International Research Journal of Natural and Applied Sciences

ISSN: (2349-4077)

Impact Factor 5.46 Volume 5, Issue 2, February 2018

Website- www.aarf.asia, **Email** : editor@aarf.asia , editoraarf@gmail.com

"Scenario of the role of Nanocomposites in the removal of the organic and inorganic pollutants from wastewater – A Review"

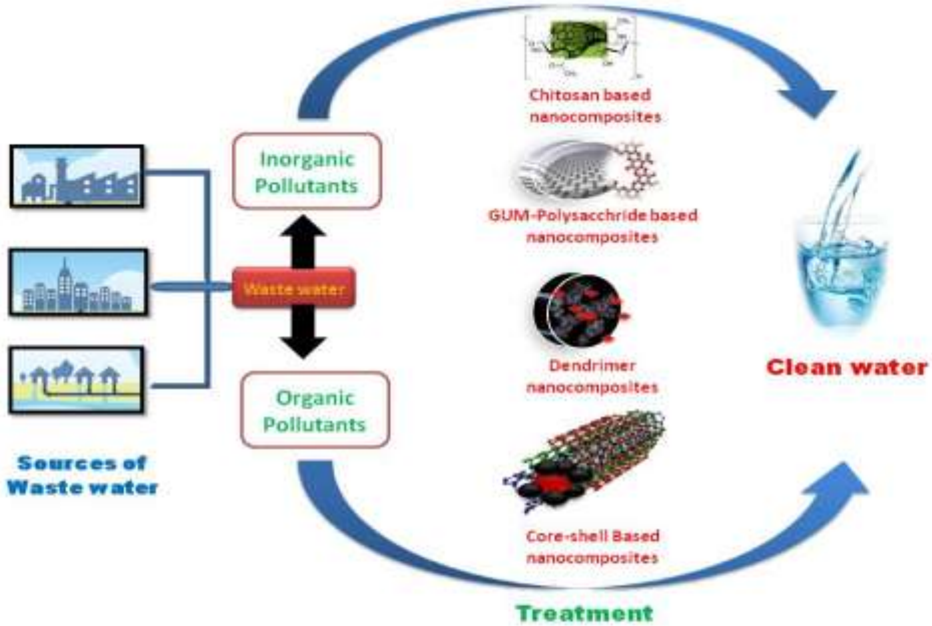
Ramkrishna Y. Patle*

*Department of Chemistry, Mahatma Gandhi College of Science, Gadchandur, Chandrapur-442908 (M.S.)

Email: ramkrishnapatle@gmail..com

Abstract

In the last two decades, developing countries like India are now on the verge of facing the challenges of wastewater remediation. The progressive growth in industrialization has led to an increase in water pollution due to incorporating the industrial and municipal wastes in the natural water resources. The effluents from the industries and household are streamlined directly or indirectly into the natural water systems are supposed to have more serious hazardous effects on biological life. The effluents from industrial waste contain hazardous organic and inorganic contaminants. The treatment of such pollutants from the industrial effluents before dumping has become one of the major challenges to face off. Various conventional techniques such as physical, chemical, and biological processes have been developed for the removal of organic and inorganic pollutants. In this review, an attempt is made to provide a summary of the various nanocomposites based on the chitosan, dendrimer, core-shell materials, and gum-polysaccharides, CNTs, and Graphene to remove organic and inorganic pollutants from wastewater.



Keywords: Wastewater, remediation, organic and inorganic pollutants, industrial effluents, etc.

Introduction

Industrial expansion in developing countries has been becoming one of the major causes of water pollution. The effluents streamlined directly or indirectly into the water bodies affect the quality of the potable water. The people from the nearby cities are showing major ill effects on health due to consumption of polluted water. The various chemical processes that have been carried out in the manufacture of different chemical-based products generate by-products. Thus, industrial effluents are outsourced as a result of the disposal of the byproducts and other chemical entities during the manufacturing. Industrial wastewater is categorized into two classes namely organic and inorganic pollutants.

