Available online at https://ap.ardabil.iau.ir/
Islamic Azad University, Ardabil Branch
Anthropogenic Pollution Journal, Vol 7 (1), 2023: 25-31
ISSN: 2783-1736- E-ISSN: 2588-4646

ORIGINAL RESEARCH PAPER

Life cycle cost of different pretreatment scenarios to increase biogas production from municipal solid waste in Tehran

Hossein Heydarian[1], Roya Mafigholami[2*], Alireza Noorpoor[3], Hossein Ghanavati[4], Sanaz Khoramipour[5]

[1]Department of Environmental Science and Engineering, West Tehran Branch, Islamic Azad University, Tehran, Iran
[2]Department of Environmental Science and Engineering, West Tehran Branch, Islamic Azad University, Tehran, Iran
[3]College of environmental Engineering, University of Tehran, Tehran, Iran
[4]Microbial Biotechnology Department, Agricultural Biotechnology Research Institute of Iran (ABRII), Agricultural Research, Extension, and Education Organization (AREEO), Karaj, Iran
[5]Department of Environmental Science and Engineering, West Tehran Branch, Islamic Azad University, Tehran, Iran

ARTICLE INFORMATION

Received: 2023.02.06
Revised: 2023.02.18
Accepted: 2023.06.22
Published online: 2023.06.22

DOI: 10.22034/AP.2023.1979381.1148

KEYWORDS

Biomethane
Life cycle cost
Municipal solid waste
Waste management

ABSTRACT

Organic wastes constitute a large part of urban solid wastes, which are the main source of environmental problems in waste management, including leachate. A suitable method for organic waste management is to use anaerobic digesters to produce biogas. However, in many cases, the low efficiency of biogas production prevents the use of this method. In this study, three pretreatment methods were used to improve biogas production in an anaerobic digester. The difference of each pretreatment method in terms of biogas production was investigated in four scenarios. Also, the cost-benefit of each scenario was calculated in a financial model based on life cycle cost analysis. The results showed that the yield of methane production without pretreatment was 229 ml/gVS, which increased to 358 ml/gVS using pretreatment methods. The capital costs of the scenario with the highest biogas production were 76% higher than the scenario without pretreatment. In this situation, the income increased up to 61.6%, but the most important impact on the life cycle cost was due to the operating costs, which increased by 140% and 155% in two scenarios of using ozone as part of the pre-treatment. Considering the low effect of using ozone as pretreatment in increasing biogas production compared to other pretreatment, as well as the negative effect of this method on the cost-benefit of the project, thermal and NaOH pretreatment were recommended as the best pretreatment for anaerobic digester.

How to Site: Heydarian H, Mafigholami R, Noorpoor A, Ghanavati H., Khoramipour S.Life cycle cost of different pretreatment scenarios to increase biogas production from municipal solid waste in Tehran, Anthropogenic Pollution Journal, Vol 7 (1), 2023: 25-31, DOI: 10.22034/AP.2023.1979381.1148

Corresponding author: r.mafigholami@wtiau.ac.ir

1. Background

The increase in urbanization and population centralization in big cities has caused the production of a large amount of solid waste in megacities (Chen, 2018). The composition of municipal solid waste depends on various economic and social factors, but organic waste, especially food waste, is one of the most important components of municipal solid waste (Burnley, 2007). The steps of managing the components of municipal solid waste are not the same. According to the characteristics of each component, the final goal is determined (Allesch and Brunner, 2014). In the past decades, the development of recycling industries and the increase in the diversity of recycled products have caused dry wastes such as plastic, paper and glass to enter the recycling routes and reduce their disposal volume (Metin et al., 2003; Masoumi et al., 2020; Saad et al., 2023). The separation of recyclable waste from municipal waste has reduced the volume of solid waste in other routes and has prevented environmental pollution caused by incineration or landfill (Arafat et al., 2015). Therefore, a significant part of the wastes that are landfilled include non-recyclable wastes, including organic wastes (Arafat et al., 2015).

