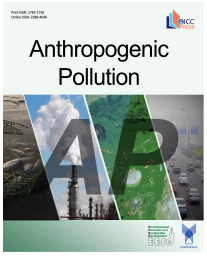


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# Evaluating the impact of source separation on the quality of biodegradable municipal waste (A case study: District 8 of Karaj city, Iran)

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**Original Research**

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**Abstract:**

The present study was conducted to determine the effects of source separation training for municipal solid waste on the quality of compostable organic waste at District 8 of Karaj Municipality, Iran. This was an experimental study, the tools of which were sampling and conducting experiments. The research data were collected using cluster sampling. To determine the chemical properties of wet waste, samples were taken from 480 households in 7 neighborhoods of District 8 of Karaj Municipality, followed by laboratory analysis. To measure the quality of compostable organic materials, first, waste from the studied households was received once without providing training and subjected to physical analysis (separation of wet and dry materials). Once again, after providing training, the waste of the studied households was collected separately, wet and dry, from the doorsteps of the homes. From the total wet waste samples taken from each neighborhood, after complete mixing, one sample was taken for chemical analysis and transported to the laboratory. The measured parameters included total nitrate, organic carbon, electrical conductivity (EC), pH, calcium, cadmium, copper, iron, potassium, magnesium, phosphorus and lead. A t-test was used to obtain the difference between the physical and chemical properties of the wet waste before and after source separation training to households. Data were analyzed using $SPSS_{27}$ software. Based on the results, there was a statistically significant difference between the values of EC, pH, cadmium, and iron at the level of 5%, as well as between the parameters of copper, potassium, magnesium, and phosphorus at the level of 1%, in the pre- and post-training stages. The EC value in the pre-training phase was 9914 µs/cm, which decreased to 7350 µs/cm after training. Calcium levels were 19,674 and 30,898 mg/kg, potassium levels were 24,006 and 18,225 mg/kg, phosphorus levels were 1987 and 3019 mg/kg, and the iron levels were 1804 and 466 before and after training, respectively. The concentration of magnesium in compostable organic waste increased significantly in the post-training phase compared to the pre-training phase. The findings of this study revealed the effectiveness of source separation of municipal solid waste in maintaining the amounts of elements present in compostable organic materials at appropriate levels.

**Keywords:** Sustainable waste management; Source separation; Municipal waste; Chemical quality; Organic waste; Karaj city

## 1. Introduction

In Iran, only about 7% of the total municipal solid waste produced is separated as dry recyclable materials, and what remains is mixed waste, more than 70% of which consists of organic materials (Rupani et al., 2019). Mixed household waste can reduce the quality of compostable products due to the presence of hazardous and toxic waste, such as batteries and dyes. Organic waste is defined as biodegradable garden and park waste, food and kitchen waste from households,

restaurants, caterers and retail premises, as well as waste from food processing plants (Hemmati et al., 2019). The organic fraction of municipal waste is today a serious environmental issue, the amount of which is increasing due to the exponential growth of the population and the increase in the per capita food consumption rate (Sadeghi and Maleki, 2022). Organic waste disposed of in mixed form creates numerous environmental, social, and economic problems and requires more energy and space for disposal. In addition to creating unpleasant odors in landfills, it also leads to greenhouse gas emissions, soil pollution, and aquatic ecosystems (Gladchenko et al., 2017; Jara-Samaniego et al., 2017). The use of organic waste as raw materials in composting has been recognized as a key solution to reduce the environmental pollution load (Alipour et al., 2023; Eskandarpour et al., 2023). In addition, composting plays an important role in maintaining and restoring soil fertility (Feizipour et al., 2024). However, heavy metals present in mixed municipal waste limit the beneficial use of organic waste recycling for composting (Jung et al., 2006).

