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DETERMINATION OF GAS POTENTIAL AND URBAN SOLID WASTE MANAGEMENT IN ELAZIĞ

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ABSTRACT

Solid wastes make the most important environmental problems caused by human all over the world. In recent years, the amount of solid waste has been increasing in Elazığ day by day with rise in the population and industrialization.

The solid waste managing systems contain the methods such as proper storage, recycling, processing the solid waste by means of biological methods (compost), and disposal with thermal methods (burning, gasification, and pyrolysis). Of these methods, the proper storage is the most common one in Elazığ. By time, using up the oxygen within the wastes stored in the proper fields, the storage gas occurs as a result the decay without oxygen (anaerobic) with the help of anaerobic bacteria proliferate in this environment.

In this study, solid waste disposal methods have been investigated for storage gas by giving Elazığ example.

1 INTRODUCTION

Because of rapidly increasing population and changing living conditions, the solid wastes of which volume increase and content change set a threat to human health and environment. Solid wastes are stored improperly especially in the towns; therefore, the microbial cases effect the occurring leakage water negatively due to the gases and smell coming out of it. Every year, 5,2 million people of them 4 million children die of the diseases emerging as a result of canalization and improperly released solid wastes. The city wastes pollute the air, soil and water in a great deal. Today, an average of 2,0 – 4,0 kg garbage is produced per capita in the world [1].

Since solid wastes are produced as a result of various kinds of human activity, their content, characteristics and amount display differences. Even these values change within themselves according to the development level. But waste production, its density and component rates change in relation with development level, geographical structure, weather conditions and social conditions and from country to country and from city to city [2]-[3].

Although the environment problems were first handled in the USA in 1869, they appeared in the fast changing world agenda in the beginning of the 1970s. And they entered in our country's agenda in 1980s [4].

In order to prevent them to harm environment and human health, it has been found out that solid wastes should be recycled and made use of properly. For this reason, determining proper disposal methods is of great importance.

Stored or thrown in the fertile agriculture fields, solid wastes cause the soil and the underground water and rivers to be polluted with the leakage waters, and air to be polluted because of bad smell and gases. When changing environmental problems are together evaluated according to the cities in our country, it is observed that water pollution with 31 %, wastes with 20% and air pollution with 20 % come in the first three pollutions [5].

Economical solutions are produced for urban solid wastes throughout the world. Hence these wastes are made use. Today many researchers and practitioners have focused on solid waste methods. For this purpose, on one hand technologies for

collecting and disposal of waste are developed; on the other hand, the studies to reduce the amount of waste are in progress.

The technologies of evaluating and disposal applied in solid waste management system can be expressed as follows:

- Recycling
- Proper storage
- Thermal transformation technologies
- Burning
- Gasification
- Pyrolysis
- Biological transformation technologies
    - Aerobic composting
    - Anaerobic composting [6].

After becoming aware of the energy value of wastes, the idea to make use of the energy they contain while disposing is becoming more common. Today, there are several plants producing energy from the urban waste in developed countries. When comes to the technologies used to obtain energy from the urban solid wastes,

- Proper storage
- Burning
- Gasification
- Anaerobic decaying processes. Technologies can be seen in (Figure 1) [7]

In this study, the solid waste volumes in Elazığ, Türkiye have been analysed. While these analyses are being carried out, they have been sorted out according to the type of solid waste; and their amount has been identified. Predicted energy values of the gathered values have been found out with the help of the data obtained after the analyses and with the help of bioenergy equations. Therefore, the energy potential of solid waste volume in this region has been tried to be found out.

