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The effects of fly ash incorporation on some available nutrient contents of wastewater sludges

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Abstract

Lignite fly ash was used as an additive in three different alkaline stabilisation processes and the effects on some chemical properties of wastewater sludge were investigated. The results of the study indicated that sludges added with fly ash only in a dose of 40% (on a dry weight basis) generally caused no significant differences in the sludge properties. However, ammonium–nitrate nitrogen, available phosphorus and soluble boron concentrations were slightly reduced in sludges which were added with 80% and 120% fly ash. On the other hand, alkaline stabilisation (10–15% quicklime + 40–120% fly ash) and alkaline pasteurisation (10–15% quicklime + 40–120% fly ash + heating at 70 °C for 30 min) processes caused a significant decrease in available forms of nitrogen and phosphorus and a significant increase in pH. Although a strong relationship between fly ash dosage and available nitrogen concentration was obtained in alkaline stabilisation process, no significant correlation was found between the two parameters in alkaline pasteurisation process. The results also suggested that using fly ash with doses of 40%, 80% and 120% in alkaline pasteurisation process caused no significant alteration in sludge properties. Heating and quicklime addition were expected to be the influential factors.

Keywords: Fertilizer value; Fly ash; Nutrients; Quicklime; Wastewater sludge

1. Introduction

Wastewater sludge which contains significant amounts of nitrogen, phosphorus, organic matter and other trace elements, represents a good source of nutrients for plant growth and a good soil conditioner to improve physical and chemical properties of soil (Davis, 1989). It may be evaluated as a slow release fertilizer especially due to the high organic nitrogen content (Kocaer et al., 2003a). Therefore, wastewater sludge is recycled in many countries for agricultural purposes. However, reuse of sludge must be performed under conditions limiting the risks liable to the pathogenic microorganisms present in sludge. In this context several methods, such as biological digestion, composting, lime stabilisation, heat treatment have been used to eliminate pathogens from sludge.

The process of lime stabilisation has been shown to reduce pathogens in sludge, enabling lime treated sludge to be safely disposed-off in landfills or applied to land (Westphal and Christensen, 1983; Jimenez-Cisneros et al., 2001). In some cases, alkaline by-products such as fly ash, cement kiln dust and carbide lime have also been used as a stabilising agent. The high CaO content of alkaline fly ash makes it potentially useful as an additive in stabilisation processes for sludge.

Many researchers demonstrated the beneficial effects of fly ash utilisation on sludge properties. Poon and Boost (1996) suggested that the use of pulverised fly ash in conjunction with lime is sufficient to produce a final sludge product with improved handling characteristics and reduced leaching potential. It was also proved that the addition of fly ash to wastewater sludges and the subsequent air drying brought about a significant reduction in

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indicator bacteria (Kocaer and Başkaya, 2004). Another study indicated that the sludge conditioned with fly ash can be disposed-off directly in landfills and used as a soil conditioner (Wang and Viraraghavan, 1997). It was reported that using fly ash as an additive in alkaline stabilisation and pasteurisation processes of sludge prevented the pH decays and regrowth of pathogens during 60 days of storage period (Kocaer et al., 2003b). It was also stated that the total coliform numbers in fly ash–sludge amended soils and leachates decreased with increasing ash ratios (Kocaer et al., 2004).

On the other hand, little is known about the influence of fly ash supplemented alkaline stabilisation and pasteurisation processes on some chemical properties of the end product. It is possible that fly ash may adversely affect the fertilizer value of the alkaline treated sludge owing to high concentrations of salts and trace elements. There exists a need to investigate the effects of fly ash supplemented alkaline stabilisation and pasteurisation processes on the concentration and composition of nutrients in sludge. The present study was undertaken to demonstrate the effects of using fly ash as an additive in three different stabilisation processes, namely, fly ash addition, quicklime–fly ash addition and quicklime–fly ash-heat addition, on some chemical properties of sludges.

2. Methods

2.1. Materials

Three sludge samples which were different in origin, were collected from Pirelli Cable Systems Company, Mauri Yeast Company and Penguen Canned Food Company (Bursa, Turkey). Sludge samples from Penguen and Mauri (Sludges A and B, respectively) originated from the treatment of both domestic and industrial wastewaters. Sludge sample from Pirelli (Sludge C) originated from the treatment of domestic wastewater.

The fly ash used in this study was obtained from Orhaneli Power Station (located at Orhaneli suburb which is 55 km south of Bursa city) where lignite is used for fuel. Technical grade anhydrous calcium oxide (quicklime, 96%) was used together with fly ash in alkaline stabilisation and pasteurisation processes. General characteristics of fly ash and sludge samples are presented in Table 1.

Raw sludge samples were treated in three different processes; fly ash addition, alkaline stabilisation and alkaline pasteurisation. Details of the processes are given in Table 2.

2.2. Chemical analyses

Electrical conductivity (EC) and pH of the samples were measured in sample extracts obtained by shaking the material with distilled water at 1:5 (w/v) sample:water ratio using a conductivity meter and pH meter, respectively (Rhoades, 1982; Mc Lean, 1982). Nitrate and ammonium nitrogen concentrations were determined in samples which were extracted using 2 M KCl. The concentrations in extracts were analysed by steam distillation with MgO and Devarda alloy (Keeney and Nelson, 1982). Total nitrogen content of samples was measured by Kjeldahl digestion method (Bremner and Mulvaney, 1982). 0.5 N $NaHCO_3$ solution was used to extract available phosphorus. PO_4^{-3}–P in extracts were measured according to ascorbic acid method (APHA, AWWA, WEF, 1998). Sludge samples were extracted with sodium acetate for soluble boron determination as described by Wolf (1971). The concentrations in extracts were determined by Azomethin-H method (Bingham, 1982).

2.3. Statistical analyses

For statistical evaluation a 3-way ANOVA was performed. Independent factors were sludge type, process type and fly ash dosage. When significant main effects were indicated by ANOVA, post hoc analysis was performed using the Tukey's HSD multiple comparison test.

In order to determine the effects of alkaline stabilisation processes on the chemical properties of sludge, the

Table 1
General characteristics of sludge samples and fly ash

Parameters[a]	Sludge samples			Fly ash
	Sludge A	Sludge B	Sludge C	
pH (1:5, solid:water)	6.6	8.7	7.1	12.0
EC (1:5, solid:water), mS	6.39	9.77	3.83	3.69
Total N, g kg^{-1}	40.5	22.4	41.5	0.121
Hydrolysable organic N, g kg^{-1}	37.0	15.8	34.4	0.005
Ammonium N, mg kg^{-1}	1030	47.8	390	8.95
Nitrate N, mg kg^{-1}	46	53.1	80.5	4.48
Total P, g kg^{-1}	5.13	9.62	9.08	3.60
Available P, mg kg^{-1}	190	526	223	25.9
Organic C, g kg^{-1}	253	120	237	0.988
Soluble boron, mg kg^{-1}	6.77	8.40	4.61	67.6
Fecal coliform, MPN g^{-1}	6.70×10^4	6.20×10^3	1.03×10^6	–

[a] Dry weight basis