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Hassan Taghipour, Parviz Nowrouz, Mohamad Asghari Jafarabadi, Jalil Nazari, Ahmad Asl Hashemi, Mohammad Mosaferi and Reza Dehghanzadeh

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E-waste management challenges in Iran: presenting some strategies for improvement of current conditions

Hassan Taghipour,[1] Parviz Nowrouz,[1] Mohamad Asghari Jafarabadi,[2] Jalil Nazari,[3] Ahmad Asl Hashemi,[1] Mohammad Mosaferi[1] and Reza Dehghanzadeh[1]

Abstract

E-waste is one of the fastest-growing waste streams in Iran, owing to an increase in consumption of electrical and electronic equipment. Nevertheless, as is the case in some other countries, E-waste management has not received sufficient attention. For the successful implementation of any waste management plan (including an E-waste management plan), the availability of sufficient and accurate information on the quantities and composition of the waste generated and on current management conditions is a fundamental prerequisite. At present, in Iran, there is no available and accurate information that describes the characteristics and generation rate of E-waste or the actual practice of management and handling of the waste. For this initial study, eight electronic products were selected for the determination of their E-waste generation rate in the country, and two cities, Tehran and Tabriz, were selected for assessment of the current condition of E-waste management. The study found that the amount of E-waste generation in the country for the eight selected electronic items alone was 115 286, 112 914 and 115 151 metric tons in 2008, 2009 and 2010, respectively. Of the types of electronic items included in the study, televisions, with an average of 42.42%, and PCs, with an average of 32.66% accounted for the greatest proportions of the total mass of E-waste generated during 2008–2010. Currently, despite the fact that primary legislation for E-waste management (as part of general waste legislation) exists in Iran, this primary legislation has not yet been implemented. In practical terms, there is no definite policy or plan for the allocation of funds to prepare suitable equipment and facilities for the management and recycling of E-waste at the end of the products' useful life. Proposed improvements in current conditions are identified, first by considering other countries' experiences and then suggesting specific practical policies, rules, and regulations that should be established and applied to all levels of E-waste management. One of the most attractive E-waste management policies is an extended producer responsibility (EPR) programme in combination with a training programme at different levels of society. An approach consisting of a mandated product take back is proposed for implementing EPR in Iran. Meanwhile, the Health Ministry and the Environmental Protection Agency should strictly supervise E-waste collection, storage, and recycling and/or disposal, and the Trade and Industry Ministries must have more control over the import and production of electronic goods.

Keywords

E-waste, management, challenges, strategies, Iran

Introduction

The terms electronic waste (E-waste) and waste electrical and electronic equipment (WEEE) describe discarded appliances that use electricity. E-waste describes waste electronic goods, such as computers, televisions, facsimile machines, high-fidelity systems, electronic games, photocopiers, radios, video recorders, DVD players and cell phones, whereas WEEE includes traditionally non-electronic goods, such as refrigerators, washing machines, dishwashers, and ovens (Robinson, 2009). Nevertheless, in other scientific studies, E-waste has been defined as 'any discarded electrically powered appliance'. Thus, according to this definition, E-waste includes both 'white' goods (e.g., refrigerators, washing machines, and microwaves) and 'brown' goods (e.g. televisions, radios, and computers) that have reached the end of their life (Khetriwal et al., 2009). However, drawing distinctions between E-waste and WEEE is becoming more difficult, owing to rapid technological advances in the manufacture of electrical and electronic equipment.

[1]Department of Environmental Health Engineering, Tabriz University of Medical Sciences, Tabriz, Iran
[2]Department of Statistics and Epidemiology, Tabriz University of Medical Sciences, Tabriz, Iran
[3]Department of Occupational Health, Tabriz University of Medical Sciences, Tabriz, Iran

Corresponding author:
Hassan Taghipour, Department of Environmental Health Engineering, Tabriz University of Medical Sciences, Tabriz, Iran
Email: hteir@yahoo.com