Using the landfill for the final disposal of organic waste, in addition to causing a lot of cost in the management of megacities, is considered as serious environmental concern due to the possibility of leaching pollution into the soil and water sources (Farsani et al., 2021; Wijekoon et al., 2022). Generation of contaminated leachate is one of the most important adverse consequences of organic waste landfill, which is very difficult to treat and manage (Farsani et al., 2022; Salem et al., 2008). Therefore, the development of methods that can reduce the volume of organic waste landfills will be effective in reducing urban management costs and also reducing the negative effects of waste on the environment. One of the alternative methods for landfill is the use of digestion to produce biogas, which, in addition to controlling the amount of landfilled waste, has a positive effect on energy recovery and improving the financial balance of municipal solid waste management (Khalid et al., 2011). Over the years, methods have been developed to improve the yield of methane from organic waste, of which the use of thermal and chemical pretreatments is one of the most important (Ariunbaatar et al., 2014; Gazijahani et al., 2017; Hosseinzadeh et al., 2013; Sadeghi et al., 2022). Using these methods and increasing the yield of biogas can be effective by creating economic attractiveness in the development of biogas production industries from organic waste.

Cost-benefit comparison of waste management development plans plays an important role in choosing the best method and is a suitable decision-making tool for managers (Morrissey et al., 2004; Fataei, 2015). Life cycle cost is one of the methods used to compare the cost-benefit of applicable scenarios in waste management (Mohsenirad and Fataei, 2021). Using this method can estimate all direct and indirect costs in developing existing plans or replacing new plans based on the needs of the organization (Mohammadi and Fataei, 2019; Parsajou and Fataei, 2019; Zheng et al., 2021, Zhu et al., 2021). The purpose of this study was to investigate four scenarios in the development of biogas production equipment from solid waste in Tehran. The scenarios are selected based on differences in pretreatment. This study was done by comparing the life cycle cost of each scenario based on direct and indirect costs as well as the income from biogas production. The simultaneous use of multiple pretreatments to increase biogas yield was an innovation in this study. Also, the definition of several different scenarios to evaluate the economic aspects of different pre-treatment methods was considered as an innovation in this study. The economic comparison of pre-treatment methods to create a decision-making tool can be considered an innovation in the location of this study.

2. Materials and Methods

Solid waste samples were prepared from Kahrizak landfill in Tehran in the amount of 300 kg per sampling. After separating the excess parts such as glass and plastic, 200 kg of the sample was taken to the laboratory for the next steps. In the laboratory, using a shredder, municipal solid waste was chopped into pieces of 4, 2, 1, and 0.5 cm and mixed well. From the crushed and mixed mixture, 50 kg of samples were separated for loading in the biogas production reactor (Heydariyan et al., 2022). Pretreatment was used in different scenarios based on the addition of NaOH at the rate of 5.8 to 8%, thermal pretreatment at the temperature of 132°C to 138°C, and the addition of ozone at the rate of 0.1 to 0.2 grams per each gram of dry weight of solids.

In this study, four scenarios were evaluated, which are shown in Table 1. In first scenario, biogas production was predicted without using the pre-treatment process and the

Table 1. Biogas production scenarios from solid waste based on the difference in the pretreatment method

Scenarios	Description
S1	Anaerobic digestion without pretreatment
S2	Anaerobic digestion with thermal pretreatment (137°C) and chemical pretreatment (NaOH 5.8%)
S3	Anaerobic digestion with thermal pretreatment (138°C) and chemical pretreatment (NaOH 8%), (O_3 0.1 gr/gr of ws)
S4	Anaerobic digestion with thermal pretreatment (132°C) and chemical pretreatment (NaOH 8%), (O_3 0.2 gr/gr of ws)

amount of produced heat and electricity was evaluated. In the second scenario, chemical pretreatment with the addition of 5.8% NaOH and thermal pretreatment at 137°C were used to increase the yield of biogas production. In the third scenario, as in the second scenario, chemical and thermal pretreatment was used. In this scenario, in addition to changes in NaOH concentration and heat, ozone was also used to increase the yield of biogas production. Finally, in the fourth scenario, the highest concentration of NaOH and ozone among the scenarios and the lowest thermal pretreatment among the scenarios were tested. The amount of electricity and heat production was evaluated in all scenarios.

