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Study the Stabilization of Heavy Metals during Co-composting process using mixture of sodium sulfide & lime as co-composting materials

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ملخص:

كان الهدف من هذا العمل هو دراسة تأثير خليط كبريتيد الصوديوم والجير على استقرار المعادن الثقيلة اثناء عملية تسميد حماه الصرف الصحي. أضيف خليط كبريتيد الصوديوم والجير الي مخلوط حمأة الصرف الصحي وقش الرز بنسب مختلفة (1.0-1.5-2.0-2.5-3.0) كنسبة مئوية الي الوزن الجاف لحمأة الصرف الصحي. تم رصد حركة أجزاء المعادن الثقيلة لعناصر النحاس والنيكل والزنك والرصاص. تبين من النتائج وصول المعادن الثيقلة الي حالة الاستقرار حيث انخفض تركيز الاجزاء الاكثر إتاحية والاسهل امتصاص من قبل النبات من المعادن الثقيلة. بناءا على نتائج التجربة تبين أنه بعد مرور 60 يوم كان مقدار التخفيض 0.0-32.4-18.1-0.0 لعناصر النحاس والنيكل والزنك والرصاص علي الترتيب.في حين بلغ معدل تخفيض لهذه الاجزاء (77.1 – 76.8 – 73.9 – 74.7) % لعناصر النحاس والنيكل والزنك والرصاص على الترتيب عن نسبة 3.0% خليط كبريتيد الصوديوم والجير. مما يدل علي أن إضافة خليط كبريتيد الصوديوم والجير كان له تأثير كبير في تقليل إتاحية المعادن الثقيلة .

Abstract

The objective of this work is to study the effect of using mixture of sodium sulfide & lime as co-composting materials on labile heavy metals fraction (LHMF) reduction during the sewage sludge co-composting process. The windrow co-composting extended to 60 days. Mixture of sodium sulfide & lime (SSL) was added to mixture sewage sludge and rice straw (RS) with different dry weight ratios of 1.0, 1.5, 2.0, 2.5 and 3.0 %. Throughout the co-composting process, labile heavy metals fraction (LHMF) for Copper (Cu), Nickel (Ni), Zink (Zn) and Lead (Pb) were monitored. Based on the results, after 60 days for sewage sludge composting, LHMF reduction percent were, 0.0, 18.1, 32.4 and 0.0 for Copper (Cu), Nickel (Ni), Zink (Zn) and Lead (Pb) respectively. However, LHMF reduction percent were, 77.1, 76.9, 73.9 and 74.7 for Cu, Ni, Zn and Pb respectively at SSL dose 3.0%. The use of SSL as co-composting material is significantly improved the sewage sludge co-composting process in term of LHMF reduction.

Keywords: Sewage sludge, composting, Co-composting, Heavy metals, SSL.