Source separation of dry and wet waste is one of the most important issues in municipal waste management to maintain the quality of recycled products, which depends on many parameters, including economic, social, environmental, and legal factors (Suchowska-Kisielewicz and Jedrczak, 2024; Amicarelli et al., 2021). Implementing educational programs based on the theory of planned behavior can be effective in improving source separation behavior (Jafarzadeh et al., 2023). The source separation process of organic waste is an effective approach to reduce the amount of waste disposed in landfills (Okonta and Mohlalifi, 2020). In general, organic waste is a suitable substrate for increasing added value through composting or fermentation for biogas production. Optimization and new designs of existing facilities require accurate data on waste composition and characteristics (Amirfazli et al., 2019), which is challenging due to seasonal variations, cultural, social and economic context of generation, as well as single or multi-family housing, urban or rural location, and municipal waste collection method (Maphanga and Madonsela, 2023; Fataei and Safavian, 2017). Dronia et al. (2023) sampled monthly source-separated compostable waste from four municipal districts and four cities, from neighborhoods with single- and multi-family housing in Poland, and found that organic waste from multi-family homes was the most polluted. The heavy metal content of the tested samples also varied in urban waste, both in terms of location and season. Therefore, if the goal is to produce biogas, impurities can lead to mechanical equipment failure, wear and clogging of pipes, and sludge formation, or the compost produced may not be of the required quality and contaminate agricultural soils. Jalalipour et al. (2020) also showed that the source-separation collection method was effective in the production of high-quality compost.

Moharami (2024) studied the effect of long-term use of compost from mixed wet municipal waste on the soil availability of heavy metals and found that continuous use of this type of compost would lead to the risk of gradual accumulation of heavy metals in the soil over time. Veeken and Hamelers (2002) in the Netherlands measured the concentrations of cadmium, copper, lead and zinc in biodegradable waste based on the size and density of the physical components of the waste. Their results showed that the concentrations of heavy metals in wet waste were positively correlated with organic particles in the size range of $0.05 - 1$ mm and organic/inorganic particles with a size of $< 0.05$ mm. Zhang et al. (2008) investigated heavy metal contamination in municipal solid waste and reported that the main heavy metals present in municipal solid waste were zinc, chromium, copper and lead (average $> 100$ mg/kg), followed by nickel, cadmium and mercury. Accordingly, they concluded that source separation could be effective in removing high levels of heavy metals from wet waste. On the other hand, Arena and Gregorio (2014) reported that in mixed organic materials used in the recycling process for composting, organic materials were converted into toxic inorganic forms and heavy metals were concentrated, while the levels of toxic materials were reduced in compost produced from source-separated organic materials. Oviedo-Ocana et al. (2019) compared the quality of compost obtained from source-separated household organic waste with mixed organic waste and found that compost obtained from source-separated waste had lower ash content, higher TOC and total phosphorus concentrations, and lower EC values compared to organic matter obtained from mixed waste. Saha et al. (2010) in India evaluated the quality of municipal compostable organic matter and found that the quality of municipal organic waste significantly depended on the collection method used, so that source separation had a pivotal role in ensuring the quality of the recycled product. Norbu et al. (2005) also compared the quality of compost produced from mixed and source-separated organic waste and showed that volatile solids were low in composts produced from source-separated organic waste.

Reportedly, about 700 tons of waste are produced daily and about 255,500 tons of waste annually in Karaj city (in the Central District of Karaj County, Alborz province, Iran), of which about 74% is wet waste, 15% is recyclable dry waste, and 11% is other waste. Therefore, achieving good quality compost requires the use of effective methods to maintain the quality of household waste. Accordingly, the present study was conducted to determine the quality of organic waste in two stages before and after providing source separation training in order to assess the impact of source separation on sustainable management of municipal waste recycling in Karaj.

## 2. Materials and methods

Karaj, the capital of Alborz Province, is the fourth most populous city in Iran and the twenty-second most populous metropolis in the Middle East (Fig. 1). It is located 36 kilometers west of Tehran. The population of this city, based on the 2016 census, was 1,378,416, which, including the population living in the suburbs, reached 1,973,470. The population growth rate in Karaj was 4.7%, which was the highest rate among all cities in the country. The present study was conducted at District 8 of Karaj Municipality, which is one of the ten districts of the city with a population

