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Full Length Research Paper

A Review on Ag/Bentonite and ZnO/Bentonite Nanocomposite: Synthesis and their Applications

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Abstract

Currently, nanotechnology is referred to be one of the attractive research sectors in several countries because of its vast potential and commercial impact. Nanotechnology includes the investigation, development, fabrication, and processing of structures and materials on a nanoscale in various fields of science, health care, agriculture, technology, and industries. As such, it has provided a steady restructuring of related technologies. The aim of this review is a critical analysis of the present phase of knowledge concerning the synthesis, application, and limitation of Ag/Bentonite and ZnO/Bentonite nanocomposites. In this review paper, more than 50 articles were reviewed on Ag/Bentonite and ZnO/Bentonite nanocomposites (NCs) along with their applications and using the clay as supporting materials for those metals in the reduction of agglomeration. Besides, a few of the groundbreaking applications of nanomaterials for different areas like in catalytic activity, photocatalytic activity, antibacterial activity, and wastewater treatments have been reviewed. Their synthesis methods and characterization tools are also discussed. From their synthesis methods, green synthesis was more efficient. Moreover, the unique characteristics and applications of those NCs, their challenges for their applications, especially their drawback has been discussed and implications has been drawn. So concerns have to be given about the transport, destiny, and transformation of those nanocomposites discharged into the environment.

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1. Introduction

Nanotechnology is the science that deals with matters at the nanoscale. These days a number of materials are being developed to meet diverse human needs. As one of the foremost promising materials in the world, the nanocomposite is very concerned and studied by researchers everywhere on the planet. In today's competitive market, the implementation of nanotechnology is imperative for food, textile, and biomedical applications due to several potential advantages. Indeed, modern technologies and up-to-date materials such as nanostructures have some key benefits, which is increasing the efficiency, stability and amending the food and biomedical products in the case of quality, safety, and security issues and overcoming future economic conditions (Bagheri et al., 2019; De Dicastillo et al., 2020).

Metal oxide nanoparticles like ZnO are attractive materials due to their low toxicity, thermal stability, and optical and antimicrobial properties (Akkari et al., 2018). These characteristics allow pure zinc oxide or nanocomposites to be used in many different applications such as photo-catalysis, paint additives, polymer products, and an antimicrobial material. However, it has not been widely employed for building surfaces. The use of supporting clay minerals could improve the adsorption capacity and surface area of metal oxides (Georgescu et al., 2018). Bentonite clay is widely used as a support to immobilize oxide nanoparticles and has attractive Physico-chemical and morphological properties such as a large specific surface area, considerable porosity, possible ion exchange, and thermal stability (Rosendo et al., 2020).

The disadvantage of using the nanoparticles alone is due to the potential dangers associated with their size which can affect humans and the environment. Considering that such nanomaterials can be hazardous and fatal, hybrid processes in combining nanoparticles with other environmentally friendly, inert, and stable materials are underway to take advantage of their full properties in various applications. Moreover, introducing nanoparticles with other substrates/fillers would result in composites of novel and enhanced properties that cannot be accomplished by the individual components. Clay minerals are excellent fillers for metal composites. Economic advantages and environmental concerns are among the reasons for the interest in clay minerals, as they are widely distributed around the world and are of low cost. Clays such as montmorillonite, bentonite, palygorskite, and zeolite are being considered low-cost fillers. The wide usefulness of clays is a result of their specific surface area, high chemical and mechanical stability, and variety of surface and structural properties (Motshekga et al., 2013).

Recent investigations on nanoparticles have revealed their potential in wastewater treatment, especially in the area of adsorption. However, there are demerits of the direct use of nanoparticles in wastewater in terms of their aggregation in fluidized systems, difficulty in separation from the treated water, and their fates in the treated water (Lofrano et al., 2016). Hence, the application of nanoparticles due to these disadvantages is very stringent. It is, therefore, imperative that nanoparticles should be encapsulated onto supporting materials such as polymers in order to reduce their release and also increase their reactivity. This approach involves the fabrication of nanocomposites of great characteristics that include high surface area, recyclability, and costeffectiveness. In particular, the high surface area will provide strong interaction between the nanocomposites and pollutants during adsorption. Nanosized-based adsorbents such as metal oxides, graphene, carbon nanotubes, and nanofibers are widely used for improving the treatment of water and wastewater. This is due to these nanomaterials being considered to have higher adsorptive performance than conventional adsorbents. The nanosized metal oxides, for example, zinc oxide (ZnO) (Chouchene et al., 2017) and titanium oxide (TiO2) (Syngouna et al., 2017), have exhibited favorable sorption toward organic and inorganic pollutants.

