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On the History of Nano-Composite Technology for Pollution Removal

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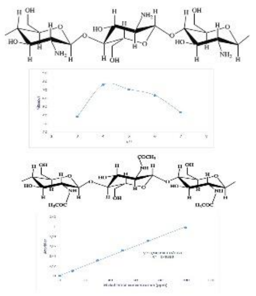
GRAPHICAL ABSTRACT



ABSTRACT

Nowadays, scientists in physics, materials, etc. have come to the conclusion that if materials can be prepared in smaller proportions, the bonds that a small material makes with its surrounding phases are much stronger than those of larger scales. Nanocomposites were therefore produced. In this type of composite material, at least one of the phases of the composite material is in nanometer dimensions. In the discussion of nanomaterials, nanocomposites have a special place. These materials have two or more nanometer components. The presence of particles and fibers in the structure usually creates strength in the substrate. In fact, when particles or fibers are distributed within a substrate, the forces applied to the composite are uniformly transmitted to the particles or fibers. Particles or fibers that are distributed within a substrate are called fillers. Properties such as strength, hardness, physiological properties, and porosity change with the distribution of fillers within the substrate. The substrate can hold the particles apart in such a way that crack growth is delayed. In other words, with proper distribution of fillers in the background material, the crack growth path in the background becomes longer and therefore crack growth is delayed. In addition, the components of nanocomposites have better properties due to the surface interaction between the substrate and the filler. The type and amount of these interactions play an important role in the various properties of nanocomposites such as solubility, optical properties, electrical and mechanical properties.

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Introduction

With the development of human civilization, the development of technology and the growing population, the world is now facing a problem called air, soil and water pollution. Water, as a compound that covers three quarters of the entire surface of the earth, is one of the essential factors for the survival of all living things, including humans, animals and plants [1-5]. The growing demand for water and the severe limitation of this vital element in many countries is one of the obstacles to sustainable development [6-9].

History of Nano-composite Technology

At the end of the twentieth century, a new field called "nanocomposites" entered the field of composite science and technology. Due to changes in the chemical composition and structure of materials at the nanometer scale and the special and unique properties of these compounds to composite materials at conventional scales, significant progress has been made in the last ten years [10-15]. It was used only as a conventional additive. In fact, clay improved its properties to some extent without chemical changes. In 1967, the Japanese company Unichica succeeded in producing the first montmorillonite-reinforced polyamide composite, and the properties obtained in this product were much better than the previous results, showing the improvement of the structure reinforcement at the nanoscale [16-19]. A decade later a research team at Toyota came up with better ways to make polyamide nanocomposites.

The first product of this company was used as a timing belt cover and in the packaging industry, and among these, more engineering properties and permeability have been considered. The team also performed experiments on epoxy, polystyrene, polyacrylic and polyamide resins. Polymer nanocomposites were originally developed by researchers at the Toyota Research and Development Center to replace some heat-resistant car parts [20-23].

In 1980, with the commercial production of nylon-based nanocomposites and clay by the center, research into the synthesis of these materials entered a new era, and since then Ubi, Unita Kita, Honeywell, and nanocomposite-based nanocomposites [Nylon 6] were introduced. A number of other companies also studied nanocomposites for commercial applications, and in late 2001 General Motors Basel introduced the first application of polyolefin-based thermoplastic nano-composites in extruded components [24-28].

Types of nanocomposites based on their base material

- Polymer-based nanocomposites
- Ceramic based nanocomposites
- Metal based nanocomposites
- Metal-based nanocomposites

Application of Hydrogels

Most hydrogels respond to environmental stimuli such as pH, ionic strength, solvent ratio, light, and electric field. These unique properties have created a wide range of applications in the use of a hydrogel effectively. These applications include tissue engineering, artificial muscles, wound dressings, biosensor enzymes, contact lenses, drug release, separation devices, artificial snow production, sensors, preparation of metal particles, reduction and removal of heavy metals in industrial effluents, health and beauty products, coal dewatering, agriculture (control of the release of fertilizers or pesticides), filters, catalysts and transparent optical materials. Depending on their application, hydrogels can be prepared in various forms such as cubes, hollow tubes, rods, sheets and films [29-34].

