Environmental Applications of Chitin

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Chitin's environmentally friendly nature has been well documented, further allowing scientists to develop novel techniques utilizing chitin in the environmental sector. Chitin has a very high surface area due to the size of the biopolymer, which is applicable as a pollutant absorber and is used for other modifications that can be made into nanocomposites, best suited for environmental applications for soil and water pollutants.

Keywords: Environmental Applications ; Chitin ; Marine sources ; GHG reduction ; Dye removal

1. Dye Removal

Water pollution is a major environmental concern that intersects with human health [1][2]. More specifically, surface and groundwater are at the most risk from pollution due to organic dyes which can catastrophically affect living organisms, causing illness, diseases, and in rare cases death [1][2]. Many colouring agents in pharmaceuticals, pesticides, and rubbers are known to contain a dye called Methylene blue [1][2]. When consumed at very low doses, Methylene blue is known to cause hemolytic anemia and skin peeling found in infants [1][2][3]. While chemical modifications, such as catalyst oxidation, membrane separation, coagulation/flocculation, and adsorption, have all been used to remedy these effects, there are several disadvantages and risks associated with these modifications [1][2]. In terms of disadvantages, most of the techniques listed above either produce secondary pollutants or have a high cost for producing the raw material to effectively remove the dye [1][2]. With such circumstances, researchers have now looked at organic possibilities that could remedy water pollution with compounds like chitin.

While there have been studies demonstrating the benefits of chitin, further research surrounding chitin as an alternative solution to issues regarding water systems must still be done. Previous studies have shown that the element itself must be modified to be used in certain situations to unlock the true potential of the biopolymer [4][5]. A recent study found that altering the structure of chitin into chitin nano-whiskers can be a promising solution for water treatment due to the functional groups associated with the nanomaterial and the high surface-to-volume ratio [4][5]. Several studies have been conducted with the purpose of wanting to understand the adsorption abilities of chitin nano-whiskers for organic dyes like crystal violet and carmine in different aqueous solutions [4][5].

Chitin's ability to adsorb dyes has been well documented due to the biopolymer's innate structure, but the next step is determining whether or not combining the biopolymer with another compound can strengthen the rate at which dyes are removed from a solution. Another recent study wanted to determine the relationship chitin has with carbon allotropes [6][7]. It has long been established that carbon, specifically charcoal, can be used for water purification mainly due to its high degree of porosity and its unique surface structure [6][7]. Moreover, carbon allotropes like graphene have drawn interest from the scientific community as a new nanostructure material that can be applied to solve water pollution [6][7]. However, the structure of graphene must be modified due to its poor solubility and lack of polar groups that could limit adsorptions [6][7]. Therefore, a novel method has arisen that would increase the hydrophilicity and reactivity through oxidative exfoliation to form graphene oxide [6][7]. Thus, when forming a composite of chitin and graphene oxide, it would theoretically increase and improve the rate of absorption that is limited when using either compound alone [6][7]. Studies wanting to understand this relationship have sought to test this hybrid on three common dyes, namely remazol black, neutral red, and methylene blue [6][7]. After experimentation, it was found that the control, chitin, and the hybrid were able to adsorb the dyes, but treatments were determined to be pH- and proportion-dependent [6]. The study concluded that chitin and graphene oxide hybrids are a promising direction with amazing functional properties, such as dimensional stability, universally adsorbent for cationic pollutants, high adsorption capacity, and ease of regeneration [6][7]. When considering the practicality of other chemical alternatives, key limiting factors, such as the pH of the dye and ratio of the hybrid compounds, must be considered as well for the successful treatment of water pollutants [6].