2. Methods

This review paper has followed a systematic review approach with a content analysis. In the review, books, review papers, and journal articles that have been published in reputable journals were reviewed. A total of 65 sources that have connection with the Ag/Bentonite and ZnO/Bentonite nanocomposite and their synthesis and applications were used in this review paper.

3. Results

3.1 Clays

Clays are considered as widely attractive an appealing substrate for immobilization of a variety of nanoparticles than other fillers. It is inexpensive, non-hazardous, flexible, and has high specific surface area. Clay also has a high chemical stability, excellent binder, and it is eco-friendly supporting materials, high swelling, and adsorption. Besides, it has ion exchange properties and very promising supports for the design and preparation of biocompatible nanocomposite material and widely available. For example, Bentonite (Aguiar et al., 2020; Anandalakshmi, 2021), kaolinite (Chen et al., 2020), and zeolite (Rad & Anbia, 2021) are some of clays used as a stable and solid support in synthesis of metal oxide/clay nanocomposites.

The features of clay minerals strongly depend on their chemical compositions, sizes, and surface layers. These characteristics allow more understanding of the nature of clay minerals. The common properties associated with clay are plasticity, surface area, and iron exchange capacity. Clays become plastic when combined with water and variations in plasticity due to conserved interstitial materials during weathering. Shrinkage determines the plasticity of clay, the greater the shrinkage the more plastic a clay material. When fired, the new form of clay is achieved without any attempt to return to the original physical and chemical properties. In general, the surface area enhances the absorption capacities that result from the negative charge on the structure of clay mineral. Importantly, the sizes and charges of the cations of clay determine its swelling property. Swelling clay has the ability to retain water and expand upon hydration (Carrier et al., 2014).

Structure, Properties, and Application of Bentonite Clay

Bentonite clay is one of the available clays in nature used as traditional habits and remedies in many cultures. Bentonite is absorbent aluminum phyllosilicate clay. It is named after Fort Benton, Wyoming where its largest sources are found. It’s other name, Montmorillonite clay, stems from the region of France called Montmorillonite, where it was first found. It has been used and eaten from ancient time till now as human believes in its therapeutic benefits (Nones et al., 2015). Bentonite is natural clay composed mainly of montmorillonite with other associated minerals such as feldspar, calcite, and quartz (Srasra & Bekri-Abbes, 2020). The bentonite layers are charged due to exchange of Al (III) with for example Mg (II) and/or Fe (II) yielding an excess of negative charges. To obtain electro neutrality bentonite clay holds, most commonly, sodium or calcium ions as counterions (Carlsson & Muurinen, 2008). Due to its layered structure, bentonite has wide application for the design of biomaterials providing; therefore, the stability of bioactive agents and preventing them from aggregation (Srasra & Bekri-Abbes, 2020).

3.2 Nanocomposite

As a general definition composites are solids made from more than one material. The two materials work together to give a composite with unique properties; however, individual material does not dissolve or blend into one another. The properties of the composite are superior to those of either individual material and depend on the chemical composition of its components, microstructure, interfaces/adhesion, and morphology. To achieve the desired properties, a particular reinforcement is chosen for a particular matrix. A nanocomposite may be a material, in which one of the components has at least one dimension in nanoscopic size (Camargo et al., 2009; Numan, 2009). Major factors that determine the properties and performance of composites are properties of the constituent materials, the size, shape, quantity, and distribution of the reinforcement.

3.3 Metal/ Clay and metal oxide/ clay nanocomposite

It has been demonstrated that using nanoparticles alone is dangerous because their sizes can affect human health and the environment. To overcome this problem, hybrid processes were introduced by combining nanoparticles with other environmentally friendly materials such as inert and stable materials to utilize nanoparticles' full properties in wide-range applications. Moreover, introducing nanoparticles with other substrates/fillers would result in composites with novel and enhanced properties that cannot be achieved by the individual components. Clay minerals are excellent fillers for metal composites and has been widely attractive to manufacturers and scientists due to low cost, high specific surface area, high chemical and mechanical stability, and variety of surfaces, high adsorption and structural properties. Their adsorption capacities help to attract contaminants into the open pores; therefore, raise the efficiency of the dispersed nanoparticles (Pouraboulghasem et al., 2016) as support materials for Ag and ZnO NPs.

Ag/bentonite nanocomposite

Silver nanoparticles (AgNPs) are among the most important transition metal particles. They are different from those encountered in massive silver (Sriramulu & Sumathi, 2017). Their most important property is the generation of the band plasmon resonance (Christopher et al., 2011) which opens the door to different applications of this metal in several fields. Therefore, the size, shape, concentration and the environment of these metallic particles all have a significant influence on their properties. In heterogeneous catalysis, silver nanoparticles (AgNPs) were dispersed on different types of supports such as oxide supports, mesoporous supports or macroporous supports (Dutta & Wang, 2019).

