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OPTIMIZATION OF BACTERIOLOGICAL QUALITY OF BIOSOLIDS BY LIME ADDITION

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ABSTRACT
Lack of well-stabilized biosolids is a basic problem for many municipal wastewater treatment plants in Iran. Disposed biosolids from west Ahvaz wastewater treatment plant were generally used for agricultural activities. Initial evidence showed that these biosolids were untreated and had the potential to transmit many pollutants to the environment and create hazards for public health, although anaerobic digester was selected for this wastewater treatment plant. The main objective of this research was to evaluate and optimize the bacteriological quality of biosolids by lime addition in west Ahvaz wastewater treatment plant. The stability and reuse potential of biosolids from existing anaerobic digester and lime added biosolids were investigated. Lime addition to biosolids was performed in the reactor with 30 L capacity. Averge amounts of fecal coliforms and viable helminthes ova in disposal biosolids from anaerobic digester were 1.3×10^{15} MPN / g of dry solids and 314 ova / 4 g of dry solids, respectively. By lime addition with the ratio about 0.265 g $Ca(OH)_2$ per g of dry solids, pH was not dropped under 12 and growth of fecal coliform was not detected after 30 days. In this regard, discharged biosolids from this plant was unstable and very dangerous for reuse or disposal. Lime addition could stabilize the biosolids and reduce fecal coliforms more than 99.99% and had concordance with class B of United State Environmental Protection Agency criteria. Lime-stabilized biosolids could hence be well used for reconditioning the poor soil and for covering of solid waste landfill-sites.

Key words: Biosolids, stabilization, lime addition, bacteriological quality

INTRODUCTION
Lime addition is generally more cost-effective and simpler than alternative biosolids options and the bacteriological quality of the resultant biosolids is often superior. These plants may be easily added to processes that have inadequate capacity to meet regulatory requirements (USEPA, 2000). In this process, lime is added to untreated biosolids in sufficient quantity to raise the pH (Yurtsever *et al*., 2006). The lime dosage required varies with the type of biosolids and solids concentration. Typical dosages are reported in Table 1 (Metcalf, 2003). The high pH creates an environment that halts or substantially retards the microbial reactions that can otherwise lead to odor production and vector attraction. The biosolids will not putrefy, create odors, or pose a health hazard so long as the pH is maintained at this level. The process can also inactivate virus, bacteria, and other microorganisms present (Lue-Hing *et al*., 1998).
Most lime treatment facilities have the flexibility to produce either class A or class B regulations recommended by United State Environmental Protection Agency (USEPA) (Christie *et al*.,

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Table 1: Typical lime doses for sludge stabilization (Metcalf and Eddy, 2003)

Type of sludge	Solids concentration (%)		Lime dosage g $Ca(OH)_2$/g dry solids	
	Range	Average	Range	Average
Primary	3-6	4.3	0.06 - 0.17	0.12
Waste activated	1-1.5	1.3	0.21- 0.43	0.30
Anaerobically digested mixed	6-7	5.5	0.14 - 0.25	0.19
Septage	1-4.5	2.7	0.09 - 0.51	0.20

2001). To meet Class B requirements using lime stabilization, the pH of the biosolids must be elevated to more than 12 for 2 h and subsequently maintained at more than 11.5 for 22 h. To meet Class A, the Class B elevated pH requirements are combined with elevated temperatures (70ºC for 30 min) (Boost and Poon, 1998). Based on the classes, the lime-stabilized biosolids may be reused as a solid waste landfill cover, commercial fertilizer or soil conditioner (Sanchez-Monedero *et al*., 2003). According to the Water Environment Federation (WEF), in1997 in the USA, almost 20 percent of all biosolids were processed with lime stabilization (National lime association, 1999). But up to now lime addition method for biosolids stabilization, has not been used in any Wastewater Treatment Plants (WWTP) in Iran . At the present time, there are not any principle activities for pollution control of disposal biosolids from municipal WWTPs in Iran. Therefore, disposed biosolids are generally unstable (Farzadkia and Mahvi, 2004). Reuse or discharging of these biosolids would lead to many hazardous materials which would pollute natural resources such as water, soil and agricultural products (Mantovi *et al*., 2006). Unfortunately, there is not any data from the relationship between this type of pollution and health hazards in Iran (Farzadkia and Taherkhani, 2005). Based on the results of the research that was done by Farzadkia in four local municipal wastewater treatment plants in Tehran, except one of them, the others disposed untreated biosolids (Farzadkia, 2002).

In this study, the degree of stabilization and reuse potential of disposal biosolids from west Ahvaz municipal WWTP was considered. The plant worked based on the activated sludge process for wastewater treatment and had two stages of anaerobic digester for biosolids stabilization. The first stage of anaerobic digester had been damaged and was out of service at the time of this study.

