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Evaluation of microbiological and chemical parameters during wastewater Sludge and Sawdust Co-composting

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ABSTRACT: Environmental specialists classified sewage sludge as a hazardous waste because of high organic compounds and pathogenic microorganisms. Therefore sewage sludge should be stabilized before disposal. Composting is an effective and economical method to stabilize sewage sludge. The object of this study is determining the optimum conditions of co- composting of dewatered sewage sludge and sawdust. Pilot scale study was performed in Isfahan municipal wastewater treatment plant. To perform this study, the dewatered sewage sludge with humidity between 78-82 percent was mixed with sawdust. Turning over did once a week for aeration. Temperature was monitored at different depths daily. Other parameters such as N, C, organic matters, pH, heavy metals, total and fecal Coliform and Salmonella were determined three times a week. The results of this study showed that after about 15th days, temperature of the mixture reached up to 55 ^{o}C, and was stabled for fifteen days. Humidity, organic matter, organic carbon and C/N ratio of the mixture decreased during of the study, due to increasing the temperature. Also organic matter and humidity mainly decreased in thermophilic phase. The number of total and fecal coliforms and also Salmonella decreased to A class standards of U.S. EPA at the end of the operation. The result indicated that co-composting of sewage sludge with sawdust is a reliable and simple method to schedule, with high flexibility and low odor production. Organic compounds and pathogenic microorganisms reduced and EPA standards were met during this method. @ JASEM

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Sewage sludge, a product of wastewater treatment, is rich in nutrients and trace elements and could be re-used in agriculture as fertilizer and soil conditioner. High odor emission, high levels of heavy metals and toxic organic compounds, and the presence of potentially pathogenic microorganisms demand pretreatment of sewage sludge before application in agriculture (Veeken and Hamelers, 1999; Tiquia et al., 2002). Environmental specialists classified sewage sludge as a hazardous waste because of high organic compounds and pathogenic microorganisms. They believe that sewage should be stabilized before disposal and so composting of sewage sludge is an effective and economical method to stabilize. Composting is a successful strategy for the sustainable recycling of organic wastes (Fermor, 1993; Tuomela et al., 2000). Composting is an aerobic process consisting of aerating sludge mixed with a co-product such as sawdust or animal manure. Composting produces excess heat, which can be used to raise the temperature of the composting mass. The mix then evolves for several weeks. Composting is increasingly being come the preferred method of treatment of municipal sludge's because the process produces a marketable end-product that can be used as a soil conditioner and organic fertilizer. The successful operation of in-vessel (mechanical) and windrow systems depends on the mixing of large amounts of sawdust bulking agent with sludge cake to increase the porosity and to adjust the moisture content of the composting mass.

Using dewatered sewage sludge in agriculture has many benefits. Organic matter content improves the soil structure while the presence of nutrients such as N, P and K increase soil fertility. Degradation of the organic matter can also increase the soil content in compounds of agricultural value (such as N, S, Mg and etc.), which are slower released than in the case of mineral fertilizers and therefore available for a longer period to crop. Organic matter is lastly an energy source for micro-organisms living in soil. Therefore sludge spreading may induce an increase of the soil population and activity, and of its mineralization capacity. Hence this substance is composted and be used for agricultural purposes and be a substitute for expensive inorganic fertilizers. Presence of pathogens and content of heavy metals are limitations in using sludge compost for agricultural purposes (Rehm and Reed ,2000). Windrow is the most common method of sludge composting, in which dewatered sludge is mixed with bulking agents. Successful compost stabilization process of dewatered sludge depends on maintaining a suitable environment for process control including: a) moisture content, b) oxygen concentration, c) carbon-nitrogen ratio, d) temperature that must be considered under all aspects of external conditions, heat production within the matrix as a consequence of biological activity, heat transfer, and heat management; e) pH, f) Physico-mechanical characteristics of the material being composted and g) macro and micronutrients. Moreover, if the prominent goal of composting is the production of a soil organic amendant that meets the qualitative standards for agricultural uses, then (h) the composition of the starting substrate biomass must be taken into account. Adjusting carbonaceous materials (plant wastes such as sawdust) to dewatered sludge compost increases its moisture content, improves the aeration and C/N ratio. Since dewatered sludge has a low C/N ratio, mixing it with bulking agents adjusts its C/N ratio. Also, dewatered sludge is often too wet and adjusting of dry bulking materials to absorb its surplus moisture increases its porosity (6). A biodegradable carbon-nitrogen (C/N) weight ratio of 25 to 35 has been found to provide optimal conditions for compost process. Lower C/N ratio increases the loss of nitrogen by leaching (e.g. nitrate mobilization) and ammonia volatilization; whereas higher levels necessitate progressively longer composting time as nitrogen becomes the microbial – limiting nutrient. Sludge normally has C/N ratios in range of 10 to 20. To offset an imbalance in the C/N ratio, compost amendments usually are necessary. Typical compost amendments include materials with high C/N ratio such as 1) sawdust, 2) leaves, 3) wood chips, 4) rice hulls and 5) old compost. Dewatered sewage sludge composting with bulking agents converts it into a useful product. Land application of sewage sludge compost is restricted due to its content of heavy metals, pathogens and persistence of organic pollutants in the sludge (Tchobanoglous and Theisen 1993). The objective of this study was to investigate the feasibility of aerobic sewage-sludge composting by using sawdust as bulking agent for complete stabilization of dewatered sludge.

