Removal of methylene blue from waste water under low power irradiation source by Zn, Mn co-doped TiO_2 photocatalyst

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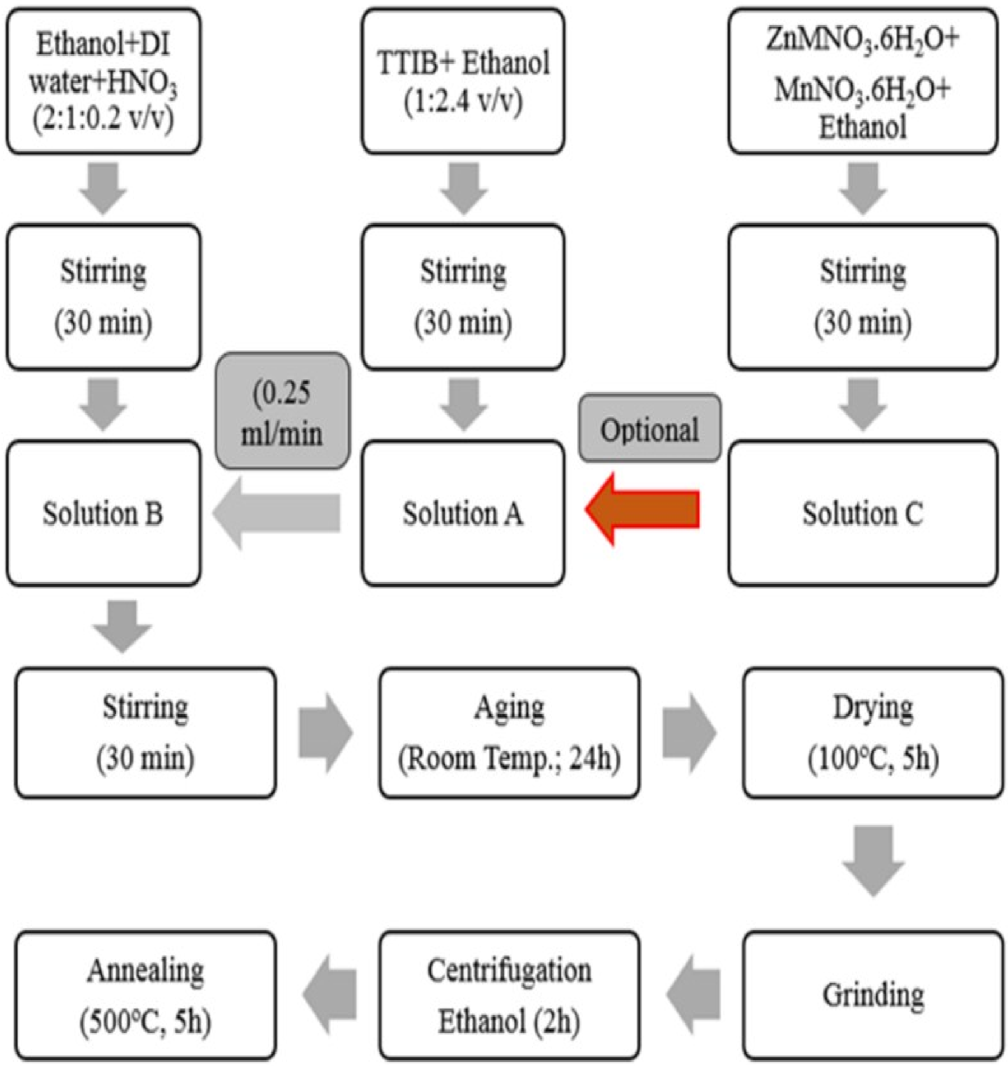

