Journal of Human Environment and Health Promotion
Print ISSN: 2476-5481 Online ISSN: 2476-549X

The Effect of Waste Separation Management on the Concentration of Heavy Metals and some Chemical Characteristics (Case study: Ardabil, Iran)

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A R T I C L E I N F O

Article type:
Original article

Article history:
Received: 31 December 2022
Revised: 26 January 2023
Accepted: 19 February 2023

DOI: 10.52547/jhehp.9.1.20

Keywords:
Municipal Waste Management
Chemical Characteristics
Compostable Organic Materials
Heavy Metals
Waste Segregation

A B S T R A C T

Background: This study investigated the effect of waste separation from the source on the chemical characteristics of wet waste in Ardabil city.
Methods: A sample of wet waste material was collected from each district of the 3rd and 4th regions of Ardabil city in order to analyze of Cd, Pb, pH, EC, TDS, OC, K, N_{totale}, and P values with standard methods.
Results: The results showed that the average concentration of Pb was determined to be 102 mg/kg in area 3 and 125 mg/kg in area 4. Also, the average concentration of Cd in municipal waste compost samples was 3.139 mg/kg and 4.21 mg/kg in regions 3 and 4. The percentage of nitrogen (N) in both managed samples of regions 3 and 4 was 0.32% and 0.18%. The average percentage of phosphorus (P) in unseparated and separated urban waste compost of region 3 was 0.089% and 0.13%, respectively. In region 4, the average percentage of P in managed municipal waste compost was 0.24% and in unmanaged was 0.201%. The concentration of potassium (K) in separated urban waste compost in areas 3 and 4 was found to be 60.2 ppm and 39 ppm, respectively.
Conclusion: According to the results, it can be said that the effect of management on the number of heavy metals in the waste was significant at the possible level of $P > 5\%$. Further, waste separation at the source systematically reduces the waste with heavy metals.

1. Introduction

Today, the human population is increasing rapidly, especially in urban areas. Urban development and population growth have increased the number of heavy metals in the environment [1, 2]. As a result, with urbanization and economic development, waste generation is rapidly increasing [3, 4]. Since the most important by-products in the city are municipal waste, the increase in the urban population causes significant pressure on services. Urban waste management has become one of the important urban issues [5, 6]. With the increase of waste, the social and environmental impacts have increased, so today its disposal is a growing social concern in developing countries [7, 8]. The increase in the types of waste threatens urban infrastructure and society [9]. In Iran, the rapid growth of population and urbanization, the expansion of industrial, commercial, and service activities and the increase in the volume of waste, have led to major problems such as environmental pollution [10]. Municipal waste management systems in most cities of Iran are very traditional and labor-based. Additionally, most of the waste is dumped in landfills or buried in the ground due to the lack of monitoring and effective management systems. Traditional waste burying is done with minimum costs due to immediate disposal. Consequently, facilities such as composting and incineration are rarely used in waste management [11]. Therefore, finding the best way to deal with waste is the most effective method that reduces

How to cite: Fekri S, Fataei E, Imani AA. The Effect of Waste Separation Management on the Concentration of Heavy Metals and some Chemical Characteristics (Case study: Ardabil, Iran). *J Hum Environ Health Promot*. 2023; 9(1): 20-6.

negative effects [12]. Considering that waste is an integral part of human life, waste management in a principled way is one of the essential issues in protecting the environment, natural resources, and urban services management [13]. Sustainable waste management requires different management methods. Producing minimal waste and maximizing energy/material recycling and providing sustainable economic, environmental, and social needs [14] are not only big challenges for society but also provide the basis for the growth of many potential businesses [15]. However, various obstacles to development include technical, financial, organizational, economic, and social factors such as activities related to the production, storage, collection, transfer and transportation, processing, and disposal of solid waste [16]. Therefore, it is very important to dispose of collected waste in a way that can, directly and indirectly, reduce the risks and damege related to people's health and the environment [17]. In general, there are four ways to deal with waste during the reverse supply chain:

1-Reduce waste production
2- Reuse of required items
3-collection, disposal, and recovery of recyclables;
4- Converting waste to energy [16].