The incorporation of industrial waste into the aquatic systems in various ways. The different sources of the emission of the organic and inorganic pollutants generalized such as gaseous emission, liquid wastes, and solid wastes. Industrial waste could be characterized in terms of the Biological oxygen demand (BOD) and Chemical oxygen demand. The organic and inorganic pollutants in the effluents originated from the different sources may have a different level of the BOD. For example, the industrial effluents from the food factories or sugar refineries have high BOD magnitude. Due to the highly efficient industrial processes involved in the Pulp and paper industry or petroleum refineries incorporate the many toxic wastes which may have high BOD while the chemical industries, pharmaceutical industries, and metal refining industries emit more toxic waste in the effluents that may have low BOD [1].

As per the case study done by Bosco et al (2005), the industrial waste released from the petrochemical industries was found to contain heavy metals such as Arsenic, Nickel, Molybdenum, selenium, sulfur, copper, platinum, palladium, lead, etc. [2]. Many dye manufacturing industries, pharmaceuticals industries, agrochemical industries, etc. are contributing a lot to introduce organic waste such as pesticides and fertilizers (viz. DDT, PCBs, HCB, phosphates, urea, etc.), HC, phenolic compounds, plasticizers, biphenyls, soap and detergents, oils, greases, pharmaceuticals, proteins, and carbohydrates, etc [3-5]. These inorganic and organic pollutants enter into the food chain of living beings and are held responsible for the hazardous effects on health.

The increasing population and industrial reforms have led to an increase in water demand. Today, the world is undergone through water crisis due to increasing demand in industries and household purposes. Thus, to sustain the water availability, effluents from the industries and residential areas should be recycled to fulfill the demand. On account of this, conventional methods have been employed for wastewater remediation. This includes coagulation-flocculation, precipitation, Ion-exchange, adsorption, membrane filtration, and electrochemical treatment [6]. But, these methods are not up to the mark and less effective in wastewater treatment due to their several limitations. The alternative method to enhance the efficiency of removing the contaminants from the wastewater is possible due to nanotechnology. The reduced size of the adsorbing particle possesses the larger surface perfectly suited for the better removal of the inorganic and organic pollutants from the industrial effluents The engineering of the nanoparticles with other organic materials that generate nanocomposites show a great efficiency towards the wastewater remediation[7]. This review article emphasizes the significant role of the nanocomposites in the removal of the inorganic as well as organic contaminants that are part of the effluents discharged in the water resources. It generates the scope for the researchers to develop functionalized nano-materials to add effectiveness in the remediation of the wastewater.

Removal of Inorganic and organic Pollutants by Nanocomposites

The potential use of nanotechnology in the generation of nanoparticles and nanocomposites raised new horizons for the treatment of wastewater. The nanocomposites are made of the two more entities clubbed in one molecular frame. There are different kinds of nanocomposites such, as carbon-based composites, polymeric composites, hybrid material composites, and biosorbent composites, etc. Nanocomposites have a wide range of applications in several fields, such as biomedical, textiles, agriculture, food packaging, catalysis, etc. The different kinds of composites have been developed till now to employ in water remediation. The extraction of the inorganic and organic contaminants is the prime motive by using nanocomposites.

Nowadays, clay-polymer nanocomposites are getting more popular in the removal of organic and inorganic pollutants. Clay-polymer nanocomposites are growing interest in the adsorption of the micropollutants present in the wastewater [8]. The carbon nanotubes based nanomaterials were prepared from the CNTs and $CoFe_2O_4$. The CNT/ $CoFe_2O_4$ NPs were embedded with pyrrole to form the polypyrrole /CNTs- $CoFe_2O_4$ magnetic nanohybrid (CNTs- $CoFe_2O_4$@PPy) [9]. The functionalized Attapulgite (AT) NPs were modified with acrylic acid and acrylonitrile through *in-situ* polymerization. It produced the inorganic-organic hybrid nanocomposites. The synthesized hybrid P(A-N)/AT nanocomposites were useful in the adsorptive removal of the heavy metals and organic contaminants from the wastewater. The adsorption capacity was enhanced by the fictionalization of Poly (Acrylic acid –Acrylonitrile) polymer with AT NPs [10]. The progressive evolution in the field of nanocomposite synthesis has opened a new way of developing novel nanocomposites. The promising applications of graphene-based nanomaterials have extended the molecular framework. This has enabled us to develop advanced adsorption and electrosorption techniques. the condensation of the graphene-based nanomaterials with porous Fe_3O_4 magnetic materials to develop the novel (Fe_3O_4)/porous graphene nanocomposites. These nanocomposites were utilized in the efficient removal of the heavy metals electrosorption for Pb2+, Cu2+, and Cd2+ ions and organic methyl violet dye from wastewater [11].

