Supporting Information

Surface disordered rutile TiO_2-graphene quantum dots hybrid: A new multifunctional material with superior photocatalytic and biofilm eradication properties

Anupam Biswas[‡], Gayatri Salunke[‡], Puneet Khandelwal[‡†], Raja Das[‡†], Pankaj Poddar[‡†*]

[‡]*Physical & Materials Chemistry Division, CSIR-National Chemical Laboratory, Pune - 411008, India*

[†]*Academy of Scientific and Innovative Research, AnusandhanBhawan, Rafi Marg, New Delhi - 110001, India*

*Corresponding author:

E-mail: p.poddar@ncl.res.in

Physical and Material Chemistry Division,

CSIR-National Chemical Laboratory,

Dr. Homi Bhabha Road

Pune- 411008, India

Phone: +91-20-2590-2580 (Office)

Fax: +91-20-2590-2636

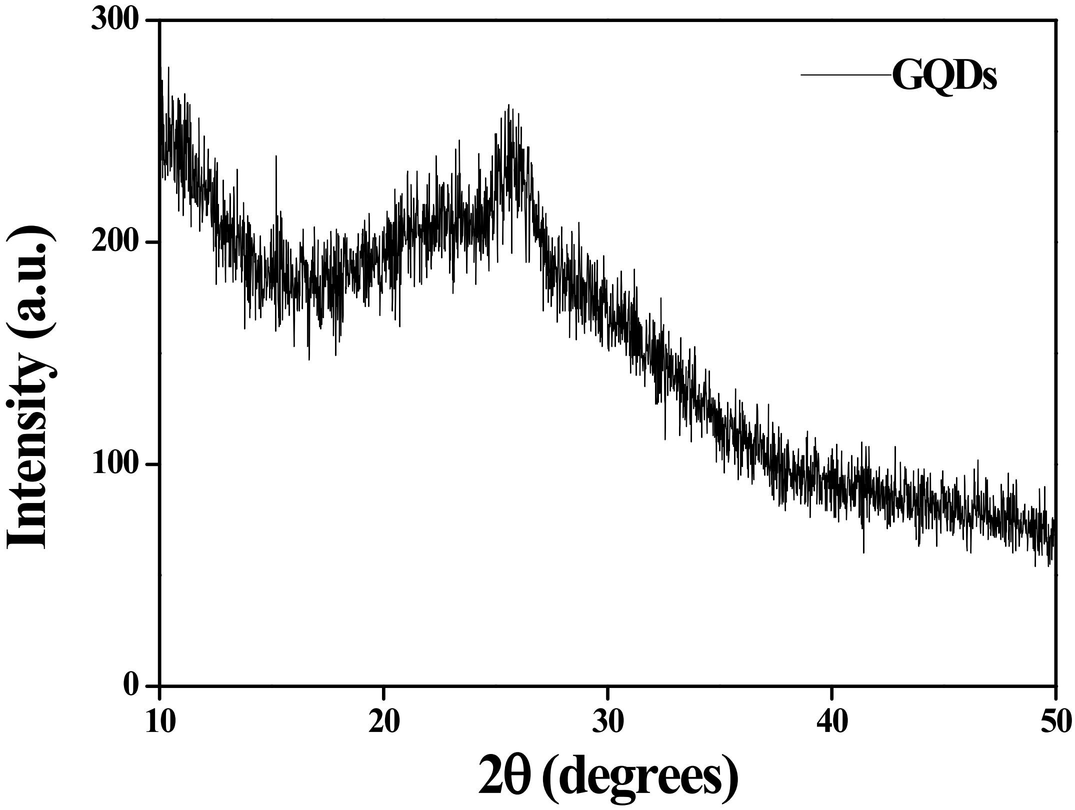

Figure S1. PXRD spectrum of GQDs showing the hump at 2θ ~25° which is a characteristic feature of graphitic carbon.

