Clean 2008, *36* (3), 330 – 334

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Research Article

Improving the Quality of Municipal Solid Waste Compost by Using Expanded Perlite and Natural Zeolite

The scope of this study was to investigate the effects of natural zeolite and expanded perlite on the quality of municipal solid waste compost. Various ratios of the materials were added as supplements to the organic fraction of municipal solid waste. These applications were periodically compared with an untreated control process. The results obtained from experimental studies clearly showed that municipal solid waste collected from the metropolitan city center of Samsun, Turkey could not be composted without any additions due to the very high moisture content, which reached up to 75 – 80%. In the untreated control process, thermophilic temperatures were not supported during the composting. In this system, ammonia and other odors became a problem because of the high pH levels, and the electrical conductivity was too high for aged compost. However, the addition of natural zeolite and expanded perlite had a positive affect on the quality of the final compost. Natural zeolite trapped ammonium and reduced nitrogen losses from the compost. Expanded perlite held excess moisture and supported improved aeration. The results also indicated that the use of natural zeolite together with expanded perlite in municipal solid waste composting processes produced mature and stable compost.

Keywords: Municipal Solid Waste; Composting; Zeolite; Perlite

Received: September 17, 2007; *revised:* December 5, 2007; *accepted:* December 12, 2007

DOI: 10.1002/clen.200700135

1 Introduction

The composting of organic waste has a fairly long history in the treatment of municipal solid wastes. The composting process has been accepted as the simplest form of recycling organic wastes back to soil for many years [1, 2].

The most important factor affecting the successful application of compost for agricultural purposes is its final quality. Compost quality is closely related to its degree of stability and maturity [3]. The application of unstable or immature compost may inhibit seed germination, reduce plant growth and damage crops by competing for oxygen or causing phytotoxicity to plants due to insufficient biodegradation of organic matter [4 – 7].

A number of criteria and parameters are proposed for testing compost stability and maturity, all of which express these characteristics as a function of composting time, independently of the composting process or feedstock composition. These include the C:N ratio, carbon dioxide evolution, NH_4^+ – N/NO_3^--N ratios, cation exchange capacity, water soluble C and production of humic substances in the final compost [3, 8, 9].

The microporous crystalline structure of zeolites is able to adsorb species with diameters that fit through surface entry channels, while larger species are excluded, giving rise to molecular sieving properties that are exploited in a wide range of commercial applications [10 – 12]. Currently, natural zeolites are used in soil benefication, in air enrichment and in water and wastewater treatment [13, 14]. Zeolite minerals have also been used to take up heavy metals and ammonia from compost [15, 16].

Expandable forms of perlite have been very important natural materials for the last decade. Due to its favorable physical and chemical characteristics, expanded perlite finds diverse utilization in various applications, e. g., as a lightweight aggregate in the construction industry, as a rooting medium and soil conditioner in horticulture, as a bleaching agent in the textile industry, as an adsorbent in the chemical industry, as a filtration aid and as a filler in miscellaneous processes [17].

The aim of this study is to investigate the effects of the addition of expanded perlite and natural zeolite to the organic fraction of municipal solid waste for composting processes. Various ratios of the natural zeolite and expanded perlite are added to the organic wastes originating from Samsun in an effort to improve the compost quality. A number of parameters are analyzed during the composting.

2 Materials and Methods

A municipal solid waste sample was collected from the metropolitan city center of Samsun which is situated in the Black Sea coastal area of Turkey. The samples were brought into the laboratory and

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Table 1. Characteristics of the organic fraction of municipal solid wastes.

Parameters	Units	Mean Values
PH	–	4.81 ± 0.18
Moisture Content	%	78.21 ± 1.31
E. Conductivity	mS/cm	1.70 ± 0.14
Salt Content*	mg KCl/L	37.14 ± 1.21
TKN*	%	1.90 ± 0.06
NH_3-N*	mg/L	10.71 ± 1.78
NO_3^- – N*	mg/L	280.45 ± 25.43
Total Carbon Content*	%	48.12 ± 3.32
C/N	–	25.33
C/P	–	155.23
Total Phosphorous*	%	0.31 ± 0.05
Total Sodium*	%	0.29 ± 0.04
Total Potassium*	%	4.03 ± 0.78

* All values were determined in dried matter.

