Pak. J. Sci. Ind. Res. 2008 **51**(5) 258-263

Studies on Textile Sludge Treatment Options

Imohimi O. Asia
Department of Chemistry, Ambrose Alli University, P. M. B. 14, Ekpoma, Nigeria

(received August 8, 2008; revised September 9, 2008; accepted September 9, 2008)

Abstract. Analysis of sludge samples of a textile processing factory revealed that the BOD and COD as well as the levels of total solids, nitrogen and phosphorus contents of sludge liquor were high needing treatment before disposal or reuse. Detention time of 60 days was established for aerobic treatment of the sludge. Optimum dosage for physico-chemical methods were established at 4 g/l, using alum and iron III chloride each and 15.5 g/l and 550 mg/l, for lime and polyelectrolyte each. Solids were reduced by 67%, through aerobic and 61% through anaerobic digestion, while the sludge treated by physicochemical method had higher solid content, recording the highest increase with lime.

Keywords: textile sludge treatment, pollution, aerobic sludge treatment, anaerobic sludge treatment

Introduction

Environmental pollution is causing widespread concern and has become an important area of interest in the field of modern research. The costs of pollution control are extremely high. Steward and Towse, back in 1984, estimated the annual cost in the United States alone, to be close to 5 billion dollars, in addition to occurrence of thousands of deaths and diseases due to pollution. Industries produce huge amounts of wastes. Careless disposal of these wastes to the environment without treatment threatens natural habitat and poses real dangers to humans, flora and fauna. Thus it is highly necessary to know the composition of individual wastes and develop the most economical way to treat all wastes (wastewaters and sludge), recycle the water, reclaim the waste chemicals and find possible applications of the treated wastes so as to ensure a safe environment.

The present research work is aimed at characterizing sludge of selected industries, assessing the degree of pollution caused by the sludge, developing simple and efficient treatment methods helpful in determining the efficiency of treatment of the sludge in terms of solid reduction, BOD and COD reduction, nitrification and denitrification, reuse or applicability of the treated sludge, the disposal option(s) most convenient for the unused waste and assessing the efficiency of the treatment methods adopted for particular sludge and for end-use applications.

Materials and Methods

Industrial sludges. The sludge used in this study was obtained from a textile processing factory located in Isolo, Lagos which manufactures mostly cotton fabrics. Main products of the factory are superprint, guarantee-superprint and minibrocade. The factory consists of various departments, which carry out different operations and produce different types of wastewater, containing acids used in desizing and dyeing and bases like caustic soda used in scouring and mercerization. They also contain inorganic chlorine compounds and other oxidants e.g., hypochlorite of sodium, hydrogen peroxide and peracetic acid used for bleaching and other oxidative applications. Organic compounds were also present e.g., dyestuff, optical bleachers, finishing chemicals, starch and related synthetic polymers used for sizing and thickening, surface active chemicals used as wetting and dispersing agents, and enzymes for desizing and degumming. Heavy metal salts present included e.g., copper, zinc salt and iron (III) chloride used as printing ingredients. All these wastes are passed into an effluent tank and then into a drainage system as shown in the flow chart (Fig.1).

Sampling of sludge. Composite samples of the sludge were obtained from primary sedimentation tanks of the factory

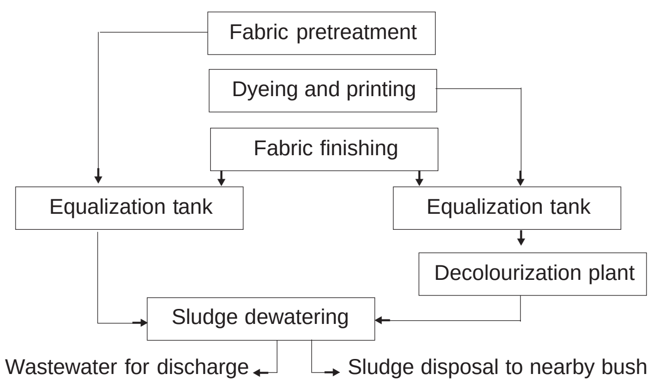

Fig. 1. Flowchart: Processing of a textile factory at Isolo Lagos, Nigeria.

