Micro- and Nanosized TiO_2 Particles Immobilized in Sintered Recycled Glass for the Degradation of THM Precursors in Surface Waters

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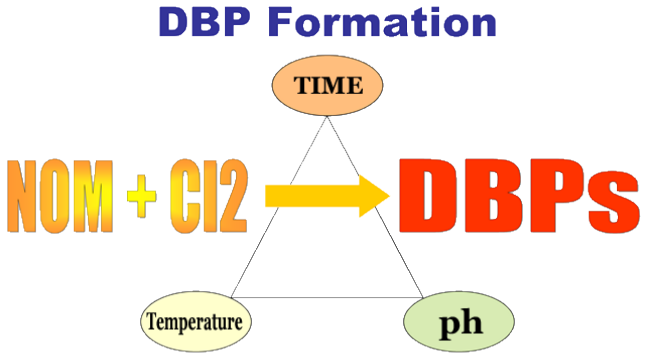
Overview

1. Trihalomethanes

- Disinfection by-products that result from the reaction of chlorine with natural organic matter (NOM) present in the water



- They are carcinogens

- MCL (USEPA) ≤ 80 ppb (0.08 µg/L)

Overview (cont.)

2. Strategies for THM Control

1. THM removal by aeration, adsorption or ion exchange processes

2. THM prevention

   - Changes in chlorination application
   - Reduction of chlorine doses
   - Change disinfectant agent
   - NOM removal (destruction or oxidation)

Goal

Develop a porous filter-like composite made out of glass to support titanium dioxide (TiO_2) micro- and nanoparticles as a low cost alternative for the destruction of THM precursors

Specific Objectives

1. Identify an appropriate sintering temperature and time range to obtain a solid, porous glass substrate.

2. Access important thermo-mechanical properties of the glass substrate to support water percolation and strength.

3. Effectively immobilize TiO_2 particles within the glass matrix in order to make a TiO_2-glass composite.

4. Observe the polymorph structure of TiO_2 for the selected sintering temperatures by x-ray diffraction analysis (XRD).

5. Evaluate the glass-TiO_2 composite capacity for the degradation of humic acid under the influence of UV light by means of total organic carbon (TOC) analyses.

Methodology

Parameters under evaluation:

1. Sieve analysis for the crushed glass

2. Structural analyses for the glass /TiO_2 composites
   - Percolation
   - Surface porosity

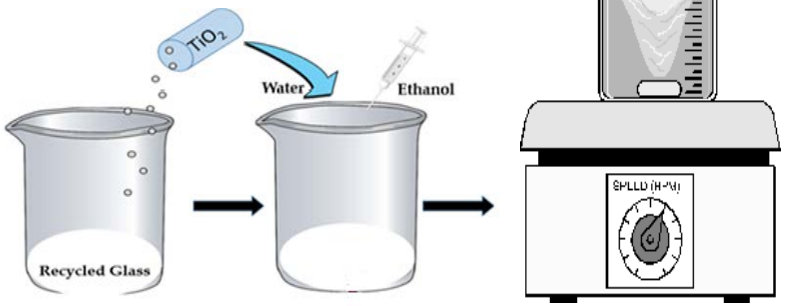
3. Mechanical analyses for the glass/TiO_2 composites
   - Compression

4. XRD analysis for the TiO_2

5. Humic acid degradation potential

Methodology (cont.)

Glass substrates and glass-TiO_2 composite preparation:



Heat and stir

Ceramic mold

950 -1,000˚C

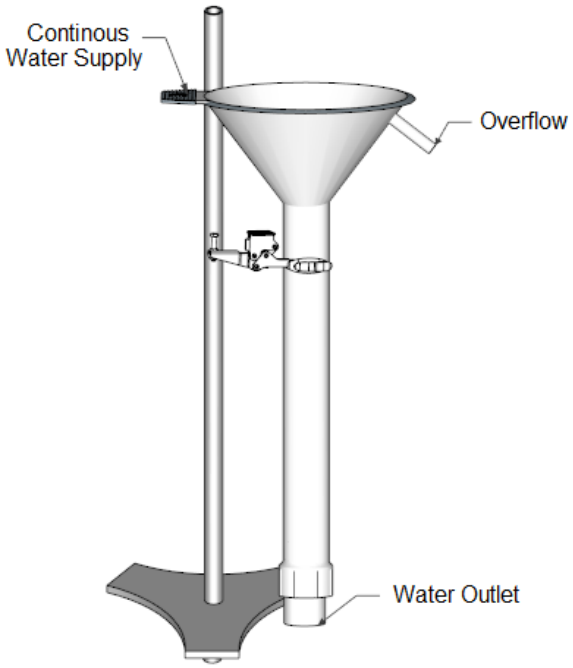
45 -75 minutes

Muffle furnace

Final Glass/TiO_2 sample

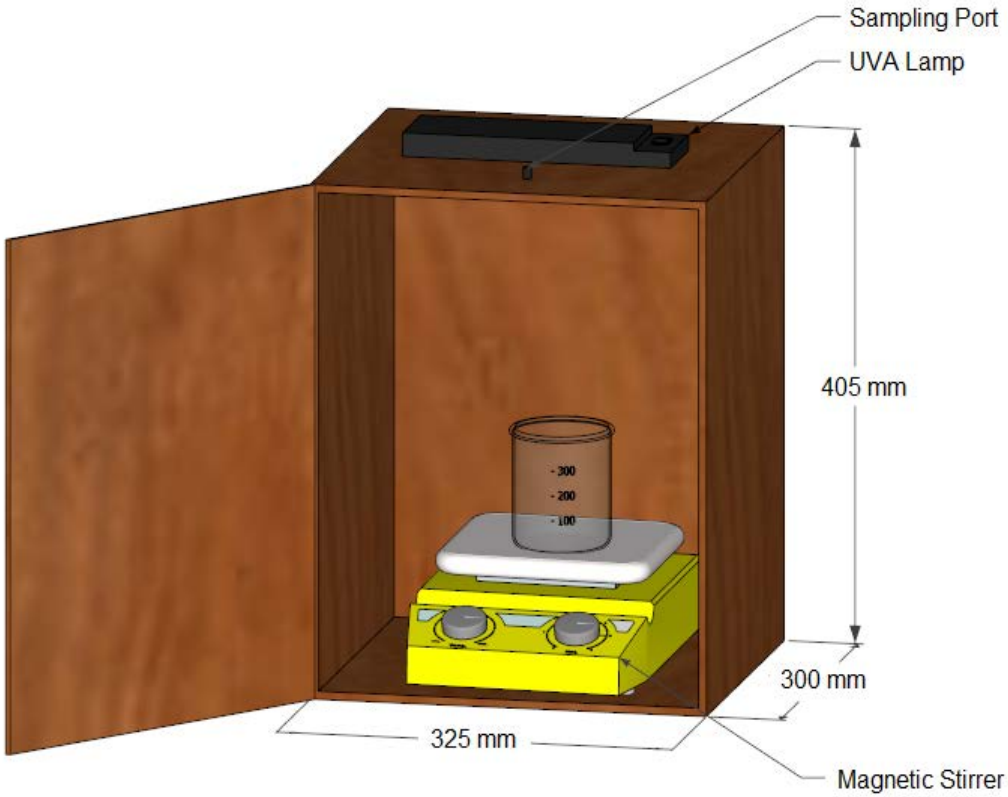
Methodology (cont.)

Percolation:



Methodology (cont.)

Photo-degradation reactor box:



$$TiO_2 + hv \leftrightarrow h^+ + e^-$$

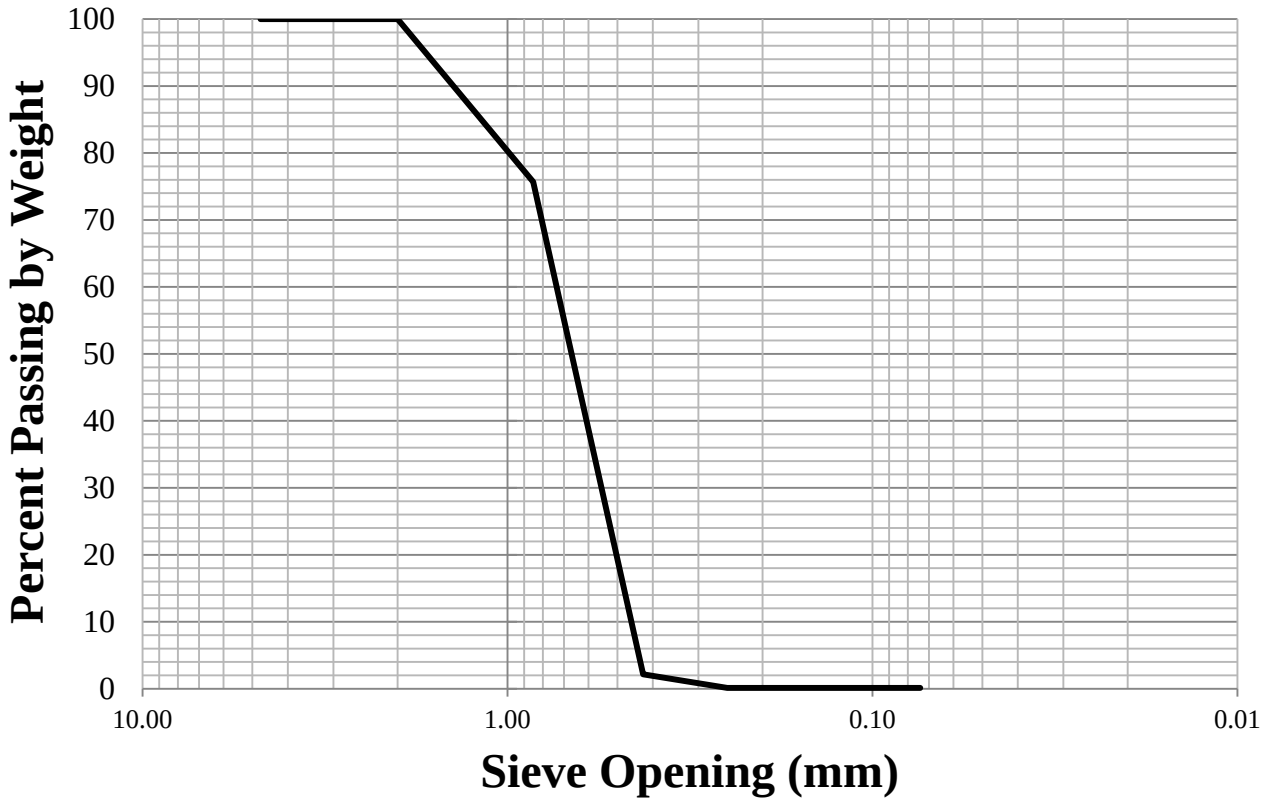
$$h^+ + H_2O \leftrightarrow H^+ + \bullet OH$$