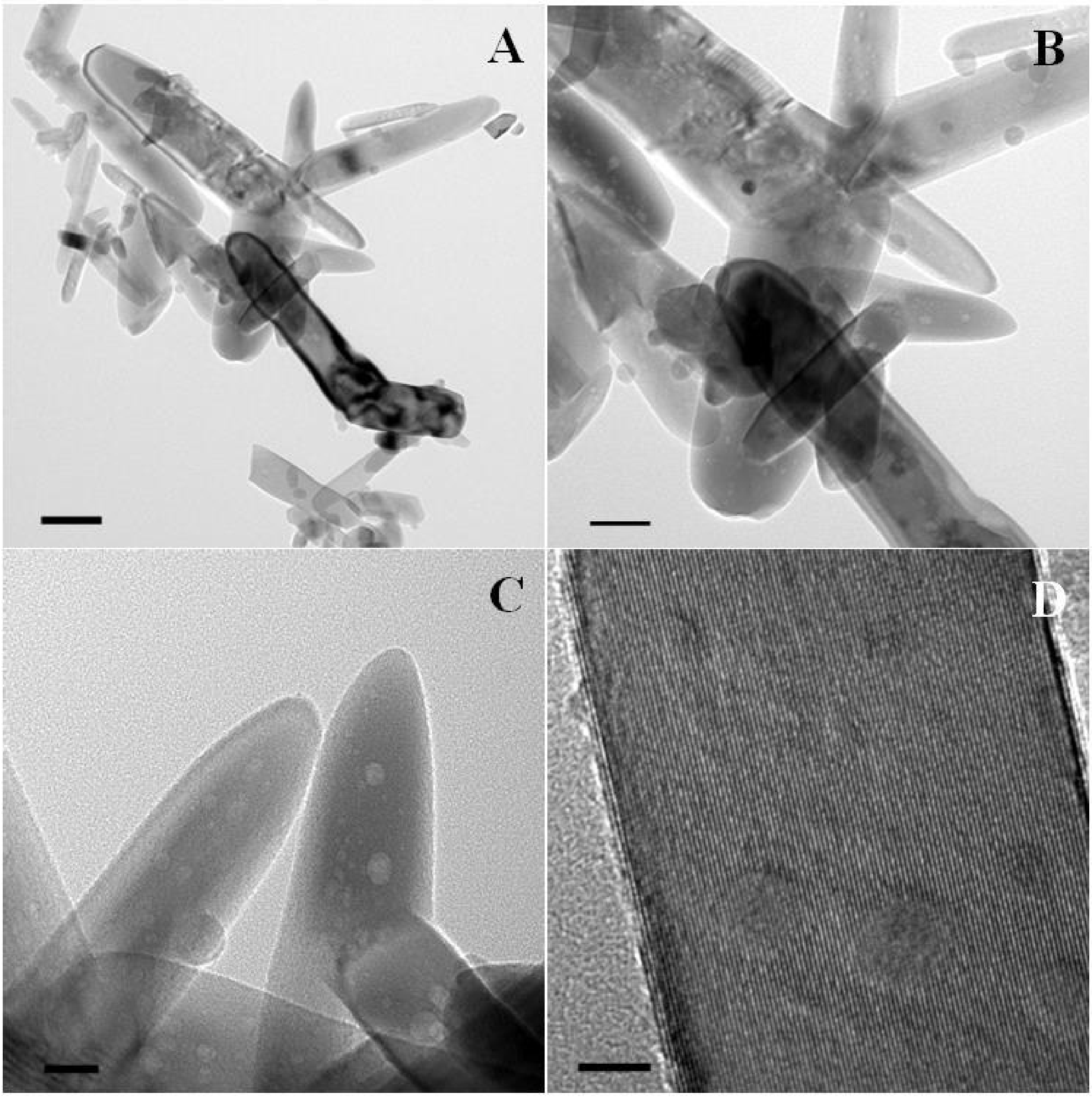

Figure S2. A, B, C) TEM images D) HR-TEM image of rutile-TiO_2 nanorods. Scale bars are 100, 50, 20, and 5 nm for A, B, C, and D, respectively.