The costs of each scenario were calculated by considering capital costs and operating costs, and the income from compost sales and electricity generation were compared in each scenario. The costs of each scenario were calculated using the following formulas and variables and symbols were described in Table 2 (Torkashvand et al., 2021).

Cc= Pc + Rc + GTc + EEc + ETc + Bc + Oc   Formula 1

OPc= Ec + Mc + Sc + Sec + Oc   Formula 2

Di= Cp + Ep + Wt   Formula 3

Life Cycle Cost (LCC)= Di – [CC + Oc]   Formula 4

Table 2. Variables and symbols used in Formulas (F1, F2, F3, and F4)

F1	**Cc**	**Pc**	**Rc**	**GTc**	**EEc**	**ETc**	**Bc**	**Oc**
	Capital cost	Pretreatment cost	Reactor cost	Gas treatment cost	Energy equipment cost	Effluent treatment cost	Building cost	Other cost
F2	OPc	Ec	Mc	Sc	Sec	Oc		
	Operation cost	Equipment cost	Material cost	Staff cost	Service cost	Other cost such as tax		
F3	Cp	Ep	Wtp					
	Compost price	Energy price	Waste tax					
F4	Di	Cc	OPc					
	Direct income	Capital cost	Operation cost					

3. Results and Discussion

The results showed that in the first scenario, when the pre-treatment method was not used, the yield of biogas and methane production was 379 ml/gVS and 229 ml/gVS, respectively. The increase in biogas and methane yield in the following scenarios where chemical and thermal pretreatment was used is shown in Figure 1. The results showed that the addition of 6% NaOH to the reactor simultaneously with thermal pretreatment at 137°C increased the yield of biogas production to 535 ml/gVS and the yield of methane production increased to 335 ml/gVS. Therefore, in the second scenario, compared to the first scenario, yield of biogas and methane increased by 41.1 and 46.2%, respectively. With the addition of ozone to the pre-treatment stages, the yield of methane and biogas production increased so that in the third scenario, the yield of biogas production and the yield of methane production were 352 ml/gVS and 563 ml/gVS, respectively. Also, in the fourth scenario, the yield of biogas production and the yield of methane production were 358 ml/gVS and 581 ml/gVS respectively, which increased by 56% and 53%, respectively, compared to the first scenario.

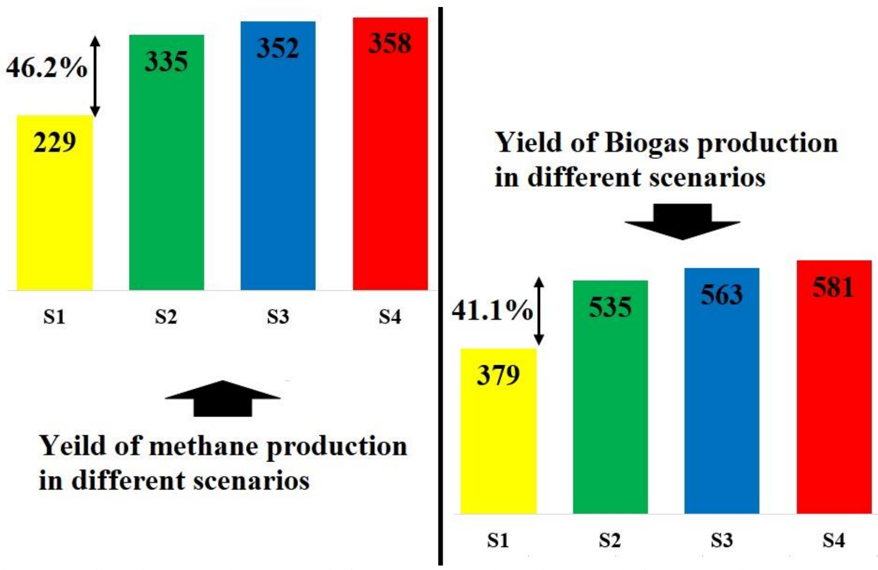

Fig 1. Yield of biogas and methane production in different scenarios based on the difference in the pretreatment method (ml/gVS)