As technology advances, people purchase increasing numbers of electronic devices (computers, entertainment electronics, mobile phones and other such devices), even though these items are not essential (Kahhat et al., 2008). Currently, the electronics industry is the world's largest and fastest-growing manufacturing industry. Rapid growth combined with rapid product obsolescence results in discarded electronics, which is now one of the fastest-growing waste streams in the world. The growing quantity of E-waste from the electronic industry is beginning to reach disastrous proportions (Wath et al., 2011). According to research studies, E-waste equals 1–3% of total solid waste worldwide (Robinson, 2009; UNEP, 2007). Indeed, Widmer et al. have reported that, even in some developed countries, E-waste may constitute 8% of municipal waste by volume (Widmer et al., 2005). Huisman et al. reported that, the 27-member-state European Union (EU-27) generated 8.3–9.1 million tonnes year^{-1} (Huisman and Magalini, 2007). The United States produced some 2.63 million tonnes in 2005 (Cobbing, 2008). In 2006, the world's production of E-waste was estimated at 20–50 million tonnes year^{-1} (Robinson, 2009). The increasing 'market penetration' in developing countries, 'replacement market' in developed countries and 'high obsolescence rate' cause greater and greater increases in WEEE and E-waste production throughout the world (in developed and developing countries) (UNEP, 2007). E-waste production data for economically developing countries are less readily available. India and Thailand are estimated to have produced just 0.33 and 0.1 million tonnes of E-waste in 2007, respectively (Robinson, 2009). While Dwivedy et al. reported that during 2007–2011 in India, the total WEEE estimates would be around 2.5 million tonnes (Dwivedy et al 2010). It was estimated that more than 80 443 tonnes (11.5 kg capita^{-1}) of E-waste is generated from non-plasma and non-liquid crystal display televisions, refrigerators, washing machines, air-conditioners and personal computers each year by Hong Kong households (Chung et al., 2011). Peralta et al. reported that, at the end of 2005, approximately 2.7 million electrical and electronic units became obsolete and approximately 1.8 million units required disposal in landfills in the Philippines. Over a 10-year period from 1995 to 2005, approximately 25 million units became obsolete in that country (Peralta et al., 2006). It is predicted that changes in the economic conditions of developing countries and technological developments in the manufacture of electrical and electronic equipment will probably increase the amount and production rate of E-waste and WEEE and for the same reasons the characteristics of this waste stream will probably change more in the future. It should be noted that, in addition to the fact that economically developing countries themselves produce a share of the world's E-waste and WEEE, huge amounts of E-waste are being exported from developed countries to these same countries. According to scientific reports, approximately 80% of the E-waste of developed countries is exported to poor or developing countries (Schmidt, 2006). China alone imports approximately 70% of all exported E-waste in the world (Liu et al., 2006). The other major importers of E-waste are India, Pakistan, Vietnam, the Philippines, Malaysia, Nigeria and Ghana (Robinson, 2009). The exporting of E-waste and WEEE to poor and developing countries makes the subject of E-waste management more complicated, both in those societies (owing to environmental and health problems) and throughout the world, because some recycled contaminated products associated with E-waste recycling are probably re-exported. E-waste and WEEE contain substantial amounts of reusable materials, such as metals, that can be recovered in the form of secondary raw materials. However, E-waste and WEEE also contain significant amounts of hazardous substances, such as metals (for example, As, Ba, Be, Cd, Pb, Ni, and Cr), polychlorinated biphenyls (PCBs), and brominated organic compounds. Some contaminants, such as heavy metals, are used in the manufacture of electronic goods, whereas others, such as polycyclic aromatic hydrocarbons (PAHs), polyhalogenated aromatic hydrocarbons (PHAHs), polychlronated dibenzo-*p*-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) are generated by the low-temperature combustion of E-waste. When these substances do not receive proper disposal, their release may represent a hazard to public health and to the environment (water, air, soil, etc) (Morf et al., 2007; Robinson, 2009). Environmental pollution due to unsuitable managing and disposal of E-waste by heavy metals, hydrocarbons, PAHs, PCBs especially in recycling areas has been reported in many studies (Jun-Hui et al., 2009; Keshav et al., 2009; Tang et al., 2010; Wen et al., 2009). Luo et al. (2007) reported that carp from the Nanyang river, near Guiyu, were bioaccumulating polybrominated diphenyl ethers (PBDEs) to concentrations of up to 766 ng g^{-1} (fresh weight). According to the results of another study, the concentration of PBDEs in the city of Guiyu atmosphere exceeds 11 000 pg m^{-3} during the daytime, decreasing to less than 5000 pg m^{-3} at night (Chen et al., 2009). Also the increased concentrations of PBDEs, PCBs, PAHs dibenzo-*p*-dioxins and dibenzofurans (PCDD/Fs) and heavy metals in soils, plants (polished rice) and in chicken tissues (Fu et al., 2008; Leung et al., 2007; Liang et al., 2008; Shen et al., 2009). The elevated levels of heavy metals (Cr, Pb and Cd), polybrominated diphenyl ether (BPDE) and dioxins reported in human milk and blood in affected area by E-waste recycling especially in Guiyu (China) (Chan et al., 2007; Huo et al., 2007; Li et al., 2008a, 2008b; Qu et al., 2007; Zheng et al., 2008).

