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Efficiency of chitosan (Poly-[D] Glucosamine) as natural organic coagulant in pre-treatment of active carbon effluent in Panacan, Davao City

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ABSTRACT

The utilization of environmental friendly coagulant is widened which can be proposed as an imperative option for water treatment. In this study, the efficiency of Chitosan, a natural organic coagulant in pre-treating Active Carbon Effluent (ACE) as alternative to conventional metal based coagulants in terms of Turbidity (T), Chemical Oxygen Demand (COD) and Total Suspended Solid (TSS) was evaluated. Collection of effluent for testing was conducted at the Philippine – Japan Active Carbon Corporation, Panacan, Davao City, Philippines. Chitosan (Deacetylated chitin; Poly- [1- 4] – β- glucosamine) was obtained from Qingdao Develop Chemistry Co., Ltd., China. Suspensions added with experimental coagulant dosages (0.1, 0.5, 1.0, 5.0 and 10.0 mgL-1) were made by sediment mixer maintained at pH 5 and analyzed with the following parameters: Total Suspended Solid (TSS), Chemical Oxygen Demand (COD) and Turbidity (T). The efficiency of the chitosan coagulation was found to be high in terms of turbidity (99.2%), Chemical Oxygen Demand (97.2%) in 5 mg/L dose of chitosan and Total Suspended Solid (99.15%) in 10 mg/L dose of chitosan. It can be concluded that Chitosan is an effective coagulant which can significantly reduce the level of turbidity, COD and TSS. A further study with different types of effluent and higher Chitosan doses are needed for recommending it for practical application as a natural organic coagulant.

Keywords: *Environmental, Technology, Active Carbon, Effluent, Davao.*

INTRODUCTION

Coagulation is basic in a couple of wastewater treatment operations. A typical case is chemical phosphorus removal and in over-loaded wastewater treatment plants, is the act of synthetically upgrading essential treatment to decrease suspended solids and organic loads from primary clarifiers (Cruden, 2015). Coagulation is a chemical process regularly utilized as a part of wastewater treatment with a specific end goal to remove suspended solids and in addition to enhance the removal of Chemical Oxygen Demand (COD). By means of this process the inclination of small particles in an aqueous suspension to attach to one another can be significantly improved. The interaction among the particles brings about the arrangement of bigger totals that can be removed from the water by sedimentation as well as filtration. The process by which the particles in suspension are modified in order to increase their tendency to aggregation is known as destabilization.

Unfortunately, the release of metal residuals in the effluent, when metal salts coagulants are used in wastewater treatment, may result in adverse effects for the receiving water body. Moreover, the sludge produced in the coagulation step may not be reused because of the presence of the metals, thus the necessity of a proper disposal will increase the management costs. On the opposite side, the use of natural organic coagulants (NOCs) could result in no toxic effect on the water bodies; moreover, the organic sludge produced from the coagulation process may be reused thus saving money for sludge disposal. NOCs have been successfully applied in the last several years in water and wastewater treatment (Crini, 2005).

Recently, the utilization of environmental friendly coagulant is widened. They can be proposed as an imperative option for water treatment. Natural organic polymers named biopolymers are naturally created or extracted from animals, plant tissues or microorganisms. These biopolymers are no toxic for human wellbeing and are biodegradable. Their utilization as coagulants is favorable in light of the fact that they are effective in low dosage and in this manner allow the reduction of sludge volume while their effect on pH and alkalinity is insignificant (Renault, et al., 2009).

Chitin and chitosan are two natural biopolymers. They have interesting properties as a component of a technique for water treatment and ecological assurance. Chitin: a Poly (N-acétyl-D-glucosamin) is the second most copious polymer in nature after cellulose. It is available in the exoskeleton of shellfish in the marine arthropods, in some seaweed and yeasts (Shahidi & Abuzaytoun, 2005). Clearly, no major studies have been done to clarify the active carbon effluent by using chitosan in coagulation process. Therefore, this study was carried out to analyze the impact of chitosan in clarifying active carbon effluent in coagulation process in different experimental conditions. The optimum dosage and mixing time needed to achieve the best performance of Chitosan in coagulation process were determined.

