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Washing cloths photo-catalytically to reduce global water pollution

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Abstract: Photocatalytic washing of cloth using TiO_2 photocatalyst and sunlight is demonstrated. Photocatalyst is recovered after washing process. Technology can drastically reduce the water pollution (*billions of liters per day*) due to use of detergents and soaps in washing cloths – Globally; if developed further.

Keywords: Photocatalysis, TiO_2, Water purification, Water Pollution, Grand Challenges.

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1 Introduction: One of the major sources of water pollution is the detergents and soaps used for washing clothes, kitchen ware, and bathing. Detergents are synthetic chemical compounds used for cleaning purpose. Soaps originate from natural substances like lye and plant saponins. Many of the laundry detergents (particularly marketed in developing countries like India) contain 35 to 75 % phosphates (for softening the hard water thereby increasing the solubility of soap and detergent, stabilizing the alkalinity of the surfactants, keeping the dissociated dirt from the cloths into the water and prevent it from re-depositing on cloths) – which causes variety of water pollution problems. Some of the European countries like Switzerland have banned the use of phosphates in detergents. Indian government did come up with eco-mark scheme in which the detergents that contain no phosphates and following other Bureau of Indian Standards (BIS) parameters would have been given the eco-mark label – to convey the environmental friendliness to the consumer. But the scheme failed due to favour to the industry and the companies not following BIS standards as they are not statutory. Detergent and soap are used almost every day by almost every person in India and world. Considering that on an average, Indian person use 5 litres (minimum) of water daily for washing the cloths; the amount of water that gets polluted on a daily basis is about 6.25 billion litres (due to use of detergents and soaps). On a global scale, this number is mind blowing. Such waste water can not be even used for secondary applications (considering primary application as drinking water) such as agriculture and hence needs to be treated for reuse. In India, the water bodies that are undergoing eutrophication are rivers, village ponds, and other water reserves. Many scientific studies have been reported on the pollution created by these detergents and soaps in the past **[1-11]**. The consumption of soaps and detergents are increasing not only in India but globally.

A simple addition of few grams of detergent/soap to a bucket of water (about 15 litres) makes it unsuitable for drinking, agriculture and any other application. Further, once the detergent/soap gets dissolved in water completely; it is very difficult to separate them from water. Such waste water produced is largely toxic and unsuitable even for secondary applications. Purification of such waste water is required before it is discharged into the environment or used for secondary application. We believe that the conventional process of washing cloths using water and detergents/soaps will be in-use for a longer time; although some technological advances have been made in the areas of washing cloths without using water; wrinkle-free, superhydrophobic, and self-cleaning textiles. This is due to the fact that the conventional washing process is simple, economical, and affordable to mass public of developing countries like India; easy availability of soaps, detergents and water; and psychological feel for humans that once the cloths are washed they become fresh and ready to use.

Considering the serious problem of huge amount of waste water generated (*several billions of liters per day*) due to use of detergents and soaps, a new method/process of washing cloths is urgently required in which the chemicals/materials used for washing cloths can be separated from water easily and reusable in washing process multiple times. This requirement has pointed us towards use of catalysts/photocatalysts – insoluble in water. We disclose here our newly invented method of washing cloths using photocatalysis phenomena. Invented process uses TiO_2 photocatalyst and sunlight for degradation of organic pollutant (here, crystal violet dye).

Since the discovery of photocatalysis by Fujishima and Honda in 1972, TiO_2 remained the most thoroughly studied and favoured photocatalytic material **[12]**. Photocatalysis is widely studied for degradation of organic pollutants such as dyes and pigments, toxic organic compounds, pharmaceuticals, and for killing micro-organisms like bacteria. It is finding applications in areas of water and air purification, self-cleaning coatings, hydrogen generation by splitting water, and chemical conversion of materials using sunlight. Various other materials have demonstrated photocatalytic effect in ultraviolet (UV) or visible region of the spectrum – depending on their optical band gap. Some of them are – metal nanoparticles (Ag-Bi, Au) coated or doped (like Co) TiO_2, oxides like ZnO, Cu_2O, V_2O_5, Iron oxides, Bi_2O_3, NiO, Nb_2O_5, Ta_2O_5, ZrO_2, CeO_2, Ga_2O_3, Bi_2MoO_6, Bi_2WO_6, $BiMoO_6$, $BiVO_4$, CdS, CdSe, WO_3, $KTiNbO_5$, $CsTaWO_6$, MoO_3, Gd_2MSbO_7 (M: Fe, In, Y), complex oxides absorbing in the UV or visible regions, graphene or graphene in combination with other photocatalytic materials, metal organic frameworks (MOFs), plasmonic nanostructures, etc. **[13-32]**.

