gembloux agro bio tech

UCL Université catholique de Louvain

Université de Liège

Influence of soluble proteins on the adherence of particulate soils

Y. Touré, P.G. Rouxhet and M. Sindic

yetioman.toure@doct.ulg.ac.be

Heat Exchanger Fouling and Cleaning x – 2013
June 09 - 14, 2013

Presentation outline

1. Introduction

- Background
- Objectives

2. Experimental aspects

- Material
- Methods

3. Results

4. Discussion

5. Conclusion

Concern ?

Particulate deposition-drying
surface ➔natural environments
➔industrial equipments

Where ?

- **Storage tanks**
- **Ducts**
- **Plates of heaters**
  coolers

➔Food and pharmaceutical processing

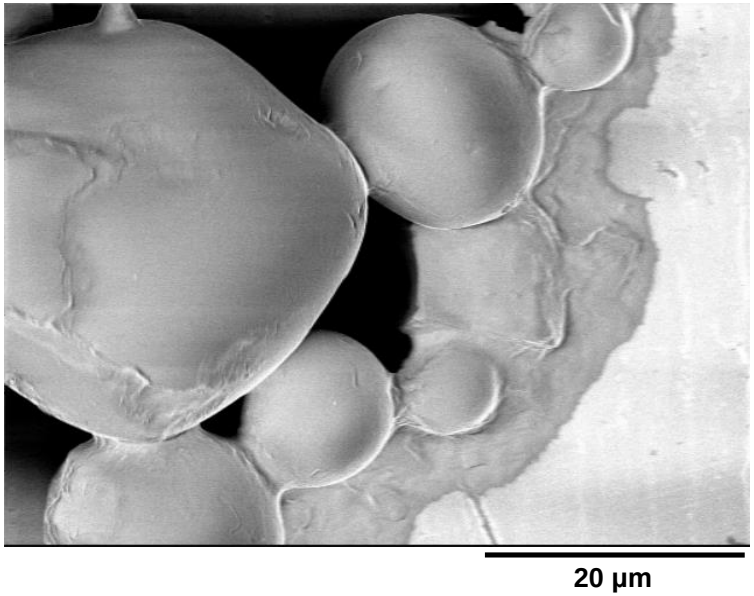
Main constituents:

- **Biopolymers, biomolecules**
  polysaccharides
  lipids
  proteins ➔bacteria initial attachment

Soil attachment and removal

Detry et al. (2011): starch deposit

- **presence of macromolecules (polysaccarides, proteins) at particule-substrate interface**
- **accumulation at substrate-particulate interface**
- **influence of:**
  - **details in the mode of drying**
  - **exposure to moisture**



Liu et al. (2006): tomato paste

- **baking ➔ effect on the subsequent removal of soils**

Understanding the influence of soluble macromolecules at interfaces on particulate soils adherence and removal

- **practical information on**
  - **incidence of surface properties of soil and substrate**
  - **influence of biomacromolecules**

- **physico-chemical mechanisms involved :**
  - **interactions solid-solution, solid-solid**
  - **biomacrolecules at interfaces**

- **designing easy-to-clean surfaces**

Objectives

Assess the influence of dissolved proteins on adhesion of particulate soils

Improve:

- **understanding mechanisms affecting soiling**
- **cleanability**

Material

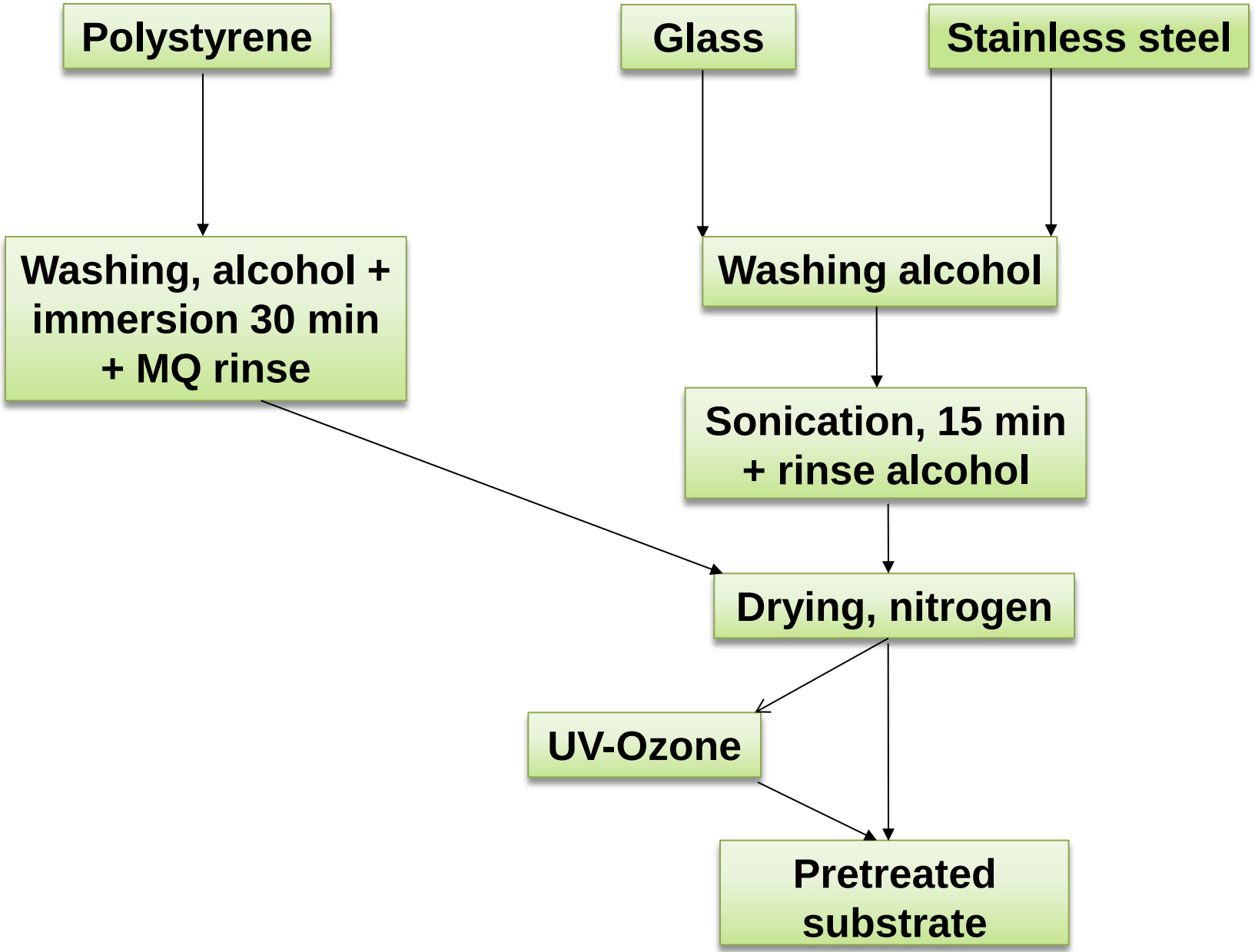
Model of soluble proteins :
- β-LGB
- BSA

Model of substrates :
- glass (hydrophilic)
- stainless steel (intermediate)
- polystyrene (hydrophobic)

Model of particulate soils : suspension of quartz particles (10-30 µm)

