



Available online freely at [www.isisn.org](http://www.isisn.org)

# Bioscience Research

Print ISSN: 1811-9506 Online ISSN: 2218-3973

Journal by Innovative Scientific Information & Services Network



RESEARCH ARTICLE

BIOSCIENCE RESEARCH, 2021 18(3): 2117-2126.

OPEN ACCESS

## The Technology of Biogas production by current urban solid waste landfills

Arda Karasakal

Member of Department of Science and Engineering, Yildirim Beyazit University, Ankara, Turkey

\*Correspondence: [icnfsci@gmail.com](mailto:icnfsci@gmail.com) Received 17-06-2021, Revised: 18-07-2021, Accepted: 20-07-2021 e-Published: 27-07-2021

Biogas is the mixture of gases produced by organic matter in the absence of oxygen (anaerobically), primarily consisting of methane and carbon dioxide. Biogas can be produced from raw materials such as agricultural waste, manure, municipal waste, plant material, sewage, green waste or food waste. Biogas is a renewable energy source. Biogas and leachate are produced by current urban solid waste landfills. Biogas production based on the amount of waste is an encouraging way to find a solution for the problem of waste treatment. Besides, the solid residuals of fermentation may be utilized again as fertilizers. The generation of biogas ( $\text{CH}_4$  and  $\text{CO}_2$ ) as fuel gas is by anaerobic fermentation of biomass like urban solid waste, sewage sludge, and manure. Wet organic waste decomposes in landfills under anaerobic conditions, releasing landfill gas. Hydrolysis, acidification, and methane formation are the three stages in the biogas process. The amount of gas emitted by landfills is influenced by the state of decomposition of the waste, moisture, and also temperature; all differ considerably in different areas of the landfill.

**Keywords:** Hydrolysis, Landfill, Methane Formation

### INTRODUCTION

Biogas is a gas that is generated when organic matter is broken down in the lack of oxygen. It, like solar and wind energy, is a renewable energy source. Biogas is also environmentally friendly and can be generated from locally present raw materials like a recycled waste. Anaerobic digestion with anaerobic bacteria or fermentation of biodegradable materials like urbane waste, manure, green waste, plant materials, crops, and sewage (Alayi et al. 2020, Arjaghi et al. 2021, Aletor, 2021). Biogas is a combustible gas mixture. It is primarily composed of carbon dioxide ( $\text{CO}_2$ ) and methane ( $\text{CH}_4$ ). If organic compounds are decomposed by anaerobic bacteria without the presence of oxygen, biogas is released. The gases produced are waste products of these decomposer microorganisms' respiration, and their composition

varies depending on the substance being decomposed. Methane production is limited when the product consists predominantly of carbohydrates like glucose and other simple sugars, as well as high-molecular compounds (polymers) like hemicellulose and hemicellulose (Esmailzadeh et al. 2020, Farhadi et al. 2020, Fataei, 2017, Barth, 2021). Nevertheless, if the fat content is high, so is the methane production. The emergence of the anaerobic digestion process determines the composition of biogas (Zhu et al. 2021, Khayatnezhad and Gholamin, 2021a, Huang et al. 2021, Ren and Khayatnezhad, 2021). Methane concentrations in landfill gas are usually about 50%. Developed technologies for treating waste can generate biogas with 55–75% methane, which can be raised to 80–90% methane in reactors with free liquids utilizing original gas purification techniques (Richards et

al. 1991). Biogas formation includes water vapor.

The fractional volume of steam is an outcome of biogas temperature; basic mathematics can simply correct measured gas volume for steam content and thermal increase, producing the standard volume of dry biogas (Fataei et al. 2018, Ghomi Avili and Makaremi, 2020, Muhibbu-din, 2020). Biogas involves siloxanes in certain instances (Khayatnezhad and Gholamin, 2021a, Gholamin and Khayatnezhad, 2020d, Jia et al. 2020). They're made up of materials used in soaps and detergents that decompose anaerobically. Silicon is produced during the combustion of biogas involving siloxanes and can mix with available oxygen or other materials in the combustion gas. Deposits production includes silicates (SixOy) or silica (Sio2) and can encompass, sulfur, calcium, phosphorus, and zinc. These white mineral deposits can be several millimeters thick on the surface and should be extracted chemically or mechanically. There are methods for eliminating siloxanes and other biogas pollutants that are both feasible and cost-effective (Omrani and Fataei, 2018, Zaeimdar et al. 2019, Hewitt, 2021). Organics make up a high percentage of urban solid waste (MSW) (30–50%). If this organic percentage is used to generate power, it could be a valuable resource. Aside from that, the rapid consumption of conventional sources of energy has caused the examination for alternative energy sources (Khayatnezhad and Nasehi, 2021, Karasakal et al. 2020a, Huang et al. 2021, Huma et al. 2021). Biogas and leachate are produced by current urban solid waste landfills. Biogas production based on the amount of waste is an encouraging way to find a solution to the problem of waste treatment. Also, the solid residuals of fermentation can be utilized again as fertilizers. Landfill gas is a gas mixture saturated in water and it has approximately 40-60% methane and mostly carbon dioxide (CO<sub>2</sub>). In addition to many other contaminants, landfill gas includes various amounts of oxygen, nitrogen, steam, and sulfur. Landfill gas is also known to contain inorganic contaminants such as mercury (Yin et al. 2021, Sun and Khayatnezhad, 2021, Khayatnezhad and Gholamin, 2021b, Gholamin and Khayatnezhad, 2021). The production of biogas differs based on the source. For instance, the amount of hydrogen sulfide in landfill gas ranged from 36 to 115 ppm,