Chitosan based nanocomposites

Recently introduced a new class of nanomaterials has been emerging as a very efficient adsorbent for the removal of the pollutants present in the wastewater. The chitosan has significance in the replacement of the conventional methods of water remediation. The chitosan form the nanocomposites with several materials like montmorillonite (MMT) clay, metal oxides, ZnO NPs, and other several materials. This confers an increase in the surface area and exchange capacity. The chitosan-based Nanocomposites show the potential application in the waste water treatment [12].

The chitosan iron oxide nanocomposites were competent nonabsorbent for heavy metals Nickel, Cadmium, and Lead. The results have shown better adsorptivity towards several selected heavy metals from the aqueous solutions [13]. Besides, the chitosan-magnetic nanocomposites were employed for the removal of the Fe(II) from the aqueous solutions [14]. The Cr(VI) ions in the wastewater sound to be hazardous. Gokila et al have prepared the chitosan –alginate-based nanop[aticle to remove the Cr(VI) from the waste water [15]. Apart from the inorganic pollutants, the chitosan nanocomposites have also been used in the removal of organic pollutants such as dyes. The multi-walled carbon nanotube (MWCNT) was tailored with chitosan (CS) and poly-2- 21 hydroxyethyl methacrylate (pHEMA) to form the Nanocomposites. It was then screened for the removal of the organic dye Methyl orange from the water [16]. Similarly, the N, O-carboxymethyl-chitosan/montmorillonite nanocomposite were evaluated for the removal of the congo red dye from the aqueous solutions [17]The zinc oxide –chitosan nanocomposites were employed for the removal of the direct black 78 dyes, acid black 26 dye, etc [18].

Thus, the nanocomposites of the chitosan with different materials provide a better platform for wastewater treatment. Hence, it would be always a better choice for the researcher to explore the removal of the organic and inorganic pollutants from the wastewater.

Gum-Polysaccharide Based nanocomposites

The emerging importance of the Polysaccharide in nanotechnology raised the hope of manufacturing the various composites for multifunctional applications. It provides novel biomaterials for the permutation of the different molecular frames [19]. Gum Karaya grafted with Poly(acrylic acid) and Silicon carbide NPs were incorporated and hydrogel nanocomposites were prepared. These biodegradable nanocomposites were observed to be the most efficient adsorptive biomaterial for cationic dyes in an aqueous solution [20]. The effective adsorption of the Methyl violet dye was possible by the nanocomposites hydrogel synthesized from the Iron oxide NPs incorporated into the gum Xanthan grafted Poly (Acrylic acid) [21].

Core-Shell Nanocomposites

Magnetic core-shell nanocomposites are cost-effective and have more efficacy in the removal of the different types of the water contaminants such as hazardous heavy metals, organic dyes, pesticides, toxic organic chemicals, and biological contaminants [22]. The magnetic Ni@$Mg(OH)_2$ nanocomposites were evaluated for the better adsorption capacity for heavy metals such as Zn^{2+} Cd^{2+} and Cu^{2+} [23]. The heavy metals Cd^{2+} and Pb^{2+} were found to be more toxic and cause more serious health issues. The functionalized magnetic core –Zeolitic shell nanocomposites were used for the removal of the Cd^{2+} and Pb^{2+} from the waste water [24]. Similarly, organic entities present in the wastewater are the major pollutants that are released from the chemical, pharmaceutical, and agrochemical industries. They approach the human habitat somehow and cause immortal health problems. The core-shell nanocomposites are the better alternatives to remove such toxic pollutants from the wastewater at low-cost capita. The core-shell nanocomposites of graphene oxide CoFe2O4@rGO were the most potent agent for the adsorption of organic pollutants such as dyes present in the wastewater. The study has shown that it has an excellent capability of recycling and regeneration [25]. Recently, Kong et al have synthesized Zeolitic imidazolate frameworks (ZIF) core-shell magnetic nanocomposite. This nanocomposite was composed of the ZnO/CdS and ZIF-8. It has a great photocatalytic degradation activity for the methylene blue dye [26].