Digestion of organic solids and production of biogas occurs in several stages, of which hydrolysis is the first stage. Proper hydrolysis of organic materials can increase the process of biological conversion of organic materials and the production of methane and biogas (Varjani et al., 2022). As shown in Figure 2, the pre-treatments used in this study made more organic materials available to organisms by affecting materials resistant to biological decomposition, and therefore, in the second to fourth scenarios, the amount of methane and biogas production increased to more than 50% compared to the first scenario. These results have also been observed in other studies. In the study by Mahmoodi et al.2018 it was found that the use of hydrothermal pre-treatment improved the performance of biogas production (Table 3). However, the difference in the yield of biogas and methane production in different pre-treatment processes used in the second to fourth scenarios is slightly different. One of the criteria for choosing the best method in a situation where the efficiency of the desired options is almost similar is to check the cost-benefit of each option (Torkashvand et al., 2021). Therefore, choosing the optimal method to increase the yield of biogas and methane production from the second to fourth scenarios, in which the difference in the yield of biogas and methane production was about 8.5% and 6.8%, respectively, was done by studying the costs of each scenario and their financial balance.

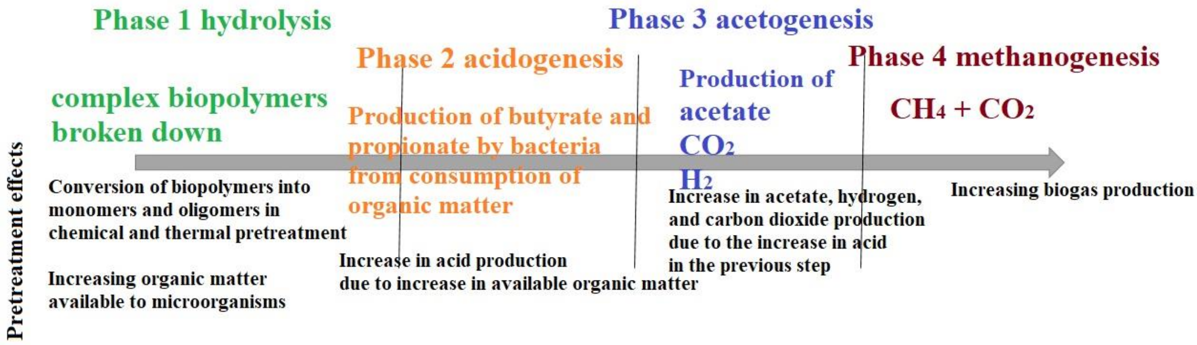

Fig 2. Effect of applied pretreatments in anaerobic digestion phases

Table 3. results of some studies about effect of pretreatment in anaerobic digestion

Pretreatment method	results	Ref.
Hydrothermal	• Operating the reactor at a temperature of 100°C to 160°C up to 60 minutes showed that the efficiency increased by 140% in the best case compared to the sample without pretreatment. • Methane production was observed up to 156 liters per kilogram of organic waste.	Mahmoodi et al., 2018
Ultrasonic	• Using this pretreatment method was effective in increasing biogas production. • Power density was an important factor in the operation of this process. • The maximum yield of biogas production was seen after 72 hours of digestion.	Rasapoor et al., 2016
NaOH	• Cumulative production of biogas increased by 20-35% after pre-treatment. • The highest efficiency of biogas and methane production was observed at pH 10, which was 407 ml/gVS and 69 ml/gVS, respectively. • The best cost-benefit conditions were calculated at pH 8-10.	Dasgupta and Chandel. 2020