Smart and self-cleaning textiles are demonstrated by several researchers by coating TiO_2 photocatalyst on textile fibers and fabrics. In all these approaches, the photocatalytic material is permanently fixed (in the form of thin film/coating or nanoparticles) on the textile fibers and fabrics. Many a times, it is also termed as 'Photocatalytic textile/fabric' **[33-39]**. Research in this area is in infancy and a realistic product development has a long way to go. The photocatalytic material (like TiO_2, ZnO) attached on the textile and fabrics contacts human skin (which is also an organic matter) directly and its adverse effects (if any) on the humans are not yet known/studied. This is an unhealthy situation for the humans. We strongly believe that attaching more and more chemicals (like photocatalysts) on the textile is not a good idea since it comes directly in contact with human skins for very long times and may have adverse effects. Instead, we come up with a simple cloths washing process in which photocatalyst (TiO_2) is used for washing cloths under direct sunlight.

1. Experimental

For demonstration of the process, white color cotton cloth is stained in crystal violet (CV) aqueous solution (0.5 M) containing a chemical linker that links/fix the dye moiety with the cotton fibers/cloth. Both the CV dye and chemical linker was donated by SOMANY EVERGREEN KNITS PVT. LTD., Solapur, Maharashtra, India. Name of the chemical linker was kept secret by the company. Color of the cotton cloth becomes violet after staining – as CV gets anchored on to the fabric. Aqueous dispersion of commercially available TiO_2 (anatase phase) is made by adding 5 gm of TiO_2 to 500 ml water, with stirring. CV stained cotton cloth is added into the aqueous dispersion of TiO_2 and stirred well under direct sunlight for about 15 min. Care is taken that both the sides of the cotton cloth gets exposed to sunlight. It was observed that the violet color of the cotton cloth fades and becomes again colorless. About 90 % of the TiO_2 photocatalyst was recovered back after the washing process; separated simply by filtration using Whatman filter paper – which can be used again.

2. Results and discussion

Figure (1) shows the photograph of the white color cotton cloth used in the process (a); CV stained cotton cloth (b); and photocatalytically washed cotton cloth (c). Figure (2) shows the absorbance spectra of the dyed cloth before and after giving the photocatalytic washing. It is observable that the characteristic broad visible absorption peak centred at 590 nm for CV dye decreases in its optical density from 0.5 to 0.3; just after one photocatalytic wash. Appearance of the absorption peak in the ultraviolet (UV) region indicates that some TiO_2 has remained anchored onto the cloth. The corresponding change in color of the cloth before and after photocatalytic washing is shown in Figure (1).

