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Effective Factors in Municipal Solid Waste Minimization and Recovery by Making Use of Citizens' Participation; Case Study of a District in Tehran City

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ABSTRACT: The purpose of this research is to quantify the potential of waste recycling in the form of participatory scenarios for separation from the source and to study the factors of minimization (reduction) of waste production in a district of Tehran. Amount of waste minimization was determined with considering a couple of citizens' participation scenarios. Source separation of valuable wastes including paper and cardboard, plastic, plastic bags, aluminum cans, bread, PET, waste metal and glass were considered in this procedure. Among 250 tons of generated dry waste within the district, 150 tons (60%) goes directly to landfill instead of getting recycled. Considering the successful experiences regarding the use of reverse vending machine (RVM) in recycling of beverage containers, this research takes RVM as a reasonable method to promote the recycling activities by citizens. In the 10% scenario, the participation for the separation of the total amount of daily materials is about 4,300 USD per day and in the 25% scenario, 10,800 USD of added value have been calculated. Also, for the participation of 10 and 25 percent during a month, 15 and 30 waste disposal services to the disposal and processing complex could get less.

Keywords: optimization, participation scenarios, recycling, reverse vending machine, source separation.

INTRODUCTION

Solid waste management includes different environmental, social, technological, economic, legislative, and issues that should be considered to find solutions that are thrifty and sustainable (Kanchanabhan et al., 2011a,b). The main waste management activities were consisted of collection and landfilling, before 1990s. With rising inaccessibility of land for waste disposal and huge attention due to the occurred health, social and environmental issues, researches and policies attempted to develop management strategies comprised waste generation, collection, transportation, treatment, and disposal (Massaruto, 2014; Naveen & Malik, 2019). Solid waste management (SWM) is a challenging issue all around the world especially in developing countries because of the urbanization, fast population growth and people's lifestyle

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changes which increase solid waste generation (Suocheng et al., 2001; Franchetti, 2009; Samadi et al., 2018; Danesh et al., 2019; Sajednia et al., 2019; Mohsenizadeh et al., 2020) and needs advanced methods in waste management (Davoudi, 2000) Certainly, as much as the amount of solid waste production increases, the costs of collection, transfer, processing and landfilling will be significantly increased (Khan et al., 2016). In developing countries, municipalities spend 20–50% of their budget on SWM which only covers less than 50% of the total population (Henry et al., 2006; Memon, 2010).

China is the world's most populous country and passed the US as the world's largest waste generator in 2004 and is estimated to have the fastest and largest increase in solid waste growth in history (Zhang et al., 2016). In Brazil, the generation of municipal solid waste (MSW) has increased in recent decades (Nascimento et al., 2015), as a result of country's economic development and lifestyle evolutions (Ibanez-Fores et al., 2018). In India, solid waste management services are poor mostly because municipal bodies perform these services which has caused many problems in urban environment as well as to the public health in most of the Indian cities and towns (Saikia & Nath, 2015).

The troubles of swift industrial development and population growth with lack of planning in Iran, has made many troubles and challenges based on risen generation of waste and its consequences. Prevalent waste management systems in Iran are not capable of covering sustainable waste management requirements (Jamshidi et al., 2011). Applying technology without knowledge of the waste materials and adaptation to local factors does not have effective outcomes. In Iran and such developing countries the degree of resource consumption, waste generation and moving toward non-sustainability is high. Accordingly, recycling is absolutely important, but unlike in developed countries, there is no belief in implementation.

Informal waste pickers are such a wicked problem in many developing countries as they collect waste from landfill sites, and garbage bins of residential or commercial areas (UN-Habitat, 2010). Their occupation are mostly unheeded and discouraged by the governments in developing countries (Sembiring & Nitivattananon, 2010). Cities have a strong will to modernize waste management systems, however the right on ownership of waste may cause struggles between informal and formal sectors (Wilson et al., 2009). It is necessary to develop a balanced system to steer clear of such situations. Encouraging citizens to participate in separating waste collection is the basic step to systematic recycling in cities (Matsui et al., 2007).