Fig. S1 Flow chart for the sol-gel synthesis of TiO_2 nanoparticles

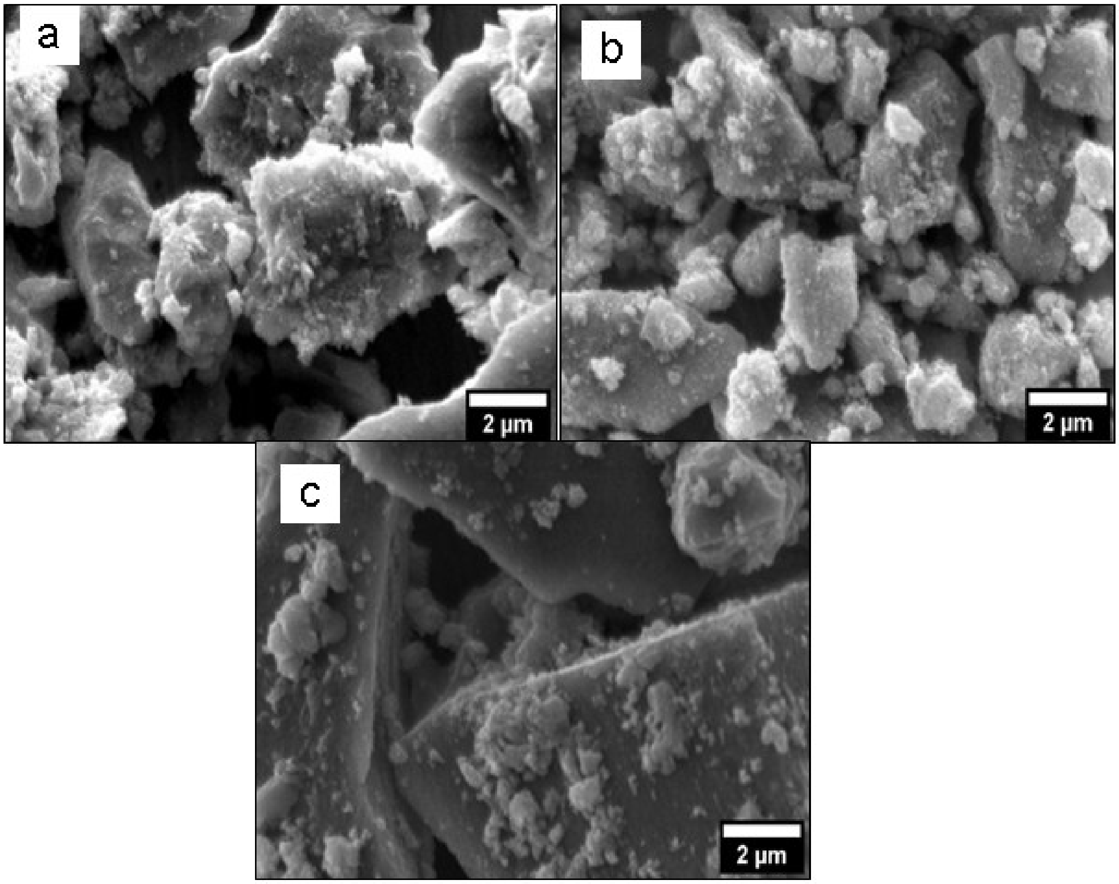

Fig. S2. SEM images of (a) TP0 (b) TP1 and (c) TP2

S1. The whole mechanism of the MB degradation in presence of visible light over TiO_2 can be explained by the following photocatalytic reactions

$$MB + h\nu \longrightarrow MB^{+} \quad (1)$$

$$MB^{+} + TiO_2 \longrightarrow MB^{+\bullet} + TiO_2\,(e^{-}) \quad (2)$$

$$TiO_2\,(e^{-}) + O_2 \longrightarrow O^{-\bullet} + TiO_2 \quad (3)$$

$$MB^{+\bullet} \longrightarrow \text{Degradation Products} \quad (4)$$

The MB molecules can be completely degraded by theses redox chain of reaction. In this photosensitization process, the presence of TiO_2 is very essential as it plays a very efficient role of electro transfer to electro acceptor [1]. Thus, it can be said that in presence of visible light, the degradation of MB dye over blank TiO_2 is occurred due to the photosensitization process.