The main objectives of this research were:

1) To evaluate the stabilization degree of disposal biosolids from Ahvaz WWTP and,

2) To optimize the bacteriological quality of biosolids by lime addition in this WWTP.

MATERIALS AND METHODS

This study was accomplished on the disposal biosolids of Ahvaz WWTP, over 12 months in two separate steps:

1) Investigation of stabilization degree and reuse potential of disposal biosolids

Samples were taken at the biosolids outlet from the WWTP. Biosolids were tested for stability and reuse potential indices such as: pH, fecal coliform (FC) and viable helminthes ova densities. Finally, the characteristics of disposal biosolids were compared with the well-stabilized biosolids criteria, recommended by USEPA (USEPA, 1999).

2) Optimization of bacteriological quality of biosolids by lime addition

A glass reactor with 30 L capacity and an electrical mixer with variable round per minute were used in this step. The reactor was loaded by raw biosolids of Ahvaz WWTP. Then sufficient amount of hydrated lime (due to the concentration of dry biosolids) was added and mixed with biosolids.

Bacteriological quality of lime-added biosolids were checked over 1 month in the reactor. During this period, pH, FC and viable helminthes ova densities were tested and compared to biosolids stabilized criteria recommended by USEPA (USEPA, 1999).

In order to determaine the optimum ratio of hydrated lime, this step was repeated 5 times. The optimum ratio was the amount of hydrated lime which could raise the pH of biosolids over 12 for 2 h and maintain it over 11 for 4 weeks (Capizzi-Banas *et al*., 2004). Analyses were done according to the methods outlined in APHA (APHA, 1995) except for the number of viable helminthes ova, which was carried out by the methods recommended by USEPA (USEPA, 1999).

RESULTS

The characteristics of disposal biosolids from Ahvaz WWTP are presented in Table 2. The minimum amounts of FC and viable helminthes ova densities are 0.64, 1.8×10^{14} MPN per g of dry solids and 221 ova per 4 g of dry solids, respectively. Based on the USEPA criteria for well-stabilized biosolids, maximum amounts of FC density are 1000 and 2×10^{6} MPN per g of dry solids for class A and class B, respectively, and viable helminthes ova density is 1ova per 4 g of dry solids for class A (USEPA, 1999). There are significant differences between these criteria and characteristics of disposal biosolids from Ahvaz WWTP (at least $p<0.01$).

As indicated in Table 3, the ratios of g added lime to g of dry biosolids in 5 series of reactor loading were 0.2, 0.22, 0.38, 0.35, and 0.265, respectively.

pH variations of lime-added biosolids with time are shown in Fig. 1, which indicates that pH was always held over 12, for all steps as 5 days, 32 days, >50 days, >50 days, and >50 days, respectively.

The results of the viable helminthes ova analysis on the lime-added biosolids are presented in Table 3. Based on these data, there are significant differences between these amounts with 1 MPN/4 g dry solids related to class A of USEPA criteria ($p<0.01$) (USEPA, 1995). The variation of FC density in lime-added biosolids in 5 times of reactor loading and the amounts of FC in classes A and B of USEPA criteria are shown in Fig. 2, which presents that, after the lime was mixed to biosolids, FC decreased to zero, and did not increase after 50 days, except for 1st and 2nd steps.

Table 2: Characteristics of biosolids of Ahvaz WWTP in 5 series of study

Parameters	Average	Min	Max	SD
pH	7.085	6.39	7.9	0.571
FC (MPN/g dry solids)	1.3×10^{15}	1.8×10^{14}	1.7×10^{15}	6.3×10^{14}
Viable helminthes ova (Ova/4g dry solids)	314	221	408	76.34

SD: Standard deviation

Table 3: Characteristics of biosolids of Ahvaz WWTP after lime addition

Parameters	Step				
	1	2	3	4	5
Activated degree of $Ca(OH)_2$ (%)	77.9	77.9	77.9	77.9	77.9
Ratio of g $Ca(OH)_2$ / g dry biosolids	0.2	0.22	0.38	0.35	0.265
Viable helminthes ova (ova/4g dry solids)	180	165	142	133	160