Among the mentioned methods, two methods of waste reduction and separation are the most important and the least expensive [18, 19]. Separation of waste is defined as wet and dry [20]. Recycling and segregation of waste play a significant role in improving the environment and economic situation of the country. A large part of dry waste has economic value, and their recycling is economical and can prevent the waste of raw resources and reserves in the country. Recycling and separation without considering the fundamental role of urban waste producers, i.e. citizens, is meaningless. Therefore, it is necessary to look for ways to create a culture and educate citizens. Among these solutions, we can mention the training of waste separation from the source by holding workshops and creating models through media [21]. In urban waste management, education occupies a special place. Every country and region should tackle the issue of education by using appropriate tools and special cultural and social conditions. Training is carried out in order to reduce the amount of waste produced by different departments and finally to cooperate in the separation program from the source [22]. Unorganized solid waste disposal in developing countries has adverse effects on the environment. Sources such as electronic goods, electroplating waste, paint waste, used batteries, etc., when disposed with municipal solid waste, increase heavy metals in landfills. The slow leaching of these heavy metals in the acidic environment during the decomposition process Pbs to leachates with high metal concentrations. Since leachates are one of the potential sources of groundwater pollution, monitoring the content of heavy metals at the waste site can facilitate the proposal of appropriate remedial measures. Therefore, the assessment of heavy metal contents in waste is extremely important in waste management [23]. One of the most important environmental effects of municipal solid waste disposal is the infiltration of heavy metals in the disposal site. The effects of heavy metals are different from the prevailing conditions in the waste places and the forms of their connection. Under high redox conditions, the binding of metals to MnO and Fe increases, while binding to carbonate, organic compounds, and sulfide tends to decrease [24]. With the possibility of more diffusion of oxygen in the upper layer of the disposal site and sufficient humidity, the rate of degradation and the acidic buffer capacity of the waste site is greatly affected. Under these conditions, there is a drop in alkalinity, pH, and sulfide oxidation, where heavy metals are readily available and free [25]. Professionals in municipal waste management often examine the leachability of metals to assess the risk of disposal sites to human health and the environment [26]. Leaching tests are often used in evaluating worst-case environmental scenarios, where sample components are dissolved and mobile. The mobility and toxicity of heavy metals in landfills depend on the chemical form of the metals. Knowing the content of heavy metals, their species and the ability to wash in different environmental conditions from the place of discharge is a prerequisite for assessing the dangerous potential for the environment. Therefore, the hazardous potential of landfills can be evaluated by separating the metal content into biological, accessible, exchangeable, water-soluble, reducible, oxidizable, and residual fractions. Biodegradable fractions are readily available for biological functions and can easily enter the food chain. Pollutants may be spread in and around landfills by heavy monsoon rains. Leachates from disposal sites may also be a significant risk to the environment. Several cases of groundwater contamination from landfill leachate have been reported [27]. The presence of heavy metals in urban waste and waste disposal sites causes acute pollution, including soil and water pollution, which may pose risks to the health of city residents. However, no study has been conducted to evaluate the content of heavy metals in urban waste and its pollution of the environment in the study area. Since there is no cultural program and implementation of source separation and recycling programs in Ardabil city, this research was conducted to investigate waste management in reducing heavy metal pollution in Ardabil city, Iran.