Dendrimer nanocomposites

The dendrimer has unique properties such as 3D structure, nano-sized, globular shape, monodisperse and low cytotoxicity, the vast number of chelating groups, and void spaces. It is chemically most stable, with low polydispersity and high solubility [27]. Tomalia et al have discovered a starburst PAMAM dendrimer that has emerged as one of the most capable chelating agents for the adsorption of the inorganic and organic pollutants from the waste water[28-30]. The synthesized PAMAM/ CuS / AA nanocomposites were evaluated for the adsorption of the Isma Fast acid yellow G dye from the wastewater. According to Langmuir adsorption isotherm, it has shown a significant capacity for the adsorption of the dye [31]. Organic chemicals such as aromatic hydrocarbons such as naphthalene, anthracene, and phenanthrene, are toxic organic pollutants that affect water quality. These magnetic nanoparticles synthesized on the PAMAM dendrimer G10 template tailored with benzaldehyde as peripheral groups were employed for the removal of these organic hydrocarbons from the wastewater [32]. PAMAM dendrimer nanocomposites are also having a noteworthy application in the adsorption of hazardous heavy metals from wastewater. The PAMAM dendrimer functionalized with the carbon nanotubes (CNT) to prepare the PAMAM/CNT nanocomposites. These nanocomposites were having prominent efficiency in the removal of the Ni^{2+}, Zn^{2+}, As^{3+}, and Co^{2+}. Similarly, TiO_2 NPs are incorporated into the PAMAM dendrimer of generation 4 to synthesize the TiO_2 – PAMAM nanocomposites. The Nanocomposites have shown a remarkable capacity for the removal of the heavy metal ion metal ions Cu^{2+}, Pb^{2+}, and Cd^{2+}.

Conclusion

The increasing population and industrial reforms have evoked the delivery of hazardous contaminants in the aquatic system. The incorporation of the organic and inorganic pollutants in the water source malpractices through industrial and municipal waste dumped non-regrettably by human activity. This has led to the malfunctioning of the body physiology and hence, witnessing non-curable diseases. To prevent the human habitat and other biotic systems, it has become necessary to treat the municipal and industrial waste before streamlining it into an aquatic system. It has been made possible by exploring the benefits of nanotechnology. The nano-engineered chemicals or biomaterials into the nanocomposites to eliminate the organic and inorganic pollutants from the wastewater. The review article has focused on the significant role of the different nanocomposites such chitosan-based nanocomposites, Gum-Polysaccharide based composites, core-shell based nanocomposites, and dendrimer based nanocomposites in the removal of the organic as well as inorganic contaminants present in the wastewater. It would provide comprehensive information relevant to the progress in the field of wastewater remediation by exploring the benefits of nanocomposites.

Conflict of interest

There are no conflicts to declare.

Acknowledgment

The author thanks the faculty of the PGTD department of Chemistry, R.T.M. Nagpur University Nagpur, and Mahatma Gandhi College of science, Gadchandur, Chandrapur for their direct and indirect support.