MATERIALS AND METHODS

This study was performed during a three month period from November to February 2002, in laboratory of Chemistry of Water and Wastewater in the School of Public Health, Isfahan university of Medical Science, ran. Dewatered sludge was collected from Isfahan sewage treatment plant. Sawdust was collected from sawmills. Sewage sludge (output from sludge dewatering unit) and sawdust were used at five different ratios: 8:1, 8.5:1.5, 1:0.6, 1:0.5, and 1:0.4 (W: W). During the study, each piles was monitored for solids, temperature, microorganisms (coliforms and salmonellae and egg of Ascaris), organic matter, C/N ratio, pH and heavy metals according to the schedule given in Tables 1 and **2.**

Moisture content based on as received weight should be between 50% and 60% and therefore regulated by spraying water on some piles. Samples were obtained three times per week, and then were transferred to the laboratory for conducting various tests according to standard methods (Lopez and Medejon 2001). Turning over method of the piles with one-week interval were applied to aerate the mixture. Temperatures were measured by inserting a thermocouple probe to depths of 30, 45 and 90 Cm into the sides of the piles and reading the temperatures on a portable digital indicator.

During the composting process, temperatures were measured daily. Also during the composting process, the chemical properties of the compost were monitored, including total nitrogen content, total organic matter, and percent of dry solids, total carbon, pH and carbon to nitrogen ratio. Total carbon content of the samples determined through combustion in ovens at 750 ^oC for 2 h. Total nitrogen analysis was performed by Kjeldahl method. Samples were digested by nitric acid 1+1 and heavy metals contain Cr, Cd, Zn, Ni and Cu analyzed by flame atomic absorption (7). Indicator and pathogenic microorganisms including total Coliforms, fecal Coliforms, salmonellae and Ascaris ova, were analyzed at the beginning and end of the composting process; also heavy metals were measured at the same time.

RESULTS

Results of daily monitoring temperature in different depths showed that temperature in the compost piles reached about 55 ◦C after 15 days of composting and continues for about 20 days. Temperatures in excess of 55◦C for several days (at least three) are usually instrumental in inactivation of pathogenic organisms, especially when septic materials such as sewage sludge are processed. Above 60◦C the metabolic activity of microorganisms begins to decline.

Water content of the substrates should be 55–65% at the start of the process, with the higher values recommended for composting with turning or based on any other mechanical mixing of the substrate biomass. If the aerobic biotransformation of initial organic waste is correctly managed, moisture progressively decreases as composting proceeds towards complete biomass stabilization. In this study water content of the substrates decreased. On the other hand, percent of dry solids increased from about 37.87 % to 66.58 % (table 1, 2). At present study, a C: N ratio of 26.63:1 is considered and at the end of composting period reached about 20.52:1 (table 1, 2).

Microbes driving compost stabilization operate best in the range of pHs between 6.5 and 8.0. Nevertheless, the natural self-correcting or buffering capacity of the process makes it possible to proceed over the much wider range of 5.5 to 9.0. Although adjustment of pH in the starting biomass is rarely required, this factor should be conditioned when matrices with high nitrogen contents are treated. Actually, pHs higher than 8.5, joined to temperatures in the thermophilic range, favour ammonification that may contribute to the unpleasant odorous emissions from composting matrices. In this research adjustment of pH in the starting biomass is not required. The pH values of all piles increased slightly by day 5 of storage and then decreased gradually up to day 40 in all piles (table 1, 2). Microbial parameters such as total and fecal Coliforms and Salmonella decreased significantly at the end of composting period (table 1, 2). The computed correlation coefficients and the P values show a significant correlation between reduction of organic content and microbial parameters (r^2 = 0.91, P< 0.001).The concentration of heavy metals (including Pb, Cu, Zn, Cd and Cr) in final compost also determined that showed in table 3.