and from 32 to 169 ppm in the farm biogas, but hydrogen sulfide was not found in the gas released by sewage digester (Kabir et al. 2021). Biogas produced by sewage digesters commonly includes 55% to 65% methane, 35% to 45% carbon dioxide, and less than 1% nitrogen; biogas released by organic waste digesters typically includes 60% to 70% methane, 30% to 40% carbon dioxide and less than 1% nitrogen; landfills typically contain 45% to 55% methane, 30% to 40% carbon dioxide and 5% to 15% nitrogen (Rasi et al. 2007, Khayatnezhad and Nasehi, 2021, Sun et al. 2021, Bi et al. 2021). Since landfill gas (biogas) is dangerous, it is essential to do some research to develop a plan for using it without causing environmental issues. This results in a qualified environment for both biogas production and use. The goal of this research is to look at the different stages of biogas production and their effects (Table 1).

**Table 1: Typical biogas composition**

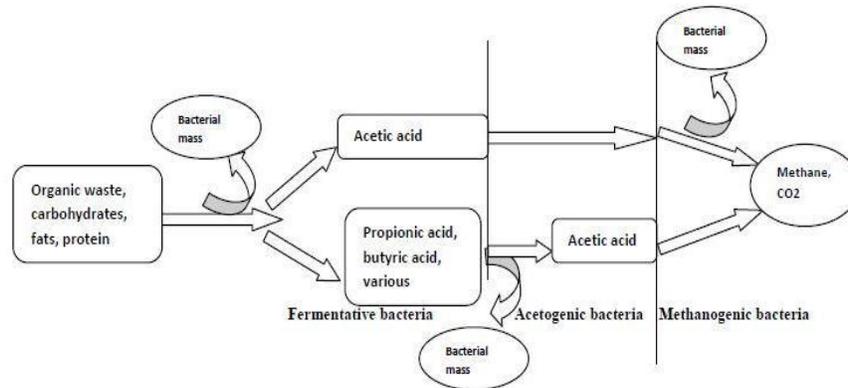
Compound	Molecular formula	%
Methane	CH <sub>4</sub>	50–75
Carbon dioxide	CO <sub>2</sub>	25–50
Nitrogen	N <sub>2</sub>	trace
Ammonia	NH <sub>3</sub>	1-2
Hydrogen	H <sub>2</sub>	0–1
Hydrogen sulphide	H <sub>2</sub> S	0–3
Oxygen	O <sub>2</sub>	0–0

### Landscapes Biogas Production

Wet organic waste decomposes in landfills under anaerobic conditions, creating landfill gas. Biogas (CH<sub>4</sub> and CO<sub>2</sub>) is a fuel gas generated by anaerobic fermentation of biomass such as sewage sludge, manure, and urban solid waste (Radmanesh, 2021).

Particular microorganisms ferment biomass. Biogas microbes are made up of a considerable group of complicated and diverse microbe species, the most remarkable of which are bacteria that produce methane.

Three stages build up the biogas production: hydrolysis, acidification, and methane production (Figure 1) (Barlaz et al. 1990, Rodríguez, 2021). There exist three kinds of bacteria.



**Figure 1: Anaerobic Biomass Fermentation in Three Stages**

## MATERIALS AND METHODS

### Hydrolysis (en-biogas)

The first step (hydrolysis) involves the decomposition of organic matters into smaller components that bacteria can break down. The main organic part of MSW is lignocellulosic material. The amount of carbon needed for biogas generation is impacted by the hydrolysis of lignocellulosic material (Khayatnezhad, 2012, Gholamin and Khayatnezhad, 2021, Ren and Khayatnezhad, 2021). In this process, extracellular enzymes (cellulase, amylase, protease, and lipase) of microorganisms enzymolyze organic matter externally. Bacteria decompose the complicated carbohydrates long chains, proteins, lipids into smaller parts. For instance, polysaccharides are changed into monosaccharides. Proteins are divided into amino acids and peptides. Leachate recirculation decreased the time waste stabilizes and was successful in increasing gas production and enhancing leachate quality, particularly regarding COD, according to the findings of a study, leachate recirculation may be increasingly efficient and waste volume decrease rate of landfills may be maximized (Khayatnezhad and Gholamin, 2012a, Si et al. 2020, Huang et al. 2021).