References

1. Literathy, P., Industrial Wastes and Water Pollution. Regional Approaches to Water Pollution in the Environment,1996, 21–32. doi:10.1007/978-94-009-0345-6_2
2. M. L. Bosco, D. Varrica and G. Dongarrà, Case study: Inorganic pollutants associated with particulate matter from an area near a petrochemical plant, 2005, 99(1), 0–30. doi:10.1016/j.envres.2004.09.011
3. Ali, I., Mohd. Asim and Tabrez A. Khan , Low-cost adsorbents for the removal of organic pollutants from wastewater, *Journal of Environmental Management*, 2012, 113,170-183.
4. Ali, I. and Aboul-Enein, H.Y., Chiral. Pollutants: Distribution, Toxicity and Analysis by Chromatography and Capillary Electrophoresis, *John Wiley & Sons*, Chichester, 2004.
5. Damià, B. Emerging Organic Pollutants in Waste Waters and Sludge. Springer, Ber- lin, 2005.
6. Zinicovscaia, Inga and Cepoi, Liliana , Cyanobacteria for Bioremediation of Wastewaters, *Conventional Methods of Wastewater Treatment. , 10.1007/978-3-319-26751-7(Chapter 3), 2016, 17–25.* doi:10.1007/978-3-319-26751-7_3
7. Mueller, N. C. and Nowack, B., Nanoparticles for Remediation: Solving Big Problems with Little Particles. Elements, *2010, 6(6), 395–400.* doi:10.2113/gselements.6.6.395
8. Unuabonah, Emmanuel I. and Taubert, Andreas, Clay–polymer nanocomposites (CPNs): Adsorbents of the future for water treatment, *Applied Clay Science*, 2014, 99, 83–92. doi:10.1016/j.clay.2014.06.016
9. Li, Xiaoli, Lu, Haijun and Zhang and Yun; He, Fu, Efficient removal of organic pollutants from aqueous media using newly synthesized polypyrrole/CNTs-CoFe 2 O 4 magnetic nanocomposites. *Chemical Engineering Journal*, 2017, 316, 893–902. doi:10.1016/j.cej.2017.02.037
10. . Xinliang Jin, Cui Yu, Yanfeng Li, Yongxin Qi, Liuqing Yang, Guanghui Zhao and Huaiyuan Hu, Preparation of novel nano-adsorbent based on organic–inorganic hybrid

and their adsorption for heavy metals and organic pollutants presented in water environment, 2011, 186(2-3), 1672–1680. doi:10.1016/j.jhazmat.2010.12.057

11. Bharath, G., Alhseinat, Emad, Ponpandian, N., Khan, Moonis Ali, Siddiqui, Masoom Raza, Ahmed, Faheem and Alsharaeh, Edreese H., Development of adsorption and electrosorption techniques for removal of organic and inorganic pollutants from wastewater using novel magnetite/porous graphene-based nanocomposites. *Separation and Purification Technology*, 2017,188, 206–218. doi:10.1016/j.seppur.2017.07.024

12. Sreejarani K. Pillai And Suprakas S. Ray, In: Natural Polymers, Volume 2: Nanocomposites, Chapter 2:Chitosan-based Nanocomposites, John J Maya and Thomas Sabu(Eds.), Royal Society of Chemistry, 2012.

13. M. Keshvardoostchokami, L. Babaei , A.A. Zamani , A.H. Parizanganeh and F. Piri, Synthesized chitosan/ iron oxide nanocomposite and shrimp shell in removal of nickel, cadmium and lead from aqueous solution, *Global J. Environ. Sci. Manage.*, 2017, 3(3): 267-278.

14. Mini Namdeo and S.K. Bajpai, Chitosan–magnetite nanocomposites (CMNs) as magnetic carrier particles for removal of Fe(III) from aqueous solutions,2008, 320(1-3), 161–168. doi:10.1016/j.colsurfa.2008.01.053

15. Gokila, S., Gomathi, T., Sudha, P.N. and Anil, Sukumaran, (2017). Removal of the heavy metal ion chromiuim(VI) using chitosan and alginate nanocomposites. *International Journal of Biological Macromolecules*, 2017. doi:10.1016/j.ijbiomac.2017.05.117

16. Mahmoodian, Hossein; Moradi, Omid; Shariatzadeha, Behnam; Salehf, Tawfik A.; Tyagi, Inderjeet; Maity, Arjun; Asif, M.; Gupta, Vinod Kumar (2015). Enhanced removal of methyl orange from aqueous solutions by poly HEMA–chitosan-MWCNT nano-composite, Journal of Molecular Liquids, 2015, 202, 189–198. doi:10.1016/j.molliq.2014.10.040

17. Li Wang and Aiqin Wang, Adsorption behaviors of Congo red on the N,O-carboxymethyl-chitosan/montmorillonite nanocomposite, *Chemical Engineering Journal*, 2008, 143, 43–50.

