Nanoparticle-loaded multifunctional natural seed gel-bits for efficient water purification

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Electronic Supplementary Information (ESI)

ESI-I : Environmental SEM images of unloaded and nanoparticles loaded seeds in the presence of water

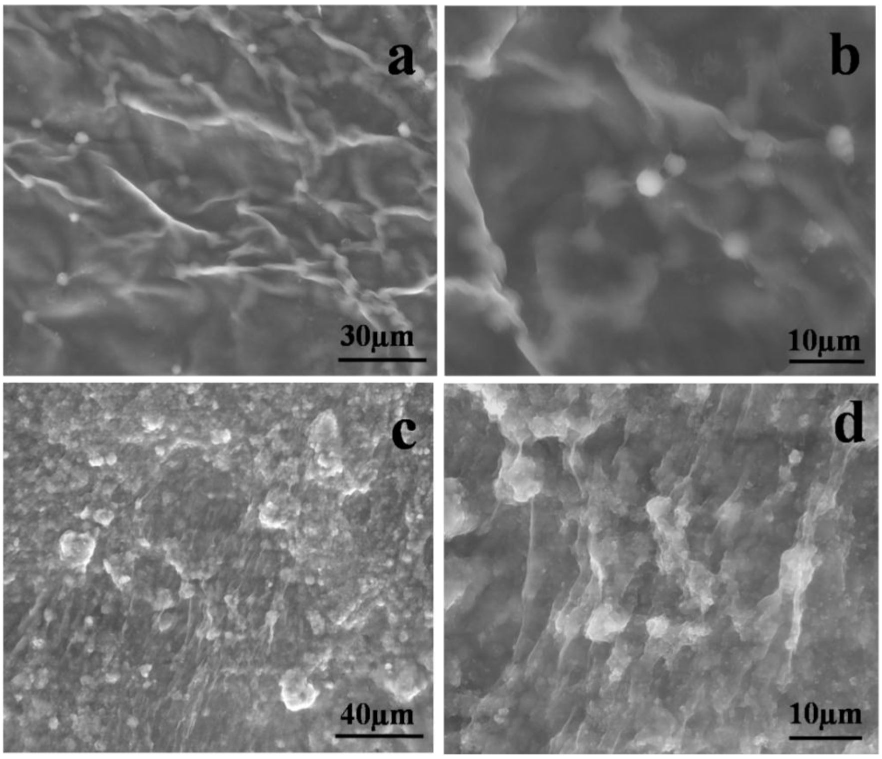

Figure S1: Environmental SEM images of (a and b) water soaked Sabja seed; (c and d) Fe_3O_4 loaded Sabja seed in presence of water.

ESI-II: Detail of ICP-OES Analysis

All the samples containing heavy metal ions (As3+, Cr6+, Pb2+, Cd2+) were dissolved in an acid mixture (HNO_3 and HCl in 1: 3 ratio). 5 ml solutions of each heavy metal ion type were dissolved in 10 ml of acid mixture to digest all the metal ions present in the solution. These solutions were kept overnight to ensure complete digestion. They were then diluted to 100ml with de-ionized water, then filtered and used for ICP analysis.

In ICP-OES analysis standard solutions of all the metal ions with known concentrations were run in the instrument for standardization. After that our samples with unknown metal ion concentrations were run to detect the heavy metal ion contents. From ICP-OES we usually get metal ion concentrations, hence for metal oxides (TiO_2 and Fe_3O_4) we had to back-calculate the oxide content. In the case of metal oxides such as TiO_2 and Fe_3O_4, HF and H_2SO_4 (1:1 ratio) acid mixture was used because TiO_2 is difficult to dissolve in the HNO_3 and HCl mixture.

