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Full Length Research Paper

Economic importance and application options of some industrial sludge conditioned by different treatment methods

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Industrial sludge was obtained from four industries: aluminium extrusion, brewery, pharmaceutical and textile processing factory and treated by aerobic, anaerobic, physicochemical, combined aerobic/physicochemical and combined anaerobic/physicochemical methods. The results showed that the final destination of the sludge would determine the type and degree of treatment required for the sludge. Physicochemical method generally increases the quantity of sludge solids, thus making the sludge suitable for land reclamation; also, the firmer and denser floc characteristics of the physicochemicallly treated sludge makes the methods a better alternative if conditioned sludge are to be used to reinforce cement for brick making. Biological treatment methods (aerobic and anaerobic) can be used to reduce the quantity of sludge before disposal. Solids destruction is closely related to biogas production. If using sludge as a source of fuel is the focus, the anaerobic biological system may be the best option. Aerobic biological method and the combined aerobic/physicochemical methods are good options for ammonia reduction. Anaerobic biological method is best for improving the nitrogen content and hence the protein content of sludge so as to use the waste sludge as feeds for poultry birds and livestock. Economic values, application and disposal options of the various sludge are discussed.

Key words: Industrial sludge, treatment, economic importance, reuse, application, disposal.

INTRODUCTION

Processing and disposal of sludge that is economical and environmental friendly is currently of great importance to local authorities and industry. The disposal or reuse of sludge is a significant part of wastewater treatment programme. The method of sludge disposal or reuse of sludge and the required quality of treated sludge and effluent influence the selection and operation of the various unit processes. The existing methods of sludge treatment consist of various combination of biological (aerobic and anaerobic) physical, chemical, and physicochemical.

Disposing sludge is not guaranteed to be without any difficulty because the disposal options required at a time may not be feasible (Bergs and Radde, 1996); that is why there is increasing agitation for sludge use or application. Often treated sludge is a resource that can be beneficially used in more than one way. Such use options might include agricultural or industrial reuse by the discharging community or direct discharge to support the aquatic environment of the receiving water.

It is necessary to change the image of sludge and sludge treatment, from a “troublesome” into a “valuable” product. One way of helping to achieve this is to view sludge as a waste product of city activities rather than as by-product of wastewater treatment. There then becomes necessary to develop a sludge treatment system based on the perception of sludge as a valuable city waste product collected through the normal sewage system. After sludge has been treated, it must be used or disposed of in an environmentally acceptable manner. Selecting the best utilization or disposal options requires analysing the sludge end products for their impact on the environment

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as well as their costs. There are potential benefits from using sludge end products. Organic matter in sludge may enhance soil quality. Also, chemical elements such as nitrogen, phosphorus, and potassium may supply nutrients for plant growth, and the heat value of sludge may supplement fossil fuels. This work is intended to determine the economic values of some industrial sludges including ash contents, protein content, fertilizer content and fuel values and streamline the areas to which they can be applied or the disposal options available.

MATERIALS AND METHODS

Sources of sludge

The sources of industrial sludges used were aluminium extrusion factory, brewery, pharmaceutical and textile processing factory (bleaching, dyeing and printing (BDP) wastes).

Analyses

The sludge under study was characterized [results are published elsewhere (Asia, 2000; Asia and Ademoroti, 2002; Asia and Oladoja, 2003)] and subjected to different treatment methods, aerobic, anaerobic, physicochemical, combined aerobic/ physicochemical and combined anaerobic/physicochemical [results are also published elsewhere (Asia, 2000; Asia and Ademoroti, 2002; Asia and Oladoja, 2003; Asia and Ademoroti, 2004; Asia and Ademoroti, 2005; Asia et al., 2006a; Asia et al., 2006b; Asia et al., 2006c)]. All samples were analyzed as described in the Standard Methods for the Examination of Water and Wastewater (APHA, 1995) and Standard Methods for water and effluents analysis (Ademoroti, 1996). Where analysis was not immediately possible, they were preserved. The economic values of sludge were determined as follows.

