Sun-Light Driven Fast Photo-Degradation of Eriochrome Black T Dye using Highly Efficient La-Doped Ag_3PO_4 Decorated with ZnS QDs

Shabana Bibi[1], Amna Bashir[2], Noshabah Tabassum[1], It Ee Lee[3,4*], Hafsa Yasmeen[2], Syed Mustansar Abbas[6], Qamar Wali[3,4], Muhammad Aamir,[5] Chingmai Ko[7], Imtiaz Ahmad*[7]

[1] Department of Environment Sciences, Fatima Jinnah Women University, The Mall, Rawalpindi, 46000, Pakistan

[2] Department of Chemistry, Fatima Jinnah Women University, The Mall, Rawalpindi, 46000, Pakistan

[3] Faculty of Artificial Intelligence and Engineering, Multimedia University, 63100 Cyberjaya, Malaysia
[4] Centre for Smart Systems and Automation, COE for Robotics and Sensing Technologies, Multimedia University, 63100 Cyberjaya, Selangor, Malaysia

[5] Department of Chemistry, Mirpur University of Science and Technology (MUST), Mirpur-10250 (AJK), Pakistan

[6] Department of Chemistry, College of Science, Imam Abdulrahman Bin Faisal University, P.O. Box 1982, Dammam, Saudi Arabia

[7] School of Electronics and Communication Engineering, Quanzhou University of Information Engineering, Quanzhou, 362000, China.

***Corresponding:** amnabashir79@yahoo.com, ielee@mmu.edu.my,*

Figure. S1. Experimental Setup for (a) Adsoprtion experiment, (b) Photocatalytic degradation.