In Tehran, the population in day time is over 13 million (Fazeli et al., 2018), and an average of seven thousand tons of waste is generated per day (Heravi et al., 2013; Nasrabadi et al., 2008). Municipal solid waste comprised more than 97% of Tehran's solid waste, while 3 other types (construction and demolition, hospital, and industrial waste) and comprised less than 3% (Damghani et al., 2008). Rapid urbanization and population growth caused a high volume of waste generation in Tehran that threatens the health of the city and citizens of the capital by facing the different kind of environmental pollution. There are 60-70% of organic compostable materials and more than 40% moisture in household waste. On the one hand, the incorrect combination of these materials with valuable and recyclable solid waste by citizens, strongly strengthens the need for planning, building of infrastructures, education and legislation of waste management in Tehran. One of the most important solutions as the first priority in urban waste management is the source separation, which is dependent on the comprehensive participation of citizens. The undeniable value of source separation of solid waste is noteworthy more than before. Moreover, the city of Tehran faces the lack of land for sanitary landfill due to its huge waste generation rate, while not paying attention to the origin of the waste to reduce its volume. A main challenge for researchers when analyzing MSWM systems is data availability and information on MSW statics is hardly approachable in Tehran, mainly due to irregular disposal, informal or disordered collection and insufficient public collection systems. Based on a recent study, waste management systems have multi-disciplinary factors. Thus, they should be examined in different social, economic, and environmental aspects in Tehran (Majlessi et al., 2015).

The purpose of this research is to quantify the potential of municipal solid waste recycling in the form of participatory scenarios for separation from the source and to study the factors of minimization (reduction) of waste production in district 1 of the municipality of Tehran.

MATERIALS AND METHODS

District 1 in municipality of Tehran has an area of about 64 km^2 with a population of 488,000. While the massive number of under construction buildings will soon bring the district's population to 500,000. It is located on northernmost part of City and has 10 regions and 27 urban neighborhoods that is undoubtedly one of the most pleasant parts of the city to live in regard to climatic conditions due to locating on the slopes of the southern Alborz Mountains and special structure, has a blend of modern and traditional urbanism and can be called the garden city. The status of district as a tourist hub is remarkable due to Tajrish Bazaar, numerous museums and amenities such ski resorts, mountain climbing, and massive urban parks. Fig. 1 shows the exact location of district on Tehran and Iran map.

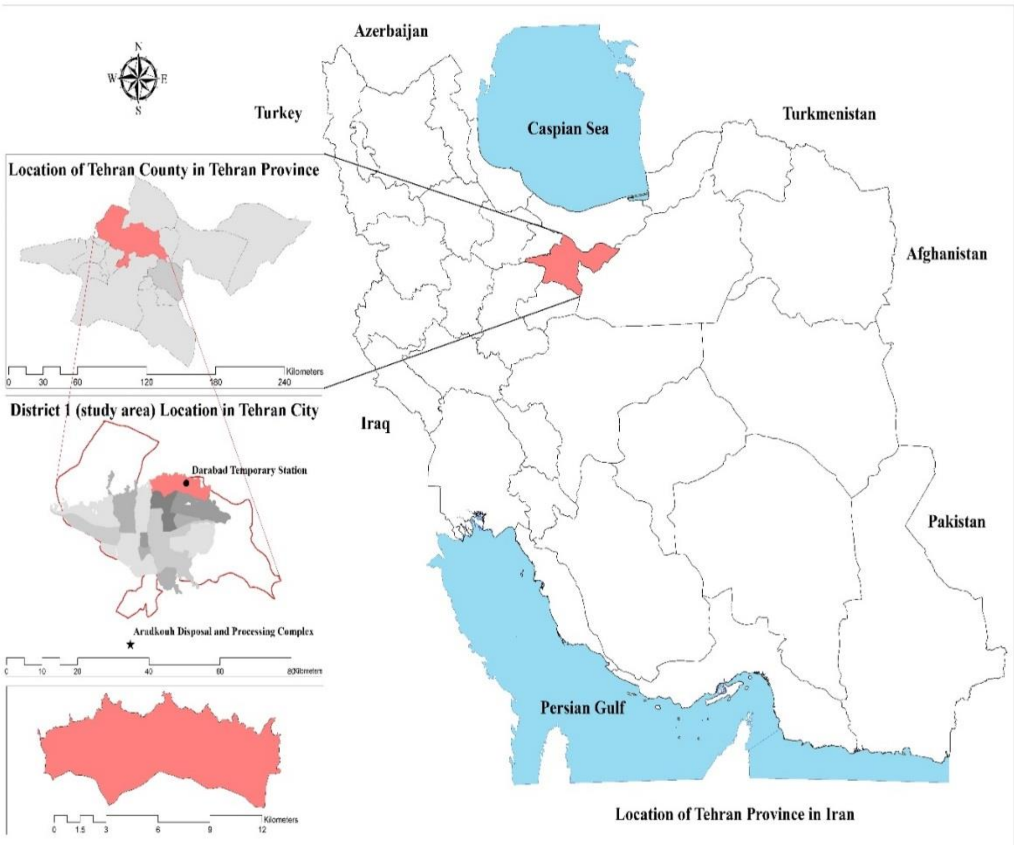

Fig. 1. Location of district one in Tehran province, Tehran city and Iran map

Required data, concerning the current status of waste generation in district one, as well as detailed information about waste collection and transport, educational programs on source separation, and waste minimization were provided via Tehran Waste Management Organization (TWMO), municipality of Tehran, and Municipality of District one in winter 2018.