Table 2. Chemical analysis of natural zeolite and expanded perlite.

Components	%w/w	
	Natural Zeolite	Expanded Perlite
Na_2O	5.6	3.29
MgO	1.0	0.18
Al_2O_5	13.7	11.9
SiO_2	65.0	72.9
P_2O_5	0.1	0.02
CaO	3.1	0.79
TiO_2	0.3	–
MnO	0.03	0.05
K_2O	1.0	4.47
Fe_2O_3	< 0.1	0.53

the organic waste was separated from inorganic material for the composting process. The organic waste was reduced to a maximum size of 20 mm in order to accelerate the biodegradation. The chemical analysis of the organic fraction of municipal solid wastes is given in Tab. 1.

The natural zeolite samples were collected from the Çankiri-Çorum basin in Turkey. The chemical composition of the samples is given in Tab. 2 [18]. The cation exchange capacity of natural zeolite is 1.45 meq g^{-1}. The samples were broken, triturated and sieved, respectively. The prepared samples were then washed with distilled water and dried at 103 to 105°C.

The expanded perlite was collected from the Izmir-Bergama region of Turkey. The results of its chemical composition are also given in Tab. 2. The moisture content is ca. 0.11% on a wet basis. The pH value of the expanded perlite samples is in the range of 5–9. The expanded perlite samples were passed through a sieve and particulates sized with a 16–20 mesh were used in experiments.

In order to observe the effect of the expanded perlite and natural zeolite on the composting of municipal solid wastes, the following samples were prepared:

S0: 100% organic fraction of MSW

S1: 5% Expanded perlite + 95% Organic fraction of MSW

S2: 5% Natural zeolite + 95% Organic fraction of MSW

S3: 10% Expanded perlite + 90% Organic fraction of MSW

S4: 10% Natural zeolite + 90% Organic fraction of MSW

S5: 5% Expanded perlite + 5% Natural zeolite + 90% organic fraction of MSW

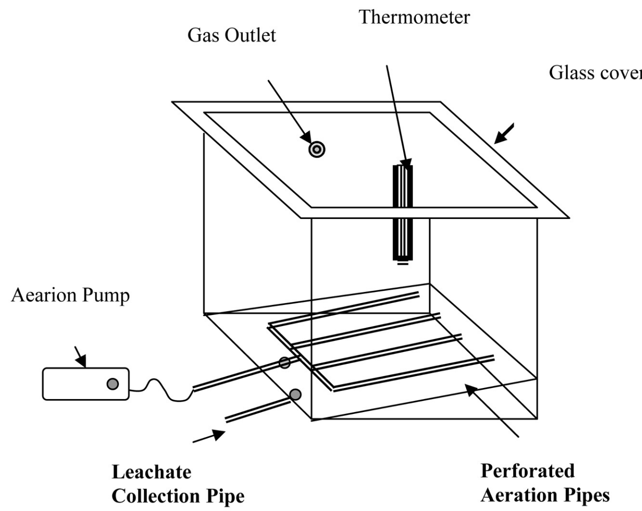

Figure 1. Schematic diagram of the experimental composting system.

S6: 10% Expanded perlite + 10% Natural zeolite + 80% organic fraction of MSW

A wet basis of the municipal solid waste was used in estimating the mixture ratios of the samples. Seven reactors were used in-vessel to simulate composting process. Each reactor had a volume of 125 L (50 cm · 50 cm · 50 cm). The reactor's equipment consists of thermometer, aeration and gas outlet systems. The thermometer was located in the middle of the reactor, and the temperature was monitored continuously by the probe. Aeration equipment was placed on the base of the reactors and connected to an aeration pump. All of the reactors were aerated at a rate of 0.8 m^3/m^3 solids min^{-1}. The reactor was covered with insulating material to minimize heat losses. During the processes, the same conditions were applied to all of the reactors. The schematic drawing of experimental system is illustrated in Fig. 1.