Zinc oxide/ bentonite nanocomposite

There are challenges in the large-scale utilization of nanoparticles such as ZnO in water treatment due to difficulty in their separation and recovery after treatment. In addition, the use of metal oxides nanoparticles for water treatment has some disadvantages namely: (1) higher colloidal stability in aqueous solution, (2) agglomeration of the nanomaterials at high concentrations, and (3) difficulty in separating and recovering the nanomaterial after use (Lei et al., 2017). However, steps have been adopted in order to overcome these shortcomings. These include doping and co-doping of metal oxide nanomaterials and immobilization of nanomaterials on suitable matrices (Soltani et al., 2016).This suitable substrate could function as support in order to overcome the difficulties involved in post-separation and recovery. Moreover, the support of nanosized semiconductor materials on matrices could help to enhance their activity when compared with ordinary nanomaterials. In this respect, various clay matrices such as kaolinite, montmorillonite, and bentonite have been successfully employed as support. An immobilizing and anchoring nanosized ZnO nanoparticle on the surface of clay minerals provide more active surface sites, reduces the agglomeration of the nanoparticles, and prevents the release of nanoparticles into the environment. Clay nanocomposites have become major components of clay with metallic nanoparticles used in recent research findings in tackling environmental pollutants. Since, ZnO nanoparticles are cheap, non-toxic, and capable of removing emerging contaminants, and given the fact that rural communities are affected by contaminants from wastewater, cheaper and environmentally friendly methods for the wastewater treatment need to be adopted for water and wastewater treatment.

3.4 Synthesis and Characterization of Ag/Bentonite and ZnO/Bentonite Nanocomposites

Synthesis Methods

Nanocomposite is synthesized through methods, depending upon the end-user property demand. Synthesis of nanomaterials has two major approaches, top-down and bottom-up approach. Composites of metal NPs supported on clay can be fabricated by using various techniques such as ion-exchange processes, solvothermal synthesis, chemical reduction methods, and sol-gel processes. However, the development of a simple and green synthetic method with environmentally friendly reagents still represents a great challenge. As an emerging class of carbon nanomaterials, carbon dots (CDs) have drawn much attention due to their outstanding photostability, low environmental risk, high biocompatibility, and interesting electron transfer behavior. In recent years, significant research efforts have been dedicated to produce noble metal NPs using CDs as the reducing agent, providing new opportunities for the synthesis and applications of metal nanomaterials (Han et al., 2016).

Recently, the use of non-toxic reagents derived from biological sources such as actinomycetes, bacteria, fungi, yeast and plant extracts, has attracted considerable attention for biological or biogenic synthesis of MNPs from the corresponding metal salts as a simple and alternative synthetic route for the chemical and physical synthetic methods because of the economic and environmental concerns The reducing agents involve various water soluble plant metabolites (*e. g.* alkaloids, terpenoids, and phenolic compounds) and co-enzymes. Phenolic compounds possess hydroxyl and ketone groups, which are capable of binding to metals and show chelating effect (Nasrollahzadeh et al., 2019).

Table 1: Summary of important Methods for Synthesis Ag/bentonite and ZnO/bentonite NCs

	Methods	Particle size they obtain	Sources
Synthesis Ag/bentonite NCs	Photo deposition	30.53,6.01 and 4.24 respectively, after 3,48and 96 hr of exposition to UV irradiations	Darroudi et al. (2009)
	Photo deposition	15 and 20 nm under UV irradiation, with a contact time of about 24 h	Xu et al. (2011)
	Microwave-assisted	9-30 nm	Motshekga et al.(2013)
	green synthesis	<32 nm	Sajadi et al.(2018)
	Deposition-Precipitation	< 2 nm	Ameur et al. (2019)
Synthesis ZnO/bentonite NCs	Microwave-assisted	15-70 nm	Motshekga et al.(2013)
	Biosynthesis (aqueous fruit jujube extract)	Eliminate more than 95% of dye molecules and 80% of total organic carbon (TOC) from the aqueous solution after four hours.	Golmohammadi et al. (2022)

