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Application of Chitosan-Based Filtration Technique for Removal of Heavy Metals from Surface Water

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Abstract

Surface water pollution in the surrounding rivers of Dhaka city has been threatening to the supply of potable water to the city dwellers. The major pollution parameters are pH, Turbidity, TDS, EC and Heavy metal concentration which indicates physical and chemical pollution in the river water. During the dry season pollution level in Buriganga River exceeds the surface water standard and it becomes unsuitable for drinking purpose. The objective of the present study was to reduce the level of physico-chemical parameters and heavy metal concentration in surface water by Chitosan adsorbent. Chitosan was prepared in laboratory. The tests were carried out with two different filter where Chitosan-sand and Charcoal-sand were used as adsorbent (filter material). pH was found in river water ranging from 7.8 to 8.0, after chitosan treatment it was reduced and ranged from 7.1 to 7.8. No significant change occurred in charcoal treatment. Highest Turbidity, TDS and EC in river water was found 116 NTU, 192 mg/l and 372 µs/cm respectively and it was reduced by Chitosan with an average efficiency of 94.01 % , 85.33 %., 84.91 %. In the case of Charcoal treatment, the average efficiency was only 23.55 %, 11.41 % and 12.26 % for Turbidity, TDS and EC respectively. Heavy metal Pb, Cr, Zn, and Ni was found in river water ranging from 8.9368 to 10.900 ppm, 70.320 to 73.576 ppm, 16.595 to 19.231 ppm and 6.003 to 6.8730 ppm respectively. This level was significantly reduced by Chitosan with an average efficiency of 99.76 %, 99.89 %, 99.89 % and 99.87% respectively. For Charcoal treatment this efficiency was too low. Using Chitosan for household water treatment process and for water treatment in remote areas or sudden flood areas where chemical treatment is not available, might be considered as an excellent option for water purification.

Keyword: Adsorbent, chitosan, charcoal, filtration, heavy metal, water treatment, water quality.

Introduction

Safe, clean and adequate Freshwater is vital to continued existence of all living organism and the smooth functioning of ecological unit, communities and economics. Since the beginning of human civilization water scarcity has been causing conflict among the users. By the year 2025, it is apprehended that two-thirds of the world's population will experience water stress condition and some countries would experience high water stress conditiont[1]. Though Bangladesh is a riverine country, has been facing different challenges from water resources. Both natural process and human activities influences the quality of surface and ground water. The surface water of Dhaka and those of other metro cities has become highly polluted due to unsystematic discharge of raw waste from textiles, tanneries and other industries, municipal wastes into water bodies, poor drainage system, increasing population and urban encroachment. For the pollution and concentration from different sources, water contains dissolved substances, non dissolved particulate matter which its often harmful for human health. Heavy metal contamination in water is an increasing world-wide environmental concern[2].

Metals which are discharged into natural waters at increased concentrations from sewage, industrial effluents or mining operations can have severe toxicological effects on humans and aquatic ecosystems. Heavy metals like As, Cr, Cd, Pb, Hg, Cu, Zn, and Ni are toxic for both plants and human being. These metals, even in trace amounts, interfere with or inactivate enzymes of living cells[3]. Therefore, their discharge into the environment should be minimized and controlled carefully.

Filtration is a common but effective technology for drinking water treatment and often it is cost effective in comparison with other advanced method. Different filter materials are used such as sand, gravel, charcoal, straw, stone etc. Chitosan is also used as filter material in assistance with Sand and It is a good absorbent for Metal as well.

Bangladesh is the 7th largest exporter of shrimp and prawn to the world[4]. so abundance of prawns shell is high and have relatively low cost. A lot of shell is wasted during processing operations and these shells being bio waste cause environmental pollution and degradation. The purpose of this study is to evaluate the effectiveness of chitosan for improving the quality of drinking water by removal of heavy metal contents and other Physico-chemical parameters. We can adopt such cost effective treatment process instead of conventional or costly methods which is economically feasible and user friendly.

