Synthesis of Photocatalytic Bismuth Vanadate (V) for Degradation of Organic Dyes

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Introduction

Problem!!

Every year, **200,000 tonnes of dyes** are dumped in water bodies (Ogugbue et al., 2011)

Organic dyes such as **Methylene Blue** and **Brilliant Green** are **toxic** & **carcinogenic**

Current methods:

- Activated Carbon
  - Recovery of dye is **difficult**
  - **High cost** incurred during disposal of dye

- Titanium Dioxide
  - **Only** responds to UV light
  - Synthesis process is **complex**

VS

Bismuth Vanadate:

Simple synthesis method

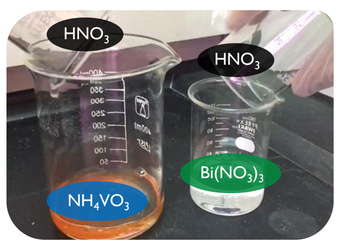
Works under **visible light**

Objectives

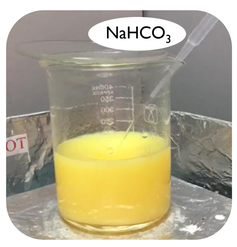
- Synthesise $BiVO_4$ via a simple co-precipitation reaction
- Evaluate the effectiveness of $BiVO_4$ in degrading **Brilliant Green** and **Methylene Blue** dyes
- Compare $BiVO_4$ with other photocatalysts: ZnO & TiO_2

Overview of Methods

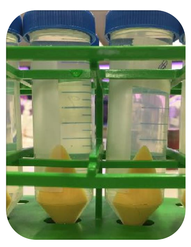
Synthesis of $BiVO_4$ by Co-Precipitation



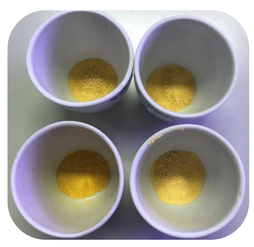
$Bi(NO_3)_3$ & NH_4VO_3 was each dissolved in HNO_3



The solutions were mixed and $NaHCO_3$ was added in excess



$BiVO_4$ suspension was heated, washed and dried



Samples were calcined at 350°C

$$Bi(NO_3)_3 + NH_4VO_3 + H_2O \rightarrow \mathbf{BiVO_4} + NH_4NO_3 + 2HNO_3$$

XRD Analysis

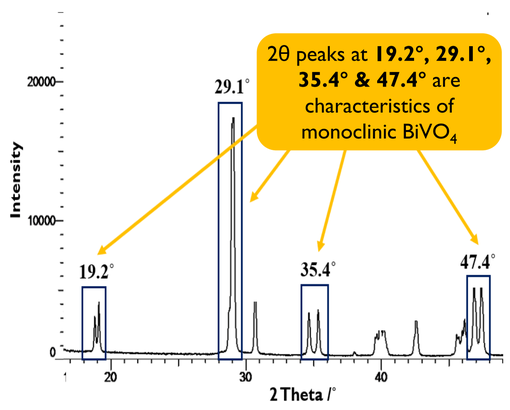
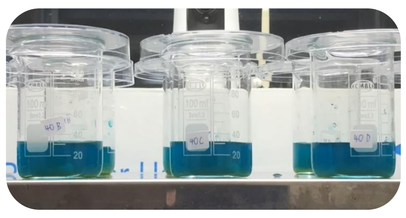


Fig 1. XRD pattern of synthesised $BiVO_4$

Degradation of Dyes



Conducted:
- Kinetic studies over a period of 75 min
- Determination of band gap of $BiVO_4$
- Analysis of dye residues

0.1g of $BiVO_4$ + 25ml of 25 mg/L Dye solution

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Stirred under UV, Visible Light & Dark conditions

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Final dye concentration analysed using UV-Vis Spectrophotometer

Results and Discussion

Photocatalytic Activity of $BiVO_4$

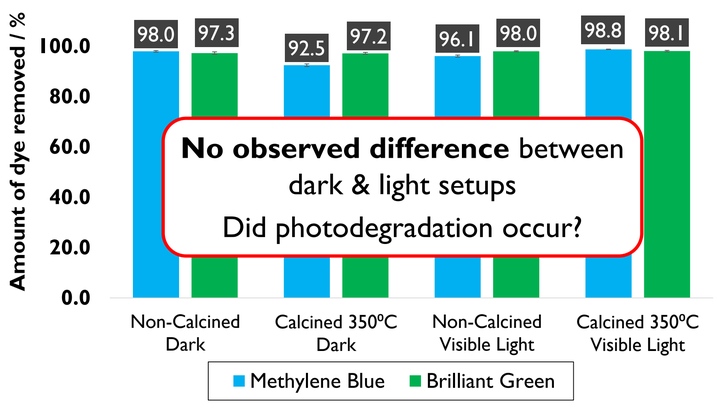


Fig 2. Comparison between amount of dye removed by calcined and non-calcined $BiVO_4$ in light & dark conditions. N=5