Ash content

The total and volatile solids of sludge samples were determined as described in standard methods (APHA, 1995). The difference between the total solids and the volatile solids gives the weight of ash and was expressed in percentage as follows:

Ash (%) = (wt of ash/wt of total solids) x 100
or

Ash (%) = 100 – Volatile solids (%) (Asia, 2000, 2002)

Protein values

This was determined by multiplying the total nitrogen as determined by the Kjeldahl method by 6.25 (Allen, 1974; APHA, 1995; Dinsdale et al., 1996; Asia, 2000)

Fertilizer value

Total nitrogen, phosphorus and potassium were determined using the standard method (APHA, 1995). The fertilizer value of sludge is the concentration of N, P, K expressed as percentage.

RESULTS AND DISCUSSION

Sludge could be considered a waste, but if properly sterilized, it can be of economic value to man and livestock because of its (I) ash value (2) food value, (3) fertilizer value and (4) fuel value. The results of the ash contents, protein contents and the fertilizer values (NPK) of the sludge studied are presented in Figures 1-3.

Ash value

The ash obtained from the incineration of sludge is high in inorganic mineral content and can be used in filling landscapes in mined areas. Figure 1 shows that the ash content obtained from the various sludge ranges from 63.63 – 83.25% for aluminium extrusion sludge, 22.69 – 54.97% for brewery, 22.85 – 69.05% and 19.76 – 62.64% for pharmaceutical and textile sludges, respectively. These ashes have also been used in the ceramics industry for making special wares (Stocchi, 1990).

Food value

Figure 2 shows that the protein content of fresh sludge estimated to be 363.4, 468.8, 417.5 and 318.1 mg/kg for aluminium extrusion, brewery, pharmaceutical and textile sludges, respectively, were found to decrease greatly for all aerobically treated sludge, while for sludge treated by anaerobic method, the protein content increased substantially. The protein contents of the anaerobically treated sludge were found as follows: for aluminium sludge 419.4 mg/kg; for brewery 603.8 mg/kg; for pharmaceutical 558.3 mg/kg; and for textile processing sludge, 564.4 mg/kg. Protein contents were estimated by multiplying total nitrogen as measured by the Kjeldahl method by 6.25 (Allen, 1974; Dinsdale et al., 1996). This observation is in line with report from researchers 'that' sludge has food value (Rudolf, 1953; Dean and Bouthilet, 1972). These results show that anaerobic treatment can be used to improve the protein level of sludge. If anaerobically treated sludge is detoxified properly, they could be used as feed for poultry birds and livestock. The anaerobic treatment method offers the best alternative in improving the protein content of sludge.

Fertilizer value

A good percentage of nitrogen, phosphorus and potassium in sludge make them valuable for agricultural production (David, 1990). Such sludge is spread on land surface and when they decompose can serve as a source of those minerals and as manure to plants. The carbon dioxide released under plants may boost their growth. Any ammonia nitrogen is oxidized to nitrate nitrogen which is readily available to plants. The fertilizer