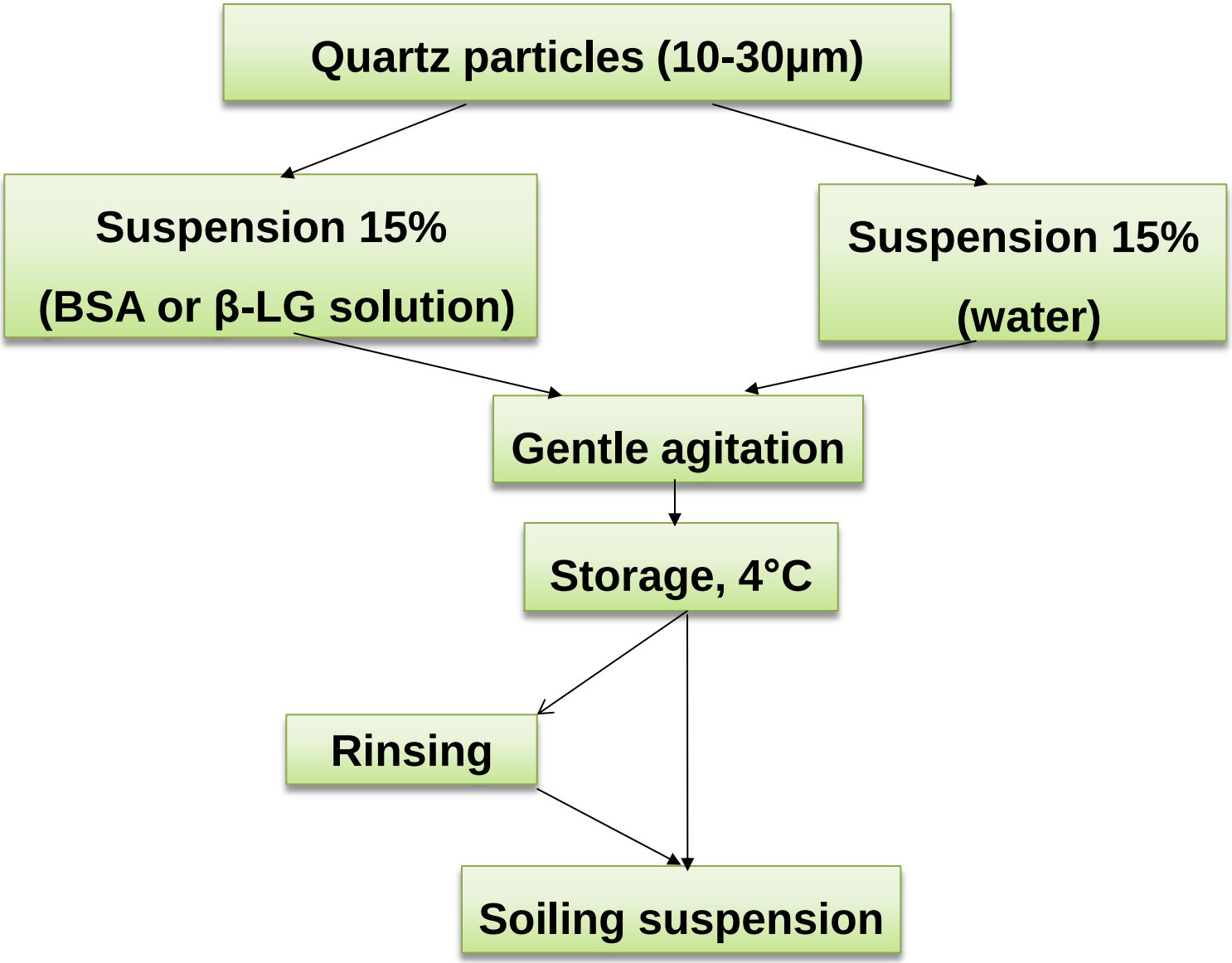
2. Experimental aspects

Substrate pretreatment



2. Experimental aspects

Soil preparation



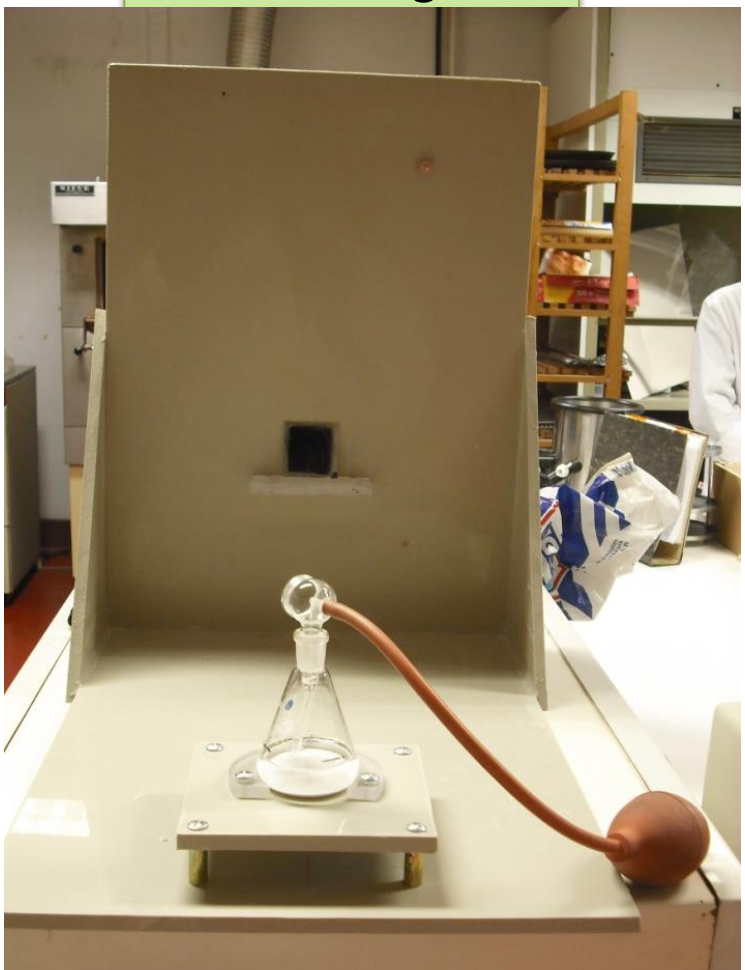
2. Experimental aspects

Soiling procedure

Pretreated substrate

Soiling suspension

Soiling



2. Experimental aspects

