FLOW-THROUGH REACTOR FOR TESTING PHOTOCATALYTIC ACTIVITY OF MULTIFUNCTIONAL FILTER CLOTHS

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Filter Media Testing, Coated Filters, antibacterial, Nano Media

ABSTRACT

Methods of measuring photocatalytic effectivity of immobilized nanolayers used e.g. on multifunctional filter clothes and membranes, described in literature, mostly suffer from mass transfer problems within the rather complex system: catalyst surface – bulk contaminant – light distribution. To avoid these drawbacks a new unit has been developed. Several strips of filter cloth are deposited side by side on inclined flat and smooth PTFE tile and covered by 4 mm thick PMMA-glass with UVA (290-380 nm) transparency > 90%. Each strip is individually flooded by solution of organic contaminant, which under UV illumination slopes down solely through the textile material, due to capillary forces and hydrophobicity of PTFE, and is finally collected in a beaker and transported again back to the input vial. The photocatalytic activity is determined via measurement of pollutant concentration change by UV-VIS spectrophotometer. Results obtained as well as advantages and drawbacks of the method are discussed in the paper.

1. Introduction

Multifunctional filter clothes and membranes are researched and intensively studied nowadays. They represent a modern option how to solve two or more problems simultaneously. The media is often deposited by a nanolayer exhibiting photocatalytic activity with the aim to combat filter and membrane clogging (1,2,3,4) or also in other fields to solve various problems like in case of self-cleaning textiles for car and aircraft seats, odor absorbing cloths etc. (e.g. (5) and many others). Such media when properly illuminated can destroy organic substances blinding or spoiling the media in situ. Therefore measuring of cloth photocatalytic activity is of common interest.

Fig. 1: Flow-through annular reactor

In literature there are described several methods of measuring photocatalytic activity of immobilized nanolayers, based on various physico-chemical principles, mostly suffering from mass transfer problems within the rather complex system: catalyst surface – bulk contaminant – light distribution. Traditional and most frequent concept of a photocatalytic reactor is a batch type mixed vessel with immersed UV lamp. Such a system suffers from poorly defined hydrodynamics of a reactor chamber which is usually mixed by some kind of stirrer. While the bulk volume of liquid is in motion, the tangential velocity of liquid, with respect to the filter media, is usually radially varying or even zero. Transport of contaminant molecules to the photocatalyst and mass transfer generally are poorly defined.