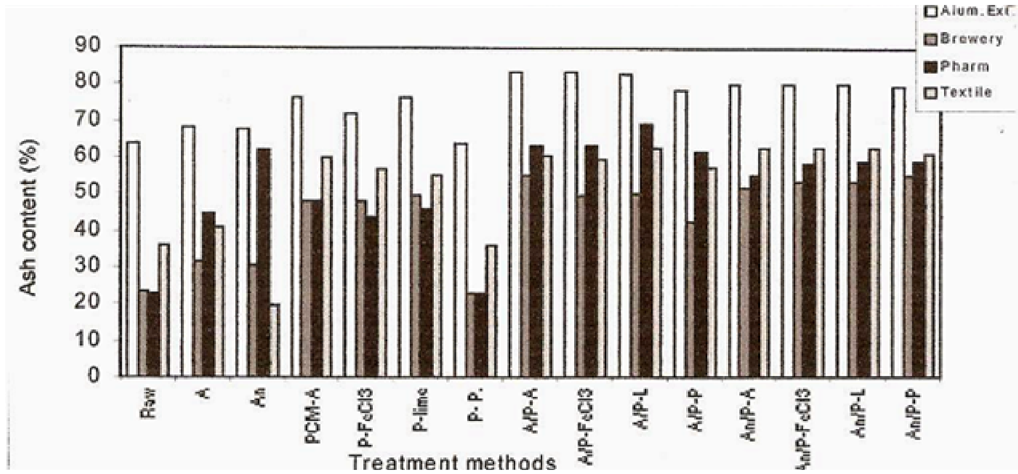

Figure 1. Ash contents of sludge (%). A = Aerobic; An = Anaerobic; PC-Alum = Physicochemical treatment with alum as coagulant; PC-$FeCl_3$ = Physicochemical treatment with iron (III) chloride as coagulant; PC-Lime = Physicochemical treatment with lime as coagulant; PC-Poly = Physicochemical treatment with polyelectrolyte as flocculant; A/PC~Alum = Aerobic/physicochemical treatment with alum as coagulant; A/PC-$FeCl_3$ = Aerobic/physicochemical treatment with iron (III) chloride as coagulant; A/PC-Lime = Aerobic/physicochemical treatment with lime as coagulant; A/PC-Poly = Aerobic/physicochemical treatment with polyelectrolyte as flocculant; An/PC~Alum = Anaerobic/physicochemical treatment with alum as coagulant; An/PC-$FeCl_3$ = Anaerobic/physicochemical treatment with iron (III) chloride as coagulant; An/PC-Lime = Anaerobic/physicochemical treatment with lime as coagulant; and An/PC-Poly = Anaerobic/physicochemical treatment with polyelectrolyte as flocculant.