1. Introduction

Composting is highly an economical method for the handling and final disposal of biodegradable wastes because it is helpful for material recycling and disposal (Villasenor J et al., 2010; Singh J et al., 2012). In the composting process, organic matter is transformed into compost, which is a stable and pathogen-free product (Mosquera-Losada et al., 2010). In some case this product may contain toxic compounds such as heavy metals which limit the reuse for the agriculture application (Mosquera-Losada et al., 2010). Unfortunately, the conventional sludge composting process does not decrease either the heavy metals contents or their availability for plant intake (Mostafa, A. M. K., 2000). Some heavy metals are essential elements required for normal growth and metabolism of plants (Singh J et al.,2012), but these metals can easily lead to poisoning when their large fractions are present in labile forms. These forms are most bioavailable factions for the plants (J. W. C. Wong and A. Selvam, 2006). Uptake of heavy metals by plants and subsequent accumulation along the food chain has a potential threat to and human and animal health (J. W. C. Wong and A. Selvam, 2006). Hence, improvement of the composting process for heavy metals stabilization is a potential area of research (Wong et al., 1997; Ho and Qiao, 1998; Fang et al., 1999; Zorpas et al., 2000; Chiang et al., 2001). Co-composting process is the enhancement of conventional process by chemical additions (Wong et al., 1997). Many researchers have carried out work on the improvement of the composting process to diminish the bioavailability of heavy metals to the plants using various alkaline materials such as natural zeolite (A. A. Zorpas et al., 2002; A. A. Zorpas et al., 2000; A. A. Zorpas et al., 2008; M. Sprynskyy et al., 2007; J. Villasenor et al., 2011), lime (J. W. C. Wong and A. Selvam 2006; M. Fang and J. W. C. Wong 1999) lime with sodium sulfide (X. Wang et al., 2008), bamboo charcoal (Y. X. Chen et al., 2010), bamboo vinegar (L. Hua et al. 2009), Red mud (Qiao and Ho,1997) and Coal fly ash, (Chiang et al. 2007). Most of the published works in the literature considered the total metal concentration is useful as an overall pollution indicator, but it does not provide useful information about their chemical form (Walter I et al.,2006; Venkateswaran P et al.,2007). It has been reported that bioavailability of heavy metals is an important evidence for metals toxicity (Nair A et al., 2008). Heavy metals in compost are divided into two parts, the first part is the inert fractions that is expected to be nontoxic fraction and it includes Organic matter, sulfide fraction and residual fraction. The second part is the labile fractions, that is expected to be possibly toxic and it includes exchangeable fraction, carbonate fraction and Fe-Mn fraction (Yobouet YA et al., 2010). To determine the availability of heavy metals, only the labile fraction has been considered bioavailable (Singh J et al.,2013a). Even if the concentration of heavy metals in the compost is lower than the regulatory limit, long-term land application of compost can accumulate and increase the labile fractions contents in the soil (Chiang KY et al., 2007). Many studies have provided that, co-composting sewage sludge with alkaline materials, such as, lime was enhancement of composting process and reducing the bioavailability of heavy metals (Chaudhuri et al., 2003; Fang and Wong, 1999; Zorpas et al., 2000; Veeresh et al., 2003; Sophia and Swaminathan, 2005). Recently, (Dalibor et al. 2006) reported that, the conversion of heavy metals involved in incineration fly ashes to heavy metal sulfide resources by sulfidation treatment with sodium sulfide, which was considered to be a suitable technique for reducing the bioavailability of heavy metals from various types of wastes**.** However**, (**X. Wang at el, 2008) reported that, no previous study describing co-composting sewage sludge with sodium sulfide has been reported. Hence, the aim of current study was at evaluating the effect of SSL on stabilization of the labile fractions of nickel, lead, copper and Zink heavy metals during sludge co-composting process.

2. Material and methods

2.1 The Municipal Sewage Sludge

Semisolid aerobic sewage sludge samples were collected from Greater Cairo Composting Production Factory after drying beds stage of Secondary Wastewater Treatment Plant at Balaqus, its capacity is approximately 600.000 m3/day which also service municipal and industrial wastewater of north Cairo. Selected Physicochemical properties of the municipal sewage sludge are given in (Table 1).

2.2 Rice Straw

Rice Straw is selected as the bulking agent, as it is readily available and has good moisture absorption capacity. Rice Straw collected from a farm at Zagazig City in EL-Sharkia Governorate, and the straw was cut by a worker for approximately 10-15 cm long. Selected Physicochemical properties of Rice Straw are given in (Table 1).

Table (1), Physicochemical properties of the municipal sewage sludge and rice straw

Parameter	Sewage sludge	Rice Straw
PH	6.82	6.37
EC (dS m^-1)	1.82	2.63
Moisture content (%)	60	8.35
Total organic carbon (% of D.W)	36.7	17.81
Total N (% of D.W)	2.73	0.612
Total P (% of D.W)	0.15	0.34
VS (%)	54	82.19
Ammonia –N(mg/kg)	420	76
Nitrate – N (mg/kg)	18	24
Salmonella spp (MPN /1g DS)	25,000	Absent
Faecal coliforms (MPN /1g DS)	300,000	Absent
Total Heavy metal for Nickel (mg/kg)	423.7	Absent
Total Heavy metal for Copper (mg/kg)	188.5	4.22
Total Heavy metal for Lead (mg/kg)	2591	18.95
Total Heavy metal for Zink (mg/kg)	506.9	23.23

2.3 Mixture of sodium sulfide & lime (SSL)

The lime was obtained from a local lime factory in EL-Salam City, Cairo.
The sodium sulfide flake (60~62%) was obtained from a Laboratory preparation of chemical compounds in Dokki, Cairo.