2. Materials and Methods

The research was conducted to investigate the effect of waste management on the concentration of heavy metals in urban waste in Ardabil city which is located in the northeast of Iran. The amount of daily production waste in Ardabil city is 400 tons. In order to carry out the research, two urban areas (areas 3 and 4) that represent the conditions of the waste composition of the entire city, should be determined from among the 5 urban areas of Ardabil (Figure1). The number of samples in the study areas was selected using Cochran's method (random sampling method). The number of 100 compostable waste (biologically decomposable waste (biowaste) is any waste that is capable of anaerobic or aerobic decomposition (e.g. foods, greenery) (Hemmati et al., 2019). Samples (50 samples as a control and 50 samples as a model society) were prepared from each district. In terms of time, sampling was done only once, and in terms of location, two areas out of the four urban areas of Ardabil were sampled. The sample preparation method was based on the standard method of sample preparation with the standard method (standard method, 2015). In the first stage of the study, sampling of the selected households was done at the appointed time. Then, in the second stage, the households of the sample community were given the necessary training regarding waste reduction at the source of production. In addition to the fact that the control group was not given any training, the control sample was emphasized not to perform any previous isolation. After one week, the production waste of both statistical communities (control and sample) was received again. The received samples in both stages were transferred to the laboratory for chemical analysis of the desired waste samples. The waste was separated into wet (compostable) and dry parts. Physical analysis of waste was done on random samples. These samples were selected following the principle of separation in such a way that each representative sample was a homogeneous mixture of urban solid waste materials of the studied areas. The physical analysis of the samples was carried out under control. For this purpose, first, three samples were randomly selected from each area on four consecutive days. To prepare a homogeneous sample, we mixed, loaded, and weighed them in a sampling container with a specified volume and weight in each half of each season. The municipal waste collection with specific dimensions was 0.66 m^3. conditions in terms of environmental factors such as wind and precipitation, etc. At each stage, the empty container was weighed and its weight was determined. After recording the weight of the container, its contents were emptied on the plastic mat and the separation of the components of the waste was carried out. Waste materials in 12 different groups including perishable organic materials, plastic, nylon, glass, metals, paper and cardboard, cardboard, wood textiles and gardening waste, and other materials (leather, dirt scraper, etc.) were separated and each material was collected in a special bag. The weight of each was measured and recorded separately with a digital scale [8]. After receiving the waste, each sample 0.24% was separated based on the constituent elements: compostable materials, paper, etc., and the weight of each was obtained, then the percentage of the constituents was determined based on the weight ratio.

2.1 Analytical Methods

After being transferred to the laboratory, the samples were weighed and dried in an oven at 65 degrees for 48 h. The oven-dried samples were weighed and their dry matter was determined. Next, the dry samples were pounded in a Chinese mortar, ground, and passed through a 0.4 mm sieve (Kononova, 1966). In order to measure the concentration of heavy elements and the general composition of the samples, 1 g of the waste passed through the sieve was transferred into the porcelain crucibles and the crucibles were placed in an electric furnace at a temperature of 450 °C for 2 h. After 24 h, the ash of the samples was digested with 2 M hydrochloric acid. After cooling down and passing through Whatman 42 filter paper, it was made up to 100 mL using distilled water inside the flask. In the prepared extract, the concentration of K was measured by Flame photometer the concentration of P was measured by the colorimetric method of the yellow complex using a spectrophotometer, at a wavelength of 470 nm, and the percentage of N was measured by the Kjeldahl method. Then the concentration of heavy metals (Cd, Pb) in the final extract was measured with an atomic absorption spectrometer.

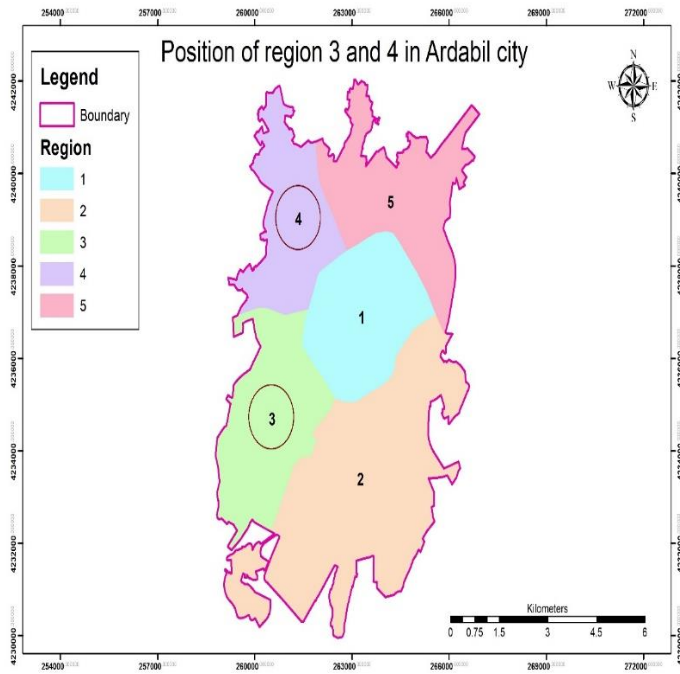

Figure 1: Map of the 3rd an 4th municipality areas of Ardabil

3. Results and Discussion

3.1 *Some physical and chemical characteristics of compost obtained from municipal waste*