The following parameters were investigated for all samples: pH, moisture content, electrical conductivity, salinity, total Kjeldahl nitrogen (TKN), ammonia nitrogen, nitrate nitrogen, total carbon content, total phosphorous, total sodium, total potassium as well as C/N and C/P ratios. The original samples were used for pH, moisture content and electrical conductivity measurements and the samples dried at 103 to 105°C were used for all other parameters. Standard methods of analyses were used in order to determine all parameters [19, 20]. Carbon dioxide evolution in the compost was measured by trapping the CO_2 in 0.5 N NaOH solution and titrating it with 0.5 N HCl after addition of saturated barium chloride [8]. Experiments were carried out continuously for 100 days. The sampling period was chosen as once per week. About 50 g of composite samples were taken from the reactor at each sampling. All analyses were carried out in triplicate and the results given are the averages with standard deviations.

3 Results and Discussion

The physical and chemical characteristics of municipal solid waste composts obtained from the experiments described above are presented in Tab. 3.

The temperature values of the composting systems are presented graphically in Fig. 2. As shown in Fig. 2, the temperatures of all reac-

Table 3. Final Properties of Composts.

Parameters	S0	S1	S2	S3	S4	S5	S6
PH	8.11 ± 0.30	5.84 ± 0.21	5.44 ± 0.27	6.54 ± 0.17	6.16 ± 0.23	7.14 ± 0.14	7.33 ± 0.18
Moisture Content (%)	59.1 ± 1.11	47.2 ± 1.19	55.0 ± 1.48	48.9 ± 1.26	49.7 ± 1.75	47.3 ± 1.28	46.6 ± 1.46
E. Conductivity (mS/cm)	2.66 ± 0.21	0.74 ± 0.07	0.78 ± 0.04	0.92 ± 0.05	1.04 ± 0.12	1.01 ± 0.09	1.12 ± 0.08
Salt Content* (mg KCl/L)	30.88 ± 2.12	6.66 ± 0.13	8.23 ± 1.31	8.55 ± 1.01	9.82 ± 1.55	9.10 ± 1.21	9.96 ± 0.11
TKN* (%)	0.97 ± 0.05	1.42 ± 0.18	1.50 ± 0.04	1.31 ± 0.11	1.33 ± 0.04	1.38 ± 0.09	1.05 ± 0.08
NH_3-N* (mg/L)	519.54 ± 23.52	183.08	130.21 ± 17.11	158.72	62.44 ± 7.41	55.31	51.28
$NO_3^- - N$* (mg/L)	157.46 ± 12.23	105.83	90.42 ± 12.58	141.71	76.15 ± 15.45	128.63	113.96
$NH_3-N/NO_3^- - N$	3.30	1.73	1.44	1.12	0.82	0.43	0.45
Total Carbon* (%)	22.81 ± 0.27	17.76 ± 0.14	18.96 ± 0.41	14.44 ± 0.28	14.30 ± 0.31	12.88 ± 0.44	9.65 ± 0.26
C/N	23.51	12.51	12.64	11.02	10.75	9.33	9.19
C/P	71.28	52.58	52.83	41.30	35.33	34.45	22.33
Total Phosphorous* (%)	0.32 ± 0.07	0.33 ± 0.05	0.36 ± 0.08	0.35 ± 0.06	0.41 ± 0.04	0.37 ± 0.06	0.43 ± 0.05
Total Sodium* (%)	0.31 ± 0.04	0.40 ± 0.06	1.74 ± 0.11	0.65 ± 0.09	2.85 ± 0.18	3.01 ± 0.14	3.51 ± 0.15
Total Potassium* (%)	4.05 ± 0.52	4.51 ± 0.41	3.95 ± 0.17	4.75 ± 0.44	3.79 ± 0.48	5.68 ± 1.22	7.41 ± 1.31

* All values were determined in dried matter.

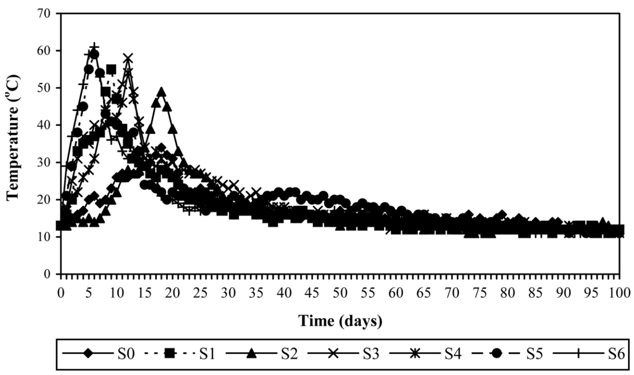

Figure 2. Changes in temperature during the composting process.