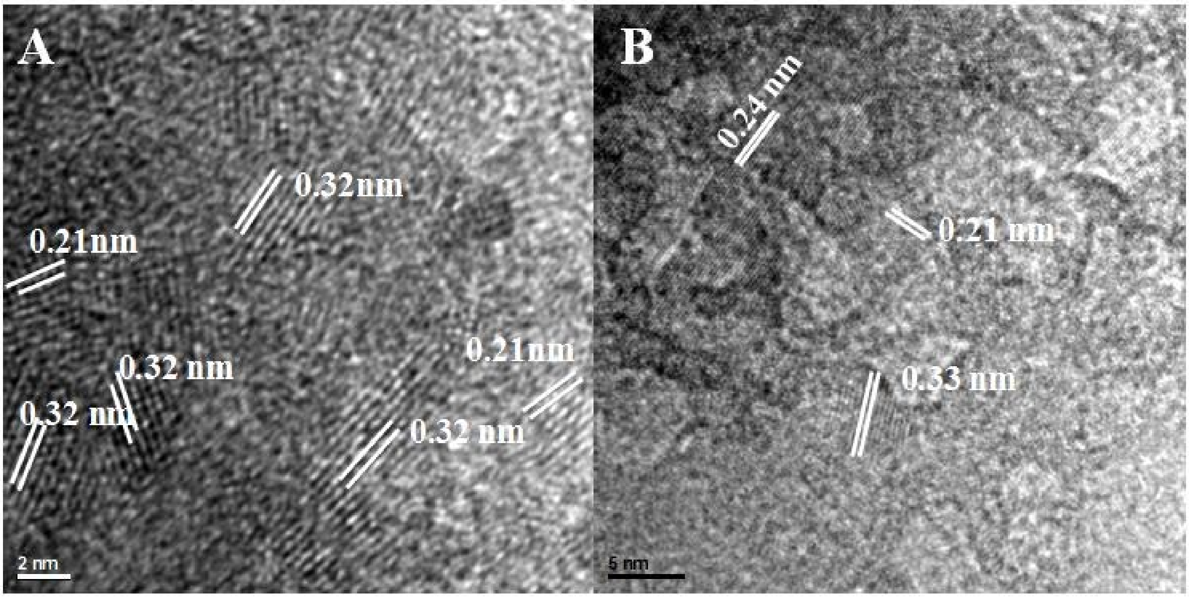

Figure S3. A, B) HR-TEM images show the distribution of rutile-TiO_2 and GQDs in TG-hybrid. Lattice spacings of 0.33 nm and 0.21 nm correspond to (111) and (100) planes of GQDs, respectively and lattice spacings of 0.32 nm and 0.24 nm correspond to rutile-TiO_2 (110) and (101) planes, respectively.