The results of the analysis of some physicochemical characteristics of the tested urban waste compost are presented in Table 1. The average pH of municipal waste compost in regions 3 and 4 is in the neutral range, which indicates the possibility of neutralizing organic acid that can be created from the anaerobic decomposition of organic materials. The average EC in the separated waste compost sample of region 3 is 15.45 dS. m^{-1} and of region 4 is 11.5 dS. m^{-1}. Sabzghabaei and Tadayonpour (2022) [28] also reported that the EC value of municipal waste compost is 21.3 dS. m^{-1}. The average TDS in both regions in separated urban waste compost is higher than in unseparated urban waste compost. According to Table 1, the highest amount of OC was obtained in zone 3 of segregated municipal waste compost at 3.2% and the lowest amount of OC was obtained in unsegregated municipal waste compost of zone 4 at 1.06%. The highest is 211 kg. m^{-3} and the lowest 122 kg. m^{-3} density of urban waste compost was observed in the unseparated sample of region 4 and the separated sample of region 3, respectively (Table 1). Domínguez et al. (2019) [29] reported the physicochemical properties of urban waste compost, compost pH is 7.41, EC is 10.19, dS m^{-1}, and organic carbon percentage is 22.63.

Table 1: Physical and chemical characteristics of obtained compost

Sample	Bd	OC	TDS	EC	pH
	(g. cm^{-3})	(%)	($mg.l^{-1}$)	(dS m^{-1})	
Separated-3	122	3.28	15.45	13.3	5.93
un Separated-3	137	2.57	13.91	12.01	5.80
Separated-4	198	1.87	13.64	11.5	5.86
Un Separated-4	211	1.06	11.75	10.42	5.70

The results showed that separation and management had a significant ($p < 0{\cdot}05$) effect on the amount of total N in urban waste compost. Thus, separation led to an increase in the amount of total N. According to Figure 2, the average percentage of N in both managed samples of regions 3 and 4 is 0.32 and 0.18. Moreover, the results of this research showed that the average percentage of P in unmanaged and managed urban waste compost of region 3 is 0.089% and 0.13%, respectively. In region 4, the average percentage of P in managed municipal waste compost was 0.24% and unmanaged 0.201% (Figure 3). The effect of waste segregation at resources on the amount of residual K was significant. In this study, the concentration of K in managed urban waste compost in areas 3 and 4 was found to be 60.2 ppm and 39 ppm, respectively, which is significantly higher in both areas compared to an unmanaged sample (Figure 4). According to the results, significant ($p < 0{\cdot}05$) changes in these parameters were observed in both study sites as a result of the impact of waste separation. Ranjbar et al. (2017) [30] reported that the percentage of N in municipal waste compost is 1.7%, absorbable P is 0.42%, and absorbable K is 7.6%. They stated that urban waste compost caused a significant increase in the concentration of highly consumed elements in soil and plants. Sabzghabaei and Tadayonpour (2022) [28] reported the amount of highly consumed elements in urban waste compost as 1.2% total N, 0.9% P, and 1.6% K.

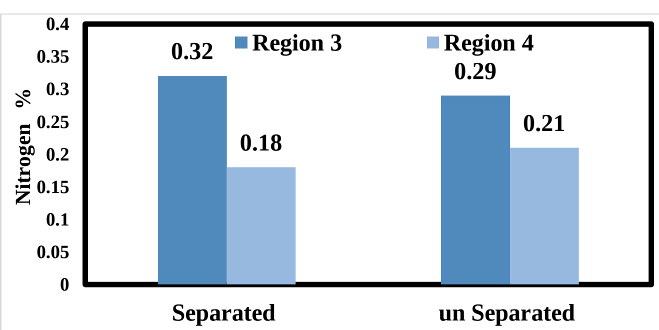

Figure 2: Comparing the mean effect of waste separation on N concentration in waste

