Hindawi
Journal of Nanomaterials
Volume 2022, Article ID 8464088, 7 pages
https://doi.org/10.1155/2022/8464088

Research Article

Polymeric Droplets on SiO_2 Nanoparticles through Wastewater Treatment of Carbon-Based Contaminants in Photocatalytic Degradation

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Received 3 May 2022; Revised 3 June 2022; Accepted 21 June 2022; Published 1 July 2022

Academic Editor: Balasubramani Ravindran

The current work focus is on utilizing sunlight to catalyze the destruction of carbon-based (organic) pollutants. To increase the morphological area and improve the proficiency of the photocatalytic technique, sodium alginate was used as a polymeric tool and arranged as drop practice. SiO_2 nanoparticles were doped into sodium alginate droplets. The developed SiO_2 nanomaterials were able to spread the wavelength diversity throughout a significant wavelength constituency. In the photocatalytic technique employing the lot photoreactor, MB was used as a sample of carbon-based pollutants. The sunlight catalytic procedure was implemented from UV-Vis or photo light droplets. The analysis of the synthesized droplets was tested using devices X-ray diffraction (XRD), scanning electron microscopy (SEM), and photoluminescence (PL) analysis. Correspondingly, the influences of different concentrations of SiO_2 nanosolution (5 ml, 10 ml, 15 ml, and 20 ml) on the photocatalytic effectiveness of the deposited nanoparticles were studied. The output result revealed that sodium alginate beads doped with SiO_2 at 20 ml were able to reduce (degrade) 98.9% underneath UV-visible light. However, in the case of using other concentrations, SiO_2 at 5, 10, and 15 ml were able to degrade 50%, 56.7%, and 67.9% under sunlight, respectively, after 2 h.

1. Introduction

Nanotechnologies are making their way into all features of our survival; these technologies are being progressively used in pharmacological and medicinal applications, makeups and individual products, energy storing and effectiveness, water treatments and air purification, environmental remediation, chemical as well as biological antennas, military defense and explosives [1], and in numerous consumer products and material. For instance, in the area of food, nanomaterials can be used to provide new tastes and flavors; functional food; hygienic food dispensation and packing; intelligent, frivolous, and strong packing; extended shelf life; and concentrated agrochemicals, colors, flavors, and preservers [2].

Nanotechnology is fundamentally operating a material at the molecular and atomic levels to create a novel structure, practical system with more significant electronic, optical, magnetic, conductive, and mechanical behavior [3, 4].

Nanotechnology is being travelled as hopeful machinery and has confirmed extraordinary undertakings in numerous fields together with wastewater desalination. Nanostructures suggest unmatched occasions to make more operative reagents as well as redox-active means for wastewater decontamination due to their minor size, great surface area, and ease of functionalization [5, 6]. Nanoparticles have been originated to be operative in the removal of numerous contaminants from wastewater such as weighty metals, carbon-based and inorganic diluters, dye as well as biological poisons, and pathogens that cause diseases like cholera and typhoid [7, 8].

Ecological contamination has extreme getting deleterious magnitudes in human life. Degradation of carbon-based contaminants, which have a poisonous influence on the health of manhood, has become an important title of the study [9]. Universally, about 1.2 billion populaces have no access to harmless drinking water, 2.6 billion people fight to fulfill basic hygiene, and millions of persons, predominantly children, have missed their survival from sicknesses interconnected via hazardous and contaminated water [10].