Cleaning test

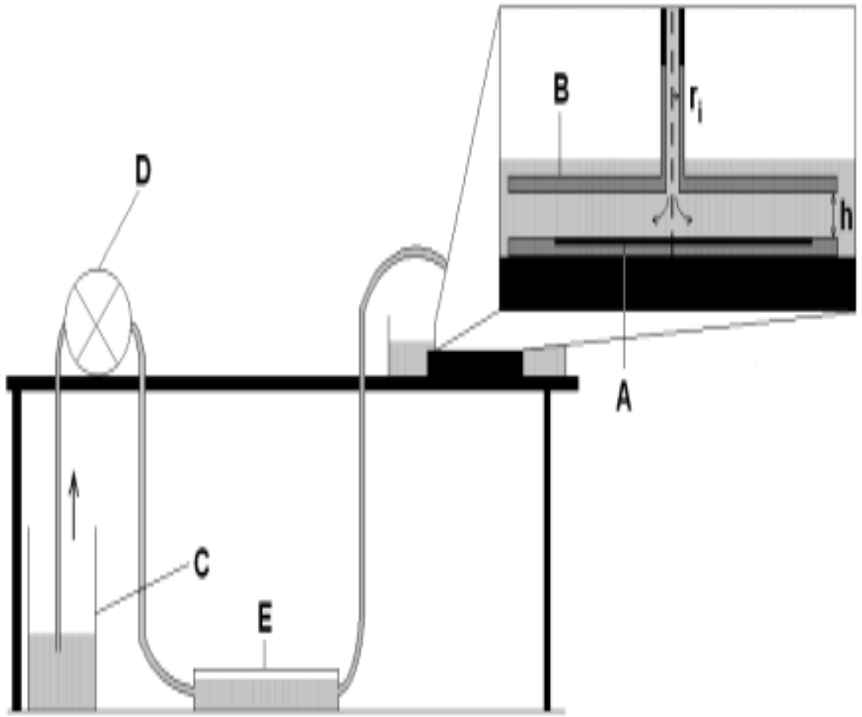
Drying, 30 min,

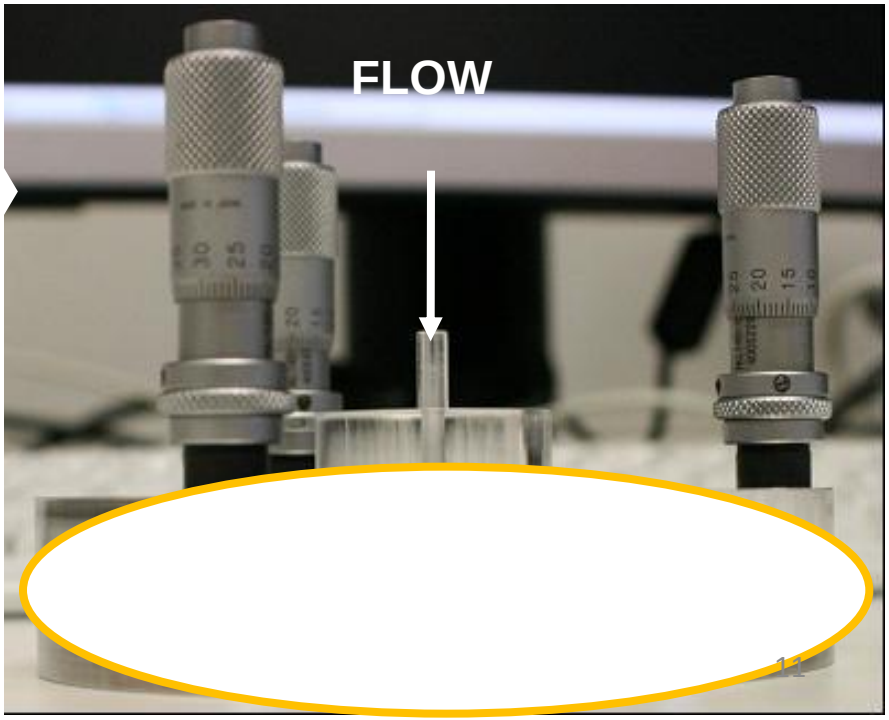
19 ± 5°C, 39% H

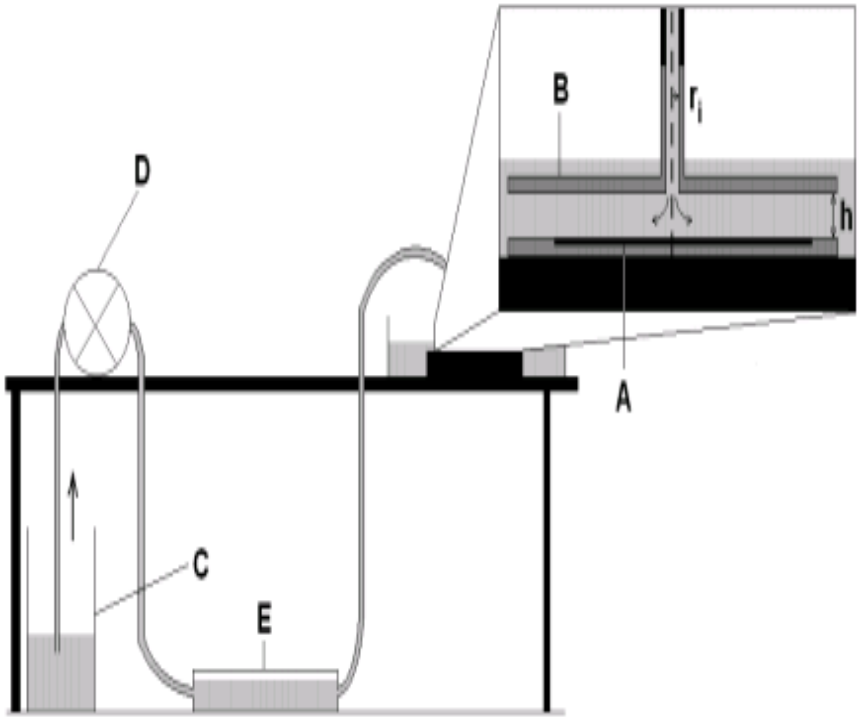
Picture I

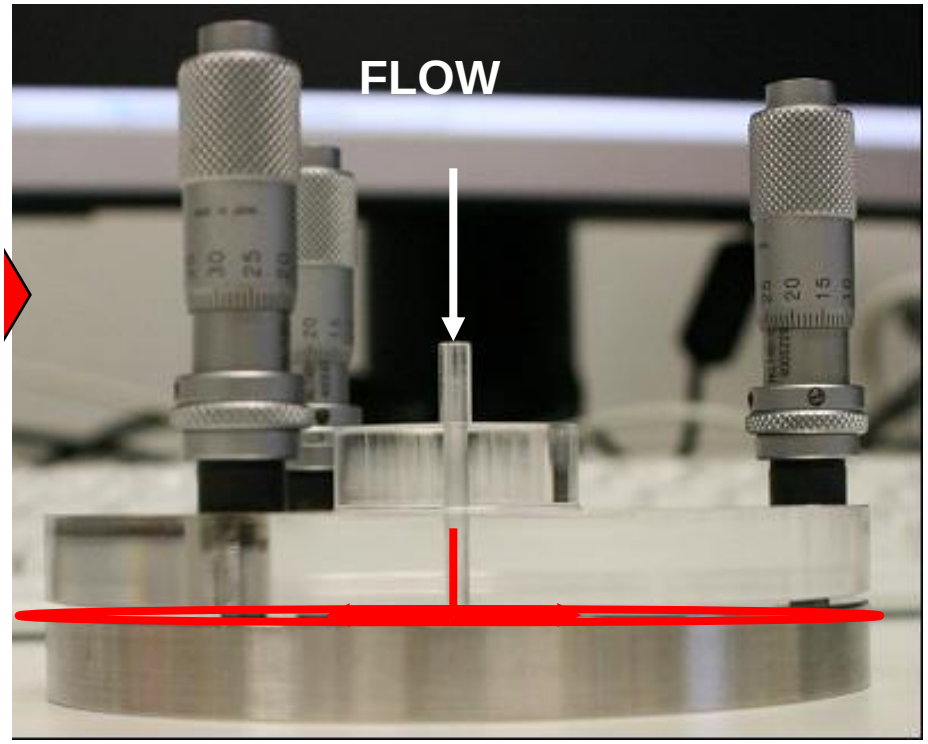
Radial-flow cell

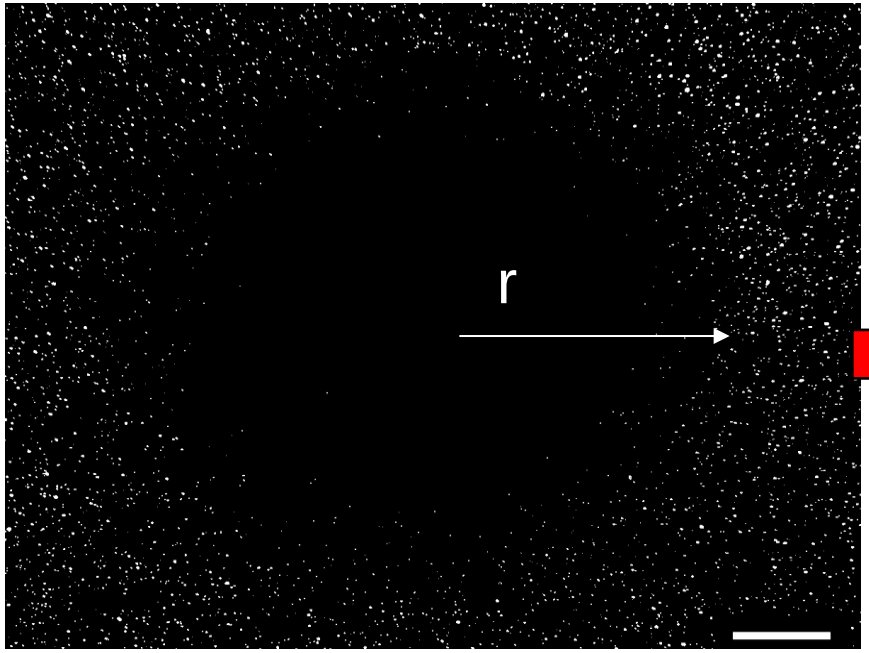
(40 ml/min)

