



Original Article



Intensity of Citizens' Perception and Behavior Towards Electronic Waste Management (A Case Study, Qom city)

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Email: mr.mehdinemati.ir@gmail.com**Abstract**

Background: The growing use of electrical and electronic equipment in recent decades has generated a noticeable volume of electronic waste (e-waste), posing a major global environmental challenge. Therefore, the current study investigated household electronic waste management behaviors among citizens of Qom province, Iran.

Methods: The data for this cross-sectional analytical study were collected via a validated questionnaire from 384 citizens visiting recycling centers in Qom. Subsequent analysis was performed using Excel and SPSS software.

Results: It was found that only 37% of the respondents perceived the severe environmental consequences of e-waste. In contrast, the majority (93%) were aware of the direct economic benefits of recycling, while 41% recognized the indirect economic benefits. Regarding management behaviors, repair and reuse were the most common strategies (reported by 45% to 94% of the respondents), whereas delivering waste to official recycling centers was the least common (less than 5%).

Conclusion: A lack of awareness regarding the environmental consequences of e-waste reduces its separation rate. Thus, decision-makers should incorporate the economic incentives that promote the sale and reuse of electronic equipment into e-waste management plans.

Keywords: E-waste, Source separation, Waste management

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Introduction

Electronic waste (e-waste) comprises discarded electronic devices that are obsolete, non-functional, or no longer wanted by consumers.¹ The production of e-waste has increased remarkably in recent decades owing to the proliferation of diverse and efficient electronic equipment. This trend is a serious concern because of e-waste's potential for environmental pollution and subsequent health consequences.^{2,3} However, only a small fraction of this waste is formally recycled.⁴ In developing countries, it is estimated that only about 5% of e-waste enters the formal recycling sector, while the remaining 95% is handled informally by street vendors, scrap dealers, and private workshops.⁵ This uncontrolled management leads to the release of pollutants, particularly heavy metals, into the environment. For instance, the cadmium contained in a single mobile phone battery can contaminate up to 600 m³ of water.^{5,6} Also, incinerating e-waste can increase the levels of toxic pollutants such as dioxins, dibenzofurans, and polycyclic aromatic hydrocarbons in exhaust gases, thereby increasing health risks, including cancer.⁷ The leakage of pollutants from e-waste into water, soil, and

even the food chain has become a serious concern in recent years—especially in developing countries. For example, landfilling e-waste can raise pollutant concentrations in leachate, contaminate water resources, and contribute to soil acidification.⁸

E-waste is a major solid waste management issue due to the risk of pollutant leakage. Nevertheless, the presence of precious metals like gold and silver makes it a prime candidate for recycling, providing a viable sustainable management strategy.^{9,10} For example, the potential for recovering valuable metals including gold, copper, silver, and palladium from a mobile phone was reported by 0.024, 9, 0.25, and 0.009 g, respectively.¹¹ However, the proportion of e-waste recycling, like other recyclables component in the municipal solid waste, depends on citizens' participation in source separation. Source separation of recyclable waste varies according to behavioral factors and factors affecting it, such as awareness, attitude, and perceived benefits in different societies.¹² For example, a study in China found that legal factors, environmental knowledge, and consumer motivation significantly affect e-waste management practices.¹³ The perceived environmental



and economic benefits of recycling different types of solid waste, including e-waste, can strongly influence citizens' willingness to participate in source separation.¹⁴

Iran, as a developing country, has experienced rapid population growth in recent decades. The average per capita generation of municipal solid waste in Iran is approximately 640 g/day.¹⁵ Although around 30% of municipal solid waste in the country is recyclable, citizens' participation in source separation remains minimal.¹⁶ In recent years, economic development and increasing access to electrical and electronic equipment have drawn more attention to e-waste management. However, citizens' behavior toward used or obsolete electrical equipment plays a crucial role in determining the quantity of e-waste that enters the recycling stream within the urban waste management hierarchy. Therefore, this study aimed to investigate the intensity of citizens' perceptions and behaviors toward e-waste, as well as to assess the perceived environmental and economic benefits of e-waste recycling in Iran. Another objective was to examine citizens' behavioral patterns in managing e-waste.