### Acidification

Lignocellulosic material makes up an important part of MSW. The biogas yield is influenced by the acidification of these materials (Khayatnezhad and Gholamin, 2012b). In the second stage, bacteria that produce acid change the intermediates of fermenting bacteria into hydrogen ( $H_2$ ), acetic acid ( $CH_3COOH$ ), and carbon dioxide ( $CO_2$ ). These bacteria are

anaerobic and their growth is in an acidic environment.

They need oxygen and carbon to create acetic acid. They do this by using oxygen that has been dissolved in the solution or bounded-oxygen. The bacteria that generate acid also produce an anaerobic environment that is important for the microorganisms that generate methane to survive. Furthermore, the reduction of compounds is done with a low molecular weight into, amino acids, alcohols, carbon dioxide, organic acids, hydrogen sulfide, and traces of methane. Because bacteria alone are incapable of maintaining the form of reaction, this process partly requires energy (i.e. only feasible with energy input) from a chemical point (Gholamin and Khayatnezhad, 2020b, Li et al. 2021, Xu et al. 2021, Ma et al. 2021).

### Methane Formation

In the third stage, compounds that have a low molecular weight are decomposed by methane-producing bacteria. For instance, they use acetic acid, carbon dioxide, and hydrogen to make methane and carbon dioxide. Microorganisms that produce methane exist in nature to the degree that anaerobic conditions are given. They are essential anaerobic and are highly susceptible to environmental changes (Karasakal et al. 2020b, Gholamin and Khayatnezhad, 2012). Consistent temperature mode is essential for the major functions of these bacteria that consume hydrogen as well. Variation in yield from MSW is because of the heterogeneous nature of MSW. Variation in predicted values of biogas regarding stoichiometry ranges from 150 to 265  $m^3$ /tone in theory (Gholamin and Khayatnezhad, 2020c). A study revealed that after source separation, household waste releases 494  $m^3$  of methane each ton of

solid waste (Khayatnezhad and Gholamin, 2021b). Even though landfills are methane sources, to raise the methane concentration, landfill gas purification is necessary (Khayatnezhad and Gholamin, 2020b, Khayatnezhad and Nasehi, 2021, Tao et al. 2021, Zhang et al. 2021).

Presorting and pretreatment are frequently carried out to increase biogas yield. Therefore, a report revealed that presorting and pretreatment account for 30% of the total cost of a biomethanation process (Gholamin and Khayatnezhad, 2020c).

### Symbiosis of Bacteria

Bacteria that produce methane and acid work in a symbiotic way. However, the creation of an atmosphere with the ideal specification for bacteria that produce methane (anaerobic conditions, compounds with low molecular weight) is due to acid-producing bacteria. Methane-producing microorganisms, on the other hand, use the acid-producing bacteria's intermediates. There would be some development in toxic conditions for microorganisms that produce acid. The production of fermentation products is not possible by any single bacteria. The subsequent elements are for the metabolic activity of microbiological metalation (Sun et al. 2021).

### Substrate Temperature

In temperatures between 3°C and nearly 70°C, anaerobic fermentation occurs. The temperature rises the bacteriological methane production. The inhibition or even reduction of the bio-digestive function could be caused by the amount of free ammonia, and it rises with temperature. If the biomass temperature reaches below 15°C, there will be low gas production and the biogas plant won't be possible from the economical aspect. Sensitivity to temperature change is seen in the process of bio-methanation (Khayatnezhad and Gholamin, 2020a).

### Available Nutrient

Several supplies of organic substances for a source of energy and carbon are needed for the growth of bacteria. Certain requirements are mineral nutrients. The production of biomass other than oxygen, carbon, and hydrogen needs a sufficient supply of sulfur, phosphorous, potassium, nitrogen, calcium, magnesium, and several trace elements like iron, manganese, etc. "Normal" substrates like agricultural residues or urban sewage generally entail adequate amounts

of the elements stated. An inhibition occurs if any individual substance is highly concentrated

### Batch-type and Continuous Plants

Only batch-type facilities can precisely define the retention time. Specific substrate constituents can have a different effective retention time. The choice of an acceptable retention time is thus affected by both the process temperature and the kind of substrate used.

### PH Value

The bacteria that produce methane grow in neutral to somewhat alkaline conditions. The pH will usually range between 7 and 8.5 when the fermentation process gets steady under anaerobic conditions, and the PH will typically be placed between 7 and 8.5. The PH level is hardly considered as an indicator of substrate acids and potential biogas release because of the buffer influence of ammonia-ammonium ( $\text{NH}_3^- \text{NH}_4^+$ ), and carbon dioxide-bicarbonate ( $\text{CO}_2^- \text{HCO}_3^-$ ). A digester having a high volatile-acid concentration needs a PH value slightly more than normal. The medium can become toxic to the methanogenic bacteria if the PH falls below 6.2.