ESI-III: Size separation experiment

These experiments were performed by using bulk α-Fe_2O_3 powder where different sizes of particles were present (from nano to micron) and apart from this a mixture of different sizes of carbon quantum dots solution was also used. In this experiment 7 gms of sabja seeds were soaked in water for 30 mins. After complete swelling these seeds were poured in a glass column with a coarse mesh at the bottom to hold them. For particulate size separation study commercial 100 mg bulk α-Fe_2O_3 was dispersed in water and sonicated for 30 mins. This solution was slowly (without impact momentum) poured on the seed loaded column by a funnel with a long dispensing tube adduct. The particle size was determined for the filtrate and the filtered solutions by Dynamic Light Scattering (DLS). Similarly TiO_2 coated seeds were also examined as a separation medium in the column.

To broaden the application context we also tested applicability of this procedure with graphene quantum dot separation from a carbon product. **Figure S1a and b** shows the average particle size (hydrodynamic radius, not the physical size) of different nanoparticle solutions before and after filtration using seed gel-bits. **Figure S1a** shows that initial mean hydrodynamic radius of bulk α-Fe_2O_3 powder in solution is 201nm (hydrodynamic radius) and post-filtration a mean hydrodynamic radius of 116 nm and 166 nm is obtained after passing the bulk powder solution through the column packed with unloaded seeds and TiO_2 loaded seeds, respectively. A higher hydrodynamic mean radius of filtrate obtained with TiO_2 loaded seeds was somewhat surprising.

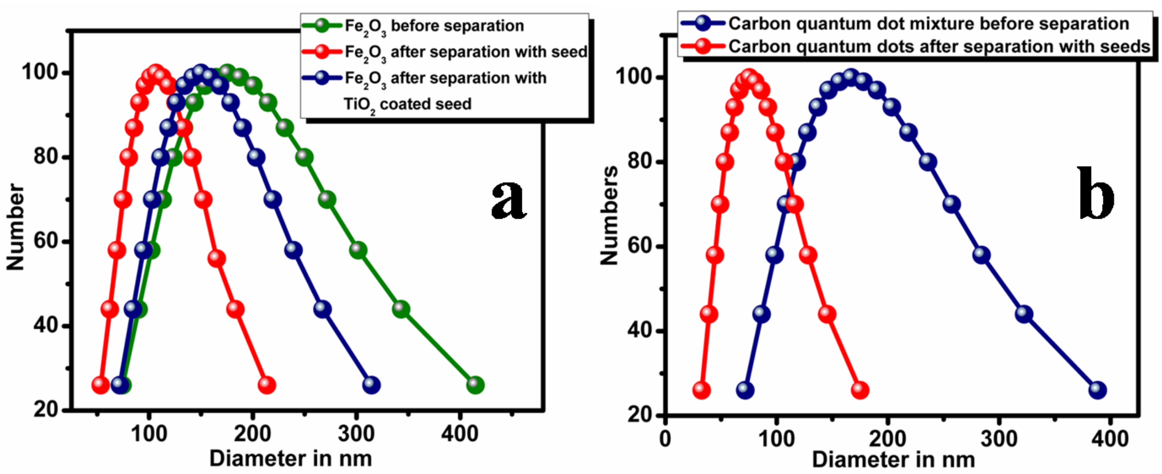

Figure S1: **a)** Particle size of bulk α-Fe_2O_3 before and after separation through seed and TiO_2 loaded seed mass, **b)** Particle size of carbon quantum dots before and after separation through seed mass.

When the swollen bare seeds are loaded in column, being a soft compressible matter they can undergo shape deformation via lateral expansion under self weight pressure, thereby forming narrow escape channels allowing small particles to pass through. On the other hand, when TiO_2 nanoparticles are loaded the swollen seeds may not undergo similar degree of deformation due to changed mechanical properties due to particle loading hence relatively bigger channels could result leading to higher mean size of particles filtered out. Similar results were also obtained in the case of graphene quantum dots. These quantum dots were synthesized from porous carbon sheets by acid functionalization. Hence this solution contained both large particles and quantum dots (broad size distribution). When this solution was passed through the column containing swollen seeds most of the larger particles were filtered out and the solution collected at the bottom contained mostly the GQDs. These results were confirmed by DLS (**Figure S1 b**) where initial quantum dots mixture showed an average hydrodynamic radius of 190nm whereas after passing through the column the solution showed an average particle size of 86nm.