Pollution 2022, 8(1): 303-314
DOI: 10.22059/POLL.2021.330183.1175

RESEARCH PAPER

# A New Sustainable Approach to Integrated Solid Waste Management in Shiraz, Iran

**Seyed Mohammadali Molayzahedi, Mohammad Ali Abdoli***

School of Environment, College of Engineering, University of Tehran, Tehran, Iran

Received: 06.08.2021, Revised: 27.11.2021, Accepted: 24.11.2021

**ABSTRACT**
Cities in developing countries like Shiraz in Iran face significant challenges due to a lack of an integrated solid waste management system. Climate change, soil, and water pollution are examples of environmental issues caused by improper Municipal Solid Waste Management Systems (MSWMS) in developing countries. The aim of this study is to find solutions for these environmental problems based on the experiences of developed countries. The data was collected using several methods such as visual observations, studying accessible documents of the current situation of the MSWMS in Shiraz, and participating in an interview with engineers the 'Shiraz Municipality Waste Management Organization' (SMWMO). Results present the current functional elements of MSWMS in Shiraz, Shiraz waste diversion rate (0.22), and its Zero Waste Index (.015). Moreover, the results present some recommendations to find a way to transform cities like Shiraz into zero-waste cities. Results indicate that establishing zero-waste policies, legal frameworks, and financial strategies as well as convincing private sector involvements in installing waste-to-energy facilities and a proper sanitary landfill to move the city toward optimum recycling and zero landfilling in addition to reducing consumption and maximizing diversion rate and finally sustainable development by the cooperation of government, NGOs and media programs would solve many problems of the MSWMS and would solve environmental issues in many cities.
**Keywords**: Sustainable development; Municipal solid waste management; Zero waste city; Shiraz.

## INTRODUCTION

Improper Municipal Solid Waste Management System (MSWMS) has caused severe environmental challenges in the world. Developing countries release a great deal of air, soil, and water pollutants(de Villiers et al., 2020; Ferronato & Torretta, 2019). They also waste considerable energy and materials due to inappropriate MSWMS (Liu et al., 2021; Nema et al., 2021). Rapid urbanization, migration, population growth, and lack of proper infrastructure have caused resource consumption and hazardous chemical emissions by improper waste disposal sites (Bui et al., 2020; David et al., 2020). This increasing amount of solid waste and poor management has led to global concerns about future environmental problems(Anchan & Palakshappa, 2021; Klemeš et al., 2020). Therefore, a holistic waste management system based on zero waste policies is required in every city (Saleh et al., 2020; Zhang et al., 2019).

Shiraz MSWMS lacks a holistic approach to manage waste. It wastes a great deal of energy and material every day. On the other hand, Shiraz landfill leachate enters Maharlu Lake posing a danger to the environment due to Shiraz geographic location. Although literature

* Corresponding author E-mail: mabdoli@ut.ac.ir

studies have analyzed the Municipal Solid Waste Management Systems (MSWMS) in developing countries (Azevedo et al., 2019; Azevedo et al., 2021; Guerrero et al., 2013; Marshall & Farahbakhsh, 2013; Sharma & Chandel, 2021), it is the first study that deals with Shiraz MSWMS, calculates the Zero Waste Index (ZWI) and gives a new holistic approach toward increasing the ZWI in megacities. This is significant because it includes strategies for managing resource supply, waste avoidance, and valorizing domestic waste, based on the innovative zero-waste performance in the current situation of not paying attention to the great value of waste for sustainable development of megacities in developing countries.

The zero-waste index (ZWI) is a modern tool that calculates potential total virgin material substituted, total energy substituted, total Green House Gases (GHG) emissions reduction, and total water saving by each waste management system (Zaman, 2014). On the other hand, Integrated Solid Waste Management (ISWM) optimizes the MSWMS by considering all the functional elements of waste management(Asefi et al., 2019). ISWM is considered as a cycle with six related steps, including generation, storage, collection, reuse, recycling, and disposal (Bahçelioğlu et al., 2020),

In this paper, the zero-waste index of Shiraz MSWMS was calculated. The aim of this study is to present current challenges of functional elements resulting in low ZWI and some suggestions towards improving the zero-waste performance of Shiraz based on the experiences of leading zero-waste cities.

Shiraz city is the center of Fars province, located in the southern part of Iran (Fig. 1). The latitude and longitude of Shiraz are 29° 36' 37.12" *N and 52° 31' 52.07" E, respectively (Pasalari et al., 2019). Agriculture, tourism, and industry are the bases of the Shiraz economy. Shiraz climate is semi-arid (Azhdari et al., 2018). The waste management site is located 18 km south of Shiraz, near Maharlu Lake. The city has been a provincial business center for longer than two thousand years. In the last 50 years, the population has grown from 304,000 in 1969 to 1,628,000 in 2020 (Shiraly & Kokabi, 2019). This population growth and economic changes have caused many changes in the quality and quantity of Shiraz solid waste.