During the coloring and ultimate processes, fabric munches substantial volumes of water [11]. Usually, it used water dealing procedure of industrial wastes including chemical sleet, lime clotting, ion altercation, reverse osmosis, solvent withdrawal, and oxidation procedures [12–14]. Chemical corrosion management can be commonly effective toward the obliteration of chromophoric constructions of colorants. The kinds of oxidation procedures depend on ozone, hydrogen peroxide, and improved oxidation procedures with photocatalysis [15, 16]. Difficulties around using ozone (O_3) comprise its unpredictability and its dangerous nature because of solid and nonselective oxidizing energy. In the current study technique, water pigmentation was detached, but habitually complete mineralization is not accomplished; chlorination and ozonation cause decolonization through chemical retorts [17–19]. The spin-offs of chlorination are chlorinated carbon-based that may be more poisonous than the colorant itself. Varied photocatalysis is painstaking the most significant method in advanced oxidation procedures, which can be effectively used to corrode many carbon-based contaminants existing in aqueous arrangements [20–22].

The important benefit of the photocatalytic procedure is its inherent damaging nature; it does not include quantity transmission, it can take place under a normal state of affairs, and may transform the principal mineralization of carbon-based carbon into carbon dioxide (CO_2) [23–26]. Photocatalytic degradation includes the use of convinced semiconductors as reagents for the preparation of anions. The tenderness of silica dioxide (SiO_2) as a reagent for the photooxidation of carbon-based composites gains conventional attention because SiO_2 is abundant, cheap, influential, and environmentally friendly [27]. Sunlight power of a convinced wavelength is completed to reduction onto a semiconductor. The power of the incident light is comparable to the energy bandgap of the semiconductor; as electrons enthusiastically move from the valence band to the semiconductor's conduction band, holes move to the left [28, 29]. The electrons and holes can undergo successive oxidation and reduction responses to any classes that also impact the adsorbed on the surface of the semiconductor to make a contribution to the essential merchandise [30]. The electrons and holes can encounter successive oxidation and reduction reactions with any class. In brown algae, sodium alginate (SA) is a polysaccharide derived from β-D-mannuronic acid as well as an acid that polymerizes through a 1,4-glycosidic bond formed between the two acids. As a carrier for nanomaterials, it is a nontoxic, logically biodegradable green material that is environmentally friendly. Occurrences of sodium alginate (SA) as a biopolymer rise bond of nanoparticles. A rationale for using sodium alginate as an important carrier substantial for nanoparticles was based on the likelihood of having accurate adsorption of carbon-based molecules; the outcome depends on their electrical custody, as a result of collaboration with the undesirable carboxylate collections on alginate as a carrier substantial for nanoparticles [31].

Numerous researches have been conducted to attain the operation of observable light for TiO_2 material, like transitional metallic ions (ZnO, SiO_2) and nonmetal element doping such as carbon nanotube (C-N-T). Nonmetal element doping conventions bandgap of titanium dioxide by providing a novel mixture energy band whose excite level is slightly higher than that of the valence band of titanium dioxide (TiO_2) [32–35]. But these methods of preparation cannot improve wastewater treatment unless the alteration of property of SiO_2 nanoparticle. The objective of the current study is the deal with the carbon-based contaminant by deposition of sodium alginate droplets doped with SiO_2 and varying the concentration of SA-doped SiO_2 nanoparticles (5, 10, 15, and 20 ml). The enactment of the synthesized polymeric droplets in water treatment of carbon-based contaminant using photocatalysis procedure was assessed.

2. Experimental Detail

2.1. Constituents and Chemicals. Sodium alginate (SA) was used as a polymeric substrate because it was readily available from laboratory supplies, Ethiopia. Methyl blue that serves as a specimen of carbon-based substance was purchased from Addis Ababa, Ethiopia. The supplementary chemicals such as diluters and inorganic salts were of logical reagent rating and lacked supplementary sanitization.