$$h^+ + OH^- \leftrightarrow \bullet OH$$

$$e^- + O_{2\,absorbed} \leftrightarrow \bullet O_2^-$$

Results

Sieve analysis for the crushed glass:



Effective Size (d_{10}): 0.47 mm
Finer Size (d_{60}): 0.74 mm
Uniformity Coefficient (UC): 1.57

Results (cont.)

Percolation data for the sintered glass substrates with time and temperature:

Sintering temperature (^oC)	Sintering time (min)	Average Percolation flux (gpm/ft^2)
	45	**17.71**
950	60	15.58
	75	12.06
	45	9.01
975	60	7.06
	75	3.64
	45	5.59
1000	60	0.17
	75	**0.059**

Results (cont.)

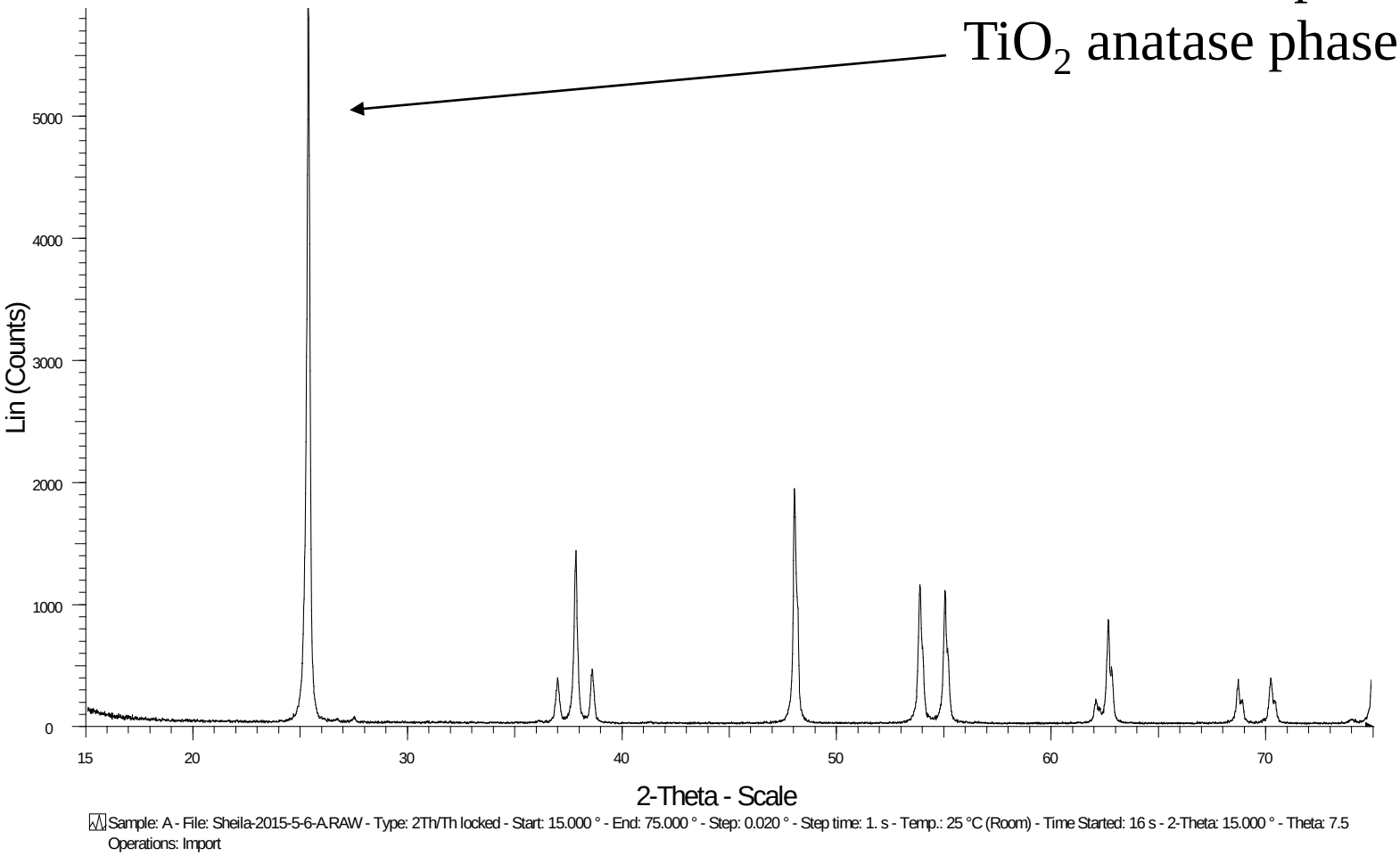
Percolation data for the glass-TiO_2 composites with time and temperature:

Sintering temperature (^oC)	Sintering time (min)	Average Percolation flux (gpm/ft^2)
	60	**36.20**
950	75	32.83
	90	27.88
	60	25.85
975	75	15.36
	90	**12.66**

Results (cont.)

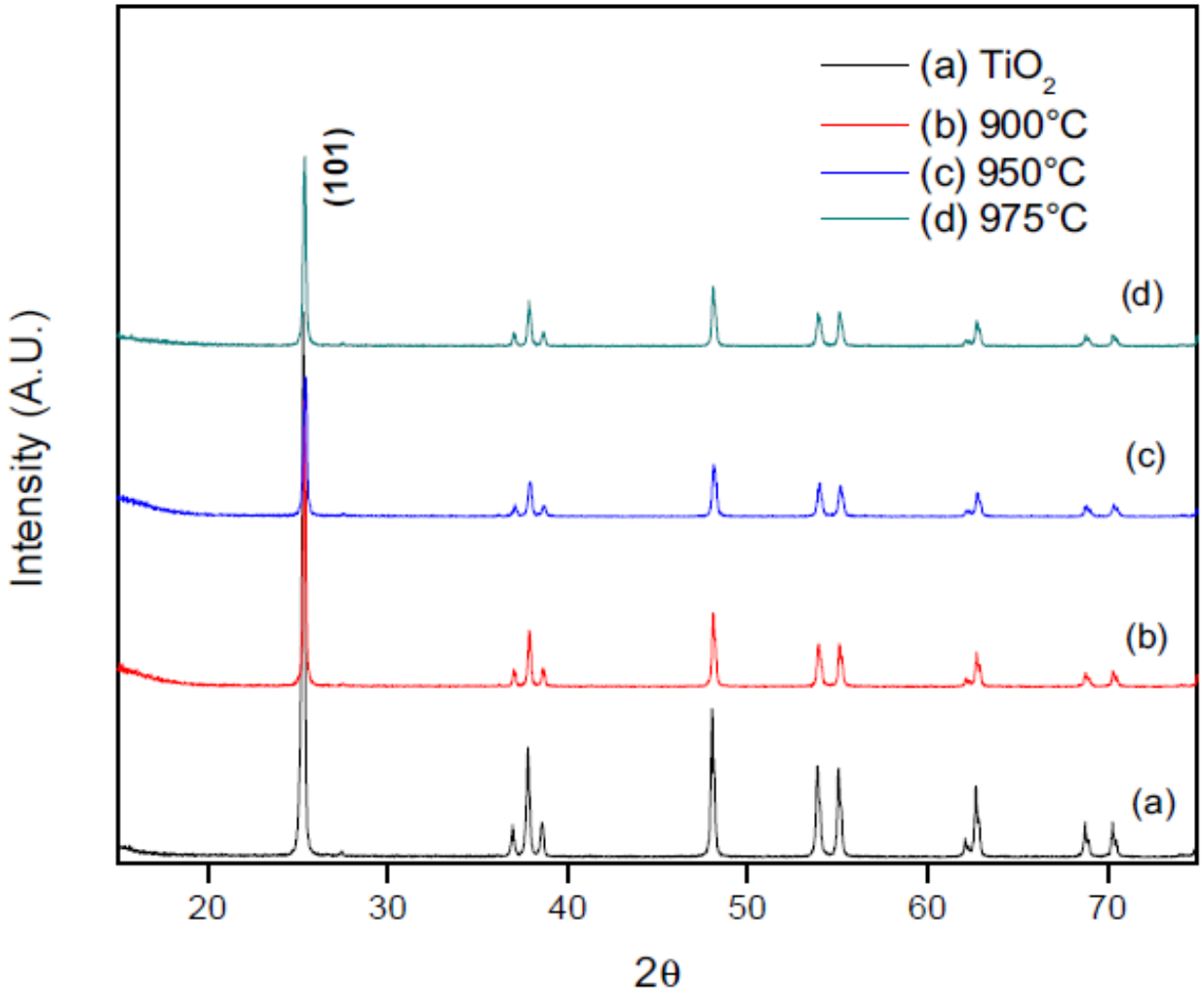
TiO_2 XRD spectrum:

Characteristic peak for TiO_2 anatase phase



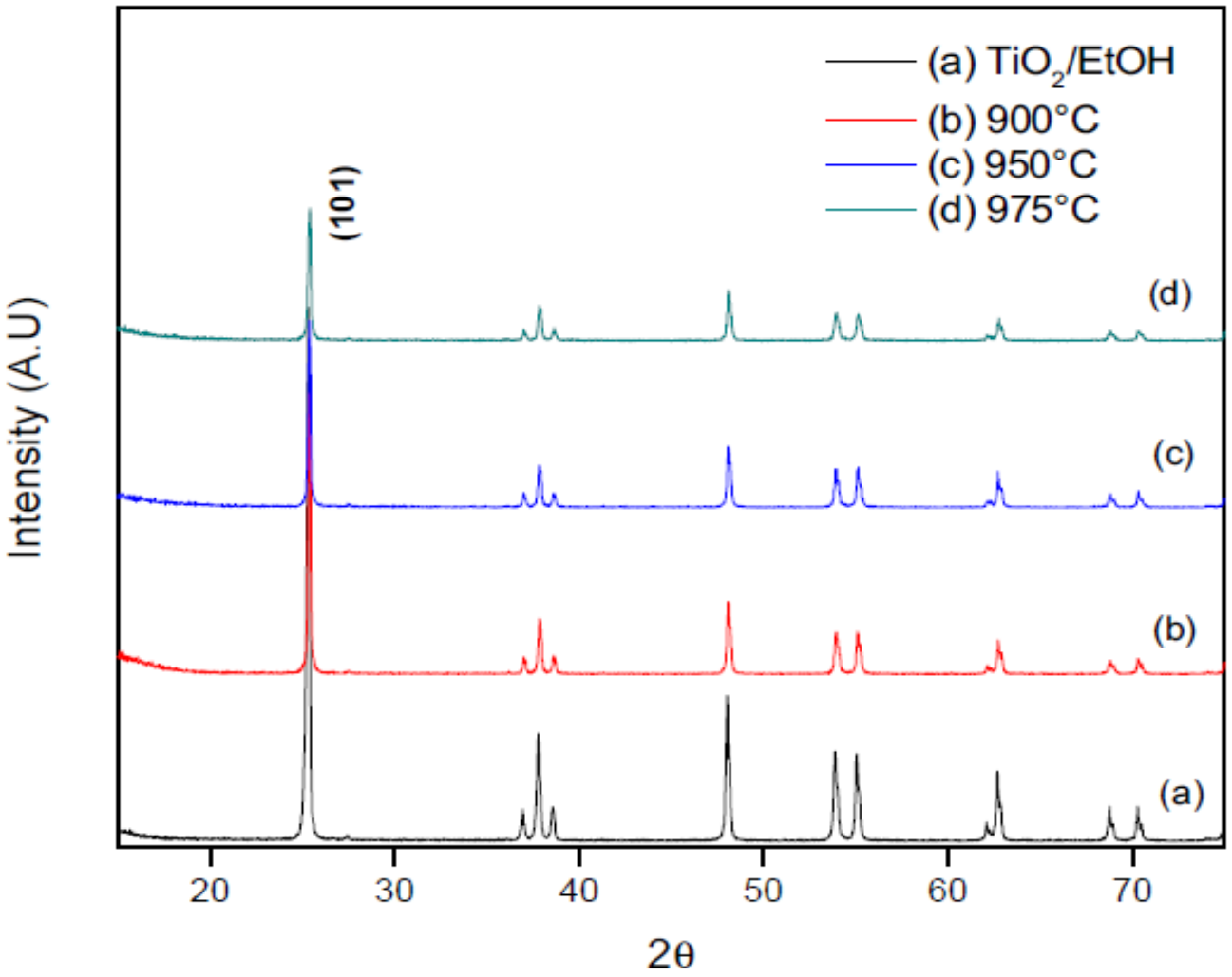
Results (cont.)

XRD spectra for TiO_2 at different temperatures:



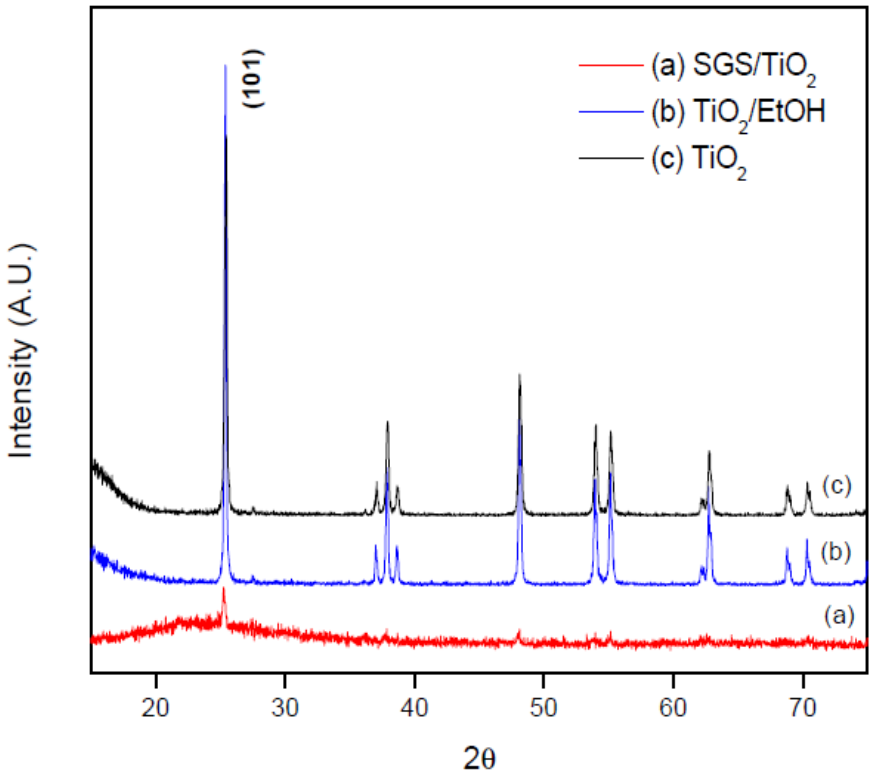
Results (cont.)