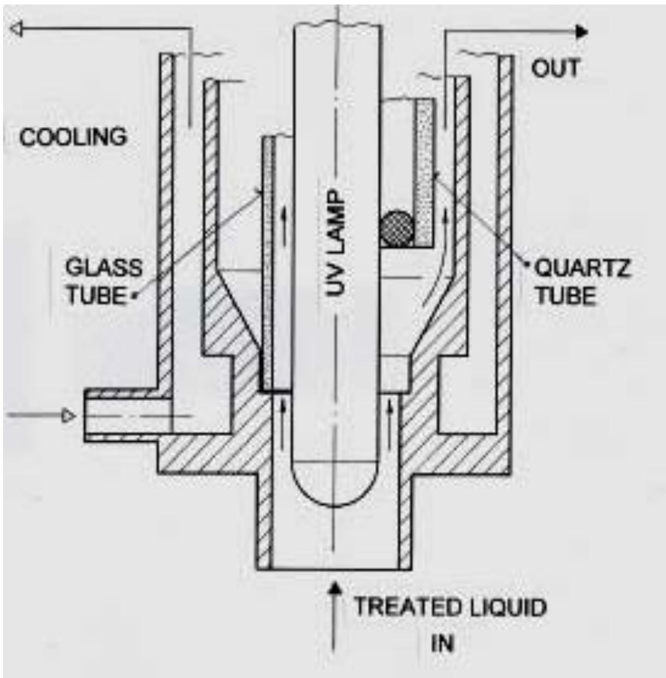

Fig. 2: Cross-section of the flow-through annular reactor

2. Flow-through method

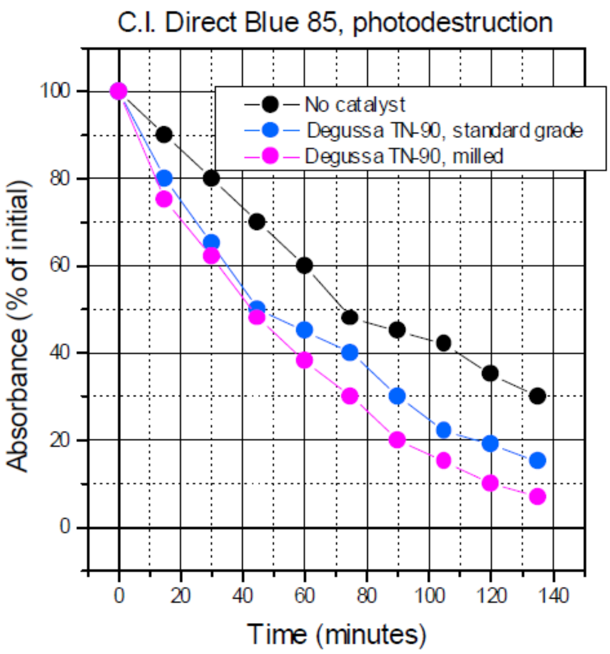

Fig.3. Typical result from flow-through annular reactor

Another system – flow-through annular reactor has been developed, manufactured and successfully used in the years 2004-2007 in the company Mikropur, s.r.o. and was described elsewhere (6). The liquid to be treated in this reactor (Fig. 1.) is continuously pumped through the flow reaction chamber surrounding the UV lamp (150 W). In the chamber there is centrally located glass or quartz cylinder (tube) coated by immobilized catalyst.

As can be seen from the left side of the Fig.2, there is a coaxial reaction space of a thickness of about 2 mm between two surfaces of glass tube and the lamp. The same gap is between the quartz tube and the wall of the reactor, as can be seen from the right side of Fig.2, if the quartz tube is used. Therefore with the glass tube one can study the illumination of photocatalyst through the treated liquid and with the quartz tube it can be studied the illumination through the photocatalyst layer under almost the same hydrodynamic conditions (the same gap thickness).

Typical diagram of results obtained for a layer deposited on a glass tube are in the Fig.3. The concentration of dyestuff in treated liquid was decreased to 10 to 35 % of its initial value dependently on types of layers. The uppermost line in black represents the concentration decrease caused by photolysis of a comparatively strong UV source. The differences between other lines and the black one are attributed to photocatalytic effect of each type of layer.

The usage of the system, however, seemed to be much time consuming namely for comparative measurements of higher numbers of samples, since there was measured only one sample of coated media at a time.

3. New method of flow-through comparative testing

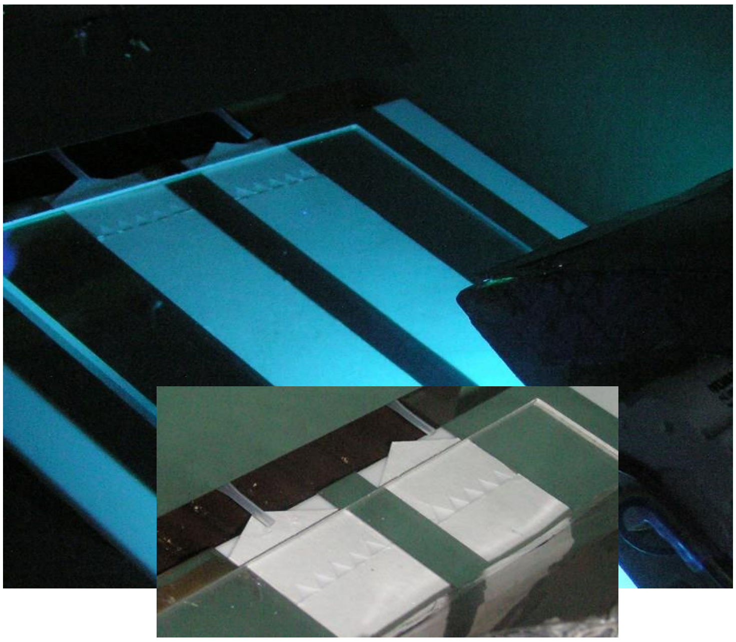

Fig. 4 Inlined flow-through reactor - individually flooded strips of filter cloth under UV illumination, entrance edge and flow distributors (in detail)