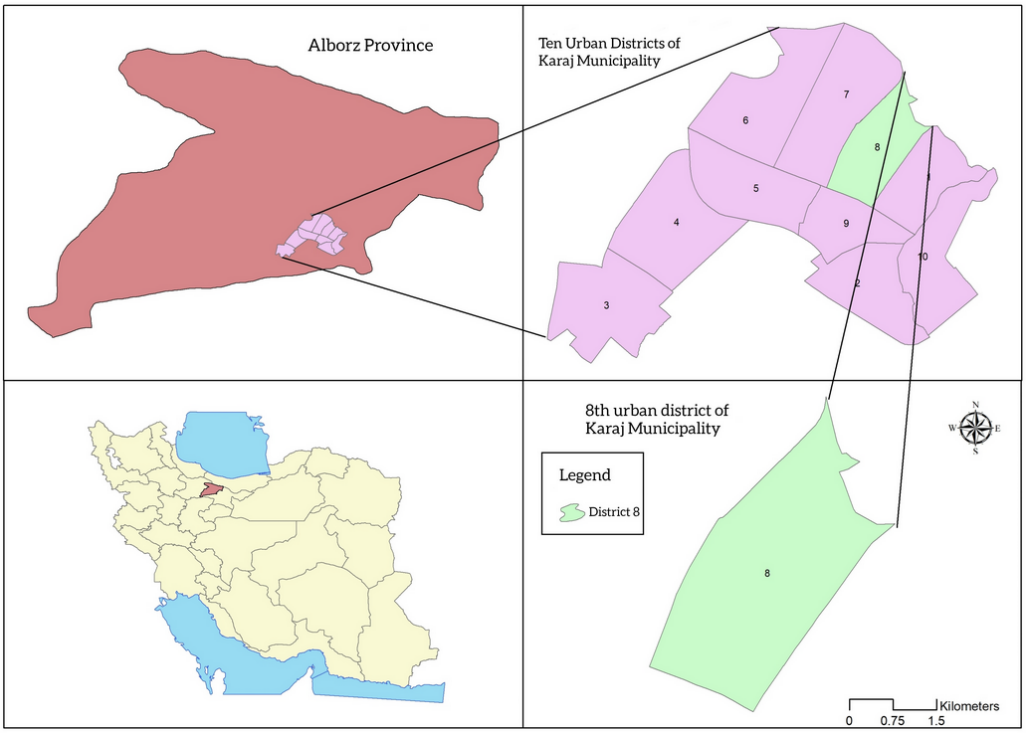



**Figure 1.** Location of the study area.

of 133,882 people and an area of 999.888 $m^2$, located in the northeast of the city. The reason for choosing this area as a case study was that the population composition in this area was diverse in terms of various cultural and socio-economic factors, which could reflect the composition of the entire population of this county.

The present research method was applied in terms of purpose and quantitative in nature. It was an experimental study whose tools were sampling and conducting experiments. Therefore, the research data were collected through cluster sampling. To determine the effect of source separation of municipal waste on the values of important quality parameters of wet waste at District 8 of Karaj Municipality in composting, wet waste was sampled in two stages before and after the source separation training. After preparation, the samples were transferred to the standard laboratory of the Environmental Organization for analysis of the parameters.

The statistical population of the study included all urban households at District 8 of Karaj Municipality, which includes 7 neighborhoods. The sample size was determined to be 471 households using G*Power to reduce the probability of type II error with an effect size of 0.19 and a 95% confidence interval. As mentioned, to compare the quality of compostable organic materials, waste samples from the studied households were collected once without providing training and subjected to physical analysis (separation of wet and dry materials). In the second round, after providing training on waste separation at source using individual face-to-face techniques and educational pamphlets, i.e., door-to-door brochures, separate wet and dry waste samples were collected from the doorsteps of households. After complete mixing, one sample was taken from the total samples from each neighborhood to measure physicochemical parameters. After drying in conditions without sun or wind and grinding, the samples were transferred to the laboratory for the required analyses. Based on the elements effective in the composting process and their importance in the quality of the produced compost, the measured parameters included total nitrate (TN), organic carbon (OC), electrical conductivity (EC), pH, calcium (Ca), cadmium (Cd), copper (Cu), iron (Fe), potassium (k), magnesium (Mg), total phosphorus (TP), and lead (Pb).