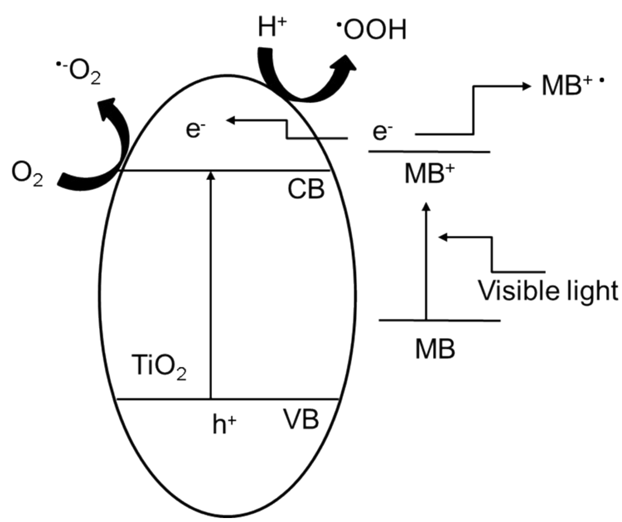

Fig. S3: Photocatalytic mechanism of TiO_2 under Visible Light Illumination

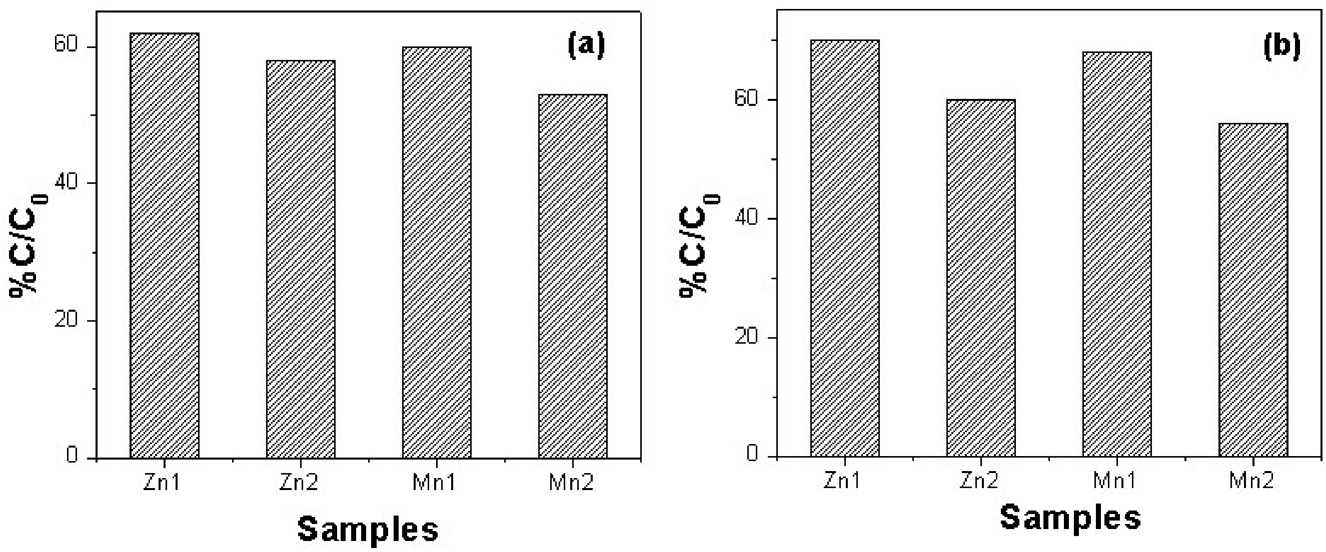

Fig. S4. Photocatalytic degradation of MB degradation in 10 hours by single Zn and Mn doped (1.0, 2.0 at.%) in presence of (a) visible light and (b) UV light.

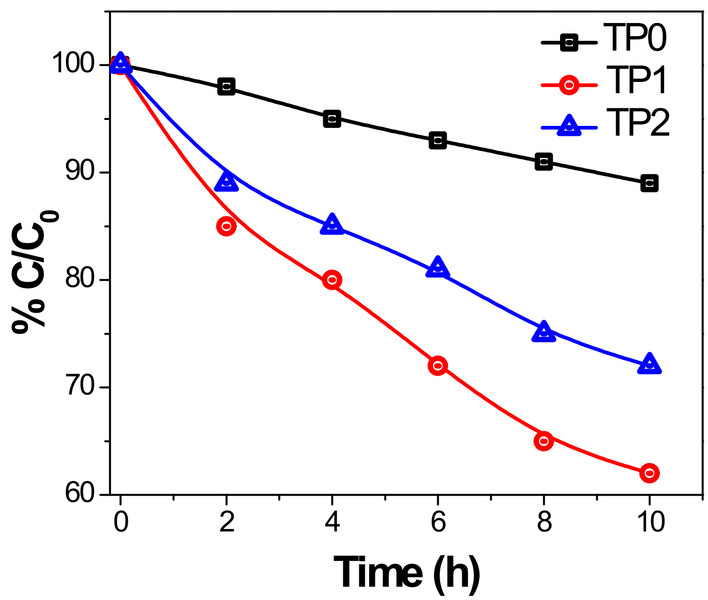

Fig. S5. The photocatalytic degradation of phenol over TP0, TP1 and TP2 under visible light irradiation.