Table 4. Capital cost details in different scenarios based on the difference in the pretreatment method

Scenarios		Oc	Bc	ETc	EEC	GTc	Rc	Pc	Total
S1	Cost	228000	28000	31580	1119297	926315	2421051	0	4754243
	%	4.7	0.59	0.66	23.54	19.48	50.92	0	-
S2	Cost	312280	42106	59649	1638596	1094736	2259648	1175438	6582453
	%	6.56	0.88	1.25	34.46	23.02	47.52	24.72	-
S3	Cost	364912	42106	59649	1814035	1150876	2259648	1975437	7666663
	%	7.67	0.88	1.25	38.15	24.20	47.52	41.54	-
S4	Cost	396491	42106	59649	1926315	1171929	2259648	2522805	8378943
	%	8.33	0.88	1.25	40.51	24.64	47.52	53.06	-

The results of studying the capital costs of the scenarios showed that the highest cost is in the Rc, and the first and fourth scenarios had the lowest and highest capital costs, respectively. As shown in Table 4, the capital costs of the fourth scenario were 76% higher than the first scenario, and in this scenario, the costs of Pc had the largest share among the capital costs. Therefore, the share of Pc, Rc, GTc, EEc, ETc, Bc, and Oc in the total capital costs in the fourth scenario is 30.1%, 26.9%, 13.9%, 23%, 0.7%, 0.5%, and 4.7% respectively. Based on this, the comparison of scenarios shows that the share of different affecting factor in capital cost is different. In first scenario, Rc included 50.9% of the capital costs, while the share of Rc in the total capital costs in the second to fourth scenarios were 34%, 29%, and 27%, respectively. However, the lowest share of capital costs was related to Bc in all the scenarios, which included about 0.5% of the total capital costs.

The high capital cost in the investigated scenarios showed that in the development of the biogas production plans, attention should be paid to the long-term efficiency. In the study of biogas production from household waste in Ghana, the high impact of capital costs on the cost-benefit of the project was pointed out and it was stated that, based on the prediction of the 5-year payback period, the economic efficiency of the project depends on the capital cost and the optimal production of methane (Mohammed et al., 2017). In addition, the economic justification of the project should be provided based on more income than capital and operating costs. In a study in Taiwan, the use of agricultural waste to produce compost and biogas was compared, and in both cases, the cost-benefit ratio was estimated to be more than 1, but one of the most effective factors in project decisions was the economic scale (Hsu, 2021). Therefore, although the highest investment cost in this study was seen in the fourth scenario, the study of situation of each scenario should be continued in the long term and based on the comparison of costs with income.

In addition to capital costs, operating costs also play an important role in choosing the optimal waste management method, especially biogas production from urban waste (Zulkepli et al., 2017). As shown in Table 5, Sec has the most ratio in operating costs, and the highest operating cost can be seen in fourth scenario, which was 155% higher than the lowest operating cost in the first scenario. Using up-to-date and high-efficiency processes can reduce operating costs (Rasapoor et al., 2016). Reducing operating costs by using new tools in the waste management, including recycling and energy recovery, is one of the methods that can improve solid waste management in developing countries (Troschinetz and Mihelcic. 2009). Therefore, although the operating costs in this study are lower than the capital costs, considering the project period of the plan and its impact on the capital costs (Torkashvand et al., 2021), focusing on reducing the operating costs will be effective in the economic justification of the scenarios.