XRD spectra for TiO_2 + ethanol at different temperatures:

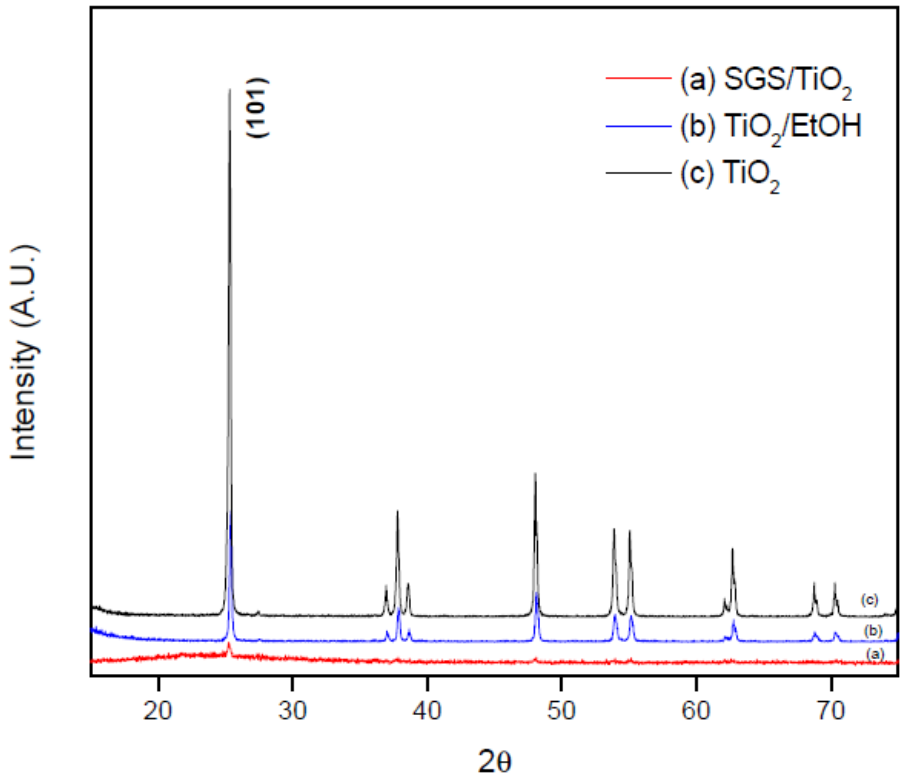


Results (cont.)

XRD spectra for glass-TiO_2 composites:



950°C

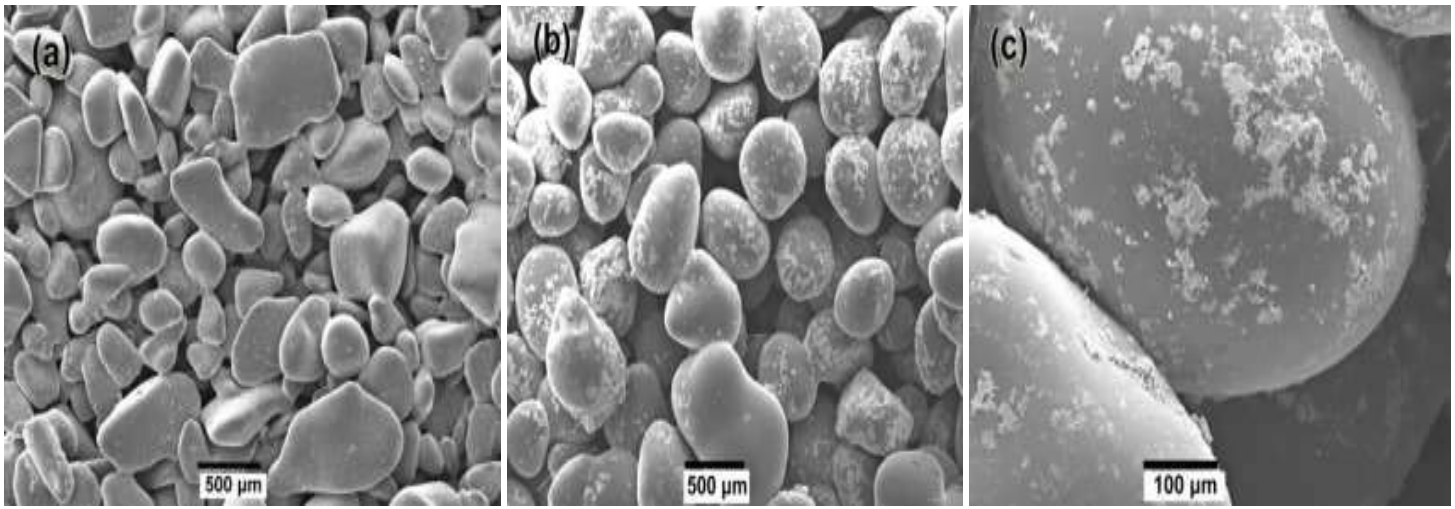


975°C

SGS = sintered glass substrate

Results (cont.)

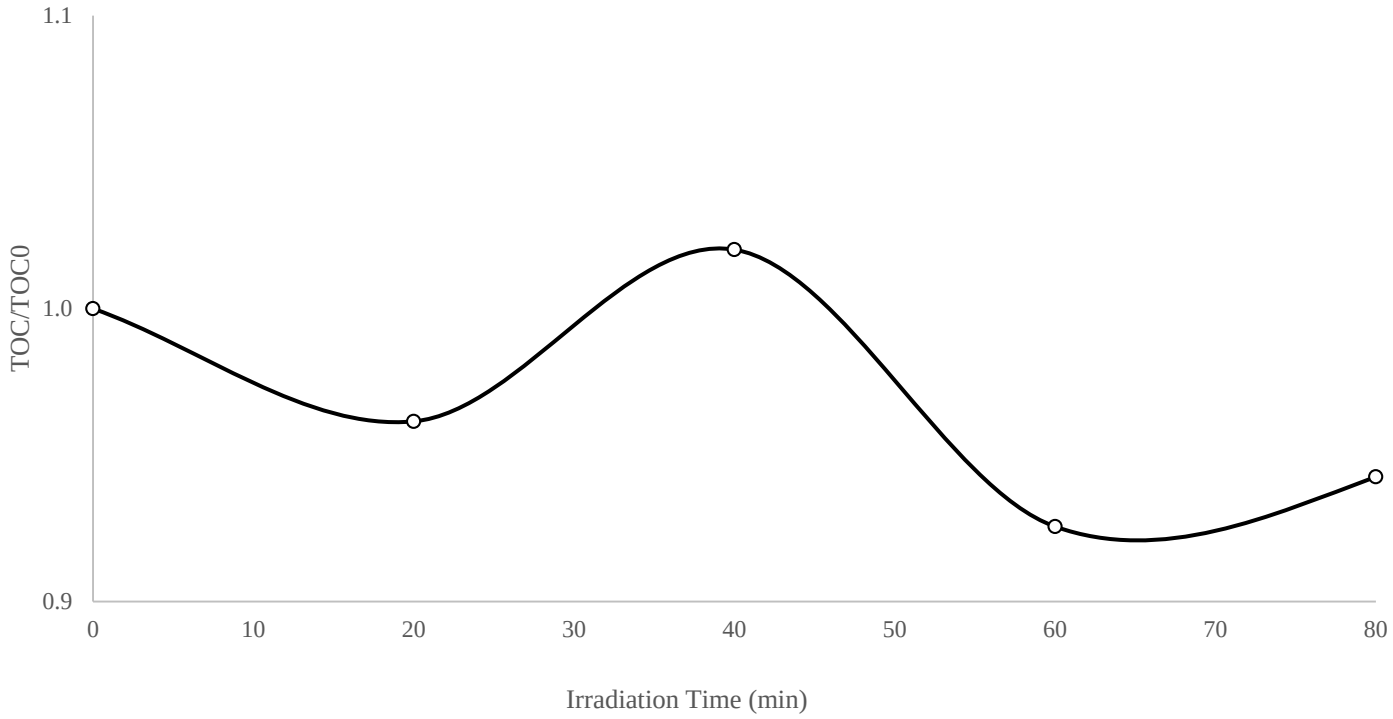
Scanning Electron Microscope (SEM)



TiO_2 deposition into the glass powder sintered at 750^{o}C for 25min. (a) 0% of TiO_2 at 500 µm (b) 1.0% of TiO_2 at 500µm (c) 1.0% of TiO_2 at 100µm