MATERIALS & METHOD

Data collection

The effluent was collected from the main catchment basin of the Philippine-Japan Active Carbon Corporation (PJAC) plant on October 5, 2015. The researchers requested for the outline of the effluent discharge process of the plant.

Sample preparation

Collection of Samples. Using polyethylene container, five gallons of sample of Active Carbon Effluent (ACE) were collected from Philippine-Japan Active Carbon Corporation (PJAC) (Fig. 1). The time and the date of the collection were recorded. Immediately, the samples were transported to Regional Soils Laboratory - RFU XI and will be stored in a refrigerator to preserve the chemical and physical content before it will be dispensed into the batch system.

A

B

Figure 1. A – Map of the Philippines; B - Location of the PJAC Plant in Davao City.

Characterization of sample

The characteristics of ACE depend on the series of activation processes. The ACE sample was characterized by initial impurities in terms of TSS (631mg/L), COD (465mgO2/L) and turbidity (250 NTU). ACE was collected after carbon washing where effluent showed high pH value at around 9.5 due to dilution effect.

Preparation of stock solutions

Preparation of Chitosan Solution. Chitosan (deacetylated chitin; poly- [1- 4] –β- glucosamine) with minimum of 85% deacetylation was prepared from crab shells and was obtained from Qingdao Develop Chemistry Co., Ltd. This was obtained in the form of a pale brown powder soluble in dilute acetic and hydrochloric acids. Mehdinejad et al. (2009) pointed out that one hundred (100) milligrams of chitosan powder will be weighed into a glass beaker, mixed with 10 mL of 0.1 M HCl solution, and kept aside for about an hour to dissolve. It was diluted to 1000 mL with distilled water. One (1) mL of this stock solution gave a concentration of 10mgL-1 when added to 1L of water. The solutions were prepared fresh before each set of experiments. The procedures were repeated for the desired dosages (0.1, 0.5, 1.0, 5.0 and 10.0 mgL-1).

pH Procedure

The pH of the suspension was adjusted by adding 0.1 M NaOH or 0.1 M H2SO4 (pH = 5 ± 1) (Takahashi, et al., 2005). Distilled water was used to dilute sulfuric acid solution and dissolve sodium hydroxide pellets to obtain desired concentrations.

Experimental procedure

Sediment mixer (Talboys Model 101 Overhead Mixer) was used for the coagulation experiment. One (1) liter of Active Carbon Effluent (ACE) as reference was subjected for initial testing of pH, total suspended solid (TSS), chemical oxygen demand (COD) and turbidity. One liter of ACE sample was prepared. Chitosan solution was added into the sample and the solution was rapidly mixed at 150 rounds per minute (rpm) for 3 min. followed by 20 min. of slow mixing (at 30 rpm), mixing time according to Rizzo et al (2010). It was kept standing for 30 min. and the supernatant from the top 5cm of the suspension was withdrawn for turbidity, TSS and COD testing (Hassan, et al., 2007). Experiment was repeated for the different desired dosages (0.1, 0.5, 1.0, 5.0 and 10.0 mgL-1) of coagulant with 3 replicates each (Fig. 2).