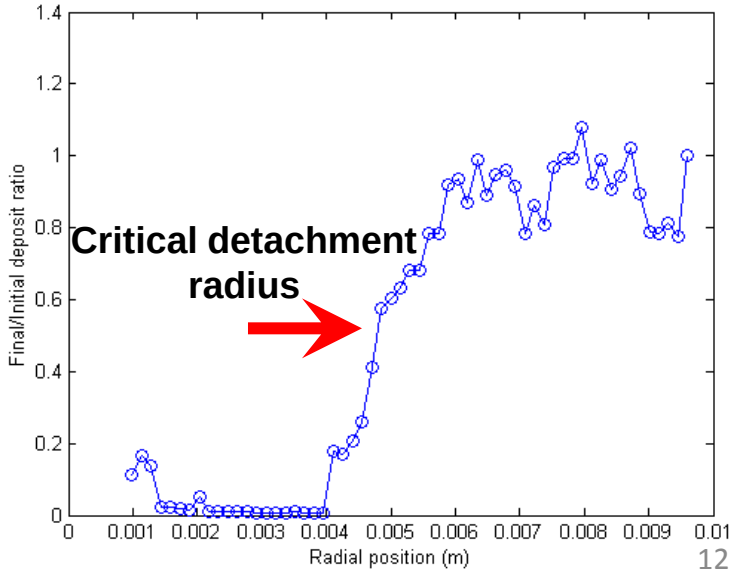





B
r_i
h
D
A
C
E

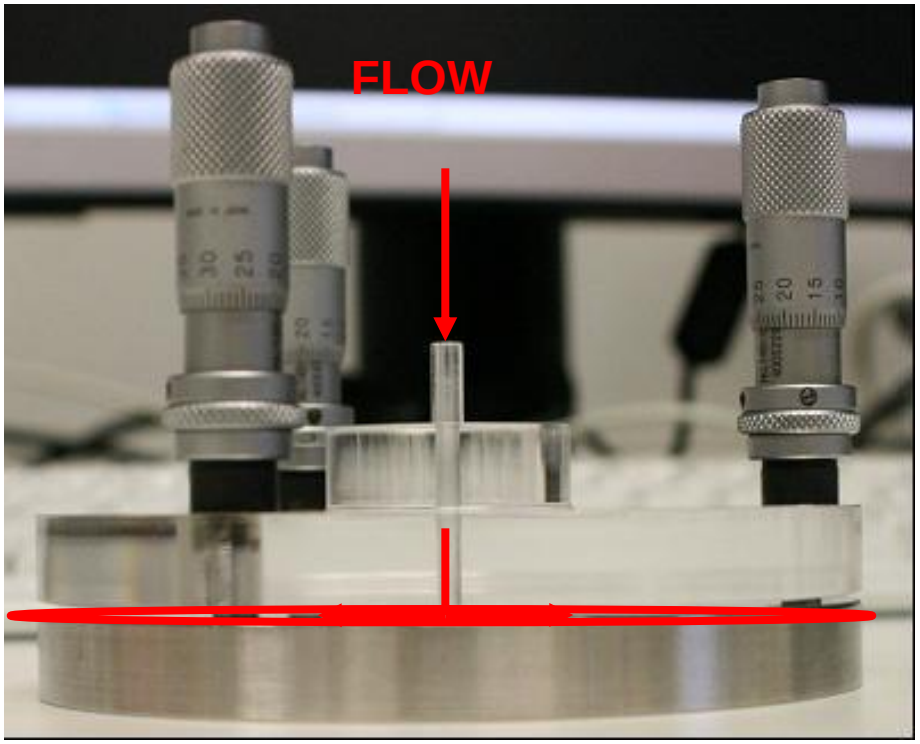

FLOW

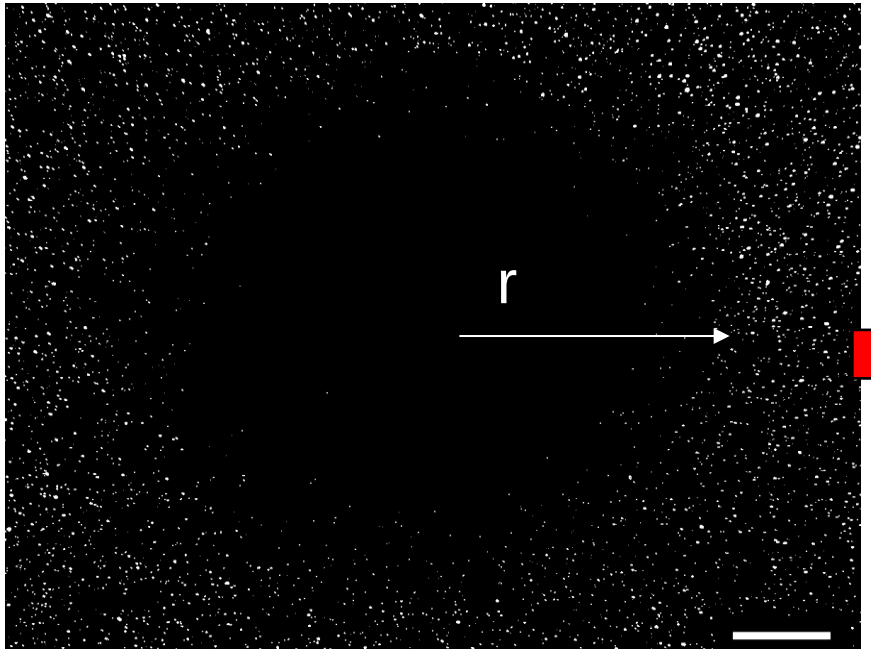

r

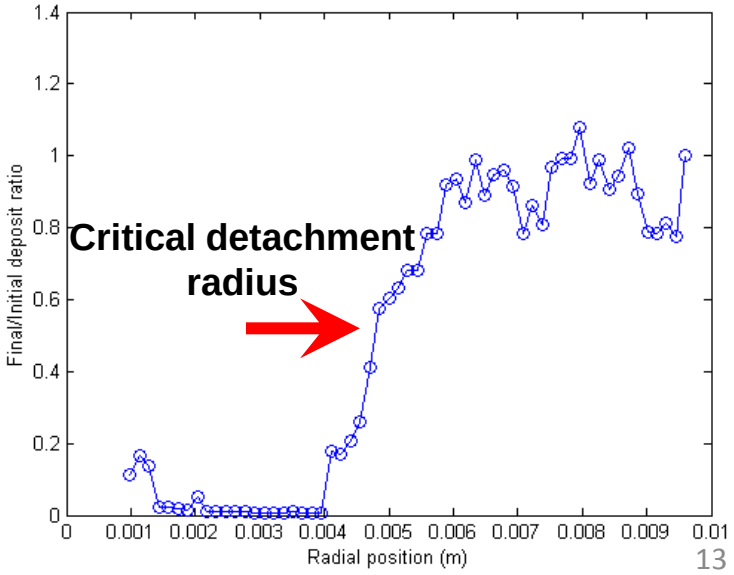

Critical detachment radius
Final/Initial deposit ratio
Radial position (m)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
0.001
0.002
0.003
0.004
0.005
0.006
0.007
0.008
0.009
0.01

- **At given flow rate:**
  Larger critical detachment radius
  ↔lower hydrodynamic drag force
  required to detach soiling

- **Increasing the flow rate**
  increasing drag force
  at critical detachment radius



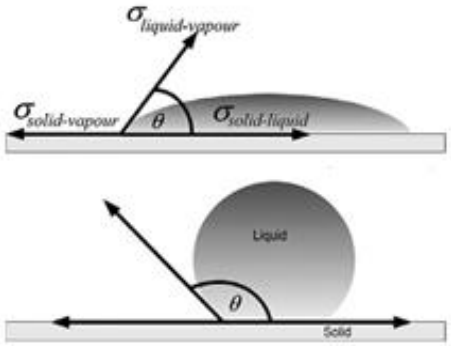




Interfacial properties

- **liquid surface tension**

- **static contact angle on substrate**



UVO treatment

Substrate	Water contact angle (°)		
	not treated	cleaned ethanol	UVO treatment
Glass	24 ± 2	17 ± 1	< 10
Stainless steel	43 ± 4	30 ± 1	10 ± 1

Surface analysis, XPS

➔ presence of carbon (Gerin et al., 1995; Rouxhet, 2013)

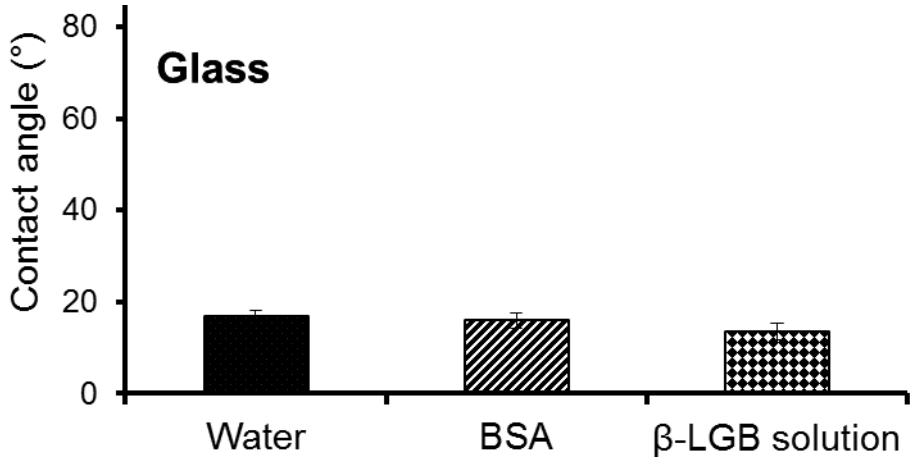
Surface pre-cleaning

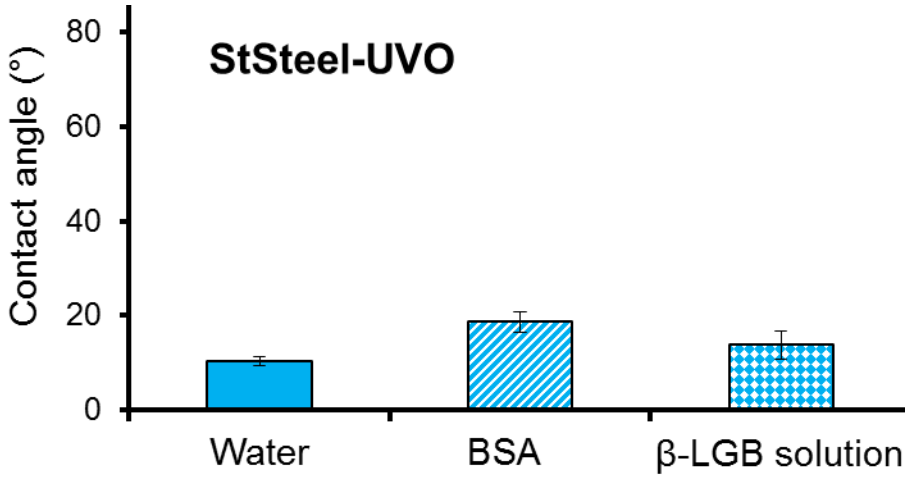
- ethanol ➔ water contact angle higher than expected
- UVO treatment