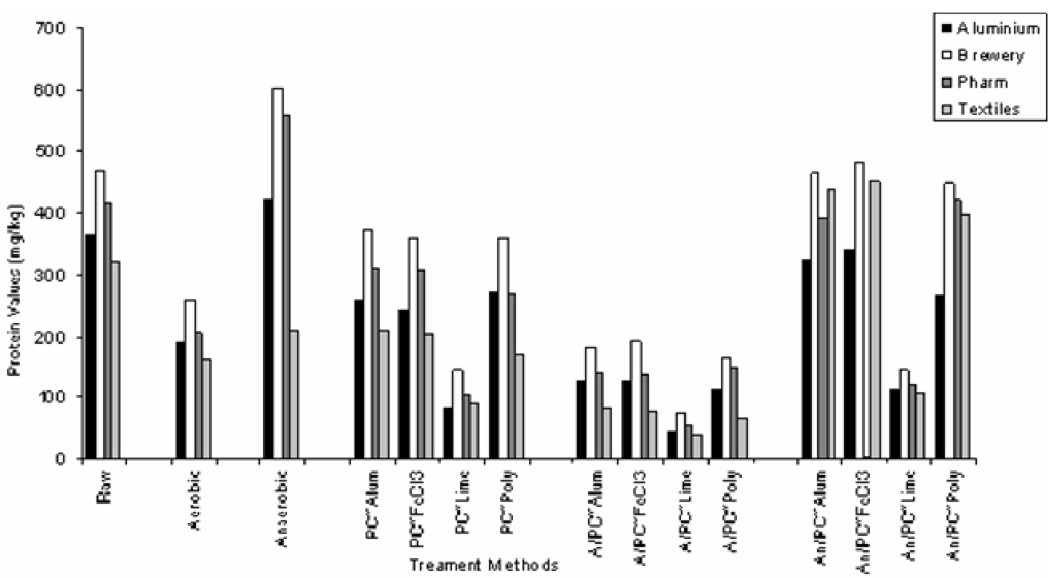

Figure 2. Protein values of raw and treated sludge (mg/kg). A = Aerobic; An = Anaerobic; PC-Alum = Physicochemical treatment with alum as coagulant; PC-$FeCl_3$ = Physicochemical treatment with iron (III) chloride as coagulant; PC-Lime = Physicochemical treatment with lime as coagulant; PC-Poly = Physicochemical treatment with polyelectrolyte as flocculant; A/PC~Alum = Aerobic/physicochemical treatment with alum as coagulant; A/PC-$FeCl_3$ = Aerobic/physicochemical treatment with iron (III) chloride as coagulant; A/PC-Lime = Aerobic/physicochemical treatment with lime as coagulant; A/PC-Poly = Aerobic/physicochemical treatment with polyelectrolyte as flocculant; An/PC~Alum = Anaerobic/physicochemical treatment with alum as coagulant; An/PC-$FeCl_3$ = Anaerobic/physicochemical treatment with iron (III) chloride as coagulant; An/PC-Lime = Anaerobic/physicochemical treatment with lime as coagulant; and An/PC-Poly = Anaerobic/physicochemical treatment with polyelectrolyte as flocculant.

value of sludge is detected by the percentage concentrations of nitrogen, phosphorous and potassium (NPK); a 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. From the results of NPK concentrations in Figure 3a-d, it is observed that the sludge studied definitely do have fertilizer values.

Aluminium extrusion sludge after aerobic treatment had N, P and K concentrations of 3.0, 0.4 and 0.2%, respectively. Brewery sludge had 4.1% N, 2.0% P and 0.6% K. Pharmaceutical sludge had 3.3% N, 1.5% P and 1.4% K and textile processing sludge had a concentration of 2.6% N, 0.5% P and 0.6% P. The results of the anaerobically digested sludge indicate that aluminium extrusion sludge had 6.7% N, 0.3% P and 0.2% K, brewery sludge had 9.7% N, 0.9% P and 1.4% K, pharmaceutical sludge had 8.9% N, 0.9% P and 0.5% K, while textile processing sludge had an N, P and K concentration of 9, 0.2 and 0.5%, respectively. If these nutrients concentration are improved upon by a suitable complementary method such as composting, they can be used to fertilize and conditions soil. The humid material in the sludge improves the physical properties and cation exchange capacity of the soil.

Fuel value

When sludge is digested anaerobically, methane (65%) and carbon (IV) oxide (20%), both burnable gases termed bio-gas is produced. This can be harnessed and utilized as fuel of high calorific value (23 Mj/kg) for domestic and industrial purposes (Tripathi and Allen, 1999). If sludge undergoes pyrolysis (incineration) either in a multiple hearth furnace or in a fluidized bed, it generates a large amount of heat energy (caloric value = 1000 BTUs/pound = 19.4 Mj/kg) (Metcalf and Eddy, 1979) that can be utilized for heating other furnaces.

Application options for sludges treated by the various methods

Land application of sludge may require some form of stabilization and disinfection to meet regulatory requirements. Stabilization renders the sludge non-putrescible and inactivates pathogenic organisms. If sludge is to be used for land application, chemical treatment offers a very promising result as sludge solids contain substantial amount of adsorbed phosphate in the form of apatite e.g. calcium hydroxyl apatite, $Ca_5OH\ (PO_4)_3$ for lime treated sludge. These render the sludge liquor free of these nutrients which may not be desirable if liquor is to be discharged into water bodies, thus, preventing the eutrophication of water bodies. Lime treatment particularly offers the best alternative among the chemicals that were used for treatment. This is because, lime, apart from having higher concentration of phosphate in the sludge solids, prevent odours, has a disinfecting action, increases the agricultural value of the sludge and also neutralizes toxic heavy metals, if present.

Physicochemical method generally increases the quantity of sludge solids. The trend is that lime treated sludge had more solids than alum; alum in turn had more solids than iron (III) chloride, while polyelectrolyte had only a marginal increase in sludge solids. The physicochemical method of treatment appears to be the best option if the sludge is to be used for land reclamation. This is because the large quantity of sludge generated during such treatment processes are needed to fill and reclaim the land. The firmer and denser floc characterristics of the physicochemically treated sludge makes the method a better alternative if conditioned sludge is to be used to reinforce cement for brick making. Physicochemical method proves more effective in terms of BOD and COD removal than the biological systems for aluminum extrusion sludge. The biological methods reduce BOD and COD better for brewery and pharmaceutical sludge, while for textile processing sludge, both methods performance are almost the same. That is, the extent of BOD and COD removal by either the biological or the physicochemical methods is dependent on the industrial sludge being treated. Polyelectrolyte, as a conditioner, is more effective than the inorganic chemical conditioners for BOD and COD reduction.