Material and Methods

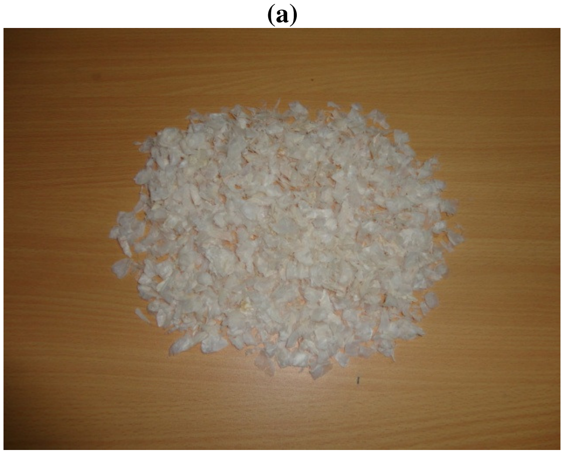
Selection of Study area: The water used in the experiment were collected from different points of Buriganga River to assess physiochemical parameter and metal, bought to the laboratory as early as possible for the experimental analysis. GPS location of the sampling sites is presented in figure 1. The samples are collected from the study area in August 2013.

Water Sample collection and preservation : Plastic container of 500 ml and 250 ml were used for sampling purpose. For the avoidance of further contamination and changes in parameter sample are carried in airtight sample bottle in insulated box with ice to maintain the temperature around 4 to 6^0C.

Preparation of Chitosan: The shell of the Shrimp were collected from a shrimp processing industry and washed thoroughly. At the time of preconditioning stage, shrimp shells were allowed to soak in 0.05 M Acetic acid solution for 24 hour. Then shells were washed thoroughly with distilled water and dried. The dried shells were de-mineralized using 0.68 M HCl (1:10 w/v) at ambient temperature (approximately 30 °C) for 6 hour. The residue was washed with distilled water until pH range was obtained 6.5- 7.5 and then the residue was dried. After that the de-mineralized shrimp shells were de proteinized using 0.62 M NaOH solution (1:10 w/v) at ambient temperature (approximately 30 °C) for 16 hours. Then the residue was washed thoroughly with water followed by distilled water until pH range 6.5- 7.5 was obtained. Chitin obtain from the above process was deacetylated in 40 % NaOH solution (1: 10 w/v) for 1 hour in 120 °C. After deacetylation, the Chitosan was washed thoroughly with water followed by distilled water until pH range of reaches 6.5- 7.5. Chitosan was dried and screened.

Figure-1
Satellite map of the sampling site Buriganga River (Source: www.Goggle Earth, 2013)

(a)



(b)

Figure-2
Different steps of the preparation of Chitosan from prawn shell (a) Acid treatment of prawn shell ;(b) Dried Chitosan.

Preparation of Filter and filtration operation: Chitosan-sand filter: Filtration was carried out in a PVC column of height 1 m and diameter 0.05 m in which filter media was placed. The sample was conveyed through a pipe of diameter 5mm. Water flow was controlled by the rate of 100 mL/min. Chitosan flakes of depth 20mm was used, above the sand layer of depth 250mm, through which sample water was passed at flow rates of 100mL/min by maintaining a constant head of 100mm from the top surface of Chitosan filter media. Sand and Chitosan were separated by cotton cloth. At the end of the pipe there was also a cotton cloth as a filter media. The particles size of Chitosan was in the range 212µm to 425µm. Sand grains were in the range of 0.6 to 1.2 mm.

Charcoal-sand filter: Filtration was carried out in a PVC column of height 1 m and diameter 0.05 m in which filter media was placed. The sample was conveyed through a pipe of diameter 5mm. Water flow was controlled by the rate of 100 mL/min. Charcoal powder were used with the depth of 25-30 mm and then sand layer of depth 250mm below[5]. The particles size of charcoal was in the range 212µm to 425µm. Sand grains were in the range of 0.6 to 1.2 mm[6].

(a)

(b)

Figure-3
(a) Sample water; (b) Filter operation process

Physico-chemical Parameter analysis of water samples before and after filtration: The turbidity was measured using (Hanna Instrument Model-H19143, Portugal), electric conductivity and total dissolved solid was measured using portable Multi parameter Meter sension^{TM}156 (HACH) and the hydrogen ion concentration (pH) was measured using pH meter (Jenway, pH meter, Model-3305, Germany).