For preparation, the samples were weighed after being transported to the laboratory. They were then dried in an oven at 65 °C for 48 hours. The obtained samples were weighed and their dry matter was determined. Subsequently, the oven-dried samples were pounded and ground in a porcelain mortar and then passed through a 0.4-mm sieve. In order to measure the concentration of heavy elements and general composition of the samples, 1 g of the filtered waste was transferred into porcelain crucibles and then the crucibles were placed in an electric furnace at 450 °C for 2 hours. After 24 hours, the resulting ash was digested in the presence of 2 M hydrochloric acid. After cooling and passing through filter paper, the volume was brought to 100 mL using distilled water in a volumetric flask. The potassium concentration in the prepared extract was calibrated using the flame photometry according to the relevant standards. TP concentration was measured by colorimetric assay using spectrophotometry at a wavelength of 470 nm. TN percentage was obtained based on the Kjeldahl method. The concentration of heavy metals (Cd, Cu, Fe, Pb and Mg) in the resulting extract was measured using Atomic Absorption Spectroscopy (AAS). To measure the values of pH and EC parameters, 2 g of sample was added

to 20 mL of ultrapure water at a L/S ratio of 10 and shaken for 2 h (Prechthai, 2008), followed by centrifugation and subsequent filtration with a 0.45-µm filter paper. Then, pH and EC values were measured using pH and EC probes, respectively. For OC measurement, the amount of organic matter was calculated via the loss-on-ignition (LOI) procedure based on high-temperature oxidation behavior. The t-test statistic was used to examine the difference between the values of physical and chemical parameters measured in wet waste samples before and after providing source separation training and to determine the effect of source separation of waste on the quality of biodegradable municipal waste. Data were analyzed using $SPSS_{27}$ software. Kolmogorov-Smirnov (KS) test was used to check the normal distribution and fit of the data. Bartlett's test was used to determine the normality of the data in the principal component analysis (PCA).

## 3. Results and discussion

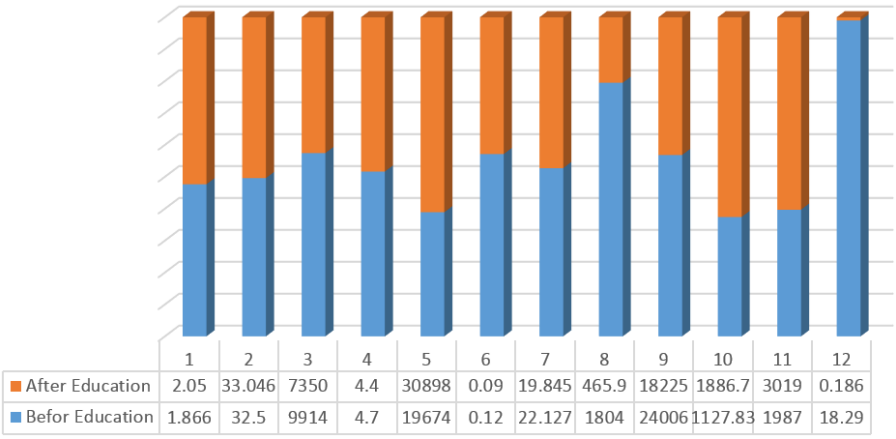
Table 1 presents the measured values of TN, OC, EC, pH, Ca, Cd, Cu, Fe, K, Mg, TP, and Pb parameters during two stages before and after source separation training for the studied households in seven neighborhoods at District 8 of Karaj Municipality in the summer of 2023.

Based on the results presented in Table 1, it can be seen that there was a difference in the measured values of most parameters between the two stages before and after the source separation training. Figure 2 presents the average measured values of the parameters studied in 7 neighborhoods at District 8 of Karaj Municipality.

Based on the mean values of the measured parameters (figure 1), the carbon to nitrogen ratio, which is one of the important parameters in the composting process of municipal waste organic materials, was 17.42 before training and 16.12 after training. Given that the value of this parameter should be in the range of 20 to 30 (Dehghani et al., 2011), the composting process of municipal waste in the study area can be acceptable if improvements are made to the carbon to nitrogen ratio in the wet waste by using carbon-containing additives, such as wheat straw waste and wood chips (Moharami, 2024). Regarding the measured heavy metal levels of Cd, Cu, and Pb, except for Pb, which was higher than the maximum allowable level for compost (10 mg/kg), the rest were within the allowable limit. In a study, Prechthai

**Table 1.** Values of physical and chemical parameters measured in wet waste during two stages before and after source separation training for municipal waste at District 8 of Karaj Municipality, Iran, in the summer (2023).