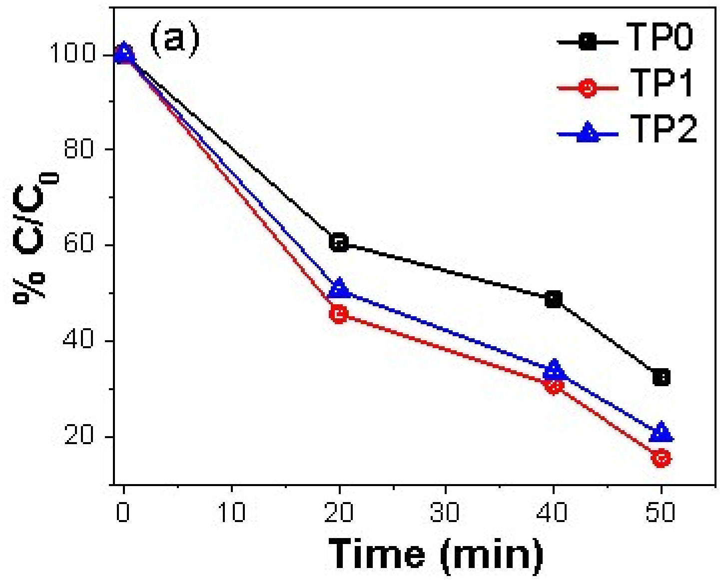

Fig. S6. Comparison of relative concentration of undoped and co-doped TiO_2 under the presence of high power 450W solar visible light source.

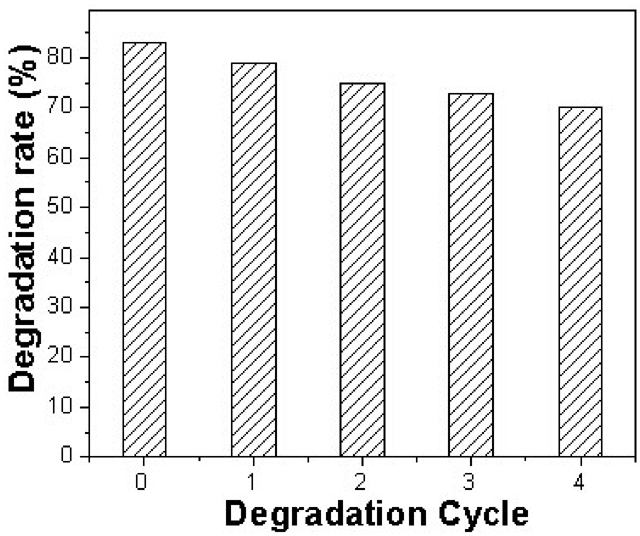

Fig. S7. Bar plot showing the degradation of MB dye for 4 cycle using TP1 catalyst in presence of visible light.

Table S1: Comparison of UV and visible radiation in terms of % degradations for 10 h and the rate constants.

Substrate	Samples	Rate constant (visible) k (h^{-1})	Rate constant (UV) k (h^{-1})
Methylene blue (MB)	TP0	0.06	0.07
	TP1	0.12	0.13
	TP2	0.10	0.11

Table S2: Comparison of visible light degradation efficiencies (Φ) of various TiO_2 photocatalysts doped with different transition metal dopants form literature to that of the present study.

Dopant concentration in TiO_2 (at.%)	Dye	Degradation time (t; min)	Intensity of visible irradiation source (L_0; Watt)	Maximum degradation ($1-C/C_0$; S)	Degradation/ Watt min (Φ)= ($S / I_0 \times t) \times 10^{-5}$
Zn^{2+} (0.37)	RhB*	30	Halogen bulb-1000W	0.99	~3.0 [2]
Mn^{2+} (0.2)	MB	360	Philips Bulb-300W	0.90	~ 0.8 [3]
Pt^{2+} (0.3)	Phenol	180	Hg(Xe) Bulb-500 W	0.9	~1 [4]
Fe^{3+} (0.1)	MB	180	Xenon Bulb-450W	0.65	~ 0.248 [5]
N	MB	160	Xenon Bulb-150 W	0.9	~ 37.5 [6]
Fe + N (0.5)	RhB*	240	Halogen Bulb-1000W	0.99	~ 0.41 [7]
Cu+N (0.9, 3.1)	Xylenol Orange	40	Hg Bulbe-500W	0.5	~ 2.5 [8]
Fe+ B (2.8, 19)	Toluene	360	Halogen Bulb-150W	0.8	~ 1.4 [9]
Zn+Mn (1.0, 1.0)	MB	600	LED Bulbs-2W	0.8	~ 66.6 (Present study)

CR*= Chromophore, RhB*= Rhodamine B,

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