**Fig. 1.** The location of Fars province and Shiraz city

As a metropolitan city, Shiraz faces significant urban problems. Environmental pollution, ecological degradation, resource depletion, and incapable urban management are examples of these urban problems (Sun et al., 2022). Furthermore, the lack of a long-term sustainable city plan for a city will lead to future problems for the city (Ahmadi & Zarghami, 2019; Ismail &

Sidjabat, 2019). Because of the environmental issues caused by leachate and landfill gases, which have a negative influence on the community, it is recommended that the present dump be relocated to a more suitable location. (Pasalari et al., 2019). Furthermore, the municipality of Shiraz has several challenges, including a lack of budgetary resources to manage trash created. As a result, they are unable to afford the high costs involved with a sanitary landfill site from an economic standpoint (Pasalari et al., 2019; Rajaeifar et al., 2017).

Due to the legislation, Shiraz municipality is liable for MSWMS in the city. The MSWMS has enhanced after establishing the 'Shiraz Municipality Waste Management Organization' (SMWMO). This organization has the prime responsibility for the MSWMS in Shiraz. It is worth noting that the MSW management organization in Shiraz is the first specialized waste management organization in Iran to perform all the functional elements of the MSWMS. According to the Waste Management Act of 2004, the mission of SMWMO is planning, organizing, monitoring, and executing operations related to production, separation, storage, collection, transportation, recycling, processing, and disposal (Woodard, 2020).

(Pietzsch et al., 2017) have analyzed 102 published articles in a systematic literature review considering zero waste methods' advantages, difficulties, and essential success elements. The findings show that there is no consensus among academics on the concept of ZWI. For future studies, it is essential that more experimental papers about ZWI implementation, especially regarding the educational practices designed to make changes in user behavior, be studied. A comprehensive review of the development of zero-waste management by (Zaman, 2015) indicates that many countries use zero-waste initiatives without having a comprehensive zero-waste plan. The report stresses that creating a national zero waste plan may help countries reach their zero waste targets. Furthermore, waste management plans should include integrating and supporting zero waste programs. (Zaman, 2017) established the key elements for developing a strategic zero waste framework, which he backed up with a survey study by waste specialists. The findings propose the following three major strategic action strategies for achieving zero waste societies: i) sustainable manufacturing via cradle-to-cradle design and product stewardship; (ii) collaborative and responsible natural resource usage; and (iii) zero waste management via resource conservation.(Saima et al., 2020) show that, even though there are many zero-waste and zero-practice methods in the current world, zero-waste strategy is a highly complex system with a lot of work to be done in this sector. (Allam, 2018) examines waste management performance in a new light, focusing on how urban policies may aid in the transition to a net-zero carbon city. There are a variety of mitigation strategies available that are linked to reducing energy, material, and water waste. The conclusions of an evaluation of technological, environmental, institutional, and socio-economic potential and difficulties associated with a 'Zero Waste' route for one small growing African city, Port Louis, are presented in this report. (Kerdlap et al., 2019) studied a framework for enabling a circular economy transition in Singapore. The paper investigates the technological challenges of adopting Zero Waste Management technology in metropolitan environments. MSWMS, from a system perspective (Eriksson et al. 2005), presents that reducing landfilling and increasing materials and energy recycling would cause fewer environmental influences. Landfilling energy-rich garbage should be banned, partly due to the harmful environmental effects from landfilling and principally due to the weak resource recovery effects from landfills (Eriksson et al., 2005). An investigation on Ontario's non-hazardous MSW diversion was studied using trend analysis (Chowdhury, Vu et al. 2017). Results recommended that waste minimization might be more efficient than recycling on Ontario diversion rates (Chowdhury et al., 2017). (Rupani et al., 2019) has studied the current status and future perspectives of MSWMS in Iran. In this paper, the

quantity, composition, and treatment of municipal and hospital rubbish were assessed in 7 Iranian cities, including Shiraz. Based on prior studies (Norouzian Baghani et al., 2017; Pazoki et al., 2015), the landfilling system is the popular way for MSWMS in these seven cities, which may typically be not a total hygienic method and could result in many environmental problems. Economic Aspects of Dry Solid Waste Recycling in Shiraz, Iran was studied by (Baghani et al., 2016), and, according to the findings, 15% of dry solid waste is recycled in this city. With appropriate planning and development of the current recycling program over a 10- to 20-year period, the economic advantages of recycling would grow to 8-18 times more than they are now.

To summarize the learning from zero waste cities and to structure an adaptive method to be used in Shiraz, it is suggested that plastic shopping bags be prohibited in the city. The waste recycling and composting facilities in Shiraz get improved to decrease the amount of waste dumped in landfills. Encouraging and educating people for reusing and repairing activities would be a beneficial waste avoidance strategy. Finally, installing an incineration system will result in the zero-waste performance improvement of the city by increasing energy saving of the waste and decreasing landfill GHG emissions.

The results of these studies are summarized in suggestions toward developing Shiraz MSW management system to structure a holistic framework for sustainable MSWMS in Shiraz.