Analysis of Heavy metal of water sample before and after filtration: Different Metal were detected and measured using Flame Atomic Absorption Spectrometer (AAS), AA-700, SHIMADZU, Serial no Shim adzucorp A336647 00580. According to AOAC Int. 83, calculation was performed. Concentration, C of metal in the test sample was calculated according to the formula:

Concentration of sample (ppm) = absorbance of sample/slope of the calibration curve X dilution factor. Detection limit 0.000 mg/L.

Results and Discussion

Physico- Chemical Parameters: Different waste materials are severely affecting the water quality. Chitosan can effectively remove these contaminations. To measure the impact on the water quality, sample were collected, treated and analyzed in the laboratory. Corresponding results related to Physico-chemical parameters are shown in table 1.

The Hydrogen Ion concentration (pH) is almost similar in different sampling site and varied slightly. The results ranged from 7.8 to 8.0 which indicate the alkaline water. After Chitosan-sand treatment a slightly decrease in value was observed and it ranged from 7.1 to 7.2. With charcoal-sand adsorption, pH value was same in water sample after treatment. The highest value of turbidity was observed in water sample-S1, 116 NTU and the value varied from 103 NTU to 116 NTU. After Chitosan adsorption it varied from only 6 to 7 NTU. According to WHO 2006, the standard for drinking purpose is 5 NTU and 10 NTU[7]. So the treatment of Chitosan-sand is effective for Turbidity reduction, here highest efficiency was 94.39 % and average efficiency was 94.01 %. Charcoal-sand is less effective than the Chitosan-sand filter. Highest efficiency was found 26.72 % where average efficiency was valued 23.55 %. WHO and DOE standard of TDS for drinking water is 1000 mg/l. Reduction of Turbidity was observed using Chitosan as adsorbent material. The highest efficiency was found 86.413 % and average efficiency was 85.332 %. Charcoal-sand filter can reduce turbidity with an average efficiency of 11.411%. The Electrical conductivity of different water sample was analyzed and the highest value was observed 387µs/cm in the water sample-S5 and lowest value found in sample S2 was 372 µs/cm. After Chitosan treatment the highest reduction efficiency was found 85.83% where average efficiency was 84.91 % found. Charcoal-sand filter can reduce EC with the efficiency of 12.26 % in an average.

Reduction of Heavy Metal Using Different Adsorbent (Filter) Material: During recent years, heavy metal pollution of the aquatic environment has become a worldwide problem because most of them have toxic effects on organisms. Both essential and non-essential heavy metals have a particular significance in human health when used for drinking purpose.

Corresponding results related to Heavy metals are shown in table 2.

Table-1
Changes in different Physico-chemical parameters using Chitosan- sand or Charcoal Sand Filter

Parameters (Unit)	Sample ID	Before treatment	Chitosan-sand Filter			Charcoal-sand Filter		
			After treatment	Efficiency (%)	Σ	After treatment	Efficiency (%)	Σ
pH	S1	7.8	7.1	8.97	8.92	7.8	0	0
	S2	7.8	7.1	8.97		7.8	0	
	S3	7.9	7.2	8.86		7.9	0	
	S4	7.7	7.1	7.79		7.7	0	
	S5	8.0	7.2	10		8.0	0	
Turbidity (NTU)	S1	116	7	93.97	94.01	85	26.72	23.55
	S2	103	6	94.18		81	21.36	
	S3	107	6	94.39		84	21.49	
	S4	114	7	93.86		85	25.44	
	S5	110	7	93.64		85	22.73	
Total Dissolved solid (mg/l)	S1	184	27	85.33	85.33	162	11.96	11.41
	S2	184	25	86.41		164	10.87	
	S3	189	29	84.66		168	11.11	
	S4	184	25	86.41		163	11.14	
	S5	192	31	83.85		169	11.98	
Electric conductivity (µS/cm)	S1	374	56	85.03	84.91	325	13.10	12.26
	S2	372	52	86.02		328	11.83	
	S3	386	61	84.20		336	12.95	
	S4	374	53	85.83		327	12.57	
	S5	387	64	83.46		345	10.86	

Table-2
Changes in different Heavy metal using Chitosan- sand or Charcoal Sand Filter