Materials and Methods Study area

This study was conducted in Qom, Iran. Qom Province, with a total area of 11,240 km², is located in the central part of the country, between 34°15' to 35°15' north latitude and 50°30' to 51°30' east longitude. The province accounts for approximately 8.6% of Iran's total land area. Qom is the seventh-largest city in Iran, with a population of about 1,435,000, and holds a prominent cultural status among Iranian cities. The per capita solid waste generation in Qom is reported to be 580 grams per day, consisting of approximately 66% organic waste, 7.2% plastic, 4.3% paper

and cardboard, and 2.3% glass.¹⁵ However, the per capita generation of e-waste in Iran, as well as its proportion within the overall municipal solid waste composition, has not been clearly reported. Similar to most Iranian cities, Qom's municipal solid waste management system relies primarily on landfilling as the final disposal method. Nevertheless, in an effort to increase recycling rates, 43 designated waste collection and delivery centers are currently operating throughout the city (Figure 1).

Study Design

A total of 384 people were randomly selected from among those visiting recycling centers and interviewed and the questions were designed in three sections:

- Personal characteristics: such as gender, age, education level, and income.
- Awareness and knowledge: citizens' understanding of the environmental benefits (e.g., preserving water and soil resources) and economic benefits of e-waste recycling.
- Citizen behavior: actions related to e-waste management, including repair and reuse, storage, delivery to recycling centers, sale, donation, or disposal.

Next, the collected data were analyzed by using Excel and SPSS software. The perceived environmental and economic benefits of e-waste recycling were analyzed by asking visitors to Qom recycling centers. The questionnaire consisted of four questions, which are listed below. The behavior of visitors to recycling centers in managing e-waste was also assessed by answering three questions. Q1 and Q2 assessed awareness of environmental benefits, and Q3 and Q4 were designed to assess citizens' awareness of the economic benefits of separating and recycling



Figure 1. Location of recycling centers in the studied area

e-waste. Also, three questions Q5 to Q7 were considered to examine citizens' behavior in managing e-waste. The questionnaire items were as follows:

1. E-waste contains toxic and carcinogenic compounds and must be separated and recycled. (I completely disagree, I disagree, I have no opinion, I agree, I completely agree)
2. Landfill or incineration of e-waste leads to health and carcinogenesis risks due to the emission of pollutants. (I completely disagree, I disagree, I have no opinion, I agree, I completely agree)
3. E-waste recycling leads to the production of low-cost products. (I completely disagree, I disagree, I have no opinion, I agree, I completely agree)
4. E-waste separating lead to income for the family from sales to recycling centers. (I completely disagree, I disagree, I have no opinion, I agree, I completely agree)
5. What do you do with white goods waste or old white goods? (Repair and reuse, Storage, delivery to Recycling center, Sale, Charity, Disposal)
6. What do you do with home appliances waste or old home appliances? (Repair and reuse, Storage, delivery to Recycling center, Sale, Charity, Disposal)
7. What do you do with digital devices waste or old digital devices? (Repair and reuse, Storage, delivery to Recycling center, Sale, Charity, Disposal)

Results and Discussion

The results of the demographic analysis of the respondents have been shown in Table 1. A total of 384 individuals participated in the study, ranging in age from 20 to over

Table 1. Demographic analysis of the respondents

		Number	%
Gender	Men	175	45.57
	Women	209	54.42
Age	20-30	92	23.95
	30-40	158	41.14
	40-50	91	23.69
	50-60	31	8.07
	+60	12	3.12
Job	Employee	79	20.57
	Freelance	156	40.62
	Housewife	102	26.56
	Unemployed	46	11.97
Education	Diploma	146	38.02
	Bachelor	216	56.25
	Master	16	4.16
	PhD	6	1.56
Income	Very low	127	33.07
	Low	66	17.18
	Middle	106	27.60
	Good	82	21.35
	Prosperous	0	0