## MATERIALS AND METHODS

Visual observations by the authors, studying available documents, and participating in a meeting with relevant managers and engineers at the 'Shiraz Municipality Waste Management Organization'(SMWMO) were used to collect data and examine the current condition of Shiraz SWMS. Furthermore, several SWMS in developing and developed countries have been analyzed as successful waste management models to develop recommendations for enhancing Shiraz zero-waste performance.

The substitution values of the resource from the waste management system provided by (Zaman 2014) were used to compute Shiraz zero waste index (Table 1). The Zero-waste index of Shiraz MSWMS is determined by using equation (1) (Zaman, 2014). The table was developed using data and research from several MSWMS life cycle assessment studies and databases. It is worth mentioning that substitution factors for Iranian cities might vary; consequently, it is best to utilize local substitution data to generate a more accurate ZWI. Due to the lack of local data in Shiraz, the replacement factors employed by (Zaman 2014) are used in this study.

**Equation (1)** (Zaman & Lehmann, 2013):

$$\text{Zero waste index} = \frac{\sum \text{potential amount of waste managed by the city} \times \text{substitution for the systems}}{\textit{total amount of waste generated in the city}}$$

## RESULTS AND DISCUSSION

The present state of the Shiraz MSWMS, its zero-waste index, diversion rate, current challenges, and our recommendations to enhance the MSWMS and transform Shiraz into a sustainable city are explained in this section.

**Table 1.** Substitution values for the zero waste index(Zaman, 2014).

| Waste management systems | Waste category | Total waste managed in Shiraz (tones) | Virgin material substitution efficiency (tones) | Energy substitution efficiency (GJLHV/tone) | GHG emissions reduction (CO2e/tone) | Water-saving (kL /tone) |
|---|---|---|---|---|---|---|
| Recycling | Paper | 10109.4597 | 0.84-1.00 | 6.33-10.76 | 0.60-3.20 | 2.91 |
| | Glass | 2936.891648 | 0.90-1.00 | 6.07-6.85 | 0.18-0.62 | 2.3 |
| | Metal | 2843.285539 | 0.79-0.96 | 36.09-191.42 | 1.40-17.8 | 5.97-181.77 |
| | Plastic | 15807.73154 | 0.90-0.97 | 38.81-64.08 | 0.95-1.88 | -11.37 |
| | Mixed | 1168 | 0.25-0.45 | 5.00-15.0 | 1.15 | 2.00-10.00 |
| Composting | Organic | 54750 | 0.60-0.65 | 0.18-0.47 | 0.25-0.75 | 0.44 |
| Landfill | Mixed MW | 313900 | 0.00 | 0.00-0.84 | (-) 0.42 - 1.2 | 0.00 |

The rate of MSW generation and its quality are affected by a variety of factors, including population growth, climate change, geographic issues, and collection frequency. To create a suitable plan for the MSWMS, collecting information on waste quantity and quality changes is essential. Due to the received data, the MSWMS generation rate in Shiraz is expected to be 0.7 kg/cap/day. As a result, the total amount of MSW generated by the population is about 1140 tonnes/d. The amounts of different solid waste categories in the year 2020 are illustrated in Figure2.