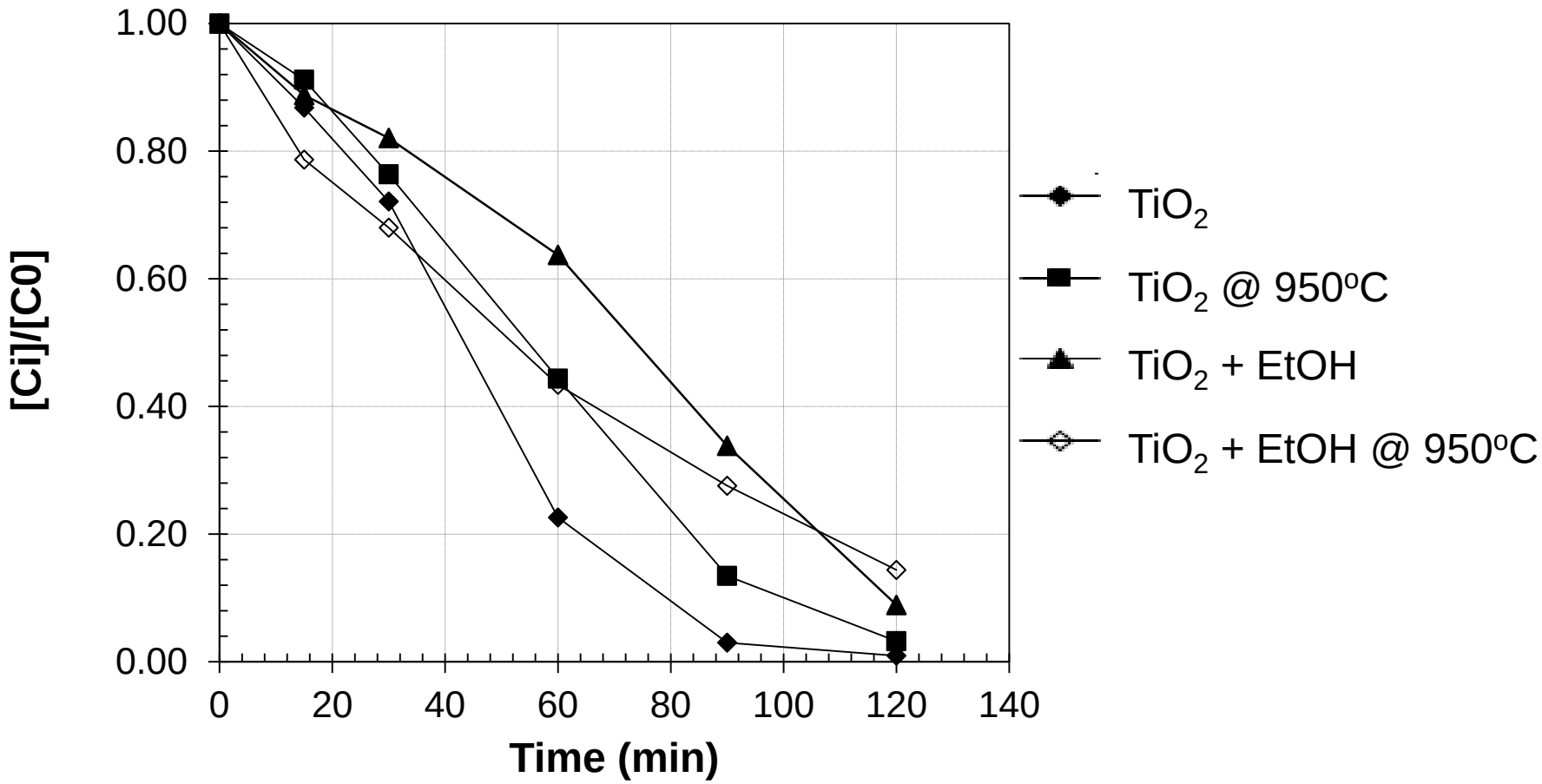
Results (cont.)

Degradation of humic acid with TiO_2-glass composites under the influence of UV light



Results (cont.)

Degradation with TiO_2 and TiO_2 mixtures suspensions at different temperatures under the influence of UV light



Summary and Conclusions

- Temperature and time affect the percolation rate; at higher values of sintering parameters less percolation rate.
- The percolation rates was higher in the composites with TiO_2 particles.
- Filtration rates similar to those found for traditional rapid sand filters can be achieved.
- The anatase phase in TiO_2 remains after exposure to high temperatures for glass sintering.
- The TiO_2 particles have photo-activation capacity, even after been exposed to the chemicals and temperatures for glass sintering.

Summary and Conclusions

- The optimal amount of TiO_2 particles that can be hold for the glass composite is 0.30 g.
- The low degradation rate of humic acid indicates low photo-activation of TiO_2 most likely due to low UV light penetration through the glass composite.
- Results are promising provided that TiO_2 is favored to promote photo-degradation, however, alternate immobilization methods for the TiO_2 that could yield in higher UV exposure for higher photo-degradation should be evaluated.

On-going and future work

- Surface porosity of the sintered glass and glass/TiO_2 composite.
- Compression analyses.
- Examine the adsorptive capacity of the sintered glass for HA.
- Perform quantitative and qualitative comparisons on different methods for the immobilization of TiO_2 in the glass substrate by deposition of TiO_2 suspension over the sintered glass surface coating the sintered glass surface.
  a. Using EtOH + nitric acid, and
  b. polyvinyl alcohol

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Thank
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