Currently, mixed dry residues weighing approximately 100 tons per day are collected from door fronts by a contractor company with pick-up trucks, and 23 recycling units have been established at the regional level so that residents can deliver their dry wastes in person. This is the maximal level of attention paid to municipal waste source separation in this district and so far no highlighted participation has been observed from the citizens’ part.

After visiting TWMO for required quantitative and qualitative statistics and calculations for this study, amount of waste minimization was determined with considering a couple of citizens' participation scenarios (minimum to maximum). Source separation of valuable wastes including paper and cardboard, plastic, plastic bags, aluminum cans, bread, PET, waste metal and glass were considered in this procedure. In the next step, quantitative calculations were made to show the amount of added value obtained with the material from the principle of recycling.

In order to final conclusion, data were summarized, information was separated and tables and figures were prepared from them. Also the data were analyzed based on different scenarios for solid waste. Within all the solid wastes, this paper focuses on PET bottles, aluminum cans and glass since the use of reverse vending machine (RVM) has been considered to promote the recycling activities by residents or consumers. The map of the appropriate locations for installing reverse vending machines was prepared using the GIS software (version 10.4.1).

RESULTS AND DISCUSSION

Fig. 2 shows the composition of municipal solid waste in district 1 of Tehran municipality obtained from TWMO. As it is seen, 61% of the total amount is putrescible, and the rest 39% is dry solid waste (35% valuable) which should definitely get separated from the source.

The average amount of waste generation in district 1 of Tehran is 530 tons per day (280 tons of putrescible plus 250 tons of dry solid waste). Approximately 430 tons of blended (dry and wet) waste and about 100 tons of separated dry waste by citizens collected with authorized or unauthorized methods are brought to Darabad Transportation Station (temporary waste transfer station of the district) every day. About 35% of the blended waste, recyclable materials weighing 150 tons, is valuable and loaded daily by semitrailers to Aradkouh site (the main waste disposal site of Tehran city). This means among 250 tons of generated dry waste within the district, only 100 tons get separated by citizens (equivalent to 40 percent). The rest 60% (150 tons) goes directly to landfill instead of getting recycled despite the fact that it is valuable and non-biodegradable.

In Table 1, weight of the non-separated valuable dry wastes and the price per kilogram in Tehran city are presented. The eight mentioned items are traded by contractors; hence, TWMO mentions them as valuable solid waste. Aluminum cans and glass are the most and least valuable materials respectively.

Table 2 shows the daily potential economic benefit of increasing citizens' participation in separating valuable solid wastes through 10, 25, 50, 75 and 100 percent scenarios in USD. As an example, with 10% increase of citizens' participation in source separation of aluminum cans, the potential economic benefit is 590 USD daily.