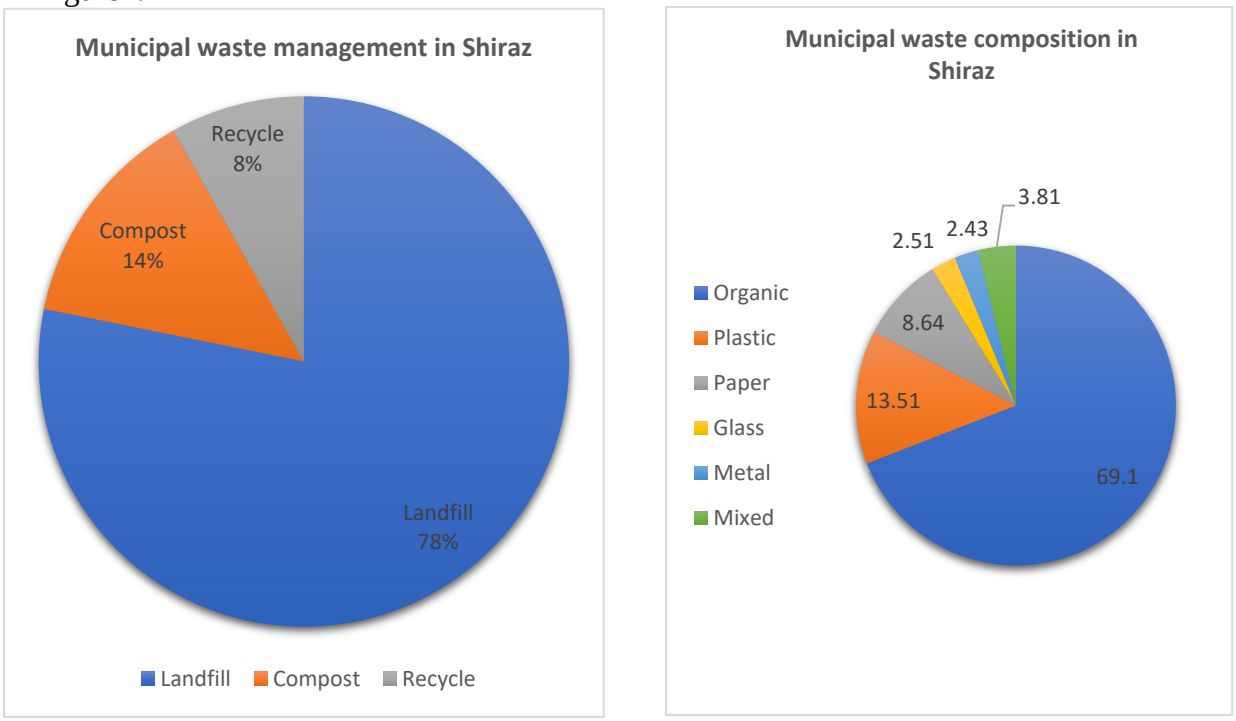


**Fig. 2.** Composition and waste management systems in Shiraz (Azadi et al., 2020).

As given in Figure2, Shiraz generates approximately 401500 tonnes of municipal solid waste each year (243kg/person. year). The organic waste percentage of Shiraz MSW is approximately high. Cities like Shiraz, where about 70 percent of MSW belongs to food waste due to the unprocessed foods used daily, should consider a suitable integrated solid waste management scenario (such as composting and incineration) to deal with the high organic

carbon waste. After that, the plastics are 13.51%, proving that plastic productions such as bottled water, soft drinks, and fast food packages are becoming more popular among citizens recently. These plastics would better be recycled and used again.

The procedure of on-side storage, handling, and processing of MSW is significantly effective in the whole system's performance. One of the most efficient material recovery and reuse methods is MSW separation from resources before collecting them. A well-organized source separation program (including plastic, paper, food waste, metal, and glass) was launched in some regions of Shiraz. However, some problems lead to the poor performance of this program. For instance, some individuals were not aware of that system's benefits and did not cooperate consequently. Therefore, it is evident that community engagement and perception of waste management operations is critical as a crucial first step in waste management activity. It is comparable to the results attained by (Nabavi-Pelesaraei et al., 2017) and (Ismail & Sidjabat, 2019).

Various storage containers have been located in different regions of Shiraz. Usually, garbage bags are used for collecting household trash, and then full bags are moved into the containers. Despite this, some of the individuals use plastic bags without any other containers.

As in many other developing countries, even if searching and collecting anything usable from discarded waste in containers decreases the amount of garbage dumped at dumpsites and increases the landfill diversion rate, these activities cause the plastic bags to be opened. As these bags are opened, the waste collection would be much more difficult. Poor people collect the worthy parts of the garbage such as papers and cardboard informally in the city and at the dumpsite, recover them, and then sell them to small recycling facilities without any standard supervision. It is estimated that about 40 tonnes per day of recyclable waste are collected and recycled with these illegal scavengers. This waste storage and processing is the same as achieved by (Ferronato & Torretta, 2019; Medina, 2000; Ogwueleka & Naveen, 2021)

Garbage collecting is a complex and expensive task. About 1100 tonnes of municipal waste is collected in Shiraz and its suburbs daily. The responsible organization for waste collection is the municipality. Municipalities collect MSW both directly, using their facilities, and indirectly with the cooperation of private sectors. At present, municipal wastes are collected using both mechanical and manual power. Approximately 96 percent of total garbage (recyclable and non-recyclable) is collected every single day. The collected waste is then transferred to transfer stations or directly to the Barmshour disposing plants in the southeast of Shiraz (Barmshour compost sites and open dumpsites).

Transfer stations have recently become popular in different Iran cities such as Shiraz, Isfahan, and Tehran. There are 11 transfer stations in 11 regions of Shiraz. Using other cities' experiences like Tehran (Habibi et al., 2017), a significant reason for constructing transfer stations is cutting operational costs. However, there was no relevant data about how the 11 transfer stations reduced transportation costs in Shiraz. Municipal solid waste is gathered by small vehicles and then unloaded into an open-top container in direct-load transfer stations. Finally, it is transferred into compost and open dumping sites.

Final disposal is one of the essential elements of ISWM. Nowadays, the most adopted systems for disposing of MSW worldwide are landfills, compost sites, and incineration facilities. In Iran, as a developing country, incineration is less operative than other disposal methods due to the cost of installing its facilities and the potential danger of poor management of the ashes and residues for people living in the neighborhood, as investigated by (Cole-Hunter et al., 2020; Gomes et al., 2020).