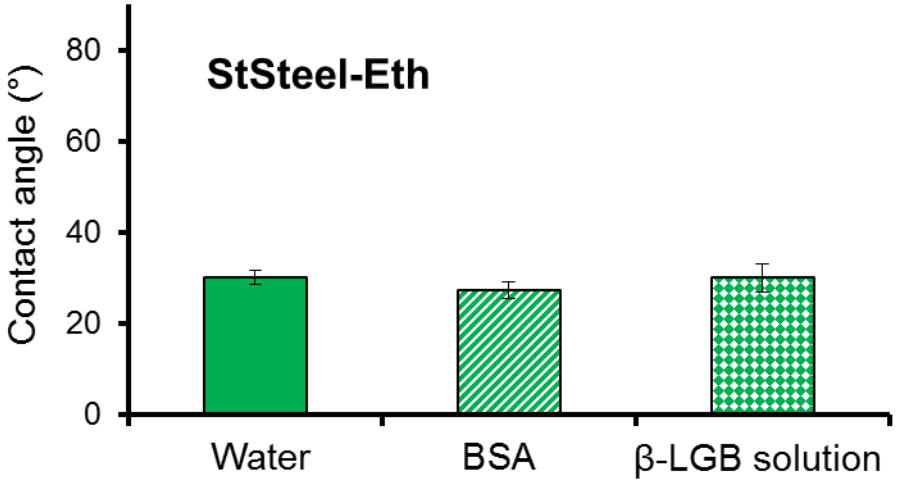
➔more effective removal of organic contaminants by oxidation

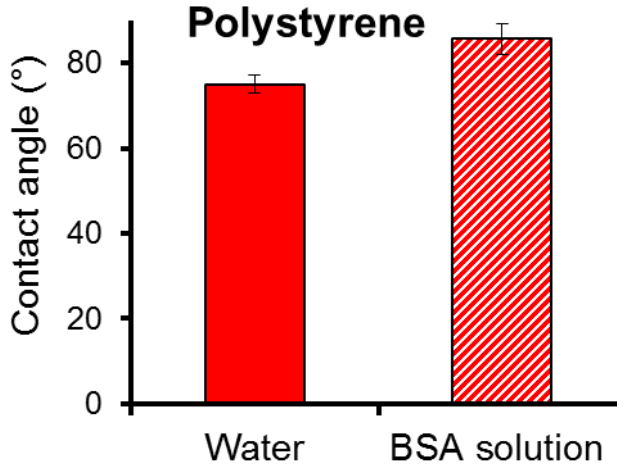
3. Results

Contact angle









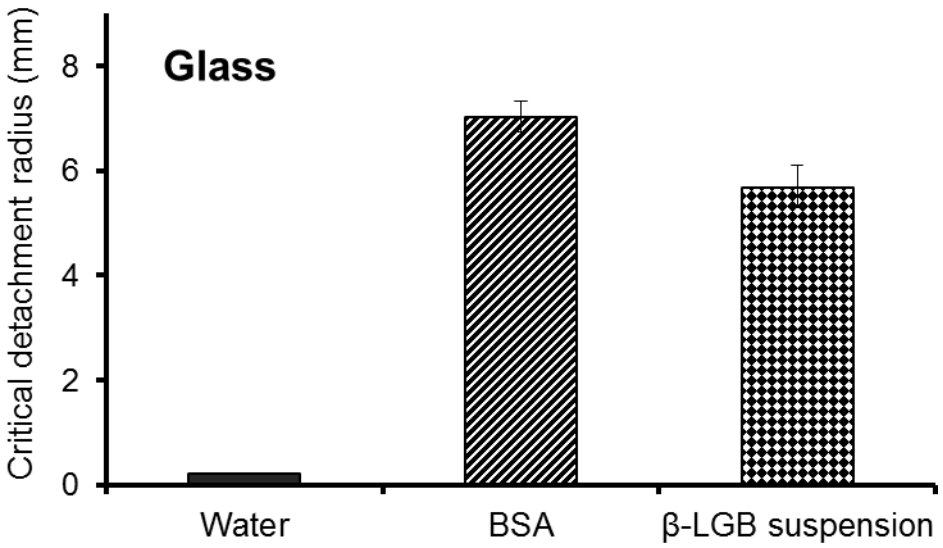
Liquid nature
no much influence

Glass < Polystyrene
expected

StSteel-UVO < StSteel-Eth
difference marked with water

3. Results

Detachment radius

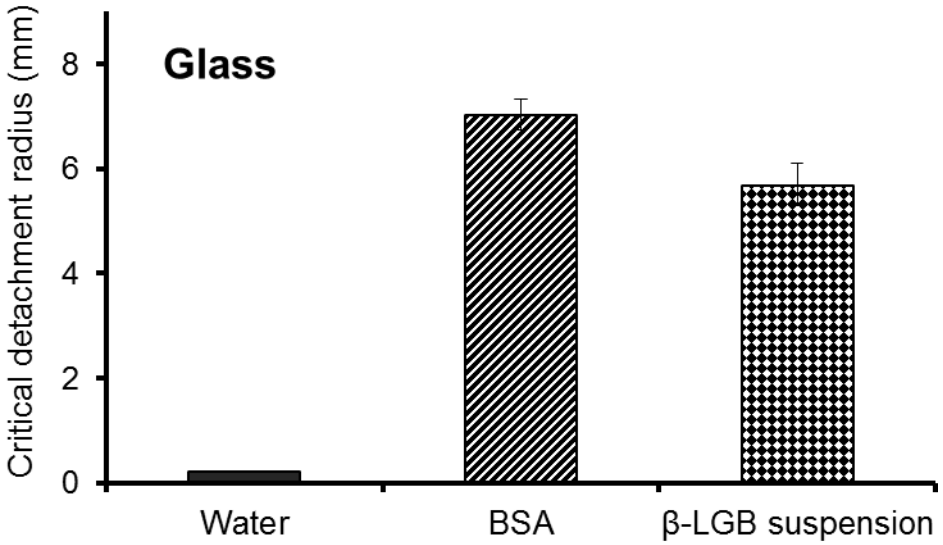


Water and BSA:
same as Glass treated by piranha

➔ **Robust data**

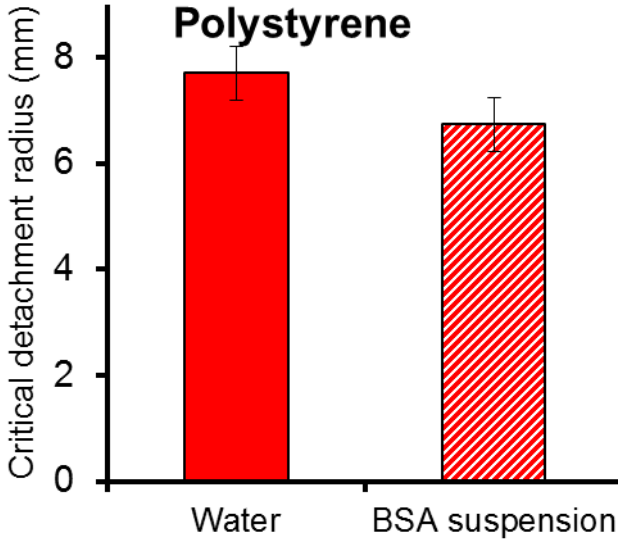
3. Results

Detachment radius



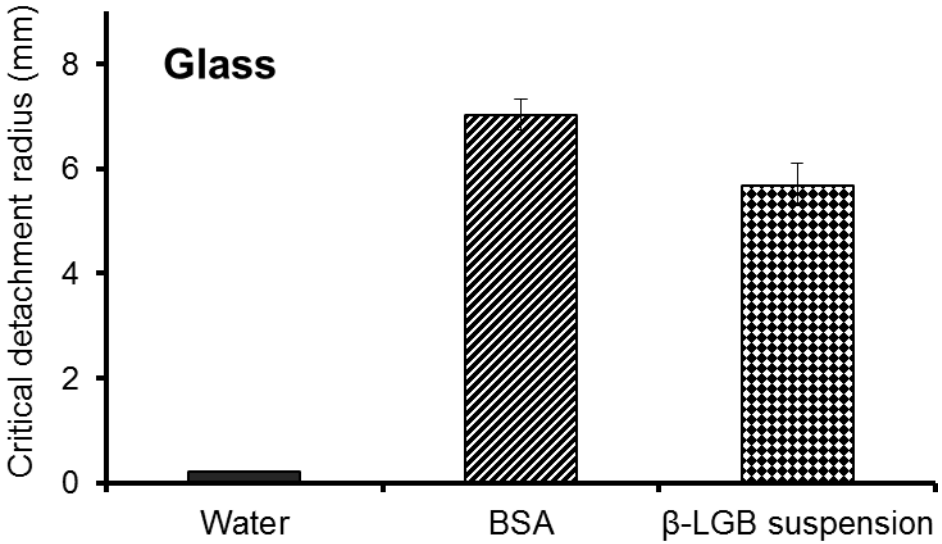
Results for glass and polystyrene reproduced after a time interval of 17 months

