Metal Contents and Composting Feasibility of Rural Waste from Abandoned Dumping Site in Zhejiang, China

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Abstract

Rural waste samples were taken from one classical dumping site in Ningbo to detect the heavy metal contents and evaluate the contamination potential. The experiment results show that the average heavy metal content in the rural waste followed the sequence of Zn > Cu > Cr > Pb > Cd, and their corresponding contents were 692.0±900.9, 402.6±452.4, 196.3±299.6, 167.3±124.5 and 3.9±4.5 mg/kg, respectively. The rural waste contains high organic material and N, implying they could provide nutrients and organic matter simultaneously to be compost. However, the rural waste could only be applied in the lawn planting to avoid the contamination of the food chain.

Keywords: rural waste; heavy metals; compost; abandoned dumping site; contamination risk

1. Introduction

As one of the most populous and richest regions in China, about 70.3% population (33.2 million people in rural area) lived in rural area of Zhejiang Province in 2009 [1], and they produced 11.0 million tons of domestic solid waste each year [2]. However, compared with the municipal solid waste in urban areas, little attention was given to the rural waste which is combined solid waste in rural residents’ daily life. After 1990s, rural waste is no longer to be one favorable agricultural fertilizer since its components changed greatly with increasing portion of hazardous and industrial waste commingled. To deal with the problem, almost each village constructed one or two dumping site to dispose these rural wastes. After
2000s, those sites were replaced with the standardized municipal landfills, and were gradually closed and abandoned.

The objective of this research: (1) to understand the potential contamination concerned with the rural waste by measuring the heavy metals contents; (2) investigating the feasibility of using rural waste as compost by comparing it with the criteria values. Here, we attempt to provide some beneficial reference for the resource utilization of rural waste. As the wide spread of dumping site in the world [3-8], this research may have practical significance.

2. Material and methods

2.1. Description of study area

Gaoqiao rural waste dumping site was abandoned about in 2005 and located in Qishan village, Ningbo. Its daily waste input, service population, land area and accumulated waste volume of the dumping site were 50 ton/day, 135000 people, 7500 m$^2$ and 52500 m$^3$, respectively. Ningbo is located in the middle part of the coastline in southeast China (latitude of 28°51’ E~30°33’ N), and is a classical subtropical monsoon climate region with an average annual precipitation of 1500 mm [9]. The city has a rural population of 5.17 million in 2007.

2.2. Sampling, sampling preparation and analysis

All of the rural waste samples were collected randomly within the dumping sites. Waste samples, from 50 to 100-cm in depth, were collected at each sampling point and mixed thoroughly to get a representative sample of 1.5 kg to 2.0 kg, and then sealed in polyethylene bags for further analyses.

The waste samples were air dried in shady and cool conditions until a constant weight was reached. The solid waste (about 500 g) was grinded and sieved with 1-mm mesh (SM200, Retsch). The pH of the solid waste was measured using glass electrodes (Sartorius, PB-10). The TN, NH$_4$-N, TP, and OM of the solid waste were measured using standard procedures [10]. For heavy metal analysis of soil and solid waste, 0.20 g solid waste was digested with 4 ml HNO$_3$, 1 ml HF and 1 ml HClO$_4$ under sealed Teflon tank for 10 hours. The Heavy metals of solid waste were measured using ICP-MS (Agilent 7500a).

2.3. Data analysis

Data analysis was carried out by using SPSS 14 and Origin 8.

3. Results and discussion

3.1. Characteristic and heavy metal contents in rural waste of Gaoqiao dumping site

The most obvious variation of the rural waste components with the municipal solid waste (MSW) from sanitary landfills [11, 12] was the zero fraction of the paper and food waste and the extraordinarily high level of inorganic (78.7%, w/w (DW)). The portion of the yard waste, metals and hazardous materials (including plastic, syringes, batteries, rubber polymers and grease, etc.) was all less than 1.0% in the dumping site. The descriptive statistics of heavy metals in rural waste of Gaoqiao dumping site was listed on Table 1.

To reflect the contamination potential of the rural waste, the contents of heavy metals in the rural waste were compared with that of the bottom ash and soil CK in Ningbo, respectively. Bottom ash from
the municipal solid waste incinerator (MSWI) was known as one of the hazardous materials [13], since most of the heavy metals in MSW were condensed into it during the incineration process. The average heavy metal contents of rural wastes follows the consequence of Zn>Cu>Cr>Pb>Cd, which agreed with that of the MSWI bottom ash [14]. The average ratios were 78.5% for Cd, 71.6% for Cu, 56.2% for Cr, 46.3% for Pb and 44.2% for Zn, as shown in Table 1. The high ratios in Table 1, especially for Cu and Cd, revealing the rural waste could be assumed to be the hazardous materials to some extent. Moreover, the ratios for Cu, Cd, Cr, Zn and Pb between the rural waste and soil CK ranged from 2.5-159.1, 0-55.4, 0.7-63.1, 0-51.4 and 0.3-13.9 times, respectively. According to the average value of the ratios (the average values for Cu, Cd, Cr, Zn and Pb were 31.7, 12.9, 9.7, 9.0 and 5.9, respectively), the contamination potentials of heavy metals in the rural waste was in the order of Cu>Cd>Cr>Zn>Pb, which reflects the high contamination potential. The source of these observed metals in the rural waste were expected to be plastic, rubber, syringe and other hazardous household waste.