Two main disposal methods in Shiraz are composting and open dumping. About 50 percent of Shiraz MSW, which contains organic waste, is transported directly to the Barmshour

compost site. The capacity of the existing composting plant is 500 tonnes per day which is supposed to be 750 tonnes/day in the next three years. About 150 tonnes of 500- tonnes is transformed into marketable compost, and the rest is returned to the landfill as a residue from the composting site. It is worth noting that the government provides initial investments for composting plants in Iran. About 90 tonnes of recyclable waste such as metals and plastics are separated daily and transferred into a recycling factory to make valuable materials from them. The remaining part (about 500 tonnes/day), and the composting residue (about 350 tonnes/day), are dumped in the Barmshour dumping site, which is located 18 kilometers southeast of Shiraz near Maharlu lake.

Total waste generated was 401500 tonnes, comprised of 554750 tonnes composted (14%), 32850 tonnes recycled (8%), and 313900 tonnes disposed to landfill (78%). Therefore, the total diversion rate in Shiraz was 0.22 %.

The zero-waste index is a tool for measuring potential raw materials compensated using zero waste management systems. Table 2 was provided to measure the zero waste index, potential total material substituted, total energy substituted, the reduction in total GHG emissions, and the total water saving applying substitution values in table 1 and equation 1.

Table 2 illustrates that the calculated zero waste index for Shiraz is 0.15, which means that 15% of total waste is reused as virgin materials and offset resource extraction by Shiraz waste management systems. Shiraz waste diversion rate was calculated at 0.22. It simply shows the percentage of waste that did not end up in landfills. However, it does not reflect the efficiency of replacing raw materials in the waste management system, which plays an essential role in protecting global natural resources.

**Table 2.** Potential substitution of resources in the zero waste index.

| WMS | Waste category | Total waste managed in the city (tonnes) (i) | Potential total virgin material substituted (tonnes) (ii) | Total energy substituted (GJLHV) | Total GHG emissions reduction (tonnes CO2e) | Total water saving (kL) | Zero waste index, (ZWI = ii/i) |
|---|---|---|---|---|---|---|---|
| Recycling | Paper | 10109.460 | 8491.946 | 53754.019 | 5095.168 | 24711.563 | 0.151 |
| | Glass | 2936.892 | 2643.202 | 16044.239 | 47577.645 | 6079.366 | |
| | Metal | 2843.286 | 2246.196 | 81065.198 | 3144.674 | 116802.170 | |
| | Plastic | 15807.732 | 14226.958 | 552148.255 | 13515.610 | -161760.517 | |
| | Mixed | 1168.000 | 292.000 | 1460.000 | 335.800 | 584.000 | |
| Composting | Organic | 54750.000 | 32850.000 | 5913.000 | 8212.500 | 14454.000 | |
| Landfill | Mixed MW | 313900.000 | 0.000 | 0.000 | 0.000 | 0.000 | |
| Total value | | 401515.368 | 60750.303 | 710384.711 | 77881.397 | 870.582 | |
| Benefits per, person per year | | 243Kg | 36.8 Kg | 0.43 GJ | 47Kg | 0.5 L | |

As shown in Table 2, Shiraz MSWMS has recovered around 15% of the municipal solid waste each year. It means that 36.8 kg of 243 kg waste (generated by each person each year) would substitute virgin material resources. Energy substitution is as crucial as the material substitution in high-consuming cities. The energy demand which MSWMS recovered in Shiraz was .43 GJ (119.54 kilowatt-hours) per person per year. Landfills greenhouse gas (GHG) emissions are one of the significant environmental impacts. Decreasing the level of

GHG emissions must be in high priority of every environmentally friendly system. Reducing the amount of waste reaching landfills will eventually decrease GHG emissions. Approximately 77881.397 tonnes of CO2e (47Kg CO2e per person per year) was saved by resource recovery from waste in Shiraz. This finding is also comparable to the Tehran study(Maghmoumi et al., 2020) and Rasht (Behrooznia et al., 2018). Resource recovery from waste saves the freshwater needed to process raw materials and make useable products from them. Total water saved by SWM systems in Shiraz is calculated to be 870 KL per year.

Key factors which lead to poor municipal solid waste management and not achieving sustainable development in Shiraz and cities with similar environmental problems are discussed as follows:

*Legal problems besides lack of zero-waste strategy:* there are not any concentrations on optimum recycling, and zero landfilling as well as decreasing consumption rate, and motivating people for buying recycled products and supporting them for repairing, reusing, and cooperating in source separation programs. There are no strategies to ban landfilling energy-rich waste such as burnable waste and organic waste in Shiraz. Another legal problem that makes the MSWMS more complicated is that the private sector involvements are low.

*Open burning and lack of an incineration facility:* Open burning creates significant risks to neighboring inhabitants and the environment. Burning plastics and other materials could lead to air pollution. Furthermore, lack of an incineration facility will result in low total energy Substituted from the waste.

*The amount of solid waste:* The quantity of waste has been rising due to population growth and industrial improvement, notably during the last 15 years.

Rate of plastic waste generation: Plastic wastes, mainly PET bottles, plastic shopping bags, and extra packaging materials, have caused trouble in MSWMS in developing countries.