### Inhibitory Factors

Heavy metals, antibiotics (Bacitracin, Monensin, Spiramycin, Flavomycin, Lasalocid, etc.), and detergents used in livestock farming can all inhibit the bio-methanation process. Biomethanogenesis was found to be toxic to lead, copper, and zinc respectively. Methane production was ceased at a concentration of 10 g/ml of lead. Iron didn't make any remarkable change in the process while manganese increased the methane production rate. The level of toxicity in lead, copper, and zinc in methane production and methanogenic bacteria rely on the dose, but greater concentrations of lead, copper, and zinc (2.5–10.0 g/ml) inhibited the rise of acetogenic bacteria. Manganese activated the development of the methanogenic bacteria, but not functioning on acetic acid production or non-methanogenic bacteria (Gholamin and Khayatnezhad, 2020a).

### Nitrogen Inhibition and C/N Ratio

#### Nitrogen Inhibition

Nitrogen is found in all substrates. Fermentation inhibition at greater PH levels might be caused by low nitrogen concentration. At a nitrogen concentration of about 1700 mg ammonium-nitrogen ( $\text{NH}_4\text{-N}$ ) each liter substrate,

significant inhibition happens. However, given sufficient time, methanogens can adapt to  $\text{NH}_4\text{-N}$  concentrations of 5000-7000 mg/l substrate, with the key requirement that the ammonia level ( $\text{NH}_3$ ) does not surpass 200-300 mg  $\text{NH}_3\text{-N}$  per liter substrate. The amount that ammonia dissociates in water is influenced by the temperature of the process and the PH of the substrate slurry. The ratios of carbon and nitrogen are essential for microorganisms to assimilate into their cell structure. Diverse studies have revealed that metabolic activity of methanogenic bacteria can be improved at a C/N ratio of about 8-20, with the best point differing from case to case relying on the nature of the substrate.

## RESULTS AND DISCUSSION

The decomposition process of the waste, as well as temperature and moisture, affect the landfill's gas production which can all differ dramatically in various areas of the landfill. As stated earlier, a vital factor in this process is microorganism activity that requires specific situations, like being an adequate nutrient for them. Therefore, case-by-case analyses are recommended to specify what amount of which nutrients, if any, still necessitates to be added. It is also worth mentioning that the design of the digester should make the removal of some solids possible since they do not digest and remain at the bottom. There is a close correlation between decomposition rates and gas yields. Each substrate entails a particular gas yield, which is measured in liters that produces per kilogram of decomposed organic matter. In the instance of pre-sorted bio-waste, average gas yields can be measured. To have an increase in biogas yield, presorting and pretreatment are commonly used. Landfill gas purification is needed to raise the methane concentration. Improving the process parameters, maintenance time, substrate quality, process temperature, and volumetric load verifies the cost-effectiveness of the biological processes. However, since each  $\text{m}^3$  digester volume has a cost, heating equipment may be expensive, and substrates that have high quality may have other uses. In biogas production, the cost-efficient optimum is generally lower than the biological optimum.

## CONCLUSION

Biogas can be compressed after removal of Carbon dioxide, the same way as natural gas is compressed to CNG, and used to power motor vehicles. In the United Kingdom, for example,

biogas is estimated to have the potential to replace around 17% of vehicle fuel.[4] It qualifies for renewable energy subsidies in some parts of the world. Biogas can be cleaned and upgraded to natural gas standards, when it becomes bio-methane. Biogas is considered to be a renewable resource because its production-and-use cycle is continuous, and it generates no net carbon dioxide. As the organic material grows, it is converted and used. It then regrows in a continually repeating cycle. From a carbon perspective, as much carbon dioxide is absorbed from the atmosphere in the growth of the primary bio-resource as is released, when the material is ultimately converted to energy.

## CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

## ACKNOWLEDGEMENT

This paper was from my own master thesis.

## AUTHOR CONTRIBUTIONS

Arda Karasakal conducted, planned, Analyzed the data, wrote manuscript and interpreted the results and involved in manuscript preparation. All authors read and approved the final version.

---

## Copyrights: © 2021@ author (s).

This is an open access article distributed under the terms of the [Creative Commons Attribution License \(CC BY 4.0\)](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original author(s) and source are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.

---

## REFERENCES

- Alayi, r., sobhani, e. & najafi, a. 2020. Analysis of environmental impacts on the characteristics of gas released from biomass. *Anthropogenic pollution journal*, 4, 1-14.
- Alayi, R., sobhani, E. & Najafi, A. 2020. Analysis of Environmental Impacts on the Characteristics of Gas Released from Biomass. *Anthropogenic Pollution Journal*, 4, 1-14.
- Aletor, s. 2021. Environmentally induced alternative livelihood strategies among the

