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Effect of Aerobic Composting on Some Environmental Health Parameters

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ABSTRACT

Environmental health properties such as total coliform (TC), fecal coliform (FC) and heavy metals were investigated during composting of Marketplace Waste (MW) and the changes in radioactivity were investigated in raw and stabile composts. The number of coliforms decreased during composting and the composts obtained in this study had heavy metals under the standards. Alpha and beta radioactivity levels decreased. The concentrations of ^{40}K and ^{137}Cs were determined. The results obtained from the investigated parameters showed that the risk for human health could not arise during the usage of these composts in soil.

Key Words: *Waste, health, composting, radioactivity, heavy metals, indicator bacteria.*

1. INTRODUCTION

Biodegradable organic wastes which have not any economical value thrown away to environment by various sources (municipal, household, agriculture etc.) and cause lots of problems associated with public health. Composting of these wastes supports the environmental and public health and economics by eliminating pathogens, decreasing radioactivity values, preventing pollution and protecting resources [1, 2].

There are many pathogens and each of them has a specific detection procedure and must be individually screened. The concentrations of these organisms, although large enough to spread disease, may be so small to make their detection impossible, like the proverbial needle in a haystack. We measure bacteriological quality with the indicator organisms [3]. To measure fecal pollution, the presence of a group of bacteria known as fecal coliforms is determined [4]. Fecal coliforms are particularly good indicator organisms because they are easily detected with a simple test, generally harmless, and do not survive long outside their host [3].

The content, behavior and significance of heavy metals in composted waste materials are important from two

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potentially conflicting aspects of environmental legislation in terms of: (a) defining end-of-waste criteria and increasing recycling of composted residuals on land and (b) protecting soil quality by preventing contamination [5]. The class of heavy metals of elemental pollutants can be considered to be one of the most harmful as they are generally associated with toxicity effects [4]. Heavy metal uptake by crops growing in contaminated soil is a potential hazard to human health because of transmission in the food chain [6, 7, 8, 9]. Intake of heavy metals via the soil-crop system has been considered as the predominant pathway of human exposure to environmental heavy metals in agricultural area [10,11]. There is also concern with regard to heavy metal transmission through natural ecosystems [9, 12, 13].

A health hazard occurs when material contaminated with α-emitting radionuclides is eaten or inhaled, or otherwise absorbed inside the body, so that organs and tissues more sensitive than skin are exposed to α radiation. Collisions between α particles and the atoms and molecules of human tissue may cause disorder of the chemical or biological structure of the tissue. Internal organs are generally protected from external β radiation, but exposed organs such as eyes are sensitive to damage. Damage may also be caused by incorporation of β emitters into the body and resulting in exposure of internal organs and tissue [3]. Background radiation varies over a range of concentrations and exposure rates from a variety of causes. The magnitude of variation can be significant over a short distance and also can vary in the same place from time to time. The background variance can be from natural as well as human activities. There are various background sources of radiation. Most anthropogenic radionuclides are short-lived, but some (e.g. ^{137}Cs) have half-lives of many years and are worthy of note [14]. ^{137}Cs is highly toxic with long half-life [15].

Usage of composts those have high amounts of pathogens, heavy metals and radioactivity causes several problems which threat both the human and environment health. Therefore, in this study, it was aimed to determine the effect of composting process on these parameters. Also, we specify that, to our knowledge, this is one of the rare reports on radioactivity concentrations of materials in composting process met in literature.

2. MATERIAL AND METHODS

The compost reactor with an internal diameter of 30 cm and a height of 50 cm was made of fiberglass and covered with glass wool for insulation (Fig. 1). The air which was controlled by timer and solenoid valve was given to the reactor by a compressor and the time of the airflow was 1.5 minutes in each 8 minutes period. The airflow rate was 10 L/min which was measured by a flow meter and controlled by pressure regulator. The MW was obtained from the marketplace of Elazığ city. Biological treatment sludge from the activated sludge treatment plant of Elazığ city was used as inoculum.

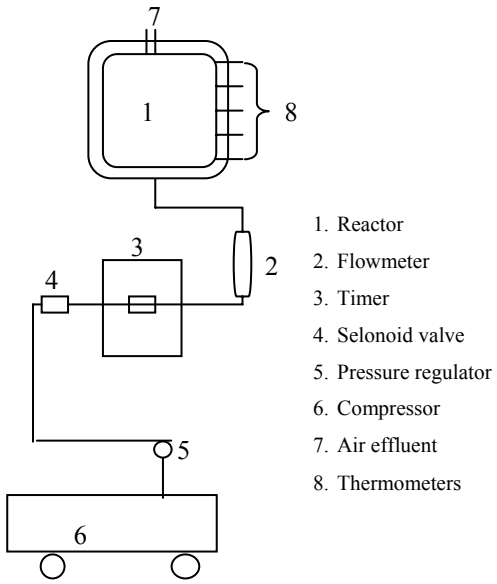

Figure 1. Schematic diagram of composting reactor.

