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Use of Municipal Solid Waste Compost and Waste Water Biosolids with Co-Composting Process

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Abstract: A pilot-scale active aeration bioreactor was studied for co-composting of municipal solid waste (MSW) and wastewater biosolids (WB). The weight ratio of the MSW to wastewater biosolids was 3:1 (dry solid basis). Obtaining compost from municipal solid waste, in comparison with other methods of solid waste disposal especially incineration, is cheaper and more economical, as in suburbs suitable fertilizers can be obtained with little investment for the development of urban green space or for sale. On the other hand, one of the problems of municipal wastewater treatment is the problem of sludge disposal. Co-composting manure can be acquired by combining these two so it overcomes the problems of municipal solid waste and wastewater treatment and finally the produced fertilizer is used for agricultural, horticultural, etc. In the second stage, to remove heavy metals and enhance the C/N ratio, Clinoptilolite and sawdust have been used.The goal of this study was the better understanding the effect of co-composting process of municipal solid waste (MSW) and sewage sludges (SS) and to fully consider the factors in research objectives.

Key words: Municipal Solid waste · Biosolids · Co-composting · Heavy metals

INTRODUCTION

Due to rapid increases in urban population, municipal solid waste (MSW) and sewage sludge (SS) have increased dramatically in recent years. Environmental pollution caused by MSW and SS has become a serious social problem which hinders urban development, especially for large cities in developing countries. It is critical that we find ways to effectively reuse such wastes and reduce their impact on the environment [1].

The organic content of waste is generally higher in developing countries; therefore, composting is an appropriate alternative for waste management [2].

However, decomposition of solid waste may cause environmental problems if emission of landfill gas is not controlled and landfill leachate seeps down to groundwaters. Therefore, MSW needs to be removed and disposed of properly [3].

Sewage Sludge is defined as the residual material removed from wastewater treatment facilities. SS usually has the characteristics of a dense structure due to its high moisture content and low C/N. Therefore, SS requires a larger amount of bulking agent (such as sawdust, vegetal remains, or straw) to absorb moisture, provide the composting mass with an appropriate degree of sponginess and aeration and increase the C/N ratio[4-5]. The intensive exploitation of the ground and the employment of inadequate cultivation methods and heavy machinery have led to a fall in the content of organic matter with a resulting loss of fertility [6].

For these reasons, the search for new organic materials with low cost and constant and punctual production becomes crucial. In this sense, the municipal solid waste organic fraction (OFMSW) and the sewage sludge (SS) could constitute an important source of organic matter [7]. Biological treatments offer a cost-effective sustainable solution for urban organic wastes. In practice, the main biological process applied for solid wastes is composting [8].

Composting is an environmentally friendly technology to treat and recycle organic wastes. Composting is not only used for the organic fraction of municipal solid wastes, but is also applied to residuals coming from industrial activities. Municipal or industrial wastewater sludge and animal by-products are examples of organic solid wastes susceptible to composting [9].

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However, composting of soils contaminated with hazardous materials is still an emerging ex situ biotreatment technology [10]. Composting has been demonstrated to be effective in biodegrading polycyclic aromatic hydrocarbons (PAHs) [11] chlorophenols [12], explosives [10] and petroleum hydrocarbons [13] at the laboratory and/or field-scales. Though these studies have shown that composting can be effective, wide variations have been reported due to the lack of control of key environmental parameters [12].

Today, different composting technologies are applied in industrial facilities. The method selection is dependent on the investment and operation cost, time required to reach compost stability and maturity, the availability of land and origin of raw materials [14].

On contrast, the open-air pile system is the simplest and requires the lowest investment. There is an increasing number of compost operations due to increasing landfill tipping fees and legislation to protect the environment [15].

Composting, recognized as a viable alternative and beneficial use of end-product for waste management, is the biological degradation of highly concentrated biodegradable organic wastes in the presence of oxygen (aerobically) to carbon dioxide and water. The final product of composting is a stable humus-like material known as compost [16]. Compost material can be used for improving soil structure, which can act as a soil conditioner or fertilizer [17].

Many aspects can be used to determine compost quality, organic matter (OM) and nutrient concentrations (mainly total N) are usually considered the most important, based on the fact that the beneficial effects of compost on soil are primarily related to these factors [18].

The main factors in the control of a composting process include environmental parameters (temperature, moisture content, pH and aeration, substrate nature parameters such as C/N ratio, particle size and nutrient content) [19].