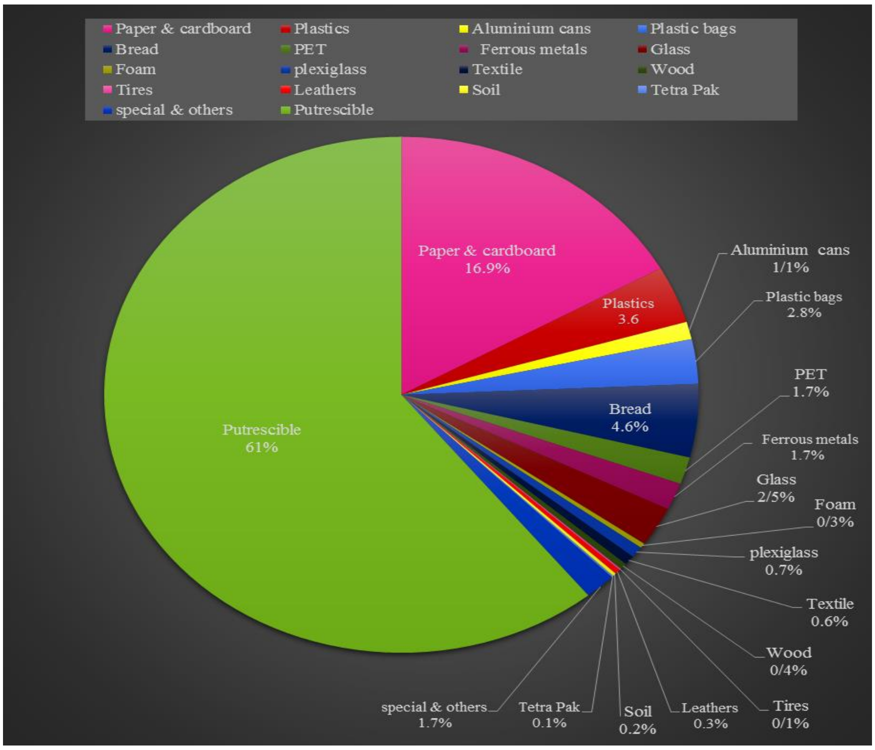

Fig. 2. Composition of municipal solid waste in District one of Tehran municipality, (TWMO)

Table 1. Weight and price of valuable solid wastes in Tehran city

Item	Percentage	Weight (kg)	Price (USD/Kg)
Paper & cardboard	16.9	72670	0.22
Bread	4.6	19780	0.14
Plastics	3.6	15480	0.62
Linen	2.8	12040	0.29
Glass	2.5	10750	0.03
PET	1.7	7310	0.37
Ferrous	1.7	7310	0.35
Aluminum cans	1.1	4730	1.25
Total valuable solid waste	35	150000	3.27

Table 2. Daily potential economic benefit of source seperation (rounded values) through different participation scenarios

Valuable solid waste	Benefit (USD)				
	10% Citizen Participation	25% Citizen Participation	50% Citizen Participation	75% Citizen Participation	100% Citizen Participation
Paper & cardboard	1600	4000	8000	12000	16000
Plastics	960	2400	4800	7200	9600
Aluminum cans	590	1475	2950	4425	5900
Plastic bags	340	850	1700	2550	3400
Bread	270	675	1350	2025	2700
PET	260	650	1300	1950	2600
Ferrous metals	250	625	1250	1875	2500
Glass	30	75	150	225	300
Total	4300	10750	21500	32250	43000

About 430 tons of blended waste is brought daily to the municipal temporary station of district 1, and average 14 Semitrailers per day transfer this residue to Aradkouh disposal and processing complex where composting and landfilling occurs. Each service has a potential capacity of 40 tons of garbage, but in result of mixing with voluminous waste such as PET bottles, beverage aluminum cans, shampoo/liquid soap containers, etc., this feature is between 25 to 35 tons per service. In addition, the compost produced in Aradkouh has a very low quality due to the mixing with a variety of non-separable materials such as glass and plastic.

For example with 10% and 25% increase of citizens' participation in source separation, about 15 and 37 tons of waste transferred to Aradkouh disposal and processing complex per day is decreased, respectively. The economized weight of waste, occupies the volume equal to the capacity of one semitrailer.

Table 3. The amount of Semitrailer load reduction in different participation scenarios of waste management in district one of Tehran city

Citizens' participation scenario (%)	Waste quantity reduced (Ton)	Decrease in the number of daily services	Financial daily saving (USD)	Decrease in the number of monthly services	Financial monthly saving (USD)
10%	15	0.5	75	15	2250
25%	37.5	1	187.5	30	5625
50%	75	2.5	375	75	11250
75%	112.5	4	562.5	120	16875
100%	150	5	750	150	22500

On the other hand, many experiences demonstrate for increment participation in recycling activities, rewarding is the most effective way around the world)Krystallidis, 2013(. To achieve the ideal participation rate, utilizing RVMs is a logistic method which the user receive a reward by giving back a recyclable item. RVM improves recycling material collection and the waste management accordingly (Tomari et al., 2016). The RVM concept is encouraging people to throwaway their waste in the right way)Lun, 2011(. Some European countries have reached 80% efficiency in community's participation in recycling (Rada, 2013). Considering the successful experience of other countries regarding the use of RVM in recycling of beverage containers, the cost of purchasing, and installing one RVM is estimated about 30 to 40 thousand USD in Tehran. The use of this machine for the municipality of Tehran will not have a financial burden, while at the same time it will be cost effective for contractors and commercial complexes. At first, these devices will be used in large chain stores, shopping centers with food court, and mountaineering/camping sites in north of district 1.

The average sale price of PET, aluminum cans and glass by the contractor is 0.37, 1.25, and 0.03 USD per kilogram, respectively; but if these wastes are collected by RVM, they will be sold at a higher price. Since these containers are not in contact with other dry wastes or contaminants for a long time, they are less polluted and can be reused easier in the food industry after the recycling process.

This plan is recommended for implementation in district 1, showing the appropriate placement locations of RVMs on Fig 3.