*Author for correspondence; E-mail: imoasia2000@yahoo.com

Seven plastic bowls of one litre capacity each were used to collect samples manually over 12 h sampling period, at 2 h intervals during 7. 00 a.m. to 7.00 p.m- this being the peak (optimum) period for work and sampling was the most convenient during this period.

Composite samples were collected from the factory once a week for seven weeks and analyzed. If analysis could not be carried out immediately, samples were preserved in a refrigerator maintained at 4 °C. At this temperature, biodegradation is inhibited.

Samples were collected on different week days to account for the cyclic and intermittent variations occurring at the work site.

Treatment of sludge. Sludge samples were treated employing different methods *viz*., aerobic, anaerobic, physicochemical, combined aerobic/physicochemical and combined anaerobic/physicochemical methods. (Asia *et al.*, 2006 ; Asia and Ademoroti, 2005, 2004, 2002; Asia and Oladoja, 2003; Asia, 2000).

Methods of analysis. All samples were analyzed as described by Ademoroti (1996) and APHA (1995). When immediate analysis was not possible, the samples were preserved at 4 °C to inhibit biodegradation.

All the reagents used for the analysis were of analytical grade and obtained from BDH Chemicals Ltd., Poole, England.

Results and Discussion

Characteristics of fresh sludge are shown in Table 1 and 2. Fresh sludge was alkaline with the pH of 8.91 and had specific gravity of 1.01, showing high moisture content (97%) i.e., 3% solid concentration. The turbidity of 2460 NTU indicates large amount of colloidal matter or high solid concentration. The high turbidity may be due to colour impact of various dyes used for fabric dyeing. Also, the total, suspended and volatile solids were relatively high. The sludge contained 6500 mg/kg TS, 3158 mg/kg SS and 4150 mg/kg VS; BOD and COD were 550 and 1694 mg/l, respectively; COD:BOD ratio was 3.08, This indicates that the sludge is capable of undergoing about 50-90% substrate biodegradation. Organic matter can undergo about 50-90% substrate biodegradation if its COD**:** BOD ratio ranges between 2 and 3.5 (Quano *et al.*, 1978); thus, aerobic and anaerobic digestion of the sludge by biological methods is possible. The conductivity values of 148 S/cm indicates presence of mobile ions suggesting that physicochemical method can be as well used for treatment of the sludge.

Nitrogen present in the sludge is more in ammoniacal form (Table 1). Consequently, if such a sludge is discharged to the environment, depletion in the oxygen resources of the

Table 1. Characteristics of fresh sludge liquor of textile processing factory

Sludge liquor characteristics	Unit	Range of values	Mean
pH	-	8.10-9.85	8.91
Temperature	°C	27.0-29.5	28
Conductivity	S/cm	140-160	148
Specific gravity	-	1.0-1.02	1.01
Turbidity	NTU	2100-2650	2460
DO	mg/1	1.50-3.50	2.8
BOD	mg/1	412-669	550
COD	mg/1	954-1932	1694
Total alkalinity	mg/1	720-1050	920
Hydrogen carbonate alkalinity	mg/1	58-80	70
Ammonia nitrogen	mg/1	25.6 -40.1	31.5
Nitrate nitrogen	mg/1	22.4-32.1	27.4
Organic nitrogen	mg/1	14.3-21.7	19.4
Chloride	mg/1	112-134	121
Sulphate	mg/1	108-130	123.4
ABS	mg/1	76.3-109.7	90
Total bacterial count	-	(3.5-4.0) x 10^6	37 x 10^6

Table 2. Characteristics of fresh settled sludge of textile processing factory

Sludge liquor characteristics	Unit	Range of values	Mean
Settleable solids	mg/kg	2990-3350	3158
Moisture	%	95-98	97
Volatile solids	mg/kg	3700-5400	4150
Total solids	mg/kg	4500-8700	6500
Ash	%	17.8-37.8	36.2
Total nitrogen	mg/kg	39.9-61.8	50.9
Phosphorous	mg/kg	3.8-6.2	5.14
Potassium	mg/kg	4.2-6.7	4.7
Oil and grease	mg/kg	160-240.3	198.7
Iron	mg/kg	0.68-1.06	0.90
Calcium	mg/kg	18.0-26.30	23.5
Magnesium	mg/kg	18.6-23.4	20.3
Manganese	mg/kg	nil	nil
Copper	mg/kg	0.2-2.5	1.2
Cadmium	mg/kg	nil	nil
Chromium	mg/kg	nil	nil
Lead	mg/kg	nil	nil
Zinc	mg/kg	2.5-5.0	3.7

receiving water may occur through oxidization of ammonia to nitrate by some groups of bacteria. This necessitates appropriate treatment of sludge before its discharge. Thus the resulting nitrates and phosphates (inorganic nutrients) could be a boost to the plant and the algal growth. Concentrations as low as 0.01 mg/l of phosphorous and 0.1 mg/l of nitrate may be sufficient for eutrophication when other elements are in excess (Henry and Heinke, 1989).