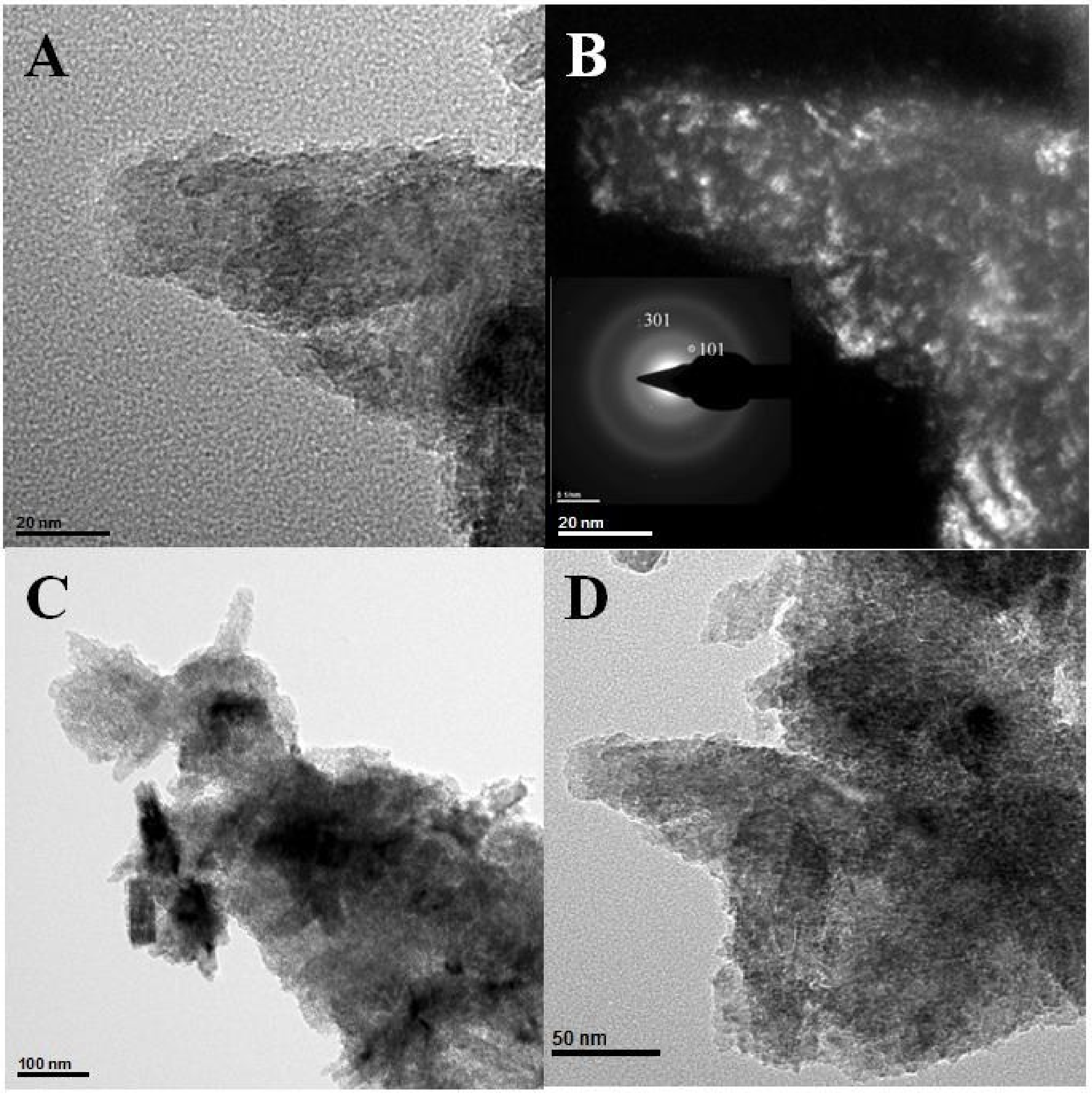

Figure S4. A, B) Comparison of bright-field and dark-field {(101) diffracted beam of TiO_2} images of the same area of rutile-TG-hybrid. Inset of B) shows the corresponding SAED pattern. Images clearly display the uniform distribution of TiO_2 and GQDs. C, D) TEM images of TG-hybrid.

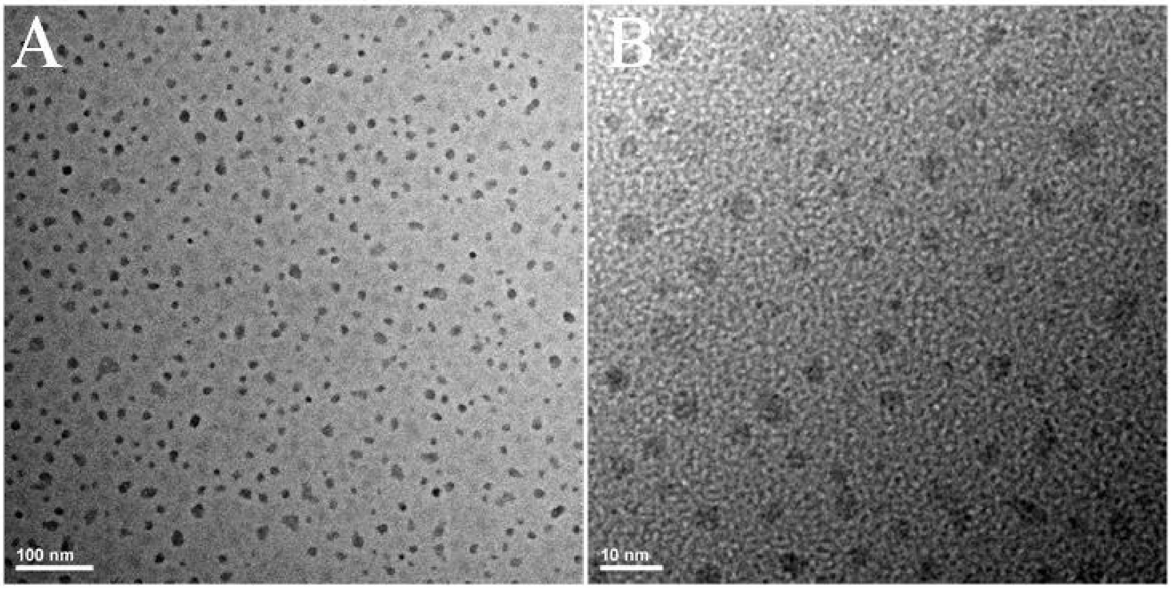

Figure S5. HR-TEM images at different magnifications showing uniform and well dispersed GQDs.

