Characterization and Treatment of Sludge from the Brewery using Chitosan.

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ABSTRACT

Sludge samples were collected from the brewery (composite sampling type). The collected sludge samples were characterized physicochemically according to standard procedures and were each found to be polluted on the basis of some parameters determined, amongst which are COD, Turbidity, and BOD. Triplicate determinations were done in each case and the mean values obtained from statistical evaluation using the Tukey-Kramer multiple comparison tests.

The values obtained for sludge were found to be 2072 mg/l, 1034 NTU. and 640mg/l for COD, Turbidity, and BOD, respectively. The Total Solids (TS) and Suspended Solids (SS) were 7307.50 mg/l and 2067.50 mg/l, respectively. Optimum dosage of the coagulant determined was 1.50 ml of 1% chitosan solution/100ml sludge. On the basis of this, the sludge was treated proportionally and the treated sludge sample, characterized.

From the results obtained, there were significant reductions (p□ 0.05) in pollution as indicated from the values of the parameters determined, thus, an improvement on the quality of the sludge samples with 81.48%, 81.72%, and 88.27% reduction in the COD, BOD, and Turbidity, respectively. The TS and SS increased by 29.01% and 18.73%, respectively. Chitosan was found to be effective at low levels, its effectiveness is less pH dependent and does not pose problems in terms of residual metal contamination and are generally more biodegradable, therefore more environmental friendly. It is ready availability and cheap. The use of the coagulant for the treatment of sludge can be so recommended as the treated sludge could either be used as soil conditioners/enhancers, land filling/reclamation or added to other materials for block making. Studies are underway in their use in the treatment of industrial effluent.

(Keywords: sludge, biological oxygen demand, BOD, chemical oxygen demand, COD, turbidity, chitosan, coagulant)

INTRODUCTION

Growing environmental awareness, even in third world countries like Nigeria, resulting in youth and societal restiveness is indicative of the concern everybody now has for the safety of our environment. The health effects associated with indiscriminate disposal of wastes emanating from our daily activities, especially industrial processes, has continued to be on the increase, coupled with the need to convert these wastes as much as possible to promote resource and environmental conservation. As a consequence, industrial wastes of which effluent and sludge form a bulk, are a major source of environmental pollution. These need adequate and specialized handling before disposal or, as desirable in recent times, to be re-used for man's beneficial purposes.

Sludge is a major by-product of almost all industrial effluents. Yale (1998) defined sludge as solids, semi-solid, or liquid waste derived from municipal, commercial, or industrial treatment facilities, wastewater treatment plants, and air pollution control. The US Environmental Protection Agency (EPA) defines sludge as the semi–liquid residue or slurry remaining from treatment of industrial water and wastewater. Spinosa (2004) also defined sludge as an accumulation of solids removed from sewage during waste treatment. Industrial wastewater solids are also referred to as sludge, whether generated from biological or physical–chemical processes (Mac Grill, 1987).

Sludge that has been treated could be used or disposed off in an environmentally acceptable manner. Direct discharge into water bodies, landfill, land reclamation, composting, soil conditioning, irrigation (effluent recovered from sludge), brick making, etc. are possible disposal methods and reuse options. Land application and use of sludge as a soil conditioner appear to be the most acceptable alternatives. Sludge, such as organic manure, should be regarded as a valuable commodity. For sludge to serve its useful purposes it must be treated and the treatment options used are dependent to a large extent on the results obtained from its characterization and the end-use of the sludge.

MATERIALS AND METHODS

Materials

The materials used for the analysis are the locally sourced (natural) coagulant, Chitosan and the sludge sample from the Brewery.

Sampling Techniques and Preservation

The composite sampling technique was used in the collection of sludge from the sedimentation tank and the bottom of the storage vat in the brewhouse. The sludge was collected at two hours intervals everyday for six days between the hours of 8.00 am and 6.00 pm. At each sampling time, one liter of the sludge was collected from the source and transferred into a 20 liter gallon and kept in the refrigerator. This was done repeatedly for six days. The purpose of the refrigeration is to prevent the growth and multiplication of microorganisms and to inhibit their actions on the sludge. Where analysis could not be carried out, samples were preserved as contained in “Sample Preservatives and Holding Periods for Selected Parameters” (Manual of Practice O.M.I, and Ademoroti, 1996).

Methods of Analysis (Physicochemical Characteristics of the Sludge Sample)

Sludge samples from different industries were analyzed as described in the *Standard Methods for the Examination of Water and Wastewater* (APHA, AWWA, WPCF, 1995) and *Standard Methods for the Water and Effluent Analysis* (Ademoroti, 1996). Where analysis was not immediately possible, the samples were preserved.

Extraction of Chitosan

Apparatus: beakers, oven, thermometer, blender.