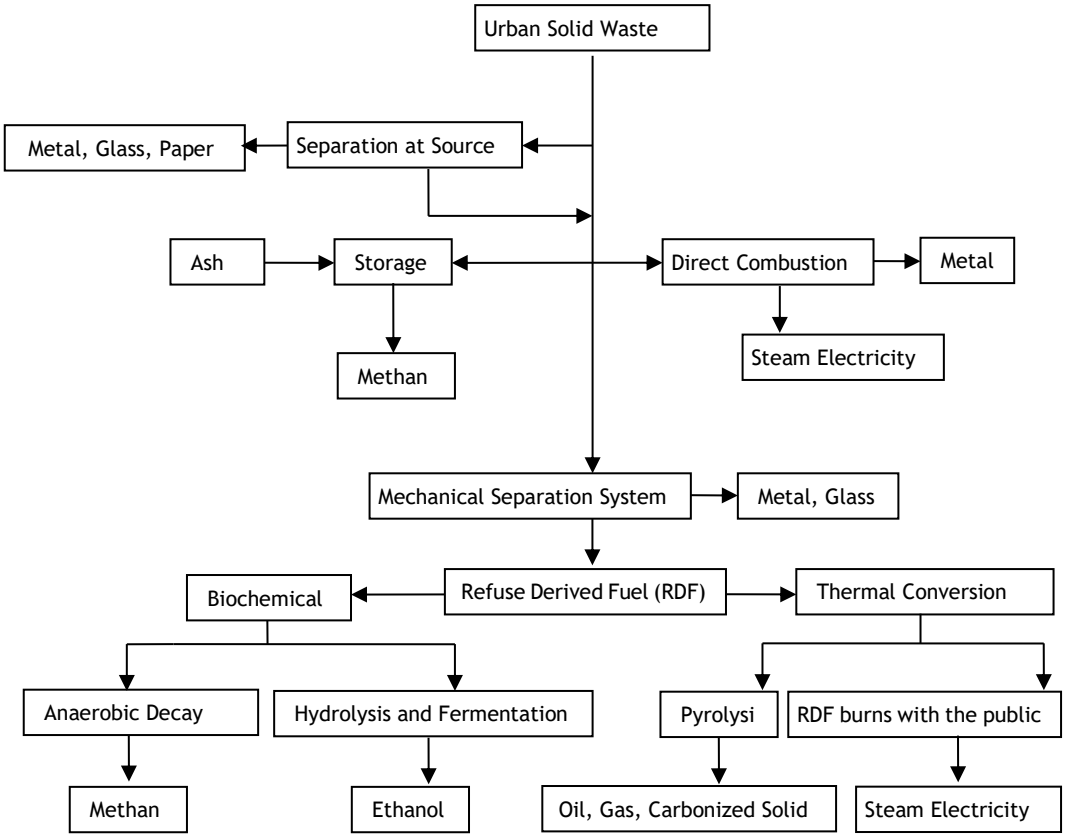

***Figure 1**. Energy production technologies of urban solid wastes [8].*

2 SOLID WASTES

Solid waste is every type of substance and material that do not contain enough liquid to be fluid and become useless as a result of living, social and economic activities of human. The solid wastes can be classified as follows according to their features [9]:

a) Organic waste
b) Inorganic waste

They can be classified as follows according to their sources:

a) Domestic wastes,
b) Industrial wastes,
c) Wastes stemming from the open areas,
d) Agricultural wastes,
e) Wastes stemming from the treatment plants,
f) Special wastes,
g) Dangerous wastes

Urban solid wastes make the biggest part of the solid wastes. The urban solid wastes are of domestic wastes, commercial and institutional wastes, park, garden and bazaar wastes, construction, demolition and excavation wastes, treatment plant wastes and hospital wastes [9].

***Table 1**. Urban solid waste sources [6].*

Settlements	Waste produced locations and activities	Solid waste types
Commercial premises	Detached dwellings, low, medium and high apartment buildings and so on.	Food waste, paper, plastic, glass and so on.
Institutions	Shops, restaurants, grocery stores, service stations and so on.	Food waste, paper, plastic, glass metal and hazardous waste
Construction and demolition	Building sites, road construction, restoration and demolition of buildings	Cardboard, food waste, paper, plastic, glass, metal, hazardous waste and special wastes
Urban activities	Parks, gardens, recreational facilities and streets	Waste and special wastes
Treatment plant and incinerator units	Waste water and industrial treatment processes	Treatment plant waste

An average of 60% of the urban solid waste is the waste coming from the houses. In connection with the urbanization ratio, these rates can change [10]. The change according to the area where urban solid wastes occur is given in (Table 2).