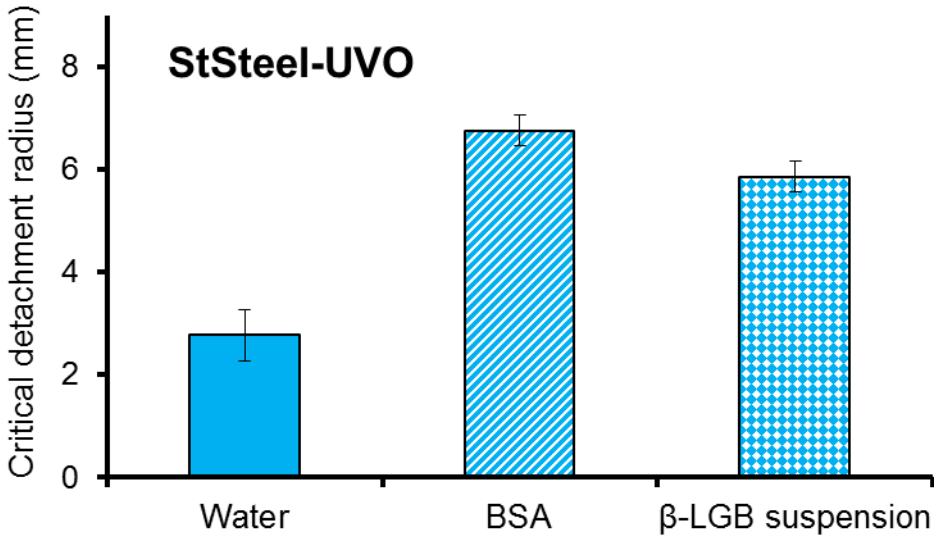
➔ • **differences significant**
• **robust observations**