60 years, with the 30–40 age group representing the largest proportion. Among the respondents, 175 (45.6%) were female and 209 (53.65%) were male. The majority of participants (40%) were employed in non-governmental occupations. In terms of education level, individuals with a bachelor's degree constituted the largest group (30.73%). Regarding income, the highest proportion of respondents (33.07%) reported a very low income level. The analysis of respondents' perceived environmental benefits of e-waste recycling has been presented in Figure 2. The findings indicated that 37% of the participants agreed or completely agreed that e-waste contains toxic and carcinogenic compounds that necessitate recycling. As a result, 63% of the respondents appeared to be unaware of the potential leakage of e-waste pollutants and their associated environmental impacts. Furthermore, 29% of respondents agreed or completely agreed that landfilling e-waste increases pollution levels in landfill leachate. This suggests that 71% of respondents lacked awareness regarding the environmental consequences of e-waste disposal through landfilling.

Although the proportion of men and women visiting the recycling centers was approximately equal, gender may influence e-waste separation behavior, a factor that could affect the study's results.¹⁷ For instance, one study found women are less likely than men to store e-waste in their homes,¹⁸ while another reported that women perform better in e-waste management overall. Ultimately, citizen behavior in separating recyclable and hazardous household waste, including e-waste, is significantly affected by their awareness and attitudes.¹² Research indicates that perceiving environmental and economic benefits from recycling promotes increased source separation, particularly for hazardous items like batteries.¹⁴ However, this study's results showed limited perceived environmental benefits regarding e-waste, likely due to a lack of public awareness about its consequences, such as heavy metal leakage. This is a common issue, especially in developing countries. For example, awareness studies have found that 44% of respondents in Kuala Lumpur were unaware of the environmental impacts of e-waste,¹⁹ a figure that rises to 70.1% in another Iranian study.²⁰ Similarly, over half of the population in Dubai was unaware,²¹ while awareness levels were as low as 9%

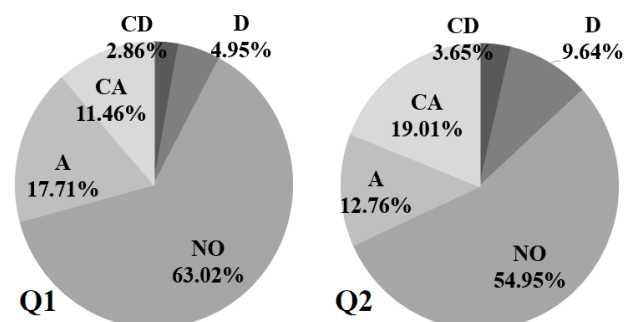


Figure 2. Proportion of responses to questions (Q1 and Q2) regarding perceived environmental benefits of e-waste recycling. CD: Completely Disagree; D: Disagree; NO: No Opinion; A: Agree; CA: Completely Agree

in Bangladesh,²² and 30% in India.²³ The analysis of the perceived economic benefits of e-waste recycling has been presented in Table 2. The results showed that while 93% of respondents agreed or strongly agreed that selling e-waste to recycling centers provides a direct financial benefit to households, only 41% agreed or strongly agreed that recycling leads to lower-cost products. This suggests a high awareness of direct economic value but a poor understanding (59% of the respondents) of its indirect economic benefits. Furthermore, the analysis of respondent behavior (Figure 3) revealed that financial incentives strongly influence e-waste management. For defective or old white goods (e.g., refrigerators, washing machines), the vast majority of the respondents choose repair, reuse, donation, or sale: 94.01% repair and reuse or donate defective white goods, 89.06% reuse or sell old white goods. Consequently, disposal is rare, with 5.98% storing such items and virtually none being delivered to recycling centers.

