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Anaerobic Digestion for Effective Waste Management: A Case Study for Sustainable Rural Development in a Moderate Climate Region

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ABSTRACT

Improper management of wet waste in cities located in temperate, humid regions with abundant rainfall leads to the production and spread of leachate across ecosystems. This not only pollutes soil and surface water but also contributes to the emission of greenhouse gases, negatively impacting both ecosystem and human health. Effective waste management can transform these wastes into valuable products, such as fertilizer and biogas, while also preventing environmental damage. In this study, we focus on a region with moderate weather conditions, which offers the potential for efficient waste management at a reasonable cost. By evaluating various technologies and methods, as well as considering global implementation approaches, anaerobic digestion emerges as a more suitable solution for waste management compared to conventional methods like burying and burning. Apart from waste reduction, anaerobic digestion offers several advantages, including reduced greenhouse gas emissions, prevention of soil, air, and water pollution, decreased toxicity and heavy metal contamination, and eradication of pathogenic organisms. Numerous types of digesters have been developed to date, and factors such as geographical location, substrate availability, construction materials, climatic conditions, cost and capital requirements, and energy consumption influence the design of these digesters. In this study, we estimate the design, construction, and management of a small-scale digester for a town with a population of 2000 people. By providing reliable information, this research aims to assist executive officials of towns and villages in establishing such units within their communities, promoting sustainable rural development.

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INTRODUCTION

The need for energy increases along with the world population's continuous growth. Fossil fuel energy production has a negative environmental impact contributing air pollution, greenhouse gas emissions, and global warming These resources take millions of years to regenerate and are non-renewable. Finding a new and alternative fuel has become necessary due to the rise in the cost of petroleum products, the depletion of resources, and the damaging impact of these fuels on the environment.(Mahanta et al., 2005; Obileke et al., 2020b; Ukpai and Nnabuchi 2012; Ajay et al., 2021b; Habibi et al., 2022; Sanaye Mozaffari Sabet and Golzary 2022; Golzary and Abdoli 2020) Fossil fuel use should be reduced and eventually eliminated by using renewable energy. Biomass, wind, solar, and water energy are examples of renewable energy sources (Obileke et al., 2020b; Golzary et al., 2021).Currently, 14% of the world's energy comes from biomass. (Mahanta et al., 2005; Azari et al., 2020) Organic material

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from plants and animals, known as biomass, can be broken down by aerobic and anaerobic microorganisms into energy and biogas Agricultural products, residues of wood processing, municipal garbage, and wet waste are some of the main sources of biomass (Bridgwater 2006; Kasani et al., 2022). Common techniques for recycling and waste management include aerobic and anaerobic digesting processes. In the aerobic process of composting, microorganisms work under controlled circumstances to decompose organic material This process generates a lot of heat and releases a lot of carbon dioxide and water vapor into the atmosphere.(Pace et al., 1995; Tavakoli and Barkdoll 2020b) In the composting method, fertilizer is the only substance that remains after the decomposition of organic matter, however in the anaerobic process, biogas is also created in addition to fertilizer. (Kothari et al., 2010) In the absence of oxygen, biomass is transformed into biogas through the process of anaerobic digestion. (Mukumba et al., 2019) The raw materials for producing biogas are affordable, renewable, and highly environmentally friendly. (Mahanta et al., 2005; Rajendran et al., 2012; Vahidi Ghazvini and Noorpoor 2022) Biogas is a flammable gas with an ignition temperature of between 650°C and 750 °C and a calorific value of 21–24 megajoules per cubic meter.(Obileke et al., 2020b; Khan and Martin 2016) A cubic meter of biogas may generate 6 KWh of energy, which is the same as 0.97 cubic meters of natural gas, 1.1 liters of gasoline, and 1.7 liters of bioethanol.(Rajendran et al., 2012; Mutungwazi et al., 2018) Air pollution is reduced when biogas is used as motor fuel It creates less than diesel fuels. In comparison to engines that run on diesel fuel, an ignition engine that burns biogas, for instance, releases approximately 62.03% less carbon monoxide, 56.42% less carbon dioxide, 63% less HC, and 50% less NOx.(Ajay et al., 2021b; Ghazvini et al., 2020)In general, biogas is composed of 50–70% methane, 30–40% carbon dioxide, 1–10% hydrogen, 1–3% nitrogen, and 0.1% oxygen, carbon monoxide, and hydrogen sulfide. However, the composition of biogas is dependent on biomass and raw materials. (Ukpai and Nnabuchi 2012; Ajay et al., 2021b; Azari et al., 2020) There are many different substrates that can be utilized to produce biogas, including used kitchen waste, urban sludge, plant and fruit waste, agricultural waste (rice straw, corn straw, wheat straw, etc.), and animal, plant, and fruit waste. (Ajay et al., 2021b; Setyobudi et al., 2021; Sawyerr et al., 2020). Kitchen waste has a considerable potential for producing biogas, according to recent studies. Numerous substances included in food scraps, such as proteins, vitamins, and fibers, encourage the development of bacteria and hence enhance gas production. (Ajay et al., 2021b) Food waste varies depending on the local food culture, but on average, it contains 46-49% carbon, 8-6% hydrogen, 37-39% oxygen, 2-3% nitrogen, and a lower content of sulfur. Food waste has a moisture level of between 70 and 80%. (Ajay et al., 2021b) It takes 15 days to make 0.25 cubic meters of biogas from 8 kg of kitchen waste. This quantity of biogas is the same as 0.13 kilogram of kerosene, 0.18 kg of coal, and 0.13 kg of gasoline. (Ajay et al., 2021b)It is conceivable to reduce the quantity of carbon dioxide from greenhouse gas emissions by up to 510 tons if we put all of the world's food waste under the anaerobic process. (Ajay et al., 2021b)Methane that is created can be utilized for energy, lighting, warmth, and cooking.(Rajendran et al., 2012; Khan and Martin 2016; Rajendran et al., 2013)Families' usage of energy has been optimized thanks to biogas digesters; according to research results, digesters can reduce household energy use by 40%. (Xiaohua et al., 2007)

MATERIALS AND METHODS

Anaerobic digestion is a three-stage method for producing biogas. Acid-forming bacteria decompose the organic components of biomass (carbohydrates, proteins, and lipids) in the first step, producing simple monomers like amino acids and fatty acids. Then, fatty acids are decomposed by acid-forming bacteria, which also release carbon dioxide and hydrogen. Methane is produced by methanogenic bacteria during the third stage. (Mahanta et al., 2005;

Obileke et al., 2020b; Ajay et al., 2021b; Kasani et al., 2022)