E-waste is one of the fastest-growing waste streams in Iran, as it is in other countries, owing to an increase in consumption by businesses and domestic users of electrical and electronic equipment. Nevertheless, as is also the case in most other economically developing countries, E-waste management has not received sufficient attention. Therefore, planning of an E-waste management programme is necessary to prevent the above mentioned effects on humans and the environment and to reduce economic losses. For the successful implementation of any waste (including E-waste) management plan, the availability of sufficient and accurate information on the quantities and composition of the generated waste and on the current management conditions is one of the fundamental prerequisites for each society.

Currently, in Iran there is no available and accurate information that describes the actual practice of management and handling of E-waste. In addition, the data available to date on E-waste characteristics and production rates in Iran are scarce. Therefore, the determination of the production rate of E-waste generated in the country is a pressing necessity. This determination is one of the key objectives of the present work. Another objective of this study is to assess E-waste handling, recycling, and the final disposal of the waste. This study also aims to assess existing policies on E-waste management in Iran. In addition, this study aims to make some practical recommendations about E-waste management in the country to improve the current situation.

Methodology

In this initial study, the following eight electronic products were considered: personal computers (PCs), laptops (notebook), televisions, radios and tape recorders (audio systems), mobile telephones (cellular telephones), photocopiers, printers, video recorders, and video projectors (VP). E-waste resulting from the obsolescence of these products is estimated by considering both domestic production and imports of these goods during the period 2004–2009. Electronic equipment that was probably illegally imported was not included in the study, owing to the uncertainty of the data.

To obtain the collaboration and support of the Iranian National Statistics Organization and Iranian Industry and Mining Ministry, a formal letter was sent to the head of each office related to the project. The highest officers relevant to the project in the organization and ministry named were involved in the project. Before the beginning of the survey, the people who were involved in the project attended a training course to gain a better perspective on the aims of the survey. The methodology used in this study to estimate the rate of generation of E-waste was based on data collected from the National Statistics Organization and Industry and Mining Ministry.

The amount of annual E-waste production (metric tons year^{-1}) was estimated for each of the items in the study, based on the mass of each item and on average lifespan assumptions as presented in Table 1 (Robinson, 2009). A multilayer perception artificial neural network using the batch training method and the gradient descent algorithm was used to forecast E-waste production. The multilayer perceptron (MLP) procedure is an artificial neural network produces a predictive model for one or more dependent (target) variables based on the values of the predictor. The MLP consists of a network of neurons which map predictor variables to dependent variables. In this procedure, each artificial neuron consists of a linear combination of weighted predictors which is passed through a non-linear activation function and hidden layers to produce the neuron's output. This structure of the network is called the architecture. The hidden layer contains unobservable network nodes (units). Each hidden unit is an activation function of the weighted sum of the inputs (predictors) and the values of the weights are determined by the estimation algorithm. A MLP can have one or two hidden layers. If the network contains a second hidden layer, each hidden unit in the second layer is a function of the weighted sum of the units in the first hidden layer. The activation function 'links' the weighted sums of units in a layer to the values of units in the succeeding layer. The output layer contains the target (dependent) variables (Fine, 1999)

It must be noted that imported E-waste was not included in this study because it is estimated that the amount of such waste is probably very small in Iran and because accurate and formal data are not available from the Trade Ministry or the Statistics Organization.

To assess current management conditions, two provinces in the centre and north-west of Iran, Tehran and East Azerbaijan, respectively, were selected from the 32 provinces of the country. The assessment was then performed in the cities of Tehran and Tabriz in the selected provinces. Tehran, the capital city, with a population of 7.08 million people, is the largest city in Iran, and Tabriz, with a population of more than 1.57 million people, is the fourth-largest city in the country and the largest in the north-west of Iran (Taghipour et al., 2009; http://amar.sci.org.ir).

A combination of methods was used in the study. These methods included completion of checklists; site visits and walkthrough surveys (observation); conversations with authorities; the use of scientific databases; and contacts with municipalities, local and national environmental protection agencies, and other organizations. E-waste handling, recycling, final disposal and existing policies on the topic were assessed. In accordance with the current conditions in the country, and with reference to other countries' relatively successful experiences, some practical management strategies will be presented to improve E-waste management and disposal in Iran.