- artisanal fishers of the kainji lake basin, nigeria. *Water and environmental sustainability*, 1, 1-7.
- Aletor, S. 2021. Environmentally Induced Alternative Livelihood Strategies among the Artisanal Fishers of the Kainji Lake Basin, Nigeria. *Water and Environmental Sustainability*, 1, 1-7.
- Arjaghi, s. K., alasl, m. K., sajjadi, n., fataei, e. & rajaei, g. E. 2021. Retraction note to: green synthesis of iron oxide nanoparticles by rs lichen extract and its application in removing heavy metals of lead and cadmium. *Biological trace element research*, 1-1.
- Arjaghi, S. K., alasl, M. K., Sajjadi, N., Fataei, E. & Rajaei, G. E. 2021. Retraction Note to: Green Synthesis of Iron Oxide Nanoparticles by RS Lichen Extract and its Application in Removing Heavy Metals of Lead and Cadmium. *Biological Trace Element Research*, 1-1.
- Barlaz, m. A., ham, r. K., schaefer, d. M. & isaacson, r. 1990. Methane production from municipal refuse: a review of enhancement techniques and microbial dynamics. *Critical reviews in environmental science and technology*, 19, 557-584.
- BARLAZ, M. A., HAM, R. K., SCHAEFER, D. M. & ISAACSON, R. 1990. Methane production from municipal refuse: a review of enhancement techniques and microbial dynamics. *Critical Reviews in Environmental Science and Technology*, 19, 557-584.
- Barth, o. 2021. The effect of supplemental instruction on educational accomplishments and behaviors of organic chemistry scholars. *Water and environmental sustainability*, 1, 30-36.
- BARTH, O. 2021. The Effect of Supplemental Instruction on Educational Accomplishments and Behaviors of Organic Chemistry Scholars. *Water and Environmental Sustainability*, 1, 30-36.
- Bi, d., dan, c., khayatnezhad, m., sayyah hashjin, z., li, z. & ma, y. 2021. Molecular identification and genetic diversity in hypericum l.: a high value medicinal plant using rapd markers markers. *Genetika*, 53, 393-405.
- BI, D., dan, c., khayatnezhad, m., sayyah hashjin, z., li, z. & ma, y. 2021. Molecular identification and genetic diversity in Hypericum L.: A high value medicinal plant using rapd markers markers. *Genetika*, 53, 393-405.
- Esmaeilzadeh, h., fataei, e. & saadati, h. 2020. NH<sub>3</sub> removal from sour water by clinoptilolite zeolite: a case study of tabriz refinery. *Chemical methodologies*, 4, 754-773.
- Esmaeilzadeh, h., fataei, e. & saadati, H. 2020. NH<sub>3</sub> Removal from Sour Water by Clinoptilolite Zeolite: A Case Study of Tabriz Refinery. *Chemical Methodologies*, 4, 754-773.
- Farhadi, h., fataei, e. & kharrat sadeghi, m. 2020. The relationship between nitrate distribution in groundwater and agricultural landuse (case study: ardebil plain, iran). *Anthropogenic pollution journal*, 4, 50-56.
- Farhadi, h., fataei, e. & kharrat sadeghi, M. 2020. The Relationship Between Nitrate Distribution in Groundwater and Agricultural Landuse (Case study: Ardebil Plain, Iran). *Anthropogenic Pollution Journal*, 4, 50-56.
- Fataei, e. 2017. Soil carbon, nitrogen and phosphorus pools under exotic tree plantations in the degraded grasslands of iran. *Agricultural & biological research*, 33, 113-127.
- Fataei, E. 2017. Soil carbon, nitrogen and phosphorus pools under exotic tree plantations in the degraded grasslands of Iran. *Agricultural & Biological Research*, 33, 113-127.
- Fataei, e., varamesh, s. & seiied safavian, s. T. 2018. Effects of afforestation on carbon stocks in fandoghloo forest area. *Pakistan journal of agricultural sciences*, 55.
- Fataei, e., varamesh, s. & seiied safavian, S. T. 2018. Effects of afforestation on carbon stocks in Fandoghloo forest area. *Pakistan Journal of Agricultural Sciences*, 55.
- Gholamin, r. & khayatnezhad, m. 2012. Effect of different levels of manganese fertilizer and drought stress on yield and agronomic use efficiency of fertilizer in durum wheat in ardebil. *Journal of food, agriculture & environment*, 10, 1326-1328.
- Gholamin, r. & khayatnezhad, M. 2012. Effect of different levels of manganese fertilizer and drought stress on yield and agronomic use efficiency of fertilizer in durum wheat in Ardebil. *Journal of Food, Agriculture & Environment*, 10, 1326-1328.
- Gholamin, r. & khayatnezhad, m. 2020a. Assessment of the correlation between chlorophyll content and drought resistance in corn cultivars (zea mays). *Helix*, 10, 93-97.
- Gholamin, r. & khayatnezhad, M. 2020a. Assessment of the Correlation between

