Bioremediation of thermal power plant effluents with chitosan and chitosan nano particels

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Abstract

Water pollution caused by thermal power plant effluent discharges has become a worrisome phenomenon due to its impact on environmental health and safety. Many treatment processes that have been used to remove heavy metals from wastewater are suffered from high cost. Chitosan is a low cost adsorbent which is biodegradable and biocompatible polymer obtained from shrimp biowaste. In the present study, both chitosan and chitosan TPP nano particles showed ability to remove the two important heavy metals like lead and Iron from thermal effluents. Chitosan TPP nano particles showed high efficiency in the adsorption of heavy metals when compare to chitosan alone. Our results showed that the adsorption process is concentration driven with high capacity of chitosan and chitosan TPP nanoparticles for the adsorption of these metal ions.

Keywords: Waste water treatment, Biopolymers, Chitosan, Heavy metals

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Introduction

Water pollution due to discharge of untreated industrial effluents into water bodies is a major problem in the global context. Nellore district is one of the nine coastal districts and is situated in the south eastern part of Andhra Pradesh. Southern Nellore is an industrial belt, with many large scale industries including public sectors undertaking, huge multinational companies, micro and small enterprises and large scale industries. Some of the important industries of the region are Mica Mines and thermal power plants. Hazardous wastes from the industrial sectors mentioned above contain heavy metals, cyanides, pesticides, complex aromatic compounds (such as PCBs), and other chemicals which are toxic, flammable, reactive, corrosive or have explosive properties affecting the environment (Ize-Iyamua *et al*., 2019). Due to their toxicity and non-biodegradability, they tend to accumulate in living organism. Therefore they cause numerous diseases and disorders. Heavy metals (Cr, Fe, Pb, Zn, Co, etc.) which exhibit in water trace in amount, but have substantial consequence on water environment and therefore human servility.

Contamination of these heavy metals deteriorates the water quality i.e. alteration of water properties such as pH, EC, TDS, etc. alter natural processes and natural resource communities, intense degradation of the aquatic environment poses consequences for fishery resources and their habitats. It is very important to identify the causes and solve it to protect the environment.

Thermal power plants play an important role in growth and development of any country but, it has direct and indirect adverse effect environment. The continuous increase in these industries has become sources of pollution. Rapid industrialization, large scale urbanization involves the use of chemicals containing toxic elements and heavy metal ions that resulted in the increased contamination of our environment (Mudasir *et al*., 2014). It is alarming that most of the cities and industries in India are without wastewater treatment facilities. In recent years studies on polymers, which bind metal ions, have increased significantly. Chitosan composites have been tested in wastewater treatments for adsorption of dyes and heavy metals (Wang and Chen, 2014). Therefore, this study was carried out to analyze the effect of chitosan and Chitosan TPP nanoparticles in bioremediation of thermal power plant effluents.

Materials and methods

Sampling of thermal power plant effluents

The study was carried out at Nellore urban industrial area which is one of the most rapidly developing and polluted industrial area of Nellore. The samples were collected from January 2019 to March 2019 from ten different stations (Table 1) of the surrounding industrial aquatic environment directly from the outlet of the factory linked to canal. Aseptically collected effluent samples

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were then filtered through filter paper (Whatman No. 42) to remove undesirable solid and suspended materials and used for analysis.

Table1: Sampling sites with sampling code in detail.

S. No	Sample ID	Collected Place
1	E1	Muthukur
2	E2	Krishnapatnam
3	E3	Nelatur
4	E4	Painapuram
5	E5	Sivarampuram
6	E6	Eruru
7	E7	Momidi
8	E8	Ankulapaturu
9	E9	Thumminapatnam
10	E10	Sivaramapuram

Treatment of water samples with chitosan and chitosan nano particles

A conventional jar test apparatus was used in the experiments to coagulate sample of thermal power plant effluent wastewater by using chitosan and chitosan TPP nanoparticles. Different concentrations of chitosan and chitosan nanoparticles (5, 10, 15, 20 mg/mL) were added to effluent samples (100mL) and processed. All tests were performed at an ambient temperature in the range of 26-30°C. All the effluent samples before and after treatment with chitosan and chitosan TPP nanoparticles were subjected for sample digestion for heavy metal analysis (Lee *et al*., 2004).