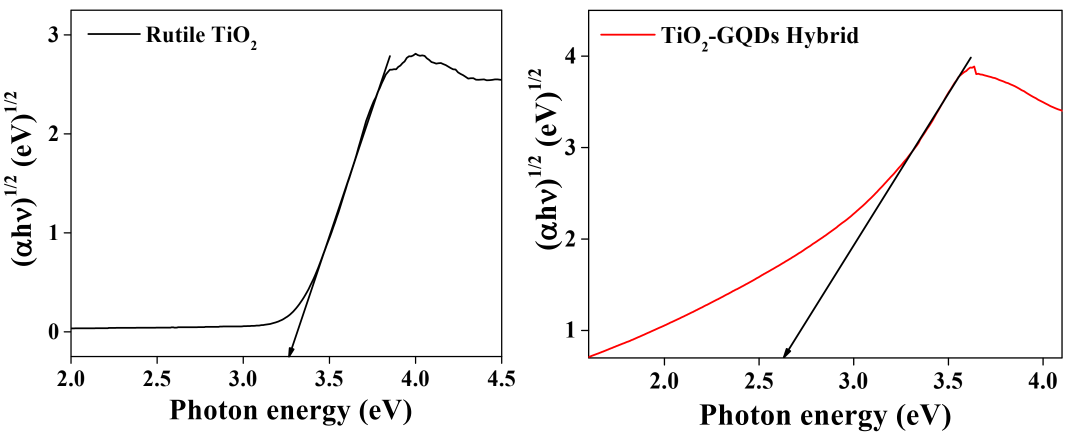

Figure S6. A Tauc plot of $(\alpha h\nu)^{1/2}$ *vs.* photon energy for as-synthesized Rutile-TiO_2 and TG-hybrid.

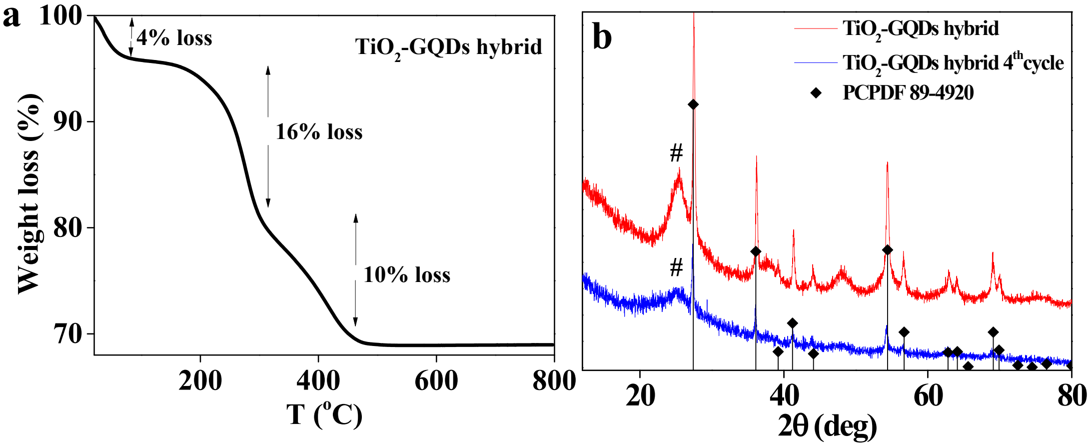

Figure S7. (a) TGA thermogram of surface-disordered TG-hybrid. (b) A comparison of room temperature XRD patterns of surface disordered TG-hybrid, TG-hybrid after 4th cycle and PCPDF#894920 data for rutile-TiO_2. The # marked peaks represent graphitic carbon.

