Photocatalytic ceramic membrane bioreactor driven by visible light -Potential applications in water treatment-

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Agenda

Background
- Existing water treatment technologies
- UV-/VIS-light photocatalysis

Goal
- Bismuth-based visible-light photocatalyst
- Ceramic-based photocatalytic membrane reactors

Experimental
- Synthesis BiOX nanoparticles/Photocatalytic batch reactor
- Layer-by-Layer deposition method/ Photocatalytic membrane reactor

Results+Discussion
- Photodegradation in batch test
- Photodegradation in photocatalytic membrane reactor

Conclusion

Existing water treatment technologies

Biological treatment technique

- Difficulties with process stability
- High sludge production
- Expertise required

Coagulation/precipitation

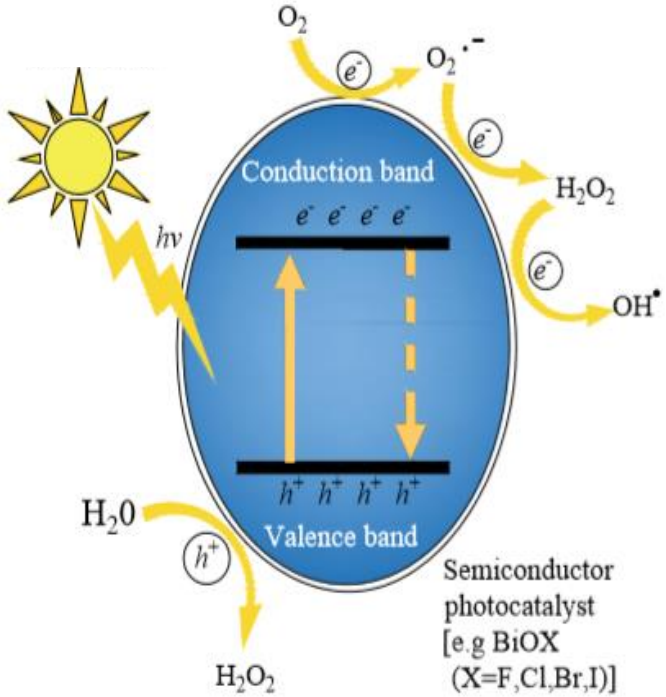
- High sludge production
- Difficult maintenance

Fenton technology

- High operation cost
- Iron sludge production

Lee, S.-Y. (2013). J. Ind. Eng. Chem.

Advanced oxidation technology: **Photocatalysis**



"catalyst that accelerates the solar photo reaction"

Lee, S.-Y. (2013). J. Ind. Eng. Chem.

- Should not participate directly in the reaction, nor should it be consumed
- Production of $\boldsymbol{OH^{\cdot}}$ trough excitation by light
- Material-dependent **band gap** defines required activation energy

UV-/VIS-light photocatalyst:

Band gab of TiO_2 range from **3.0-3.2 eV**

→ limits photo-reaction to UV-light irradiation lower than 400nm

→ Limited under natural sunlight; 5 % of total solar energy consists of UV radiation

→ High energy costs

→ Limited lifespan of UV-lamp

Garg, S. (2019). J. Nanosci. Nanotec. 19: 280-294

UV-/VIS-light photocatalyst:

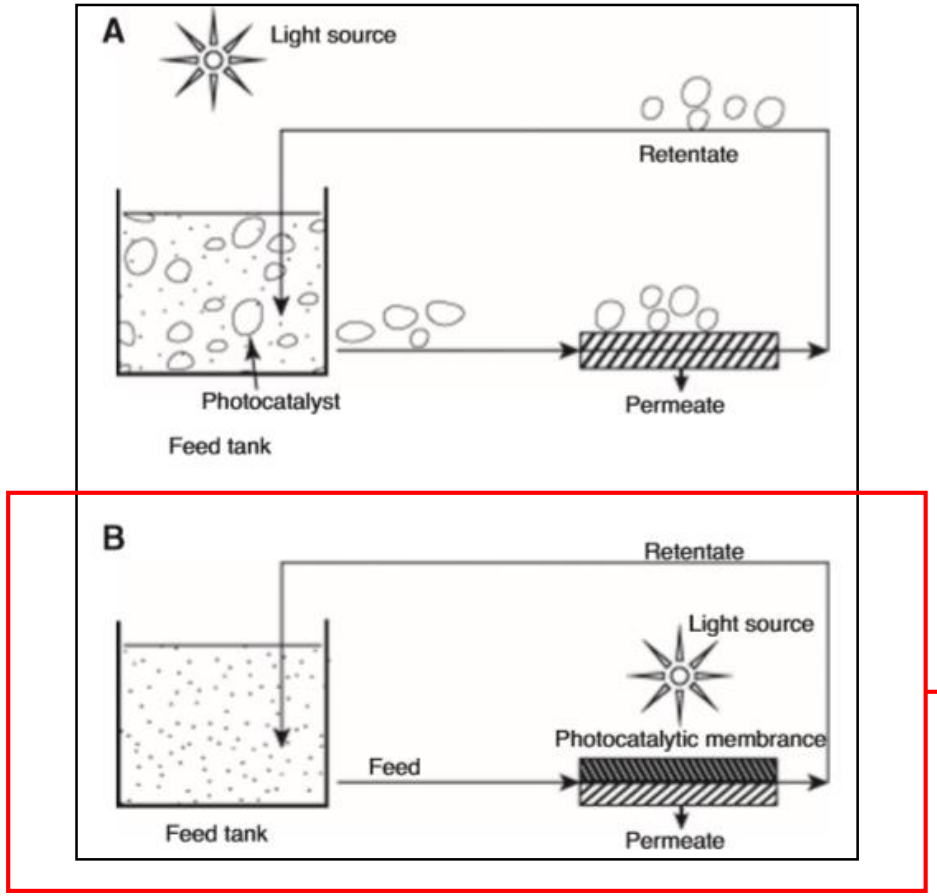
VIS-light driven photocatalyst are more effective and efficient in the presence of **sunlight**!

