WO3 (Tungsten Trioxide)-based Photocatalysis & viruses: scientific literature & laboratory tests

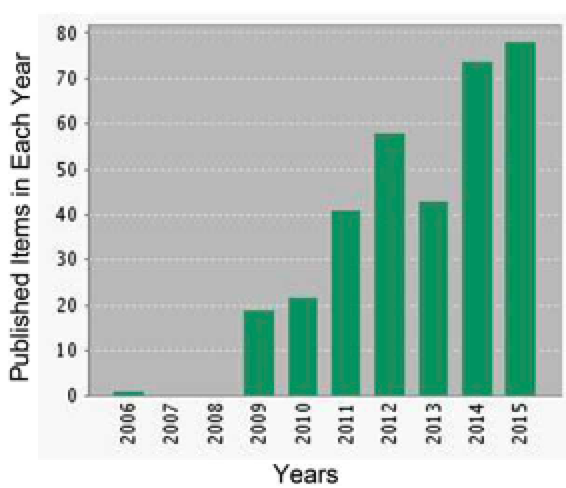
Tungsten Trioxyde (WO3) is considered **one of the most promising semi-conductive photocatalyst for the degradation of organic compounds,** mainly thanks to its **small *bandgap*** (which varies between 2,4 and 2,8 eV), allowing thus to **activate the photocatalytic reaction with a lower energy input.**

Furthermore, compared to other photocatalysts, Tungsten Trioxide presents **other advantages:**

- It's a **very stable material** in water-based solutions in acid conditions;
- It's **activated by visible light** and thus **avoids the problems** associated with the use **of UltraViolet (UV) light sources,** such as those needed for ex. with Titanium Dioxide (TiO2), one of the most widely used photocatalysts:
    - Much **more energy efficient** (up to 90% less energy consumption);
    - **Totally safe**, since there's **NO ozone emission** *(irritating for lungs)* and it's **NOT dangerous for the eyes** if observed directly.

The main applications of WO3-based are **photodegradation of organic substances, air purification**, **virus & bacteria disinfection**, self-cleaning, CO2 photo-reduction, treatment with heavy metal ions and hydrogen production from water scission.

For these reasons, **in the last years the research is focusing on this new photocatalyst** for the disinfection of surfaces, air and water: researchers have indeed proved that WO3-based photocatalysis can **kill a wide range of viruses, Gram-negative and Gram-positive bacteria, filamentous unicellular fungi, algae and protozoa.**



PICTURE: Number of *Journal Citation Reports* (JCR) per year from 2006 to 2015 (december), as found in "*Web of Science*" (apps.webofknowledge.com); keywords are "WO3" and "photocatalysis".

The **elimination mechanism** is based on the **degradation of the cell wall and of the cytoplasmic membrane through the Reactive Oxygen Species (ROS) created by the photocatalysis,** such as hydroxyl radicals and hydrogen peroxide. The collision between bacteria, viruses and the Reactive Oxygen Species causes cell lysis and can result in the complete mineralisation of the microorganism. Of course, t**he closer the contact between the microorganisms and the WO3 catalyst, the more efficient the elimination.**

Lastly, WO3-based photocatalytic filters can be enriched through the addition of platinum, gold and silver, in order to maximize the photocatalysis effectiveness.

Laboratory Tests for WO3-based Photocatalytic Technology

Category	Microorganism / Pollutant	Reduction %	Time (hours)
BACTERIA	Staphylococcus aureus	100%	6 h
	Escherichia coli	100%	24 h
	Klebsiella pneumoniae	100%	24 h
	Pseudomonas aeruginosa	100%	24 h
VIRUSES	Avian influenza virus	60%	4 h
	Feline calicivirus	40%	6 h
	Influenza A	75%	8 h
	Adenovirus	33%	8 h

Photocatalysis Disinfection - Detailed explanation

The **photocatalytic disinfection of viruses** and other microorganisms happens **mainly through chemical oxidation carried out by Reactive Oxygen Species (ROS)**, such as •OH e H2O2, created by the photocatalyst.
The disinfection mechanism entails therefore the **creation of ROS** and consequent **decomposition of the viruses' cell wall and cytoplasmatic membrane** through various steps as described below:

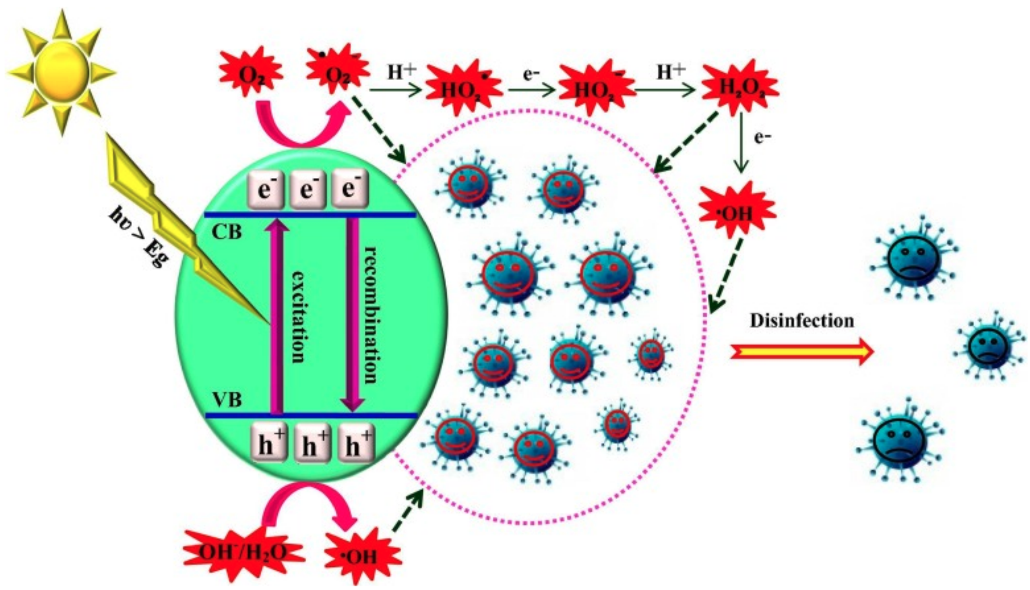
1) The photocatalyst's excitation electronically charges its surface and thus the couples electron/hole (e−/h+) are created.

2) The holes in the valence band react with the species OH- o H2O adsorbed on the filter's surface, thus generating the hydroxil radical (•OH), which in turn oxydizes the virus'

chemical substances (specifically, the envelope and the capsid) adsorbed on the photocatalyst's surface.

3) The electrons in the conduction band react with Oxygen (O2) and as a result produce highly efficient radicals (•O2 −, •OH e •OOH). Therefore, the ROS created in this way starts the reactions, which culminate in the destruction of the virus adsorbed on the photcatalyst's surface.

As explained above, therefore, the various highly efficient **ROS produced on the photocatalyst's surface can oxydize the viruses** adsorbed on the same surface, destroying them and thus effectively disinfecting the medium (whether gaseous, liquid or solid)**.** The following image shows the whole process: creation of the couples e−/h+, recombination phase, ROS generation and the viral disinfection.



Photocatalythic Disinfection Process - Image taken from Habibi-Yangjeh et al. (3):
www.ncbi.nlm.nih.gov/pmc/articles/PMC7361121/

Thus, **the more ROS a photocatalyst can generate, the more efficient it will be in terms of virus disinfection (and more in general against all target pollutants).**
N.B. The catalyst only acts as accelerator of the process and doesn't release any substance on its own. All photocatalysts indeed release/produce ROS: what changes is the reaction kinetics, that is, the speed of the pollutant's reduction.

Summary of findings in scientific literature

Below are some of the main findings from **scientific literature on WO3-based photocatalysis:**

- Takehara *et al.* (5) have tested the Pt-WO3 photocatalyst with visible light **against the avian influenza virus H1N1**. The virus has been **inactivated in less than two hours.**

- Akhavan *et al.* (6) have tested a Graphene-WO3 photocatalyst (composite film) **against Bacterophage MS2 viruses**; **after 3 hours**, at room temperature, the **virus protein had been almost completely destroyed** and a substantial increase in RNA efflux was observed.

Other studies on the antiviral effectiveness of photocatalysis are listed int he Bibliography section below. We suggest to start from the following paper (Habibi-Yangjeh *et al.* - nr. 3), as a general up-to-date review (2020) on the topic: www.ncbi.nlm.nih.gov/pmc/articles/PMC7361121/

Bibliography

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