Advantages of hydrogel adsorbents

High adsorption capacity, compared with other adsorbents, has adsorption rate in a short time, wide pH range, and the ability to reduce hydrogel adsorbents [35-39].

Classification of hydrogels

Hydrogels are classified into two main groups: Natural and synthetic. Natural polymers such as polysaccharides such as chitosan, alginate, starch, cellulose and its derivatives or pyronins such as gelatin and collagen are used in natural base types [40-42]. One of the most important advantages of natural base hydrogels over synthetic base is their biodegradability [43]. Absorbent hydrogels, especially natural base types, despite their high ability to absorb water and aqueous fluids, are weak in terms of physical properties such as mechanical and thermal strength [44].

Polysaccharides

Polysaccharides are one of the most common ingredients in the preparation of natural base hydrogels. Polysaccharides are often found in plants, crustaceans, fungi, and algae. Due to the biodegradability of polysaccharides and their compatibility with the environment and living organisms, these materials are of great interest to scientists and several studies are conducted in this field. In short, abundance, renewability, cheapness, non-toxicity, ability and ease of chemical and biochemical modification are among the reasons that have led to widespread production and consumption of polysaccharides [45-48].

Polysaccharide based hydrogel

Chitin: Chitin (citin) is a white, hard, inflexible substance with the chemical formula n ($C_8H_{13}O_5N$) and with a scientific name. Chitin is the most abundant natural biopolymer after cellulose. Chitin is a natural polysaccharide and is found prominently in crustaceans such as crabs and shrimp, insect cuticles, and fungal cell walls. Chitin and chitosan are widely used in medicine and industry as a natural amino polysaccharide with unique structure and versatile properties. Their salient features include high biocompatibility, acceptable biodegradability along with low toxicity, as well as their antibacterial and anti-allergic properties [49].

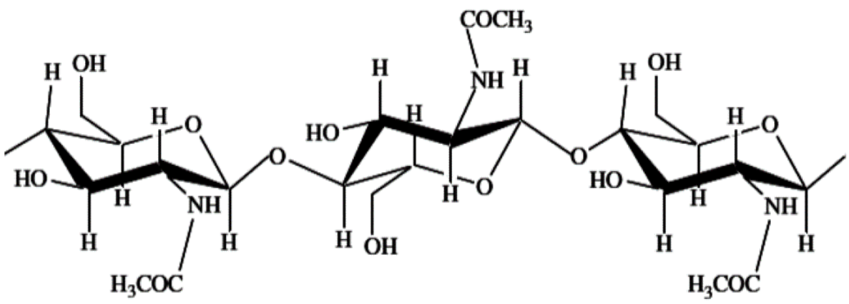

Figure (1). The molecular structure of chitin [50]

Chitosan: Chitosan is one of the remarkable and high-performance natural polymers that has been used as a natural adsorbent due to the presence of amino groups in its structure. Chitosan is a derivative of chitin with the chemical formula $(C_6H_{11}O_4N)$ n. The number of steel groups on the polymer chain determines the difference between the two polymers. A polymer in which 100% of its amine groups are acetylated is called chitin and a polymer without amide groups (100% of amine groups) is called chitosan. Conventionally, the presence of 50% of amide groups is considered as the boundary between chitin and chitosan [15].

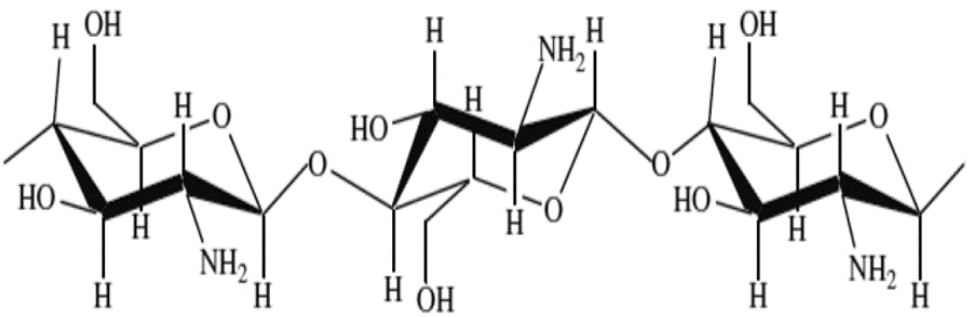

Figure (2). Molecular structure of chitosan [51]