Temperature, pH, C/N ratio, total moisture, input feed dilution rate, and residence time are only a few of the variables that might affect anaerobic digestion and the amount of gas produced (Mahanta et al., 2005; Obileke et al., 2020b; Ajay et al., 2021b; Ukpai and Nnabuchi 2012; Mukumba et al., 2019; Rajendran et al., 2012; Obileke et al., 2021). The activity and life of bacteria, retention duration, and pH value are all impacted by temperature, which also has a significant impact on the effectiveness of the anaerobic digestion process. (Obileke et al., 2021) The temperature of the input mixture, the ground, and the surrounding air all affect the digestion process. (Obileke et al., 2020b)Different temperatures can be used for anaerobic digestion. Anaerobic digestion can be performed at three different temperatures: psychrophilic (10–20°C), mesophilic (25–40°C), and thermophilic (50–60°C).(Mahanta et al., 2005; Mukumba et al., 2019; Habibi et al., 2022)At temperatures below 10 °C, biogas production completely halts. The mesophilic range is the best temperature range because methanogenic bacteria function best at 35 °C, and generally, the amount of gas generated is ideal in this temperature range. (Mahanta et al., 2005)Anaerobic digesters operate less efficiently during the winter. In order to generate ideas for biogas, research can be done by combining solar energy with biogas. Another strategy to maximize performance during the night and during the cold season is to insulate the digester.(Mutungwazi et al., 2018; Setyobudi et al., 2021) The shelf life of the slurry is also impacted by temperature, as was previously mentioned. The shelf life is greater than 100 days when the temperature is 15 °C, and it is less than a month when the temperature is 35 ° c. (Mahanta et al., 2005)

If the retention time is too short, the ingredients won’t fully decompose and the digesting process won’t be as effective.(Setyobudi et al., 2021)At a pH of 6.5 to 7.5, the digestive process operates at its most effective level. The input feed’s pH level is important, but it’s also important because it directly affects the activity of bacteria and the effectiveness of methane production. (Mahanta et al., 2005; Obileke et al., 2021) The atmosphere turns acidic and the pH drops as a result of the accumulation of volatile fatty acids throughout the digestive process. Adding substances like CaO, NaHCO3, NaOH, or NH4HCO3 might prevent an extreme pH drop (Ajay et al., 2021b).The C/N value is another aspect that influences anaerobic digestion. This ratio should be between 25 and 30 in order for microorganisms to function more effectively.(Mahanta et al., 2005; Ajay et al., 2021b)Because the concentration of total solid (TS) should be between 7 and 10% for optimal performance, the degree of dilution of the input mixture in the amount of generated gas is important. (Mahanta et al., 2005; Ajay et al., 2021b) The feed is often mixed with water at a 1:1 ratio to achieve this. The mixture will settle, and the amount of gas produced will reduce if it is extremely dilute. Additionally, if the mixture concentrated , the particles stop gas from forming and moving. (Mahanta et al., 2005)Other parameters that affect digestion rate include mixing, material loading rate, COD and BOD amount, presence of mineral ions, heavy metals, and additives.(Mahanta et al., 2005; Mukumba et al., 2019)

The production of waste and garbage has increased because of the world’s population growth. Currently, over 1.6 billion tons of trash are produced globally annually (Ajay et al., 2021b). Waste management strategies such as anaerobic digestion may be appropriate (Rajendran et al., 2013; Alkhalidi et al., 2019). In addition to volume reduction, the anaerobic digestion process for waste management has other advantages over more conventional approaches like burial and incineration, such as the emission of greenhouse gases, the removal of dust from the air, water, and soil, as well as the reduction and elimination of pathogenic organisms that carry heavy metals, as noted(Ukpai and Nnabuchi 2012; Mukumba et al., 2019; Setyobudi et al., 2021; Garfí et al., 2019). The amount of energy that could be produced utilizing anaerobic digestion from all available wastes would be between 900 and 1100 KWH, or enough to power 112 to 135 million people (Ajay et al., 2021b).Numerous distinct digester designs have been presented since the 1957 debut of the biogas digester(Sawyerr et al., 2020). Geographical location, the availability

Table 1. lists some building supplies for various digesters (Rajendran et al., 2012)

Materials	Advantages	Disadvantages
Poly vinyl chloride(PVC)	Less weight Easily portable	Short life span of plastics
Polyethylene(PE)	PE is much cheaper compared to pvc	
Neoprene and rubber	Weather resistance elastic	Expensive Low pressure Less life span
Bricks and concrete	Everlasting,less maintenance costs	Gas could 1scape through concrete por when pressure increases. Built underground Difficult to clean Occupies more space
Steel drum	Produce gad at a constant flow Leak proof	Corrosion Heavy weight of gas holder

of substrate and construction materials, climatic conditions, cost and capital requirements, and the amount of energy needed all have an impact on the design of digesters(Rajendran et al., 2012; Ioannou-Ttofa et al., 2021). Table 1 lists some items needed to build various types of digesters.