Despite the low perceived environmental benefits among the studied citizens, awareness of the economic advantages of e-waste separation was strong, with 93% of respondents recognizing the direct income from sales and 89% acknowledging the indirect benefit of lower-cost products, underscoring that financial incentives are a key driver for recyclable waste separation.¹⁶ However, because of the low source separation rate in Iran, the results showed that e-waste separation was also carried out partially. In addition, old and defective electrical equipment was often

repaired and reused. This situation could be due to the lack of planning of the municipal waste management system for specific e-waste management or the lack of awareness of citizens about the current programs. Programs developed based on permanent e-waste collection points can facilitate citizen participation, which has been experienced in Finland and is well known.²⁴ Also, in the United Kingdom, only 31% of people are unaware of the e-waste recycling program, which is a successful example of e-waste management.²⁵ But, in Australia, 67.58% of citizens were unaware of the collection and recycling program for defective mobile phones,²⁶ and in China, 45.9% of people dispose of e-waste in inappropriate ways due to lack of awareness of official recycling channels.²⁷ Considering these evidences, informing about recycling centers in cities by special posters and brochures in places where citizens are most present is effective. Places such as cinemas, libraries, electronics retail stores, shopping malls, and parks can be useful for delivering awareness messages to citizens.²⁶

It was found that repair and reuse, and sale had the largest share in citizens' behavioral choices in managing defective or old home appliances, including irons, vacuum cleaners, rice cookers, juicers, fryers, and the like. Also, on average, storing defective home appliances was reported by 23.17% of respondents. Donating and delivering to recycling centers accounted for 10.15% and 4.94% of respondents' behaviors in managing defective and old home appliances, respectively. A similar pattern was also observed for defective or old digital devices. The results showed that repair and reuse, and sale were the declared options of 82.05% of respondents in managing defective or old digital devices including televisions, cameras, radios, laptops, mobile phones, game consoles, and the like. 2.86% of the respondents reported disposing of old and defective digital devices. Donating and delivering to recycling centers accounted for 3.64 and 2.08% of the total

Table 2. Proportion of responses to questions (Q3 and Q4) regarding perceived economic benefits. All values in parentheses are expressed as percentages.

	CD*	D	NO	A	CA
Q3	7(1.82)	14(3.65)	42(10.94)	224(58.33)	97(25.26)
Q4	0(0)	3(0.78)	19(4.95)	94(24.48)	268(69.79)

* CD: Completely Disagree, D: Disagree, NO: No Opinion, A: Agree, CA: Completely Agree