2.2. The Process of Preparing Droplets. It was necessary to liquefy sodium alginate in order to use rousing double-distilled water. In this study, silica nanoparticles (SiO_2) were isolated in water over a 2-hour period and spread out using sonication; the spreading was varied depending on the polymer elucidation. In a conical flask containing cross-linking solution that controlled glutaraldehyde (99.8%) in an 80 : 20 mixture of acetones (99.9%) and water, the combination was decanted as a drop way to custom droplets after stringing and allowing a doped polymer bath with nanomaterials. The obtained droplets were allowed to harden in this solution for 48 hours before being washed so many times with tap water until the pH value reached 7, at which point

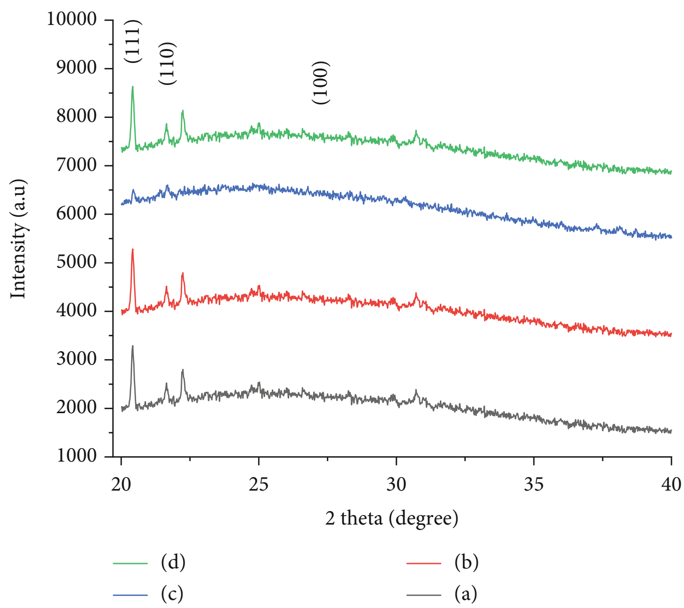

FIGURE 1: XRD pattern of SA-doped SiO_2 nanomaterials at a different concentration as (a) 5 ml, (b) 10 ml, (c) 15 ml, and (d) 20 ml, respectively.

TABLE 1: The crystalline parameters gained from XRD results.

Samples	The volume of SA concentration	2 theta (2θ)	The volume of SA concentration	Theta (2θ)	Crystal size D (nm)
1	5	19.94396	9.97198	3.55557	2.268595
2	10	21.67296	10.83648	0.0883	91.60278
3	15	23.83215	11.916075	16.85256	0.481781
4	20	43.98658	21.99329	5.27112	1.62542

it was pounded and stored in double-distilled water until the next characterization.

2.3. Photocatalytic Experimentations. Consignment photo reactor involves double covers which were through Pyrex. An innermost tube has a radius of 2.50 cm and 35 cm lengthy. An Ultra Violet-C spotlight with a 20 W tiny pressure mercury type lamp was assembled in the middle of the reactor. The outer tube was covered with protective black foils, which collected all of the UV lamp radiations that entered the object constituent of methyl blue liquid. Air was completely eradicated from the mixture by using an air drive, which created a good spreading and an incessant motion of the used droplet all over the laboratory space. The experimental procedure was started after 25 minutes of interaction time in complete darkness, in the midst of the ready methyl blue solution as well as the utilized droplets that have been motioned into the ultraviolet reactor and achieved a noble dispersal. Subsequently, the ultraviolet lamp was opened to start the photocatalytic procedure. The specimen of the verified solution was created by taking a 10 millilitre volume syringe every 1 h.

The concentration alteration of methyl blue (MB) was dogged by the UV-Vis spectrophotometer. The following formula was used to evaluate the degradation rate of MB solution:

$$d = \frac{C0 - C}{C0} \times 100\% = \frac{A0 - A}{A0} \times 100\%, \quad (1)$$

where d is the deprivation rate and $C0$, $A0$, C, and A are indicating meditation and absorbance of the MB solution at the absorption topmost and 464 nm in adsorption steadiness prior to and following ultraviolet treatment, respectively [36].