- Chlorophyll Content and Drought Resistance in Corn Cultivars (*Zea Mays*). *Helix*, 10, 93-97.
- Gholamin, r. & khayatnezhad, m. 2020b. The effect of dry season stretch on chlorophyll content and rwc of wheat genotypes (triticum durum l.). *Bioscience biotechnology research communications*, 13, 1833-1829.
- Gholamin, r. & khayatnezhad, M. 2020b. The effect of dry season stretch on Chlorophyll Content and RWC of Wheat Genotypes (Triticum Durum L.). *Bioscience Biotechnology Research Communications*, 13, 1833-1829.
- Gholamin, r. & khayatnezhad, m. 2020c. Study of bread wheat genotype physiological and biochemical responses to drought stress. *Helix*, 10, 87-92.
- Gholamin, r. & khayatnezhad, M. 2020c. Study of Bread Wheat Genotype Physiological and Biochemical Responses to Drought Stress. *Helix*, 10, 87-92.
- Gholamin, r. & khayatnezhad, m. 2020d. The study of path analysis for durum wheat (triticum durum desf.) Yield components. *Bioscience biotechnology research communications*, 13, 2139-2144.
- Gholamin, r. & khayatnezhad, M. 2020d. The Study of Path Analysis for Durum Wheat (Triticum durum Desf.) Yield Components. *Bioscience Biotechnology Research Communications*, 13, 2139-2144.
- Gholamin, r. & khayatnezhad, m. 2021. Impacts of peg-6000-induced drought stress on chlorophyll content, relative water content (rwc), and rna content of peanut (*arachis hypogaea l.*) Roots and leaves. *Bioscience research*, 18, 393-402.
- Gholamin, r. & khayatnezhad, M. 2021. Impacts of PEG-6000-induced Drought Stress on Chlorophyll Content, Relative Water Content (RWC), and RNA Content of Peanut (*Arachis hypogaea L.*) Roots and Leaves. *Bioscience Research*, 18, 393-402.
- Ghomi avili, f. & makaremi, m. 2020. Predicting model of arsenic transport and transformation in soil columns and ground water contamination (case study: gorgan plain, iran). *Anthropogenic pollution journal*, 4, 57-64.
- GHOMI AVILI, F. & MAKAREMI, M. 2020. Predicting Model of Arsenic Transport and Transformation in Soil Columns and Ground Water Contamination (Case study: Gorgan Plain, Iran). *Anthropogenic Pollution Journal*, 4, 57-64.
- Hewitt, e. 2021. Ecological plunging and wireless filming for science education: a new zealand pilot experimeent. *Water and environmental sustainability*, 1, 24-29.
- Hewitt, E. 2021. Ecological Plunging and Wireless Filming for Science Education: A New Zealand Pilot Experimeent. *Water and Environmental Sustainability*, 1, 24-29.
- Huang, d., wang, j. & khayatnezhad, m. 2021. Estimation of actual evapotranspiration using soil moisture balance and remote sensing. *Iranian journal of science and technology, transactions of civil engineering*, 1-8.
- Huang, d., wang, j. & khayatnezhad, M. 2021. Estimation of Actual Evapotranspiration Using Soil Moisture Balance and Remote Sensing. *Iranian Journal of Science and Technology, Transactions of Civil Engineering*, 1-8.
- Huma, z., lin, g. & hyder, s. L. 2021. Promoting resilience and health of urban citizen through urban green space. *Water and environmental sustainability*, 1, 37-43.
- Huma, z., lin, g. & hyder, S. L. 2021. Promoting Resilience and Health of Urban Citizen through Urban Green Space. *Water and Environmental Sustainability*, 1, 37-43.
- Jia, y., khayatnezhad, m. & mehri, s. 2020. Population differentiation and gene flow in rrodium cicutarium: a potential medicinal plant. *Genetika*, 52, 1127-1144.
- Jia, y., khayatnezhad, m. & mehri, S. 2020. Population differentiation and gene flow in Rrodium cicutarium: A potential medicinal plant. *Genetika*, 52, 1127-1144.
- Kabir, k., arefin, s. M. A. & hosain, m. T. 2021. Analysis of momentary variations in the quality of water on specific criteria in cole mere. *Water and environmental sustainability*, 1, 8-12.
- Kabir, k., arefin, s. M. A. & hosain, m. T. 2021. Analysis of Momentary Variations in the Quality of Water on Specific Criteria in Cole Mere. *Water and Environmental Sustainability*, 1, 8-12.
- Karasakal, a., khayatnezhad, m. & gholamin, r. 2020a. The durum wheat gene sequence response assessment of triticum durum for dehydration situations utilizing different indicators of water deficiency. *Bioscience biotechnology research communications*, 13, 2050-2057.
- Karasakal, a., khayatnezhad, m. & gholamin, r. 2020a. The durum wheat gene sequence