Table 5. Operating cost details in different scenarios based on the difference in the pretreatment method

Scenarios	Oc	Sc	Sec	Ec and Mc	Total
S1	3509	122807	417544	24562	568422
S2	7017	143860	614035	301754	1066666
S3	7017	143860	807017	407017	1364911
S4	7017	143860	894736	407017	1452630

TDespite the fact that the use of pre-treatment methods increased the capital and operating costs in the second and fourth scenarios, the increase in income resulting from the improvement of the biological process and yield of biogas production can affect the financial balance of the scenarios. The income of each of the studied scenarios is shown in Figure 3. The highest income was seen in the fourth scenario, which was 61.63% more than the first scenario. However, the income of the second and third scenarios was slightly different compared to the income of the fourth scenario. The reason for the lack of a significant increase in the income of the third and fourth scenarios compared to the second scenario is the slight increase in the yield of biogas and methane production. Meanwhile, due to the high increase in the yield of biogas production in the second scenario compared to the first scenario,

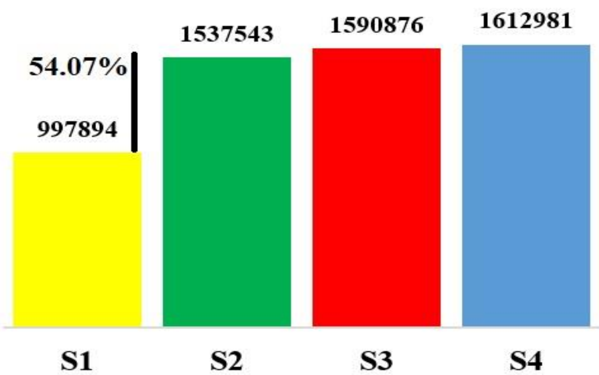

Fig 3. Related income in different scenarios based on the difference in the pretreatment method (USD)

the income increased by 54.07%. Assuming a 30-year project period for capital costs, as shown in Figure 4, the economic balance of each scenario was different based on Equation 4.

Investigating the possibility of municipal solid waste recycling in highway Pavement showed that parameters such as reducing greenhouse gases, reducing energy consumption, and reducing costs have a positive effect on the life cycle cost, while increasing the distance of waste transfer and the possibility of heavy metal leakage are important parameters that have a negative impact was on life cycle cost (Li et al.,2019). Based on this, it can be said that in our study, increasing the production of biogas and reactor by-products had a positive impact on the life cycle cost, while operating costs, especially the cost of energy consumption and equipment service, were the most important negative factors in the life cycle cost. The study of different waste management scenarios in Mumbai using life cycle cost analysis showed that the incineration scenario was the most expensive scenario due to high capital costs, while the combined recycling and landfill scenario was the cheapest scenario due to lower operating costs (Sharma and Chandel. 2021). It was also found that operating and maintenance costs had the greatest impact on the life cycle cost (Sharma and Chandel. 2021), which was consistent with our findings regarding the third and fourth scenarios.

Fig 4. Annual cost-benefit of different scenarios based on the difference in the pretreatment method (USD)

4. Conclusion

The methods of increasing the yield of biogas and methane production from the solid wastes in anaerobic digester were investigated. The economic analysis of four scenarios was done based on the difference in the type of pre-treatment and its impact on the costs and income of each scenario using life cycle cost analysis. The results showed that the use of thermal and chemical pretreatment methods increased the production of methane and biogas by 40-50%. The yield of methane production in the digester without pretreatment was 229 ml/gVS in the first scenario while using thermal and NaOH pretreatment, the yield of methane production increased to 335 ml/gVS in the second scenario. By adding ozone in different concentration to the pretreatment process, the yield of methane production increased in third and fourth scenarios by 352 ml/gVS and 358 ml/gVS, respectively. The cost-benefit balance in the first scenario was 271000 (USD), while in the pre-treatment scenarios, including the second, third, and fourth scenarios, the cost-benefit balance was 250000 (USD), -30000 (USD), and -120000 (USD), respectively. The operating costs in the scenarios of using ozone as a part of the pre-treatment method increased significantly and finally caused the economic balance of these scenarios to become negative. The scenario of using thermal and chemical pretreatment without ozone had a positive economic balance due to lower capital and operating cost, which showed a payback period of 14 years. This scenario was 62% more profitable than the scenario without using pre-treatment. The use of life cycle cost analysis showed that operating costs had the most impact on the project's economy, and the use of ozone for pretreatment of anaerobic digesters is not recommended.