2.4 Experimental design for windrow co-composting.

The sewage sludge was mixed with Rice Straw as a bulking agent at 2:1 (w/w fresh weight) to obtain a C/N ratio between (25 ~ 30). Eleventh co-composting windrow piles with dimensions approximately about (1.5m × 1.25m × 1.25m) (length × width × height) were built and were design randomly with Machine and manual turning. The sewage sludge– Rice Straw mixture was then mixed thoroughly with SSL. The windrows were turned every one week to encourage aeration. Moisture losses were adjusted by the addition of H_20, maintaining the moisture level at 40-60%. Co-Composting process was performed during the period from October to December 2016 (two months). Mixtures for different co-composting piles were mixed as described in Table (2):

Table (02)

Run	name	S.S (%)F.W	Bulking agents (%)F.W	Lime (%)D. W	Sodium Sulfide (%)Dry Wight
Run 01	W0	67	33	0.00	0.00
Run 02	W1	67	33	0.50	0.50
Run 03	W2	67	33	0.75	0.75
Run 04	W3	67	33	1.00	1.00
Run 05	W4	67	33	1.25	1.25
Run 06	W5	67	33	1.50	1.50

2.5 Sampling procedures: -

Compost mixtures were turned and samples were taken on days 2, 20, 40 and 60 for labile fractions of heavy metals.

2.6 Sample analyses

LHMF (Cu, Ni, Zn and Pb) in composting and co-composting process were measured using a sequential extraction method (Tessier et al. 1979). In this method, LHMF concentrations were determined by flame atomic absorption spectrophotometry (FAAS).

3. Results and discussion

3.1 The Variation of pH

The pH value of a solution strongly influences not only the site dissolution of biomass surface, but also the solution chemistry of heavy metals: hydrolysis, complexation by organic and or/inorganic ligands, redox reaction, precipitation, the speciation and biosorption availability of the heavy metals (Wang et al.,2009). Figure 1 shows the variation of pH in control and SSL added composting process during 60days of co-composting process. initial pH of the co-compost mixtures was higher than control compost mixture but it decreased gradually thereafter to nearly neutral. Maximum pH values were observed about 7.9, 8.95, 9.1, 9.25, 9.42 and 9.6 at SSL dose 0.0, 1.0, 1.5, 2.0, 2.5 and 3.0%, respectively, after 10days of co-composting process (Fig. 1). However, in the final co-compost pH values were in the range of 6.5 –7.7 (Fig. 1). The reduction in pH could be ascribed to CO_2 and organic acids produced during microbial metabolism (Haimi and Hutha, 1986). Similar trends of Ph change was also observed by other studies in the literature (J. W. C. Wong et al.2006; M. Fang et al.1999).

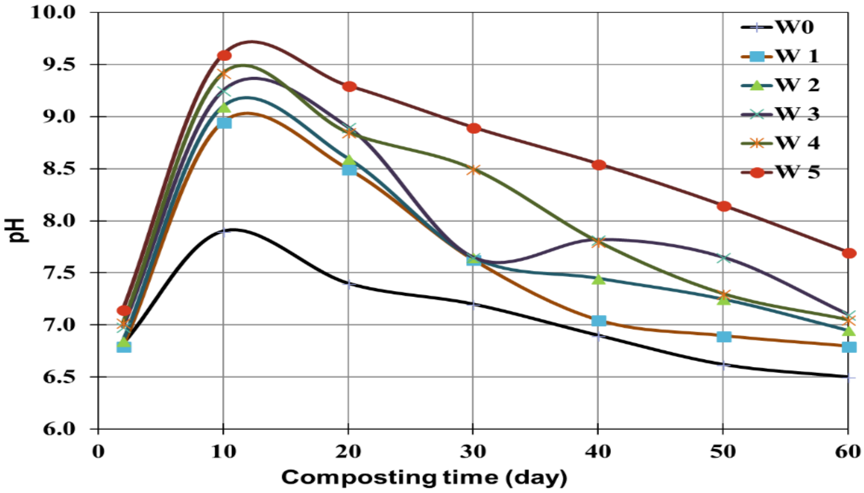

Fig.1. Effect of co-composting process with SSL on pH during co-composting process

