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STORMWATER QUALITY ENHANCEMENT USING SNAIL SHELL POWDER AS A NATURAL COAGULANT

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Abstract

The use of snail shell powder as a natural coagulant to reduce the levels of turbidity, chemical oxygen demand (COD) and total suspended solids (TSS) in stormwater runoff was investigated. Conventional jar tests were conducted to evaluate the effects of coagulant dose, pH and settling time on the coagulation process. Maximum removal efficiencies of 90, 67 and 89 % were achieved for turbidity, COD and TSS respectively at pH 3. The removal efficiencies increased with increase in coagulant dose and settling time. The findings demonstrate the potential for the effective utilization of raw snail shell powder in stormwater quality enhancement before discharge or further treatment for reuse.

Keywords: Snail shell, Coagulation, Stormwater runoff, Turbidity, COD, TSS

1. Introduction

Stormwater management is a major challenge in developing countries due to inadequate drainage systems, poor maintenance and lack of treatment facilities. Stormwater treatment is required due to elevated pollutants concentrations from anthropogenic activities, land-use and erosion of unpaved roads, indiscriminate solid waste disposal and atmospheric depositions from vehicular traffic which contribute to deterioration of receiving waters [1-3]. Stormwater is a valuable resource which can be used to supplement existing surface and groundwater sources. Methods of stormwater treatment include detention ponds, infiltration basins, wetlands, bio retention media, biofilters, coagulation and flocculation (1-2]. In coagulation negatively charged colloidal particles are destabilized by the addition of a coagulant, resulting in the formation of large selttlable flocs [4]. The principal mechanisms involved are double layer compression, adsorption and charge neutralization, adsorption and interparticle bridging. The process is influenced by several factors including coagulant type and dosage, water quality, settling time and mixing intensity [5]. Chemical coagulants such as aluminum sulfate (alum) and ferric sulphate have been used in stormwater treatment [1, 6-7]. However they are associated with large volumes of sludge and residuals which cause human health and environmental problems at the high doses required [5, 8]. Hence several studies have explored natural coagulants as safe cost effective alternatives. Natural coagulants that have been studied include *Moringa oleifera* seeds, *Plantago ovata*, *Hibiscus escelentus* seedpods, Okra mucilage and snail shell powder [3, 9-13].

African giant land snails are gastropods which are indigenous to Africa and found in abundance in the dense tropical forests. They are consumed as food due to their high protein and low fat content [14-15]. The shells are increasingly being used as additives in the production of animal feed [14], pharmaceutical and medicinal substances, cosmetics [16-17], adsorbents [13, 18-20] and biocoagulants [10,12]. Snail shells are composed of mainly calcium carbonate ($CaCO_3$) and chitin $(C_8H_{13}NO_5)_n$ [21]. Chitin can be transformed into chitosan with a wide range of applications as an antibacterial agent and a biosorbent [17]. Other minor compounds present include zinc, copper, manganese and iron [21]. The African giant snail *archachatina marginata* has a calcium carbonate content of 81% [22].

The use of snail shell as a natural coagulant has been reported in the literature. However studies have focused on turbidity removal from wastewater streams or applications as a coagulant aid [10, 12-13, 18, 23]. Ani et al. reported the use of snail shell biomass for the removal of turbidity in fibre cement effluent with optimum turbidity removal of 92% at pH6 [10].

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Oladoja et al. evaluated the performance of snail shell as a coagulant aid in the alum precipitation of aniline blue from aqueous solutions [23]. In another study, snail shell biomass was used as a coagulant to treat abattoir wastewater with 94.39% removal of turbidity recorded at pH2 and settling time of 50 minutes [12]. Snail shells have also been used in the treatment of pharmaceutical wastewater [18] and Brewery wastewater [13].
Therefore this study evaluates the potential of raw snail shell powder as a natural coagulant for the removal of turbidity, chemical oxygen demand (COD) and total suspended solids (TSS) from stormwater runoff to enhance the quality. The effect of coagulant dosage, pH and settling time on the process is also investigated.