***Table 2**. Classification of Urban Solid Waste According to Formation Areas [11].*

Sources	Examples
Residential (Single or multi-family waste)	Newspapers, clothing, Disposable products, packaging, PET bottles and cans
Commercial (Wholesale and retail businesses, offices)	Cardboard boxes, wooden materials, office papers, disposable materials
Corporate (Schools, Hospitals, Prisons)	Resting place, cafeterias, classrooms, and medical wastes
Industrial (Packaging, Administrative Affairs)	Paperboard, plastic films, food waste, wood pallets

Generally, by years the solid waste amount that people cause is increasing. Part from these, the waste produced is directly proportional with the population of the cities (U.S). In (Table 3) waste compounds belonging to different countries have been given.

***Table 3**. Composes of solid wastes for different countries [12].*

Component	Amount of Waste Component (%)			
	Türkiye	Western Europe	U.S.	Middle East
Organics	20-90	21,3	22,6	62,3
Paper and cardboard	0,5-15	27,4	45,6	25,3
Plastic	1,5-12	3,1	2,6	5,8
Textile	0,3-5	3,5	4,5	1,4
Glass	0,3-5	9,5	6,2	1,0
Metal	0,3-5	8,5	9,1	2,8
Ash	--	19,8	7,6	--
Other	--	6,9	1,8	1,4

In parallel with rapid urbanization, changes in living conditions and increasing consuming tendencies, a constant increase in the amount of solid waste production for per capita is the matter of question. In (Table 4) the daily amount of domestic solid waste in some countries has been displayed.

***Table 4**. Daily Amount of Domestic Solid Waste per capita in Some Countries [13].*

Country	**Amount of Waste (kg / person-day)**
Türkiye	0,67
Germany	0,71
U. S.	1,4

Approximately 65 tonnes of waste are produced a day in Türkiye. This amount in our country is very changeable. While it is about 0.25 kg/per person/day in some rural areas, it rises up to 2 -3 kg/per person/day in some settlement places. In (Table 5), the solid waste amounts produced a day for per capita in some countries have been given [14].

***Table 5**. Amount of solid waste produced a day for per capita in some countries (kg) [14].*

Country	Amount of Waste (Kg / person-day)
Developed Countries	
U. S.	**2,17**
England	**1,37**
Middle Income Level Countries	
Mexico	**1,33**
Türkiye	**0,95**
Singapore	**0,87**
Low Income Level Countries	
Indonesia	**0,56**
Pakistan	**0,55**
India	**0,51**

The solid wastes the amounts of which increase each passing day are stored improperly especially in underdeveloped countries and cities, and effect human health negatively due to leakage water, microbial diseases gas and smell outgoing. Therefore, the fact that the solid wastes should be collected effectively and efficiently in the settlement places, and they should be transported, evaluated and made harmless with proper methods are the basic problems that the local governments face.

3 SOLID WASTE MANAGEMENT

As a result of potential risks related to the pollution that solid wastes make up are increasing day by day and the natural sources are gradually decreasing, solid waste management has gained a complex structure. Although a lot of definitions have been made about solid waste management, in general sense, solid waste management is determining, application and improvement of an efficient and economical serving system with the aim that all kinds of solid waste should not give any harm to soil, water and air, and they should not spoil animal and plant kingdom, natural wealth and ecological balance, and they should be collected, carried, stored and purified or disposed in the shortest time under healthy conditions [15]

An efficient solid waste management contains six basic features, such as;

- Generation of waste
- Classification, accumulating, selecting and processing in the source
- Collecting
- Transporting and transfer
- Separating, processing and transformation
- Final disposal

In (Figure 2), integrated solid waste management current diagram has been given.