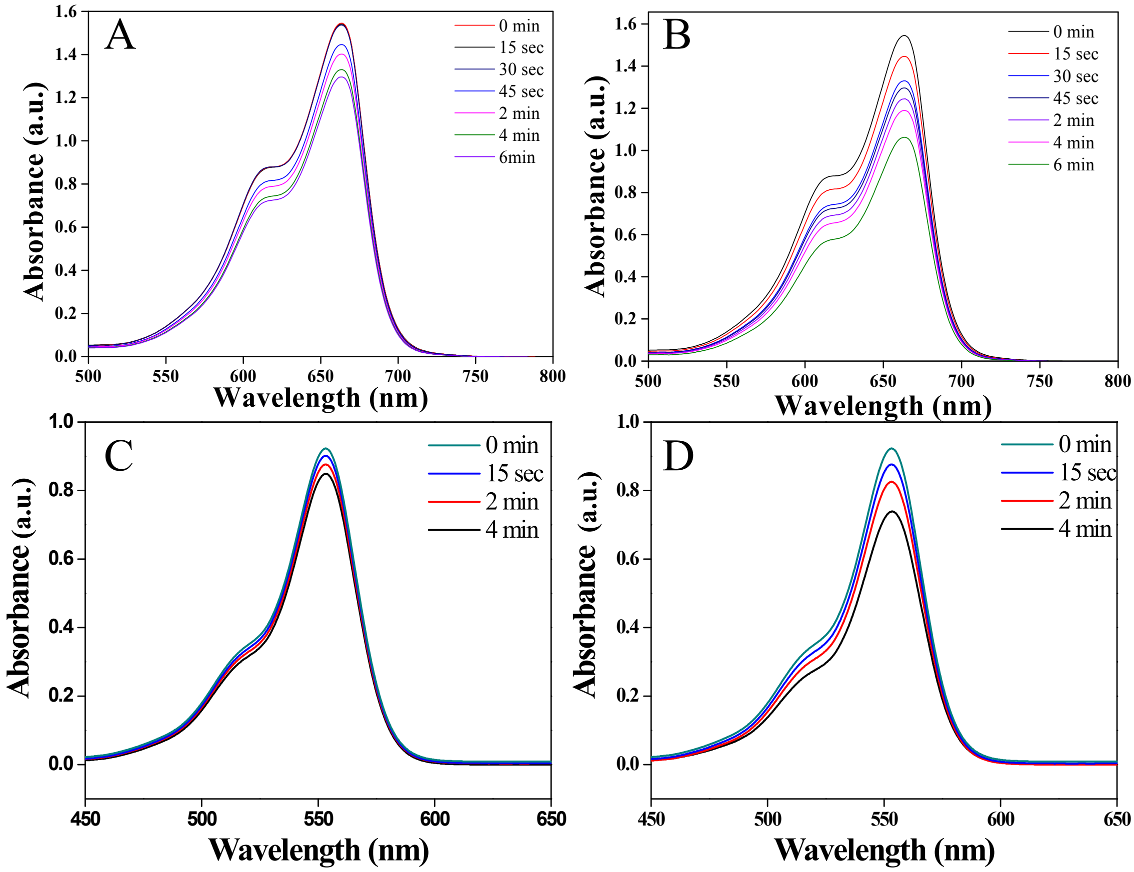

Figure S8. Photodegradation of methylene blue (MB, 5 x 10^{-5} M) and rhodamine B (RhB, 10^{-5} M) for rutile-TiO_2 and GQDs in presence of natural sunlight after 1st cycle. (A) Photodegradation of MB by GQDs. (B) Photodegradation of MB by TiO_2. (C) Photodegradation of RhB by GQDs. (D) Photodegradation of RhB by TiO_2.