To avoid the drawbacks described above a new unit has been developed – inclined flow-through reactor. One of the main field of application is testing of multifunction textile materials with deposited active photocatalytic layers. The new system was developed in order to compare active textile media vs. original textile media or to compare several functionalized filter media.

In the new test unit (Fig.4.) several strips of textile material are deposited side by side on inclined flat and smooth 4 mm thick PTFE tile and covered by special 4 mm thick PMMA-glass UVT Solar with UVA (290-380 nm) transparency > 90%. Each strip is individually flooded by solution of organic dyestuff (C.I. Direct.Orange 39) from an input vial. The solution slopes down solely through the textile material due to capillary forces and hydrophobicity of PTFE and is finally collected in a beaker and transported again back to the input vial. The reactor space is illuminated by 2 pcs of fluorescent tubes Sylvania Blacklight BL350, 18W. The photocatalytic activity is determined via measurement of dyestuff concentration descending by UV-VIS spectrophotometer Pye-Unicam PU 8800.

The typical result of photocatalytic efficiency evaluation for several coatings on non-woven glass textile strips can be seen in Fig.5. Black line with void circles indicates measurement of a strip without any coating. In this case the absorbance, representing concentration of dyestuff, remains unchanged during the whole test. Photocatalytic destruction without photocatalyst does not occur and also it is evident, that photolysis, which might be evoked by the light, is zero due to comparatively weak UV source. The bunch of slightly inclined lines in blue and black are individual measurements of the same thin coating consisting of one deposited layer of TiO_2, black interrupted lines indicate repeated tests of the same sample, while blue line indicates another fresh sample coated with the same TiO_2 layer. Two red, markedly inclined lines, indicate repeated measurements of thicker coating, consisting of two deposited layers of TiO_2. All coatings are deposited on the same non woven glass textile strip.