Results and discussion

Generation rates

The amount of equipment belonging to the categories studied (Table 1) and produced in or imported to the country from 2005 to 2010 is presented in Table 2. The amount of E-waste

Table 1. List of electronic equipment included in the study and the typical lifetimes of these items. After the end of a product's lifetime, it is considered to be E-waste.

Item	Typical lifetime (years)[a]
Personal computer (PC)	3
Laptop or notebook (NB)	3
Television (TV)	5
Radio and tape recorder (audio systems)	10
Mobile telephone	2
Photocopier	10
Printer	5
Video projector (VP)	5

[a]Robinson (2009).

Table 2. The amount of selected items of electronic equipment produced or imported in Iran from 2005 to 2010 (metric tons).

Year	Computer (PC)	Laptop	Television	Radio	Mobile telephone	Photocopier	Printer	Video projector	Total (all items)
2005	37 476	258	43 269	21 846	2341	2583	1265	208	109 246
2006	36 010	419	40 735	29 107	946	2211	4036	68	113 532
2007	38 643	846	38 438	25 415	300	3633	4438	117	144 529
2008	34 848	1476	29 228	16 074	484	2460	4121	87	88 778
2009	35 008	2422	24 647	26 119	281	1146	3886	103	93 612
2010	34 688	3558	22 886	8244	377	660	2222	103	72 738

Table 3. The estimated amount of generated E-waste represented by the items in the study (artificial neural network estimates for Iran for the years 2007 to 2016).

Year	Computer (PC)	Laptop	Television	Radio	Mobile telephone	Photocopier	Printer	Video projector	Total (all items)
2007	37 797	142	48 781	22 722	2341	3623	1322	371	117 099
2008	37 476	258	48 732	22 604	946	3574	1322	374	115 286
2009	36 010	419	48 602	22 384	300	3505	1322	372	112 914
2010	38 643	846	48 309	21 988	484	3408	1265	208	115 151
2011	34 848	1476	47 705	21 264	281	3262	4036	68	112 940
2012	35 008	2422	46 540	20 024	377	3022	4438	117	111 948
2013	34 688	3558	43 269	17 982	171	2583	4121	87	106 459
2014	35 282	3668	40 735	14 356	144	2211	3886	103	100 385
2015	35 184	3956	38 438	21 846	123	3633	2222	103	138 204
2016	35 122	4095	29 228	29 107	105	2460	4570	102	104 789

represented by this equipment was predicted by considering the amount of equipment produced or imported and the typical lifetimes of these items (Table 1).

A multilayer perception artificial neural network using the batch training method and the gradient descent algorithm was used to forecast the E-waste production from 2007 to 2016 (Table 3). Analyses were performed utilising SPSS 17 statistical software (SPSS inc, Chicago, Delaware, USA). The results of our survey indicated that the rates of E-waste generation in the country for only the eight electronic items selected were, 115 286, 112 914 and 115 151 tonnes year^{-1} for 2008, 2009 and 2010, respectively. The estimation of the rates of generation for 2011–2016 indicated that this rate will probably vary from 100 385 to 138 204 tonnes annually. During 2008–2010, of the types of electronic equipment studied, TVs, with an average of 42.42%, and PCs, with an average of 32.66%, accounted for the greatest proportions of the total mass of E-waste generated (Figure 1). It should be noted, as previously explained, that data on only eight types of electronic equipment were analysed and that the research team was not able to properly collect certain data on illegal imports of electronic equipment to the country. Therefore, illegally imported equipment could not be included in the estimate of E-waste generation for the country. Thus, if all electrical and electronic equipment and appliances (including both 'white' goods, such as refrigerators, washing machines, and microwaves, and 'brown' goods, such as televisions, radios, and computers that use electricity) and illegally imported items were included in the dataset, the total estimated amount of E-waste could be considerably higher than the amount estimated by the present study.