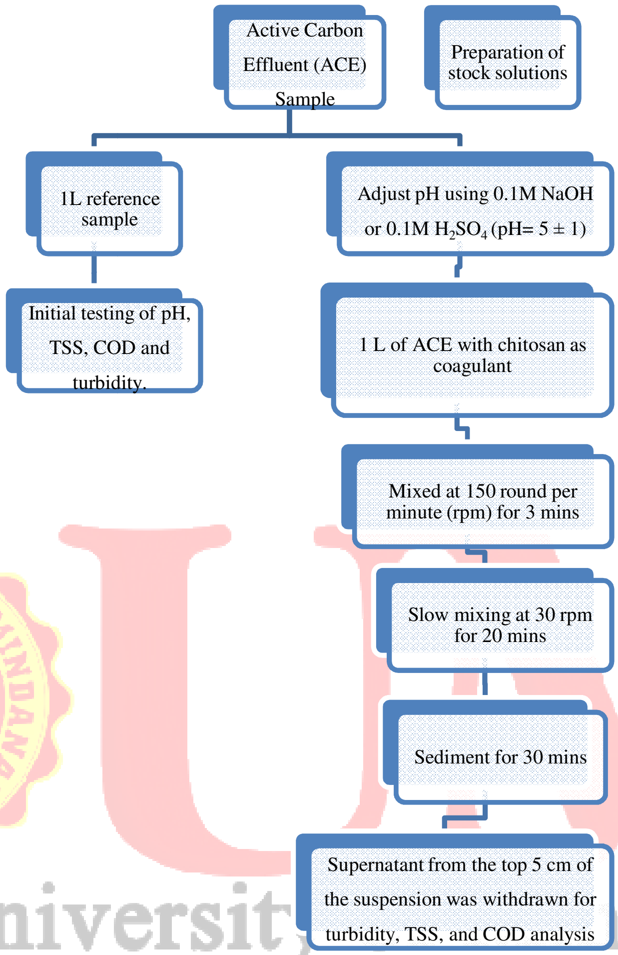
A B

Figure 2. A - Mixing effluent with 10 mg/L concentration; B - Samples with different Chitosan concentration of Chitosan

Analysis

Experimental Analysis. Analysis of turbidity, COD and TSS were carried out using nephelometric, gravimetric and closed reflux titrimetric methods respectively. T-test was used to looked at tdistribution and degrees of freedom to determine a probability value to determine whether the treatment means differ.

The Experimental Process



RESULTS AND DISCUSSION

Effect of chitosan as coagulant

The efficiency of Chitosan for the removal of turbidity, COD and TSS from ACE is shown in Table 1, 2, and 3 respectively. Table 1 below shows the initial amount of turbidity (250.00 NTU) and the amounts of residual turbidity as different dosage of Chitosan were added.

Table 1. Efficiency of Chitosan as a natural coagulant for pre-treatment of ACE in terms of Turbidity

Dosage	Ave Turbidity (NTU)	t-test value	Remark
Controlled	250.00		
0.1 mg/L	20.53	13.543	There is significant difference

0.5 mg/L	7.50	40.187	There is significant difference
1.0 mg/L	2.99	1.338	There is significant difference
5.0 mg/L	1.97	377.760	There is significant difference
10.0 mg/L	2.47	355.461	There is significant difference

All doses (0.1, 0.5, 1.0, 5.0 and 10.0 mgL-1) of Chitosan showed significant differences compared to the controlled value and therefore indicates that coagulation mechanism by Chitosan has effectively reduced the turbidity level by both the polymer bridging and charge neutralization between the impurities and Chitosan (Zemmouri, et al., 2013).