Biological treatment methods (aerobic and anaerobic) can be used to reduce the quantity of sludge generated by industrial processes before disposal. If sludge treatment is intended to reduce the quantity of solids before disposal, the biological methods offer the best alternative.

Solids destruction is closely related to biogas production. If using sludge, as a source of fuel is the focus, the anaerobic biological system may be the best options. Large amount of methane and carbon (iv) oxide gases, which if harnessed can serve as valuable fuels are produced as biogas by this method.

Aerobic biological method and the combined aerobic/physicochemical method are good options for ammonia reduction. Ammonia is toxic to fish, nitrification through aerobic treatment and reductions through the combined aerobic/physicochemical treatment are inexpensive methods for ammonia reduction before disposal. But if sludges are to be used for irrigation or agricultural purposes, nitrification is desirable and aerobic biological system is the best option as it ensures improvement in the nitrate content of sludge.

Anaerobic biological method is best for improving the nitrogen content of sludge. If treatment is aimed at enhancing the food (protein) value of sludge, so as to use the waste sludge as feeds for poultry birds and livestock, the anaerobic method is therefore a more promising option. The anaerobic method also, is the best option if phosphorous removal from sludge solids is intended before disposal of the solids. Also, if improvement in phosphorous concentration is desired so as to use the

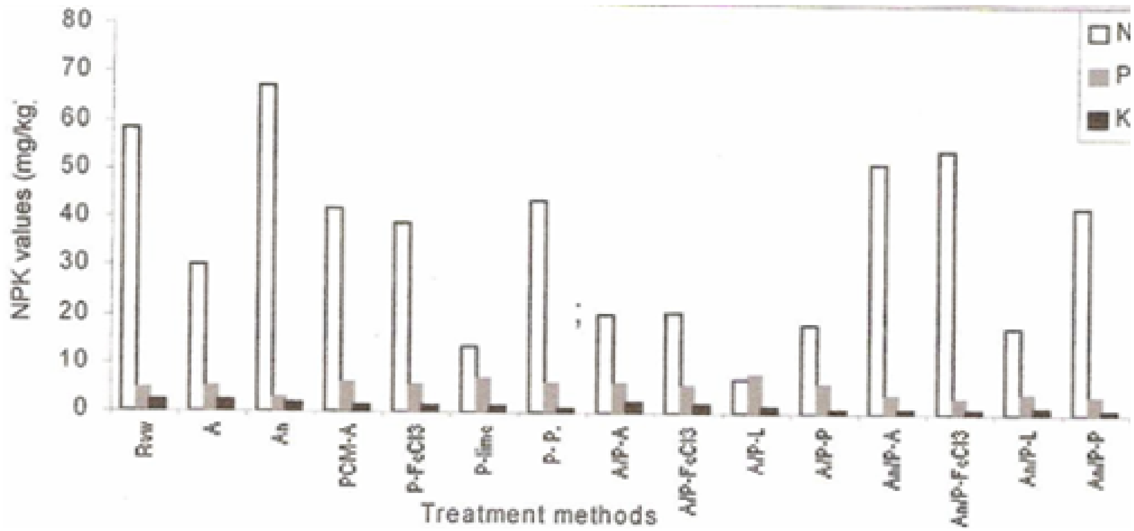