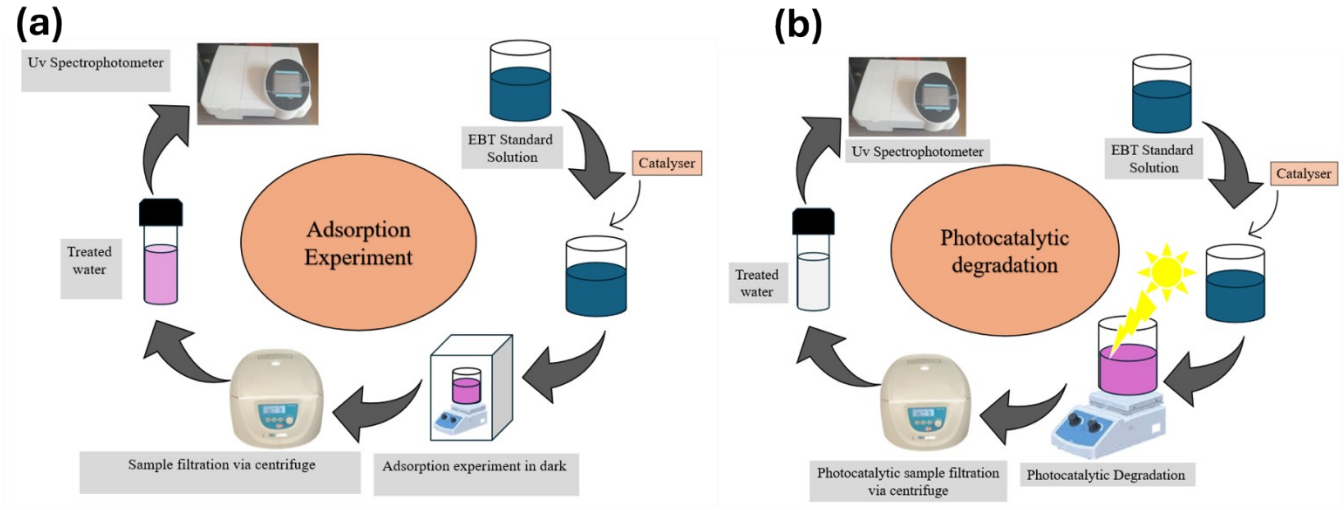

Table S1: XRD parameters of synthesized materials

Sample Name	2θ	FWHM (°)	Average Crystaline size (nm)	Dislocation Density $\delta = 1/D^2$	Microstrain $\varepsilon = \beta / (4\tan\theta)$
ZnS QDs	29.2 48.53 57.52	4.0881 3.2886 4.9258	2.26	0.210	0.0465
Ag_3PO_4	20.96 29.77 33.39 36.66 42.57 47.89 52.78 55.11 57.38	0.09103 0.05438 0.05361 0.04913 0.04059 0.05095 0.05452 0.04934 0.05365	158.13	4.62326E-05	0.000749
2% La-doped Ag_3PO_4	20.96 29.79 33.39 36.68 42.55 47.91 52.78 55.11 57.38	0.13979 0.14077 0.12758 0.157 0.26199 0.10533 0.09436 0.09603 0.10398	73.07	0.000262602	0.001773
6% La-doped Ag_3PO_4	20.98 29.79 33.41 36.68 42.59 47.91 52.8 55.13 57.4	0.09519 0.11711 0.06976 0.07329 0.09446 0.06409 0.07397 0.07953 0.08013	118	9.02064E-05	0.001088
Ag_3PO_4/ZnS QDs	20.22 29.02 31.53 34.4 36.84 43.41 47.82 48.51 53.34	4.46288 2.4354 0.52277 0.48287 0.79919 0.51409 0.69062 2.52653 1.15687	10.33	0.03986	0.018548

2% La-doped Ag_3PO_4/ZnS QDs	20.9678 29.0956 31.5821 34.4514 36.9144 43.4197 47.7973 48.0844 53.3002	2.4621 0.26778 0.05361 0.39625 0.37353 0.55764 0.7416 0.32601 0.32601	37.80	0.010899	0.010365
6% La-doped Ag_3PO_4/ZnS QDs	20.203 29.0238 31.5582 34.4753 36.8427 43.5154 47.8212 48.8021 52.6063	0.76012 0.45228 0.45951 0.56428 0.71282 0.61419 0.2392 0.56032 0.18996	21.54	0.003808	0.007416

Table S2: comparison of pore sizes, BET Area , and crystallites sizes

Samples	Crystallite sizes (nm)	BET surface area (m^2/g)	Pore Volume (cc/g)	Pore Radius (Å)
Pure Ag_3PO_4	158.13	130.109	0.036	15.578
2%-La Ag_3PO_4	73.06	89.934	0.031	15.564
6%-La Ag_3PO_4	118	133.446	0.038	15.581
ZnS QDs	2.26	116.537	0.040	15.610
6%-Ag_3PO_4/ZnS QDs	10.33	141.120	0.053	14.761

Figure. S2. XPS analysis of (a) C1s, (b) Complete Survey

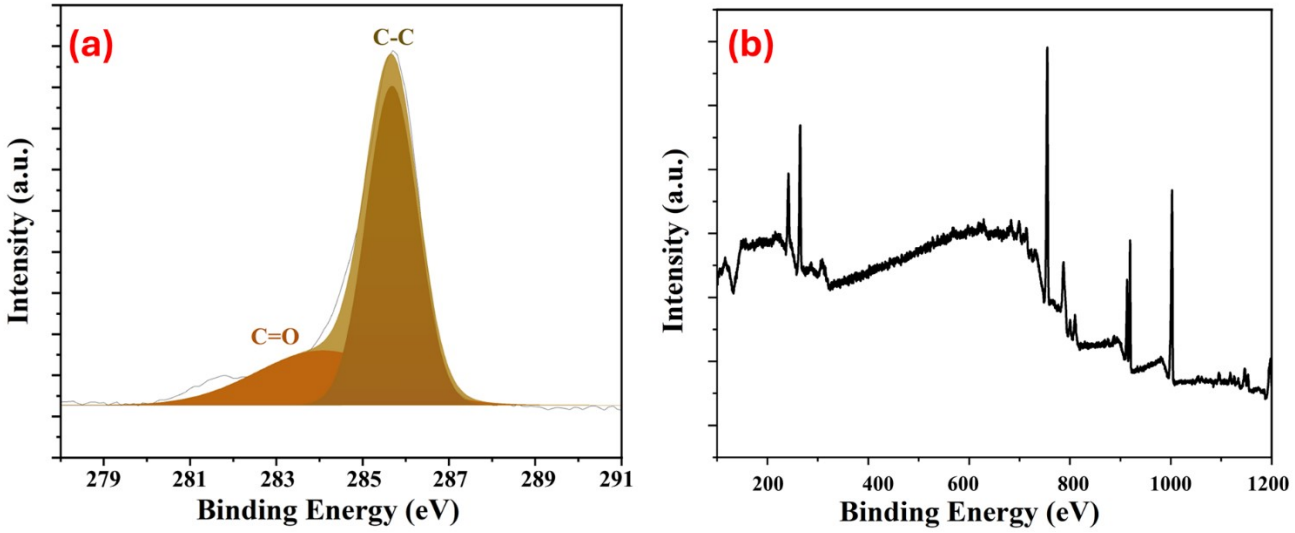

Figure. S3. % adsorption capacities of different nano catalysts.