2. Remediation of Inorganic Contaminants

Many environmental agencies have now determined a new substantial ecological and global health risk that plagues our water filtrations systems in the form of heavy metals [8]. The determining factors that classify elements as heavy metals are the following: naturally occurring elements that are unique for their high atomic weight/density and at low concentrations are hazardous or toxic if consumed [8][9]. These metals must be removed from aquatic environments as they are refractory, cannot break down, and attach to and accumulate in organisms [8][9]. Heavy metals such as chromium are commonly found in leather tanning, pigment production, and stainless-steel manufacturing [8]. Heavy metals found in water systems can result in toxic effects that can be additive/synergistic or antagonistic to all those that drink and use the contaminated water [8][9]. The eco-friendly nature of chitin being another alternative source of coagulants and flocculants can be used to remove metal ions from contaminated water systems [8][9]. The ability of chitin, specifically chitosan, to catatonically change the medium to support ion-exchange interaction and electrostatic attraction can be manipulated to allow for the dissolution and absorption of the heavy metal from a solution [8][9].

As it has been long established that metals are non-biodegradable, the removal of potentially harmful metals from waste requires different techniques, such as precipitation, ion exchange, cementation, electrodepositing, and membrane separation [10][11]. These techniques are legally mandated and follow heavy scrutiny for proper waste management. However, the high cost may result in researchers finding other novel techniques that are more cost-effective [10][11]. As mentioned before, chitin itself is limited in its adsorbent capabilities due to its relatively low mechanical and chemical resistance to other biopolymers, affecting real scale adsorbent rates [10][11]. Due to this common flaw found in the molecular structure of chitin, it was determined that forming a bio-composite with chitin and other synthetic compounds would drastically increase adsorption capabilities [10][11]. The reasoning behind this idea came from studies proving that different combinations of the composite material would have increased strength even at high temperatures with higher corrosion and oxidation resistance [10][11]. Of those different combinations with chitin, bentonite has much better resistance to an acidic environment and adsorption capacity [10][11]. The chitin–bentonite bio-composite has high potential as an alternative to traditional adsorption methods, but pH is a factor that must be considered [10][11].

3. Remediation of Organic Contaminants

Another growing concern regarding water filtration systems is the removal of organic contaminants. Organic contaminants represent another subsection of water pollutants that are not only harmful to humans, but also to neighboring ecosystems, where the compounds leach out [12]. The substances that fall under the classification of organic contaminants include pesticides, pharmaceuticals drugs, illicit drugs, endocrine disrupting compounds, steroids, hormones, fire/flame retardants, volatile organic compounds, and aromatic hydrocarbons [12][13]. Pesticides are used on crops by farmers to remove weeds and unwanted pests but can be highly toxic when exposed indirectly or directly to the human body as they can bioaccumulate through the food chain [12][13]. Pharmaceutical drugs, a staple of modern medicine, are key to warding off infections and diseases, but if improperly handled and disposed of, may become disease carriers and can have various adverse effects on aquatic systems [12][13]. The toxic by-products of many synthetic chemicals in liquid form can transition into a state of various volatile gases and when exposed to the environment can have harmful effects to those exposed [12].

With all the negative effects associated with organic contaminants leeching into our water systems, scientists are now looking for more environmentally friendly bio-sorbents that will remedy pollutants as much as or better than conventional practices. Pharmaceuticals are very different from normal water contaminants, as they are made to be biologically active at low concentrations well before reaching the targeted area [14]. By design, this allows for bioaccumulation with relative ease, causing harmful effects on aquatic ecosystems [14]. This is why researchers are using the adsorption methods recorded in many studies as another way to remove waste from water [14]. A recent study tracking the adsorption abilities of chitin and lignin tested hazardous non-steroidal anti-inflammatory drugs to determine if binding both biopolymers was a better choice than conventional methods [14]. The limitation of chitin at the molecular level has been well studied, but lignin can further strengthen the structure, making it more adaptable for functional groups and a much better adsorber for hydrophobic impurities [14]. Chitin/lignin bio-sorbents follow pseudo-second-order, which means the model was relatively linear [14]. It was also determined that the increasing dependent factors such as sorbent dosage saw an increase in adsorption effectiveness for both anti-inflammatory drugs that were tested [14]. The rate of adsorption depended on the pH of the solution for maximum removal, which was determined to be around a pH of 2–6 [14].

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