Figure 3a. NPK values of sludge from the aluminium extrusion factory (mg/kg). A = Aerobic; An = Anaerobic; PC-Alum = Physicochemical treatment with alum as coagulant; PC-$FeCl_3$ = Physicochemical treatment with iron (III) chloride as coagulant; PC-Lime = Physicochemical treatment with lime as coagulant; PC-Poly = Physicochemical treatment with polyelectrolyte as flocculant; A/PC~Alum = Aerobic/physicochemical treatment with alum as coagulant; A/PC-$FeCl_3$ = Aerobic/physicochemical treatment with iron (III) chloride as coagulant; A/PC-Lime = Aerobic/physicochemical treatment with lime as coagulant; A/PC-Poly = Aerobic/physicochemical treatment with polyelectrolyte as flocculant; An/PC~Alum = Anaerobic/physicochemical treatment with alum as coagulant; An/PC-$FeCl_3$ = Anaerobic/physicochemical treatment with iron (III) chloride as coagulant; An/PC-Lime = Anaerobic/physicochemical treatment with lime as coagulant; and An/PC-Poly = Anaerobic/physicochemical treatment with polyelectrolyte as flocculant.

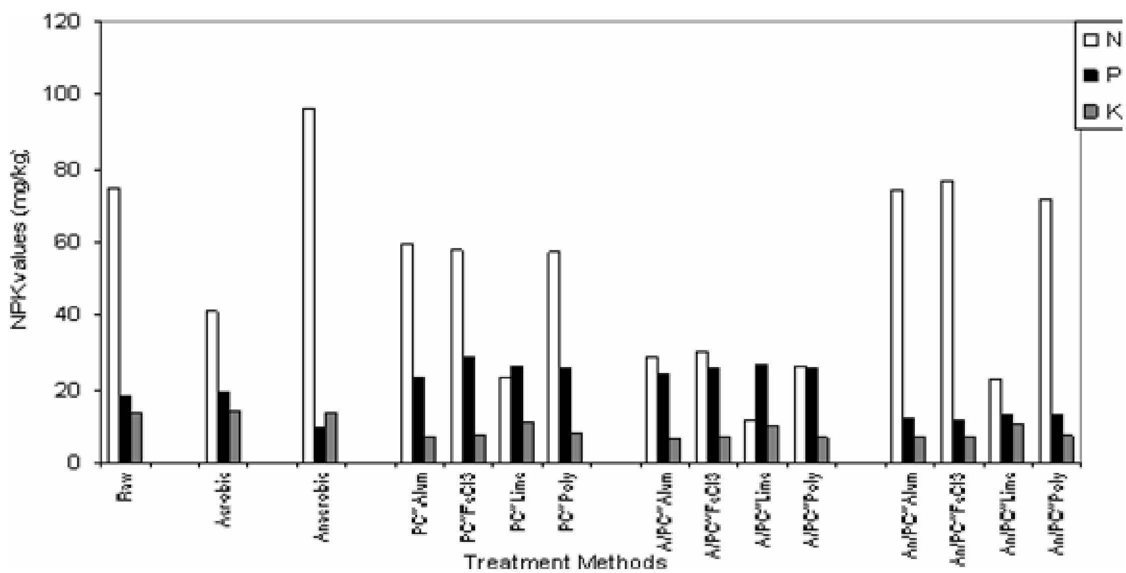

Figure 3b. NPK values of raw and treated sludge from brewery industry (mg/kg). A = Aerobic; An = Anaerobic; PC-Alum = Physicochemical treatment with alum as coagulant; PC-$FeCl_3$ = Physicochemical treatment with iron (III) chloride as coagulant; PC-Lime = Physicochemical treatment with lime as coagulant; PC-Poly = Physicochemical treatment with polyelectrolyte as flocculant; A/PC~Alum = Aerobic/physicochemical treatment with alum as coagulant; A/PC-$FeCl_3$ = Aerobic/physicochemical treatment with iron (III) chloride as coagulant; A/PC-Lime = Aerobic/physicochemical treatment with lime as coagulant; A/PC-Poly = Aerobic/physicochemical treatment with polyelectrolyte as flocculant; An/PC~Alum = Anaerobic/physicochemical treatment with alum as coagulant; An/PC-$FeCl_3$ = Anaerobic/physicochemical treatment with iron (III) chloride as coagulant; An/PC-Lime = Anaerobic/physicochemical treatment with lime as coagulant; and An/PC-Poly = Anaerobic/physicochemical treatment with polyelectrolyte as flocculant.