Analysis of Degradation Residue using Mass Spectrometry

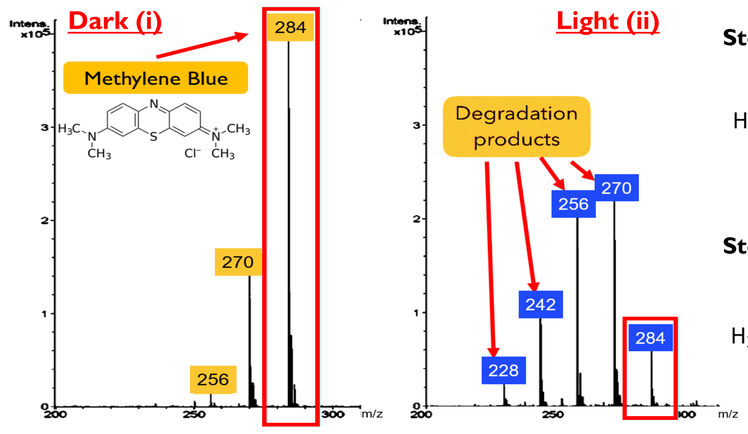


Fig 3. Mass spectra of degradation residue (calcined $BiVO_4$) in (i) dark & (ii) light conditions

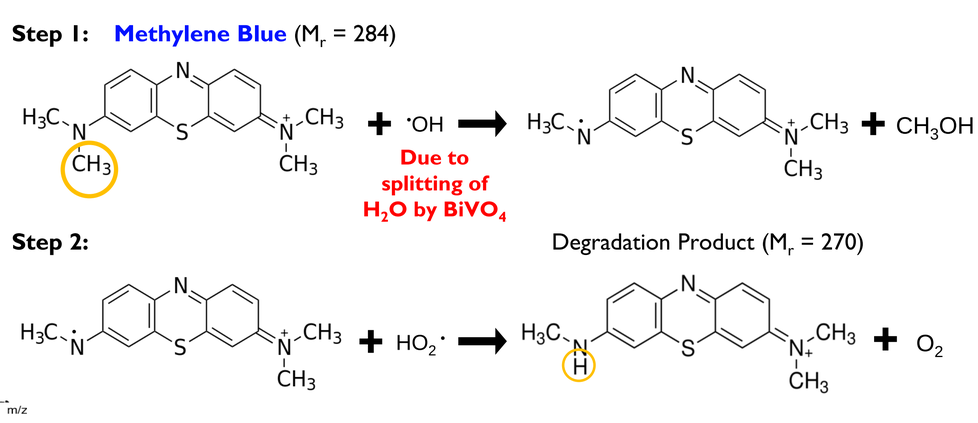


Fig 4. Proposed mechanism for photodegradation of methylene blue dye

Kinetics Studies of $BiVO_4$

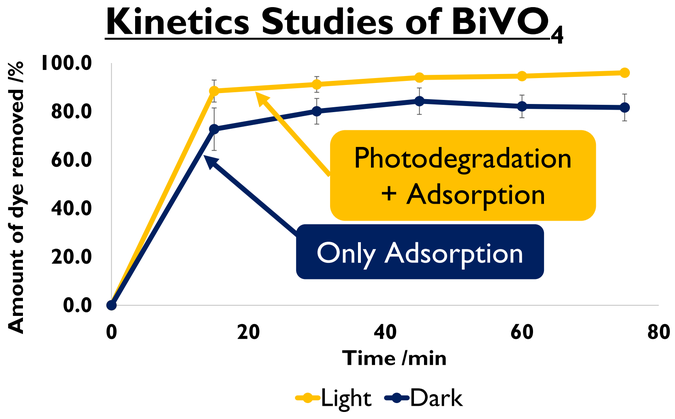


Fig 5. Kinetic studies on degradation of methylene blue by calcined $BiVO_4$ in light & dark conditions. N=3