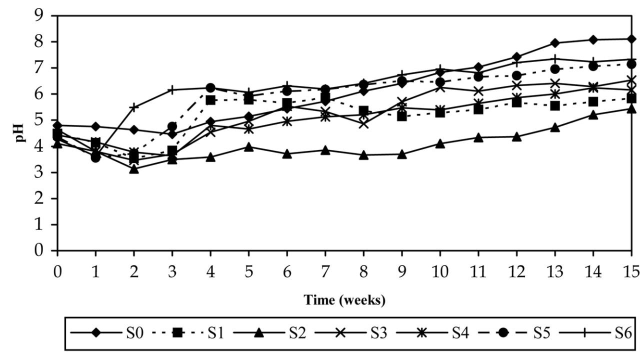

Figure 3. Changes in pH during the composting process.

tors increased during the early weeks and then decreased. Using either the within-vessel composting method or the static aerated pile composting method, the temperature of the biosolids was maintained at 55°C or higher for 3 days [21]. The highest temperatures were obtained from S5 and S6. In these systems, the maximum temperature reached ca. 60°C. The maximum temperature values were in the range of 50 to 58°C in the other systems with natural zeolite and expanded perlite. In the untreated control process, S0, the maximum temperature was only 34°C. This may be due to the high moisture content of municipal solid waste, which can create anaerobic conditions that do not permit the growth of aerobic thermophilic microorganisms [22].

During the initial phase of composting, the pH dropped in the processes due to the high concentrations of organic acids. Soon afterwards, the pH increased during the composting. Bertoldi et al. suggested that the optimum pH values for composting are between 5.5 and 8.0 [23]. The pH value of the final compost in the untreated control process, S0, was higher than the optimum value. As seen in Fig. 3, the pH values of the final composts were significantly affected by the amount of natural zeolite and expanded perlite added. As the natural zeolite and expanded perlite were added, the pH values were seen to decrease at the end of the processes. The pH values were in the optimum range for the final composts containing natural zeolite, expanded perlite and mixtures of expanded perlite and natural zeolite.

The moisture content of the organic wastes collected from Samsun city center was too high at the beginning of the processes to generate good compost. The high moisture, 78%, results in lower temperatures. For this reason, the compost without any addition did not mature during the composting process. As seen in Fig. 4, the addition of either natural zeolite or expanded perlite resulted in a reduction in the moisture content of composts to optimum values, which are in the range of 50 to 60% [24, 25]. The moisture removal level correlated well with the water holding capacities of these minerals.

The soluble salt content is generally expressed as the electrical conductivity of compost. The electrical conductivity of the final compost without any addition, S0, was observed to be 2.66 ± 0.21 mS/cm. According to Petrik, the ideal compost should have an electrical conductivity no higher than 2 mS/cm [26]. Therefore, the conductivity grade of the compost produced by the natural process can be described as "saline". The conductivity grades of all composts were seen to decrease below 2 mS/cm using the natural zeolite and expanded perlite.

The changes in concentration of nitrogen types were varied by adding natural zeolite and expanded perlite. As seen in Tab. 1, the total Kjeldahl nitrogen (TKN) concentration of organic wastes collected from Samsun city center was 1.90 ± 0.06%. At the end of the process, the TKN value of untreated compost was reduced to 0.97 ± 0.05% and approximately 50% nitrogen was lost or mineralized. The

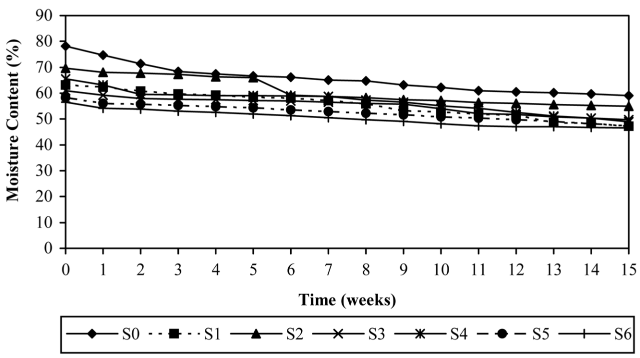

Figure 4. Changes in moisture content during the composting process.