18. Raziyeh Salehi, Mokhtar Arami, Niyaz Mohammad Mahmoodi, Hajir Bahrami and Shooka Khorramfar, Novel biocompatible composite (Chitosan–zinc oxide nanoparticle): Preparation, characterization and dye adsorption properties ,2010, 80(1), 86–93. doi:10.1016/j.colsurfb.2010.05.039

19. Mittal, Hemant; Maity, Arjun; Ray, Suprakas Sinha (2016). Gum karaya based hydrogel nanocomposites for the effective removal of cationic dyes from aqueous solutions, *Applied Surface Science, 2016.* doi:10.1016/j.apsusc.2015.12.241

20. Zheng Yingying, Monty Jonathan and Linhardt Robert J., Polysaccharide-based nanocomposites and their applications, *Carbohydrate Research*, 2015, 405, 23–32. doi:10.1016/j.carres.2014.07.016

21. H. Mittal, Vaneet Kumar, Saruchi and Suprakas Sinha Raya, Adsorption of methyl violet from aqueous solution using gum xanthan/Fe3O4 based nanocomposite hydrogel, *International Journal of Biological Macromolecules*, 2016, 89, 1–11.

22. Nasrullah Shah, Frederick Claessyns, Stephen Rimmer, Muhammad Balal Arain, Touseef Rehan, Aref Wazwaz, Mohammad Wasi Ahmad and Mazhar Ul-Islam, Effective Role of Magnetic Core-Shell Nanocomposites in Removing Organic and Inorganic Wastes from Water, *Recent Patents on Nanotechnology, 2016, 10(3),202-212.*

23. Zhang, M., Song, W., Chen, Q., Miao, B., and He, W., One-Pot Synthesis of Magnetic Ni@Mg(OH)2 Core–Shell Nanocomposites as a Recyclable Removal Agent for Heavy Metals. *ACS Applied Materials & Interfaces*, 2015, 7(3), 1533–1540. doi:10.1021/am506643b

24. Padervand, M., and Gholami, M.R., Removal of toxic heavy metal ions from waste water by functionalized magnetic core–zeolitic shell nanocomposites as adsorbents. *Environ Sci Pollut Res.,2013,* **20,** 3900–3909.

25. Song, Z. J., Ran, W., and Wei, F. Y. , One-step approach for the synthesis of CoFe 2 O 4 @rGO core-shell nanocomposites as efficient adsorbent for removal of organic pollutants, *Water Science and Technology*, 2016, 75(2), 397–405. doi:10.2166/wst.2016.52

26. Kong, R.-M., Zhao, Y., Zheng, Y., & Qu, F., Facile synthesis of ZnO/CdS@ZIF-8 core–shell nanocomposites and their applications in photocatalytic degradation of organic dyes, *RSC Advances*, 2016, 7(50), 31365–31371. doi:10.1039/c7ra03918b

27. Abbasi, E., Aval, S.F., Akbarzadeh, A. *et al.* Dendrimers: synthesis, applications, and properties. *Nanoscale Res Lett.*, 2014, **9,** 247. https://doi.org/10.1186/1556-276X-9-247

28. Tomalia, D. A.; Dewald, J R.; "Dense star polymers having core, core branches, terminal groups" *U.S. Patent* 4, 507, 466, 1983.

29. Tomalia, D. A; Baker, H; Dewald, J; Hall, M; Kallos, G; Martin, S; Roeck, J; Ryder, J; Smith P. "A New Class of Polymers: Starburst-Dendritic Macromolecules". *Polymer Journal*. 1985, *17*, 117–132

30. Tomalia, D. A.; Fréchet, J. M. J., Discovery of dendrimers and dendritic polymers: A brief historical perspective. *Journal of Polymer Science Part A: Polymer Chemistry*, 2002, 40(16), 2719–2728.

31. Abou Taleb, M. F., El-Trass, A. and El-Sigeny, S., Synthesis of polyamidoamine dendrimer (PAMAM/CuS/AA) nanocomposite and its application in the removal of Isma acid fast yellow G Dye, *Polymers for Advanced Technologies, 2015,* 26(8), 994–1002.

32. Aliannejadi, S., Hassani, A. H., Panahi, H. A. and Borghei, S. M., Fabrication and characterization of high-branched recyclable PAMAM dendrimer polymers on the modified magnetic nanoparticles for removing naphthalene from aqueous solutions. *Microchemical Journal*. 2019, 145, 767–777.