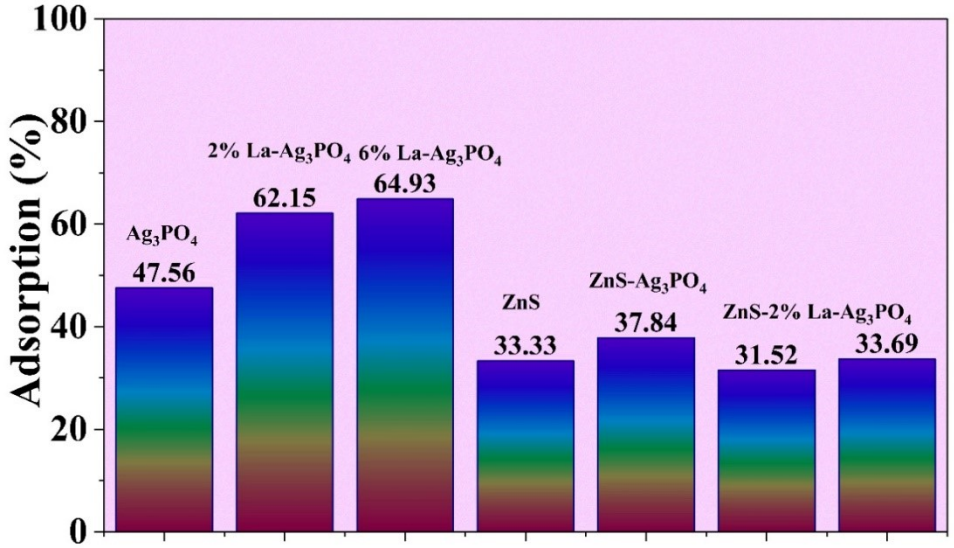

Figure. S4. Change in absorbance of standard dye solution (15 ppm) with time for 6% La-doped Ag_3PO_4/ZnS Quantum Dots

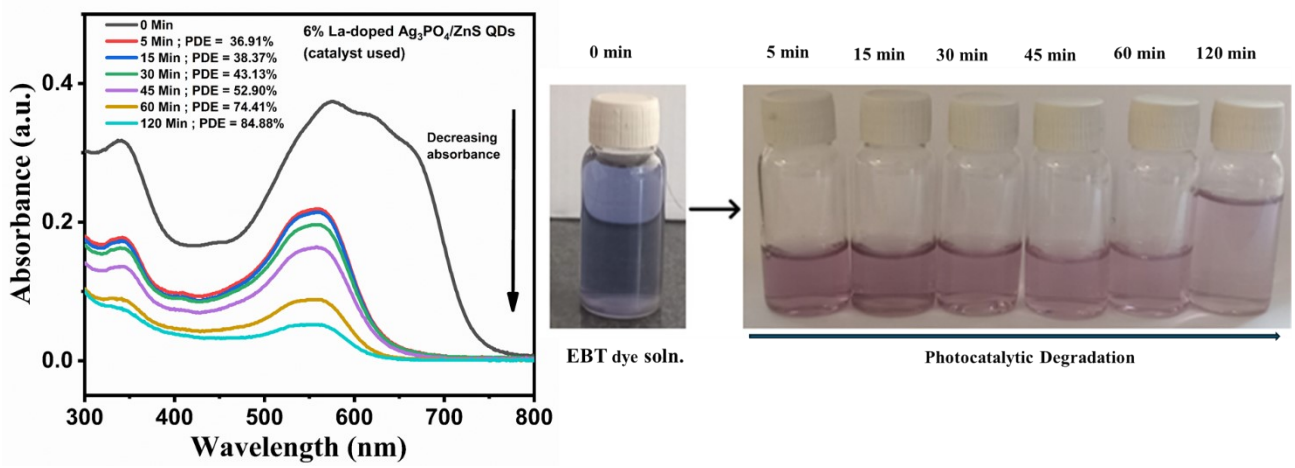

Figure. S5. Effect of initial dye concentration on the photocatalytic degradation of Eriochrome Black T using seven different catalysts