2.4. Analysis of Polymeric Droplets

2.4.1. Enlargement, Transfiguration, and Gelation (%) Calibration. The enlargement, transfiguration, and gelation (%) for droplets were restrained as a suggestion of impenetrable sodium alginate percentage in aquatic. Dry droplet well-known weights were engrossed in water at 27°C till equilibrium had been get hold. Droplets were detached and strategized by a permeable paper rapidly deliberated. The enlargement (%) was

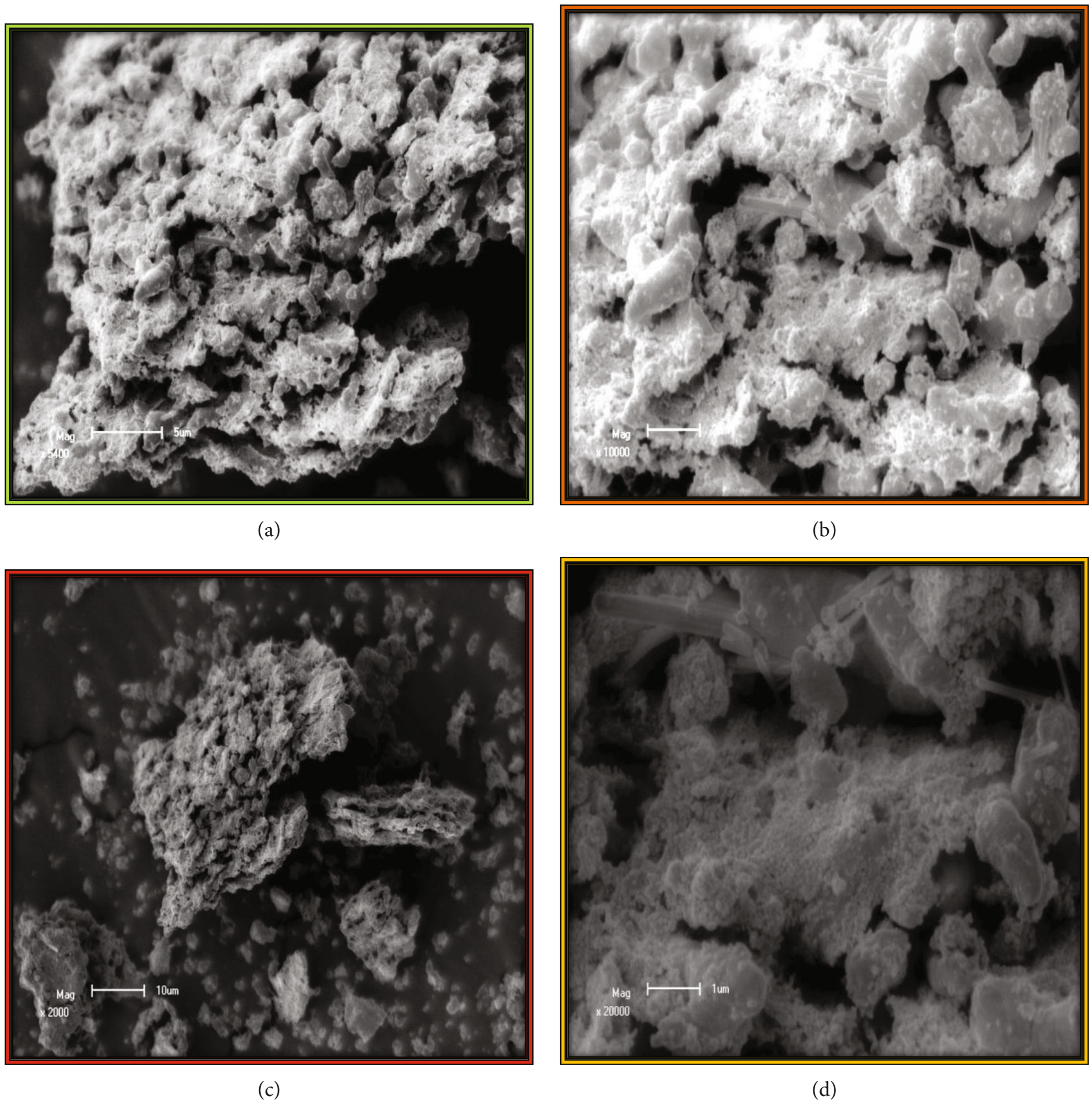

Figure 2: SEM micrograph of SA-doped SiO_2 nanomaterials at a different concentration as (a) 5 ml, (b)10 ml, (c)15 ml, and (d) 20 ml, respectively.