TC and FC analyses were conducted according to Standard Methods [16] by the Most Probable Number (MPN) method. The samples taken from the reactors were dried at 65 ^{o}C during 48 hours for heavy metal determinations. The dried samples were ground in a coffee mill after they were homogenized in a blender and then ground to pass through a 60 mesh (0.250 mm) sieve for analyses. Heavy metal determinations were done according to Hseu, 2004 [17] by nitric acid digestion method that partly modified from the method of Zheljazkov and Nielson [18]. An ATI UNICAM Model 929 flame atomic absorbtion spectrophotometer equipped with ATI UNICAM hollow cathode lamp was used for the heavy metal determinations. The samples taken from reactors were dried at 105 ^{o}C for 24 hours for radioactivity determinations. The dried samples were

ground in a coffee mill after they were homogenised in a blender and then ground to pass through a 60 mesh (0.250 mm) sieve for analyses. Radioactivity determinations were done according to Doğru et al, 2001 [19]. The radioactivity concentration in the prepared samples was determined by using a β-radiation-sensitive plastic scintillator (2059 plastic scintillator from NE Tech. Inc.) supported by a suitable photo multiplier tube and SR-8 Low Level Radiation Counter from the same company. The α-radioactivity concentration was determined by using a ZnS(Ag) scintillator detector with Low Level Alpha Spectrometer from NE Tech. Inc. and calculated by using ‘‘equation (1)’’. The β-activity concentration in the samples was calculated by using ‘‘equation (2)’’ [20]. The potassium concentration was determined by gamma spectroscopy with NaI(TI) detector.

$$A\alpha = (NxECF) / 2.22 \quad (1)$$

$$A\beta = (0.391xRxNm) / N0 \quad (2)$$

Table 1. Characteristics of the compost.

Parameter	Value
pH	8.23
EC (µS/cm)	803
VS (%)	87.71
C (%)	48.73
N (%)	1.40
C/N	34.08
Cellulose (%)	30.3

where, A_α and A_β is the alpha and beta radioactivity in pCi, N is the sample net count per minute for alphas, ECF is the efficiency correction factor, R is the net β-count in minutes, N_m is the specific mass of samples in mg cm^{-2}, N_0 is the count obtained from a calibration curve [21].

Volatile Solid (VS) was determined as described in Standard Methods [16]. Cellulose was performed according to the AOAC Methods [22]. Carbon (C) was calculated according to Adams et al. [23]. Nitrogen (N) was determined as described in Methods of Soil Analysis [24]. pH and Electrical Conductivity (EC) were measured in the compost-water (1:10 w/v) extract by using a pH probe (WTW pH 330) and an EC probe (WTW LF 330), respectively.

3. RESULTS AND DISCUSSION

The characteristics of the obtained compost of interest for this study were given in Table 1.

The temperatures seen during composting process was given in Figure 2. The MW reached maximum temperature of 53°C within 1 day. The thermophilic phase ended after 7 days. After then, the temperature decreased to the mesophilic values. Similarly, Lin, 2008 [25] was reported high temperature (65 °C) in the first day of composting study. In their study, the temperature gradually dropped to 35 °C at the end of the process similar to ours. In our study, The number of TC and FC especially decreased after the high temperature values. Also, TC and FC declined (99%) at the end of the process as seen from Table 2. In the study of Lin [25], the initial TC of 1100 MPN/100 mL decreased to 240 MPN/100 mL with increasing temperature on the first day, in agreement with our study. Also, in accordance with our results, they were reported that the TC decreased to below 3 MPN/100 mL after the process entering the thermophilic fermentation period on the 14th day, and the final compost contained TC below 3 MPN/100 mL with a removal of above 99%.

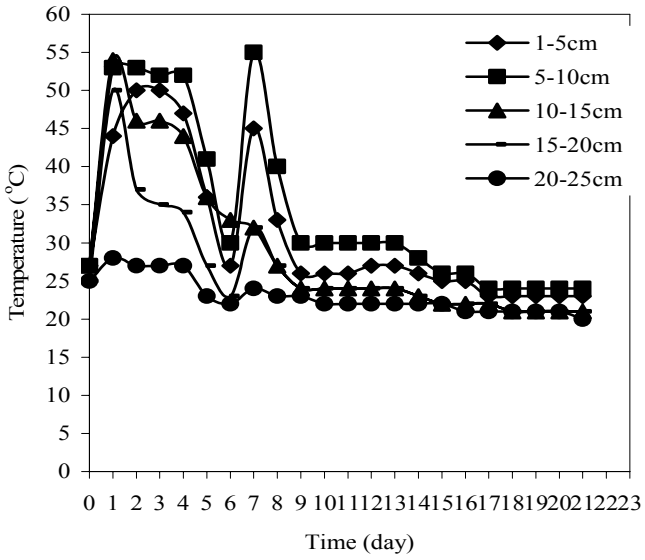

Figure 2. Changes in temperature during composting of Marketplace Waste (MW).