Determination of heavy metals

The determination of different heavy metals (lead and cobalt) in water samples was done by using an Atomic Absorption Spectrophotometer (AAS) (Varian Spectra AA55B, Australia). A standard line was prepared by plotting the absorbance reading on Y-axis versus the concentration of each standard solution of metal on X-axis. Then, the concentration of metal was calculated in the water samples of interest by plotting the AAS reading on the standard line (APHA, 1995).

Data analysis

Statistical analysis of the data generated out of the chemical analysis of water samples was done. The SPSS 25 and Microsoft Office Excel software were used for data analysis and presentation.

Results and discussion

Adsorption studies on lead

In the present study the adsorption of lead (II) from thermal power plant effluents on to chitosan and chitosan TPP nanoparticles was investigated. In all effluent samples the concentration of lead were found above 8 mg/L. After treatment with chitosan and chitosan TPP nanoparticles the concentration of lead reduced to 0.213 ppm (Table 2 and Fig. 1). Chitosan TPP nanoparticles showed high efficiency in the removal of lead from effluents compared to chitosan. Two-way ANOVA was employed to find the significant differences in adsorption of lead over a concentration of 5, 10, 15 and 20

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between chitosan and chitosan TPP nano particles. Bonferroni Post-T replicates by row were performed to compare the significance of means. The considered significant level is at $p<0.05$ by using the statistical software package Graph Pad Prism V5.

Table 2: Concentrations of lead (PPM) of thermal power plant effluents before and after treatment with different concentrations of chitosan and chitosan TPP nano particles.

Sample ID	Lead concentration (ppm) before treatment	Concentrations of lead (ppm) after treatment							
		Chitosan concentration(mg/mL)				Chitosan TPP nano particles concentration(mg/mL)			
		5	10	15	20	5	10	15	20
E1	10.674	8.175	5.610	3.961	1.501	6.931	4.803	2.300	0.290
E2	10.301	7.901	5.729	4.169	1.532	6.830	4.789	2.327	0.309
E3	9.482	7.800	5.871	4.170	1.439	6.951	3.980	2.150	0.276
E4	10.900	8.130	5.800	5.000	1.007	5.999	4.671	2.169	0.303
E5	8.200	8.000	5.961	4.733	1.301	5.706	4.078	2.377	0.410
E6	11.023	8.099	4.789	3.780	1.578	6.013	4.781	2.159	0.307
E7	8.970	8.539	5.800	4.111	1.439	6.097	4.169	2.067	0.298
E8	9.796	7.800	4.234	4.700	1.507	5.786	3.708	2.153	0.250
E9	11.366	8.173	5.950	4.506	1.676	6.003	3.095	2.639	0.276
E10	10.439	8.241	5.094	4.890	1.320	6.000	4.756	2.157	0.213

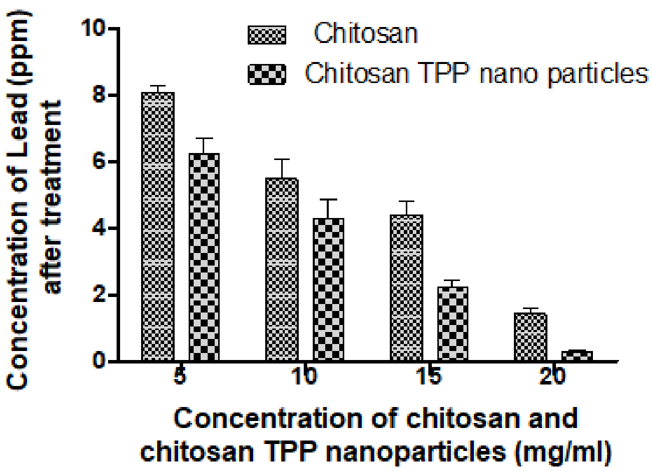

Figure 1: Effect of chitosan and chitosan TPP nanoparticles dosage on adsorption of lead (ppm) in thermal power plant effluents.

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Capacity of lead onto chitosan hydrogels beads and reported that amine groups in chitosan were found to play the major role in the adsorption of lead ions or humic acids, and when these two were simultaneously adsorbed their removal was significantly lower.