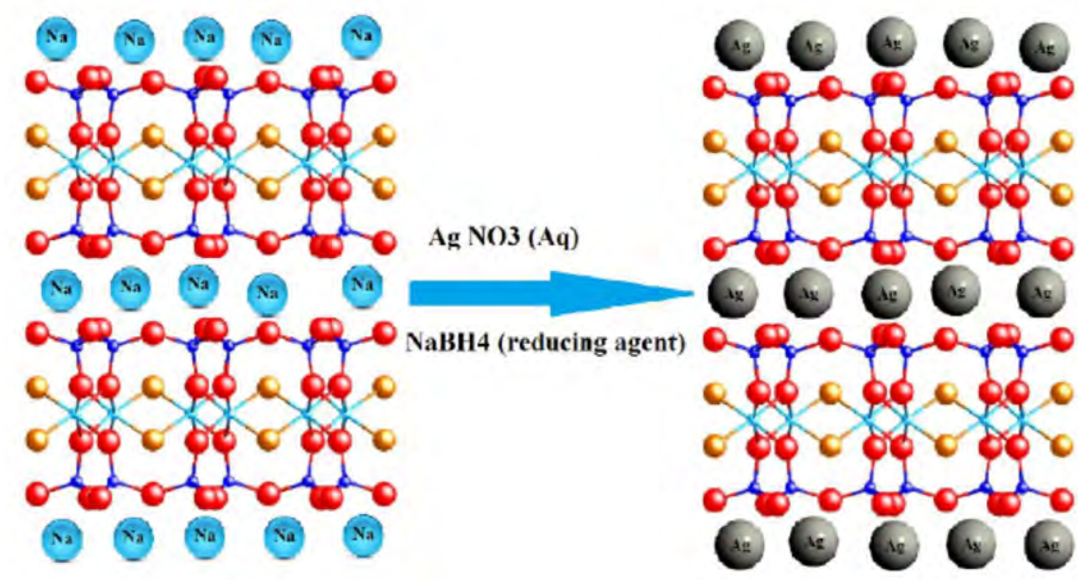

Figure 1: Schematic diagram of synthesis of Ag/bentonite NCs (Saljoghi et al., 2020).

Characterization Techniques of Ag/bentonite and ZnO/bentonite NCs

Nano-metals and their synthesized composites are characterized by using different analytical methods like Atomic Force Microscopy (AFM), X-ray Diffraction (XRD), Cyclic voltammetry (CV), Transmission Electron Microscopy (TEM), X-ray Photoelectron Spectroscopy (XPS), Ultraviolet–Visible Spectroscopy (UV–vis), High-Resolution TEM (HRTEM), Fourier-Transform Infrared Spectroscopy (FTIR), Electrochemical Impedance Spectroscopy for physical, chemical, morphological and electrochemical properties. TEM, HRTEM, and SEM are popular electron microscopy tools for determining morphological characteristics of materials. Table 1 has provided an overview of the different characterization approaches for nanomaterials (Mazari et al., 2021).

Table 2: Summary of important tools for the characterization of the NCs

Properties to be analysis	Characterization techniques	Parameters and information obtained from the characterization techniques	Sources
Analysis of NPs formation	UV-Visible spectroscopy	Confirmation for the NPs synthesis and their stability	Nasrollahzadeh et al., (2019); Thapliyal & Chandra, (2018)
	Atomic Force Microscope (AFM)	Size, morphology, surface roughness and texture	
	TEM	Topology, size, morphology and crystallographic structure	Ameur et al. (2019)

Size and morphology analysis	SEM	Topology, size, morphology, crystallographic structure	Ameur et al. (2019); Shen & Guo, (2006)

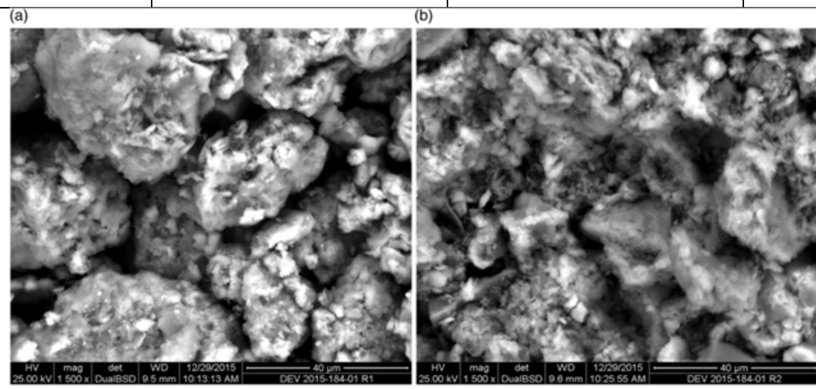

Figure 2: SEM micrographs of (a) raw Bentonite and (b) ZnO/Bentonite (Boutra & Trari, 2016).