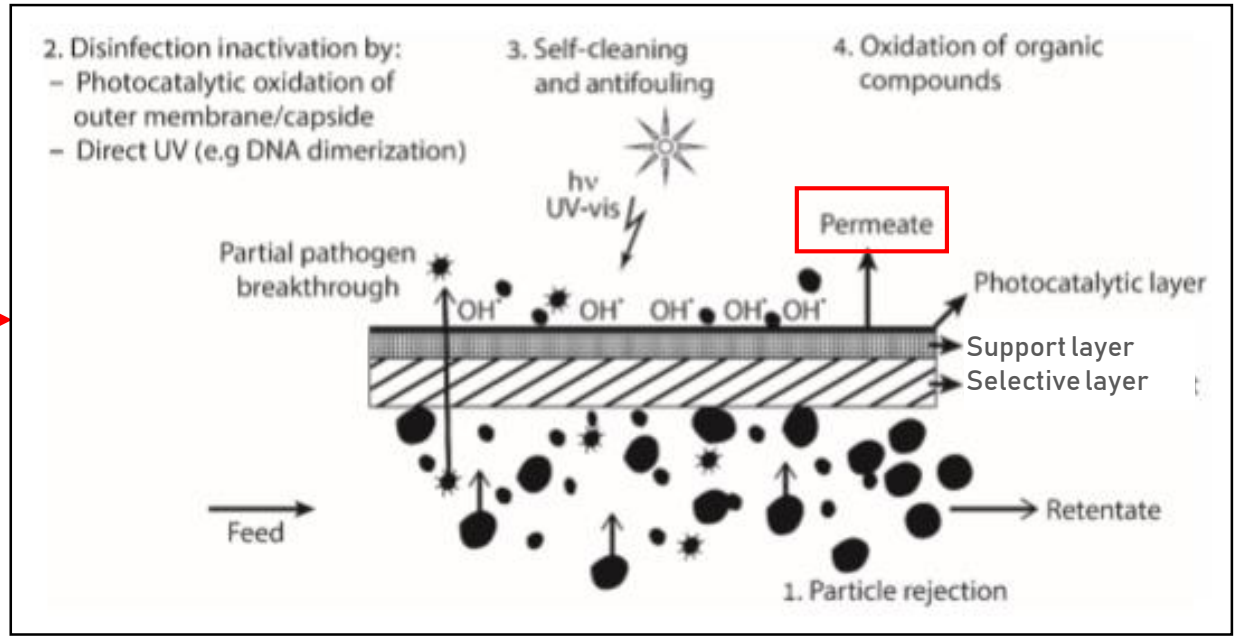
***BiOX* (X=Cl, Br and I)** immense potential for optical and electrical properties!

BiOX decrease band gabs: *BiOCl* $(\sim 3.1 - 3.5\ eV)$, *BiOBr* $(\sim 2.8\ eV)$, *BiOI* $(\sim 1.7 - 1.9\ eV)$

Garg, S. (2019). J. Nanosci. Nanotec. 19: 280-294

Ceramic-based photocatalytic membrane reactors:



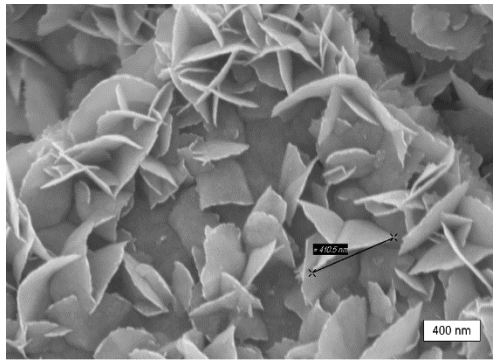


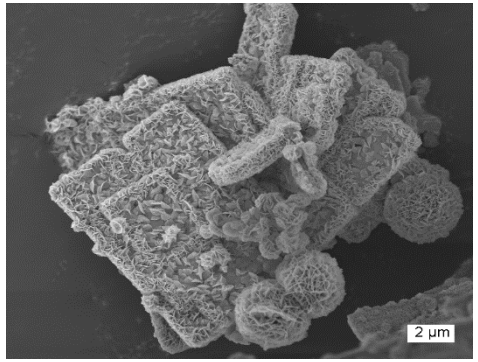
Horovitz, I. (2019). Rev. Chem. Eng.

Experimental 1.1:

Synthesis

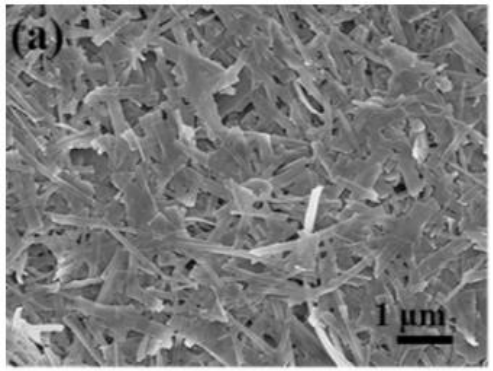
$Bi_7O_9I_3$ *microplates*

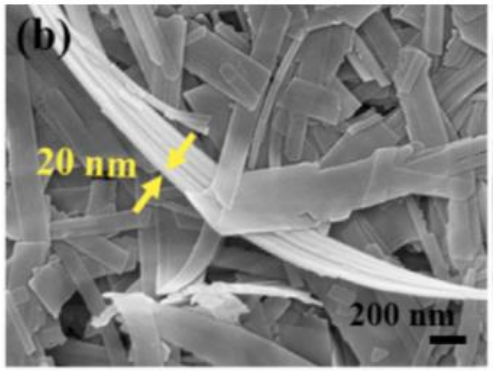




$Xiao\ et\ al.\ RSC\ Advances, 2011,1, 1099 - 11065$

$Bi_{12}O_{17}Cl_2$ *nanobelts*

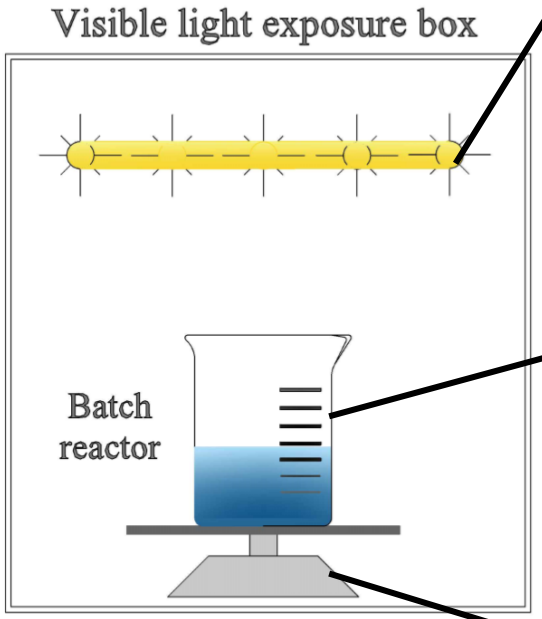




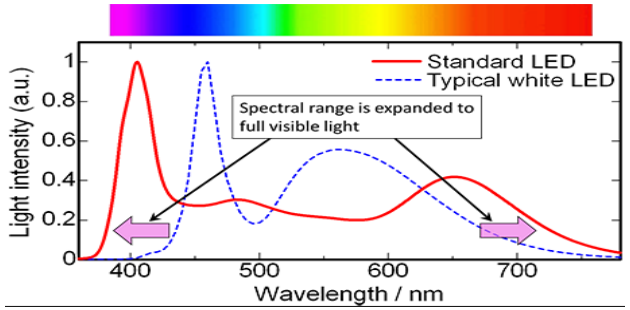
Wang et al. Applied Catalysis B: Environmental 2017, 200, 659-665

Experimental 1.2:

Batch photoreactor



50 W **LED** lamp (Maviju S.A., $T_{colour} = 6500K$)



Model pollutant:
Bisphenol A; Rohdamine B

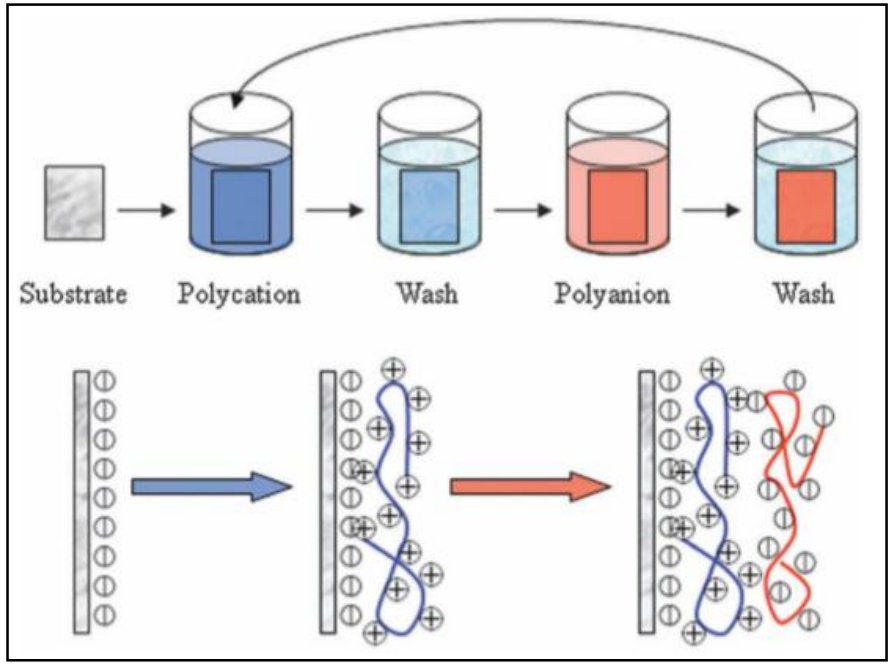
$$c_{catalyst} = 1\frac{g}{L}$$

$$c_{MP} = 20\frac{mg}{L}$$

Continuous stirring

Experimental 2.1:

Layer-by-layer self-assembly



$[(\mathrm{PDADMAC/PAA})_4 + \mathrm{TiO_2}]_5$

$[(\mathrm{PDADMAC/PAA})_4 + Bi_{12}O_{17}Cl_2]_5$

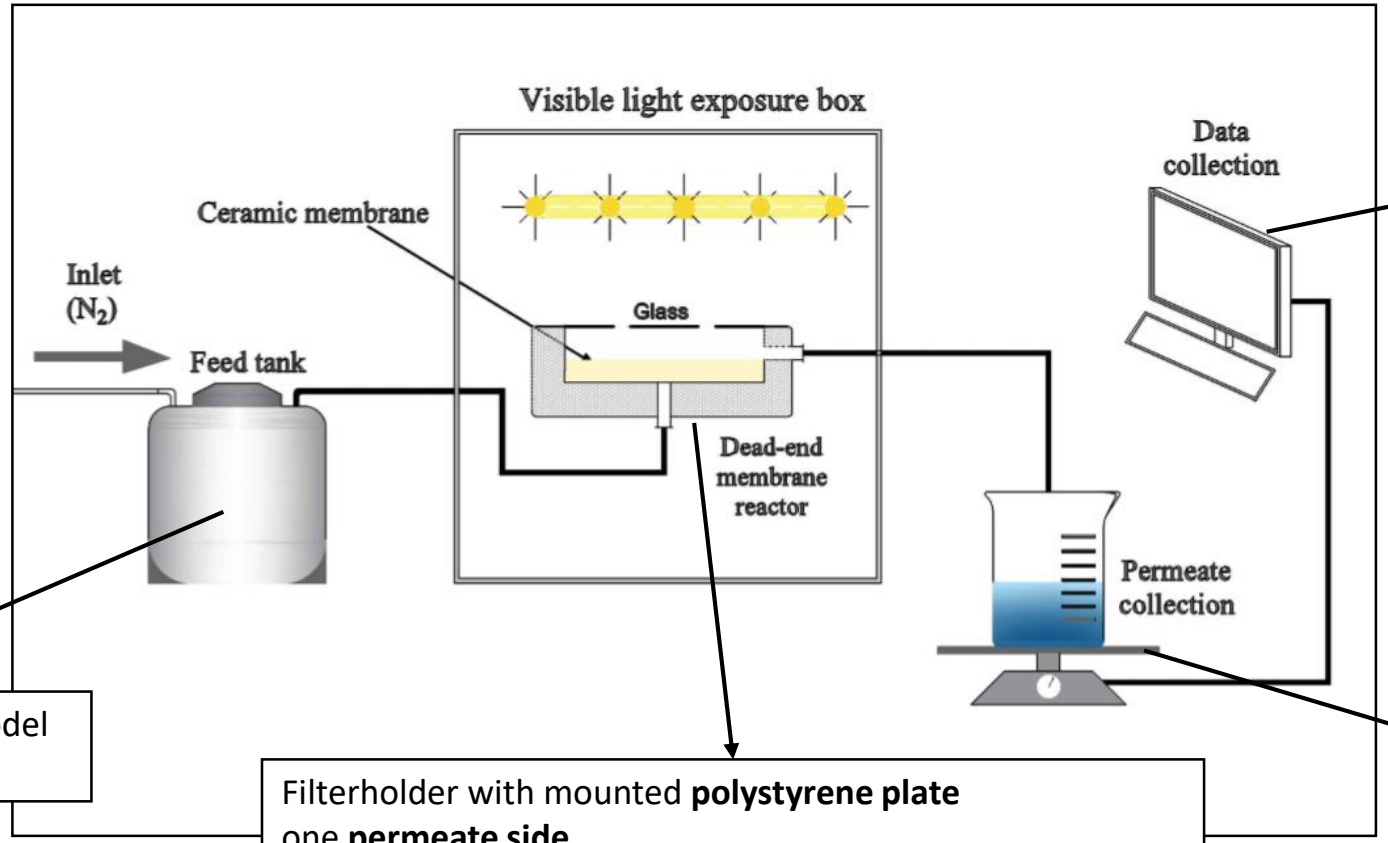
$[(\mathrm{PDADMAC/PAA})_4 + Bi_7O_9I_3]_5$