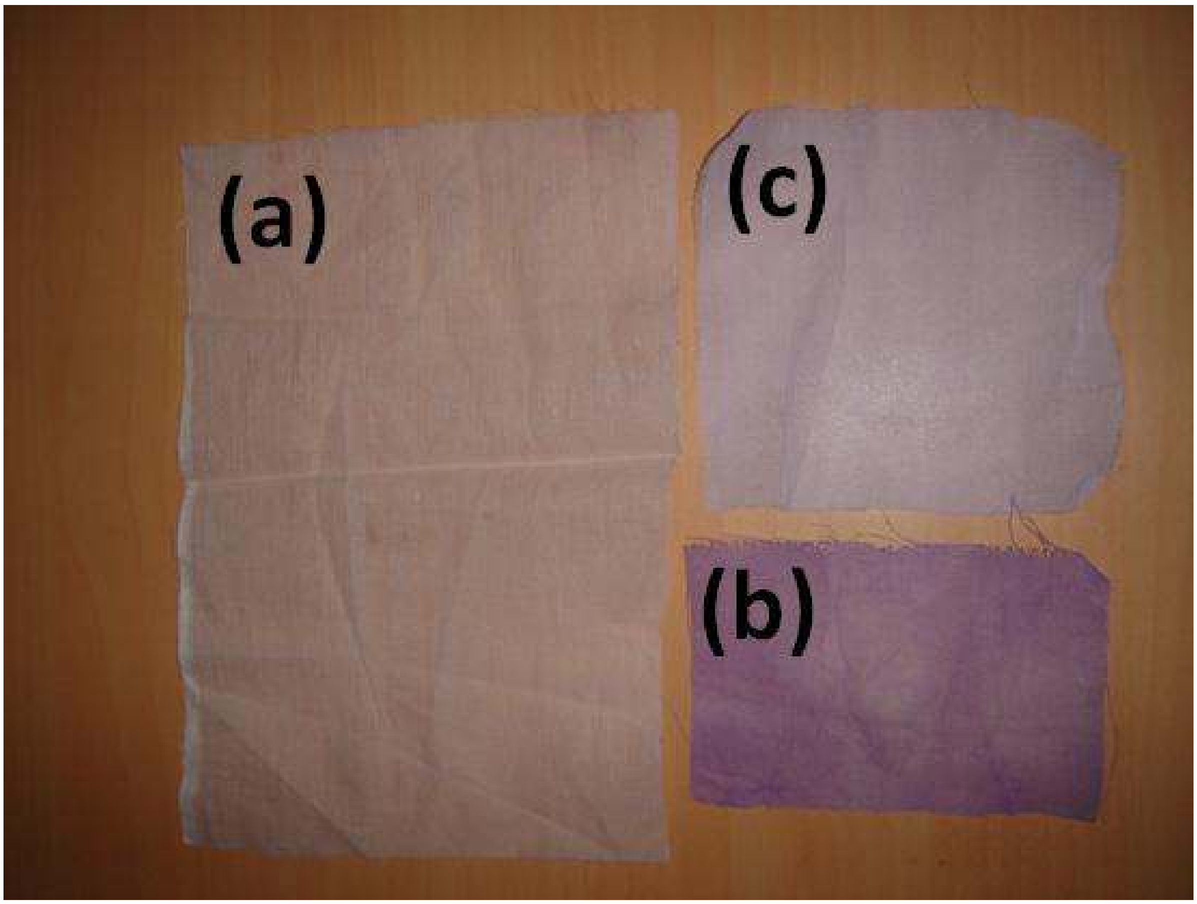

Figure (1). Photograph of the white color cotton cloth used in the process (a); CV stained cotton cloth (b); and photocatalytically washed cotton cloth (c).

Considering the present limitation / drawback of the photocatalysis i.e. non-selectivity; present demonstrated method works well for white cloths. We strongly believe that with more advances in the area of photocatalysis, present demonstrated method should be applicable for colored cloths also – in future.

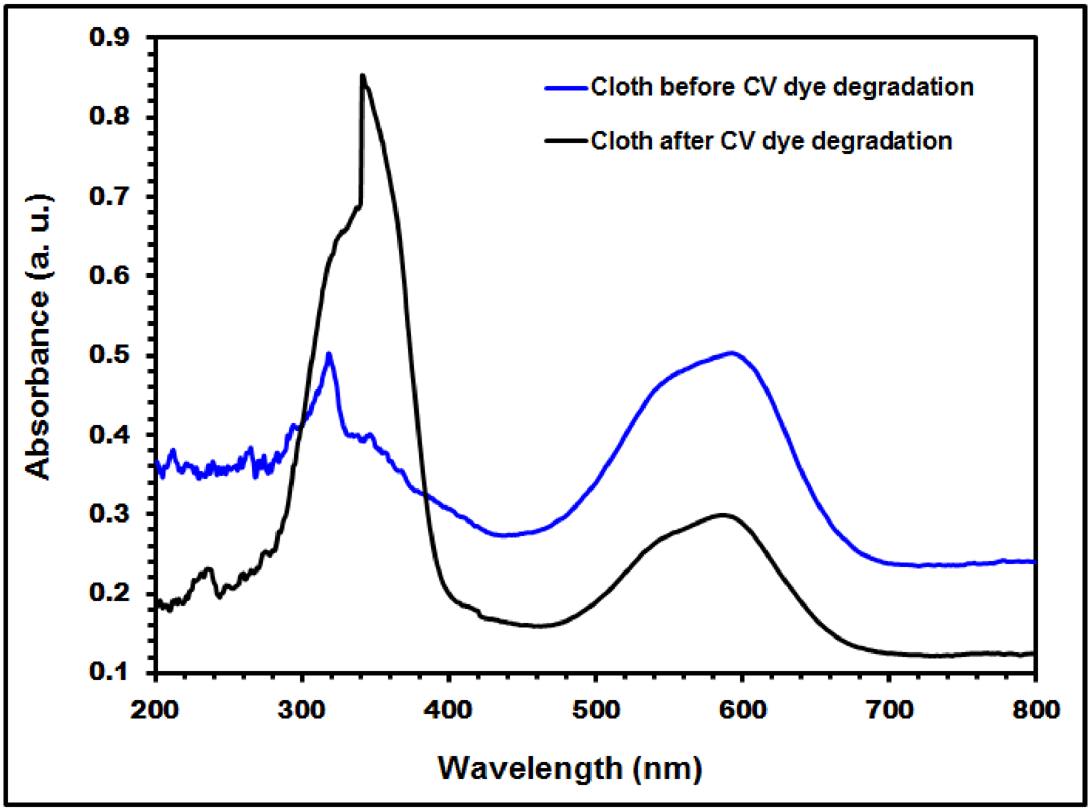

Figure (2): UV-VIS spectra of the cloth before and after photocatalytic washing.

3. Conclusions

In conclusion, photocatalytic washing of cloths using TiO_2 photocatalyst and sunlight is demonstrated. About 90 % of the photocatalyst is recovered after washing process. Photocatalytically washing of cloths can drastically reduce the water pollution caused by use of detergents and soaps (*billions of litres per day*) – Globally; if developed further.

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