The digester with floating cover (Indian model), fixed tank digester (Chinese model), and balloon tank digesters are some of the most popular types of digesters (Ukpai and Nnabuchi 2012; Cheng et al., 2014). The fixed tank digester, also called the Chinese model digester, is made up of an integrated fermentation tank that is placed on top of this dome-shaped tank to collect the gas it produces, as well as an intake or mixing tank and an exit tank (Mahanta et al., 2005).The initial cost of building this kind of digester is low. It has a 20-year life span, roughly. Its maintenance costs are also affordable because it doesn't have any moving or metallic parts. This digester requires a small size of land if it is constructed underground. Although the amount of gas generated is not immediately apparent, the installation of this digester demands high technical expertise and professional supervision (Ajay et al., 2021b; Rajendran et al., 2012; Garfí et al., 2019; Cheng et al., 2014). Bricks, aggregate, cement, and sand are used to create fixed tank digesters.(Obileke et al., 2020a; Tavakoli and Barkdoll 2020a) The moving drum digester is made up of a gas tank with a steel lid and a stone-brick tank that is joined to the intake and outlet tanks. Digesters of this kind are constructed underground.(Mahanta et al., 2005) Due to the steel cover, this form of digester is more expensive to construct than the fixed tank digester. The preparation of the steel cover represents around 40% of the total construction expenditures. Additionally, because they contain metal parts, they require lengthy periods of painting to prevent breakage, which raises maintenance and repair costs. Furthermore, because they use a metal cover, they have a shorter lifespan than fixed tank digesters. This kind of digester is not appropriate for wet or rainy climates.(Mahanta et al., 2005; Ajay et al., 2021b; Cheng et al., 2014) We may include the convenience of construction, straightforward and clear operation, stability of the gas pressure, and the ability to gauge the volume of gas produced as benefits of the mobile drum digester.(Cheng et al., 2014) Balloon tank digesters are susceptible to mechanical damage and have a short lifespan. It is not easy to repair their plastic tanks and they are less environmentally friendly than other methods. (Mukumba et al., 2019; Cheng et al., 2014; Kabyanga et al., 2018)Although these digesters are transportable and simple to maintain, they are susceptible to climatic changes and low gas pressure.(Cheng et al., 2014) Plug-in (tubular) digesters, portable digesters, and prefabricated digesters are further types of digesters (Ajay et al., 2021b; Cheng et al., 2014). Tubular digesters have a slow rate of material conversion and requires regular maintenance, but their design is simple, they are cost-effective to build, and they can be moved and transported.(Ajay et al., 2021b)Portable digesters are more expensive and are manufactured smaller. It is impossible to regulate the temperature in these digesters, and their mixing system is ineffective. (Ajay et al., 2021b)Prefabricated digesters are manufactured off-site using components with unique qualities like as glass fibers, fiber-reinforced plastics, and other modified plastics(Garfí et al., 2019). Unfortunately, prefabricated digesters have not yet reached their full potential and lack guidelines for design, production, and material selection. On the other hand, research on composite materials and chemicals costs a lot of money.(Cheng et al., 2014). Ajay et al (2020) investigated the different kitchen waste management techniques, they discusses different types of biomass feedstock and provides a general approach to designing a portable biogas unit. This study confirms that the systematic design of biogas units and proper feeding of kitchen waste provides the advantage of efficient use of waste in decentralized energy production(Ajay et al., 2021a). Connor et al (2022) studied the , Biogas production from small-scale anaerobic digestion plants on European farms, and This study showed that the national support framework is an important factor in the adoption rate of small-scale anaerobic digestion in European countries, where improving the conditions significantly increases the uptake rate(O'Connor et al., 2021).

Anaerobic digestion has financial benefits in addition to environmental ones. Anaerobic digestion not only creates biogas but also fertilizer, which can have an impact on people's livelihoods. (Mukumba et al., 2019)Anaerobic digester fertilizer is a valuable fertilizer that is full of N, P, K, and other beneficial nutrients for the soil.(Mukumba et al., 2019) The fertilizer performs better for the environment the more biomass organic matter is employed in the digester.(Pizarro-Loaiza et al., 2021) Digester products can cut the cost of cooking, buying fuel, and buying gasoline for individuals, particularly in rural areas, by 80%. (Garfí et al., 2019) Other social benefits of these digesters include reducing the need to collect firewood, generating local employment, and assisting in the prevention of deforestation(Jegede et al., 2018). Anaerobic digester use can reduce annual energy costs for households by roughly $249.(Alkhalidi et al., 2019)Digesters are widely used in Southeast Asia. (Khan and Martin 2016)For rural residents in China, Bangladesh, India, Indonesia, and Nepal, this technology is quite popular.(Setyobudi et al., 2021) The high biomass potential is one of the factors contributing to the widespread adoption of these digesters in India. These businesses, including pulp and paper, poultry, and slaughterhouses, provide the biomass. In general, it may be said that biomass is composed of substances derived from living things like plants and animals, with plants, wood, and trash being the most prevalent. Finally, it results in the daily production of a significant volume of biogas.(Kamalimeera and Kirubakaran 2021) While home anaerobic digesters are more popular in India and China than in Europe and North America—there are more than 30 million home digesters in China, more than 3.8 million in India, and more than 200,000 in Nepal—biogas production facilities there are designed as massive industrial units.(Rajendran et al., 2012; Alkhalidi et al., 2019) The first methane generating digester was constructed in Iran in 1354 in the Lorestan village of Niazabad. This machine, which has a 5-cubic-meter capacity, was utilized for the village's cow dung. The Sistan and Baluchistan, Ilam and Kurdistan, Golestan, and Alborz provinces all had 10 biogas units built by the New Energy Research Center of the Atomic Energy Organization between the years 1982–1986. The usage of these digesters in the north of the country may be due to the prevalence of animal husbandry, the existence of animal and poultry waste, the prevention of deforestation, the creation of local jobs, and a decrease in the consumption of firewood. After reviewing the article by (Ajay, Mohan, and Dinesha 2021), we assessed the feed quantity and ingredients, as well as the percentage of each ingredient. We also analyzed the reaction conditions and effects based on the findings from (Obileke et al., 2020) The suitability of this type of digester for Gilan's moderate climate was determined through studies conducted by (Ukpai and Nnabuchi n.d.), Furthermore, we examined the design and construction of Iran’s largest livestock biogas pilot by referencing (H.Nakagaraw 1981) and using the design and construction of Iran’s largest livestock biogas pilot, we examined the design. Furthermore, we obtained values for digester design from articles by (Nakagawa and Honquilada 1985a; Nijaguna 2006a; Kaur et al., 2017; Sawyerr et al., 2020). We evaluated the different materials used for each part of the digester by examining (B.T. Nijiguna 2006).

RESULTS AND DISCUSSION

In this study, we design a fixed tank digester (Chinese model) with a feed input capacity of 1 ton of food waste per day for a village of 2000 residents in Gilan province, Iran. The fixed tank digester is more appropriate because this area experiences frequent rain. Because underground digesters have higher biogas production efficiency due to more consistent digestion tank temperature and longer retention time, this digester was installed underground. The china digester also performs better in terms of insulation than the portable drum digester. (Ukpai and Nnabuchi 2012; Rajendran et al., 2012)Chinese digesters are popular because of how convenient it is to design them with prefabricated plastic, concrete, or bricks which are the factors contributing to their popularity. (Jegede et al., 2018) Due to the seasonal temperature variations in Gilan province, the anaerobic digestion process in this project operates within a mesophilic temperature range. The climate change in Gilan province over the past year and the amount of precipitation was obtained from (accuweather.com (2022)) and (Bakhshipour et al., 2020) respectively. The annual temperature fluctuations for this region are shown in Figure 1.