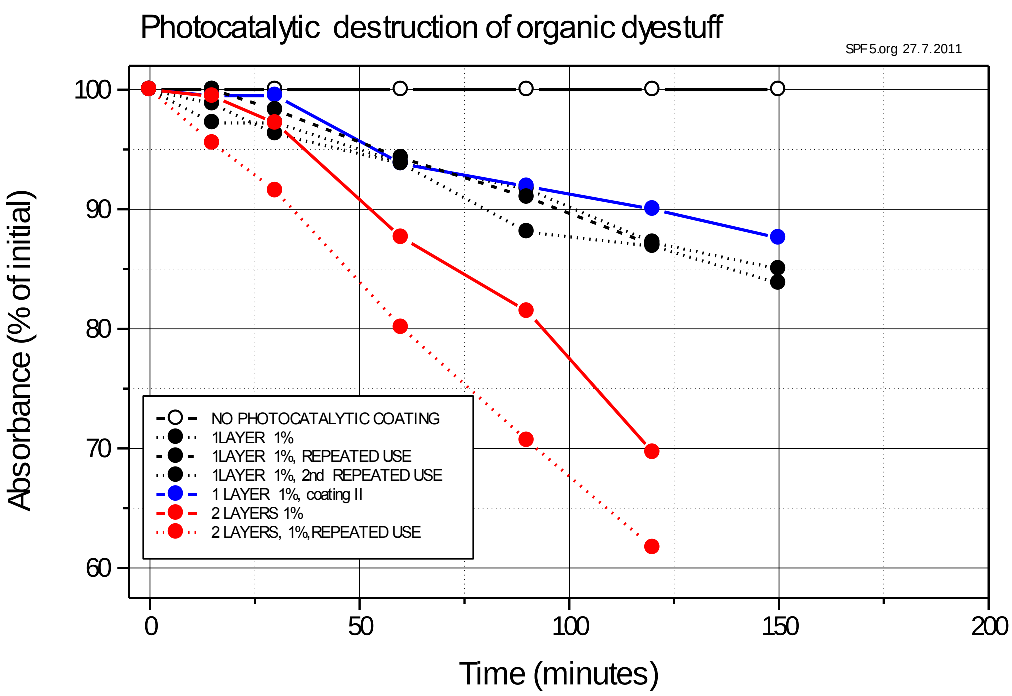

Fig. 5. Evaluation of photocatalytic efficiency of several coatings on non-woven glass textile

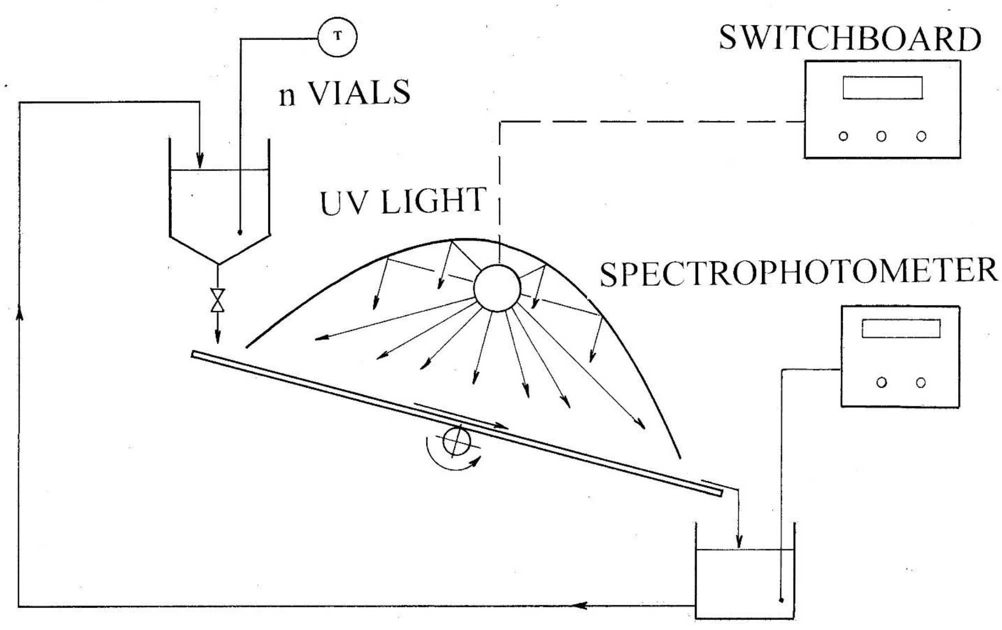

Fig. 6. Lay-out of the inlined flow-through reactor

4. Results and discussion

Experimental data obtained by the measurement method described, served for technology research of nanolayers' preparation. There were investigated simultaneous influences of three factors applied in technology of nanolayer formation on photocatalytic efficiency of the nanolayer. The factors were calcination temperature, hydrochloric acid concentration (HCl) and acetic acid concentration (HAc). Software Modde 3.0 from Umetri AB, Sweden was used, combinations of factors and rates of dyestuff destruction are depicted in the table attached.

Calcination temperature (^{o}C)	200				250			
HCl (mol/1 mol Ti)	1		0,1		1		0,1	
HAc (mol/1 mol Ti)	1	0	1	0	1	0	1	0
Destruction rate K (%.min^{-1}) period 60 – 150 min	-0,255	-0,299	-0,277	-0,266	-0,200	-0,258	-0,333	-0,321

Closefitting of the model was found to be 0.85, indicating that the noise level of the experimental setup was acceptable, see Fig. 8.