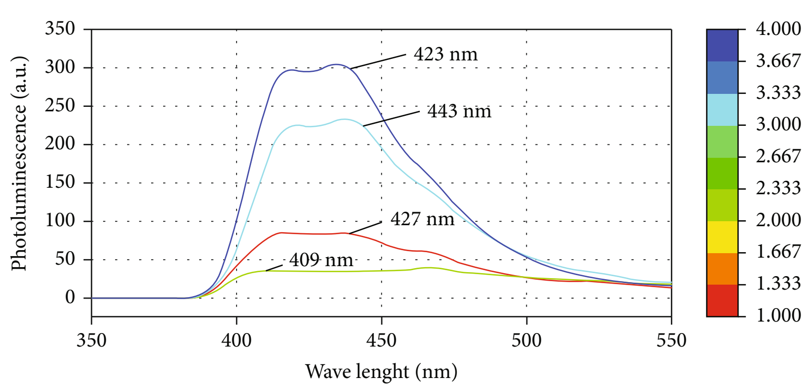

Figure 3: Photoluminescence spectral analysis of SA-doped SiO_2 nanomaterials at a different concentration as (a) 5 ml, (b) 10 ml, (c) 15 ml, and (d) 20 ml, respectively.

Table 2: The influence of SA concentration on parameters is discussed.

Sample	Sodium alginate concentration (ml)	Enlargement (%)	Transfiguration (%)	Gelation (%)
1	5 ml	58.8	93.3	88.7
2	10 ml	67.1	95.1	90.9
3	15 ml	75.6	92.9	91.5
4	20 ml	82.7	96.5	93.9

measured as follows:

$$\text{Enlargement}(\%) = \frac{\left(W_{\text{wet}} - W_{\text{dry}}\right)}{W_{\text{dry}}} \times 100, \tag{2}$$

where W_{dry} and W_{wet} indicate the weights of the dry and wet droplets, correspondingly.

The percentages of transfiguration and gelation of the synthesized droplets were deliberated as follows:

$$\text{Transfiguration}(\%) = \frac{W_{\text{dry}}}{W0} \times 100, \tag{3}$$

$$\text{Gelation}(\%) = \frac{W_{\text{dryhot}}}{W0} \times 100. \tag{4}$$

3. Results and Discussion

3.1. Structural Characterization. The rock crystal configurations of the organized droplets were characterized by X-ray diffractometry (X'Pert PRO, PANalytical) using copper potassium alpha (α) particle emission in the angular district of $2\theta = 19^\circ$ to 43°. The apparatus was activated at 40 kilovolt, and the spectra were noted down at a skimming speed of 8°/minute.

As piloted in Figure 1, XRD pattern reveals that the deposited beads were crystalline with *hkl* indexes crystal plane of (111), (110), and (100), and the shape of the prepared materials was regular spherical. As the concentration of SA increased, the peaks were increased. This result is in agreement with the reported works [37].

By using the Scherer formula, the average crystal size $D = 23.99$ nm is calculated.

The crystalline parameters gained from XRD results are discussed in Table 1.

3.2. Morphological Characterization. The microscopic micrograph of the arranged and the doped sodium alginate droplets with silicate (SiO_2) nanoparticles was conducted using a scanning electron microscopy (SEM) FEI, Quanta 250 FEG type.