Gilan province is among the 10 most populous provinces of Iran and has a population of more than 2503696 people. The area of this province is equal to 14044 square kilometers. This area is located in the north of Iran with the geographical coordinates of 37.1172°N 49.5280°E. According to the survey, the average amount of waste produced in this area is about 7876 tons per day, which includes 5076 tons of agricultural waste (64%), 2200 tons of household waste (28%), and 600 tons of industrial waste (8%). will be The analysis of each type of waste is shown in Figure 2, 3 and 4.

management techniques include landfilling, burning waste, using waste incinerators, and constructing a compost production plant. Burning garbage is one of the traditional methods that is extremely destructive to the environment. This procedure increases the risk of cancer,

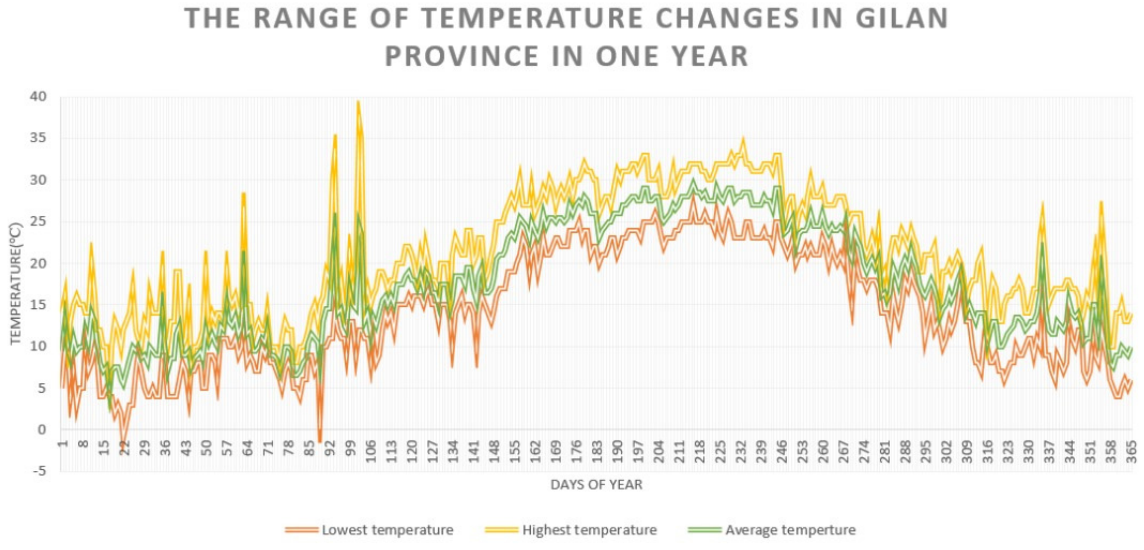


Fig. 1. Temperature range of Gilan region during one year.(accuweather.com 2022)

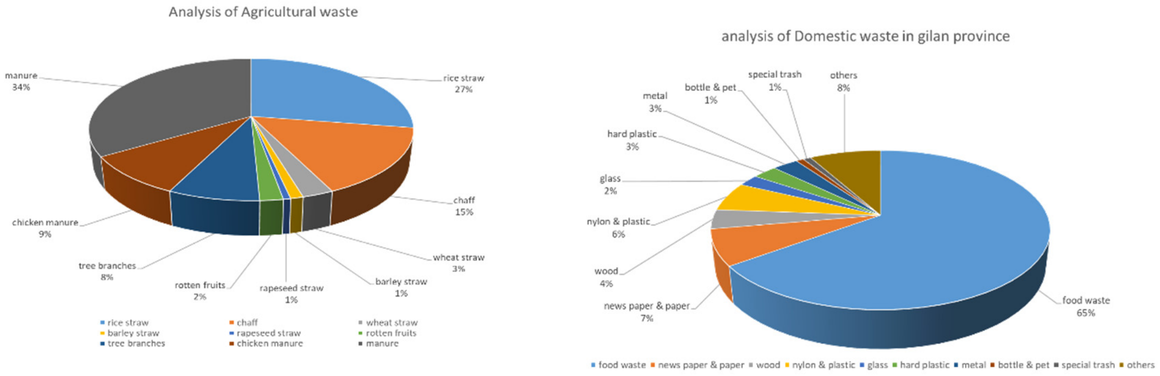


Fig. 2. Analysis of Domestic & Agricultural waste

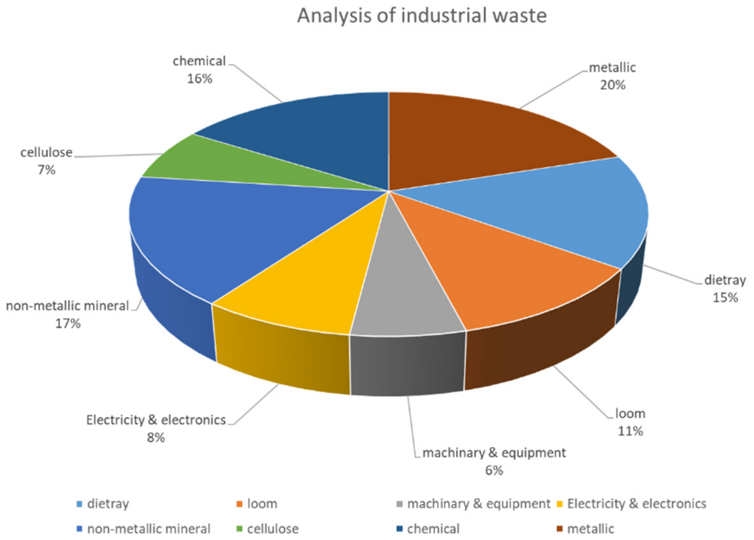


Fig. 3. Analysis of industrial waste

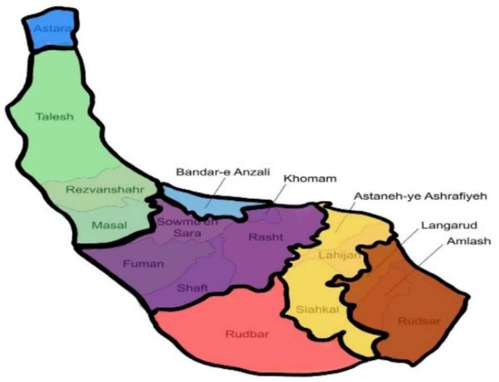
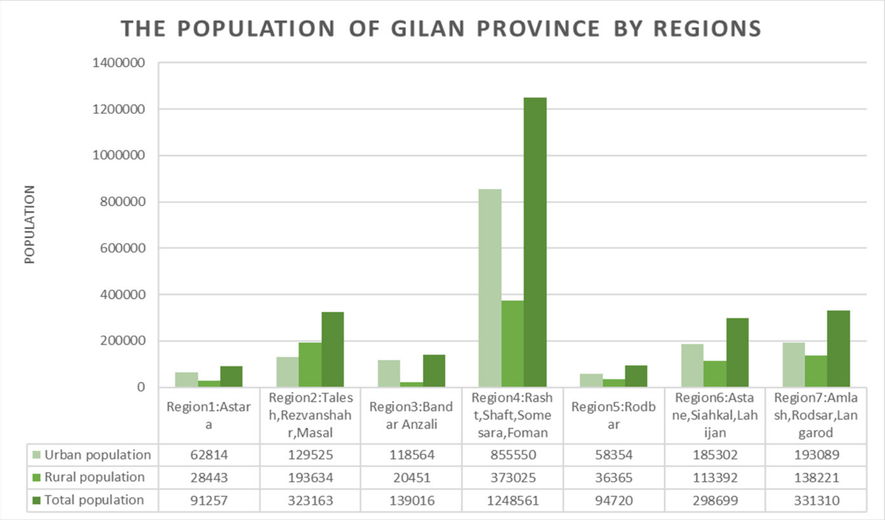
Astara Talesh Rezvanshahr, Masal Bandar Anzali Rasht,Shaft, Somesara, Foman Rodbar AStane,Siahkal, Lahijan Amlash,Rodsar, Langrod	