Effect of sludge age on pH during aerobic digestion. The effect of age of sludge on its pH during aerobic digestion is shown in Fig. 2. The sludge detention time for textile processing sludge was 60 days. The steady pH during this period was due to complete stabilization during aerobic biodegradation. Sludge detention time is dependent on temperature and hence on the climatic conditions prevailing in the area.

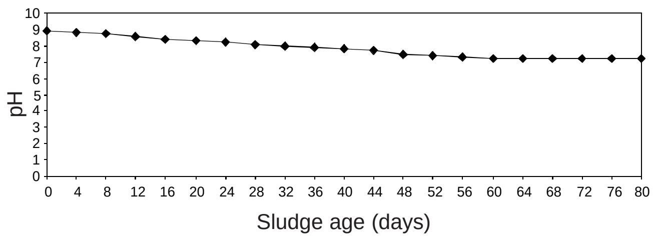

Fig. 2. Sludge age determination.

Characteristics of aerobic and anaerobic digested sludge. Some parameters that affect biological processes are shown in Table 2. A pH drop was observed for the sludge treated by aerobic and anaerobic biological methods. After digestion, it was found that pH of the sludge dropped from 8.91 to 5.81 and from 8.91 to 5.60 for aerobic and anaerobic systems, respectively. The drop in pH could have occurred due to the digestion products. Two products of aerobic digestion suspected for lowering the digester pH are carbon (IV) oxide and hydrogen ions.

$$C_5H_7NO_2 + 7O_2 + \text{bacteria} \rightarrow 5CO_2 + 3H_2O + NO_3 + H^+$$

In the case of anaerobic system, the depression in pH was due to the volatile acids released into the digestion medium. The microbes in the digester convert the organic content of the sludge to lower molecular weight organic acids principally ethanoic and propanoic acids and consequently to carbon (IV) oxides, which dissolve in water to give trioxocarbonate (IV) acid (H_2CO_3).

The reaction products (acids and CO_2) raise the acidic levels in the digester thereby lowering the pH.

Optimum coagulants/flocculant dosages for sludge treatment. Fig. 3a-d show the optimum coagulant/flocculant dosages needed for the treatment of the sludge. For quick

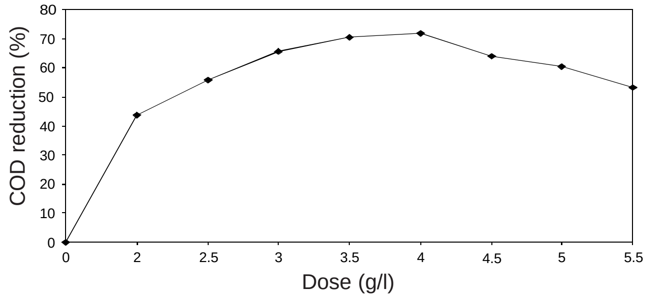

Fig. 3a. Optimum dosage determination using alum.

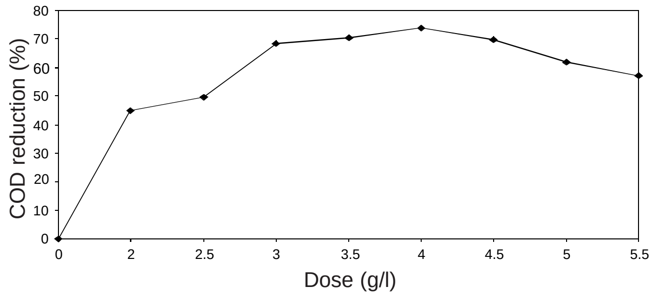

Fig. 3b. Optimum dosage determination using iron (III) chloride.