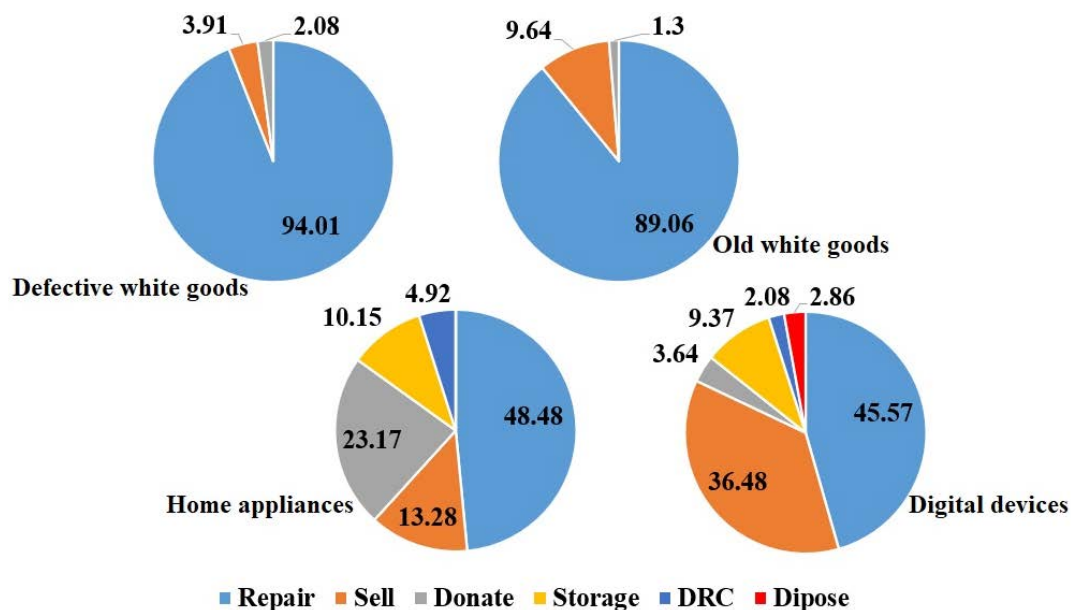


Figure 3. Analysis of respondents' behavioral choices in e-waste management (%), DRC: Delivery to Recycling Centers

responses, respectively.

In addition to awareness and perceived environmental and health benefits, external factors also influence citizens' participation in proper e-waste management and separation. Motivation, convenience, and security were found to be the three main factors ensuring the participation of consumers of electrical appliances in waste management.²⁸ Therefore, financial incentives were the main factor in repairing and reusing electrical appliances. Also, the lack of separate e-waste disposal facilities in the waste management structure can make it difficult for citizens to separate this type of waste, which is one of the factors affecting the low source separation rate. Financial incentives are a major factor in many developing countries, such as India and Bangladesh, where individuals are rewarded for delivering e-waste to informal centers.²² In this study, the sale of e-waste or old electrical equipment may have been motivated by financial incentives. This is in contrast to many developed countries, such as Switzerland, where consumers have to pay for recycling.²⁹

Conclusion

In this study, 384 citizens who visited recycling centers were analyzed by answering relevant questions. The results showed that 37% of the respondents knew the environmental necessity of separating and recycling e-waste. Also, 93% of the respondents were aware of the direct and 41% of the respondents were aware of the indirect economic consequences of e-waste recycling, including the production of low-cost products and earning income from the sale of e-waste. Repair and reuse had the highest share (79%) in citizens' behavior in managing various types of e-waste and old electrical equipment, followed by sale (24%) reported by respondents as the second behavioral option. Although increasing citizens' awareness of the environmental consequences of landfilling or incinerating e-waste, including the emission of pollutants such as heavy metals, is necessary, however, it is necessary to considering financial incentives for separating this type of waste. Also, development a structure for collection of separated e-waste from home can facilitate the management of separated waste and increase citizen cooperation. The results of the public opinion study on e-waste in the city of Qom provide information to city managers and help them direct their efforts towards choosing an e-waste management method with a view to preserving the economic and environmental interests of citizens.

Authors' Contribution

Conceptualization: Mehdi Nemati, Ahmad Nohegar.

Data curation: Mehdi Nemati.

Formal analysis: Mehdi Nemati.

Funding acquisition: Ahmad Nohegar.

Investigation: Mehdi Nemati, Ahmad Nohegar, Ali Daryabeigi Zand.

Methodology: Mehdi Nemati, Ahmad Nohegar, Ali Daryabeigi Zand.

Project administration: Ahmad Nohegar.

Resources: Mehdi Nemati.

Software: Mehdi Nemati.

Supervision: Mehdi Nemati.

Validation: Mehdi Nemati, Ahmad Nohegar.

Visualization: Mehdi Nemati, Ahmad Nohegar.

Writing—original draft: Mehdi Nemati, Ahmad Nohegar, Ali Daryabeigi Zand.

Writing—review & editing: Mehdi Nemati, Ahmad Nohegar, Ali Daryabeigi Zand.

Competing Interests

The author declares no conflict of interest.

Ethical Approval

There were no ethical considerations to be considered in this research.

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