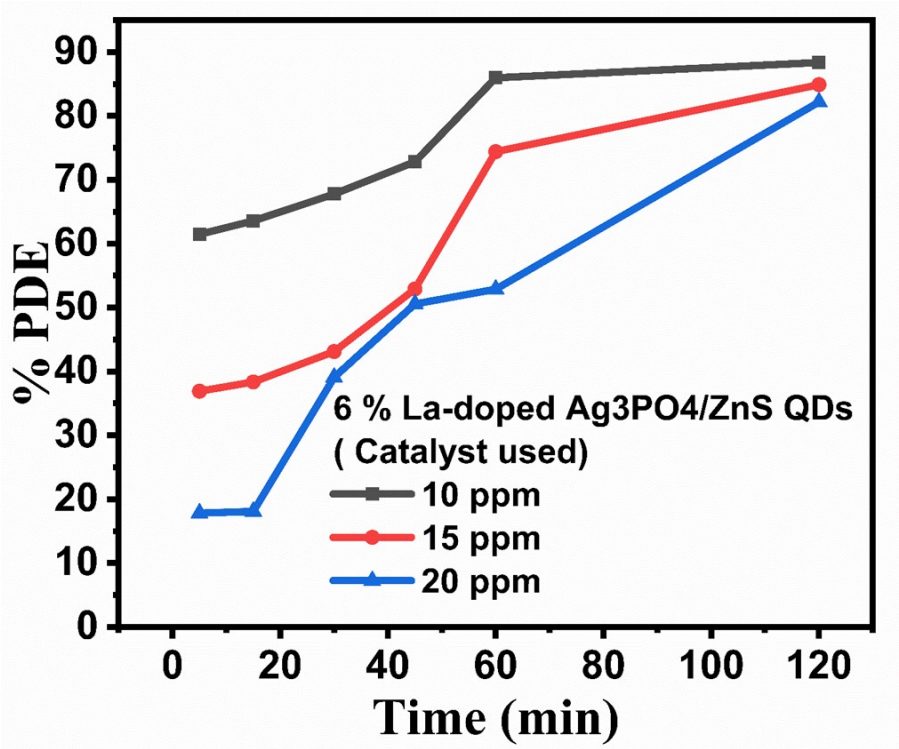

Figure S6: Effect of catalyst loading on the time-dependent photodegradation efficiency of Eriochrome Black T for catalysts, each tested at three dosage levels.