Fig. 4. Gilan province has been divided into 7 regions

causes severe air pollution, and increases the number of suspended particles in the atmosphere. (Chaudhary et al., 2022) The landfilling process results in the absorption and spread of infectious agents and dangerous insects in addition to damaging the nearby soil and water. Additionally, this approach needs a lot of land. (Mukherjee et al., 2021; Mayer et al., 2020) This province has been divided into 7 waste management zones as part of the comprehensive waste management plan for Gilan to strengthen the waste management system. These areas are shown in Figure 4.

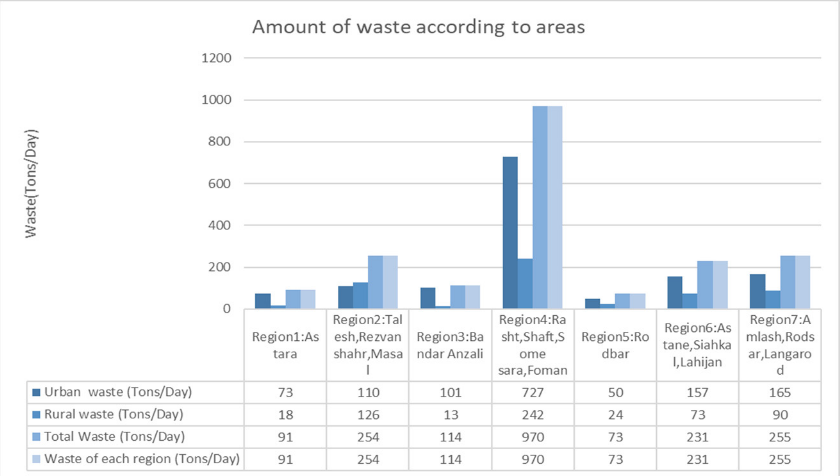
The population and waste production rate of each region are different from each other. The amount of waste production and the amount of population of each region is based on Figure 5 and 6.

The utilization of an anaerobic digester and the production of biogas is recommended as a solution for improved waste management. In addition to its management and environmental advantages, the installation of a digester also promotes the local population's economic well-being. The fixed dome digester is advised for this study among the various types of digesters. Because this type of digester has a straightforward design and operation and requires less money



	Region1:Astara	Region2:Talesh,Rezvanshahr,Masal	Region3:Bandar Anzali	Region4:Rasht,Shaft,Somesara,Foman	Region5:Rodbar	Region6:Astane,Siahkal,Lahijan	Region7:Amlash,Rodsar,Langarod
🟩 Urban population	62814	129525	118564	855550	58354	185302	193089
🟩 Rural population	28443	193634	20451	373025	36365	113392	138221
🟩 Total population	91257	323163	139016	1248561	94720	298699	331310

Fig. 5. The population of Gilan province by regions



	Region1:Astara	Region2:Talesh,Rezvanshahr,Masal	Region3:Bandar Anzali	Region4:Rasht,Shaft,Some sara,Foman	Region5:Rodbar	Region6:Astane,Siahkal,Lahijan	Region7:Amlash,Rodsar,Langarod
🟦 Urban waste (Tons/Day)	73	110	101	727	50	157	165
🟦 Rural waste (Tons/Day)	18	126	13	242	24	73	90
🟦 Total Waste (Tons/Day)	91	254	114	970	73	231	255
🟦 Waste of each region (Tons/Day)	91	254	114	970	73	231	255

Fig. 6. Amount of waste production of Gilan province by regions

for construction and maintenance than other designs. (Design, Construction and Maintenance of a Biogas Generator 2011)This sort of digester has greater performance and a longer lifespan, according to the weather in the Gilan province. Gilan province has a humid environment with an average annual humidity of 81.2% due to its proximity to the Caspian Lake, and its 20-year average rainfall is about 1100 mm per year.(Bakhshipour et al., 2021)All fixed dome digesters have 7 fixed parts. These 7 parts include inlet tank (or mixer tank), inlet pipe, digester with a dome-shaped structure as a gas tank, outlet tank, outlet pipe and gas outlet pipe, and backfilling section. Backfill protects the concrete dome from sunlight and weather conditions and plays the role of insulation. To fill this part, you should use a mixture of soil and gravel with a ratio of 70:30. Sometimes in the design of the digester, agitator and manhole inlet are also considered for repairs.(Nakagawa and Honquilada 1985b)Figure 8 and 7 show the schematics of the proposed

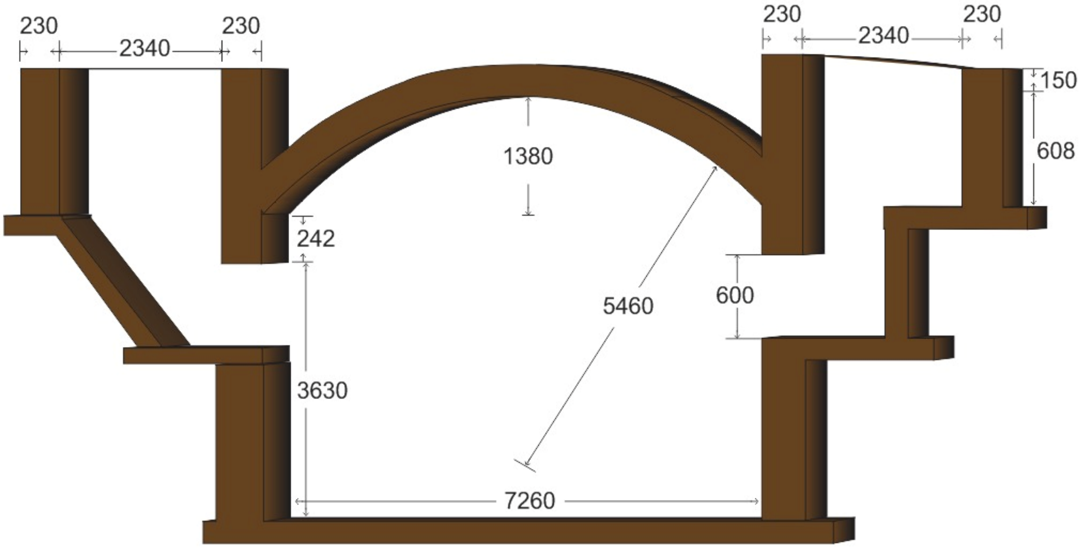


Fig. 7. Sectional view of fixed dome digester (cm)