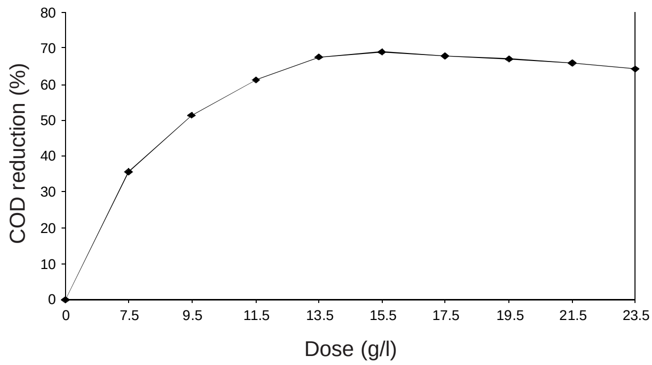

Fig. 3c. Optimum dosage determination using lime.

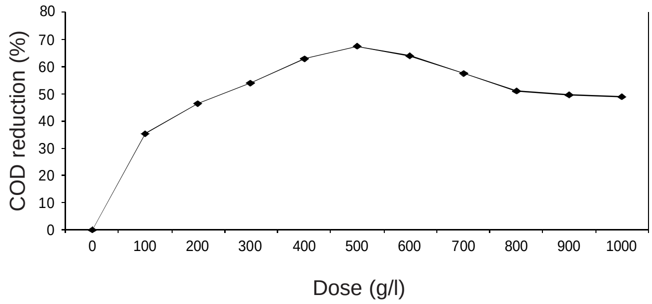

Fig. 3d. Optimum dosage determination using polyelectrolyte.

analysis, COD was chosen to assess the degree of treatment as there is a correlation between COD on one hand and BOD, SS and TS on the other hand (Ademoroti, 1980). The optimum coagulant dosages established were 4g/l for alum and iron (III) chloride, each, 13.5 g/l for lime and 550 mg/l for polyelectrolyte.

The solids. The amount of solids present in raw sludge and sludge treated aerobically, anaerobically, physicochemically and by combined methods are shown in Fig. 4.

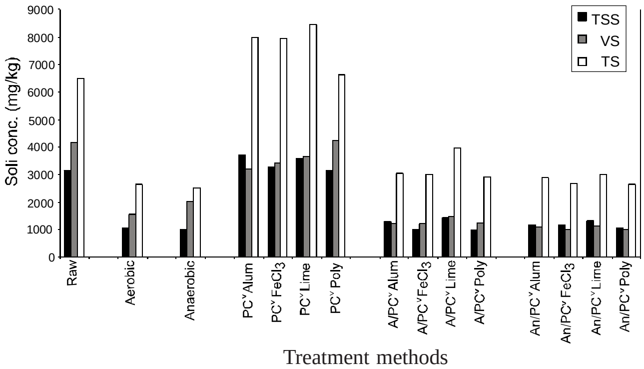

Fig. 4. Amount of solids in raw and treated textile sludge.

Solid reduction of about 59% TS, 67% SS and 62% VS were achieved for aerobic system and 61% TS, 68% SS and 51% VS, for anaerobic system. The ash produced here was 38% and 33% of total solids for aerobic and anaerobic processes, respectively.

The products of the anaerobic digestion process are methane gas and carbon (IV) oxide; both are burnable gases termed biogas which, if harnessed, may be used as useful fuel for heating purpose and for powering industrial plants.

Oxygen demand values. The results of the oxygen demand concentrations of raw and treated sludge are shown in Fig. 5. The BOD and COD values of fresh sludge of textile processing industry were 550 and 1694 mg/l, respectively. However, after aerobic treatment, BOD and COD reduction of about 87 and 90%, was respectively achieved.

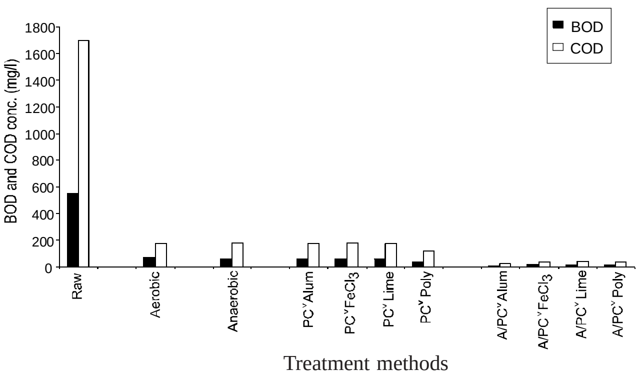

Fig. 5. BOD and COD of raw and treated textile sludges (mg/l).