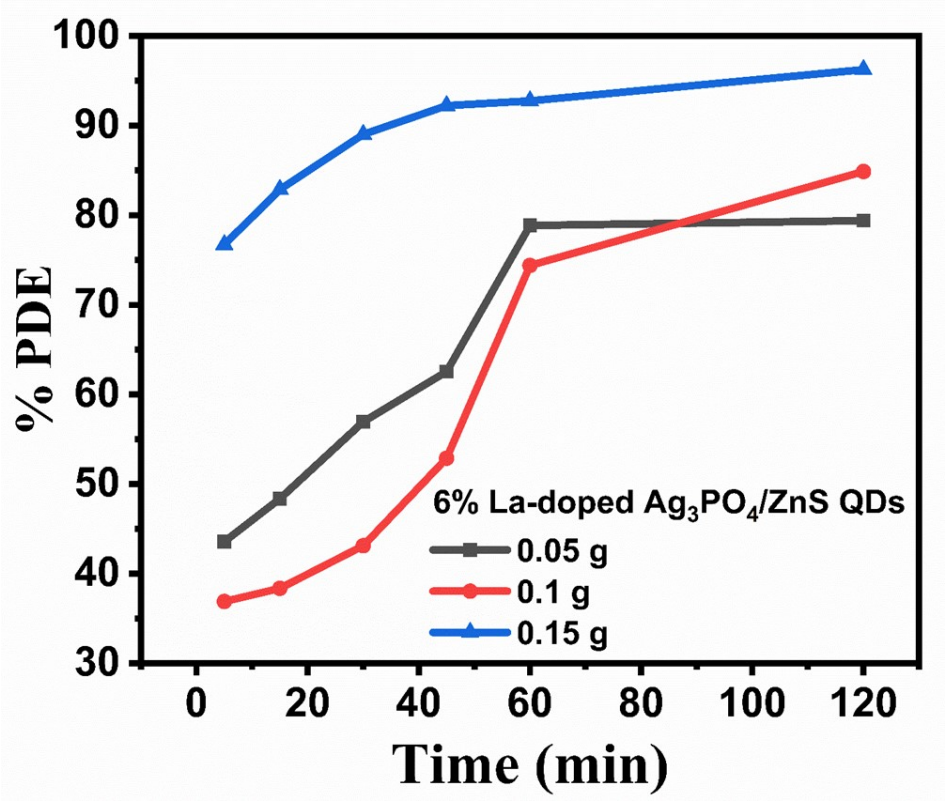

Figure S7 (a-b): Effect of pH on photodegradation efficiency of EBT using two different catalysts, (c-d) Effect of temperature on photodegradation efficiency of EBT using two different catalysts.

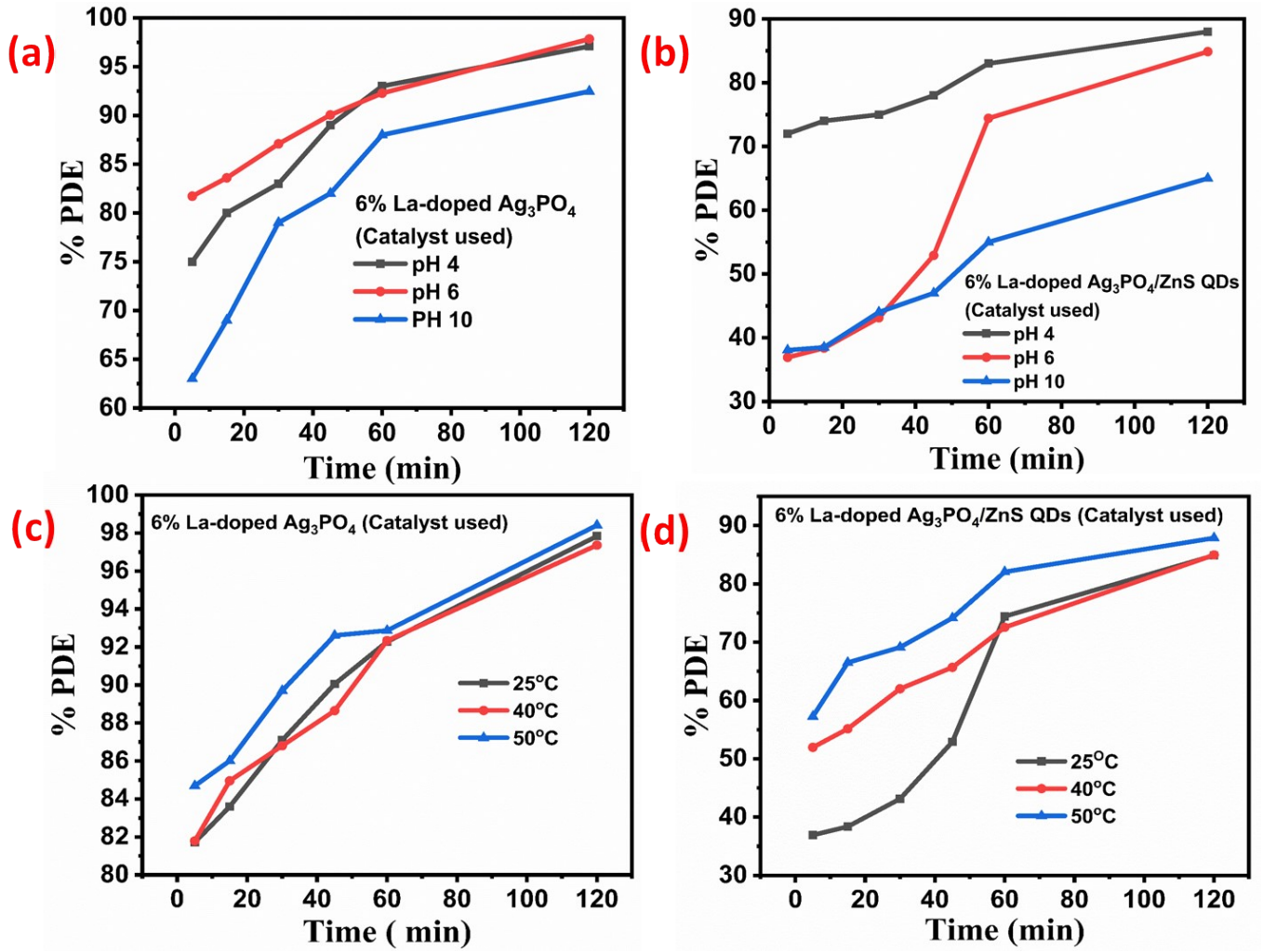

Figure S8: Kinetic study of the photodegradation process of EBT for all catalysts