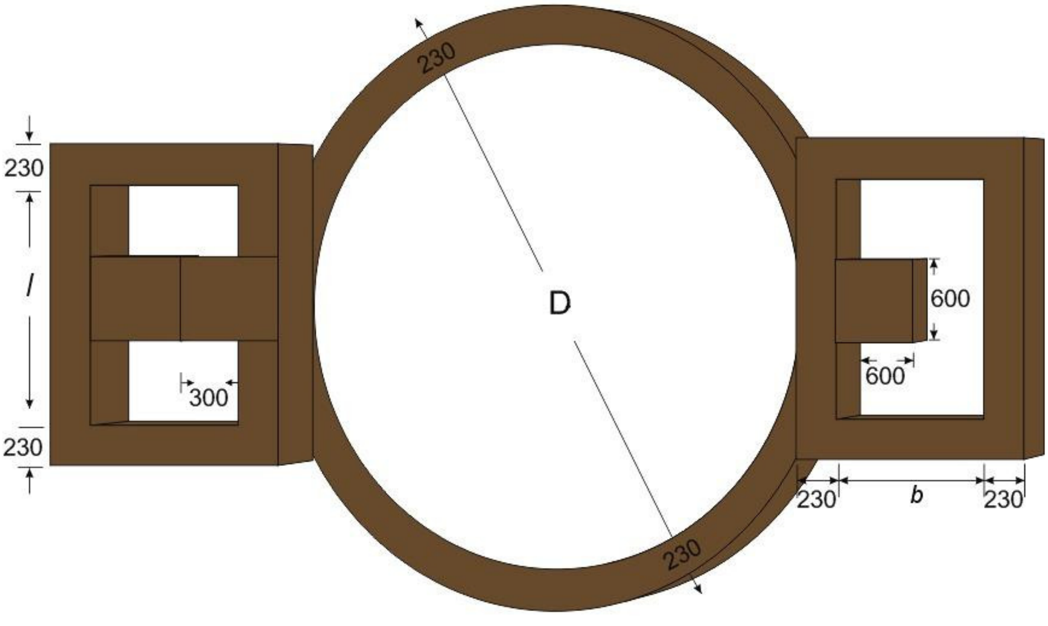


Fig. 8. Above view of fixed dome digester (cm)

fixed dome digester. The plan of faced dome drawled by Catia software.

Each region's rate of waste production is influenced by factors like weather, culture, income, and recycling levels. (Abdoli and Pazoki 2014) The statistics obtained show that the province of Gilan collects roughly 1430 tons of food waste per day. These wastes have an average humidity level of 70%. When the feed's TS value is equal to 8%, the digester operates at its peak efficiency. The digester's assumed feed (W) is equivalent to 1000 kilograms of food waste per day. The amount of daily efficiency and the pace of biogas production determine the digester's volume. The province of Gilan produces biogas from organic waste at a rate of approximately 0.04 m3/kg. (Abdoli and Pazoki 2014) For all digesters, regardless of capacity, the inlet and outlet channels that join the inlet and outlet tanks to the digester tank are typically measured as being 0.6 × 0.6 m2. The digestive system can be repaired by entering and exiting through these pathways. (Nijaguna 2006b) If we want to link the inlet and outlet tanks to the digester tank using a pipe rather than a channel, the pipe's diameter should be 8 inches, and the outlet tank's volume should be roughly one-third of the digester.(Nakagawa and Honquilada 1985b) Table 2 lists the assumptions and parameters needed for the digester's construction.(Nijaguna 2006b; Kaur et al., 2017; Sawyerr et al., 2020)

Table 2. Calculotion Of Design A Fixed Dome Digester

Item	Formula	COLCULATION	Output
G(Gas Production Rate)	G=W×K K=0.04 m^3/Kg For Iran W=1000 kg/day	G=1000kg×0.4 (m^3/kg) =40 m^3	40 m^3
Total influent	The percentage of TS that makes the influent is assumed 8% 1kg TS = 100/8kg influent TS for food waste=30%	Total influent=30%×1000×(100/8) =3750 kg	3750 kg
Water needed	Water needed to make 8% concentration of TS=Total influent-food waste	Water needed=3750-1000 =2750 kg	2750 kg
Vs(Active slurry volume)	Vs=HRT×(total influent/1000) HRT=40 days	Vs=40×(3750/1000) =150 m^3	150 m^3
H and D	D/H=2 H=(Vs/π)1/3	H=(150/π)1/3 H=3.63 m D=2×H =7.26 m	H=3.63 m D=7.26 m
Vsd (slurry displacement volume) ×this item depends upon gas usage pattern. we assume total using time of biogas is 6 hours a day. Also, the total amount of gas production is 50%.	Vsd +(6/24)G=0.5G Vsd =0.25 G	Vsd =0.25×40 =10 m^3	10 m^3
d (slurry displacement inside digester)	(π/4)×D2×d=0.25G d=0.25G/(D2×(π/4)) or d=0.25×(H/3.75)=(H/15)	d =3.63/15 =0.242 m	0.242 m
h (slurry displacement in the let & outlet chambers	h +d =0.85	h=0.85-0.242 =0.608 m	0.608 m

Continued Table 2. Calculotion Of Design A Fixed Dome Digester

Item	Formula	COLCULATION	Output
L & b (length & breadth of the inlet & outlet chambers)	2×L×b×h=Vsd=0.25×G (L=1.5×b) b =((0.25×G)/(3×h))1/2	b =((0.25×40)/(3×0.608))1/2 b=2.34 m L=1.5×2.34 =3.5 m	b = 2.34 m L=3.5 m
Vd (dome volume)	Vd=G-(0.25×G) =0.75×G	Vd=0.75×40 =30 m^3	30 m^3
dh (dome height)	Vd=(π/6)×dh×(3×(D/2)2+d2h)	dh =1.38 m	1.38 m
r (radius of the dome)	r=((D/2)2+d2h)/2dh	r=5.46 m	5.46 m
Boxes connect(inlet & outlet opening)	0.6×0.6=0.36 m^2	0.36 m^2	0.36m^2
Dimension of base of outlet box	0.75m×1m	0.75×1=0.75m^2	0.75m^2
Dimension of base of inlet box	1.05 m×1m	1.05×1m=1.05m^2	1.05 m^2
Wall thickness	0.23 m	0.23 m	0.23 m
Boxes thickness	0.115 m	0.115m	0.115 m
Upper layer thickness for curved bottoms	0.075m	0.075m	0.075m
Lower layer thickness for curved bottoms	0.115m	0.115m	0.115m
Concreting thickness	0.1m	0.1m	0.1m

