Journal of
Bioremediation & Biodegradation

Rajiv Gandhi, J Bioremed Biodeg 2016, 7:3
DOI: 10.4172/2155-6199.1000e173

Editorial Open Access

Recent Advances in Chitosan Based Biosorbent for Environmental Clean-Up

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Chitin, a polymer composed of poly (*β* -(1 → 4)-*N*-acetyl-D-glucosamine, extracted from crab and shrimp shells, is the second most abundant biopolymer in nature, next to cellulose. Chitosan, poly (*β* -(1 → 4)-D-glucosamine is prepared from chitin by deactylating its acetamido groups with strong alkaline solutions. Currently chitin and chitosan biopolymers represent an interesting, attractive and more effective biosorbents because of their unique characteristics such as non-toxicity, hydrophilicity, biocompatibility, biodegradability and bifunctionality, abundant and cost effective. Chitin and chitosan have a variety of potential applications in the areas of biotechnology, biomedicine and food ingredients and appear to be more useful biopolymers reported for the high potential of sorption of toxic metal ions, dyes, phenol, polychlorinated biphenyls and oil etc. The lone pair of electrons on the acetamido/amino groups of chitin and chitosan enables them to act as active sites for the toxic ion adsorption. Chitosan appears to be more useful as compared to chitin, since it possesses more number of chelating amino groups and can be chemically modified. The presence of amino groups is responsible for the uptake of metal cations by a chelation mechanism and the amino groups can be easily protonated which attract the metal anions too. However, pristine chitosan flakes/powder are not very appropriate for the development of technology due to its clogging effects, poor chemical stability, low mechanical strength, etc. and these disadvantages outweigh its advantages of biodegradability and indigenous. One of the most important advantages of chitosan is versatility and hence the material can readily be modified physically/chemically. In order to overcome the above mentioned drawbacks and to suit chitosan for a variety of field applications, chitosan were modified into nanoparticles, gel beads, membranes, sponge, composite honeycomb, fibres or hollow fibres. Attempts were made to convert chitosan into bead form which provides the potential for good adsorption, regeneration and reuse in the field applications. Further, the chemical stabilities of the chitosan beads were improved through chemical cross-linking of the surfaces with cross-linking agents such as ethylene glycol diglycidyl ether, glutaric dialdehyde and epichlorhydrine. However, most of the chemical cross-linking agents are prone to react with the amine groups and as a consequence, the adsorption capacity of the cross-linked chitosan beads decreases. The cross-linking chitosan beads is found to be largely reducing the number of amino groups of the chitosan which are known to be the main chelating sites for many heavy metal ions and dyes. Chemical modifications of a large numbers of hydroxyl and amino groups present in chitosan can improve the physical and chemical properties of chitosan. Modification of chitosan with different functionalities, such as amine, carboxyl, sulphoxine, thiol, tripolyphosphate etc. leads to the versatile applicability in various water purification applications. In recent years, functionalized chitosan beads have received great attention because of their multifunctional properties, morphological features and potential use in drug delivery, food ingredients, water treatment, host-guest chemistry, cosmetics, and dendritic catalysts etc. The limitations of available water treatment technologies necessitate the development of emerging techniques. Modified chitosan based biosorption technology has emerged, as an alternative for commercial adsorbents viz., activated carbon, and polymeric resins have been pioneered to remove toxic heavy metals and organic contaminants from industrial effluents. Chitosan biosorbent is very effective and showed extensive water treatment applications than commercial adsorbents. Chitosan based adsorbents is very similar to the use of ion exchange resins which can also perform the clean-up work. The difference is in the price of the substances used; commercial ion exchange resins are sold for US$ 80-100/kg. With the same performance, new chitosan based biosorbents could cost less than US $ 8-10/kg. Cost-effective chitosan biosorbent has a special edge for opening up huge environmental applicability in near future. Development of various kind of chitosan based biosorbent will replace the use of polymeric resins, activated carbon or clay materials in waste water treatment and their further developments would throw more light on the field of water treatment. Chitosan based biopolymers can be potentially used as coagulant, flocculants for removal of turbidity, water clarification, solids removal etc. Chitosan biosorbent showed promising adsorption efficiency towards various toxic anions i.e., nitrate, phosphate, chromate, fluoride and arsenic etc. Chitosan and modified chitosan adsorbent were showed excellent of sorption of metal ions viz., Cu(II), Pb(II), Zn(II), Ni(II), Mn(II), Pd(II), Cd(II) and low level radioactive liquid wastes (^{137}Cs, ^{54}Mn, ^{90}Sr and ^{60}Co). Recently, domestic water purification devices were fabricated using chitosan based material for the removal of bacteria, virus, arsenic, fluoride, iron and various heavy metals from drinking water. Chitosan based adsorbents were used for the removal of various dyes and chitosan-metal oxide composites were widely used as photocatalysts under UV/visible/solar light for decolorization, detoxification and degradation of various dye effluents. Recently, chitosan based adsorbents were used for the removal low levels of emerging contaminants, various persistent organic pollutants, pesticides, pharmaceuticals and personal care products etc. from wastewater streams. Currently, powdered activated carbon was widely used for the removal of various types of contaminants in water effluents and it requires an additional coagulation step to separate the carbon after use. In comparison with conventional technique, the bioremediation using chitosan based materials will be an innovative and environmentally friendly technique in near future. Chitosan based materials can be potentially used as adsorbents/photocatalysts/coagulants/flocculants etc. for a range of contaminants in drinking water and waste water treatment technologies in practical utilization. The use of chitosan based ecological polymeric materials could potentially contribute to the environmental friendly method for water treatment.

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Received March 28, 2016; **Accepted** April 01, 2016; **Published** April 05, 2016

Citation: Rajiv Gandhi M (2016) Recent Advances in Chitosan Based Biosorbent for Environmental Clean-Up. J Bioremed Biodeg 7: e173. doi:10.4172/2155-6199.1000e173