2. Materials and Methods

2.1. Preparation of Snail shell coagulant

Giant African land snails (*archachatina marginata*) were purchased from a local market (Uselu market, Benin City) and removed from their shells after boiling. The shells were washed with salt and tap water to remove slime and surface impurities, rinsed thoroughly with distilled water and sun-dried for three days. The shells were processed into powder using a grinder and sieved with a 0.2mm laboratory sieve. The snail shell powder obtained was utilized untreated as a natural coagulant.

2.2. Collection of Stormwater Runoff Samples

Stormwater runoff was obtained, from an un-lined open drain adjacent to a major road in Isiohor, Benin City, immediately after a storm event. Grab samples were collected in pre-rinsed plastic bottles. The bottles were tightly sealed to prevent oxidation and contamination, labeled and transported to the laboratory for analysis and subsequent experimental studies.

2.3. Coagulation Experiments:

Coagulation experiments were carried out using a jar test apparatus. Stormwater samples (500mL) in 1L capacity beakers were dosed with specified quantities of the coagulant. The suspensions were stirred rapidly at 120rpm for 1 minute, followed by 30 minutes of slow mixing at 30rpm. The effect of coagulant dose on the removal of turbidity, chemical oxygen demand (COD) and total suspended solids (TSS) was studied by varying the snail shell powder dosage from 10-250mg. The impact of pH (3-10) and settling time (0-60 minutes) on the coagulation process were also investigated. The pH of stormwater was adjusted to the desired value using 1M H_2SO_4 or 1M NaOH.
At the end of each experimental run, samples were withdrawn from the supernatant at a depth 2-4cm below the liquid level and analyzed for the residual turbidity, COD and TSS. All experiments were conducted at room temperature (27-30˚C). The percentage removal of pollutant (turbidity, COD or TSS) was determined using the following formula:

$$\%\ Pollutant\ Removal = \frac{C_i - C_f}{C_i} \times 100 \quad (1)$$

Where C_i and C_f are the initial and final pollutant concentrations (Turbidity as NTU or COD in mg/L or TSS in mg/L).

2.4. Stormwater Characterization

Some physical and chemical parameters of the stormwater were as shown in Table 1. The pH was measured using a pH meter calibrated with standard solutions before measurement. The COD was determined using a Hach UV spectrophotometer and the turbidity was measured using a Hach turbidimeter. The TSS was measured by passing amount of water through a pre-weighed filter paper which was dried at 105˚C and then weighed.

Table 1: Stormwater runoff characteristics

Parameter	Stormwater Runoff
pH	8.70
Turbidity (NTU)	358.41
COD (mg/L)	162
TSS (mg/L)	750

3. Results and Discussion

3.2 Effect of snail shell powder dosage on turbidity, COD and TSS removal

The dosage of coagulant is an important parameter that influences the efficiency of the coagulation process. The effect of snail shell powder dosage (10-250mg) on the stormwater quality in terms of turbidity, COD and TSS removal efficiencies was studied and the result is presented in Figure 1. It can be observed that there was a general increase in pollutant removal efficiency as the coagulant dose increased up to the maximum 250mg applied in this study. The turbidity removal efficiency increased from 10 % to 21% as the coagulant dose increased from 10 to 250mg. The COD removal efficiency increased from 25 to 47% as the coagulant dose increased. Similarly the TSS removal efficiency increased from 15 to 53% as the coagulant dose increased.

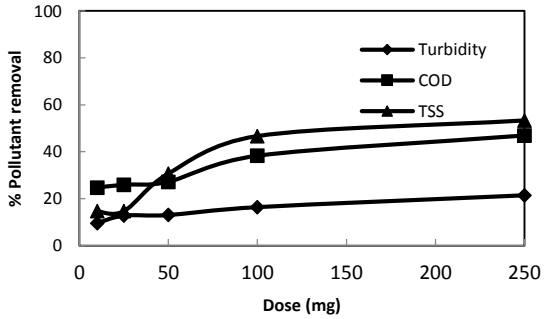

Figure 1: Effect of snail shell powder dosage on the percent removal of turbidity, COD and TSS from stormwater runoff.