The heavy metal contents in rural waste of Gaoqiao dumping site is shown in Table 1. Among these parameters, the coefficient variability (CV) is one of the powerful factors used to descriptive the variability of the variables. When CV is more than 90%, it shows great variability [15]. Table 1 shows that the CVs of waste metals were higher than 100% except Pb, indicating the extensive variability in the study area and the moderate heterogeneous distribution of Pb in the rural waste. In addition, particle size of solid waste would affect the CVs of parameters greatly, i.e., with decreasing particle size the CV of soil decreased significantly. Compared with bottom ash [14], higher metal CVs of rural waste were mainly due to that the particle size (less than 2 mm) of rural waste were far greater than that of latter (less than 154 µm [14]).

Table 1 Descriptive statistics of heavy metal contents in rural waste (n=19) and comparison with bottom ash (mg/kg DW).

| Element | Mean | Range | CV, % | Ratio, % | Mean value of bottom ash |
|---------|------|-------|-------|----------|--------------------------|
| Zn      | 692.0±900.9 | 0.0-3960.0 | 130.2 | 44.2 | 1567.0±1048.7 |
| Cu      | 402.6±452.4 | 30.5-2020.6 | 112.4 | 71.6 | 562.5±439.6 |
| Cr      | 196.3±299.6 | 14.8-1274.1 | 152.6 | 56.2 | 349.4±432.1 |
| Pb      | 167.3±124.5 | 8.1-395.8 | 74.4 | 46.3 | 361.2±141.0 |
| Cd      | 3.9±4.5 | 0.0-16.6 | 115.4 | 78.5 | 5.0±2.3 |

Note: the ratio was the value of the element concentrations in Gaoqiao rural waste to the corresponding concentrations in the bottom ash. The heavy metal contents of bottom ash were calculated according to the data from Yao and Li et al. [14].

Of most concern in the rural waste was Cd and Cu (average and maximum level were 3.9 and 402.6 mg/kg, respectively in table 1), but the contents of Cr and Zn should be cautiously too. As mentioned in section 3.1, since the toxicity of the heavy metals had been proved to environment [16], the high ratios imply the potential environment pollution of the rural wastes to be a hazardous waste, especially Cu and Cd risk. According to MAC limit of China (GB15618-1995), 1 kg rural waste could cause 13.0 kg, 8.1 kg and 3.5 kg soil to exceed the Cd, Cu and Zn warning threshold, respectively. Therefore, it is strongly advised that rural waste of dumping site be well treated to eliminate its serious environmental risk.

3.2. Feasibility of compost utilization of rural waste

Composting MSW is used to reduce the volume of organic wastes to produce a stable humus-like material whose beneficial has been proved as a good soil amendment to increase the aggregate stability and improve soil structure (higher C/N ratios) [17]. Moreover, Moldes et al. [18] found MSW compost could be an excellent as a plant growing media component by mixing MSW compost with composted
pine bark. However, the heavy metal contamination of the compost is still a growing concern, particularly the possible food chain accumulation [19]. According to the report of Breslin [20], it is found that the trace elements (Pb, Cd, Cu and Zn) in soil would increase following MSW compost additions.

The rural waste was slightly alkaline with high organic material and N (average LOI, OM and TN were 171.0 and 60.7 g/(kg DW) (dry weight) and 3195.0 mg/(kg DW), respectively (Table 2), implying they could provide nutrients and organic matter simultaneously. Thusly, it was an excellent candidate for the production of compost. However, despite the valuable potential of biosolids as a nutrient source and soil amendment, one main issue with biosolid application (MSW compost) to land is transport of detrimental elements through the food chain. Therefore, the rural waste could only be applied in the forestry or lawn planting to avoid the heavy metals contaminating the food chain through bioaccumulation of fruit or crop plants. As one cost-effective alternative way to dispose the rural waste, MSW composting would be viable for rural communities along with the increasing concern over the environmental safety in landfills.

Table 2 Nutrients in Gaoqiao rural waste (n=19)

| Parameter | pH | LOI | OM  | TN           | NH4-N | TP          |
|-----------|----|-----|-----|--------------|-------|-------------|
| Mean±S.D. | 7.8±0.7 | 171.0±174.9 | 60.7±53.5 | 3195.0±1955.8 | 130.9±156.2 | 936.8±819.7 |

S.D., standard deviation.

4. Conclusions

Average heavy metal content in the rural waste followed the sequence of Zn > Cu > Cr > Pb > Cd, and the ratio of metal contents between the rural waste with the contents of bottom ash and soil CK was especially high for Cu and Cd, whose metal contents were 402.6 and 3.9 mg/kg, respectively, which implies high contamination potential on the environment.

The rural waste was an excellent soil amendment due to its high organic matter and nutrients. Whereas, utilization of rural waste should be cautiously since its heavy metal contents were relatively high. Rural waste could be applied in forestry or lawn planting as a plant growing media component. The work could be useful for the using of the resource utilization of rural waste from the dumping site, and provide some baseline information needed for the planning of the further environmental management.

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