Composting followed by land application represents one of the most economical ways for the treatment and final disposal of sewage sludge because it combines material recycling and sludge disposal at the same time [20].

The term co-composting means the composting of two or more raw materials together. Many examples of different materials being composted together are available [21].

Co-composting processes have been reported for composting of agroindustrial wastes with wastewaters. For example, co-composting of exhausted grape marc with different biowaste [22], of winery and distillery wastes [23], of olive mill wastes and sewage sludge with industrial waste has been reported [24]. Composting of wastewater treatment plant sludge has been practiced but co-composting of wastewater treatment plant sludge and municipal solid waste is not wide spread [25]. In addition to solid waste, wastewater treatment plant sludge can be co-composted with agricultural, forestry and some agro-industry residues such as tobacco residue. These residues would behave as bulking agent and may improve the pile structure by allowing air circulation [16].

At the end of a successful co-composting process, both inputs would have been stabilised into a solid product that may be used as a fertilizer. Thus, by appropriate control of the operational parameters, co-composting may be used for either the maximization of the solid waste treatment, or the maximization of the wastewater treatment or for both [26].

The aim of the present work was to improve the optimization of MSW compost, in terms of OM and nutrient concentrations, by means of co-composting with sewage sludge. This study may provide a guide for application on an industrial scale.

MATERIALS AND METHODS

Experiment Establishment and Sampling: Wastewater treatment plant sludge and solid waste were required for the experimental studies. MSW and SS from an urban waste solid composting plant and an urban wastewater treatment plant in Iran were used in this study. The MSW contained many oversized materials (diameter>100 mm), such as plastic bags and clothing, due to the limits of economic conditions and source separation; these would affect aeration and retard composting periods. In addition, the moisture content of the waste could be as high as 80% during the rainy season. The raw MSW with large-sized materials and high moisture content was first deposited for 20 days to remove excessive water, in order to aid in the subsequent separation. The wastes were then screened through a rotary drum sieve to retain contents sized smaller than 40 mm. After these pretreatments, the MSW was uniform and its structure was incompact. SS was taken from the sludge dewatering workroom in the urban wastewater treatment plant. The main characteristics of MSW and SS are shown in Table 1.

Table 1: Selected physicochemical characteristics of municipal solid waste and sewage sludge

Parameter	Municipal solid waste	Wastewater biosolids
Organic matter (%)	65.7 ± 0.5	76.3 ± 0.6
Dry matter (%)	36± 0.3	18.7± 0.4
Moisture content (%)	63.2 ± 1.2	76.8 ± 2.4
pH	6.28 ± 0.12	7.68 ± 0.08
Organic carbon (gKg^{-1})	296.6 ± 3.3	264.8 ± 3.5
Total nitrogen (gKg^{-1})	12.33 ± 0.41	25.05 ± 0.23
Ratio of carbon and nitrogen (C/N)	34 ± 1	11 ± 1
NH_4^+ -N (gKg^{-1})	12.45 ± 0.61	3.16 ± 0.14
P (gKg^{-1})	4.94 ± 0.52	10.25 ± 0.35
K (gKg^{-1})	29.44 ± 2.87	3.84 ± 0.23

Table 2: The chemical and physical profile of Clinoptilolite

	Composition (%)							
Sample	SiO_2	Al_2O_3	Fe_2O_3	Na_2O	K_2O	CaO	MgO	LOI
Clinoptilolite	66.52	11.82	1.25	2.3	2.41	3.1	0.7	12.25

Table 1. Experimental studies were carried out as two stages. In first stage, SS is mechanically thickened. Thickened sludge is dewatered using a belt press system and it is stored in sludge storage area. In first and second stages, sludge is thickened in trays and then dewatered in belt press.In order to remove heavy metals in the second stage, raising the C/N ratio, increasing porosity and improving aeration, natural Clinoptilolite and sawdust were used as bulking agents.