| Parameters | Neighborhood 1 | | Neighborhood 2 | | Neighborhood 3 | | Neighborhood 4 | | Neighborhood 5 | | Neighborhood 6 | | Neighborhood 7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Before training | After training | Before training | After training | Before training | After training | Before training | After training | Before training | After training | Before training | After training | Before training | After training |
| TN (%) | 1.895 | 1.913 | 1.71 | 1.78 | 1.92 | 1.81 | 2.47 | 1.92 | 1.53 | 2.40 | 1.70 | 2.42 | 1.84 | 2.10 |
| OC (%) | 32.43 | 31.98 | 30.49 | 34.31 | 32.11 | 31.93 | 32.28 | 34.19 | 31.15 | 33.13 | 32.92 | 32.81 | 32.22 | 22.98 |
| EC (µs/cm) | 8980 | 8700 | 10524 | 8489 | 8576 | 10755 | 12385 | 5219 | 9858 | 6924 | 7080 | 6201 | 9814 | 7340 |
| pH | 5.46 | 5.07 | 5.01 | 4.41 | 4.66 | 4.29 | 4.62 | 4.16 | 4.24 | 4.44 | 4.26 | 4.24 | 4.68 | 4.09 |
| Ca (mg/kg) | 3657.4 | 5801.3 | 29341 | 18992 | 30057 | 31736 | 30305 | 31929 | 18466 | 65096 | 13487 | 32121 | 22755 | 20264 |
| Cd (mg/kg) | 11.00 | < 0.01 | 0.11 | 0.10 | 0.14 | 0.12 | 0.13 | 0.10 | 0.13 | 0.12 | 0.12 | 0.10 | 0.11 | 0.10 |
| Cu (mg/kg) | 26.9 | 18.3 | 44 | 16 | 23 | 15 | 20 | 16 | 21 | 21 | 18 | 20 | 22 | 15 |
| Fe (mg/kg) | 1464.0 | 496.1 | 2957 | 397 | 1877 | 397 | 1875 | 583 | 1504 | 770 | 1143 | 446 | 18111 | 172 |
| K (mg/kg) | 39109.9 | 28046.3 | 29051 | 19893 | 19575 | 23573 | 19600 | 10238 | 13229 | 16506 | 16653 | 20945 | 23256 | 15944 |
| Mg (mg/kg) | 922.8 | 1943 | 2587 | 727 | 1313 | 1458 | 1318 | 1133 | 1386 | 2055 | 880 | 1661 | 2185 | 1533 |
| TP (mg/kg) | 2483 | 3173 | 2310 | 1864 | 3736 | 1632 | 3772 | 2431 | 1861 | 3758 | 1848 | 2081 | 1793 | 2304 |
| Pb (mg/kg) | 22.0 | < 0.01 | 12 | < 0.01 | 1 | < 0.01 | 2 | < 0.01 | 42 | < 0.01 | 1 | < 0.01 | 156 | < 0.01 |



| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| After Education | 2.05 | 33.046 | 7350 | 4.4 | 30898 | 0.09 | 19.845 | 465.9 | 18225 | 1886.7 | 3019 | 0.186 |
| Befor Education | 1.866 | 32.5 | 9914 | 4.7 | 19674 | 0.12 | 22.127 | 1804 | 24006 | 1127.83 | 1987 | 18.29 |

**Figure 2.** Comparison of the mean values of physicochemical parameters measured in wet waste from seven neighborhoods at District 8 of Karaj Municipality, Iran, between the two stages before and after waste separation training in the summer (2023).
1: TN (%), 2: OC (%), 3: EC (%), 4: pH, 5: Ca (ppm), 6: Cd (ppm), 7: Cu (ppm), 8: Fe (ppm), 9: K (ppm), 10: Mg (ppm), 11: P (ppm), 12: Pb (ppm)