Metals	Sample ID	Metal Conc. Before Treatment (ppm)	Chitosan-sand Filter			Charcoal-sand Filter		
			Metal Conc. After Treatment (ppm)	Efficiency (%)	Σ	Metal Conc. After Treatment (ppm)	Efficiency (%)	Σ
Lead (Pb)	S1	8.9368	0.0056	99.94	99.76	7.0923	20.63	26.28
	S2	8.5680	0.0032	99.96		7.0938	17.21	
	S3	10.345	0.0342	99.67		7.0083	32.25	
	S4	10.874	0.0065	99.94		8.0092	25.58	
	S5	10.900	0.0753	99.31		7.0043	35.74	
Chromium (Cr)	S1	71.653	0.0475	99.93	99.89	69.006	3.69	3.82
	S2	73.576	0.0740	99.90		69.081	6.10	
	S3	70.320	0.0394	99.94		68.207	3.00	
	S4	70.630	0.0291	99.96		68.703	2.73	
	S5	71.734	0.1892	99.74		69.149	3.60	
Zinc (Zn)	S1	17.322	0.0253	99.85	99.89	15.990	7.68	12.05
	S2	16.595	0.0034	99.98		14.094	15.07	
	S3	16.983	0.0074	99.96		14.832	12.67	
	S4	17.647	0.0478	99.73		15.038	14.78	
	S5	19.231	0.1243	99.94		17.304	10.03	
Nickel (Ni)	S1	6.2515	0.0038	99.94	99.87	6.0031	3.97	6.44
	S2	6.3502	0.0276	99.57		5.8903	7.24	
	S3	6.0998	0.0028	99.95		5.9034	3.21	
	S4	6.8730	0.0030	99.96		5.9235	13.81	
	S5	6.0003	0.0042	99.93		5.8920	3.97	

In the present study the concentration of lead in Buriganga river water ranged from 8.9368 to 10.900 ppm. The concentration of lead in water is higher than optimum value 0.05 ppm recommended by WHO. In the case of Chitosan-sand filter the highest efficiency was observed 99.96 % in sample S2, where average efficiency was 99.76 %. In the case of Charcoal-sand filter the highest efficiency was observed 35.74 % in sample S5 where average efficiency was 26.28%. The concentration of Chromium was recorded in water sample ranging from 70.320 to 73.576 ppm. After Chitosan–sand treatment, metal concentration ranged from 0.0291 to 0.1892 ppm. The efficiency of Cr removal was 99.74 to 99.96 %. The highest efficiency rate was found in sample-S4. Recommended value for drinking water by WHO is 0.05 ppm and Chitosan can remove chromium below the approved range. The average efficiency was 99.89 % here. In the case of charcoal-sand filter the highest efficiency was observed 6.10 % in sample S2, where average efficiency was 3.82 %. The concentration of Zn in water sample ranged from 16.595to 19.21 ppm. In case of Chitosan–sand filter the highest efficiency was observed as 99.98 % and the average efficiency was found 99.89 %. In the case of Charcoal-sand filter the highest efficiency was observed 15.07 % in sample-S2, where average efficiency was 12.05 %. The concentration of Zn in water sample filtrated by Chitosan-sand filter lower than the optimum value 5 ppm for drinking water.The concentration of Ni in water is less than optimum value 0.10 ppm recommended by World Health Organization. Significant different observed between water sample filtrater by Chitosan-sand and Charcoal-sand. This could be due to the Chemical properties and adsorption rate of chitosan and charcoal. Adsorption rate of Chitosan is higher than the Charcoal. In the case of Chitosan-sand filter the highest Efficiency was observed 99.96 % in sample S4, where average efficiency was 99.87 %. In the case of Charcoal-sand filter the highest Efficiency was observed 13.81 % in sample S4 where average efficiency was 6.44 %. Adsorption rate of Chitosan is higher than the Charcoal.

Conclusion

The study indicated that Removal rate of metal is excellent and up to 99.00 % efficient for Pb, Cr, Zn and Ni by Chitosan-sand filter but In Charcoal-sand filter, efficiency is only 3.82 to 26.28 %.Chitosan based adsorbent may offer an alternative to traditional treatment methods. The unique properties of Chitosan together with availability, makes Chitosan an exciting and promising agent for the purification of surface water for household drinking purpose.

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