After choosing the location and constructing the primary digester building, the completion of this unit will be done in 3 stages. These 3 steps are: 1. Concreting 2. Brickwork 3. Plastering and filling .(Nijaguna 2006b) There are standards for the construction and completion of the digester construction. These assumptions are equal to:

1. The amount and thickness of concreting on the bottom of the main tank of the digester, the bottom of the channels and the inlet and outlet tanks to the digester should be equal to 100 mm.

2. The wall of the digester tank should be completely bricked and the bricks should be placed in such a way that the thickness of the wall is equal to 230 mm. The wall of the entrance and exit channels to the digester should be constructed in such a way that the wall thickness is equal to 115 mm.

4. For each fixed dome digester with any capacity, the floor dimensions of the inlet channels are considered equal to 0.75 m x 1 m and the floor dimensions of the outlet channels are considered equal to 1 m x 1.05 m.

5. After the concreting stage, the brickwork stage should be done with cement sand with a ratio of 1:5.

6. The dimensions of each brick are equal to 0.23m x 0.115m x 0.075m.

Tables 5, 4, and 3 show the amount of materials required for each stage of construction completion.(Nijaguna 2006b)

By calculating the amount of required materials, you can easily calculate the required cost of the project. Of course, the calculated cost only includes the cost of materials and does not include the cost of transportation, wages of people and other costs.

In Table 6, the cost required for the preparation of materials is calculated.(Nijaguna 2006b; Sawyerr et al., 2020)

Table 3. Calculation Of The Needed Materials For Concreting

Concreting Area	**Formula**	**Calculation**	**Output**	**Needed Material For 1m^3**	**Needed Material For Final Volume**
Bottom of digester	Volume of concreting: (π/4)×(D+2×(digester wall thickness)+0.2)2×0.1 ×The digester wall thickness=0.23m	(π/4)×(7.26+2×(0.23)+0.2)2×0.1 =4.93 m^3	4.93 m^3	Cement: 0.22 m^3 (6.6 bags)	2.01 m^3 (60.3 bags)
Inlet & outlet boxes	Volume of concreting: (area of inlet box × thickness)+(area of outlet box × thickness)	(0.75×1×0.1)+(1.05×1×0.1) =0.18 m^3	0.18 m^3		
Inlet & outlet chambers	Volume of concreting: 2×(L+0.46+0.2)×(b+0.46+0.2)×0.1 Volume concreting of Deduction area : -((0.6×0.6×0.1)×(b×0.6×0.1)) Total volume=v1+v2	2×(3.5+0.46+0.2)×(2.34+0.46+0.2)×0.1 =2.5 m^3 -((0.6×0.6×0.1)+(2.34×0.6×0.1)) =0.1764 m3 Total volume=2.33 m^3	2.33 m^3	Sand(coarse): 0.44 m^3	4.02 m^3
lentils	Volume of concreting: 2×0.9×0.23×0.1	2×0.9×0.23×0.1=0.04 m^3	0.04 m^3		
Cover slabs for inlet & outlet chambers	Volume of concreting: 2×(L+0.46)×(b+0.46)×0.075	2×(3.5+0.46)×(2.34+0.46)×0.075 =1.66 m^3	1.66 m^3	Stone ballast (25 mm) :0.88 m^3	8.04 m^3
Total volume	VT=∑V1+V2+V3+V4+V5	VT=9.14 m^3	9.14 m^3		

Table 4. Calculation Of The Needed Materials For Bricks

Brick Works Area	Formula	Calculation	Output	Needed Material For 1m^3/m^2	Needed Material For Final Volume
Digester wall	Volume of concreting: (π/4)×((D+0.46)2-D2)×(H+D)	(π/4)×((7.26+0.46)2-7.262)×(3.63+7.26) =58.94 m^3	58.73 m^3	Cement: 0.05 m^3 Sand (coarse): 0.25 m^3	2.94 m^3 14.68 m^3
	Inlet &outlet opening(deduction): 2×(0.6×0.23×0.6)	2×(0.6×0.23×0.6) =0.17 m^3		Bricks: (0.23m× 0.115m× 0.075m) 500 numbers	29365 bricks
	Inlets (deduction): 2×(0.9×0.23×0.1)	2×(0.9×0.23×0.1) =0.04 m^3			
Inlet & outlet boxes	Inlet box side walls: 2×((0.4+(b+0.1))/2)×(0.6+d-0.1)	2×((0.4+(2.34+0.1))/2)×(0.6+0.242-0.1) =2.11 m^2	4.9 m^2	Cement :0.005 m^3	0.025 m^3
	Inlet box sloping wall: ((b-0.3)2+(0.6+d-0.1)2)1/2×0.6	((2.34-0.3)2+(0.6+0.242-0.1)2)1/2×0.6 =1.3 m^2		Sand(coarse): 0.025 m^3	0.123 m3
	Outlet box: 2×0.7×(0.6+d-0.1)	2×0.7×(0.6+0.242-0.1) =1.04 m^2		Bricks:50 numbers	245 bricks
	Side walls: 1×0.6×(0.6+d-0.1)	1×0.6×(0.6+0.242-0.1) =0.45 m^2			
Inlet & outlet chambers	4×(L+b+0.46)×(h+0.15)×0.23	4×(3.5+2.34+0.46)×(0.608+0.15)×0.23 =4.4 m^3	4.4 m^3	Cement: 0.05 m^3 Sand (coarse): 0.25 m^3 Bricks: (0.23m× 0.115m× 0.075m) 500 numbers	0.22 m^3 1.1 m^3 2200 bricks