References

Allesch, A., & Brunner, P. H. (2014). Assessment methods for solid waste management: A literature review. Waste Management & Research, 32(6), 461-473.

Arafat, H. A., Jijakli, K., & Ahsan, A. (2015). Environmental performance and energy recovery potential of five processes for municipal solid waste treatment. Journal of Cleaner Production, 105, 233-240.

Ariunbaatar, J., Panico, A., Esposito, G., Pirozzi, F., & Lens, P. N. (2014). Pretreatment methods to enhance anaerobic digestion of organic solid waste. Applied energy, 123, 143-156.

Burnley, S. J. (2007). A review of municipal solid waste composition in the United Kingdom. Waste management, 27(10), 1274-1285.

Chen, Y. C. (2018). Effects of urbanization on municipal solid waste composition. Waste management, 79, 828-836.

Dasgupta, A., & Chandel, M. K. (2020). Enhancement of biogas production from organic fraction of municipal solid waste using alkali pretreatment. Journal of Material Cycles and Waste Management, 22, 757-767.

Farsani, M. H., Yengejeh, R. J., Mirzahosseini, A. H., Monavari, M., Hassani, A. H., & Mengelizadeh, N. (2022). Effective leachate treatment by a pilot-scale submerged electro-membrane bioreactor. Environmental Science and Pollution Research, 29, 9218–9231.

Fataei, E. (2015). Determining the Best Environmental Suitable Scenario for Municipal Solid Waste Disposal of Ardabil City by Life Cycle Assessment. Indian Journal of Natural Sciences, 5(30), 6833-6846

Gazijahani, F. S., Hosseinzadeh, H., Tagizadeghan, N., & Salehi, J. (2017, 19-20 April 2017). A new point estimate method for stochastic optimal operation of smart distribution systems considering demand response programs. Paper presented at the 2017 Conference on Electrical Power Distribution Networks Conference (EPDC).

Heidari Farsani, M., Jalilzadeh Yengejeh, R., Hajiseyed Mirzahosseini, A., Monavari, M., Hassani, A. H., & Mengelizadeh, N. (2021). Study of the performance of bench-scale electro-membranes bioreactor in leachate treatment. Advances in Environmental Technology, 7(3), 209-220.

Heydariyan, H., Mafigholami, R., Noorpoor, A., Ghanavati, H., & Khoramipour, S. (2022). Simultaneous study of the interaction effect of chemical and hydrothermal pretreatment on the yield of methane produced from municipal waste. Journal of Environmental Science and Health, Part A, 57(6), 494-509.

Hosseinzadeh, H., Jabbari, A., & Razani, A. (2013). Fixed-Point Theorems and Common Fixed-Point Theorems on Spaces Equipped With Vector-Valued Metrics. Ukrainian Mathematical Journal, 65(5), 814-822. doi:10.1007/s11253-013-0819-1

Hsu, E. (2021). Cost-benefit analysis for recycling of agricultural wastes in Taiwan. Waste Management, 120, 424-432.

Khalid, A., Arshad, M., Anjum, M., Mahmood, T., & Dawson, L. (2011). The anaerobic digestion of solid organic waste. Waste management, 31(8), 1737-1744.

Li, J., Xiao, F., Zhang, L., & Amirkhanian, S. N. (2019). Life cycle assessment and life cycle cost analysis of recycled solid waste materials in highway pavement: A review. Journal of Cleaner Production, 233, 1182-1206.

Mahmoodi, P., Karimi, K., & Taherzadeh, M. J. (2018). Hydrothermal processing as pretreatment for efficient production of ethanol and biogas from municipal solid waste. Bioresource Technology, 261, 166-175.

Masoumi, A., & Yengejeh, R. J. (2020). Study of chemical wastes in the Iranian petroleum industry and feasibility of hazardous waste disposal. Journal of Environmental Health Science and Engineering, 18(2), 1037-1044.

Metin, E., Eröztürk, A., & Neyim, C. (2003). Solid waste management practices and review of recovery and recycling operations in Turkey. Waste management, 23(5), 425-432.