Reagents: NaOH, (50%), O.IM HCI

Procedure: The procedure adopted was that of Hong and Samuel Meyers (1989). The seafood, crawfish was collected, sun dried for several days until it was very dried. The dried crawfish was grinded/blended with a blender, and when it was almost fine powder, it was transferred into a 250 ml beaker where it was boiled with 50% NaOH at 100^{o}C for 30 minutes in a solvent ratio of 1:10 (w/v). Following deacetylation, the hot mixture was transferred to a beaker of cold water for rapid cooling. Filtration was done and the filtrate discarded while to the residue 0.1M HCl was added to remove the mineral components before washing in running tap water till it was free of acid. Rinsing of the residue with deionized water and subsequent drying at 60^{o}C for 4hours was done to get the desired chitosan that was used for the sludge treatment.

Determination of Optimum Dosage of Chitosan for the Abattoir Sludge Treatment: COD determinations were carried out with equal amounts of the sludge sample (100ml) but with varying amounts of the chitosan (the coagulant) for each determination. pH readings were also taken. At the end of each determination, the titre value was noted from where the COD value and % COD reduction were calculated. The COD determination was repeated with the same quantity of the sludge sample but varying the amount/quantity of coagulant added at each determination.

$$\% \text{ COD reduction} = \frac{\text{COD raw} - \text{COD treated}}{\text{COD raw}} \times 100$$

COD raw = COD of the raw (untreated) sludge

COD treated = COD of the repeated determinations with the different coagulant dose.

Treatment of the Samples: 1Litre of the brewery sludge was collected and 15.00 ml of 1% chitosan solution was added almost simultaneously. The solution was thoroughly shaken and stirred for homogeneity with a magnetic stirrer for about 1 minute, after which it was slowly stirred for about 15 minutes before it was allowed to stand for 1 hour in order for the coagulation and flocculation processes to effectively take place. After this treatment, the physicochemical parameters of the treated sludge were determined (using the liquor and settled portion of the sludge) as was done for the raw sludge.

RESULTS AND DISCUSSION

Table 1 presents the results of the characterization of the sludge samples from the Brewery. From the results, the pH value of the sludge was 6.7 indicating that the sludge was weakly acidic.

The high values 1034.00NTU, 640.00mg/l, and 2072.19mg/l for Turbidity, BOD, and COD, respectively, show that the sludge has high pollution potentials and as a result, appropriate management must be done before the sludge is put to use or disposed of.

The TS and SS values of 7307.50mg/l and 2067.50mg/l, respectively, were quite high which implies that the sludge solid contents can be used for several purposes like land filling/reclamation and as a follow up. With the relatively high values of the nutrients and low values of heavy metals (which are within the allowable FEPA standard/limit for industrial discharge into the environment) the sludge can be used as a soil conditioner.

The Electrical Conductivity value of 154.00 µs/cm, indicates that the sludge sample contains ions, consequently the coagulation and flocculation method can be very suitable for the treatment of this sludge.

The Sludge Volume Index (SVI) of 69.50, being less than 100, indicates that they are all well settling sludges (Dick and Vesilind, 1969). The SVI is can be used for estimating the quantity of sludge that can be produced from wastewater treatment plants and indeed other potential sludge sources.

Table1: Results Obtained from the Quadruple Characterization Of Untreated/Raw Sludge Samples from the Brewery.

Parameters	Mean ± S.D (From Triplicate Determinations)
pH	6.7 ± 0.10
Turbidity NTU	1034.00 ± 4.10
Suspended Solids (SS) mg/l	2067.50 ± 5.20
Volatile Solids (VS) mg/l	5242.00 ± 5.45
Total Solids (TS) mg/l	7307.50 ± 7.60
DO mg/l	2.65 ± 0.04
BOD_5 mg/l	640.00 ± 6.00
COD mg/l	2072.19 ± 6.55
HCO_3 mg/l	47.00 ± 2.00
Ca mg/l	26.85 ± 1.25
Mg mg/l	27.80 ± 1.20
K mg/l	12.80 ± 0.55
PO_4 mg/g	14.05 ± 0.48
NH_3-N mg/l	56.00 ± 2.78
NO_2-N mg/l	12.60 ± 0.60
NO_3-N mg/l	15.50 ± 0.42
Fe mg/l	0.91 ± 0.02
Zn mg/l	3.20 ± 1.00
Cr mg/l	ND
Pb mg/l	0.29 ± 0.01
Elect. Conductivity µs/cm	154.00 ± 3.20
Temperature ^oC	30.5 ± 0.20
Total Coliform Count TCC	3.90×10^8 ± 60.00
Sludge Volume Index SVI ml/g	69.50 ± 2.40

S.D= Standard Deviation.

Table 2 presents the results of the treated brewery sludge sample using chitosan. Table 3 and Figure 1 show the optimum dosage determination of chitosan.

Triplicate determinations were done in each case and the mean values and standard deviations obtained from statistical evaluation using the Tukey-Kramer multiple comparison tests. From the results obtained, there were significant reductions (p□0.05) in pollution in measured parameters, including an improvement on the quality of the sludge samples with COD reduction by 81.48% and BOD by 81.72% indicating that the treatment was effective.

Table 2: Characterization of Treated Brewery Sludge Sample with Chitosan.