The increase in pollutant removal with increase in snail shell powder dosage can be attributed to the increased surface area and the resultant increase in contact between the colloidal particles and the powder [24]. The mechanisms involved in the coagulation process include adsorption which is dependent on available surface area, charge neutralization and interparticle bridging [5]. However the results also indicate that the dose of coagulant could have been increased further to determine the optimum dose and to achieve better levels of pollutant removal, especially with respect to turbidity.

3.1. Effect of pH on coagulation process

The effect of pH (3-10) on the removal of turbidity, COD and TSS was studied and the results are illustrated in Figure 2. The original pH of the stormwater before treatment was 8.70.The results show that the removal of turbidity, COD and TSS was influenced by the pH of the solution, with decreasing removal efficiencies as the pH levels increased. Maximum removal efficiencies were observed at pH3, with 90% reduction in turbidity, 67% reduction in COD and 89% reduction in TSS levels. Alkaline conditions (pH 10) resulted in lower removal efficiencies of 15, 30 and 30% for turbidity, COD and TSS respectively. Similar observations were reported by some researchers who observed maximum removal of turbidity (94.39%) from abbatoir wastewater at lower pH levels (pH 2) [12].They attributed this phenomenon to the enhancement of the charge neutralization capability of the coagulant due to the presence of more positive ions in the solution. According to Ani et al., higher levels of protonation of the snail shell amine groups may occur at lower pH values [10]. These results indicate that the performance of the snail shell is greatly enhanced by an acidic medium.

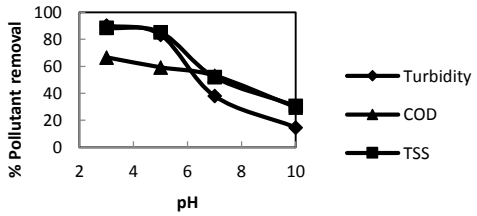

Figure 2: Effect of pH on the percent removal of turbidity, COD and TSS from stormwater runoff.

3.2. Effect of settling time on the coagulation process

The effect of settling time on the removal of turbidity, COD and TSS was studied as shown in Figure 3. The removal efficiencies increased as the settling time increased, with 20, 46 and 56% reduction in turbidity, COD and TSS after 60 minutes. In a similar study, the turbidity removal efficiency of snail shell biomass used to treat abattoir wastewater increased with settling time, as there was more opportunity for particles with lower settling speeds to settle [12].

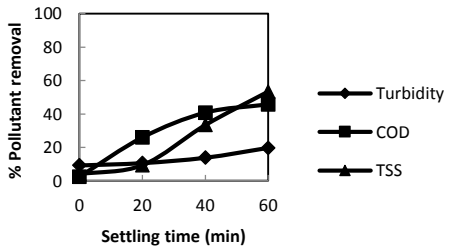

Figure 3: Effect of settling time on the percent removal of turbidity, COD and TSS from stormwater runoff.

4. Conclusion

The removal of turbidity, COD and TSS using snail shell powder as a coagulant was investigated. The results obtained show that coagulation was influenced by coagulant dose, pH and settling time. Maximum removal efficiencies of 90,67 and 89 % were achieved for turbidity, COD and TSS respectively at coagulant dose of 250mg and pH 3, indicating that an acidic medium was favorable to the performance of the snail shell powder coagulant. The removal of pollutants increased with increase in coagulant dose and settling time as reported in other studies. The findings of the study highlight the need for further investigations of the influence of pH and other operating parameters on the performance of snail shell powder with a view to determining a range of optimal conditions and understanding the principal mechanisms involved. However, the results indicate that snail shell powder is a promising natural coagulant that can be used in enhancing the quality of stormwater for safe discharge or potential reuse.

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