Clinoptilolite is a natural zeolite comprising a microporous arrangement of silica and alumina tetrahedra. Among more than 40 natural zeolites, clinoptilolite is the most abundant and the most often used one. It has the complex formula: $(Na,K,Ca)_{2-3}Al_3(Al,Si)_2Si_{13}O_{36}\bullet 12(H_2O)$. Table 2 displays the features chemical profile of Clinoptilolite. It forms as white to reddish tabular monoclinic tectosilicate crystals with a Mohs hardness of 3.5 to 4 and a specific gravity of 2.1 to 2.2. It commonly occurs as a devitrification product of volcanic glass shards in tuff and as vesicle fillings in Basalts, Andesites and Rhyolites. It is also used as fertilizer and sold as a deodorizer in the form of pebble-sized chunks contained in a mesh bag. Among the most frequently studied natural zeolites, clinoptilolite was shown to have high selectivity for certain heavy metals such as lead, cadmium and nickel[27]. *Natural clinoptilolite was prepared from the deposits located in the north of Semnan region, Iran, selecting diameters of <5 mm, which were washed by distilled water to remove turbidity and dried at room temperature (air-drying)* [28].

RESULTS AND DISCUSSION

Overview: In the first part of experimental studies, co-compostability of solid waste and sewage sludge was investigated. Mechanically pre-processed (separated and sorted) solid waste was taken from urban waste solid composting plant and sewage sludge was taken from urban wastewater treatment plants were used in the experimental studies. Experimental studies were carried out as two stages.

Temperature of composting materials was measured daily using a digital thermometer. Temperatures were measured in different part of reactor and average value was accepted as the temperature of composting material. In addition to the temperature of composting material, ambient air temperature was also measured to see its effect.

In composting systems, temperature may increase up to 65-70 °C as a result of biological degradation of organic materials in solid waste or other organic matter in first days of composting process. High moisture content and low amount of composting material mass were the reasons for low temperatures.

In all stages, our initial moisture contents were suitable for optimum start up of composting process. The initial moisture content must be 45-60%. The reactor was loaded with about 10 kilograms of composting material which is too low compared to materials in windrow systems.

Water, product of degradation, was expected to vaporize to atmosphere through the effluent gases.

Table 3: Characteristics of the composted materials used in this study

Parameter	Co-composting Stage 1	Co-composting Stage 2
Organic matter (%)	74.6 ± 0.3	75 ± 0.5
Dry matter (%)	39.4± 0.2	38.5± 0.3
pH	9.73 ± 0.08	10.05 ± 0.12
C/N ratio	31.7 ± 3	41.7 ± 2

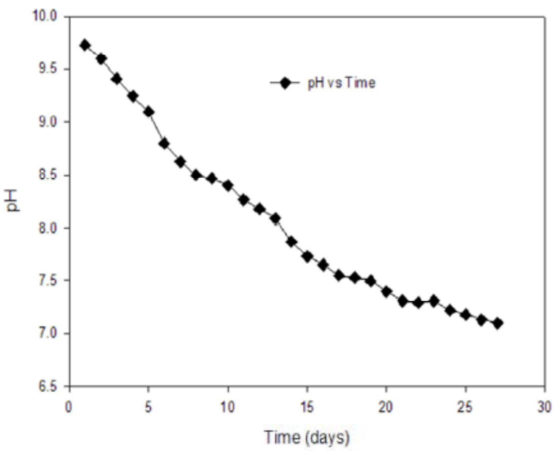

Fig. 1: pH values in mixtures during composting in stage 1

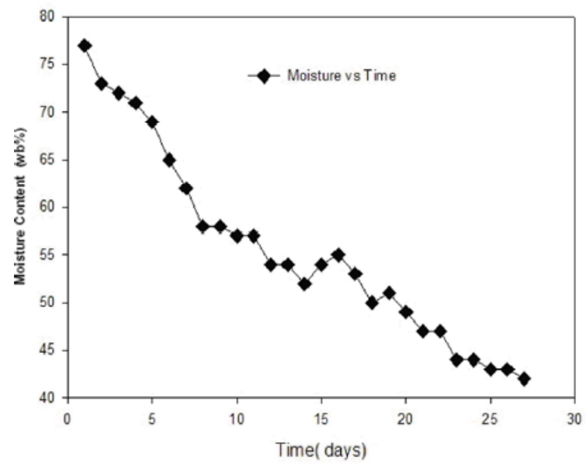

Fig. 3: Moisture content changes in mixtures during composting in stage 1

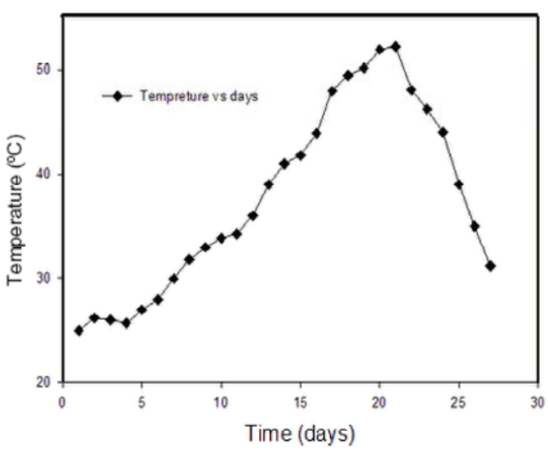

Fig. 2: Temperature changes in mixtures during composting in stage 1

In the reactor, water condensed on inner surface of cover and remained in the system.