- response assessment of triticum durum for dehydration situations utilizing different indicators of water deficiency. *Bioscience biotechnology research communications*, 13, 2050-2057.
- Karasakal, a., khayatnezhad, m. & gholamin, r. 2020b. The effect of saline, drought, and presowing salt stress on nitrate reductase activity in varieties of eleusine coracana (gaertn). *Bioscience biotechnology research communications*, 13, 2087-2091.
- Karasakal, a., khayatnezhad, m. & gholamin, r. 2020b. The effect of saline, drought, and presowing salt stress on nitrate reductase activity in varieties of eleusine coracana (gaertn). *Bioscience biotechnology research communications*, 13, 2087-2091.
- Khayatnezhad, m. & gholamin, r. 2012a. The effect of drought stress on leaf chlorophyll content and stress resistance in maize cultivars (zea mays). *African journal of microbiology research*, 6, 2844-2848.
- Khayatnezhad, m. & gholamin, r. 2012a. The effect of drought stress on leaf chlorophyll content and stress resistance in maize cultivars (zea mays). *African journal of microbiology research*, 6, 2844-2848.
- Khayatnezhad, m. & gholamin, r. 2012b. Effect of nitrogen fertilizer levels on different planting remobilization of dry matter of durum wheat varieties seimareh. *African journal of microbiology research*, 6, 1534-1539.
- Khayatnezhad, m. & gholamin, r. 2012b. Effect of nitrogen fertilizer levels on different planting remobilization of dry matter of durum wheat varieties seimareh. *African journal of microbiology research*, 6, 1534-1539.
- Khayatnezhad, m. & gholamin, r. 2020. A modern equation for determining the dry-spell resistance of crops to identify suitable seeds for the breeding program using modified stress tolerance index (msti). *Bioscience biotechnology research communications*, 13, 2114-2117.
- Khayatnezhad, m. & gholamin, r. 2020a. A modern equation for determining the dry-spell resistance of crops to identify suitable seeds for the breeding program using modified stress tolerance index (msti). *Bioscience biotechnology research communications*, 13, 2114-2117.
- Khayatnezhad, m. & gholamin, r. 2020b. Study of durum wheat genotypes' response to drought stress conditions. *Helix*, 10, 98-103.
- Khayatnezhad, m. & gholamin, r. 2021a. The effect of drought stress on the superoxide dismutase and chlorophyll content in durum wheat genotypes. *Advancements in life sciences*, 8, 119-123.
- Khayatnezhad, m. & gholamin, r. 2021a. The effect of drought stress on the superoxide dismutase and chlorophyll content in durum wheat genotypes. *Advancements in life sciences*, 8, 119-123.
- Khayatnezhad, m. & gholamin, r. 2021b. Impacts of drought stress on corn cultivars (zea mays l.) At the germination stage. *Bioscience research*, 18, 409-414.
- Khayatnezhad, m. & gholamin, r. 2021b. Impacts of drought stress on corn cultivars (zea mays l.) At the germination stage. *Bioscience research*, 18, 409-414.
- Khayatnezhad, m. & nasehi, f. 2021. Industrial pesticides and a methods assessment for the reduction of associated risks: a review. *Advancements in life sciences*, 8, 202-210.
- Khayatnezhad, m. & nasehi, f. 2021. Industrial pesticides and a methods assessment for the reduction of associated risks: a review. *Advancements in life sciences*, 8, 202-210.
- Khayatnezhad, m. 2012. Evaluation of the reaction of durum wheat genotypes (triticum durum desf.) To drought conditions using various stress tolerance indices. *African journal of microbiology research*, 6, 4315-4323.
- Khayatnezhad, m. 2012. Evaluation of the reaction of durum wheat genotypes (triticum durum desf.) To drought conditions using various stress tolerance indices. *African journal of microbiology research*, 6, 4315-4323.
- Li, a., mu, x., zhao, x., xu, j., khayatnezhad, m. & lalehzari, r. 2021. Developing the non-dimensional framework for water distribution formulation to evaluate sprinkler irrigation. *Irrigation and drainage*.
- Li, a., mu, x., zhao, x., xu, j., khayatnezhad, m. & lalehzari, r. 2021. Developing the non-dimensional framework for water distribution formulation to evaluate sprinkler irrigation. *Irrigation and drainage*.
- Ma, a., ji, j. & khayatnezhad, m. 2021. Risk-constrained non-probabilistic scheduling of coordinated power-to-gas conversion facility and natural gas storage in power and gas based energy systems. *Sustainable energy, grids and networks*, 100478.
- Ma, a., ji, j. & khayatnezhad, m. 2021. Risk-constrained non-probabilistic scheduling of