loss of nitrogen reduces the usefulness of compost as a fertilizer [27]. In the experiments, nitrogen losses were reduced by using natural zeolite and expanded perlite. Increasing the addition ratio from 5 to 10% greatly reduced the TKN value. A higher addition ratio resulted in better aerobic conditions due to greater porosity. In the systems containing 5% and 10% expanded perlite, S1 and S3, the TKN losses obtained were ca. 20% and 17%, respectively. In addition, in the systems containing 5 and 10% natural zeolite, S2 and S4, the TKN losses were determined as ca. 11 and 9%, respectively. As seen from the results, the natural zeolite resulted in lower nitrogen losses than expanded perlite. The least nitrogen losses occurred in the system with a mixture of natural zeolite and expanded perlite. The concentrations of both NH_4^+–N and NO_3^-–N increased initially and then decreased as a result of increased levels of N-fixing bacteria. The anaerobic and partially aerobic conditions can result in ammonia release to the atmosphere. It also appears that the ammonia nitrogen content in the final product decreased when the amount of natural zeolite used was increased. The NH_4^+–N/NO_3^- –N ratio and total NH_4^+–N concentration are good indicators for compost maturity [28]. According to the Compost Maturity Index, if NH_4^+–N/NO_3^- –N ratios are higher than 3 and NH_4^+–N concentrations are higher than 500 mg L^{-1}, the final composts are believed to be "immature". As observed in Tab. 3, the parameters of NH_4^+–N/NO_3^-N ratios and NH_4^+–N concentrations were lower than the values for composts where natural zeolite and expanded perlite is added. Therefore, the untreated control compost, S0, can be viewed as immature, while the other composts are mature.

The amount of CO_2 evolved from various treatments during the composting is shown in Fig. 5a). As seen in Fig. 5a), the CO_2 content of the treated samples reached maximum evolution within two to three weeks, which coincided with the rise in temperature and the beginning of the thermophilic phase. Following the initial rise, CO_2 evolution decreased significantly in all treatments, which was presumably due to the thermal inhibition of microbial activity and the decrease in readily soluble nutrients [29]. The highest level of CO_2 evolution occurred from the untreated control process. The addition of natural zeolite and expanded perlite resulted in a reduction in maximum CO_2 evolution. The amount of CO_2 evolution was lowest in composts prepared from an expanded perlite and natural zeolite mixture. After three to four weeks, the respiration rate was less than 10 mg g^{-1} compost for the mixture treatments. The cumulative amount of CO_2 evolved for the control treatment was significantly higher than that of the samples with additions. In the control treatment, the cumulative amount of CO_2 evolved was 733 mg g^{-1}.