Co-composting Processes: In this section, the effect of moisture, temperature level, aeration rate, pH and amount of C/N in the co-composting process are to be examined. Table 3 shows initial factors of mixed compost.

First Stage of Co-composting Tests: After loading compost mass, in order to ensure optimum performance process, the monitoring process operation, measuring factors such as pH, temperature and moisture percentage were on the agenda. These experiments have been conducted for 27 days.

Controlling measures and setting the index factors in the process of aerated masses will be done mainly through the system timing and aeration amount. Figures (1) to (3) display the changing process of pH, temperature level and moisture percentage during the process.

Analysis of the pH changes curve on the basis of time in fig. 1 shows that the compost mass pH, which at the onset of the process was 9.73, declined over time and was moderated to the neutralization level. Fig. 2 shows that while reducing pH, biological operations of microorganisms started in the mass and the process of temperature changes shows an ascending state from the fifth day onward. From the fifth day until the twenty-first day, the temperature rise inside the mass continues and at this time the temperature at the center of the mass reaches 52.3 C °.After this stage, the curve moves downward and even with the reduction and cessation during aeration, the process has not stopped.

Fig. 3 indicates moisture loss during the process from around 77% initially to 44% average in the end.This curve shows that for a new leachate production

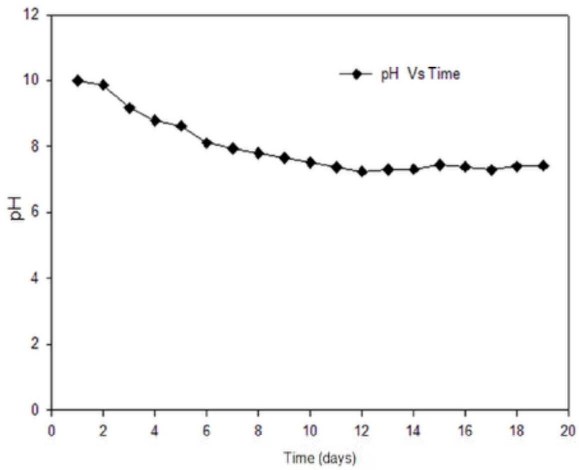

Fig. 4: pH values in mixtures during composting in stage 2

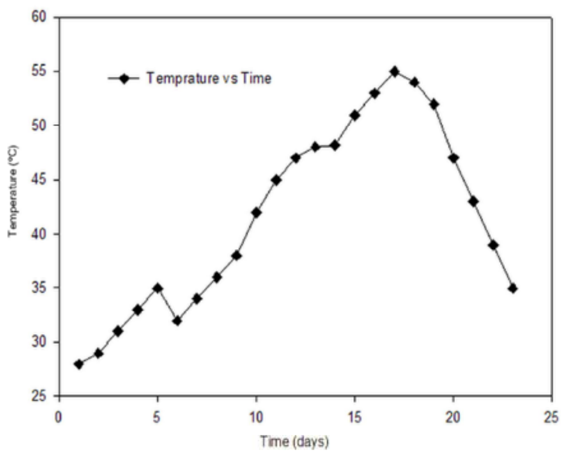

Fig. 5: Temperature changes in mixtures during composting in stage 2

in the first eight days, moisture loss was felt, but from the eighth day on, the moisture loss encountered a slow race. Regularly, aeration took place every 8 hours for 5 minutes and the mixer was working at the same time. At the end of the first week the aeration time was reduced to 4 hours, instead of 8. This change was conducted in order to control the temperature rate and moisture.