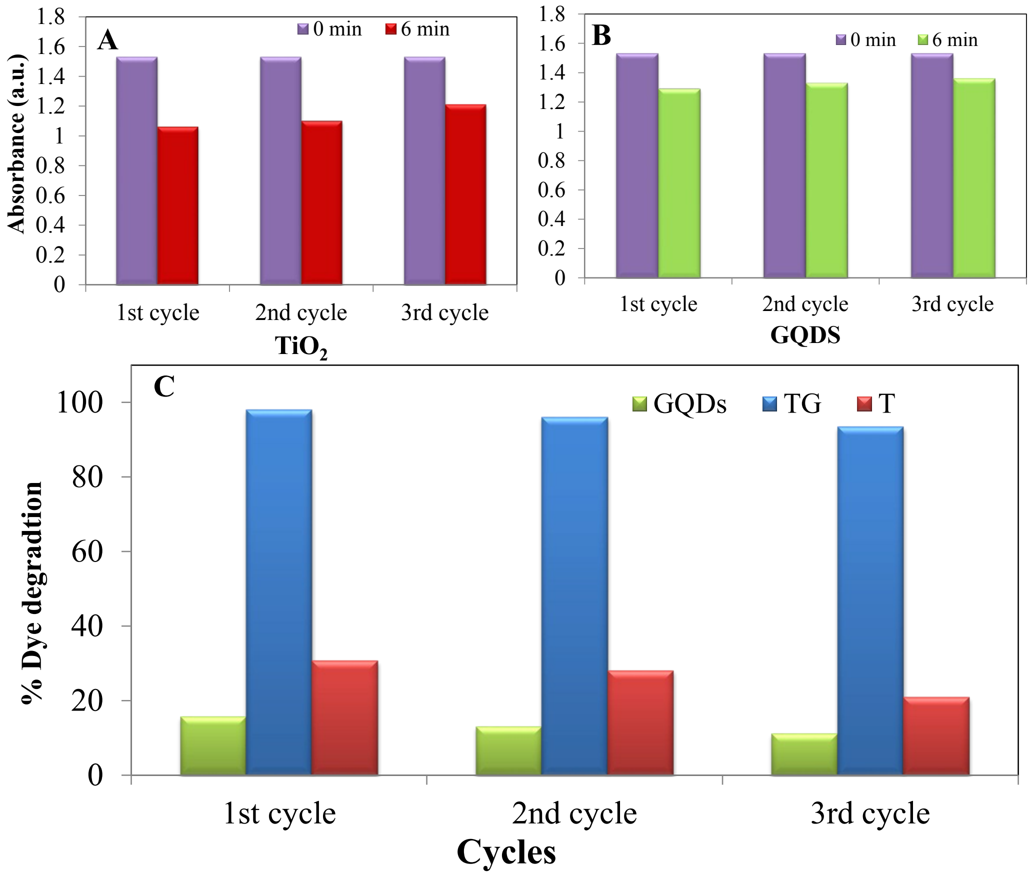

Figure S9. Comparative photodegradation of MB by GQDs, TiO_2 and TiO_2-GQDs hybrid under natural sunlight A) MB dye degradation by GQDs measured after 6 min. B) MB dye degradation by TiO_2 measured after 6 min. C) Comparison of MB dye degradation by GQDs, TiO_2 (T) and TiO_2-GQDs hybrid (TG).