Current regulation and management conditions

Currently, in Iran, general legislation concerning waste management is in place. This legislation also applies to E-waste (Waste Management Regulations of Iran, 2009). This legislation was proposed by the government and approved by the parliament in 2004. According to clause 12 of the executive instruction included in that legislation, all electrical and electronic equipment producer and importer companies are responsible for the recycling of their E-waste. If they do not recycle their E-waste, they are to pay 0.005% of the value of the goods produced and/or imported goods to a special fund. The money in that fund should be used for the recycling of E-waste. According to the notes to clause 12 of the executive instruction cited, the companies that do not accept their responsibility must pay financial penalties, the companies that use recycled material in their production processes are granted an exemption, and manufacturers and importers that voluntarily take back products at the end of the products' useful life or that export their products are also exempt. The Ministry of Health and national Environmental Protection

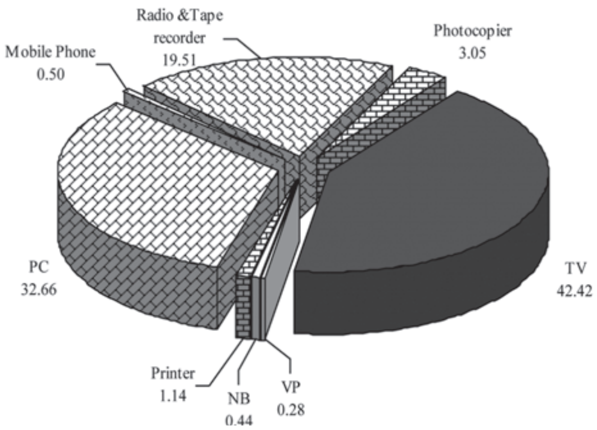

Figure 1. Comparison of average percentage of E-waste for the items included in the study during 2008–2010.

Agency have the responsibility for applying pressure for the implementation of the legislation.

Although that general regulation did not offer an exact explanation of the practical details (even the categories of electrical and electronic equipment and E-waste were not clearly defined), if the legislation is implemented, it can lead to great progress in proper management of E-waste and in reduction of the associated environmental and health problems.

The results of the assessment of the current condition of E-waste management in the cities of Tehran and Tabriz are presented in Table 4. As indicated in that table, the current E-waste management legislation only consists of rules at the national level. The rules have not yet been put into effect in the area studied. (The same conditions exist in other provinces and cities.) In practical terms, no definite policy or plan exists for the allocation of funds to prepare suitable equipment and facilities for the management and recycling of E-waste at the end of the products' useful life.

The segregation of E-waste is generally done unsystematically and non-industrially, for example by workers in repair shops, by municipal solid-waste personnel, and sometimes by those who illegally separate trash at landfill sites (especially in Tabriz city). E-waste is being recycled legally or illegally under non-organized conditions by small companies, sometimes with a low level of technology. The remainder of the E-waste generated is largely handled and discarded by municipalities along with domestic wastes. This practice can create health risks for municipal workers, the public, and the environment.

It should be noted that most of the other cities and provinces in the country exhibit the same conditions. Even before this study, the quantity and quality of E-waste in the country was not estimated. Only one limited study, performed by Abdouli et al. in 2005, has investigated E-waste resulting from personal computers (PCs) (Abdouli et al., 2005).

Extended producer responsibility

There are many experiences in other countries in E-waste managing. Most developed countries have in place legislation mandating electronic manufacturers and importers to take-back used electronic products at their end-of-life (EoL) based on extended

Table 4. Summary of current E-waste management in the study area (Tehran and Tabriz cites).

Subject surveyed		Result in cities studied	
		Tehran	Tabriz
1	Having a scientific and exact definition for E-waste	No	No
2	Having a preliminary regulation for E-waste management	Yes	Yes
3	Implementation of current regulation for E-waste management	No	No
4	Available and accurate data on quantity and quality of produced E-waste	No	No
5	Having a responsible organization or office for the management of E-waste	No	No
6	Non-industrial recycling (manual and traditional recycling)	Yes	Yes
7	Use of protective measures and training for E-waste recycling personnel	No	No
8	Final disposal method of non-recycled E-waste	Landfill	Landfill
9	Recycling and illegal segregation in the landfill	No	Yes
10	Payment of any cost for disposal of E-waste by importers or producers of electronic equipment	No	No
11	Payment of any direct cost for disposal of E-waste by people (consumers)	No	No
12	Practical cooperation of large importer or producer companies in E-waste management or recycling	No	No
13	Having a defined programme for scientific E-waste managing or recycling in the near future	No	No
14	Having any programme for reducing the amount of E-waste	No	No
16	Implementation of any extended producer responsibility (EPR) programme	No	No
17	Implementation of any advance recycling fee (ARF) or advance disposal fee (ADF) and deposit-refund schemes	No	No
18	Mandated product takeback programme	No	No

Table 5. Policy instruments used in the implementation of EPR.