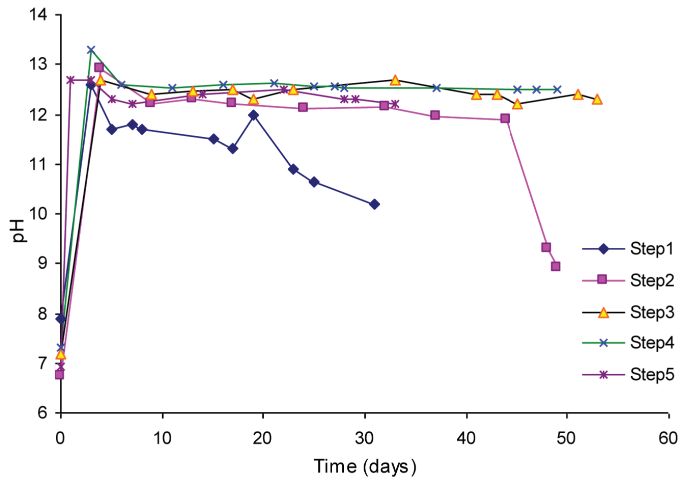

Fig. 1: pH variations in lime-added biosolids

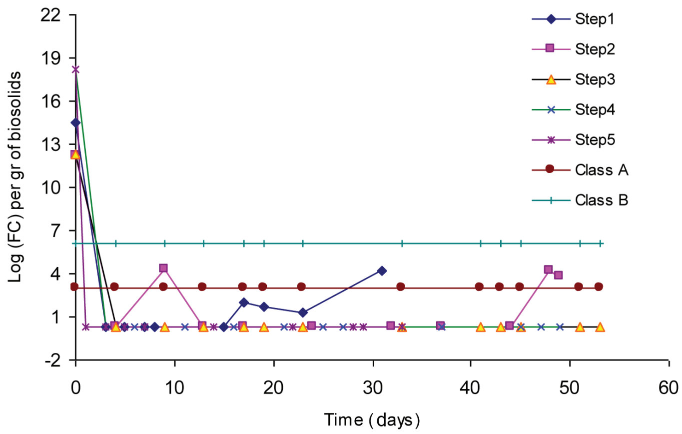

Fig. 2: Variation of FC density in lime added biosolids and in class A and B of USEPA criteria

DISCUSSION

At the time of this study, spesefic standard for reuse or disposal of biosolids was not published by Iran Department of Environment (DOE). Therefore, other reliable criteria such as USEPA indices were used. Comparison of the microbial quality of disposal biosolids in Ahvaz WWTP and USEPA criteria showed that the biosolids were not in class A or B conditions. Hence, the biosolids should not be disposed to the environment or reused for any purpose (Jimenez *et al*., 2000). This result was in agreement with the earlier work of Farzadkia on some WWTPs in Tehran (Farzadkia, 2002). The similar trend was also reported by Mahvi and Kia, in the study on helminth eggs in raw and treated wastewater in Tehran and Isfahan cities. It was found that helminth eggs in raw wastewater of these cities were higher than the reuse standards of Iran, while after treatment, the number of eggs/L decreased to ≤1. Results had shown the removal of helminth eggs accumulated in the settled sludge (Mahvi and Kia, 2006). The disposed biosolids from Ahvaz WWTP have been reused as a fertilizer in farmlands at that time, therefore led to environmental pollution and was dangerous for public health in this area. Consequently, the stabilization of these biosolids before reusing or disposal should be noted accurately.

For lime stabilization of biosolids, 0.2 g of hydrated lime was added per g of dry solids, in the first step. pH dropped under 12 after 5 days and FC increased from 17th day to 16000 per g of dry biosolids after 30 days. For maintaning pH>12, lime addition was increased to 0.22 in the second step. In this step, pH dropped under 12 after 32 days and FC increased to 6680 per g of dry biosolids after 49 days. For removing this problem in the third step, 0.38 g of hydrated lime was added per g of dry solids. In this step, pH did not drop under 12 and FC did not grow after 50 days. For minimization of lime dosage in the forth and fifth steps, 0.35 and 0.265 g of hydrated lime were added per g of dry biosolids. In these steps, again pH did not drop under 12 and FC did not grow 50 days.

As indicated in Figs. 1 and 2, in the lime addition reactor, pH and FC removal efficiency increased with increasing the lime dosage from 0.2 to 0.38 g $Ca(OH)_2$/g of dry biosolids. However, these Fig.s indicate that there is a little benefit in the operating of reactor over than the ratio of 0.265. Therefore, this amount can be considered as an optimum ratio of lime addition for Ahvaz WWTP biosolids stabilization.

The results of microbial analysis showed that lime-stabilized biosolids may be classified in class B of USEPA category in the best conditions. Based on the studies conducted by Christie, the stabilized biosolids could be beneficially reused as a landfill cover material, poor soil reconditioning, and co-composting material (Christie, 2001). If fertilizer using of disposal biosolids would be noted, the microbial quality of the mixture must be improved upto class A of USEPA category (Sanchez-Monedero *et al.*, 2003). For finding the class A condition in lime-stabilized biosolids, the US National Lime Association recommends the application of quicklime with exothermic reaction (National Lime Association, 1999).

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