The anaerobic systems yielded a BOD and COD reduction of 89 and 90 percent, respectively.

Nitrogen amount. Nitrogen content of raw and treated textile sludge was 66.8 and 50.9 mg/l, respectively (Fig.6). Aerobic treatment of the sludge resulted in about 33-49% reduction. This could have resulted from oxidation of some ammonium nitrogen (which contributed substantially to the total nitrogen) to nitrate through nitrification, raising the nitrate level of aerobically treated sludge.

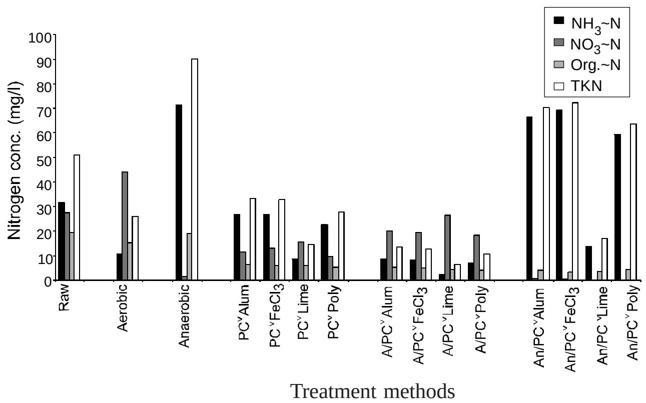

Fig. 6. Nitrogen concentration of raw and treated textile sludge (mg/l).

The anaerobic treatment method increased the total nitrogen content of the sludge. The increase in total nitrogen in the case of the anaerobic system may be attributed to the addition of (urea), a nutrient supplement also for the microbial population in the processed sludge enabling completion of the digestion process.

Phosphorus concentration. Results for phosphorus concentrations of treated sludge (liquor and cakes) are shown in Fig. 7. Sludge treated through biological aerobic systems had higher phosphorous concentrations while the concentration in the liquor decreased to the tune of 5-12 percent. On the other hand, the anaerobically treated sludge had significant reduction of about 37-53 percent in the sludge cake while the liquor was heavily laden with phosphorous with an increase of about 55-64 percent. This may be attributed to the solubilization of phosphorus during anaerobic digestion process. Pitman (1992) and Pitman *et al.* (1991) confirmed that sludge handling liquors from biological nutrient removal plants with anaerobic digesters contained high phosphorus concentrations.

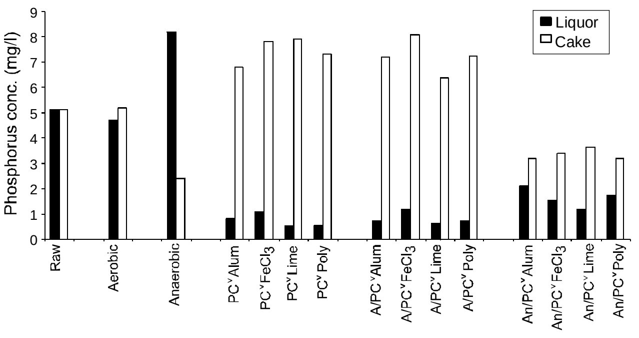

Fig. 7. Phosphorus concentration of raw and treated textile sludge (mg/l).

NPK (fertilizer) values. The levels of nitrogen, phosphorus and potassium have to be critical if the sludge is to be used for agricultural purposes (Sommers, 1977). The fertilizer value of sludge is detected by the percentage concentration of nitrogen, phosphorus and potassium (NPK); typical NPK fertilizer has a composition of 8% N, 8% P and 8% K. It may be difficult to achieve these levels of nutrients in sludge. It was observed that the studied sludge had definite fertilizer values (Fig. 8). It had a concentration of 2.6% N, 0.5% P and 0.6% K. The anaerobically digested sludge had N,P,K concentrations of 9%, 0.2% and 0.5%, respectively. If these nutrient concentrations are improved through some suitable complementary method such as composting, the sludge could be used to fertilize and condition soil. Humid material in the sludge improves the physical properties and cation exchange capacity of the soil.