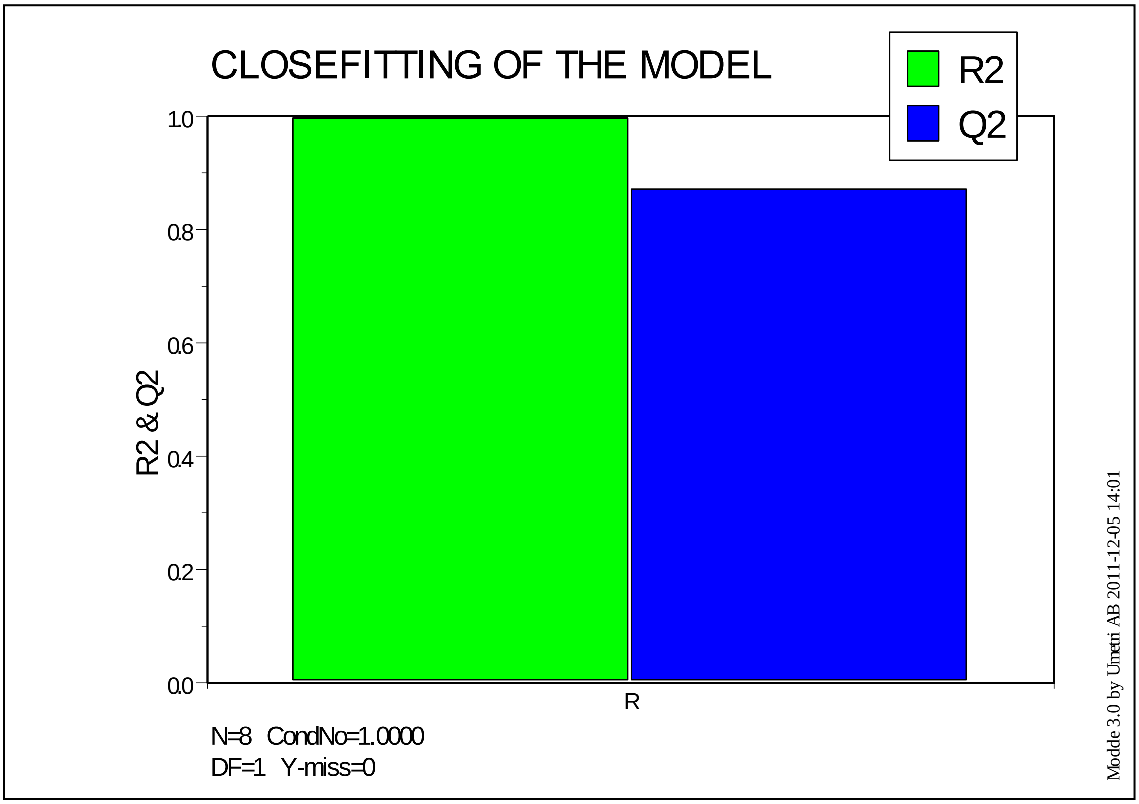

Fig. 8.

The last Fig. 9. shows the influences of the factors studied. The interaction of calcination temperature and HCl concentration was found to be the most influencing experimental factor, followed by independent factor of HCl concentration. The minor influence was found for independent factors of calcination temperature and HAc concentration.

Advantages and drawbacks of the newly proposed method and equipment, emerged during operation of the unit, are as follows:

Advantages:

- Several layers can be measured and compared simultaneously under almost identical conditions.
- The measurement is productive and requires only very simple laboratory technique.

Drawbacks:

- Filter cloth strip squeezed between two flat and smooth parallel hydrophobic plane surfaces conducts and leads test liquid in the direction of a fall line and does not permit releasing test liquid to flow in the direction perpendicular to the fall line. Inserting the textile strip into any groove or channel was not necessary. Any deviation from parallelism of bottom and cover tiles however, due to e.g. temperature distortion, should be strictly avoided, since in such a case side capillary forces may drain out liquid to the neighboring strip.
- Measuring layers with weak photoactivity leads to testing of broader strips up to 5 cm wide. In such a case, namely for more hydrophobic surfaces, the distribution of testing liquid along the strip's width is not uniform enough and requires additional care, like distributors at the entrance of the strip (Fig. 4).