Table 2. TC and FC amounts during composting.

	(MPN/ 100 g wet weight)				
	Day 0	Day 3	Day 9	Day 15	Day 22
TC	$\geq 2400 \times 10^7$	1100×10^7	110×10^7	23×10^7	11×10^7
FC	4×10^7	4×10^7	0.04×10^7	0.011×10^7	0.011×10^7

Heavy metal contents (Cr, Cd, Zn, Mg, Cu, Co, Fe, Ni, Mn) of the compost are given in Table 3. Heavy metal concentrations of the final composts were below the limits of Soil Pollution Control Regulation (Table 3). The increases in the concentrations of the heavy metals at the beginning and ending of the process could be explained by loss of mass. As Richard, 1992 [26] was reported, heavy metals do not degrade throughout the composting process, and can become concentrated due to the loss of carbon and water from the compost due to the microbial respiration. Similar to our results, Farrell and Jones [27] found that total Cu, Pb and Zn concentrations increased over time due to the progressive mineralization of the compost feedstock. Also in the study of Ko et al. [28], Zn Cu, Pb, Cr, Ni, Pb and Cd concentrations at the end of the composting stage were higher than those at the initial stage. Similarly, when Cai et al. [29] composted sewage sludge from different wastewater treatment plants the concentrations of Cd, Cu, Pb and Zn increased at the end of the process.

Table 3. Heavy metal contents of the composts and the limits.

Heavy metal (mg/kg)	Day 0	Day 22	Turkey**
Zn	160.8	178.9	4000
Ni	10.98	14.80	400
Cr	17.2	17.2	1200
Cd	*	*	40
Cu	17.8	18.9	1750
Mg	346.9	1429.2	-
Co	6.35	7.45	-
Fe	2126.30	2997.43	-
Mn	75.43	86.58	-

* Below detection limit

** Soil Pollution Control Regulation for stabilized treatment sludges used in soil. (The regulation does not include heavy metal limit values for composts used in soil.)

In our study, the raw material we used in the composting process was plant originated. Plants can become contaminated with radionuclides via three pathways: root uptake, foliar absorption and surface adhesion of resuspended contamination on leaves and stems [30]. Breshears et al. [31] were reported that agroecosystems can become contaminated by atmospherically released radionuclides. The subsequent concentrations of

radionuclides in foods are dependent on numerous environmental, physiological, and management factors [31]. In our study, the α radioactivity was exist in the composting material (Table 4). The variations of the β-radioactivity concentration at the beginning and end of the composting process are given in Table 4. As seen from Table 4, the β radioactivity decreased at the end of the process similar to the composting studies of Arslan et al. (Accepted-a and b). It was suggested that β-radioactivity had arisen from ^{40}K. Potassium activity was decreased in range of 19% (Table 4). One of the primary non-series radionuclides contributes to background dose, ^{40}K. Potassium-40 is a beta (87.3%) and gamma (10.67%) emitter and contributes to both internal and external doses. It exists as a constant fraction of stable potassium (0.0117%). Its contribution to external dose is variable, depending on its concentration in rocks and soil. Potassium is metabolically regulated by the body and is not controlled by intake [14].

In our study, ^{137}Cs concentration in studied samples was very low and decreased by composting process (Table 4). From the beginning of the nuclear era, much attention has been paid to the determination of ^{137}Cs because of its production in abundance with a nuclear fallout, health hazard nature and with having relatively long half-life of ~ 30 years. The separation of ^{137}Cs from nuclear waste streams is of major environmental concern, as if it is separated this can minimize the possible damage to man and the environment [32]. Anthropogenic radioisotopes with long physical half-lives derived from atmospheric fallout remain in the environment for decades after deposition. The longer lived radioisotopes, such as ^{137}Cs, remain in the environment for decades after deposition providing considerable potential for subsequent redistribution within upland ecosystems [33].

Table 4. The radioactivity levels of raw materials and obtained compost.

Sample	Gross α-radioactivity (Bq/g)	Gross β-radioactivity (Bq/g)	^{137}Cs (Bq/g)	^{40}K (Bq/g)
Day 0	0.1760 ± 0.0080	0.0479 ± 0.0007	0.0044 ± 0.0002	0.944
Day 22	0.0388 ± 0.0075	0.0270 ± 0.0006	0.0032 ± 0.0003	0.762

4. CONCLUSIONS

The composting process used was efficiently reduced the indicators TC and FC, α and β radioactivity in MW. Also, measured heavy metal concentrations (Cr, Cd, Zn, Mg, Cu, Co, Fe, Ni, Mn) were under the heavy metal limits of Soil Pollution Control Regulation. The obtained compost was suitable for application to the soil according to the investigated parameters.

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