Parameters	Mean ± S.D (From Triplicate Determinations)
pH	1.9 ± 0.10
Turbidity NTU	121.34 ± 4.62
SS mg/l	2454.80 ± 6.00
VS mg/l	4560.82 ± 6.60
TS mg/l	9427.35 ± 4.50
DO mg/l	2.90 ± 0.03
BOD_5 mg/l	117.00 ± 4.00
COD mg/l	383.75 ± 5.50
HCO_3 mg/l	36.06 ± 1.42
Ca mg/l	22.90 ± 1.02
Mg mg/l	21.75 ± 0.78
K mg/l	8.00 ± 0.26
PO_4 mg/g	16.50 ± 0.50
NH_3-N mg/l	40.44 ± 1.36
NO_2-N mg/l	9.00 ± 0.42
NO_3-N mg/l	11.25 ± 0.30
Fe mg/l	0.80 ± 0.04
Zn mg/l	1.82 ± 0.05
Cr mg/l	ND
Pb mg/l	0.21 ± 0.1
Temperature	30.6 ± 0.1
TCC	1.61×10^4 ± 42.50

S.D= Standard Deviation.

The pH of the treated sludge changed (increased) very slightly by 2.90%. The turbidity reduced by 88.27%, which shows that most of the colloidal particles have been removed by the coagulant. This is also indicative in the TS and SS values, where 29.01% and 18.73% increment respectively, were recorded. There was reduction, in the NH_3-N levels. This could be due to the conversion to nitrite and nitrate by some bacteria present in the sludge. According to Ademoroti (1996) and Eddy & Metcalf (1981), some groups of bacteria (Nitrosomonas and Nitrobacter) do bring about such conversion.

Table 3: Coagulant's Optimum Dosage Determination for the Treatment of the Sludge Sample.

COD Raw = 2072.19mg/l.   Sludge pH = 6.7

Doses of Coagulants (ml)	COD	%COD Reduction
1.00	872.39	57.90
1.20	758.42	63.40
1.40	663.11	68.00
1.45	600.93	71.00
1.50	**538.77**	**74.00**
1.55	634.09	71.40
1.60	714.90	65.50
1.70	845.45	59.20
2.00	944.92	54.40
2.50	1031.95	50.20
3.00	1149.86	44.51

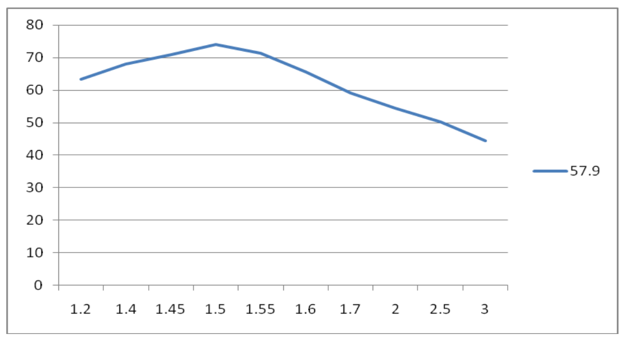

Figure 1: Optimum Dosage Determination of Chitosan for the Treatment of Brewery Sludge per 100ml.

The following equations illustrate this;

$$2NH_3 + 3O_2 = 2NO_2^- + 2H^+ + 2H_2O$$
(by Nitrosomonas)

$$2NO_2^+ + O_2 = 2NO_3$$
(by action of Nitrobacter)

As a consequence, this accounts for the increase in the nitrites and nitrates levels, invariably improving on the nutrients levels of the sludge for use as soil conditioner, as nitrate is a valuable plant nutrient (Ademoroti, 1996; Eddy & Metcalf, 1981; and Sawyer, McCarty and Parkin, 1994).

The phosphate level increased by 17.44% thus an enhancing the fertilizer value of the treated sludge. There was a very significant reduction, (p□0.05), 99.99% in the microbial load. The toxic/heavy metals contents reduced appreciably by over 25% rendering the sludge more useful for agricultural practices. The high solid contents make the sludge appropriate to be used for land filling/reclamation and also could be used in addition with other components for block making.

The sludge can contribute to the firmness and consistency in bricks as the flocs generated are large and bound together. Eikelboom (1997), reported the use of treated sludge with aluminum salt to have generated firmer and larger flocs. The results obtained competes favorably well with other locally sourced coagulants like *Jatropha gossypifolia* stem latex and known/conventional coagulant, alum (Ize-Iyamu, et al., 2009).

CONCLUSIONS AND RECOMMENDATIONS

Treated sludge has been used for decades as a valuable soil addition. Environmentally acceptable disposal methods, and more importantly, reuse options, like for agricultural purposes, are very important as they relate to sludge. Physical characteristics of soil, such as water holding capacity, can improve when sludge is added to it.

The use of locally sourced coagulant proved effective for the treatment of sludge, and consequently could be used alongside synthetic coagulants and in the very near future be a possible replacement for the synthetic ones, not only in sludge treatment, but also in water and wastewater treatment and indeed whenever coagulation and flocculation is desired. The numerous advantages of the locally sourced coagulant over the synthetic ones include their effectiveness in very low dosage, their non corrosive nature, ease of handling, and safety for use. Chitosan doesn't pose problems in terms of residual metal contamination and is cheap and readily available locally.

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