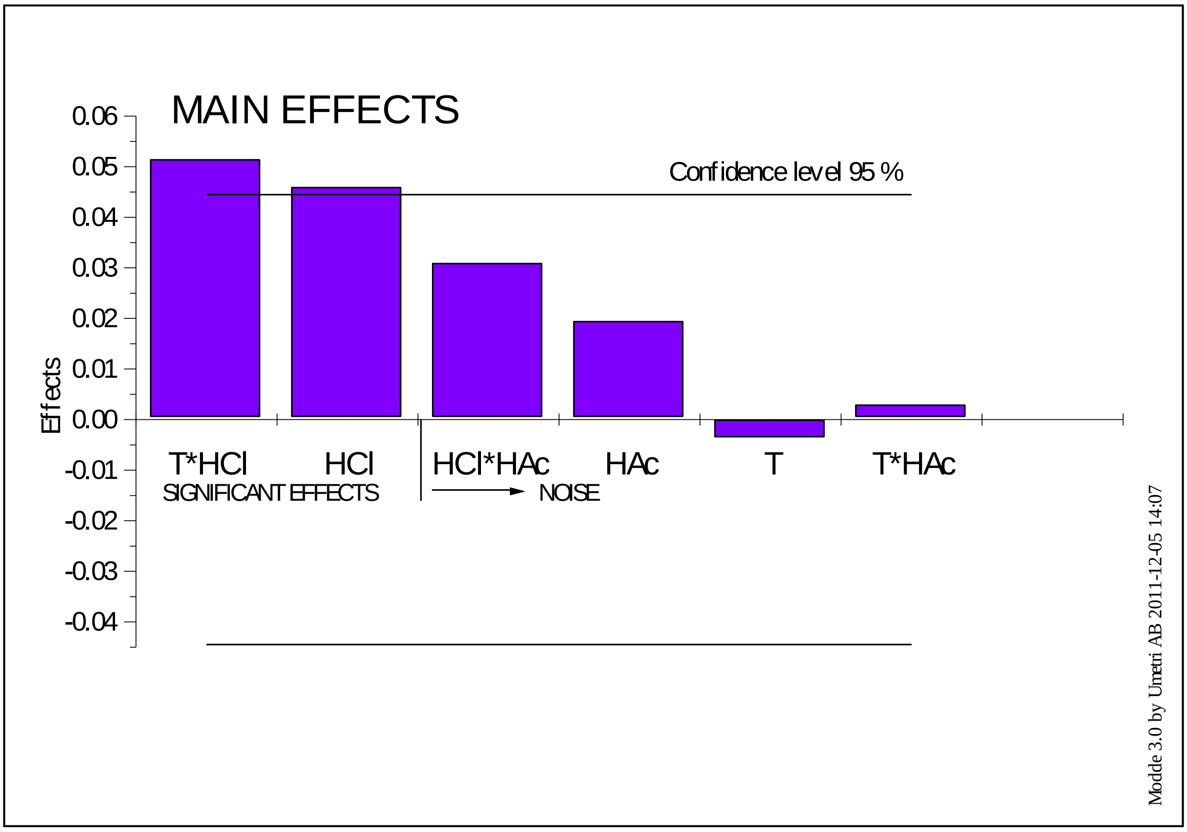

Fig. 9. Influence of individual factors on photoactivity of the sample

5. Conclusion

New unit for measuring photocatalytic effectivity of immobilized nanolayers deposited e.g. on multifunctional filter clothes or membranes has been developed. Several strips of filter cloth are deposited side by side on inclined, flat and smooth surface. Each strip is individually flooded by solution of organic contaminant. Photocatalytic activity is determined via measurement of contaminant concentration decrease in the solution. The method and the unit proved to be efficient for comparative testing of activity of various nanolayers.

Acknowledgement:

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