Mohammadi, M., & Fataei, E. (2019). Comparative life cycle assessment of municipal wastewater treatment systems: lagoon and activated sludge. Caspian Journal of Environmental Sciences, 17(4), 327-336.

Mohammed, M., Egyir, I. S., Donkor, A. K., Amoah, P., Nyarko, S., Boateng, K. K., & Ziwu, C. (2017). Feasibility study for biogas integration into waste treatment plants in Ghana. Egyptian Journal of Petroleum, 26(3), 695-703.

Mohsenirad, B., & Fataei, E. (2021). Life Cycle Assessment of Ball Bladder Production With and Without Recycled Rubbers. Journal of Advances in Environmental Health Research, 9(3), 183-190.

Morrissey, A. J., & Browne, J. (2004). Waste management models and their application to sustainable waste management. Waste management, 24(3), 297-308.

Parsajou, H., & Fataei, E. (2019). Environmental assessment of the life cycle of sludge treatment systems of ardabil and khalkhal wastewater treatment plants. Amirkabir Journal of Civil Engineering, 51(2), 243-256.

Rasapoor, M., Ajabshirchi, Y., Adl, M., Abdi, R., & Gharibi, A. (2016). The effect of ultrasonic pretreatment on biogas generation yield from organic fraction of municipal solid waste under medium solids concentration circumstance. Energy Conversion and Management, 119, 444-452.

Saad, A. ., Ali, E. ., El-Didamony, M. ., & Azam, M. . (2023). The kinetics of strawberry quality changes during the shelf-life . Current Research in Agricultural Sciences, 10(1), 11–21. https://doi.org/10.18488/cras.v10i1.3304.

Sadeghi, B., Shafaghatian, N., Alayi, R., El Haj Assad, M., Zishan, F., & Hosseinzadeh, H. (2022). Optimization of synchronized frequency and voltage control for a distributed generation system using the Black Widow Optimization algorithm. Clean Energy, 6(1), 105-118.

Salem, Z., Hamouri, K., Djemaa, R., & Allia, K. (2008). Evaluation of landfill leachate pollution and treatment. Desalination, 220(1-3), 108-114.

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

Torkashvand, J., Emamjomeh, M. M., Gholami, M., & Farzadkia, M. (2021). Analysis of cost–benefit in life-cycle of plastic solid waste: combining waste flow analysis and life cycle cost as a decision support tool to the selection of optimum scenario. Environment, Development and Sustainability, 1-19.

Troschinetz, A. M., & Mihelcic, J. R. (2009). Sustainable recycling of municipal solid waste in developing countries. Waste management, 29(2), 915-923.

Varjani, S., Sivashanmugam, P., Tyagi, V. K., & Gunasekaran, M. (2022). Breakthrough in hydrolysis of waste biomass by physico-chemical pretreatment processes for efficient anaerobic digestion. Chemosphere, 294, 133617.

Wijekoon, P., Koliyabandara, P. A., Cooray, A. T., Lam, S. S., Athapattu, B. C., & Vithanage, M. (2022). Progress and prospects in mitigation of landfill leachate pollution: Risk, pollution potential, treatment and challenges. Journal of hazardous materials, 421, 126627.

Zheng, R., Zhao, S., Khayyatnezhad, M. & Shah, S. A. 2021. Comparative study and genetic diversity in Salvia (Lamiaceae) using RAPD Molecular Markers. Caryologia, 74, 45-56.

Zhu, K., Liu, L., Li, S., Li, B., Khayatnezhad, M. & Shakoor, A. 2021. Morphological method and molecular marker determine genetic diversity and population structure in Allochrusa. Caryologia, 74, 121-130.

Zulkepli, N. E., Muis, Z. A., Mahmood, N. A. N., Hashim, H., & Ho, W. S. (2017). Cost benefit analysis of composting and anaerobic digestion in a community: a review. Chemical Engineering Transactions, 56, 1777-1782.