The SEM analysis was used to investigate the morphology of the samples; the images (figure 3) show that the bentonite has a porous structure, suitable for ZnO immobilization. ZnO was successfully supported on the Bentonite surface. As observed in (Figure 3a) the structure of the hetero-system (Figure 3b) has evidently changed and the Bentonite matrix is covered by ZnO nano-particles which occupy the pores, thus decreasing the specific surface area.

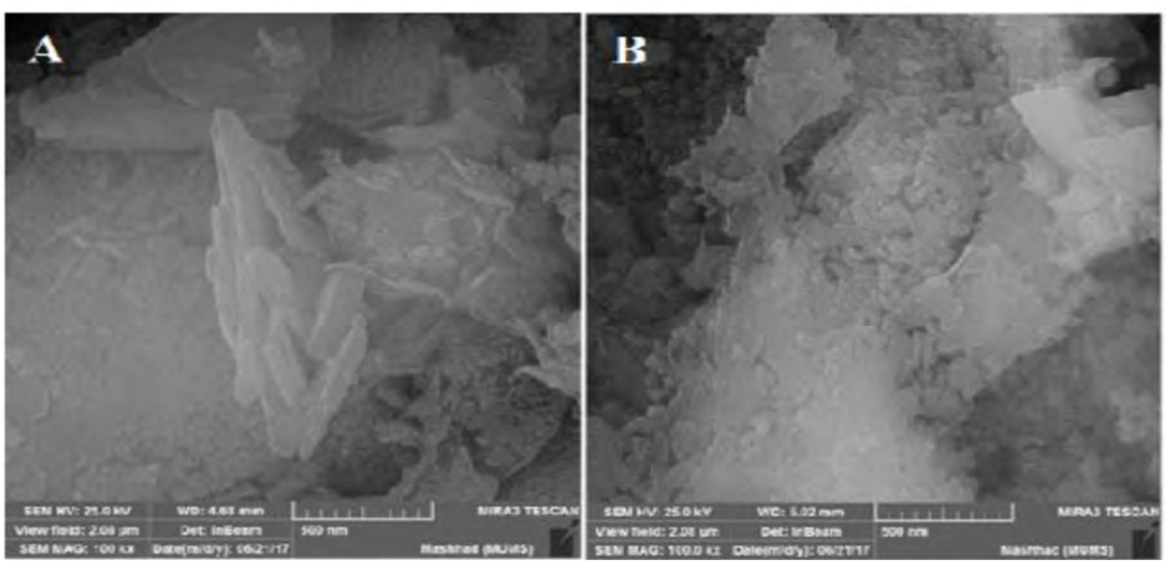

Figure 3: SEM micrographs of bentonite and silver/bentonite nanocomposites (Saljoghi et al., 2020).

SEM images of the raw bentonite and Ag/bentonite NCs are presented in Fig.4. The surface morphology of bentonite demonstrated a layered surface with some large flakes, a typical structure of bentonite (Fig. 4 A). The exterior morphology for Ag/bentonite NCs, showed layered surfaces with large flakes. However, significant morphological differences were observed (Fig. 4 B).

3.4.1 Application of Ag/Bentonite and ZnO/Bentonite nanocomposite

Antibacterial activity

Antibacterial activity is defined as the action by which bacterial growth is inhibited or destroyed. Bacteria are classified into Gram positive (Gram $^{+}$) and Gram negative (Gram $^{-}$) depending on whether they give positive or negative result on Gram's stain test. That is, while those which retain the initial pink color of crystal violet stain, by virtue of their thick peptidoglycan layer in their cell walls are named Gram positive, those that are decolorized are Gram negative. Antibacterial activity can be measured by activity index (AI) which is obtained by dividing the inhibition zone of the sample to that of the positive control, both measured in millimeters. Zone of inhibition or clearance zone is the area where there is no growth of any bacteria observed due to the antibacterial action of the applied test nanocrystals suspended in appropriate solvent such as dimethyl sulfoxide, which doesn't kill bacteria itself. Standard antibiotics such as ampicillin, chloramphenicol are used as positive control against which the inhibition zone of test solutions are compared (Weldegebrieal, 2020). Both natural and synthesized adsorbents have been developed in recent years including clay minerals, nanoparticles, clay-supported metal/oxide nanoparticles, and clay-based nanocomposites for the removal of microbial organisms from water (Annan et al., 2018).