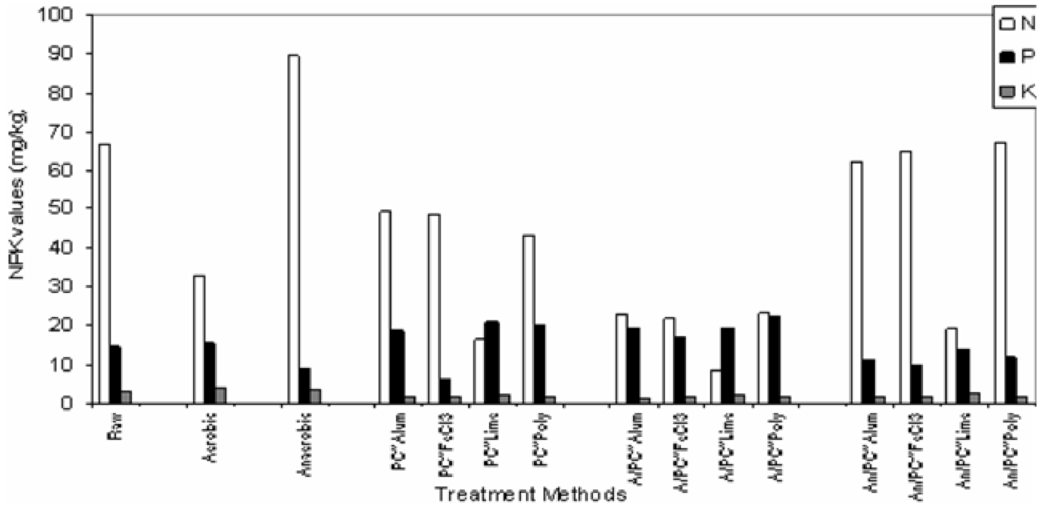

Figure 3c. NPK values of sludge from the pharmaceutical industry (mg/kg). A = Aerobic; An = Anaerobic; PC-Alum = Physicochemical treatment with alum as coagulant; PC-$FeCl_3$ = Physicochemical treatment with iron (III) chloride as coagulant; PC-Lime = Physicochemical treatment with lime as coagulant; PC-Poly = Physicochemical treatment with polyelectrolyte as flocculant; A/PC~Alum = Aerobic/physicochemical treatment with alum as coagulant; A/PC-$FeCl_3$ = Aerobic/physicochemical treatment with iron (III) chloride as coagulant; A/PC-Lime = Aerobic/physicochemical treatment with lime as coagulant; A/PC-Poly = Aerobic/physicochemical treatment with polyelectrolyte as flocculant; An/PC~Alum = Anaerobic/physicochemical treatment with alum as coagulant; An/PC-$FeCl_3$ = Anaerobic/physicochemical treatment with iron (III) chloride as coagulant; An/PC-Lime = Anaerobic/physicochemical treatment with lime as coagulant; and An/PC-Poly = Anaerobic/physicochemical treatment with polyelectrolyte as flocculant.