Continued Table 4. Calculation Of The Needed Materials For Bricks

Brick Works Area	**Formula**	**Calculation**	**Output**	**Needed Material For 1m^3/m^2**	**Needed Material For Final Volume**
Dome construction	Area of dome: 2×π×(r+0.05)×(dh+0.05)	2×π×(5.46+0.05)×(1.38+0.05) =49.51 m^2	51.79 m^2	Cement :0.005 m3	0.26 m^3
	One layer around the dome along with the first ring: π×D×0.1	π×7.26×0.1 =2.28 m^2		Sand(coarse): 0.011 m^3	0.57 m^3
				Bricks:37 numbers	1917 bricks
Brick tiles for dome	The total area of brick tile: 2×π×(r+0.17)×(dh+0.17)	2×π×(5.46+0.17)×(1.38+0.17) =54.8 m^3	54.8 m^3	Cement :0.01 m^3	0.55 m^3
				Sand(coarse): 0.004 m^3	0.22 m^3
				Bricks:37 numbers	2028 bricks
Total needed material	Total cement:			3.99 m^3	
	Total sand:			16.693 m^3	
	Total bricks:			35755 bricks	

Table 5. Calculation Of The Needed Materials For Plastering & Filling

Plastering & Filling Area	Formula	Calculation	Output	Needed Material For 1 m^3/m^2	Needed Material For Final Volume
In the canal between dome and side wall filling	For the first ring: π×(D+0.23)×0.1×0.1	π×(7.26+0.23)×0.1×0.1 =0.235 m^3	0.242 m^3	Cement: 0.42 m^3	0.102 m^3
	In the corners of the dome: π×D×((0.025)2/2)	π×7.26×((0.025)2/2) =0.007 m^3		Sand (coarse): 0.84 m^3	0.203 m^3
In the canal between dome and side wall plastering	Dome inside: 2×π×r×dh	2×π×5.46×1.38 =47.34 m^2	52.86 m^2	Cement :0.006 m^3	0.32 m^3
	Side walls in the gas storage: π×D×d	π×7.26×0.242 =5.52 m^2		Sand(coarse): 0.012 m^3	0.64 m^3
Neat cement plaster	For dome inside: 2×π×r×dh	2×π×5.46×1.38 =47.34 m^2	52.86 m^2	Cement :0.0022 m^3	0.12 m^3
	Side walls in the gas storage: π×D×d	π×7.26×0.242 =5.52 m2			
plastering	Digester inside wall π×D×H	π×7.26×3.63 =82.8 m^2	233.8 m^2	Cement :0.004 m3 (1.2 bags)	0.94 m^3 (281 bags)
	Digester bottom: (π/4)×D^2	(π/4)×7.262 =41.4 m^3			
	Lintel bottom: 2×0.6×0.23	2×0.6×0.23 =0.28 m^2			
	Digester outside: π×(D+0.46)×0.3	π×(7.26+0.46)×0.3 =7.28 m^2			
	Over and below brick tiles: 2×π×(r+0.15)×(dh+0.15)	2×π×(5.46+0.15)×(1.38+0.15) =53.93 m^2			
	Inlet box side walls: (0.3+b)×(0.6+d)	(0.3+2.34)×(0.6+0.242) =2.22 m^2		Sand(coarse): 0.018 m^3	4.21 m^3
	Inlet box sloping wall: ((b-0.3)2+(d+0.6)2)1/2×0.6	((2.34-0.3)2+(0.242+0.6)2)1/2×0.6 =1.33 m^2			
	Inlet box bottom: 0.53×0.6	0.53×0.6 =0.32 m^2			
	Outlet box side walls: 3×0.6×(d+0.6)	3×0.6×(0.242+0.6) =1.52 m^2			

Continued Table 5. Calculation Of The Needed Materials For Plastering & Filling

Plastering & Filling Area	Formula	Calculation	Output	Needed Material For 1 m^3/m^2	Needed Material For Final Volume
	Outlet box bottom: 0.83×0.6	0.83×0.6 =0.498 m^2			
	Inlet & outlet chambers inside: 2 × 2 (L + b) × (h +0.15)	2 × 2 (3.5+2.34) × (0.608 +0.15) =17.71 m^2			
	Inlet & outlet chambers outside: 2 × (L + b +0.92) ×0.3	2×(3.5+2.34+0.92)×0.3 =4.06 m^2			
	Inlet & outlet chambers top & bottom : 2 × ((L + 0.46) (b + 0.46))	2×(3.5+0.46)×(2.34+0.46) =22.18 m^2			
	Inlet chamber bottom(Deductions): b×0.6	2.34×0.6 =1.404 m^2			
	Outlet chamber bottom(deductions): 0.6×0.6	0.6×0.6 =0.36 m^2			
	Steel ring around the base of dome: 2×π×(D+0.5)	2×π×(7.26+0.5) =48.76 m			
Miscellaneous	Chicken wire mesh : 2×π×(r+0.1)×(dh+0.1)×1.25	2×π×(5.46+0.1)×(1.38+0.1)×1.25 =64.63 m^2			
	Gl pipe for gas outlet: 0.45 m	0.45 m		--	
	Bamboos or (s) hooks for dome construction	7-8 numbers			
Others	Material for scaffolding measuring tape rope nails etc.	---			
Total needed material	Total cement:			1.482 m^3	
	Total sand:			5.053 m^3	

Table 6. Total needed material and final cost

material	Needed volume		Cost for per unit	Final cost
Cement	7.49 m^3	10.786 ton	48.87 $/ton	527.067 $
Sand	25.77 m^3	41.2835 ton	3.57 $/ton	147.383 $
Stone ballast	8.04 m^3	12.864 ton	72 $/ton	926.208 $
bricks	35755 numbers	------------	0.0873 $/number	3122.6 $
Steel ring	48.76 m	------------	0.97 $/meter	47.134 $
Chicken wire mesh	64.63 m	------------	1.67 $/meter	107.717 $
Gl pipe	0.45 m	------------	2.167 $/meter	1 $
Bamboos or (s) hooks for dome construction	7-8 numbers	------------	63.33 $ price of each	523.33 $
Total	------------	------------	-----------	5402.446 $

CONCLUSION

The growth of cities, the rise in population, the wave of immigration to Iran's northern cities, and the unchecked and unsustainable development of villages have had a significant negative impact on the environment and ecosystem. Water and soil contamination, biodiversity loss, and harm to human health due to leachate formation from improper waste management are some of the largest environmental harms. An affordable, ethical, and simple approach for handling wet wastes, which are the source of leachate, has been given in this study. A community of 2000 people has been presented with, constructed, and engineered for anaerobic digestion for the management of wet waste, and all the intricacies of its have been given , which shows that for the construction of such a system, the minimum space required... square meters and the cost of setting it up... it is estimated that the fertilizer and gas produced from it can It should be used in the development of green space and heat production and rural heating, that this design, engineering and introduction can be implemented quickly in one of the villages and with the lowest cost, the highest efficiency and the lowest environmental effects, the wet wastes of temperate and high rainfall areas can be managed.

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CONFLICT OF INTEREST

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

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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