(2008) reported the content of heavy metals Pb and Cd as 112 and 0.77 mg/kg, respectively. Research results have shown that Pb is one of the most important contaminants in municipal solid waste (MSW) compost (Warman et al., 2004) and that the use of this type of compost will increase the concentration of Pb in the soil. Therefore, the increase in soil Pb concentration due to the use of MSW compost is one of the most important factors limiting the use of this substance. Marjovvi and Mashayekhi (2019) evaluated the concentration of Pb and Cd in MSW compost and stated that the high levels of these elements caused toxicity in plants. The presence of heavy metals in municipal waste and unsanitary landfills of municipal waste causes pollution, including contamination of water and soil resources, which poses risks to public health (Fekri et al., 2023).
The results showed that the EC value, which is one of the limiting parameters in the composting process (its maximum allowable value is 10,000 µs/cm and its minimum suitable value is 1,000 µs/cm (Seilsepour, 2021)) in the compostable waste sampled before and after the training stage was 9,914 µs/cm and 6,300 µs/cm, respectively, indicating the effect of source separation training in reducing the value of this parameter to the desired level (735 µs/cm). The results of research by Seilsepour (2021) on the use of MSW compost in Tehran for the production of agricultural products showed that the use of MSW compost caused a significant increase in the EC value of the saturated soil extract. Therefore, the source separation can play an effective role in reducing the EC value of MSW compost and, overall, in increasing the quality of the resulting compost. The measured pH values before and after training were 4.7 and 4.40, respectively, indicating that its value was in the acidic range in both stages. Given that the optimal pH range for active bacteria in composting is neutral and within the range of $6.5 - 7.0$, a low pH value can act as a limiting factor in the composting process (Dehghani et al., 2012). Regarding the measured values of TP, TN, K and Ca, except for TP, the values of the other elements increased. The Ca value was 19674 and 30898 mg/kg, the K value was 24006 and 18225 mg/kg, and the TP value was 1987 and 3019 mg/kg before and after training, respectively. In addition, the Fe content before and after training was 1804 and 466 mg/kg, while on the contrary, the Mg content before and after training was 1987 and 3019 mg/kg, which had increased significantly. Ranjbar et al. (2017) reported that the use of MSW compost in agricultural production significantly increased the concentration of macronutrients in soil and plants.
Table 2 presents the results of the t-test statistic on the parameters studied in two stages of receiving waste from 7 neighborhoods at District 8 of Karaj Municipality to determine the significant effect of waste separation training on the measured quality parameters.
The t-test results showed that the concentrations of Pb and Cd before and after training were significantly different at the 5% level. Thus, the mean concentration of Pb and Cd before training was 18.29 and 0.12 mg/kg, which decreased to 0.186 and 0.09 mg/kg after training, respectively. According to Moharami (2024), since compost produced from wet waste from mixed municipal waste (without source separation) contains high amounts of heavy metals, long-term use of MSW compost can pose risks of heavy metal accumulation in the soil. Zhang et al. (2008) in Shanghai, China, investigated heavy metal contamination in municipal waste and reported that source separation of waste could be used as an effective method to reduce heavy metal levels. Arena and Arena and Gregorio (2014) also reported that mixed organic materials used in the recycling process were contaminated with heavy metals, while the levels of toxic substances were reduced in recycled materials derived from the source-separated organic materials.
Based on the results of the t-test statistic (Table 2), it was revealed that there was a significant difference at the 5% level in the EC value between the two stages before and after the source separation training. The mean EC value was 9914 µs/cm before training, while it decreased to 7350 µs/cm after training. The TP value measured in compostable organic

**Table 2.** Results of parametric t-test statistic for quality parameters of wet waste at District 8 of Karaj Municipality, Iran, before and after source separation training.

| Parameters | Confidence interval | | Mean | Decision criterion | Degrees of freedom | t-test |
|---|---|---|---|---|---|---|
| | Upper | Lower | | | | |
| TN (%) | 0.26884 | -0.63398 | -0.18257 | 0.361 | 6 | -0.990 |
| OC (%) | 0.63470 | -2.27184 | -0.81857 | 0.217 | 6 | -1.378 |
| EC (µs/cm) | 4625.22438 | 502.48991 | 2563.85714 | 0.023 | 6 | 3.043 |
| pH | 0.59569 | 0.04146 | 0.31857 | 0.031 | 6 | 2.813 |
| Ca (ppm) | 4629.51449 | -27077.78 | -11224.13 | 0.134 | 6 | -1.732 |
| Cd (ppm) | 0.05851 | -0.0014 | 0.02857 | 0.058 | 6 | 2.335 |
| Cu (ppm) | 1937.78699 | 739.33 | 1338.55714 | 0.002 | 6 | 5.466 |
| Fe (ppm) | 10535.78781 | 1026.098 | 5780.94286 | 0.025 | 6 | 2.975 |
| K (ppm) | -224.00131 | -1293.77 | -758.88571 | 0.013 | 6 | -3.472 |
| Mg (ppm) | -339.30479 | -1724.12 | -1031.71429 | 0.011 | 6 | -3.646 |
| TP (ppm) | 30.90014 | 5.63414 | 18.26714 | 0.012 | 6 | 3.538 |
| Pb (ppm) | 0.26884 | -0.63398 | -0.18257 | 0.036 | 6 | -0.990 |