Rhazi *et al*. (2002) studied the adsorption capacity of lead on to chitosan hydrogels beads and reported that amine groups in chitosan were found to play the major role in the adsorption of lead ions or humic acids, and when these two were simultaneously adsorbed their removal was significantly lower.

Adsorption studies on cobalt

The effluent samples collected from the different industrial area contained cobalt varied from 15.461 to 10.081 ppm (Table 3 and Fig. 2). The highest concentration (15.46 ppm) was found at the point E3 and the lowest concentration (10.081 ppm) was found at the point E5. After treatment with chitosan and chitosan nano particles the concentration of cobalt ranged from 10.001 to 0.388 ppm, With chitosan the concentration of cobalt was found to decrease up to 1.004 ppm with sample E1 where as with chitosan nano particles it was 0.388 ppm for the sample E7.

Table 3: Concentrations of Cobalt (PPM) of thermal power plant effluents before and after treatment with different concentrations of chitosan and chitosan TPP nano particles.

Sample ID	Cobalt concentration (ppm) before treatment	Chitosan concentration(mg/mL)				Chitosan TPP nano particles concentration(mg/mL)			
		5	10	15	20	5	10	15	20
E1	11.561	9.150	4.300	4.211	1.004	5.969	3.950	2.316	0.451
E2	12.309	9.059	4.924	4.200	1.538	6.005	3.001	2.007	0.478
E3	15.461	10.001	4.257	4.118	1.678	7.000	3.200	3.991	0.600
E4	11.560	6.488	3.800	4.970	1.509	5.305	3.468	2.611	0.444
E5	10.081	6.091	3.976	3.861	1.499	4.807	2.978	2.008	0.444
E6	10.610	7.096	4.888	4.159	1.500	5.715	3.000	2.161	0.462
E7	14.710	9.260	5.009	5.555	1.599	7.006	4.161	2.777	0.388
E8	17.016	9.277	5.100	5.171	1.700	8.675	3.500	2.800	0.517
E9	11.079	6.555	4.007	4.203	1.500	5.490	3.470	2.255	0.543
E10	13.413	9.988	4.620	4.004	1.670	6.700	3.666	2.765	0.499

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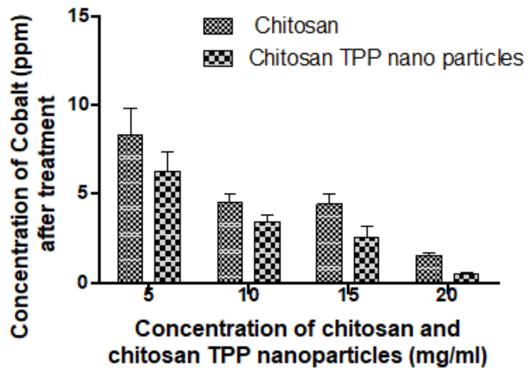

Figure 2: Effect of chitosan and chitosan TPP nanoparticles dosage on adsorption of cobalt (ppm) in thermal power plant effluents.

Two-way ANOVA was employed to find the significant differences in adsorption of Iron over a concentration of 5, 10, 15 and 20 between chitosan and chitosan TPP nano particles. Bonferroni Post-T replicates by row were performed to compare the significance of means. The considered significant level is at $p<0.05$ by using the statistical software package Graph Pad Prism V5.

Guibal (2004) investigated the removal of Co (II) by EDTA-modified chitosan. The material prepared has specific surface area of 0.71 m^2/g and 1.8×10^{-3} cm^3/g total pore volume (610 Å average pore size). This adsorbent tested for Co (II) removal and showed Q_m equal to 1.35 mmol/g (Langmuir, Sips equations).

Conclusions

In the present investigation, thermal power plant effluents were collected and analyzed to assess traces metal pollution (Lead and Cobalt) and tested the adsorption ability of chitosan and chitosan TPP nanoparticles for heavy metals from thermal power station effluents. ANOVA and α level of 0.05 (95% confidence) were used to determine the statistical significance of the independent variables and their interactions. ANOVA showed that all effects were statistically significant ($p<0.05$) at 95% confidence levels. This study showed that chitosan and chitosan TPP nanoparticles were efficient for the reductive removal of environmentally toxic and hazardous metal ions as newer approach towards remediation of heavy metals from thermal effluents. Chitosan as a result of its bioavailability would be economically useful for the treatment of waste water containing heavy metals.

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