- coordinated power-to-gas conversion facility and natural gas storage in power and gas based energy systems. *Sustainable energy, grids and networks*, 100478.
- Muhibbu-din, i. 2020. Investigation of ambient aromatic volatile organic compounds in mosimi petroleum products depot, sagamu, nigeria. *Anthropogenic pollution journal*, 4, 65-78.
- Muhibbu-din, i. 2020. Investigation of ambient aromatic volatile organic compounds in mosimi petroleum products depot, sagamu, nigeria. *Anthropogenic pollution journal*, 4, 65-78.
- Omrani, m. & fataei, e. 2018. Synthesizing colloidal zinc oxide nanoparticles for effective disinfection; impact on the inhibitory growth of pseudomonas aeruginosa on the surface of an infectious unit. *Polish journal of environmental studies*, 27.
- Omrani, m. & fataei, e. 2018. Synthesizing colloidal zinc oxide nanoparticles for effective disinfection; impact on the inhibitory growth of pseudomonas aeruginosa on the surface of an infectious unit. *Polish journal of environmental studies*, 27.
- Radmanesh, m. 2021. Evaluation of the efficient management of greenhouses for healthy items in the province of alborz. *Water and environmental sustainability*, 1, 20-23.
- Radmanesh, m. 2021. Evaluation of the efficient management of greenhouses for healthy items in the province of alborz. *Water and environmental sustainability*, 1, 20-23.
- Rasi, s., veijanen, a. & rintala, j. 2007. Trace compounds of biogas from different biogas production plants. *Energy*, 32, 1375-1380.
- Rasi, s., veijanen, a. & rintala, j. 2007. Trace compounds of biogas from different biogas production plants. *Energy*, 32, 1375-1380.
- Ren, j. & khayatnezhad, m. 2021. Evaluating the stormwater management model to improve urban water allocation system in drought conditions. *Water supply*.
- Ren, j. & khayatnezhad, m. 2021. Evaluating the stormwater management model to improve urban water allocation system in drought conditions. *Water supply*.
- Richards, b. K., cummings, r. J., white, t. E. & jewell, w. J. 1991. Methods for kinetic analysis of methane fermentation in high solids biomass digesters. *Biomass and bioenergy*, 1, 65-73.
- Richards, b. K., cummings, r. J., white, t. E. & jewell, w. J. 1991. Methods for kinetic analysis of methane fermentation in high solids biomass digesters. *Biomass and bioenergy*, 1, 65-73.
- Rodríguez, r. 2021. The study of enzyme-water mutualism theory. *Water and environmental sustainability*, 1, 44-49.
- Rodríguez, r. 2021. The study of enzyme-water mutualism theory. *Water and environmental sustainability*, 1, 44-49.
- Si, x., gao, l., song, y., khayatnezhad, m. & minaeifar, a. A. 2020. Understanding population differentiation using geographical, morphological and genetic characterization in erodium cicunium. *Indian j. Genet*, 80, 459-467.
- Si, x., gao, l., song, y., khayatnezhad, m. & minaeifar, a. A. 2020. Understanding population differentiation using geographical, morphological and genetic characterization in erodium cicunium. *Indian j. Genet*, 80, 459-467.
- Sun, q., lin, d., khayatnezhad, m. & taghavi, m. 2021. Investigation of phosphoric acid fuel cell, linear fresnel solar reflector and organic rankine cycle polygeneration energy system in different climatic conditions. *Process safety and environmental protection*, 147, 993-1008.
- Sun, q., lin, d., khayatnezhad, m. & taghavi, m. 2021. Investigation of phosphoric acid fuel cell, linear fresnel solar reflector and organic rankine cycle polygeneration energy system in different climatic conditions. *Process safety and environmental protection*, 147, 993-1008.
- Sun, x. & khayatnezhad, m. 2021. Fuzzy-probabilistic modeling the flood characteristics using bivariate frequency analysis and  $\alpha$ -cut decomposition. *Water supply*.
- Sun, x. & khayatnezhad, m. 2021. Fuzzy-probabilistic modeling the flood characteristics using bivariate frequency analysis and  $\alpha$ -cut decomposition. *Water supply*.
- Tao, z., cui, z., yu, j. & khayatnezhad, m. 2021. Finite difference modelings of groundwater flow for constructing artificial recharge structures. *Iranian journal of science and technology, transactions of civil engineering*.
- Xu, y.-p., ouyang, p., xing, s.-m., qi, l.-y., khayatnezhad, m. & jafari, h. 2021. Optimal structure design of a pv/fc hres using amended water strider algorithm. *Energy reports*, 7, 2057-2067.

- Xu, y.-p., ouyang, p., xing, s.-m., qi, l.-y., khayatnezhad, m. & jafari, h. 2021. Optimal structure design of a pv/fc hres using amended water strider algorithm. *Energy reports*, 7, 2057-2067.
- Yin, j., khayatnezhad, m. & shakoor, a. 2021. Evaluation of genetic diversity in geranium (geraniaceae) using rapd marker. *Genetika*, 53, 363-378.
- Yin, j., khayatnezhad, m. & shakoor, a. 2021. Evaluation of genetic diversity in geranium (geraniaceae) using rapd marker. *Genetika*, 53, 363-378.
- Zaeimdar, m., tavakoli, f. & lahijanian, a. 2019. The impact of environmental education on the environmental behavior of elementary school students (case study: students in tehran). *Anthropogenic pollution journal*, 3, 37-42.
- Zaeimdar, m., tavakoli, f. & lahijanian, a. 2019. The impact of environmental education on the environmental behavior of elementary school students (case study: students in tehran). *Anthropogenic pollution journal*, 3, 37-42.
- Zhang, h., khayatnezhad, m. & davarpanah, a. 2021. Experimental investigation on the application of carbon dioxide adsorption for a shale reservoir. *Energy science & engineering*, n/a.
- Zhu, p., saadati, h. & khayatnezhad, m. 2021. Application of probability decision system and particle swarm optimization for improving soil moisture content. *Water supply*.
- Zhu, p., saadati, h. & khayatnezhad, m. 2021. Application of probability decision system and particle swarm optimization for improving soil moisture content. *Water supply*.