materials showed a significant difference between the two stages at the 1 level, such that its average value increased from 1987 mg/kg before the training to 3019 mg/kg after the training on source separation. Oviedo-Ocana et al. (2019) determined the constituents of compostable organic waste. The results of the analysis of physicochemical parameters after source separation indicated that TP values were higher and EC values were lower than those corresponding to the stage of using organic matter from mixed waste in composting.

Based on the findings, implementing the waste source separation plan in managing the quality of composting from biodegradable municipal waste can play an effective role in changing its composition. In this regard, Jalalipour et al. (2020) and Saha et al. (2010) also showed that waste separation at source was effective in high-quality composting. The results of the present study, similar to the findings of Huynh et al. (2023), highlighted the impact of source separation in paving a sustainable path for municipal waste management through its impact on the quality of compostable organic materials. Therefore, the first and most important step in the recycling process is to develop prior knowledge among participants in order to maintain the quality of products resulting from recycling activities (Vistharakula et al., 2021).

## 4. Conclusion

Disposal of mixed municipal waste leads to the generation of excessive amounts of leachate and gas, resulting in serious environmental threats such as soil, air, surface water, and groundwater. Therefore, addressing these concerns requires the adoption of appropriate collection and disposal methods. The present study was conducted to achieve sustainable quality management of municipal waste in Karaj, Iran, and to evaluate the impact of source separation training on the quality of biodegradable organic materials compared to the mixed waste collection method without providing source separation training. The results showed that there was a statistically significant difference in the values of EC, pH, Cd, and Fe at the 5% level and the parameters of Cu, K, Mg, and TP at the 1% level between the two stages before and after the training on source separation of compostable wet waste at District 8 of Karaj Municipality. According to the results, the limiting values of the composting process and quality, such as EC, Pb, and Cd, were significantly reduced after source separation training. On the other hand, the amount of nutrients effective in the proper performance of the composting process, such as Fe, Cu, Mg, K, and TP, was significantly higher in the compostable wet waste collected in the post-training stage compared to the waste collected in the pre-training and mixed disposal stage. The quality analysis of organic matter showed that the quality of municipal organic waste was significantly dependent on the collection method. In addition, it was found that the source separation played a central role in ensuring the quality of organic matter, and that improper solid waste source separation system could reduce the quality of recyclable material. High levels of toxic elements such as heavy metals can easily enter the food chain and cause health risks in case of unsanitary burial, either indirectly or directly through accumulation in compost used in the production of agricultural and horticultural products.

The results of the present study can be effectively used in the sustainable management of municipal waste recycling in Karaj in order to maintain the quality of recycled materials and also control environmental pollution. Based on the results of measuring the concentration of heavy metals in biodegradable waste samples separated and not separated at source, it could be stated that proper waste

management through source separation could reduce the concentration of heavy elements in composting and, as a result, it could be reliably used in the production of agricultural products without environmental concerns. Considering that source-separated waste recycling significantly contributes to extending the life of landfills and the development of green communities, and considering the importance of the topic and the significant impact of source separation training for households, waste management organizations should seriously include source separation training programs in their management programs in order to manage the quality of waste recycling materials. Source separation of large volumes of household waste not only prevents capital waste and environmental pollution, but also helps optimize biodegradable waste recycling processes.

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**Authors contributions**
Marjan Potki: Conceptualization; Funding acquisition; Investigation; Visualization, and Writing. Ebrahim Fataei: Methodology; Project administration; Supervision, and Validation. Ali Akbar Imani: Formal analysis, and Software. Marjaneh Kharrat Sadeghi, Resources.

**Availability of data and materials**
All data generated or analysed during this study are available from the corresponding author upon reasonable request.

**Conflict of interests**
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.



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