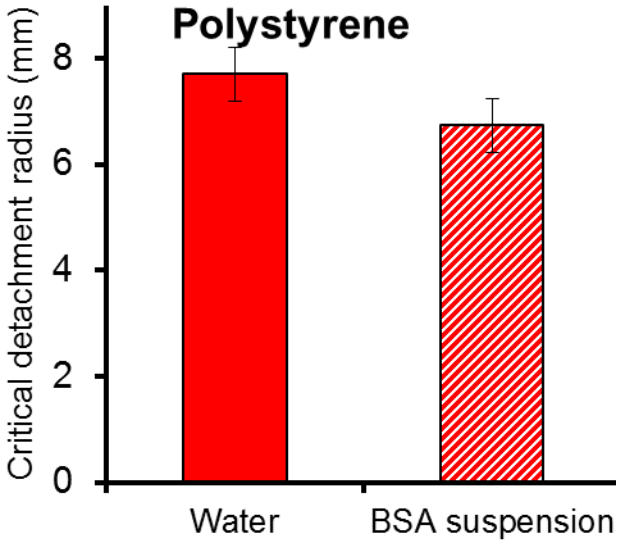


3. Results

Detachment radius

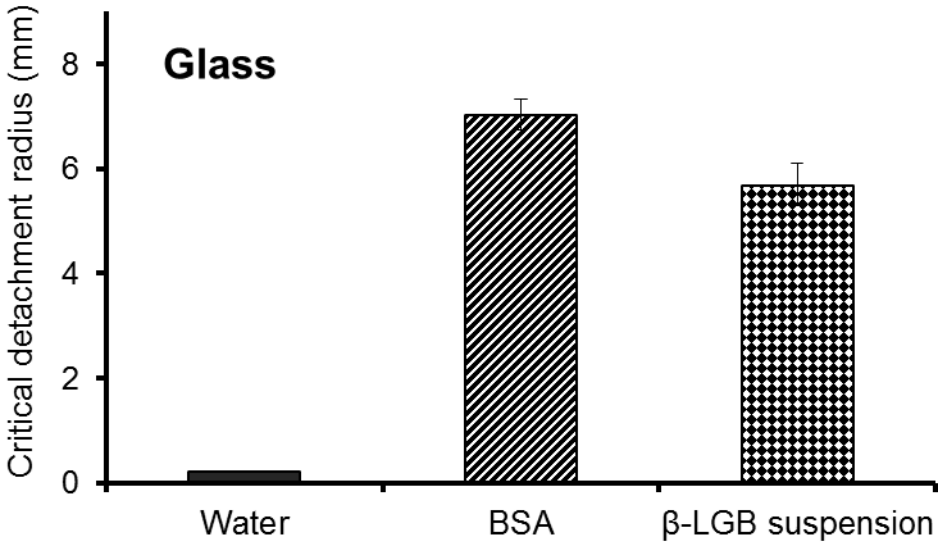


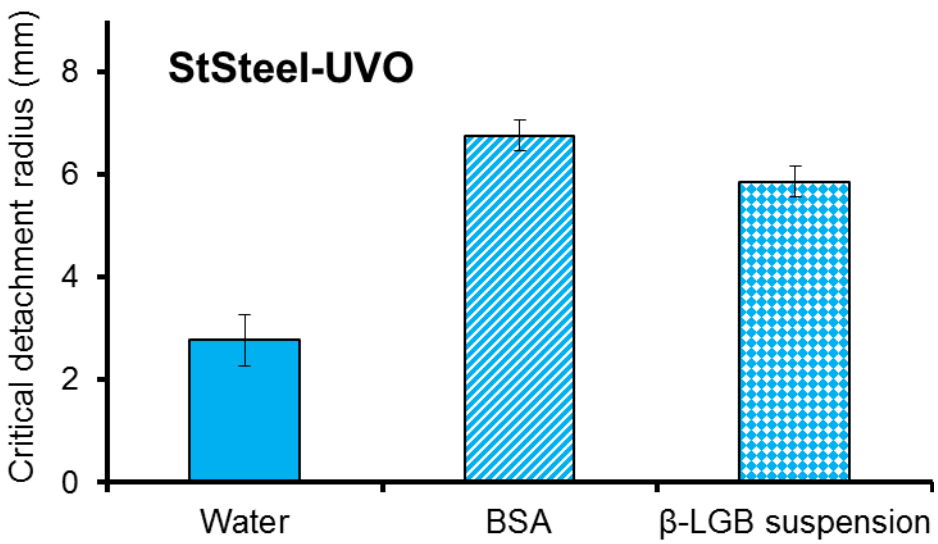


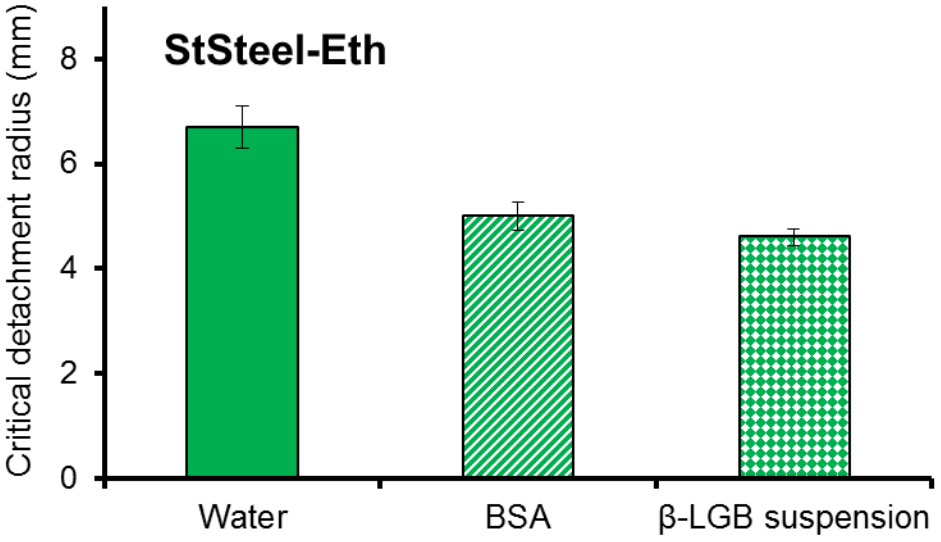


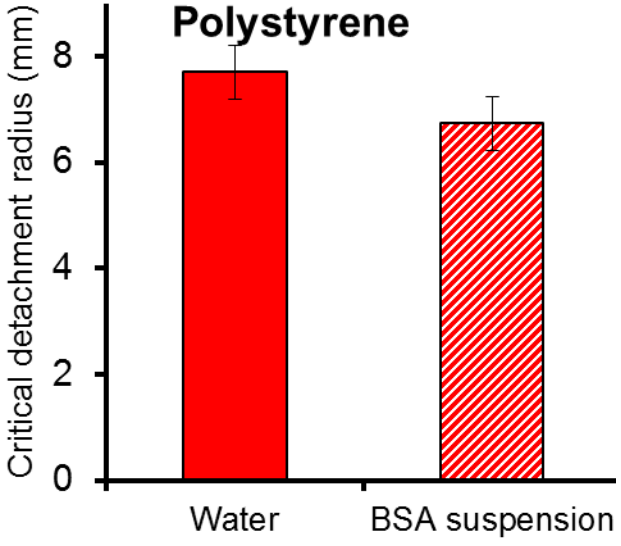
3. Results

Detachment radius



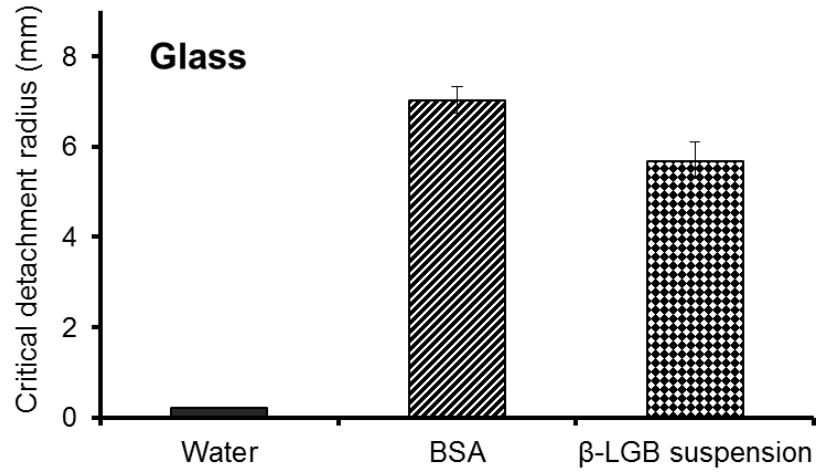


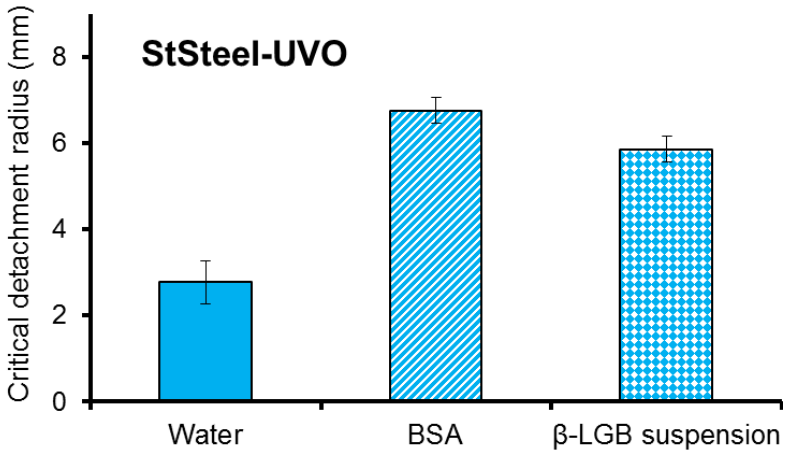


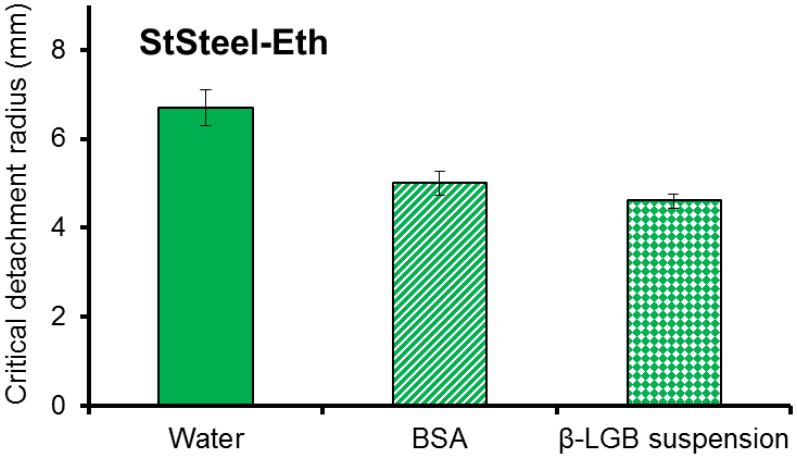


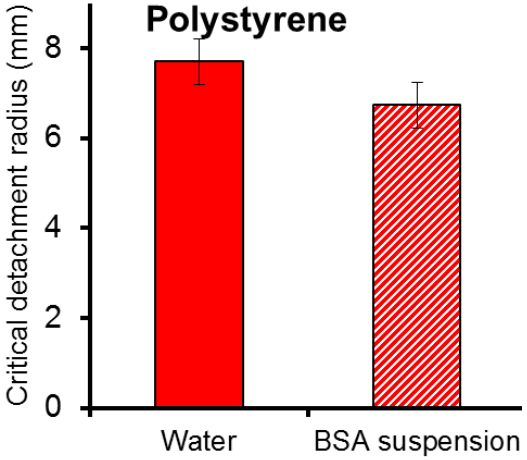
3. Results

Detachment radius





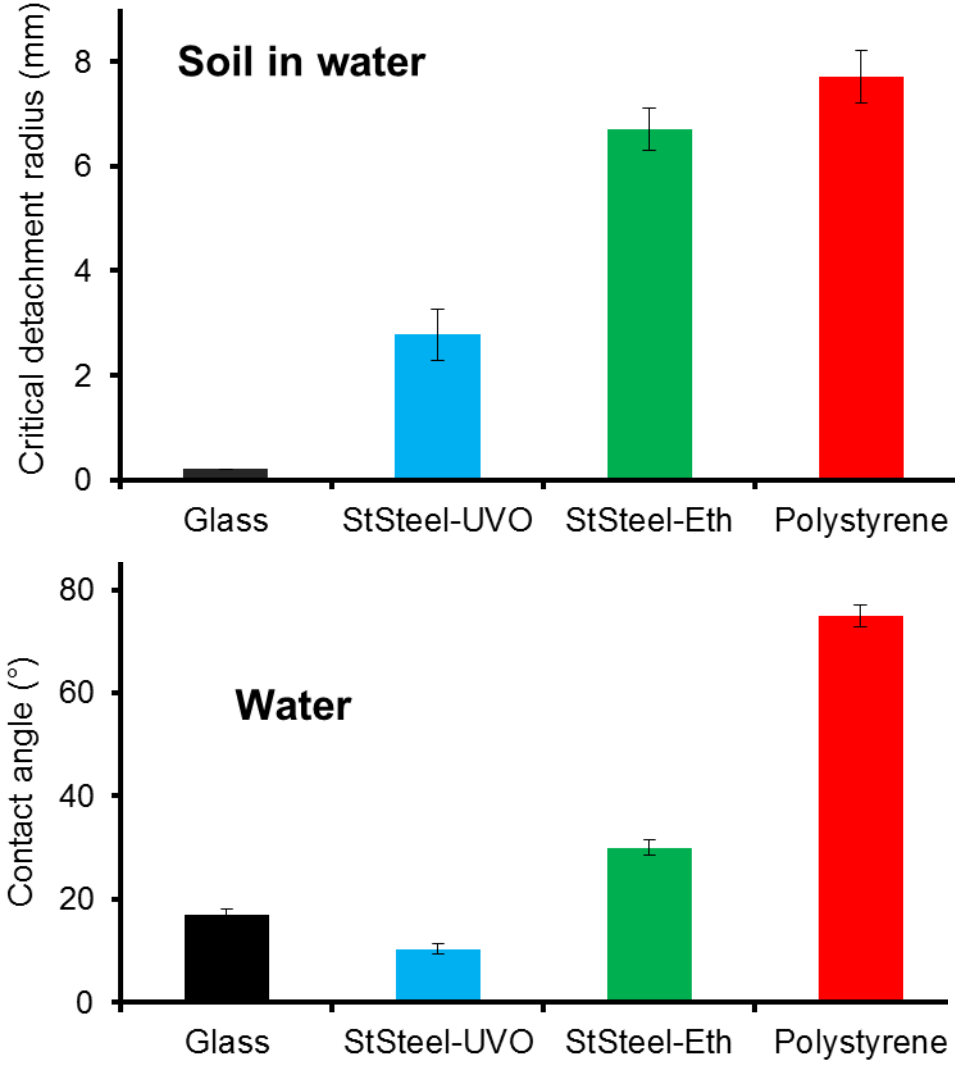




	Adherence
• **Soil in water** :	Glass > StSteel-UVO > StSteel-Eth > Polystyrene
• **Glass and StSteel-UVO:**	water > protein solution
• **StSteel-Eth** :	water < protein solution
• **Polystyrene** :	water ≈ protein solution