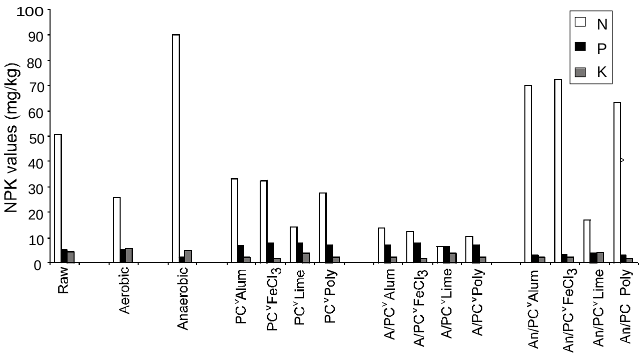

Fig. 8. NPK concentration of raw and treated textile sludges (mg/l).

Physicochemical method of treatment. *The solids.* The quantities of sludge were found to increase for all coagulants used in the treatment. A common trend noticed was that the lime treated sludge had more quantity of solids than the alum treated one, which in turn had more solids than iron (III) chloride treated sludge. Polyelectrolyte treated sludge had only a marginal increase in the sludge solids. The increase in total solids (TS) was in the range of 14-23.7 percent for iron (III) chloride treated sludge, 21-25 percent for alum and 25-29.5 percent for lime treated one. Suspended solids (SS) also increased in the range of 4.2-19.7 percent for iron (III) chloride, 17.5-24.3 percent for alum and 14-25.9 percent for lime treated sludge. Volatile solids (VS), however, decreased in all types of sludge treated with chemical coagulants. Polyelectrolyte flocculant, however, improved the volatile content of sludge, thereby enhancing the biogas (fuel value) production of the sludge.

Oxygen demand values. The percentage BOD and COD reduction achieved in the physicochemical method was in the range of 88-92.6 and 89-92.8 percent, respectively. The phy-sicochemical methods were more effective in terms of BOD and COD removal than the biological systems (Fig.5).

Nitrogens amount. The total Kjeldahl nitrogen (TKN), ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_3-N) and organic nitrogen (org.-N) were reduced in all the samples, more being in the sludge treated with lime.

Phosphorus concentration. The sludge solids contained higher concentration of phosphorus than the fresh sludge while the liquors were almost free of phosphorus (Fig. 7). About 90-93 percent phosphorus was removed from the liquor.

NPK values. Physicochemically treated sludge had little fertilizer values. However, the fertilizer values of raw sludge were higher than the physicochemically treated one.

Combined biological and physicochemical methods of treatment: *The solids.* It was found that the combined aerobic/physicochemically treated sludge had solid reduction ranging from 19.4-27.8 percent total solids, 27-35 percent suspended solids and 36-49 percent volatile solids.

Percentage solid reduction achieved using combined aerobic/physicochemical treatment of sludge was not as high as either the aerobic or the anaerobic method and so, for reduction in sludge quantity, either of the biological methods is more promising than the combined one.

The anaerobic/physicochemical method resulted in better solid reduction comparable to the combined aerobic/physicochemical method, the former being in the range of 26.2-29.4 percent TS, 24-28.4 percent SS and 31.3-37 percent VS; however, this method may not be preferred to any of the biological methods in terms of solid reduction. The lime treated biological sludge had the least amount of solids reduced.

Oxygen demand values. The combined biological and physicochemical treatment methods proved more efficient than either the biological or the physicochemical method individually in terms of BOD and COD reduction. About 96.1-98.2 percent BOD and 96.8-98.4 percent COD reduction was achieved for aerobic/physicochemically treated sludge, while 96.8-98.8 percent BOD and 96.8-98.9 percent COD reduction was achieved by the combined method.

Nitrogen. There was considerable reduction in the nitrogen content of the treated sludge. The highest reduction was noticed in lime treated aerobic sludge. Ammonia nitrogen reduction of this sludge was about 85.2-93.3 percent. This may be due to the nitrification process during the digestion stage while ammonia was further reduced by the physicochemical treatment. Total nitrogen was also reduced in the sludge using the combined aerobic/physicochemical method, in the range of 74.5-87.6 percent. The highest reduction occured in the lime treated aerobic sludge thus lime is a better coagulant for nitrogen removal from aerobically digested sludge.

In combined anaerobic/physicochemically treated sludge, ammonia nitrogen concentration increased considerably with other coagulants and was reduced in lime treated anaerobic sludge whereas nitrate nitrogen was reduced to zero.