Xanthan: Xanthan gum is the first new generation of extracellular polysaccharide in biotechnology that is produced by several microorganisms such as the bacterium Xanthomonas compressis. It is an extracellular polysaccharide gum produced by a variety of Xanthomonas. The main constituents of this gum are glucose, mannose and galacturonic acid. Despite its high molecular weight, xanthan gum dissolves easily in hot and cold water and produces very concentrated solutions even in small amounts. But its viscosity decreases due to disturbance. PH changes have little effect on it. This gum is used in a variety of beverages, canned foods and frozen foods. Considering molecular structure of xanthan gum, it is a hetero-poly-saccharide that has repeating Penta saccharide units. This Penta saccharide contains 2 units of mannose, 2 units of glucose and 1 unit of glucuronic acid. The side chains make up about 12% of the weight of the xanthan molecule. They are responsible for many of the unique properties of xanthan and protect it against enzymatic and chemical attacks [52-55].

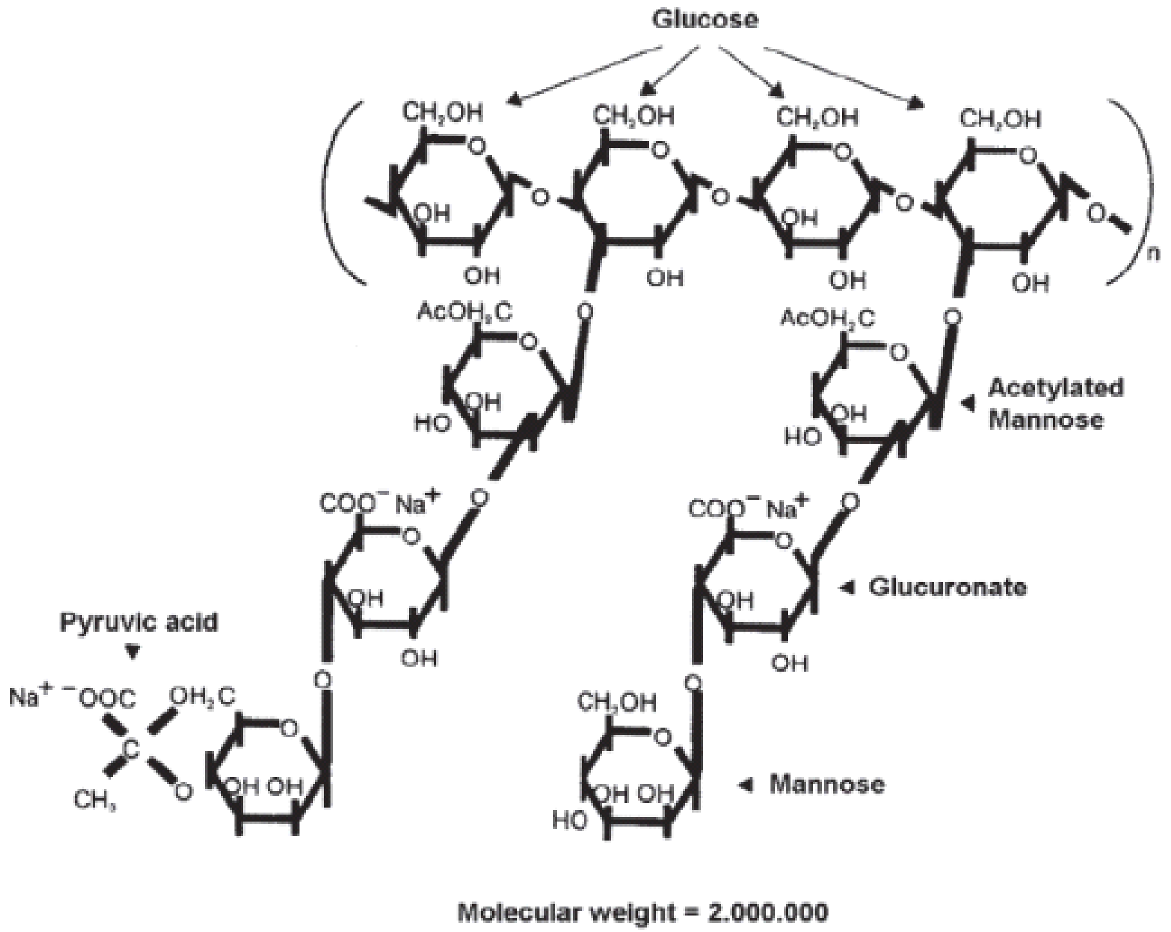

Figure (3). The initial structure of xanthan gum

Magnetite (iron ferrite) and its characteristics: Magnetite with the formula Fe_3O_4 is one of the metal oxides that sometimes has the ability to absorb heavy metal ions. But when modified by other compounds, it becomes an excellent adsorbent for the adsorption of metal ions and most dyes. Fe_3O_4 particles have received great attention due to their special properties such as magnetic orientation, paramagnetic properties and the ability to bond with functional groups at their surface [56], resulting in their wide application in the field of paramagnetic materials [57]. In