A lot of findings on the antibacterial activity of clay have been documented; robust applications of clay based nanocomposites such as clay/TiO_2, clay/ZnO, and clay/TiO_2/ZnO in microbial water treatment are not yet fully established. However, the information obtained so far signifies that these nanocomposites could emerge as a promising alternative for the removal of bacteria in water. The mechanism of the antibacterial activity of clay-based nanocomposites can be classified into two stages namely: adhesion and killing. The application of nanoparticles and nanocomposites strongly depends on the classes or types of bacteria in water and the physicochemical characteristics of the nanomaterials. Other parameters worthy of consideration are involved in particle size concentration, morphology, pH, and calcination temperature of the nanomaterials. The antibacterial study on ZnO–nanoclay hybrids against Escherichia coli and Staphylococcus aureus was conducted under the influence of contact time and temperature by Garshasbi et al. (2017). It was established that the two aforementioned factors affected the pore sizes of the nanoclay particles and the type of bacteria in the results. The obtained results indicated that the toxic effect on the bacteria was attributable to the photocatalytic activity of ZnO nanoparticles, along with the generation of hydrogen peroxide leading to the degradation of the cell wall of the bacteria.

Catalytic Activity

Sajadi et al. (2018) reported that catalytic activity of Ag/bentonite nanocomposite was investigated in the reduction of 4-nitrophenol (4-NP) and some organic dyes including Congo red (CR), Methylene blue (MB) and Rhodamine B (RhB). According to their catalytic results, the biosynthesized Ag/bentonite nanocomposite can be used as an appropriate catalyst for an efficient, simple and economic strategy to degrade various organic dyes from wastewaters. Their recyclability tests demonstrated catalyst stability and its capability in practical applications.

Photocatalyst Activity

In particular, clay-based catalysts, i.e. metal oxide supported clays, have been frequently used in heterogeneous photocatalytic applications. These catalysts have been employed in the photocatalytic degradation of organic pollutants such as phenol and of some phenolic derivate, organic dyes (Motshekga et al., 2013) and other persistent compounds. For example, A ZnO/Clay composite, i.e. ZnO immobilized on Tunisian clay, was prepared by sol-gel method and characterized in order to gain more insight about its structure, morphology and physico-chemical properties. The ZnO/Clay composite was used in the photocatalytic degradation of Red Congo and Malachite Green in aqueous solutions. The photocatalytic reaction was found to be sensitive to several operational parameters, such as pH of the solution, catalyst dosage, and concentration of the dyes, irradiation source, and the presence of inorganic ions. The results showed that both dyes could be effectively removed from the aqueous media by means a heterogeneous photocatalytic process in the presence of ZnO/Clay, even in the presence of solar irradiation, thus demonstrating the feasibility of using this particular Tunisian clay in the present application (Bel Hadjltaief et al., 2018). The photodegradation of methyl orange (MO) by ZnO/bentonite composites were 84% for the composites prepared by precipitation methods. Photocatalytic activities of the composites were evaluated by the photodegradation of methyl orange (100 ml, 25 ppm) under 4 W UVA-light radiations (Shen & Guo, 2006). Golmohammadi et al. (2022) reported that, ZnO/Bentonite NCs eliminate more than 95% of dye molecules and 80% of total organic carbon (TOC) from the aqueous solution after four hours.

The photocatalytic activity of ZnO/Clay photocatalyst can be directly related to the holes induced through the release of electrons (e−) from valance band to conduction band under UV light illumination Electron in the conduction band may reduce oxygen molecule to yield super oxide radical and holes generated in the conduction band may react with hydroxyl ions to form hydroxyl radicals. These radicals are strong oxidative agent leading to organic molecules conversion into CO_2 and H_2O molecules (Fig. 5).