Phosphorus**.** The results revealed that, the combined anaerobic/physicochemical method can be used to reduce phosphorus both in the sludge cake and in the liquor. This method is the best choice if complete disposal of sludge is intended with removal of nitrates and phosphates.

NPK values. Sludge treated by combined anaerobic/physicochemical method had reduced NPK concentration, (Fig. 8) lower even than the raw sludge. Therefore, for improvement in fertilizer value, this method is not recommended.

Conclusion

Proper sludge management requires an understanding of the place of origin of the sludge within the wastewater treatment process, the age and characteristics of the sludge, various methods available for sludge treatment, the economic potential of treated and untreated sludge and the disposal options available for the unused waste.

The final destination of the sludge will determine degree of the treatment required and the effect on the environment.

For landfill, composting, brick making and incineration, it is unnecessary and undesirable to biologically digest the sludge as heat value of the sludge might be lost as biogas.

For land application of sludge, physicochemical treatment offers a very promising result as sludge solids contain substantial amount of adsorbed phosphate as apatite e.g., calcium hydroxyl apatite, $Ca_5OH\ (PO_4)_3$ in the lime treated sludge.

Biological treatment methods (aerobic and anaerobic) can be used to reduce the quantity of solids in the sludge generated by industrial processes before disposal.

Aerobic biological method and the combined aerobic/physicochemical method are good options for ammonia reduction. The anaerobic method is the best if phosphorous removal from sludge solids is intended before disposal of the solids.

The basic nutrients in sludge, nitrates and phosphates are best removed by the combined anaerobic/physicochemical method. Thus, for prevention of eutrophication of water bodies, this method of treatment is more promising.

References

Ademoroti, C.M.A. 1996. *Standard Method For Water and Effluents Analysis*, Foludex Press Ltd., Ibadan, Nigeria.

Ademoroti, C.M.A. 1980. The effect of pH on wastewater purification. *Effl. Wat. Treat. J.* **20:** 541-549.

APHA 1995. *Standard Methods for the Examination of Water and Wastewaters*, 19th edition, American Public Health Association, Washington DC., USA.

Asia, I.O., Oladoja, N.A., Bamuza-Pemu, E.E. 2006. Treatment of textile sludge using anaerobic technology. *African J. Biotechnol.* **5:** 1678-1683.

Asia, I.O., Ademoroti, C.M.A. 2005. Combined aerobic/physicochemical treatment of pharmaceutical sludge. *Pak. J. Sci. Ind. Res.* **48:** 322-328.

Asia, I.O., Ademoroti, C.M.A. 2004. Integrated biological/chemical treatment of brewery sludge. *Pak. J. Sci. Ind. Res.* **47:** 281-291.

Asia, I.O., Oladoja, N.A. 2003. Determination of optimum dosage of chemical coagulants/flocculants needed for sludge treatment. *J. Sci. Eng. Technol.* **10:** 5031-5043.

Asia, I.O., Ademoroti, C. M. A. 2002. Mesophilic anaerobic treatment of brewery sludge. *World J. Biotechnol.* **3:** 568-577.

Asia, I.O. 2000. Studies on Industrial Sludge Treatment Options. *Ph.D. Thesis*. University of Benin, Nigeria.

Henry, J.G., Heinke, W.G. 1989. *Environmental Science and Engineering*, Eaglewood Cliffs, New Jersey, USA.

Pitman, A.R. 1992. *The Handling of Sludge Liquors*, Paper Presented at the IAWPRC Study for Biological Nutrient Removal and Anaerobic Digestion. Johannesburg, S. Africa.

Pitman, A.R., Deacon, S.L., Alexander, W.V. 1991. The thickening and treatment of sewage sludges to minimize phosphorous release. *Water Res.* **25:** 1285-1294.

Quano, E.A.R., Lohani, B.N., Thanh, N.C. 1978. *Water Pollution Control in Developing Countries*, 567 p, AIT.

Sommers, L.E. 1977. Chemical composition of sewage sludge and analysis of their potential use as fertilizers. *J. Environ. Qual.* **6:** 225-232.

Steward, J.W., Towse, P.J. 1984. *Chemical Technology in Africa: A Resource Book*, Ist edition, Cambridge University Press, London, UK.