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Opinion

Polymer/2D-NMs-Composite Photocatalysts Fast Growing Market for POU Water Filtration Units

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Opinion

The manufacturers of cost-effective water treatment products for potable water with lower maintenance and installation costs have been trying hard to explore state-of-the-art water filtration technologies based on nanostructured materials and advanced membrane systems. Five latest water purification technologies, identified recently, have been projected as emerging alternatives to the existing ones, include photo oxidation as one of them (PR-01). Ongoing studies of 2D-nanomaterials (2D-NMs) have already established their photocatalytic properties. Lamellar 2D-NMs based nanocomposites appear still more promising for designing photocatalysts with enhanced capabilities. Some of these nanocomposites, examined recently, are being designed for their uses in the Point-Of-Use (POU) water filtration units that are independent of the quality of input water. Such POU water filtration units are expected to gain considerable importance once developed fully as the nanocomposites employed therein would be capable of thoroughly removing the bacterial contaminants in water particularly [1-3]. 2D-NMs have been explored extensively as a filler for polymer composites for enhancing the performance even at extremely small loading. In a recent review, a number of relevant aspects of 2D-NM-fillers for polymer composites were discussed including their dispersion in the polymers, surface decoration of 2D materials, and interface bonding between 2D-NM and polymers. The challenges involved in preparing 2D-NMs/polymer composites, and future perspectives for using these novel composites were discussed [4].

Hydrophilic surfaces charged negatively in case of lamellar MXenes (i.e., Ti_3C_2) were found making intimate contact with bacterial membranes inactivated the micro-organisms. Antibacterial activity of its derivatives with Ag, Pd, Au-nanoclusters (Au-NCs) got further improved against the Gram-positive and Gram-negative strains. The bactericidal efficiency of the conjugation was enhanced >96% by damaging the bacterial DNAs resulting in improved anti-bacterial properties [5]. In this context, a comprehensive R&D program was undertaken to study the structural and optical properties of CdO-NPs, ZnO-NPs, Cd-ZnO-NPs, g-C_3N_4 NSs, and g-C_3N_4/Cd-ZnO-NCs with the help of extensive analytical techniques (XRD, SEM, EDX, TEM, FTIR, UV-Vis, ESR, and PL spectroscopies) followed by determining their bactericidal efficacies against Gram-positive and Gram-negative bacterial strains. These experiments enabled the involved research group to prepare some novel formulations with potentials for cost-effective production at mass scale [3]. On-site, cost-effective, and easy to maintain POU water filtration units are foreseen to prevent a number of water borne diseases specially in the rural areas of underdeveloped countries. POU-devices must, however, provide potable water without microbial contaminations independent of input water sources. These units should be

reliable, simple, and recyclable. In this context, the investigations made by Jakubczak, et al. [3], reported a significant breakthrough in synthesizing a nanocomposite filtration material (2D-Ti_3C_2/Al_2O_3/Ag/Cu) with future applications in POU water filters with 99.6% removal of bacterial contaminations. Antibacterial properties combined with the inhibition of biofilm formation in the presence of 2D-MXenes were examined recently after observing that MXene activated membranes eliminated the bacterial cells from the filtered water. Surface decorations with Zn, Ti, Mn, or Nb-NPs were noted to further improve their antimicrobial properties. Filtration materials based on polypropylene fabrics modified with 2D-Ti_3C_2, Al_2O_3, Ag, and Cu-NPs were found possessing self-disinfecting abilities, efficient filtration, and with almost negligible release of nanoparticulate species into the filtrate, as observed during the study of surface oxidation of MXene Ti_3C_2/Al_2O_3/Ag/Cu-NPs modified polypropylene fabric [3].