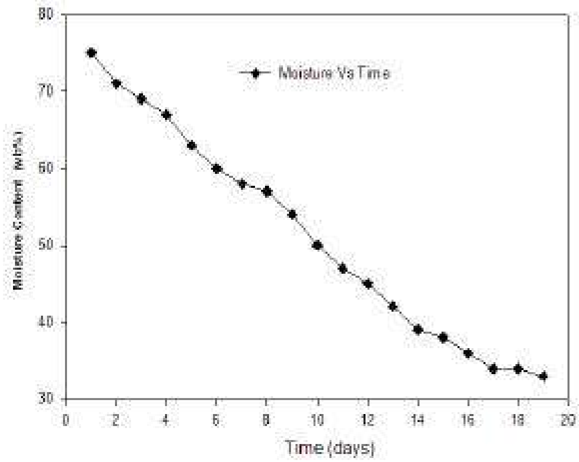

Fig. 6: Moisture content changes in mixtures during composting in stage 2

Second Stage of Co-composting Test: In this experiment the Clinoptilolite was used to the amount of 15 to 30 percent of the total sample in order to remove heavy metals. Using this kind of stone in the industry is because of ion exchange properties in it.

A main issue of the produced compost made of urban wastes is heavy metals, as it was mentioned earlier; sawdust because of its low content heavy metals can lead to dilution in metals in compost. Figures (4) to (6), show pH chart, temperature and moisture respectively. The test has been done based on experience in previous experiments, but this time for some reasons. Aeration rate of 480 l/min and aeration cycle is off for 240 minutes and it is on for five minutes. One of the findings of this test is the temperature remain above 50 degrees Celsius at the beginning of the second week; meaning the tenth day onward which had favorable results.

Remaining temperature over 50 degrees Celsius for 6 to 7 days, removing heavy metals found in compost in a very good level, obtaining the final product with a better face quality than the previous steps, reducing the overall moisture to the expected level, reducing the organic matters in comparison with the previous steps

Table 4: Comparison of the removal of heavy metal at different stages with sludge

Heavy metals	Cd dry weight (mg kg^{-1})	Cr dry weight (mg kg^{-1})	Cu dry weight (mg kg^{-1})	Zn dry weight (mg kg^{-1})
Stage 1	9.08	29.5	11.3	42
Stage 2	0.0	0.0	0.0	2.17
Sludge	1.42	89	21	87.6

considering clinoptilolite and adding sawdust, no unpleasant odor emissions due to increased C/N ratio, creating porosity and reduction in the duration of compost production, were the results of this step.

Heavy Metals: Unfortunately, the presence of high levels of heavy metals often hinders agricultural land application of the composted sludge. The total heavy metal content in sewage sludge is about 0.5-2% on a dry weight basis and in some cases, about 4% [29].

Uptake of heavy metals by plants and subsequent accumulation along the food chain is a potential threat to animal and human health. Consequently, focus on the improvement of the composting process to minimize the mobility of heavy metals using various additives is receiving more attention [17].Clinoptilolite is a porous crystal material, which adsorption properties of clinotiolite are strongly related to the framework structure, which has performance for the physical adsorption and ion exchange. Using Clinoptilolite decreases heavy metals from sewage sludge in compost. (Table 4). Sawdust dilutes metals and it also causes a decrease in concentrations of heavy elements in combined compost mass.

CONCLUSIONS

This work aimed to study the optimization of the co-composting of MSW and SS. The process of composting, through over turned, OFMSW, sewage sludge and its mixture in proportion 3:1 after more than 3 months, has provided a compost with visibly positive properties for agricultural use.

Adding sawdust reduced pH levels of masses of the final compost. pH levels at the end of the test in the masses of compost in the first stage to the second, respectively, were 7.1, 7.13 and 7.17. Sawdust, due to low content of heavy metals, decreased these elements in the compost mass. Mixed compost at the second stage, due to sawdust, concentrations of heavy metals such as chromium, cadmium, copper and zinc in the zero level has been minimal.

Water is one of the main elements for microorganisms. If humidity is high, many problems may arise in the process of fermentation. Appropriate amount of water in the range of 60 percent is recommended. Another important element of nutrition for microorganisms is oxygen. Because of high moisture content and size of material, bulking agents should be used to create suitable porosity in the mass. In order to make balanced and homogeneous temperature in the whole mass and mechanical aeration, in the intervals of 4-6 days, issues of relocation and material's turning over should be taken into account.

The addition of sewage sludge provides stabilized and innocuous compost in a shorter period of time, with a higher proportion of organic matter and nutrients besides. Physical and Chemical parameters analyzed are subject to a high degree of variability and do not take into account biological activity that takes place in the material that is being composted.

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