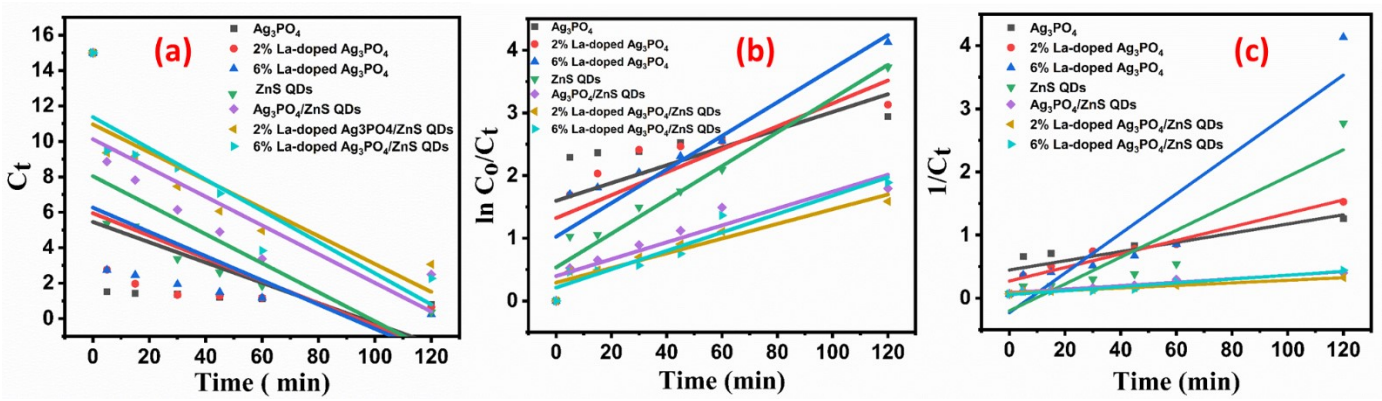

Table S3 shows recently reported efficiencies of different photocatalysts for Eriochrome Black T (EBT). **6% La-doped Ag_3PO_4** and **ZnS QDs** show superior performance under natural sunlight, achieving **97.84%** and **97.59%** degradation of EBT, respectively, in 120 minutes. Compared to reported studies, the high degradation efficiencies of 6% **La-doped Ag_3PO_4 and ZnS QDs** under sunlight and moderate reaction time highlight their strong potential for **practical, solar-driven wastewater treatment,** combining both efficiency and operational simplicity.

Table S3. Comparison of Reported EBT degradation efficiencies of different photocatalyst.

Sr. No.	Photocatalyst	Dyes	Light source	Degradation (%)	Time (min)	References
1	TiO_2	EBT	UV light	82	90	[1]
2	N-doped TiO_2 (N-TiO_2)	EBT	UV light	62	180	[2]
3	SnS	EBT	Sunlight	93	120	[3]
4	TiO_2-biochar composite	EBT	UV light	99.14	124	[4]
5	SnS_2	EBT	Sunlight	90	120	[3]
6	CMO NC	EBT	UV light	95.5	120	[5]
7	$Zn_{0.5}Cu_{0.5}Fe_2O_4/C_3N_4$	EBT	Visible light irradiation	97.08	120	[6]
8	PVA-Ag:ZnS	EBT	Sunlight	91	80	[7]
9	CNT@Nb_2O_5	EBT	Visible light irradiation	89.89	180	[8]
10	TiO_2/g-C_3N_4	EBT	UV light	100	150	[9]
11	Silica–Titania fibers	EBT	UV light	98	480	[10]
12	Li_2MnO_3	EBT	UV light	73	60	[11]
13	$CuAl_2O_4$	EBT	Sunlight	100	180	[12]
14	6% La-doped Ag_3PO_4	EBT	Sunlight	97.84	120	This study
15	ZnS QDs	EBT	Sunlight	97.59	120	This study
16	6% La-doped Ag_3PO_4/ZnS QDs	EBT	Sunlight	84.88	120	This Study