*Problems with source separation programs*: not much of the source separation programs have been performed yet. For instance, public participation in separating recyclable and non-recyclable waste is low, making recycling operations much more difficult. Not separating broken glasses and plastic shopping bags from biodegradable waste would cause difficulties for the composting sites, leading to low compost quality. Household hazardous waste is collected with the same machine, which is another problem due to the health impacts of the waste management system. This health impact could be a potential HSE danger for the workers in touch with these kinds of waste.

*Insufficient budget and inappropriate landfill and equipment*: Insufficient budget is a result of the poor economy. As it is thought that MSWMS is not the city's priority, its budget is not as proper as it must be. Besides, the collection system is old and out of order in some low-income regions of the city. Soil and underground-water pollution may occur as a result of a lack of a proper sanitary landfill and improper leachate management

*Lack of well-trained staff, NGO and media activities:* Inadequate human resources and the absence of trained staff is another factor which makes the problem worse. NGO and social media activities are not enough to train and inspire citizens to improve the SWM system programs, leading to better environmental conditions and their children lives.

According to this paper, there are eight principle recommendations presented to enhance the state of Shiraz and cities like Shiraz waste management organization:

Establishing zero-waste policies, legal frameworks, and financial strategies to move the city toward optimum recycling and zero landfilling in addition to reducing consumption and maximizing diversion rate.

Encourage participation NGOs and social media to encourage citizens to enhance reuse, repair, green purchasing, and participate in source separation programs.

Installing waste-to-energy facilities and preventing landfilling energy-rich waste such as burnable waste and organic waste in Shiraz to transfer the city to a resource-efficient region. It is recommended to burn the recycling factory residue of plastics and papers and the high organic carbon parts of compost residue.

Prohibiting plastic shopping bags and extra packaging materials and replacing them with new eco-friendly plastic alternatives such as Biodegradable and Bio-Based Polymers will lead us to a more sustainable society.

Developing a strategy to collect household hazardous waste separately from MSW and in a more hygienic way, such as installing special containers for these kinds of waste in different city regions.

Constructing a proper sanitary landfill will prevent soil and underground water pollution. It also keeps the greenhouse gases from getting into the atmosphere and causing global warming.

Convincing private sector involvement in financing buying the appropriate equipment, upgrading vehicles, funding Waste-to-Energy facilities, and establishing a sanitary landfill.

Deployment of well-trained and educated staff with an appropriate budget would lead to more efficient management and improve the MSWMS properly.

These recommendations are based on the experience of the other successful waste management models, such as (Pietzsch et al., 2017) and (Pazoki, Delarestaghi et al. 2015, Norouzian Baghani, Dehghani et al. 2017).

## CONCLUSIONS

Like other cities in developing countries, the MSWMS in Shiraz deals with many issues such as rapid urbanization, migration from smaller cities, high rate of population growth, and lack of proper infrastructures. Therefore, this study aimed to investigate the previous experiences of developed countries to find a way to transform Shiraz into more sustainability. In developed countries, the MSWMS strategies attributed to sustainability, zero-waste concept, and landfill diversion rate increase.

This study shows that the municipal waste generation rate of Shiraz is 243 Kg per person per year, out of which 14% is composted, 8 % recycled, and the remaining is landfilled. Therefore, the waste diversion rate for Shiraz is 0.22, and the ZWI is 0.15. The total GHG emission reduction, total energy substituted, and total water saving in Shiraz MSWMS are 47Kg carbon dioxide equivalent, 0.43 GJ, and 0.5 L per person per year, respectively. It is suggested that SMWMO establish zero-waste policies, encourage NGOs and social media to get involved in training programs, install waste-to-energy facilities, and construct a proper sanitary landfill.

Since we only have one planet to live on, both the government and NGOs in cities should make efforts to accomplish sustainable development goals, such as adopting zero-waste legislation and boosting public awareness and engagement through the media, as many other industrialized countries have done.

## ACKNOWLEDGMENTS

The authors would like to gratefully thank Professor Dr. Atiq Zaman (Curtin University Sustainability Policy Institute, Australia) for his helpful comments during the research. The authors would also appreciate the kind help of engineers working in the Shiraz Municipality Waste Management Organization for providing valuable data for this research.

## GRANT SUPPORT DETAILS

The present research did not receive any financial support.

## CONFLICT OF INTEREST

The authors declare that there is not any conflict of interest 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 have been completely observed by the authors.

## LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

## REFERENCES

Ahmadi, M. H. and Zarghami, M. (2019). Should water supply for megacities depend on outside resources? A Monte-Carlo system dynamics simulation for Shiraz, Iran. Sustainable cities and society 44: 163-170.

Allam, Z. (2018). The zero-waste city: Case study of Port Louis, Mauritius.

Anchan, S. S. and Palakshappa, K. (2021). Public Perception and Concern Towards Solid Waste Management: A Case Study of Mangaluru City, India.

Asefi, H., Lim, S., Maghrebi, M. and Shahparvari, S. (2019). Mathematical modelling and heuristic approaches to the location-routing problem of a cost-effective integrated solid waste management. Annals of Operations Research 273: 75-110.