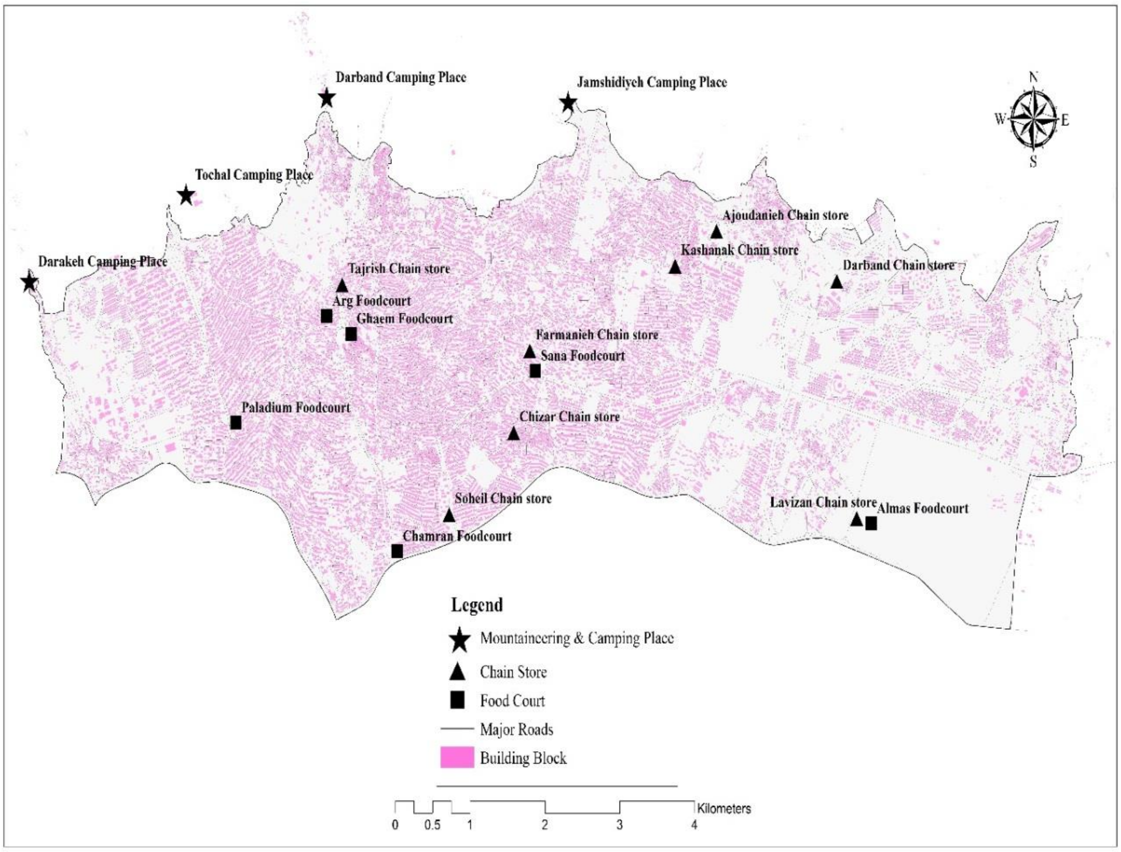

Fig. 3. Appropriate placement locations of RVMs in district one of Tehran city

CONCLUSIONS

There is no doubt that in the city of Tehran, which generates too much municipal waste annually and its spatial growth is significant, the production of dry wastes is increasing.

As it is announced in Table 3, in the 10% scenario, the benefit from citizens' participation for the separation of total daily waste is about 4,300 USD, while in the 25% scenario, 10,800 USD has been economized. This means although, the ideal level of engagement should be close to 100%, raising the participation level even in low rates, could cause a considerable benefit. With the increase in participation of 10%, a remarkable economic and environmental output could be created for district 1. Furthermore, due to even least participation levels of 10 and 25 percent during a month, 15 and 30 waste disposal services from Darabad Station to the Aradkouh disposal and processing complex would be omitted. Such achievement would decrease the traffic load between mentioned stations (around 50 kilometers one-way). When considering an altitude difference of around 700 meters between the stations, the reduced amount of air pollutants emitted from semitrailers due to implementation of scenarios would be more tangible. Moreover, the purity of the putrescible waste used to produce compost would increase and a compost with high degree of quality could be obtained. With the increase in participation of 50%, a remarkable economic and environmental output could be created for district 1.The achieved capital in the municipality may be used to promote civil and infrastructures of the area or to equip the region with new technologies and to develop its use.

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The present research did not receive any financial support.

CONFLICT OF INTEREST

The authors declare that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, and redundancy has been completely observed by the authors.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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