Table 1. Physical, chemical and microbial characteristics of primary mixture

Parameters										
Pilot number	Mixture ratio (w:w)	Dry solids, %	Organic matter, %	Total nitrogen, %	Total carbon, %	C/N ratio	pH	Total coliforms. $\times10^8$ MPN/gr	Fecal coliforms. $\times10^7$ MPN/gr	Salmonella MPN/4gr
1	8:1	31.3	69.12	1.68	32.82	19.54	8.51	1.39	4.36	20.45
2	8.5:1.5	33.6	69.75	1.66	33.28	20.06	7.87	2.88	2.08	18.65
3	1:0.6	41.8	82.71	1.28	40.22	31.43	8.35	1.05	2.55	21.15
4	1:0.5	43.5	80.42	1.25	38.98	31.18	7.78	3.6	1.23	16.3
5	1:0.4	39.16	80.19	1.24	38.48	30.95	7.79	2.69	2.09	22.14
$\bar{X}$		37.87	76.44	1.42	36.76	26.63	8.06	2.32	2.46	*19.74*

DISCUSSION

After a few decades of debate on composting as an ecological alternative to mass burning and land-filling of garbage, solid-phase bio-oxidative stabilization of the organic fraction from such urban residue, either source-collected or mechanically sorted, represents a reliable technology for reducing the environmental impact of municipal solid waste management. Although composting cannot be looked at as an exhaustive treatment for the whole stream of urban wasted materials, it undoubtedly makes a great contribution to the solution of the problems concerned with processing of putrescibles, which represent the most critical fraction of municipal waste. Similarly, agricultural and industrial by-products, fermentable in nature, may also be economically treated by compost stabilization and, possibly, reclaimed as organic amendants. During the storage of primary mixture of compost some of the organic substances undergo decomposition and the product obtained is less odorous and also safer from the hygienic point of view. In dependence on the conditions of storage (temperature, aeration, humidity, and pH) organic matter is decomposed at various speeds at several temperature stages at which specific microorganisms play a dominant role. Stentiford (1996) suggested that temperatures higher than 55°C maximized sanitation, those between 45 and 55°C maximized the biodegradation rates, and between 35 and 40 °C maximized microbial diversity in the composting process (Stentiford, 1996). According to Strauch and Ballarini (1994) only the thermophilic range of 55 °C is sufficient to destroy pathogens (Strauch and Ballarini, 1994). The EPA recommended exposure standard of 15 days at 55°C in the windrow or piles (U.S.E.P.A., 1984). Throughout the experimental period, the ambient temperature ranged from 4 to 24.7 °C. The core temperature exceeded 55 °C on day 15 and persisted above this level for 20 days which sufficed to ensure devitalization of potentially present pathogens. The highest temperature reached was 61.1. By days 35–38, the core temperatures in the substrates decreased gradually to the ambient temperature and followed its course. This temperature can destroy pathogens and parasites. The C/N ratio is one of the vital aspects of composting. Values between 25:1 and 35:1 are considered to be optimal. If the C/N ratio exceeds 35:1 the composting process is slowed down, while a ratio less than 20:1 results in a loss of nitrogen which occurs mainly as NH_3 gaseous emissions (Martins and Dewes, 1992). The bioavailability of especially carbon is also important. During the composting process the biologically degradable organic matter is converted into volatile CO_2 and H_2O and is removed from the compost and the total N content increases which results in a C/N decrease toward the end of composting (Vuorinen and Saharinen, 1997).

Table 2. Physical, chemical and microbial parameters of final compost

Parameters									
Pilot number	Dry solids, %	Organic matter, %	Total nitrogen, %	Total carbon, %	C/N ratio	pH	Total coliform MPN/gr	Fecal coliform MPN/gr	Salmonella MPN/4gr
1	70.2	49.38	1.31	21.91	16.6	7.03	41687	631	1.09
2	58.3	50.37	1.41	22.45	15.92	7.18	123027	2055	0.78
3	72.06	53.21	1.08	22.38	20.72	7.01	8913	871	0.13
4	68.54	58.31	1.1	26.77	24.34	7.11	47863	708	0.16
5	63.78	55.94	1.02	25.52	25.02	7.09	8913	525	0.18
$\bar{x}$	66.58	53.44	1.19	23.81	20.52	7.08	28840	958	0.47

Microbial parameters such as total and fecal Coliforms and Salmonella decreased significantly at the end of composting period and covered A class standards of EPA for its application in agricultural lands. Also in final compost no observed any Ascaris ova. Sewage sludge's usually contain heavy metals and toxic organic matter that if apply in agricultural lands can cause dangerous condition for human, animals and plants. On the other hand, presence of high amounts of heavy metals in sewage sludge is one of the most significant reasons that restricted its application in agricultural lands. The results of this study showed that the concentration of cadmium (as contamination index) in final compost is less than maximum contaminant level in sewage sludge compost that established by U.S.EPA. Also the concentration of other heavy metals in final compost was less than EPA standards; hence its application for agricultural lands is safe and not detrimental. Therefore, co-composting of dewatered sewage sludge with sawdust is a reliable and simple method to schedule, with high flexibility and low odor production.

Table 3. Summary of average heavy metals concentration in final compost product

	Parameters				
Pilot number	Pb,mg/kg	Cu,mg/kg	Zn,mg/kg	Cd, mg/kg	Cr, mg/kg
1	79.12	89.31	255.27	0	45.6
2	163.97	319.24	292.07	1.33	32.13
3	98.29	164.8	184.84	0	71.47
4	114.77	104.72	173.16	2.67	27.6
5	102.16	131.91	223.04	0	40.93
Standard value	300	1500	2800	39	*1200*

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