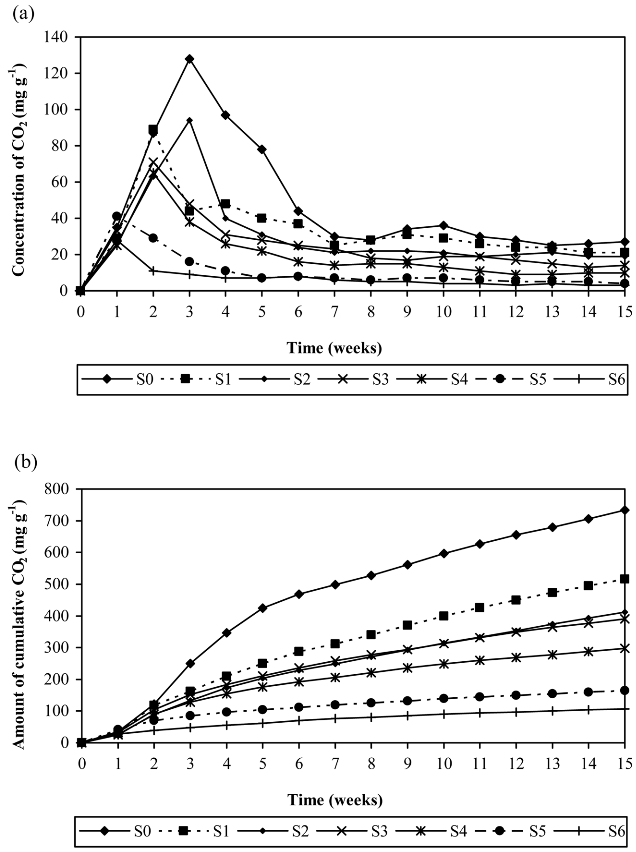

Figure 5. (a) Changes in CO_2 evolution, and (b) cumulative amount of CO_2 during composting of municipal solid wastes.

The cumulative amount of CO_2 released after 100 days of natural material supplemented compost ranged from 516 to 107 mg g^{-1}, see Fig. 5b), decreasing in the order: S1 > S2 > S3 > S4 > S5 > S6. The cumulative amount of CO_2 evolved for all treatments during composting revealed that decomposition of biodegradable municipal solid waste was most vigorous during the first six weeks, since CO_2 evolution in this period accounted for ca. 60 to 70% of total CO_2 production.

The C/N ratio has been used to indicate the stability of compost. In this study, the C/N ratio of composts containing natural zeolite, expanded perlite and the mixture of these compounds were below 20 which is indicative of acceptable compost maturity [3]. However, the C/N ratio of the compost without any addition, S0, was higher than 20.

It was observed that the total concentrations of Na and K in the final composts with natural zeolite increased due to the fact that natural zeolite has the ability to exchange sodium and potassium. The amount of total P increased at the end of the composting process. This increase depends on the chemical content of the natural zeolite and expanded perlite.

4 Conclusions

Based on the experimental data obtained, it can be concluded that natural zeolite and expanded perlite have good potential for effective composting of municipal solid waste. The temperature of the composting without any additions did not reach the thermophilic phase because of the high moisture content of the waste with values up to 78%. The temperature of municipal solid waste compost was maintained at 55°C or higher for three days by using 5 to 10% natural zeolite and expanded perlite. Expanded perlite held the excess moisture of organic wastes during the composting. Natural zeolite exhibited good ion exchange properties for ammonium ions in composting. The nitrogen losses were found at the lowest levels for compost containing 10% natural zeolite and 10% expanded perlite. The pH and salinity of compost without any additions were higher for mature compost. Both natural zeolite and expanded perlite reduced the pH and salinity. Therefore, it is possible to conclude that the general improvement of municipal solid waste compost is supported by the use of combined natural zeolite and expanded perlite as addition materials.

The authors have declared no conflicts of interest.

References

[1] M. D. LaGrega, P. L. Buckingham, J. C. Evans, *Composting in Hazardous Waste Management*, McGraw-Hill, New York **1994**.

[2] P. Williams, *Composting-Waste is Valuable Resource*, Technical Document, Crop & Food Research Ltd., New Zealand **1999**.

[3] S. Goyal, S. K. Dhull, K. K. Kapoor, Chemical and Biological Changes During Composting of Different Organic Wastes and Assessment of Compost Maturity, *Bioresour. Technol.* **2005**, *96*, 1584.

[4] L. J. Brewer, D. M. Sullivan, Maturity and Stability Evaluation of Composted Yard Trimmings, *Compost Sci. Util.* **2003**, *11*, 96.

[5] L. R. Cooperband, A. G. Stone, M. R. Fryda, J. L. Ravet, Relating Compost Measures of Stability and Maturity to Plant Growth, *Compost Sci. Util.* **2003**, *11*, 113.

[6] L. Wu, L. Q. Ma, G. A. Martinez, Comparison of Methods for Evaluating Stability and Maturity of Biosolids Compost, *J. Environ. Qual.* **2000**, *27*, 424.

[7] D. Said-Pullicino, F. G. Erriquens, G. Gigliotti, Changes in the Chemical Characteristics of Water-Extractable Organic Matter During Composting and Their Influence on Compost Stability and Maturity, *Bioresour. Technol.* **2007**, *98*, 1822.