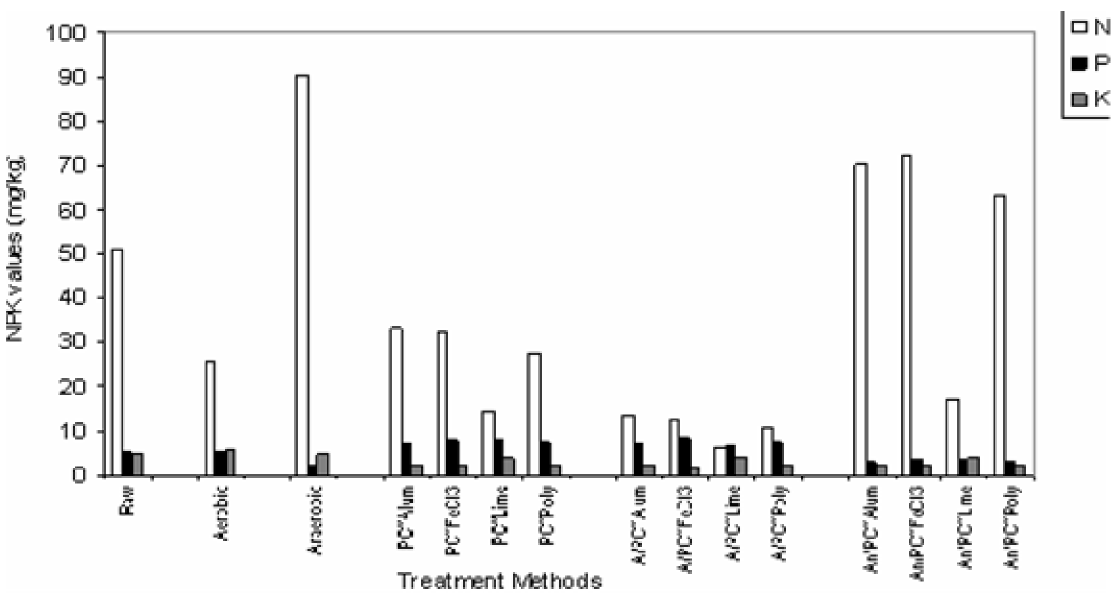

Figure 3d. NPK values of raw and treated sludge from textile industry (mg/kg). A = Aerobic; An = Anaerobic; PC-Alum = Physicochemical treatment with alum as coagulant; PC-$FeCl_3$ = Physicochemical treatment with iron (III) chloride as coagulant; PC-Lime = Physicochemical treatment with lime as coagulant; PC-Poly = Physicochemical treatment with polyelectrolyte as flocculant; A/PC~Alum = Aerobic/physicochemical treatment with alum as coagulant; A/PC-$FeCl_3$ = Aerobic/physicochemical treatment with iron (III) chloride as coagulant; A/PC-Lime = Aerobic/physicochemical treatment with lime as coagulant; A/PC-Poly = Aerobic/physicochemical treatment with polyelectrolyte as flocculant; An/PC~Alum = Anaerobic/physicochemical treatment with alum as coagulant; An/PC-$FeCl_3$ = Anaerobic/physicochemical treatment with iron (III) chloride as coagulant; An/PC-Lime = Anaerobic/physicochemical treatment with lime as coagulant; and An/PC-Poly = Anaerobic/physicochemical treatment with polyelectrolyte as flocculant.

liquor for irrigation or agricultural purposes, this method is also the best, since the phosphate is leached from the solids into the liquid.

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.

pH and temperature were found to be major factors affecting sludge stabilization. The pH of the sludge influences treatment effectiveness

The treatment technologies for heavy metals removal from sludge generally include precipitation process if the effluent is to be set free from such heavy metals or solubilization followed by filtration processes if the sludge solids are to be freed of heavy metals. In some instances, effective treatment may require a chemical oxidation step before precipitation or solubilization (Brown, 1997).

Conclusion

The treatment of industrial sludge depends on the sludge characteristics, the particular pollutant requiring removal and the degree of treatment needed. After sludge has been treated, it must be used or disposed of in an environmentally acceptable manner. Possible disposal methods and reuse options include:

- Direct discharge to receiving water.
- Landfill and land reclamation.
- Soil conditioning.
- Composting.
- Irrigation (effluent).
- Brick making.
- Feeds for poultry and livestock.
- Fuel (biogas) generation.
- Incineration and ash disposal to a landfill.

Of these, land application and use of sludge as a soil conditioner appear to be the most acceptable alternatives. Sludge, as any organic manure, should be regarded as valuable commodity especially in warm arid countries particularly where there is an urgent need for horizontal expansion of land that may be needed for agriculture for the fast growing population. Reclaimed desert soils in particular have a high demand for organic manure, which is important for moisture retention and the supply of nutrients and trace elements. Soils in Delta areas also can benefit from organic manure from sludge.

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