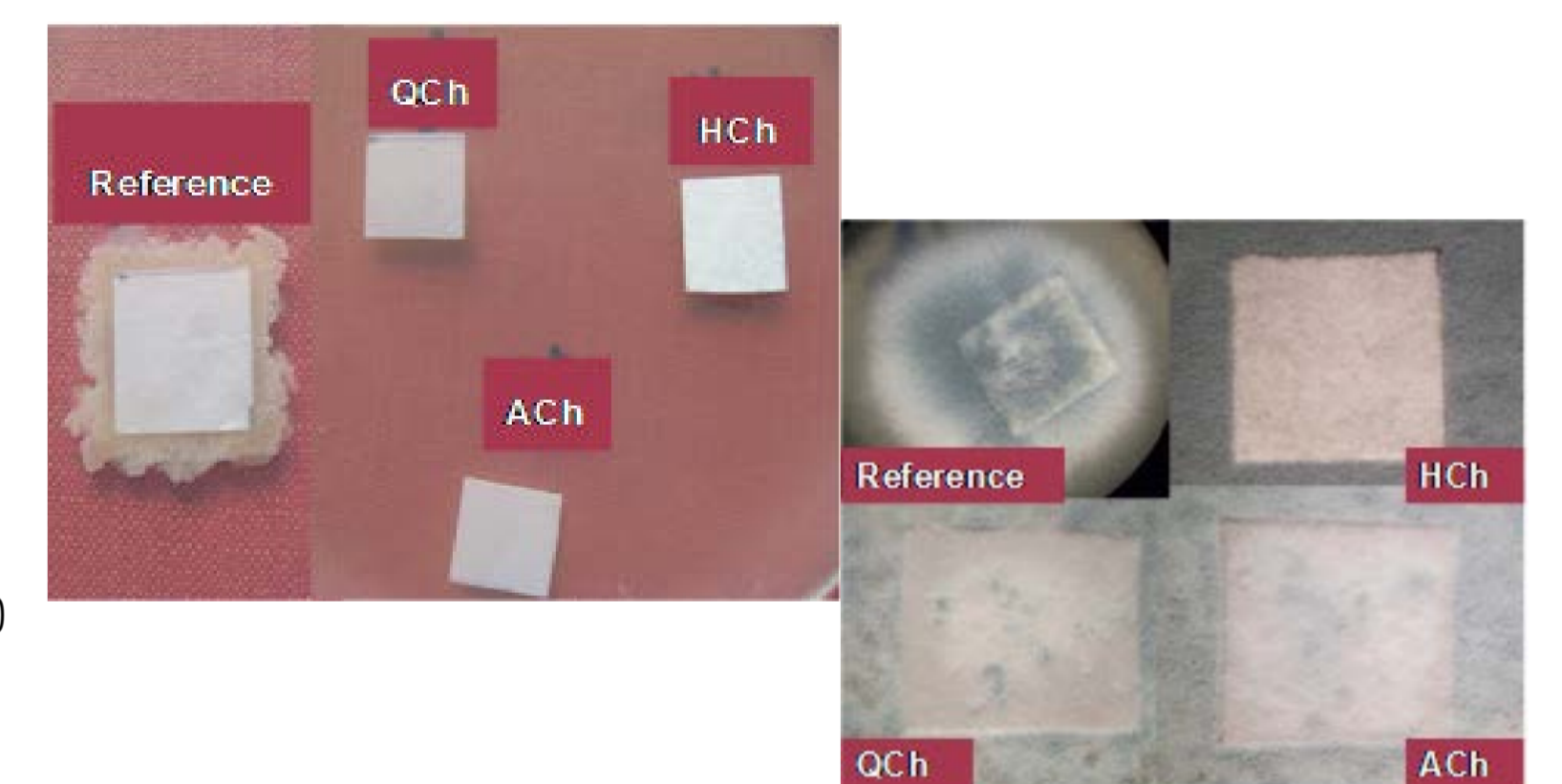
**Strength improvements: QCh > ACh > HCh**



**Barrier to water: HCh > QCh > ACh**



**Bacteria inhibition: ACh > QCh > HCh**  
**Fungi inhibition: HCh > QCh > ACh**



### HF cold plasma: effects assessment and extended functionality



#### Results on existing plasma plant

- Full decontamination requests 10 -20 minute, depending on the fungi and bacteria species.
- Strength decreases by 20-30% and total de-sizing of paper occurs.



#### Plasma plant with afterglow discharge:

- Full decontamination can be occurred at shorter time (3-9 minute).
- Strength decreases by 10-20% and total desizing of paper occurs, which has positive effects on consolidation.

### Integration of plasma with ChDs coating: main results

Sequence of treatment	Double folds		Contact angle, degree	Bacteria growth		Fungi growth	
	L	T		<i>Bacillus sp.</i>	<i>Pseudomonas sp.</i>	<i>Penicillium notatum</i>	<i>Aspergillus niger</i>
R	19	10	90	+++	+++	++-	++-
R + PI	18	8	20	++-	++-	+--	+--
R+PI+QCh/HCh	32	19	115	---	---	---	---
R+P+ACh/HCh	79	63	112	---	+--	---	---
R+PI+MC/MC	86	62	69	++-	++-	+++	+--

Note: The experiments, performed on natural aged paper without patrimonial value and involved following sequences of treatment: R – reference; R+PI – R + plasma treatment, which was followed by 2 layers coating of ChDs (QCh/HCh, ACh/HCh) and by 2 layers of methylcellulose- MC/MC, which is a conventional material used in paper heritage conservation.

### Conclusions:

Chitosan derivatives (ChDs) proved high effectiveness in paper conservation by achieving high strength increase, barrier to water and effective inhibition of bacteria/fungi growth. Therefore, CHDs offer more efficient and sustainable alternatives to conventional materials, like cellulose derivatives.

Plasma treatment is a green solution to the use of the toxic chemicals for paper decontamination. Its negative effects on paper strength can be overcome totally by treatment with chitosan derivatives since higher hydrophilicity enhance the effectiveness of ChDs.