3.2 Labile Heavy Metals Fraction (LHMF) in composting process

LHMF of Cu, Ni, Zn and Pb in control is given in Fig. 2. As shown in (Fig. 2a), Cu and Pb labile fractions increased with the increase of composting time during the composting process. This could be ascribed to weight reduction resulted from decomposition of organic matter (Wagner et al. 1990; Simeoni et al. 1984; Wong and Selvam 2006; Canaruttto et al. 1991). this agree well with other studies in the literature (Wagner et al. 1990); Simeoni et al. 1984; Wong and Selvam 2006; Canaruttto et al. 1991). However, Ni and Zn labile fractions decreased with the increase of composting time during the composting process (Fig. 2b). This could be ascribed to the formation of Ni and Zn complex with humic substances formed in composting process (Cai et al., 2007; Kumpiene et al., 2008). Thus, the metal bioavailability decreased. This agree well with other studies in the literature (Cai et al., 2007; Kumpiene et al., 2008; Singh J et al., 2013c). After 60 days of composting, LHMF reduction percent were, 18.0 and 32.4 for Ni and Zn respectively. However, LHMF increase percent for Cu and Pb were, 50.8 and 33.2 respectively.

a

b

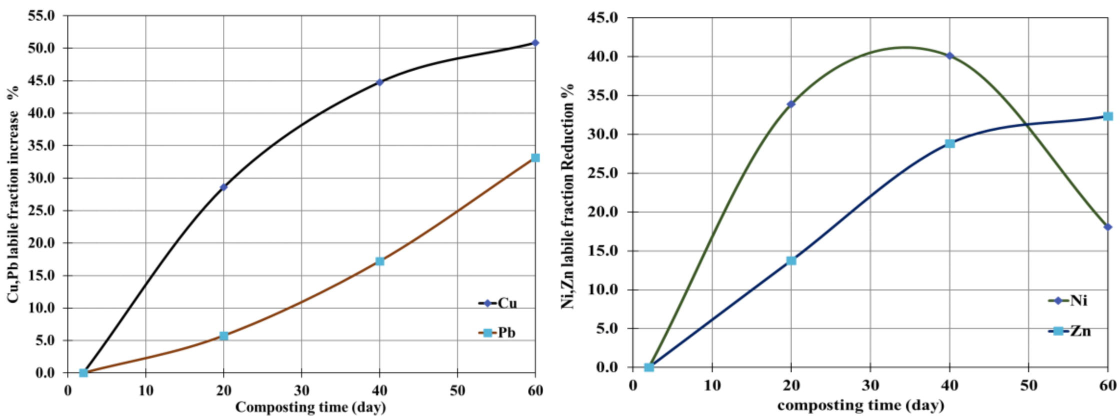

Fig.2. Effect of composting process on LHMF of Cu, Ni, Zn and Pb for control (W0)

3.3 **Labile Heavy Metals Fraction (LHMF) in co-composting process**

Figure 3 shows the reduction of Cu, Ni, Zn and Pb LHMF during co-composting process using SSL. LHMF reduction increased with the increase of co-composting time for different metals. After 60days of co-composting process using SSL, LHMF reduction percent for Cu were 67.5, 65.3, 67.8, 68.9 and 77.1 at SSL dose 1.0, 1.5, 2.0, 2.5 and 3.0%, respectively (Fig. 2a). However, LHMF reduction percent for Ni were 69.53, 71.5, 74, 85.3 and 76.8 at SSL dose 1.0, 1.5, 2.0, 2.5 and 3.0%, respectively (Fig. 2b). In case of Zn, LHMF reduction percent were 75.3, 75.9, 81.3, 81.4 and 73.9 at SSL dose 1.0, 1.5, 2.0, 2.5 and 3.0%, respectively (Fig. 2c). Regarding Pb LHMF reduction percent were 75.9, 78.7, 78.4 and 74.7 at SSL dose 1.0, 1.5, 2.0, 2.5 and 3.0%, respectively (Fig. 2d). The reduction in the LHMF could be ascribed to precipitation of metals with sulfides due to added Na_2S to sewage sludge composting, under these conditions the heavy metals are converted to metal sulfides by the sulfidation reaction (Levy et al. 1992). This agree well with other studies in the literature (Wong and Selvam, 2006; Kumpiene et al., 2008).