Azadi, S., Karimi-Jashni, A., Talebbeydokhti, N., Khoshbakht, R. and Haghighi, A. B. (2020). Industrial composting of commingled municipal solid waste: a case study of Shiraz City, Iran. Journal of Environmental Treatment Techniques 8: 1292-1303.

Azevedo, B. D., Scavarda, L. F. and Caiado, R. G. G. (2019). Urban solid waste management in developing countries from the sustainable supply chain management perspective: A case study of Brazil's largest slum. Journal of cleaner production 233: 1377-1386.

Azevedo, B. D., Scavarda, L. F., Caiado, R. G. G. and Fuss, M. (2021). Improving urban household solid waste management in developing countries based on the German experience. Waste management 120: 772-783.

Azhdari, A., Soltani, A. and Alidadi, M. (2018). Urban morphology and landscape structure effect on land surface temperature: Evidence from Shiraz, a semi-arid city. Sustainable cities and society 41: 853-864.

Baghani, A. N., Farzadkia, M., Azari, A., Zazouli, M. A., Vaziri, Y., Delikhoon, M. and Shafi, A. A. (2016). Economic aspects of dry solid waste recycling in Shiraz, Iran. Journal of Mazandaran University of Medical Sciences 25: 330-334.

Bahçelioğlu, E., Buğdaycı, E. S., Doğan, N. B., Şimşek, N., Kaya, S. Ö. and Alp, E. (2020). Integrated solid waste management strategy of a large campus: A comprehensive study on METU campus, Turkey. Journal of Cleaner Production 265: 121715.

Behrooznia, L., Sharifi, M., Alimardani, R. and Mousavi-Avval, S. H. (2018). Sustainability analysis of landfilling and composting-landfilling for municipal solid waste management in the north of Iran. Journal of cleaner production 203: 1028-1038.

Bui, T. D., Tsai, F. M., Tseng, M.-L. and Ali, M. H. (2020). Identifying sustainable solid waste management barriers in practice using the fuzzy Delphi method. Resources, conservation and recycling 154: 104625.

Chowdhury, A., Vu, H. L., Ng, K. T., Richter, A. and Bruce, N. (2017). An investigation on Ontario's

non-hazardous municipal solid waste diversion using trend analysis. Canadian Journal of Civil Engineering 44: 861-870.
Cole-Hunter, T., Johnston, F. H., Marks, G. B., Morawska, L., Morgan, G. G., Overs, M., Porta-Cubas, A. and Cowie, C. T. (2020). The health impacts of waste-to-energy emissions: a systematic review of the literature. Environmental Research Letters 15: 123006.
David, V. E., John, Y. and Hussain, S. (2020). Rethinking sustainability: a review of Liberia's municipal solid waste management systems, status, and challenges. Journal of Material Cycles and Waste Management: 1-19.
de Villiers, N., Van As, H. and Botha, J. (2020). The enforceability of the by-laws of district municipalities on local municipalities: the case of solid waste disposal. Stellenbosch Law Review 31: 315-343.
Eriksson, O., Reich, M. C., Frostell, B., Björklund, A., Assefa, G., Sundqvist, J.-O., Granath, J., Baky, A. and Thyselius, L. (2005). Municipal solid waste management from a systems perspective. Journal of cleaner production 13: 241-252.
Ferronato, N. and Torretta, V. (2019). Waste mismanagement in developing countries: A review of global issues. International journal of environmental research and public health 16: 1060.
Gomes, H. I., Funari, V. and Ferrari, R. (2020). Bioleaching for resource recovery from low-grade wastes like fly and bottom ashes from municipal incinerators: A SWOT analysis. Science of The Total Environment 715: 136945.
Guerrero, L. A., Maas, G. and Hogland, W. (2013). Solid waste management challenges for cities in developing countries. Waste management 33: 220-232.
Habibi, F., Asadi, E., Sadjadi, S. J. and Barzinpour, F. (2017). A multi-objective robust optimization model for site-selection and capacity allocation of municipal solid waste facilities: A case study in Tehran. Journal of cleaner production 166: 816-834.
Ismail, Y. and Sidjabat, F. M. (2019). Community empowerment in household waste management. JCE| Journal of Community Engagement 1: 24-29.
Kerdlap, P., Low, J. S. C. and Ramakrishna, S. (2019). Zero waste manufacturing: A framework and review of technology, research, and implementation barriers for enabling a circular economy transition in Singapore. Resources, Conservation and Recycling 151: 104438. doi:https://doi.org/10.1016/j.resconrec.2019.104438.
Klemeš, J. J., Van Fan, Y., Tan, R. R. and Jiang, P. (2020). Minimising the present and future plastic waste, energy and environmental footprints related to COVID-19. Renewable and Sustainable Energy Reviews 127: 109883.
Liu, J., Goel, A., Kua, H., Wang, C. and Peng, Y. (2021). Evaluating the urban metabolism sustainability of municipal solid waste management system: An extended exergy accounting and indexing perspective. Applied Energy 300: 117254.
Maghmoumi, A., Marashi, F. and Houshfar, E. (2020). Environmental and economic assessment of sustainable municipal solid waste management strategies in Iran. Sustainable Cities and Society 59: 102161.
Marshall, R. E. and Farahbakhsh, K. (2013). Systems approaches to integrated solid waste management in developing countries. Waste management 33: 988-1003.
Medina, M. (2000). Scavenger cooperatives in Asia and Latin America. Resources, conservation and recycling 31: 51-69.
Nabavi-Pelesaraei, A., Bayat, R., Hosseinzadeh-Bandbafha, H., Afrasyabi, H. and Chau, K.-w. (2017). Modeling of energy consumption and environmental life cycle assessment for incineration and landfill systems of municipal solid waste management-A case study in Tehran Metropolis of Iran. Journal of Cleaner Production 148: 427-440.
Nema, A., Zacharia, K. M. B., Kumar, A., Singh, E., Varma, V. S. and Sharma, D. (2021). Challenges and opportunities associated with municipal solid waste management. Current Developments in Biotechnology and Bioengineering: 231-258.
Norouzian Baghani, A., Dehghani, S., Farzadkia, M., Delikhoon, M. and Emamjomeh, M. M. (2017). Comparative study of municipal solid waste generation and composition in Shiraz city (2014). The Journal of Qazvin University of Medical Sciences 21: 57-65.