Administrative instruments	Collection and/or take-back of discarded products, reuse and recycling targets, setting emission limits, recovery obligation, product standards technical standards
Economic instruments	Material/product taxes, subsidies, advance recycling fee systems, deposit-refund systems, upstream combined tax/subsidies
Informative instruments	Environmental reports, environmental labeling, information provision to recyclers about the structure and substances used in products, consultation with authorities about collection network

Nnorom and Osibanjo (2008).

producer responsibility (EPR) (Nnorom and Osibanjo, 2008). There are many definitions of EPR. The Organization for Economic Cooperation and Development (OECD) defined EPR as 'an environmental policy approach in which a producers' responsibility for a product is extended to the post-consumer stage of a products life cycle including its final disposal' (Nnorom and Osibanjo, 2008). In addition, EPR is defined as a strategy that makes the manufacturer of the product responsible for the entire life-cycle of the product and especially for the take back, recycling and final disposal of the product. The main goals of EPR are: (1) source reduction (natural resource conservation/materials conservation); (2) waste prevention and reduction; (3) design of more environmentally compatible products; (4) closure of material loops to promote sustainable development; (5) product reuse; (6) increased use of recycled materials in production; (7) internalization of environmental costs into product prices; and (8) energy recovery when incineration is considered appropriate (Khetriwal et al., 2009; Nnorom and Osibanjo, 2008). EPR can be implemented through administrative, economics and informative instruments (Table 5). Therefore, EPR policy instruments can include different types of product fees and taxes, such as advance recycling fees (ARFs), product take-back mandates, virgin material taxes, and even combinations of these instruments. The EPR implementation can differ from one country to the other according to the dominant condition. The differences manifest themselves in, among other things, scope (e.g. all EEE vs. large home appliances), range and type of producer responsibility (e.g. collective responsibility vs. individual responsibility), and funding mechanism (i.e. who pays how much, at which points?) (Khetriwal et al., 2009). Therefore different countries (such as Switzerland, Denmark, Netherlands, Norway, Belgium, Japan, and Sweden) implemented different programme.

Recommendations

According to the results of our study and the local conditions, the following items are suggested for the improvement of E-waste management in Iran.

- Specific practical policies, rules and regulations should be established and applied to all levels of E-waste management.
- In the preparation of sustainable practical regulations, the experiences of other countries must be considered. One of the most frequently recommended E-waste management policies is the extended producer responsibility (EPR) programme. An EPR programme would represent a suitable candidate policy for managing E-waste in Iran. Its many advantages include waste prevention and reduction, product reuse, increased use of recycled materials in production, reduced natural resource consumption, internalization of environmental costs in product prices, and energy recovery when incineration is considered appropriate.
- The range of instrumental approaches for implementing EPR includes mandated product take-back, voluntary product take-back, and particular economic instruments in accord with other countries' experiences. mandated product take-back for Iran is recommended. With this policy approach, the government mandates that manufacturers, importers and/or retailers take back products at the end of the products' useful life.
- To prepare for the costs of recycling or disposal of electronic and electrical equipment at the end of the life of the items (EoL) in the proposed EPR programme, the advance recycling fee (ARF) as economic instruments can be implemented. Moreover, to encourage the consumer to take back the product at the end of the product's useful life, a proportion of the ARF (for example, 50%) can be refunded.
- Initially, it is better to begin work with some categories of electronic or electrical equipment that are used more and that involve high amounts of waste. Examples include TVs and PCs among brown goods and refrigerators and washing machines among white goods. The programme can then be extended to cover other equipment.
- The Health Ministry and the Environmental Protection Agency should more strictly supervise E-waste collection, storage, and recycling and/or disposal, and the Trade and Industry Ministries must have more control over the import and production of electronic goods.
- In Iran, as in most other countries, the most frequently consumed electronic or electrical equipment consists of famous multinational brands produced by rich companies that obtain high benefits from the country. Therefore, if the EPR programme is seriously enforced by the authorities, these companies should accept more responsibility for the protection of the environment.

Conclusions

The problem of E-waste is reaching alarming proportions in Iran, as it is in most other countries. In this initial study, only data on eight selected types of electronic equipment were analysed. If all electrical and electronic equipment and appliances were included in the dataset, the estimated amount of E-waste could be considerably higher than the amount estimated by the present study. Therefore, the effects of unsuitable managing and disposal of E-waste on environment and public health could be considerably higher. There is urgent need for the implementation of legislation dealing specifically with E-waste, the implementation of EPR programme and allocation of funds to prepare suitable equipment and facilities for the managing and recycling in the Iran.

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