References

1. Kansal, S. K.; Sood, S.; Umar, A.; Mehta, S. K., Photocatalytic degradation of Eriochrome Black T dye using well-crystalline anatase TiO2 nanoparticles. *Journal of Alloys and Compounds* **2013,** *581*, 392-397.
2. Sacco, O.; Mancuso, A.; Venditto, V.; Pragliola, S.; Vaiano, V., Behavior of N-doped TiO2 and N-doped ZnO in photocatalytic azo dye degradation under UV and visible light irradiation: a preliminary investigation. *Catalysts* **2022,** *12* (10), 1208.
3. maamria, J.; Soli, J.; Elaloui, E., Enhanced photocatalytic degradation of rhodamine (RhB) and erichrome black (EBT) by nanoparticles of SnS and SnS2 prepared by the sol–gel method. *Journal of Materials Science: Materials in Electronics* **2025,** *36* (34), 2181.
4. Abdu, M.; Tibebu, S.; Babaee, S.; Worku, A.; Msagati, T. A.; Nure, J. F., Optimization of photocatalytic degradation of Eriochrome Black T from aqueous solution using TiO2-biochar composite. *Results in Engineering* **2025,** *25*, 104036.
5. Sobhani, A.; Rouhani, E.; Mousavi-Kamazani, M., First photocatalytic investigation on Cd–Mn–O nanocomposites for the degradation of Eriochrome Black T. *Applied Water Science* **2025,** *15* (10), 260.
6. Liu, Z.; Liu, J.; Tian, Y.; Hu, Y.; Zou, Q., A novel catalyst Zn0. 5Cu0. 5Fe2O4/C3N4 photocatalytic synergistic activation of persulfate for efficient degradation of Eriochrome black T. *Ceramics International* **2025,** *51* (6), 7411-7419.
7. Sumadevi, K.; Krishnamurthy, G.; Walmik, P.; Rani, R. P.; Naik, S.; Naik, H. B.; Naik, N., Photocatalytic degradation of Eriochrome black-T and Evan's blue dyes under the visible light using PVA capped and uncapped Ag doped ZnS nanoparticles. *Emergent Materials* **2021,** *4* (2), 447-456.
8. Kaufmann, C. G.; Druzian, D. M.; Da Silva, W. L.; Zampiva, R. Y. S.; Rossi, M.; Pavoski, G.; Espinosa, D. C. R.; Alves, A. K.; Bergmann, C. P.; Rhoden, C. R. B., A novel nanocatalyst of the multi-walled carbon nanotubes decorated with niobium pentoxide for the Eriochrome black T dye degradation. *Environmental Science and Pollution Research* **2025,** *32* (34), 20528-20542.
9. Hassan, F.; Bonnet, P.; Dangwang Dikdim, J. M.; Gatcha Bandjoun, N.; Caperaa, C.; Dalhatou, S.; Kane, A.; Zeghioud, H., Synthesis and investigation of TiO2/g-C3N4 performance for photocatalytic degradation of bromophenol blue and Eriochrome Black T: experimental design optimization and reactive oxygen species contribution. *Water* **2022,** *14* (20), 3331.
10. Aldama-Huerta, O. A.; Medellín-Castillo, N. A.; Carrasco Marín, F.; Reyes-López, S. Y., Photocatalytic Degradation of Methyl Orange, Eriochrome Black T, and Methylene Blue by Silica–Titania Fibers. *Applied Sciences* **2025,** *15* (22), 12084.
11. Alabi, A. B.; Villani, M.; Sinisi, V.; Rampino, S.; Coppede, N.; Adebayo, S.; Adegoke, H. I.; Akinsola, S. I., Lithium Manganese Oxide (Li2MnO3) as a promising photocatalyst for the degradation of Eriochrome Black T. *Journal of Materials Science: Materials in Engineering* **2025,** *20* (1), 61.
12. Lahmar, H.; Douafer, S.; Laouici, R.; Hamdi, M.; Souici, A.; Trari, M.; Benamira, M., Synthesis and characterization of CuAl2O4 nanoparticles: Application for the removal of Eriochrome Black T under solar light irradiation. *Inorganic Chemistry Communications* **2024,** *163*, 112316.