All sodium alginate droplet pictures with a scanning electron microscope (SEM) showed a comparatively regular spherical form. The external surface was rather uneven and grooved with many crinkles and wrinkles, which increased contact surface area between carbon-based dyes and the composite droplets and afford more vigorous places, thus refining their adsorption enactments, as shown in Figure 2, and this result was in agreement with previous work of [38–40]. Doping SA with SiO_2 (Figures 2(b) and 2(d)) reveal the dispersion of SiO_2 nanomaterial from low to high concentrations. By increasing SiO_2 concentration, there was an agglomeration of nanomaterial on the superficial. Images of droplets in Figures 2(a) to 2(d) divulge the SA doped with a mixture of SiO_2; there is uneven arrival caused by the existence of nanomaterial, which establishes themselves as combinations throughout the SA environment [41].

3.3. Photoluminescence (PL) Spectral Analysis. Photoluminescence spectroscopy (PL) is a noncontact, nondestructive technique to investigate the optical properties of the prepared materials. Strength and specter at the ease of producing photoluminescence is a straight calibration of significant material behaviors, including bandgap determination, impurity stages, and defect discovery; that is, the photoluminescence spectroscopy at low specimen temperature habitually tells ghostlike peaks related with contaminations involved within the multitude material [42–45]. An extraordinary sensitivity of these methods is possible to classify enormously little meditations of premeditated and unintentional doping which can powerfully upset material quality and instrumental enactment.

To explain the optical behaviors of the prepared SA-doped SiO_2 nanomaterials, photoluminescence is also applied. In the wavelength range from 350 nm to 550 nm at low concentration, shown in Figure 3, the photoluminescence (PL) spectra of the synthesized were testified. The maximum PL hardness is mostly due to self-trapped exciton recombination, prepared from particle size, which what we call defect centres. The PL intensity decreases instantaneously with the ageing time for all higher concentrations [46–48]. In comparison, the photoluminescence intensity for wavelengths of higher wavelength for 60 min and 50 min is smaller than 40 min for wavelength.

Figure 3 shows the optical properties of the prepared material with the application in organic wastewater treatment.

The influence of SA concentration in the preparation of beads is calculated and explained in Table 2. As the concentration of SA increases, the enlargement (%) increases, and gelation (%) increases while transfiguration increases for samples 1 and 2. The decreases at sample 3 then increase at sample 4 [49, 50].

4. Conclusion

A novel SA nanocomposite with high enlargement volume and relatively high adsorption efficiency for methyl blue (MB) dyes was prepared. Methyl blue solution was successfully decolorized by photocatalytic reaction under feeble illumination conditions. In the current work, the concerning issue is the sunlight catalytic degradation procedure to eradicate the carbon-based (organic) contaminants. The prepared SiO_2 nanomaterials were accomplished to spread wavelength variety to the visible wavelength constituency. Methyl blue (MB) was taken as a specimen of carbon-based contaminants in the photocatalytic procedure using the lot photo reactor. The sunlight catalytic procedure was implemented from UV-Vis or photo light droplets. The analysis of synthesized droplets was tested using XRD, scanning electron microscopy (SEM), and photoluminescence (PL) characterization devices. Correspondingly, the influences of different concentrations of SiO_2 nanosolution (5 ml, 10 ml, 15 ml, and 20 ml) on the photocatalytic effectiveness of the deposited nanoparticles were studied. The output result revealed that sodium alginate beads doped with SiO_2 at 20 ml were able to reduce (degrade) 98.9% underneath UV-visible light, although in the case of using other concentrations, SiO_2 at 5, 10, and 15 ml were able to degrade 50%, 56.7%, and 67.9% under sunlight, respectively, after 2 h. Therefore, the nanocomposite is promising for the degradation of carbon-based contaminants.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare no conflict of interest.

Acknowledgments

This study was performed as a part of the employment of the authors (Dambi Dollo University).

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