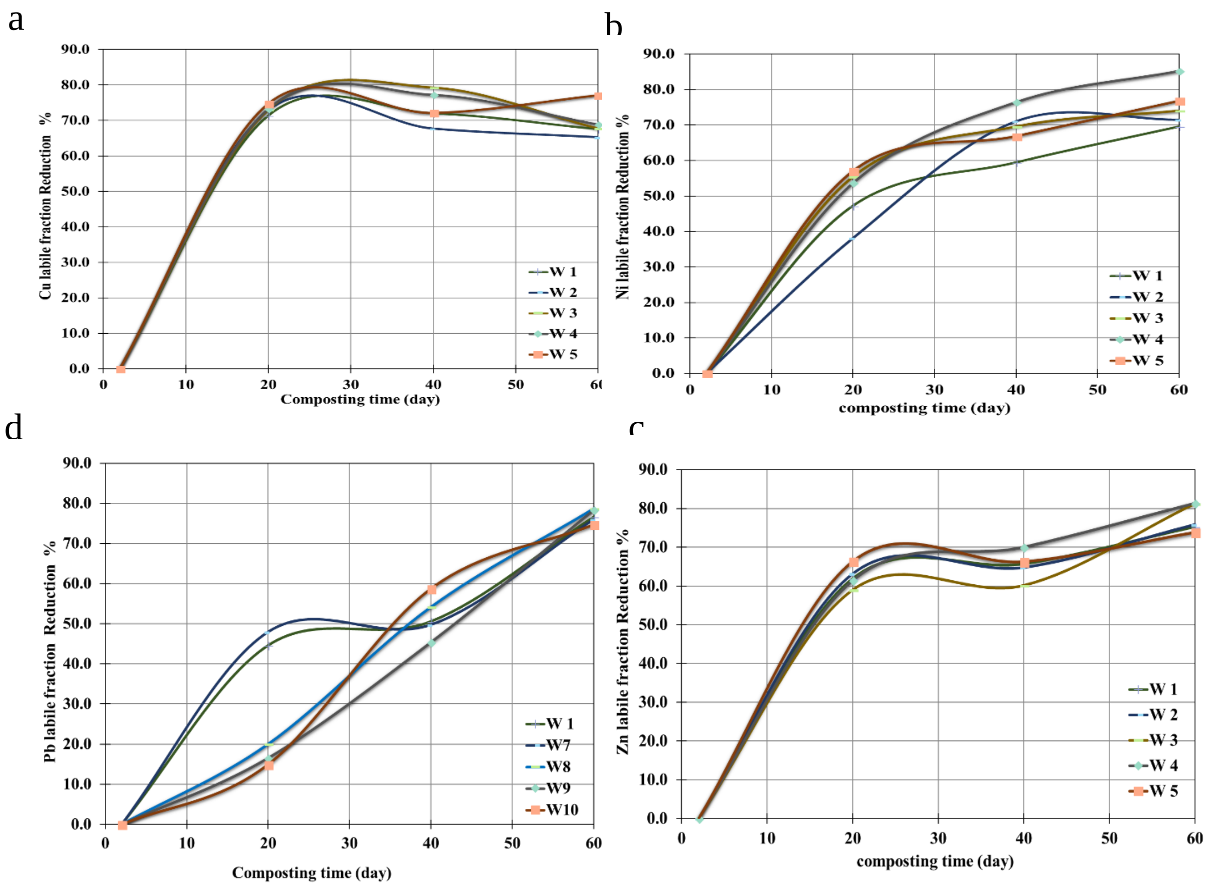

Fig.3. Effect of co-composting process with SSL on LHMF redaction during co-composting process

4. Conclusions

I. This study concluded that the application of Composting process achieved reduction in Ni, Zn. However, did not achieved reduction in Cu and Pb.

II. This study concluded that the application of SSL was successful for reducing bioavailability of the selected heavy metals (Cu, Ni, Zn, Pb) during co-composting process.

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