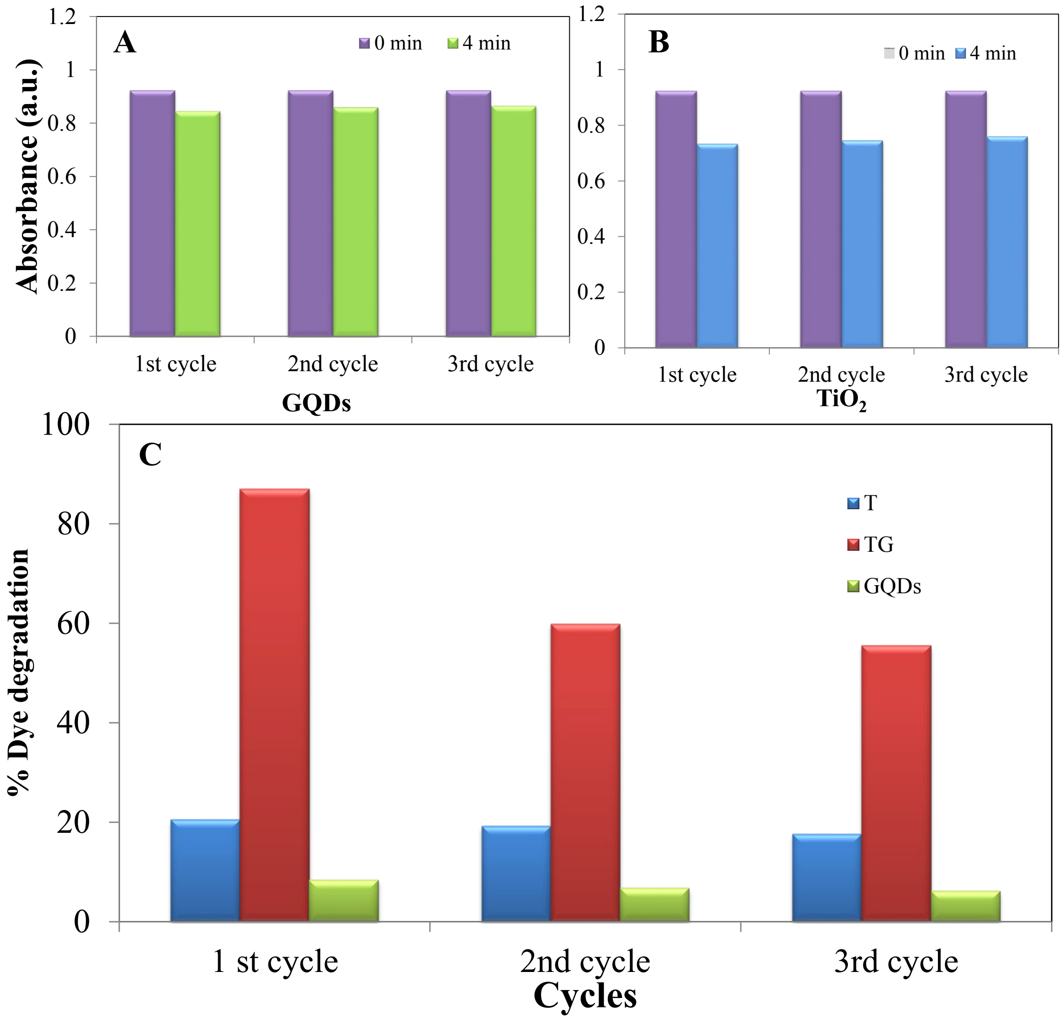

Figure S10. Comparative photodegradation of RhB by GQDs, TiO_2 and TiO_2-GQDs hybrid under natural sunlight A) RhB dye degradation by GQDs after 4 min. B) RhB dye degradation by TiO_2 after 4 min. C) Comparison of RhB dye degradation by GQDs, TiO_2 (T) and TG-hybrid (TG).

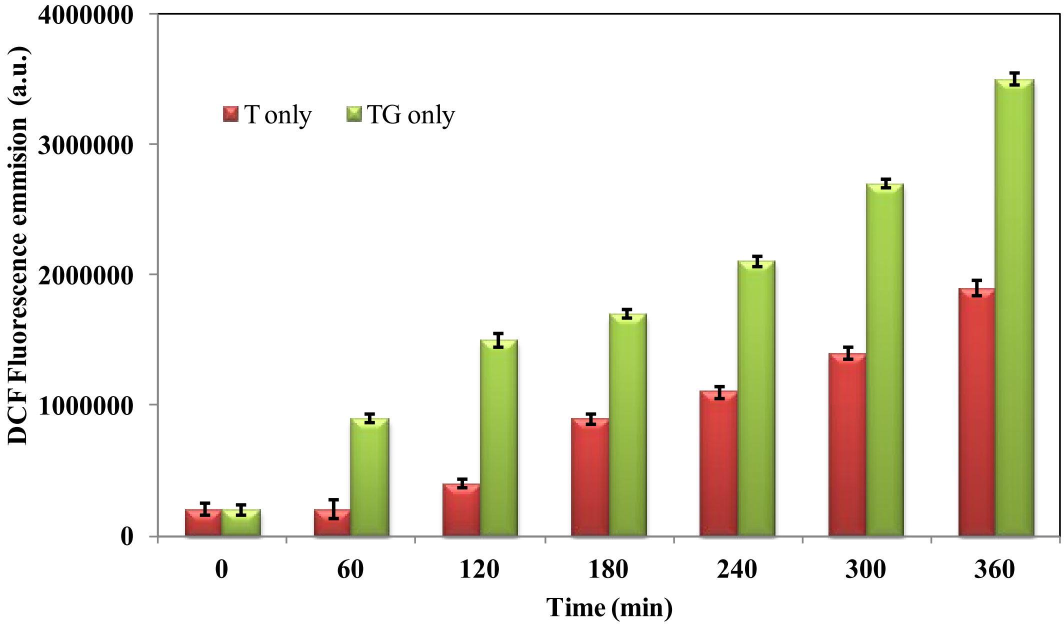

Figure S11. Measurement of ROS production using DCF fluorescence (λ_{em}= 523 nm) in presence of only rutile TiO_2 and TG-hybrid illuminated with sunlight for 360 min.

Abbreviations: T: rutile TiO_2; TG: TiO_2-GQDs hybrid.

Table S1: Comparison of photo degradation for methylene blue.

Author	**Article**	**Time taken for degradation of methylene blue (MB)**
Chen *et. al.*	*Science* **2011**, *331*, 746–750.(Ref:23) Light condition: solar simulator of 1 Sun power.	8 minutes
Pan et. al.	*ACS Appl. Mater. Interfaces* **2012**, *4*, 3944–3950.(Ref:49) Light condition: natural solar light	10 minutes
Our TG-hybrid	Light condition: natural solar light	6 minutes