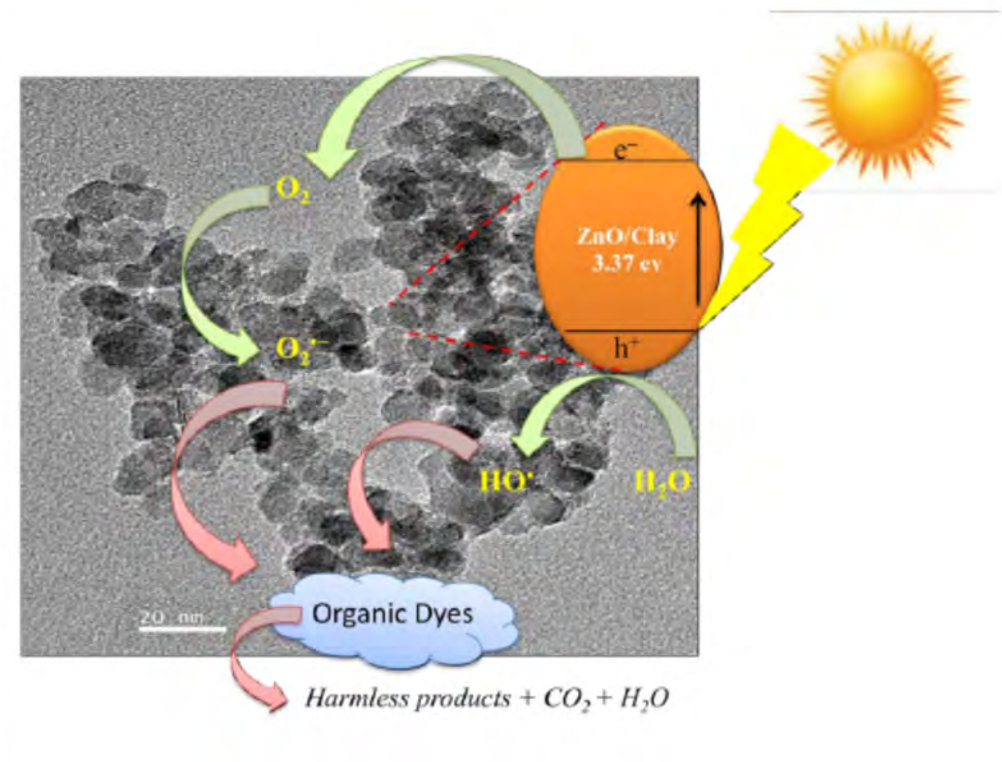

Figure 4. Mechanism of photocatalytic degradation of organic dyes (Hadjltaief et al., 2018).

$ZnO + h\nu \rightarrow h^{+}(VB) + e^{-}(CB)$

$h^{+}(VB) + H_2O \rightarrow HO^{\bullet} + H^{+}$

$e^{-}(CB) + O_2 \rightarrow O^{-2}$

$HO^{\bullet}$ + organic pollutants → intermidiates → $CO_2 \uparrow + H_2O$ +other degradation products.

Waste water treatment

Nanocomposites like clay/TiO_2, clay/ZnO, and clay/ TiO_2/ZnO are multiphase solid materials in nanosized explored as good adsorbents for water treatment. The formation of new materials with unique flexibility and improved properties such as affinity to contaminants, mitigate the release of nanoparticles, and enhanced strong antibacterial activity is a welcome idea. The development of nanomaterials that have been shown to possess most of these properties is attracting the attention of researchers. Thus, researchers have considered their applications to be important in the field of water sanitation (Mustapha et al., 2020). Wastewater management approaches for the supply of safe water are difficult due to the stringent and fast-growing demand for clean water. Thus, understanding water treatment methods which are basically aimed at remediating water pollution problems is necessary. In this vein, wastewater treatment methods with high efficacy that will require less processing time and production of non-toxic by-products in the water are urgently required. Several conventional detoxification techniques have been practiced (Sani et al., 2017; Vahidhabanu et al., 2017).

Among the aforementioned polymeric materials, wide documentations on clay minerals for examples kaolinite, bentonite, montmorillonites (smectite), illites, vermiculites, and chlorites that are mainly made up of silica, alumina, water, and weathered rock which could serve as alternative cheap materials for remediation of wastewater, have been studied (Uddin, 2017). They possess some unique characteristics among other natural adsorbents, used for adsorption of heavy metals and also serve as a remedy for ailments. Therefore, they can be used as excellent adsorbents for environmental bioremediation and bacteria removal from wastewater (Unuabonah et al., 2018). Advanced studies in recent years in nanotechnology have facilitated the application of nanomaterials of high performance in order to tackle problems related to water and wastewater treatment. Nanoscale materials are dimensional substances smaller than 100 nm that exhibit some great physical and chemical features for water treatment (Zhang et al., 2016). These nanoparticles are used as functional materials in forms of metals/oxides, zeolites, and carbonaceous materials (Tripathi, 2017; Wang et al., 2017).

Limitation of Ag/ Bentonite and Zinc Oxide/Bentonite Nanocomposite

Apart from diverse characteristics and applications, nanomaterials come with some serious challenges like application limitations, desired property control, toxicities, environmental concerns, bulk material production, and their waste management recycling (de Marchi et al., 2019). Apart from considerable progress in nanomaterials, data in terms of the possible effects of nanomaterials on human health and the environment is yet insufficient. Since nanomaterials typically are not visible after released into the environment, they may cause different kinds of environmental issues (Mazari et al., 2021).