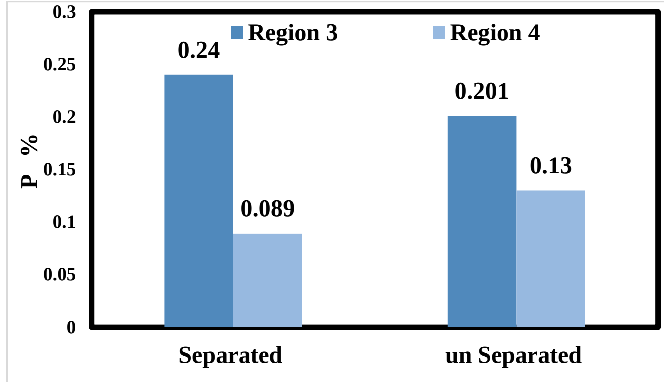

Figure 3: Comparing the mean Effect of waste Separated on P concentration in waste

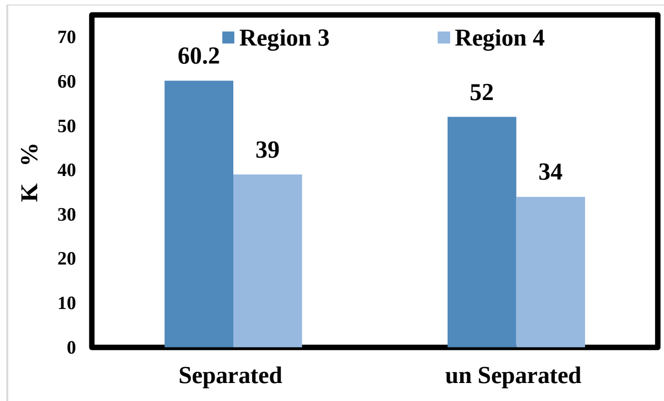

Figure 4: Comparing the mean effect of waste management on K concentration in waste

3.2 The effect of waste management on the content of heavy metals in municipal waste compost

The results showed that waste separation at the source had a significant ($p < 0{\cdot}05$) effect on the concentration of studied heavy elements. The content of average concentration of heavy metals is presented in Figures 1 and 2. According to Figure 5, the average concentration of Pb was determined to be 125 mg/kg in area 4 and 12 mg/kg in area 3. Also, the average concentration of Cd in municipal waste compost samples in two regions was 4.21 mg/kg and 3.139 mg/kg in region 3 (Figure 6).

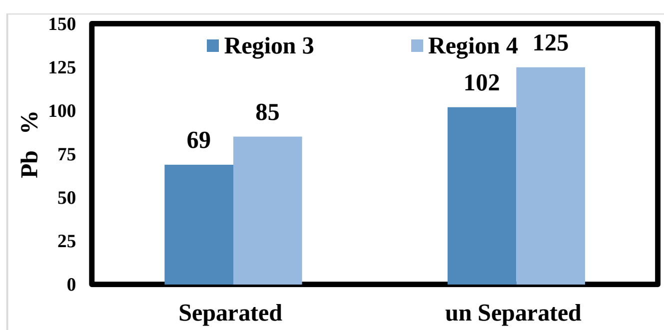

Figure 5: Comparing the mean effect of waste management on pb concentration in waste

Based on the results obtained from the study in both areas, separation at the source has a high impact on the concentration of heavy metals in the waste compost. The results showed that waste management and separation from the source reduced the volume of waste with the level of significant ($p < 0.05$) of contamination of waste with heavy metals. Therefore, in urban planning and management, according to the state of the society and the cultural, social, and economic conditions of each region, the type of educational system should be determined and expert forces with health and environmental perspectives should be used in solid waste management.

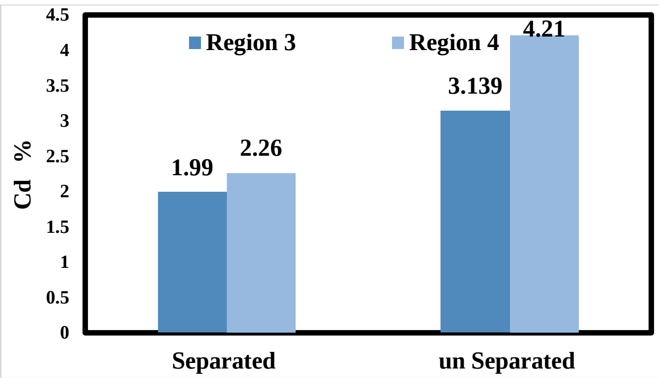

Figure 6: Comparing the mean effect of waste management on the concentration of Cd in waste