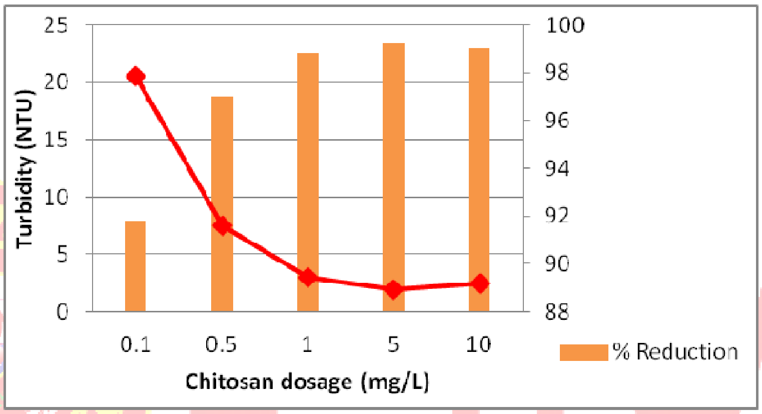


Figure 5. Effect of various amounts of Chitosan on turbidity removal

Figure 5 shows the effects of various Chitosan dosages on turbidity level and the percentage turbidity removal using Chitosan. From the outcome, turbidity level was inversely proportional to the percentage of turbidity reduction and Chitosan doses. That is, increasing amounts of Chitosan would result to lower turbidity level. For turbidity, the optimum Chitosan dosage was found to be 5.0mg/L which achieved the lowest level of turbidity and the highest percentage turbidity removal of 1.97 NTU and 99.2% respectively. From the dosage 0.1 mg/L to 5.0 mg/L, the percentage removal for turbidity was increased (Fig. 6). However, there was a decrease in efficiency when Chitosan dosage was increased from 5.0 to 10.0 mg/L obtaining 99.0% of turbidity removal. This result conformed to the study of Ariffin et al (2009) which indicates that it requires minimal amount of the Chitosan to destabilize the particles in the solution.

Table 2 below shows the initial amount of COD (435.00 mgO_2/L) and the amounts of residual COD as different dosage of Chitosan were added. All doses (0.1, 0.5, 1.0, 5.0 and 10.0 mgL^{-1}) of Chitosan showed significant differences compared to the controlled value.

Table 2.Efficiency of chitosan as a natural coagulant for pre-treatment of ACE in terms of COD.

Dosage	Ave COD (mgO_2/L)	t-test value	Remark
Controlled	435.00		
0.1 mg/L	80.50	8.258	Significant difference

0.5 mg/L	53.17	7.502	Significant difference
1.0 mg/L	39.50	44.497	Significant difference
5.0 mg/L	12.00	67.73	Significant difference
10.0 mg/L	19.50	34.63	Significant difference

However, too much dose of Chitosan beyond optimum dose can cause decrease in the removal efficiencies due to reversal of surface charge and re-stabilization of coagulated particles as shown in Figures 6 and 7. Exceeding the saturation of polymer bridging by overdosing the Chitosan, it could ruin the polymer bridging between particles, thus increasing residual turbidity. Weber (1972) stated that once the polymer exceeds its optimum dose, re-stabilized particles occur due to unavailable site for the bridge formation, which results in steric repulsion.

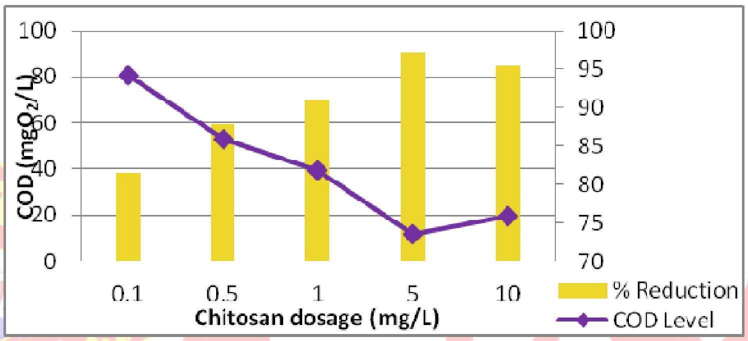


Figure 6.Effect of various amounts of Chitosan on COD

Changes in organic matter concentration (measured as COD) in ACE after coagulation tests with different Chitosan dosages (0.1, 0.5, 1.0, 5.0, 10.0 mg/L) are shown in (Fig. 4). The best results for ACE were obtained at 5.0 mg/L dosage corresponding to 97.2% of COD removal. It was observed that in 10mg/L dosage, the COD removal decreased (95.5). On the other hand, higher concentration of Chitosan resulted to decrease of COD removal efficiency as also observed with the results of Devi et al.,(2012) study stating that this was due to excess polymer adsorbed on the colloidal surfaces that produced re-stabilized colloids and caused repulsion among the suspended particles.

Data in table 3 showed the initial amounts of TSS (631.00 mg/L) and the residual TSS values as different dosage of Chitosan were added. All doses (0.1, 0.5, 1.0, 5.0 and 10.0 mg/L) of Chitosan showed significant differences compared to the controlled value.

Table 3. Efficiency of chitosan as a natural coagulant for pre-treatment of ACE in terms of TSS.