4. Discussion

Relation with wetting



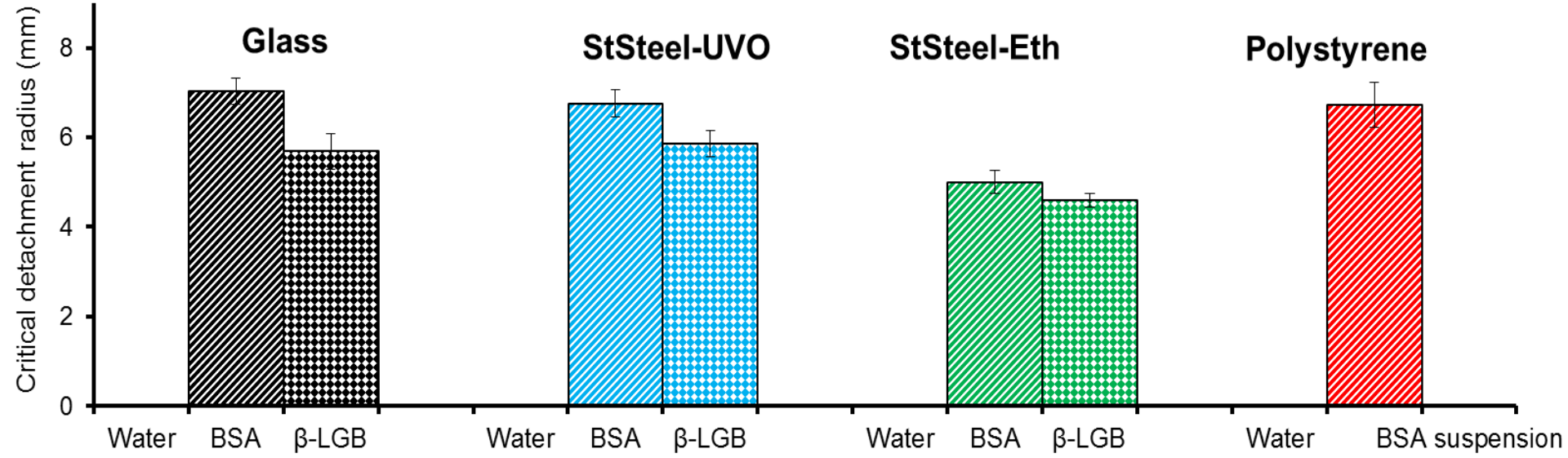
Adherence ↗ as water contact angle ↘ excepted StSteel-UVO

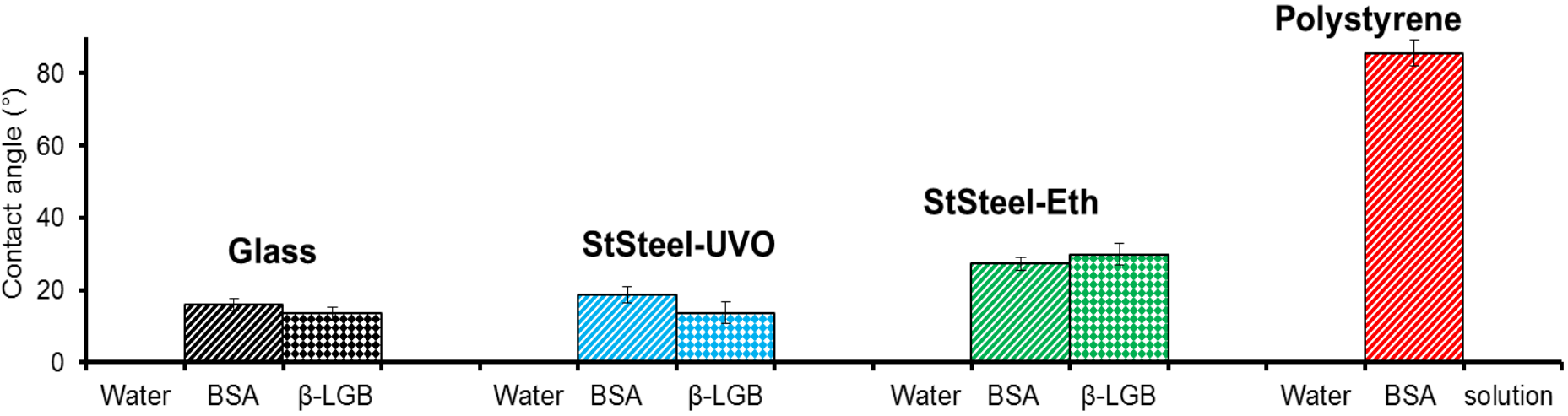
⬅➡ • **droplet spreading:** shape of dried soil, efficiency of shear force

• **strength of capillary forces:** strength of particle-substrate contact

4. Discussion

Soil with proteins

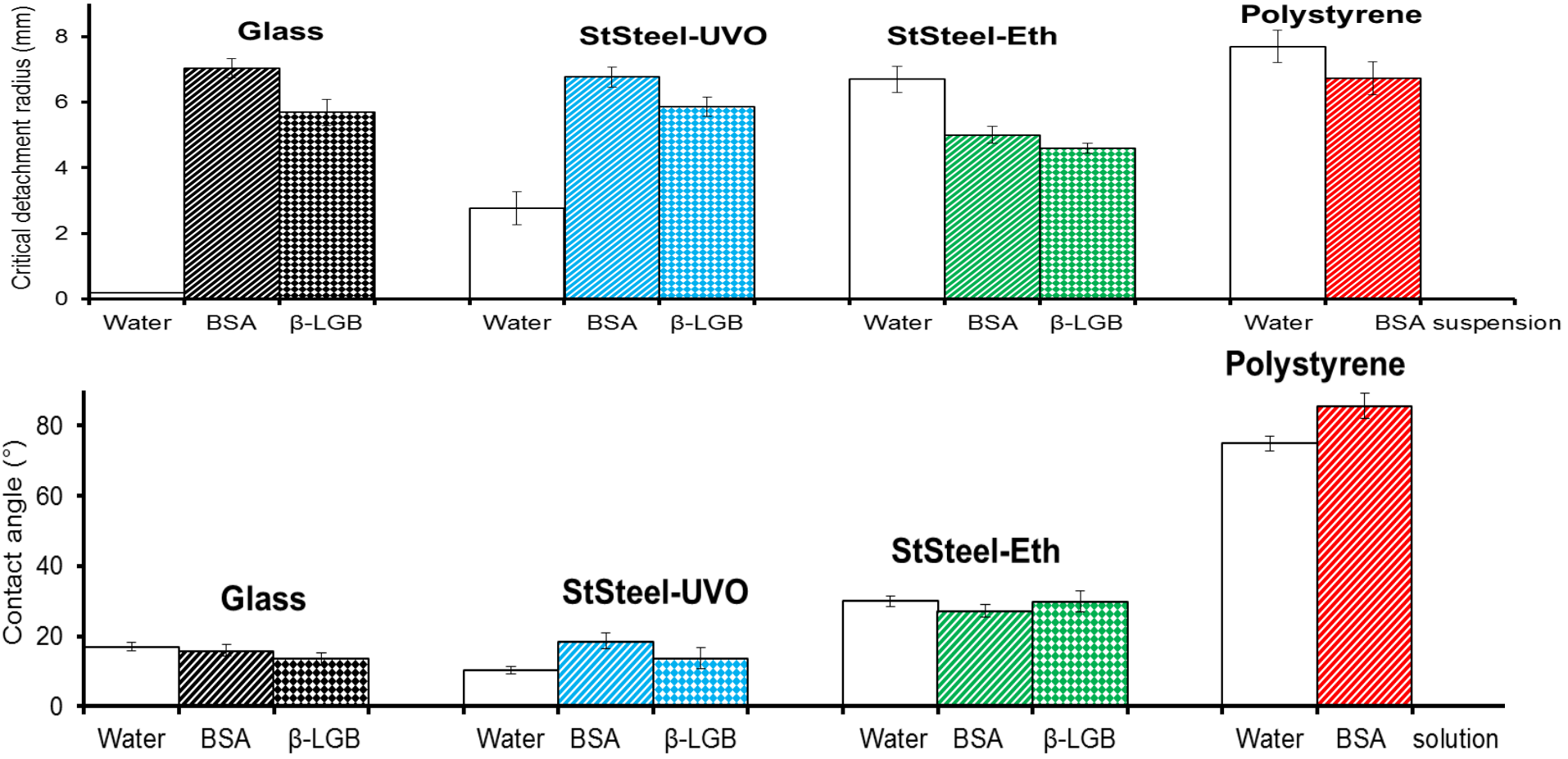




Adherence ↘ as solution contact angle ↗ excepted Polystyrene

4. Discussion

Soil with proteins



Comparison protein solution/water

	contact angle	adherence
Glass, StSteel-UVO	≈	protein **<<** water
StSteel-Eth, Polystyrene	≈	protein **>** water

⬅➡? liquid surface tension, adsorbed or accumulated proteins, receding contact angle?

5. Conclusion

Different substrates,
suspension in water
substrate hydrophobicity ↗, particle adherence ↘
droplet spreading and capillary force upon drying

Different substrates (excepted polystyrene)
suspension in protein solution
contact angle ↗, particle adherence ↗

Suspension in protein solutions vs water

- contact angle about the same
- adherence: Glass, StSteel-UVO: protein **<<** water
  StSteel-Eth, Polystyrene: protein **>** water

Not simple relation with contact angle

Possible explanation

- suspending medium surface tension
- proteins behavior at interfces
  - during drying
  - rehydration during cleaning
- role of receding contact angle

4. Conclusion

Possible explanation

- suspending medium surface tension
- proteins behavior at interfces
  - during drying
  - rehydration during cleaning
- role of receding contact angle

Broader study, including protein denaturation, is under way

Remark on influence of substrate on soiling

To be kept in mind:

high surface energy solids (metals, oxides)

- contaminated in contact with air ➔ hydrophobicity decreased

Thank you for your attention !