Household waste is mainly disposed of in dumping sites, and the lack of resource recycling in primary, secondary, and final disposal sites is the main cause of the increasing heavy metal content in waste [31]. In a similar study, in evaluating the content of heavy metals in waste, the maximum amount of Pb and Cd was reported as 112 mg/kg and 77 mg/kg, respectively [32]. In the assessment of heavy metal contamination in urban solid waste, they reported that Pb with a concentration of 127 mg/kg and Cd mg/kg with a concentration of 38 mg/kg in urban waste compost causes plant toxicity. Moreover, Marjovi and Meshaikhi (2018) [33] reported the concentration of Pb and Cd in municipal waste compost as 178 and 16.6 mg/kg, respectively. The increase in population in the world has led to the production of a high amount of urban waste caused by people's consumption, which has led to an increase in environmental pollution [34, 35]. Urban waste management is an important issue not only in terms of maintaining human health but also in environmental, social, and economic terms around the world. The goals of waste management in general are to protect human health and the environment and preserve resources. However, the priority given to waste management problems varies greatly according to the standard of living in the environment in which it is implemented. Today, in developing countries, the goal is to increase the coverage of waste collection services and minimize illegal dumping. In contrast, in developed countries or economies in transition, the priority is to minimize production and promote the prevention and recovery of resources [36]. Accumulation of waste in cities has become a big problem, and this large amount of all types of urban waste, especially in densely populated areas, has inevitably led the related planners and practitioners to the principled and correct management of waste disposal. One of the common solutions in this direction is the process of converting organic materials in urban waste into organic fertilizer or so-called compost. On the one hand, the production process of urban waste compost helps to clean the environment from urban pollutants. On the other hand, it can be used as an organic fertilizer in agriculture due to its significant amount of nutrients. Using municipal waste compost increases the amount of some nutrients needed by plants, including P, K, and N in the soil and increases the ability to absorb nutrients. In addition, urban waste compost in agricultural lands can play an important role in producing products based on the principles of sustainable agriculture. In fact, urban waste compost is a suitable solution to improve soil organic matter. Sharholy et al. (2008) [37] stated that municipal waste compost and sewage sludge, especially at higher levels in the soil, in addition to increasing the organic matter of the soil up to two times, the concentration of nutrients required by the plant in the soil, including P, K, zinc, copper, it also increased usable manganese and iron. Using these organic materials in the short term did not increase the amount of Pb and Cd heavy elements in the soil, but the use of waste compost for several years in a row increased the absorbable Pb in the soil.

4. Conclusion

The analysis results showed that the average concentration of heavy metals (Pb, Cd) in unseparated municipal waste compost in regions 4 and 3 is higher than the average concentration of heavy metals in the same regions with the difference that they have been trained and separated. These findings may be useful as a first step in assessing heavy metal pollution in some areas of Ardabil city. Using the separation method of urban solid waste at the source can be a key step in waste management and the source of environmental pollution. Finally, it can be said that turning urban waste into compost is one of the appropriate methods for waste disposal. According to the measurement of the concentration of heavy elements in these samples and the difference in their concentration in separated and unseparated samples, it can be said that waste management and separation at the source caused a decrease in the concentration of heavy elements in separated samples and it can be more effectively used in agriculture without environmental concerns. According to the results obtained from the study in both areas, separation at the source has a high impact on the concentration of heavy metals in municipal waste compost. The results showed that waste management and separation from the source have reduced the volume of waste and the level of contamination of waste with heavy metals.

Authors' Contributions

Sima Fekri: preparation of the introduction sections; data collection. Ebrahim Fataei: writing the research method of the article; completing the discussion section of the article and research conclusions. Ali Akbar Imani: data analysis.

Conflicts of Interest

The authors declare no conflicts of interest.

Acknowledgements

This article has been adapted from the MSc. thesis in environmental science and engineering by Sima Fekri at Islamic Azad University, Ardabil Branch, Ardabil, Iran. The authors would like to express their gratitude for the support of this university in implementing the current project. (No: 11950508951010).

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