→Flat disc **ceramic** membranes (TAMI Industries, **d = 47mm, 0.14μm pore size**)

Keeney, M. (2015). J. Mater. Chm.

Experimental 2.2:

Photocatalytic membrane reactor



Data acquisition system

Three different permeate flows through feed tank pressures adjustment:

1 bar / 0,7bar / 0,3 bar

10 L feed tank with **5 mg/L** model pollutant concentration

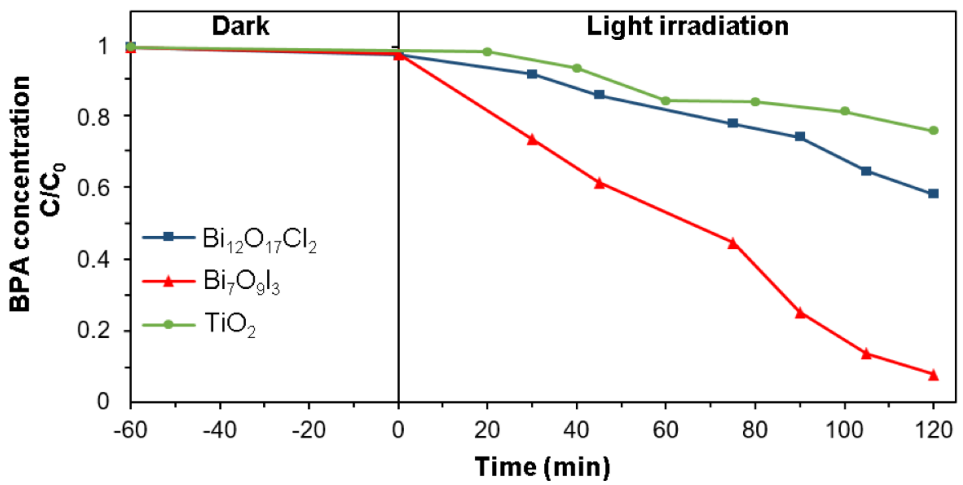
Filterholder with mounted **polystyrene plate** one **permeate side**.
Effectively irradiated membrane area → **10.75 cm^2**

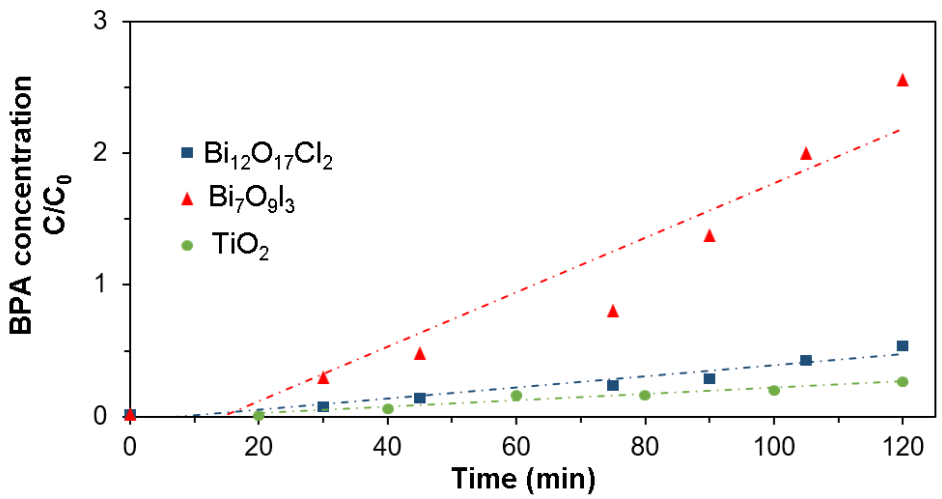
Massbalance for permeate flow detection

Discussion 1.1:

Batch test

Bisphenol A

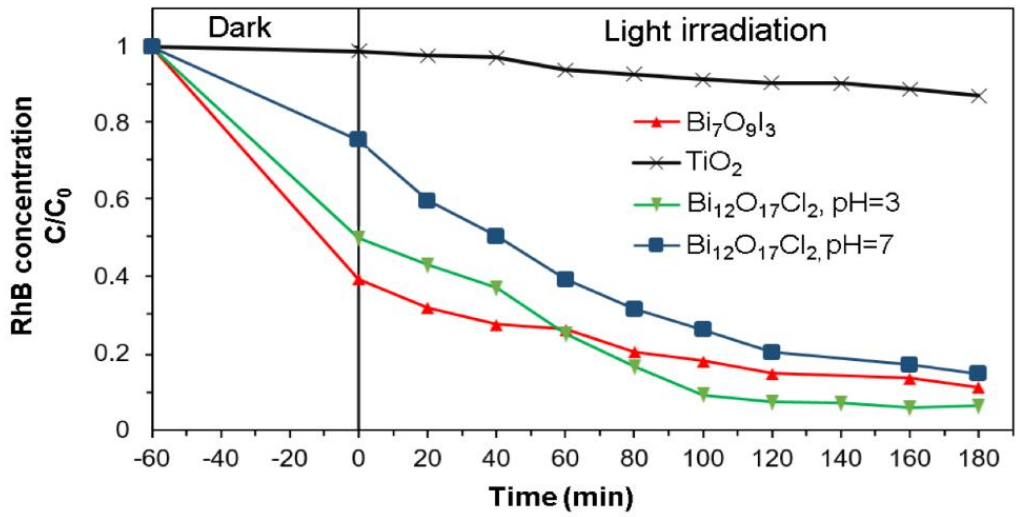


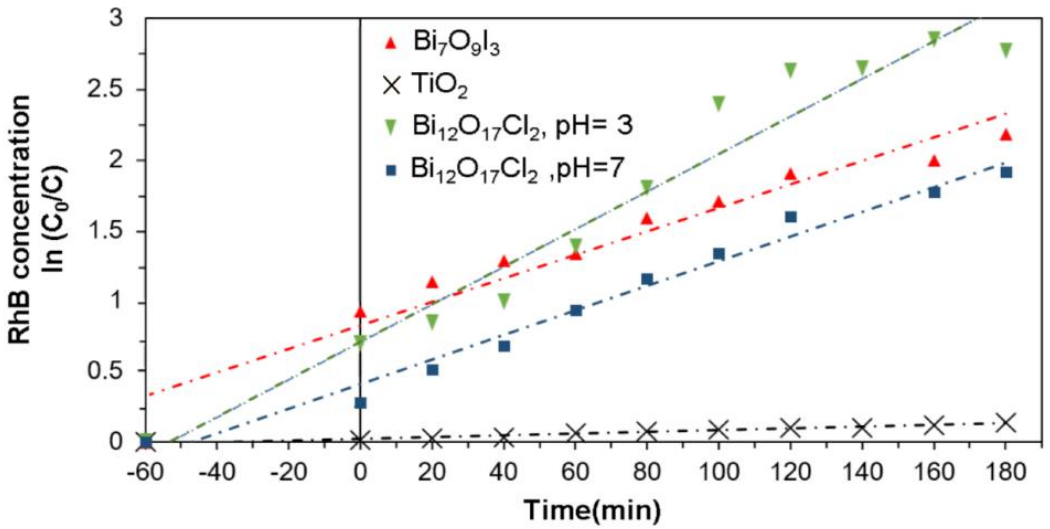


Discussion 1.2:

Batch test

Rohdamine B

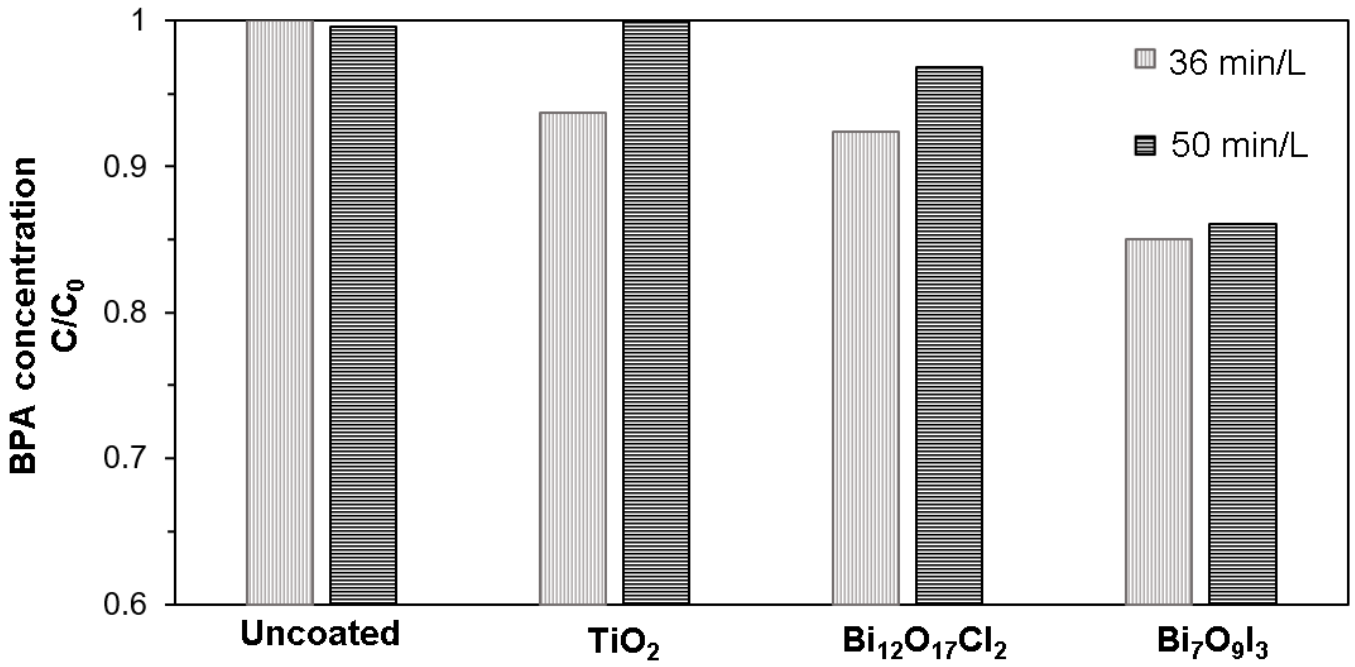




Discussion 2:

Photocatalytic membrane reactor test

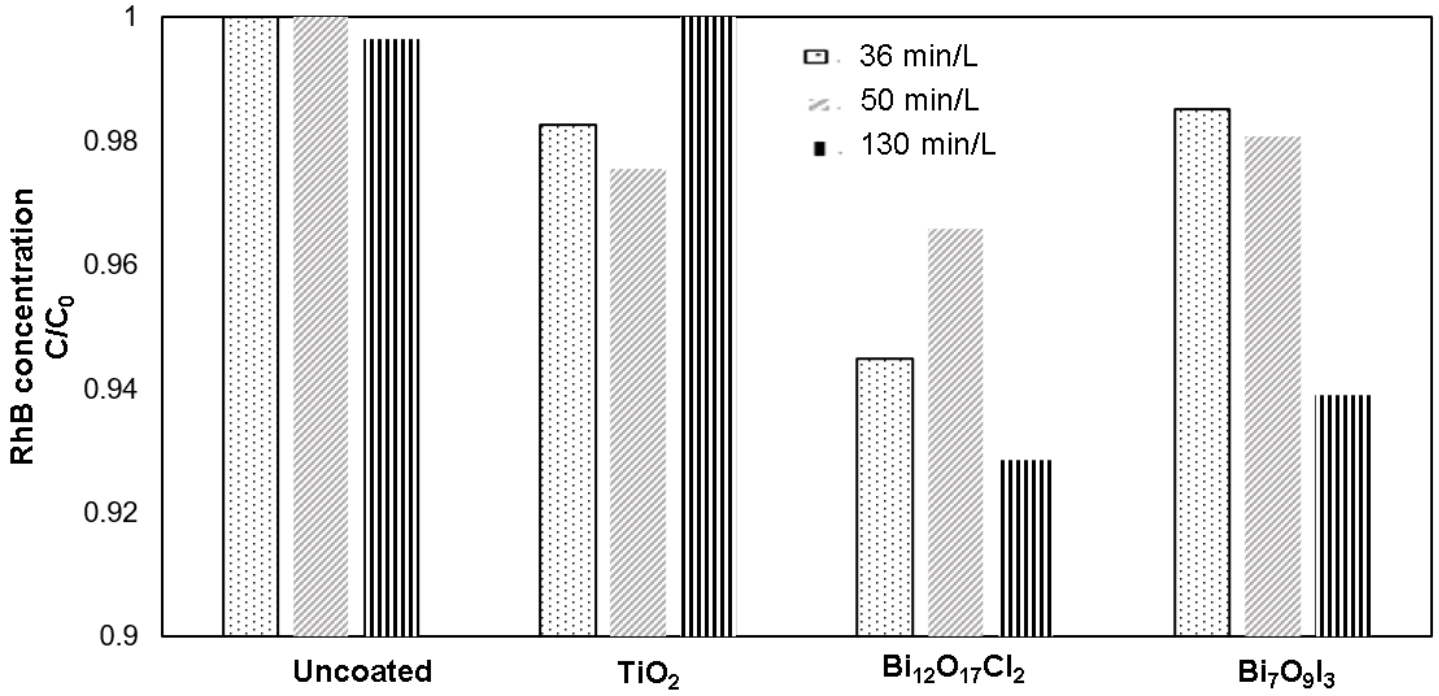
Bisphenol A



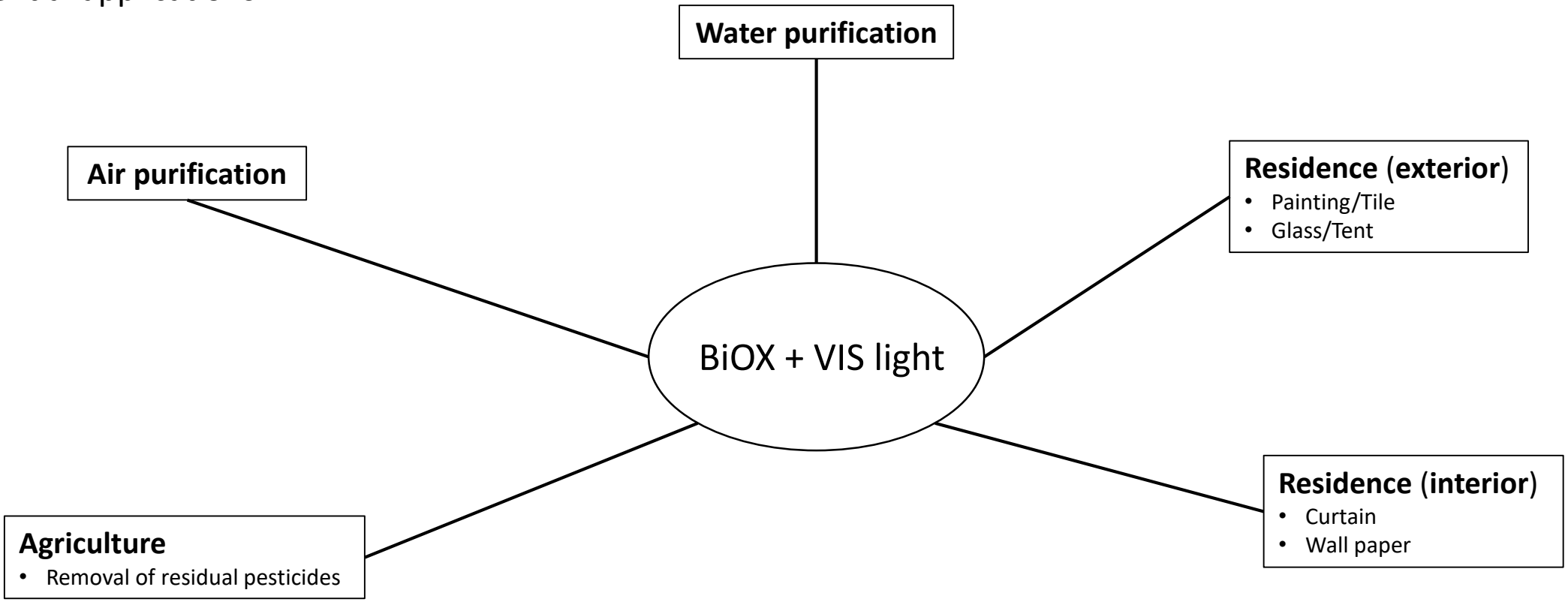
Discussion 3:

Photocatalytic membrane reactor test

Rohdamine B



Potential applications:



Lee, S.-Y. (2013). J. Ind. Eng. Chem.

Conclusion:

Two bismuth-containing photocatalysts capable of degrading two different model pollutants under visible light were successful synthesized

Deposition of BiOX nanoparticles on ceramic ultrafiltration membranes was achieved

Ceramic based BiOX visible-light photocatalytic membranes show degradability of model pollutants

Starting point of combining ultrafiltration ceramic membranes with photocatalytic degradation for advanced water purification technologies

Acknowledgments:

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HI-WATER

PARQUE