Nanomaterials have drawbacks in their applications. One of the principal difficulties of the two nanoparticles under consideration, TiO_2 and ZnO, is the large bandgap energy of the photocatalysts which require excitation by UV on applications during photodegradation of the contaminants in wastewater. In most articles, these nanoparticles are not classified as pollutants but their stability in water is paramount in assessing their potential risks. Considering their application in water, another crucial problem is regeneration. These nanoparticles in suspension are difficult to recover and reuse, therefore, effort needs to be devoted in order to overcome these problems. To achieve this, incorporating nanoparticles in clay has attracted much attention (Mustapha et al., 2020). The challenges such as the recovery of the nanocomposites need to be overcome in order to effectively apply this technology. Nanocomposites provide more active surface sites and reduce the agglomeration of the nanoparticles, but leaching has been their shortcomings (Mustapha et al., 2020; Thapliyal & Chandra, 2018).

Leaching

Increasingly, environmental pollution of heavy metals is becoming a problem and has become of significant concern around the world because of its adverse effects. Due to the rapidly expanding agricultural and metal industries, improper waste management, fertilizers, and pesticides, these industrial contaminants are released into soils and water bodies (Briffa et al., 2020). Heavy metals such as cadmium (Cd), copper (Cu), nickel (Ni), and zinc (Zn) are considered to be toxic and hazardous constituents even at low concentration in the environment and their impact through the food chain can be carcinogenic for humans. The effect of ZnO and MgO NPs especially in combination with zeolite on the leaching of heavy metals in Sewage sludge (SS)-amended soil was not studied before. From both agro-environmental, technical, and sustainability evaluation points of view, the assessment of these adsorbents' ability to stabilize heavy metals in SS-amended soil in leaching experiments has high relevance (Feizi & Jalali, 2021). ZnO anchored on clay have been found to be good promising sequesters and have been explored for wastewater remediation via nanotechnology. This water treatment method includes adsorption/absorption, photocatalysis, and microbial disinfection. These nanocomposites provide more active surface sites and reduce the agglomeration of the nanoparticles, but leaching has been their shortcomings (Mustapha et al., 2020).

Toxicity

Toxicity of some nano-sized chemicals in comparison to the respective bulk materials arises from the fact that nanoparticles have a very high surface-to-volume (S/V) ratio which makes them highly reactive .This relates to other chemicals as well as to the physiological environment of different tissues in the human body (Singh et al., 2019).

Toxicity of the nanomaterials is one of the major challenges for chemists, engineers, and scientists involved in nanomaterial development. The toxicities of the nanomaterials include cytotoxicity, dermal toxicity, pulmonary toxicity, genotoxicity, carcinogenic toxicity, liver toxicity, cardiovascular toxicity, hemolytic toxicity, and immune toxicity (Z. Chen et al., 2020). The potential mechanisms of the toxicities of the nanomaterials are apoptosis, reactive oxygen species, free radical formation, formation of granuloma, increased inflammatory response (Huang et al., 2018). Toxicity varies with the type of the nanomaterial, their physiochemical characteristics like morphology, electrical properties, magnetic properties, optical properties, surface properties, charge, size and size distribution, surface chemistry, oxidation, composition and crystalline structure, aggregation, and concentration, dispersion state, synthesis methods, etc. (Gao & Lowry, 2018). The toxicities of the nanomaterials increase with an increase in their concentration. The proteins, biomolecules, and micronutrients might get altered by the presence of different functional groups (Li et al., 2017). The synthesis methods are also reported to affect the toxicities of the nanomaterials, due to impurity residues and improper finishing. The nanomaterials can be dangerous for human beings and badly affect their cardiovascular and central nervous system, malfunctions in different organ systems, cause neurotoxicity, or immunotoxicity. To assess the toxicity of nanomaterials, the comparison of their noxious effects with nanoparticles and different bulk types can be examined. Many research studies have been conducted and examined in other reviews (Mazari et al., 2021).

4. Conclusion and Future Research Directions

Generally, Ag/Bentonite and ZnO/Bentonite NCs can be synthesised through different chemicals and green methods. As mentioned in this literature review synthesis of those materials in green way was very good in different application. Hence, those methods reduce the toxicity of those materials. Applications of those NCs include catalytic activity, photocatalytic activity, antibacterial activity, and waste water treatments etc. There are enormous, exciting potential and feasible applications of those NCs, several concerns and challenges stay unsolved up to date. Nanocomposites have already exhibited environmental and health risks; hence their proper waste management and recycling can mitigate their toxicities.

After the end-of-life a nanocomposites product may end up in a recycling system, incinerated or landfilled. These particles can flow through the air, water, and soil. Nanomaterials have the potential to become emerging pollutants if not managed, treated, or recycled properly. So the use of those nanocomposites in different fields requires several concerns such as un-known ecological effects, fouling properties, regeneration, inadequate detection limits, environmental soundness and deposition.

Conflict of Interests

The authors declare that there's no conflict of interest concerning to the publication of this article

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