Dosage	Ave TSS (mg/L)	t-test value	Remark
Controlled	631.00		
0.1 mg/L	53.00	13.841	Significant difference
0.5 mg/L	18.33	43.419	Significant difference
1.0 mg/L	10.00	68.858	Significant difference
5.0 mg/L	6.33	109.67	Significant difference
10.0 mg/L	5.33	114.66	Significant difference

Moreover, Rizzo et al. (2010) suggested that a re-suspension might have occurred because of the cationic nature of Chitosan. At lower coagulant dosages, the polymer neutralized the average negative charge of the suspension but as the coagulant dosage was increased over the point of zero charge, the average electric charge moved to a positive value and suspension was stabilized. Hence, decreasing level of Chitosan would increase turbidity (Fig.5) and COD (Fig.6) removal.

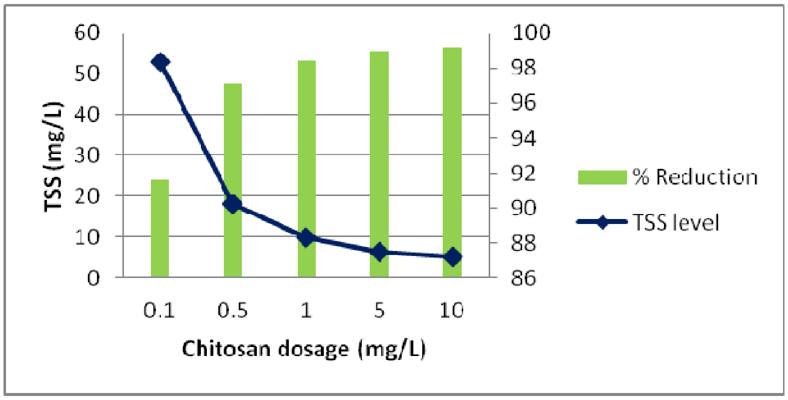


Figure 7. Effect of various amounts of chitosan on TSS removal

Figure 7 shows that 0.1mgL-1, 0.5mgL-1, 1.0 mgL-1, 5.0 mgL-1 and 10.0 mgL-1 have effectively removed 91.6%, 97.09%, 98.42%, 98.99% and 99.15% TSS respectively. This occurrence could be clarified taking into account the charge density, which Chitosan has a higher charge density contrasted to conventional coagulants (Ahmad et al, 2006). Furthermore, polymer adsorption increased as the charge density of the polymer increased (Arrifin et al, 2005). Thus, this denotes the rapid destabilization of the particles; and can infer that the amount of coagulant necessary to destabilize the particles is less for coagulant of higher charge density– Chitosan. In addition, the amino groups of Chitosan in acidic solution are protonated and during these conditions Chitosan will act as a typical polyelectrolyte (Roberts, 1992). The Chitosan will now be positively charged (act as cationic poly-electrolytes) due to the protonation of amino groups of Chitosan in aqueous solution and since the particles of ACE suspension is negatively charged, Chitosan is very attractive as coagulant by letting the molecule to bind to negatively charged surface which could happen through hydrogen bonding or ionic bonding (Gamage, 2003). Results showed that Chitosan worked best at 10 mg/L dose on TSS level of 5.3mg/L or 99.2% removal. It was observed that the in 10 mg/L dosage, the TSS removal increased. This indicates that impurities of effluent have an effect on the amount of Chitosan needed. The higher the initial TSS value, the higher coagulant dose required in the coagulation process, thus the coagulant dose is affected by combination factors such as the initial TSS of the wastewater and the pH of the effluent (Divakaran, et. al., 2001 and Pan, et. al., 1999).

CONCLSUION

Chitosan as NOC has effectively removed turbidity, COD and TSS (99.2%, 97.2% and 99.2%) respectively. The performance of Chitosan was highly dependent on dosage and initial loads of impurities. In addition, 5mg/L is the optimum dosage and has the highest percentage of turbidity and COD removal (99.2% & 97.2%) respectively and 10mg/L for TSS which has 99.2% removal. Therefore, Chitosan could be an alternative for metal-based salts coagulants. . A further study with different types of effluent and higher Chitosan doses are needed for recommending it for practical application as a natural organic coagulant.

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