In another set of experiments, Sher, et al, demonstrated that Cd-doped ZnO nanocomposites involving g-C_3N_4 (Cd-ZnO/g-C_3N_4-NCs) were found effective against Gram-positive and Gram-negative bacterial strains by eliminating them during applications. The in situ growth of well-dispersed Cd-doped ZnO-NPs (Cd-ZnO-NPs) onto g-C_3N_4-NSs was realized through the co-precipitation forming Cd-doped ZnO-nanocomposites with g-C_3N_4 (Cd-ZnO/g-C_3N_4 NCs). Study of composition specific photocatalytic properties of the ternary nanocomposites (Cd-ZnO/g-C_3N_4-NCs) exhibited optimum performance in case of composition with 60% g-C_3N_4 hybridized with 7% Cd-doped ZnO (g-C_3N_4/Cd-ZnO) NCs for visible-light-driven photocatalytic degradation of methylene blue dye mainly due to the increase in the generation of photogenerated charge carriers resulting in creation of reactive oxygen species (ROS), O^{2-}, and $^{\cdot}OH$ radicals. Superoxide and hydroxyl radicals (ESR) were found degrading MB with enhanced stability observed in high degradation rates for 10 successive catalytic cycles [6]. Based on these studies, Qamar, et al, reported another efficient and cost-effective photocatalyst termed as NiZG (Ni/ZnO/g-C_3N_4), using Ni-doped ZnO-NPs with g-C_3N_4 by chemical co-precipitation method. The catalytic efficiencies of NiZG composites were evaluated by determining the UV-vis absorption spectra for methylene blue and testing the bactericidal effects against Gram-positive and Gram-negative microbes. The NiZG-70 composite (i.e., 3% Ni/ZnO and 70% g-C_3N_4) demonstrated superior bactericidal and photocatalytic properties under solar irradiation compared to Ni/ZnO, g-C_3N_4 alone. Reduced electron-hole recombination in the composite enabling the Ni-atoms to function as electron transmitters at the interfaces. The recycling measurement of the NiZG exhibited it as a practical candidate for environmental remediation applications [6].

Market growth of POU water filtration units

Market research forecast of global POU water treatment systems, expected to grow from USD 15.0 billion in 2020 to USD 23.4 billion by 2025, at a CAGR of 9.29% (2020 to 2025), is a fairly clear indicator of this emerging technology. The POU water treatment systems market is expected to witness significant future growth due to its increased demands in residential and non-residential points of use. Various factors like better awareness of using quality potable water, increasing demands at affordable cost, technology development in water treatment industry, combined with increasing income of the consumers in the emerging economies, are likely to support the growth of the POU water treatment systems market during the forecast period (MRR-01). Out of many water treatment technologies developed so far, those deploying low-cost POU treatment systems must deploy mature technology of removing waterborne pathogens using techniques like flocculation and coagulation, filtration, and disinfection [7]. Here, the process of flocculation and coagulation remove not only the water turbidity but also reduce the support for microbial growth in addition to finally removing all of them larger in size than the pore size of the membrane. Disinfection in the form of inactivation and destruction of microorganisms makes it appropriate for regular usage.

Despite having made considerable efforts by the manufacturers World over, there are still challenges to address to as indicated below. The major concern is expensive installation of POU water treatment systems in general. In addition, operating and maintenance costs of the POU water treatment systems is also high. In underdeveloped countries the lack of basic infrastructure for the distribution and storage of potable water could prove to be another challenge in the installation of POU water treatment system. Developing and under-developed countries lacking in financial stability are unable to provide clean drinking water to their whole population. WHO noted diarrhoea as a major disease responsible for 8.5% and 7.7% of all deaths in Asia and Africa, respectively (MRR-01). A major challenge influencing the POU water treatment systems market came from the bottled water manufacturers who succeeded in solving the problem of unpotable water by offering convenient solutions. The increasing demand of counter-top units dominated the market in 2019 due to their convenient usage at low maintenance, and installation costs. Moreover, these units also helped in reducing the contamination like dirt, chlorine, particulates, rust, lead, mercury, sediment, copper, benzene, cadmium, cysts including bacteria (MRR-01). The demand of residential segment accounting for a larger share in 2019 was projected to grow at a higher CAGR from 2020 to 2025 [8,9]. The increasing demand for clean water across the globe and limited freshwater resources makes it crucial to treat water for residential and non-residential applications at affordable costs. Factors like improving global economy, expanding working population, rapid urbanization, growing awareness about water purification technologies, growth in the middle-class population, and rise in income are projected to drive the demand for the POU treatment systems in the Asia Pacific during the forecast period. Europe is projected to follow the Asia Pacific (MRR-01).

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