Comparison to ZnO and TiO_2

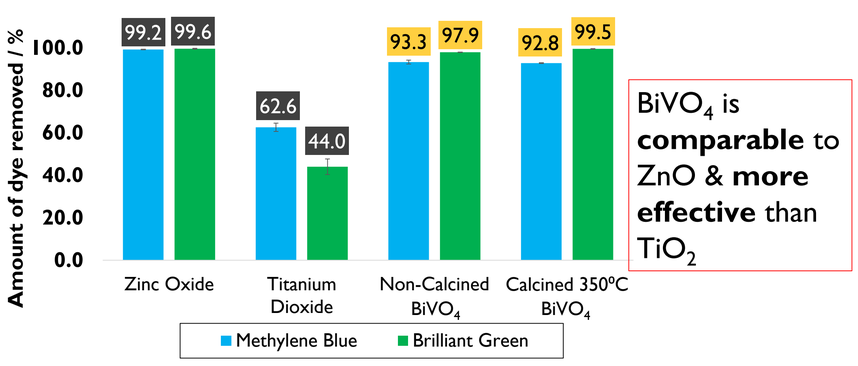
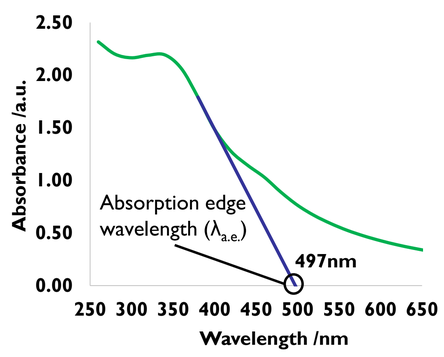


Fig 6. Comparison between amount of dye removed by different photocatalysts under (a) UV & (b) visible light. N=5

Calculation of Band Gap for calcined $BiVO_4$



Using Planck-Einstein relation

$$E_g = \frac{hc}{\lambda_{a.e.}}$$

$$\approx \frac{1.986 \times 10^{-25}}{497 \times 10^{-9}}$$

$$= 3.99 \times 10^{-19} \text{ J (3s.f.)}$$

$$= 2.50\text{eV (3s.f.)}$$

Where:
E_g is the band gap
h is Planck's constant (6.626×10^{-34} m^2 kg/s)
c is the speed of light (2.998×10^8 m/s)

Fig 7. Calculation of optimal band gap (E_g) from UV-Vis Spectrum of calcined $BiVO_4$

Comparison of Band Gap

Photocatalyst	Band Gap /eV	Reference
Non-Calcined $BiVO_4$	3.0	This study
$BiVO_4$ Calcined at 350°C	**2.5**	
ZnO	3.2	(Dodd, Mckinley, Tsuzuki, & Saunders, 2009)
TiO_2	3.0 – 3.2	

Large Scale Industrial Application of $BiVO_4$

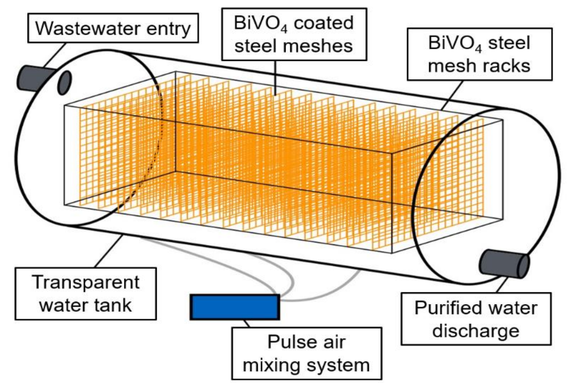


Fig 8. Proposal of how $BiVO_4$ coated steel meshes can be used to remove dyes on a large scale

Future Work

1. Doping of $BiVO_4$ with transition metals to further lower band gap
2. Testing $BiVO_4$ on other **organic compounds** (bacteria/ anionic dyes)

Conclusion

Bismuth Vanadate ($BiVO_4$)

SIMPLE Synthesis Method

FAST & EFFICIENT photocatalyst

OUTPERFORMS conventional photocatalysts

Selected References

Chequer, F.M.D., de Oliveira, G.A.R., Ferraz, E.R.A., Cardoso, J.C., Zanoni, M.V.B., de Oliveira, D.P. (2013). Textile dyes: dyeing process and environmental impact. In: Gunay M (ed). Eco-friendly textile dyeing and finishing (pp. 152) doi: 10.5772/53659

Dodd, A., Mckinley, A., Tsuzuki, T. & Saunders, M. (2009). Tailoring the photocatalytic activity of nanoparticulate zinc oxide by transition metal oxide doping. Materials Chemistry and Physics, 114(1), 382-386. doi:10.1016/j.matchemphys.2008.09.041

Images/ graphs/ photos in this poster were self-drawn or taken unless otherwise stated.

Icons from Flaticon. (www.flaticon.com): "Waste", "Danger" by Freepik, "Drop" by Good Ware, "Forbidden" by Smashicon, "Like" by Gregor Cresnar. "Medal" by Vectors Market. Activated carbon image from https://4.imimg.com/data4/CI/UE/MY-12851131/granular-activated-carbon-250x250.jpg, Titanium dioxide image from https://images-na.ssl-images-amazon.com/images/I/416fmsgRVIL.jpg