Ogwueleka, T. C. and Naveen, B. (2021). Activities of informal recycling sector in North-Central, Nigeria. Energy Nexus 1: 100003.

Pasalari, H., Nodehi, R. N., Mahvi, A. H., Yaghmaeian, K. and Charrahi, Z. (2019). Landfill site selection using a hybrid system of AHP-Fuzzy in GIS environment: A case study in Shiraz city, Iran. MethodsX 6: 1454-1466.

Pazoki, M., Delarestaghi, R. M., Rezvanian, M. R., Ghasemzade, R. and Dalaei, P. (2015). Gas production potential in the landfill of Tehran by landfill methane outreach program. Jundishapur Journal of health sciences 7.

Pietzsch, N., Ribeiro, J. L. D. and de Medeiros, J. F. (2017). Benefits, challenges and critical factors of success for Zero Waste: A systematic literature review. Waste Management 67: 324-353.

Rajaeifar, M. A., Ghanavati, H., Dashti, B. B., Heijungs, R., Aghbashlo, M. and Tabatabaei, M. (2017). Electricity generation and GHG emission reduction potentials through different municipal solid waste management technologies: a comparative review. Renewable and Sustainable Energy Reviews 79: 414-439.

Rupani, P. F., Delarestaghi, R. M., Abbaspour, M., Rupani, M. M., EL-Mesery, H. S. and Shao, W. (2019). Current status and future perspectives of solid waste management in Iran: a critical overview of Iranian metropolitan cities. Environmental Science and Pollution Research: 1-13.

Saima, H., Bhat Mohd, S. and Muzaffar Ahmad, B. (2020). Zero Waste: A Sustainable Approach for Waste Management: Innovative Waste Management Technologies for Sustainable Development (ed. by B Rouf Ahmad, Q Humaira, W Khursheed Ahmad, D Gowhar Hamid & M Mohammad Aneesul) IGI Global, Hershey, PA, USA, pp. 134-155.

Saleh, H., Surya, B. and Hamsina, H. (2020). Implementation of sustainable development goals to makassar zero waste and energy source. International Journal of Energy Economics and Policy 10: 530.

Sharma, B. K. and Chandel, M. K. (2021). Life cycle cost analysis of municipal solid waste management scenarios for Mumbai, India. Waste Management 124: 293-302.

Shiraly, R. and Kokabi, E. (2019). Prevalence and Factors Associated with Suicidal Ideation in General population of Shiraz, 2017. scientific journal of ilam university of medical sciences 27: 27-36.

Sun, X., Zhu, B., Zhang, S., Zeng, H., Li, K., Wang, B., Dong, Z. and Zhou, C. (2022). New indices system for quantifying the nexus between economic-social development, natural resources consumption, and environmental pollution in China during 1978–2018. Science of The Total Environment 804: 150180.

Woodard, R. (2020). Waste management in Small and Medium Enterprises (SMEs)–A barrier to developing circular cities. Waste Management 118: 369-379.

Zaman, A. U. (2014). Measuring waste management performance using the 'Zero Waste Index': the case of Adelaide, Australia. Journal of Cleaner Production 66: 407-419.

Zaman, A. U. (2015). A comprehensive review of the development of zero waste management: lessons learned and guidelines. Journal of Cleaner Production 91: 12-25.

Zaman, A. U. and Lehmann, S. (2013). The zero waste index: a performance measurement tool for waste management systems in a 'zero waste city'. Journal of Cleaner Production 50: 123-132.

Zhang, A., Venkatesh, V., Liu, Y., Wan, M., Qu, T. and Huisingh, D. (2019). Barriers to smart waste management for a circular economy in China. Journal of Cleaner Production 240: 118198.