[8] C. Garcia, T. Hernandez, F. Costa, M. Ayuso, Evaluation of the Maturity of Municipal Waste Compost Using Simple Chemical Parameters, *Commun. Soil Sci. Plant Anal.* **1992**, *23*, 1501.

[9] G. Ranalli et al., Composting of Solid and Sludge Residues from Agricultural and Food Industries – Bioindicators of Monitoring and Compost Maturing. *J. Environ. Sci. Health*, **2001**, *36*, 415.

[10] R. A. Munson, R. A. Sheppard, Natural Zeolites: Their Properties, Occurences and Uses, *Miner. Sci. Eng.* **1974**, *6*, 19.

[11] E. A. Ortega, C. Cheeseman, J. Knight, M. Loizidou, Properties of Alkali-Activated Clinoptilolite. *Cem. Concr. Res.* **2000**, *30*, 1641.

[12] E. Álvarez-Ayuso, A. García-Sánchez, X. Querol, Purification of Metal Electroplating Waste Waters Using Zeolites, *Water Res.* **2003**, *37*, 4855.

[13] C. Constantopoulou, M. Loizidou, Z. Loizou, N. Spyrellis, Thorium Equilibria with the Sodium form of Clinoptilolite and Mordenite. *J. Radioanal. Nucl. Chem.* **1994**, *178*, 143.

[14] J. W. C., Wong, S. W. Y. Li, M. H. Wong, Coal Fly Ash as a Composting Material for Sewage Sludge: Effects on Microbial Activities, *Environ. Technol.* **1995**, *16*, 527.

[15] A. A. Zorpas, A. G. Vlyssides, M. Loizidou, Dewatered Anaerobically-Stabilized Primary Sewage Sludge Composting: Metal Leachability and Uptake by Natural Clinoptilolite, *Commun. Soil Sci. Plant Anal.* **1999**, *30 (11 – 12)*, 1603.

[16] N. G. Turan, O. N. Ergun, Ammonia Uptake by Natural Zeolite in Municipal Solid Waste Compost, *Environ. Prog.* **2007**, *26 (2)*, 149.

[17] I. B. Topçu, B. Isikdag, Manufacture of High Heat Conductivity Resistant Clay Bricks Containing Perlite, *Build. Environ.* **2007**, *42*, 3540.

[18] O. N. Ergun, Sedimentology of Tertiary Evaporites from Ugurludag Area Çankiri-Çorum Basin, Turkey, *Ph.D. Thesis*, University of London, England **1977**.

[19] APHA, *Standard Methods for the Examination of Water and Wastewater* (Eds: A. D. Eaton, L. S. Clesceri, A. E. Greenberg), 19th ed., American Public Health Association, Water Environment Federation, Washington, D.C. **1995**.

[20] FCQAO, *Methods Book for Analysis of Compost*, Federal Compost Quality Assurance Organization, Stuttgart, Germany **1994**.

[21] *A Plain English Guide to the EPA Part 503 Biosolids Rule*, EPA/832/R-93/003, EPA, Washington, D.C. **1994**.

[22] N. G. Turan, A. Akdemir, O. N. Ergun, Emission of Volatile Organic Compounds during Composting of Poultry Litter, *Water, Air, Soil Pollut.* **2007**, *184*, 177.

[23] M. Bertoldi, G. Vallini, A. Pera, The Biology of Composting, *Waste Manage. Res.* **1983**, *1*, 157.

[24] R. Rynk, *On Farm Composting Handbook*, Northeast Regional Agricultural Engineering Service, Cornel University, Ithaca, NY **1992**.

[25] E. Epstein, *The Science of Composting*, Technomic, Lancaster, PA **1997**.

[26] V. Petrik, *Quality of Compost Explained*, Petrik Technology & Approach, Petrik Laboratories, Inc., USA **1985**.

[27] C. N. Sawyer, P. L. McCarty, G. F. Parkin, *Chemistry for Environmental Engineering*, 4th ed., McGraw Hill, New York **1994**.

[28] WERL, *Compost Quality in America*, Technical Document, Woods End Research Laboratory, Inc., USA **2000**.

[29] M. Viel, D. Sayag, A. Peyre, L. André, Optimization of In-vessel Co-Composting through Heat Recovery, *Biol. Wastes* **1987**, *20*, 167.