particular, Fe_3O_4 nanoparticles have been considered as suitable candidates for biological applications such as drug delivery to cancer sites for treatment and other activities for medical diagnosis [58]. So far, they have succeeded in preparing Fe_3O_4 nanoparticles by several methods, such as precipitation, micro-emulsions, chemo-thermal reaction and aqueous thermal method, etc. [59]. Nano-materials engineering in the form of nanometallic oxides was designed to eliminate heavy metals from aqueous solutions. The properties of these particles go back to their high level, removal capacity and selectivity. Other cases are excellent [60-62]. The use of magnetic iron oxide nanoparticles is an example of the widespread use of metal oxides. Magnetite has been the focus of chemical and environmental engineers as an adsorbent for the removal of heavy metals in order to solve problems, giving importance to these particles [63]. Due to their simple separation from secondary metals using an external field, magnetic nanoparticles are limited to the presence of hydroxyl groups on the surface [64]. In addition, the high capacity and selectivity of these particles in the interaction and reaction can be severely reduced or lost. In order to overcome this limitation, other methods have been proposed to change the surface by loading (depositing) chemical species or biological materials in different matrices.

Table (1). Adsorption values for different initial concentrations of hydrated nickel nitrate

Nickel Initial conc (ppm)	0	10	30	50	70	100
Absorption	0/00	0/098	0/315	0/515	0/715	0/985

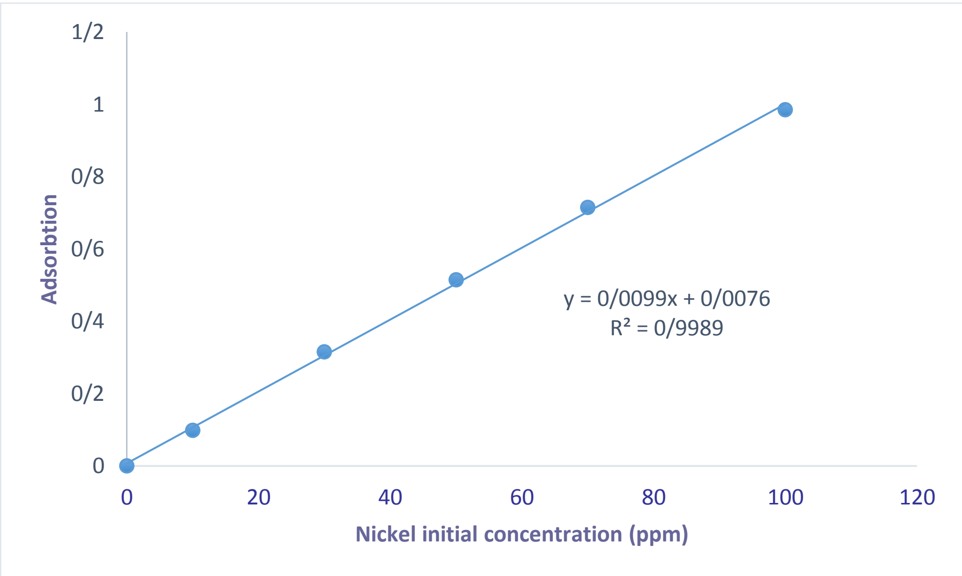

Figure (4). Adsorption calibration curve in terms of different initial concentrations of nickel nitrate

Table (2). Results of calculations related to the adsorption of nickel (II) ions at different pHs

pH	Adsorption of equilibrium solution	Equilibrium solution concentration (ppm)	Delete percentage
3	0/312	30/74	38/5
4	0/125	11/85	76/3
5	0152	14/58	70/8
6	0/187	18/12	63/7
7	0/286	28/12	43/7

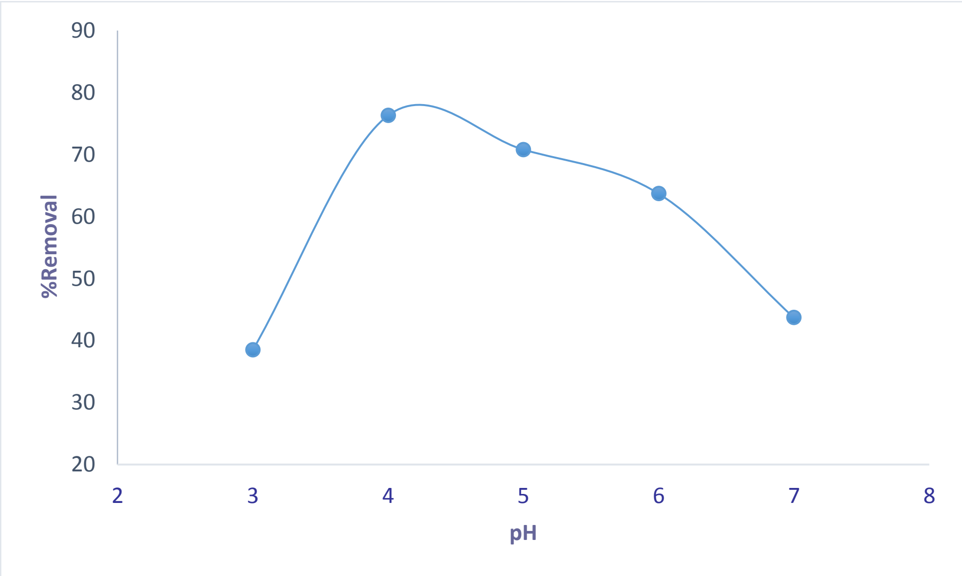

Figure (5). The effect of pH on the adsorption rate of nickel ion (II) by the adsorbent of xanthan biocompatible nano-composite xanthan

According to the pH chart, the optimum for the experiments is 4. As the pH decreases, the removal percentage decreases, which can be due to the competition of ambient H^+ with Ni^{+2}, because by adding acid chloride, the number of H^+ in the environment increases, where H^+ neutralizes the negative charge of the adsorbent and reduces the tendency of Ni^{+2} to settle on the adsorbent decreases and the adsorption decreases. By adding sodium to the nickel solution, the nickel reacts with OH to form an insoluble Ni $(OH)_3$ precipitate, causing a measurement error. Therefore, the pH was not measured in the play medium.

Conclusion

Adsorption is a convenient and inexpensive way to eliminate toxic hazardous substances into the environment. Among the many adsorbents used in this regard, we can mention an inexpensive bio sorbent with high adsorption capacity and environmentally friendly, the aforementioned adsorbent nano-composite of Xanthan magnetic biocompatible, on which little research has been done. It is suggested that more research be done on such adsorbents in the future to develop environmentally friendly technologies.

1) Kinetic studies show that the adsorption of nickel (II) on the adsorbent of xanthan magnetic biocompatible nano-composite follows quasi-second order kinetics.
2) Increasing the temperature reduces the adsorption process, so the adsorption process can be considered as an exothermic process.
3) The negative free energy of the Gibbs standard indicates that the absorption process is spontaneous.

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