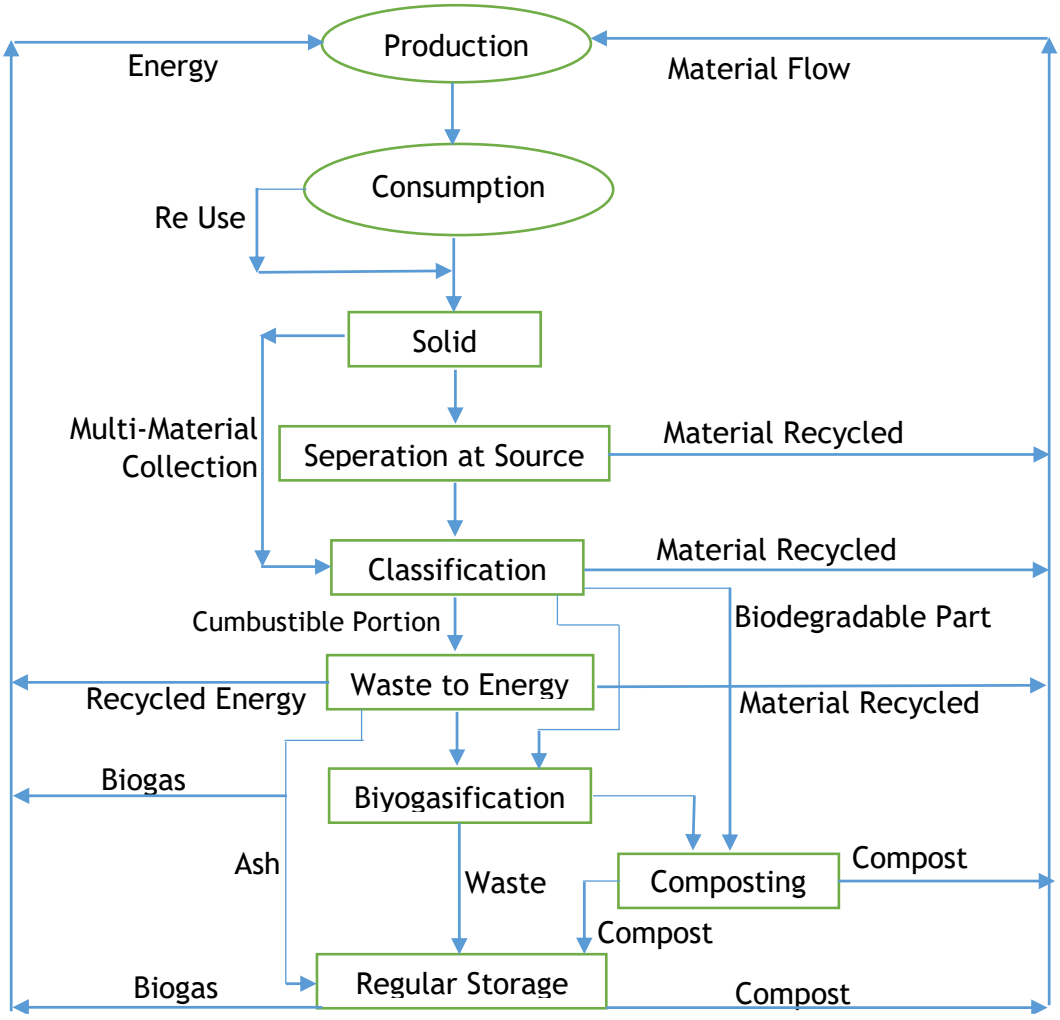

***Figure 2**. Integrated solid waste management current diagram [16].*

In the feasibility of a technically efficient solid waste management system, the following parameters should be taken into consideration:

- Determination of the present situation;
- Predictions to the future;
- Accumulation and collecting options:
- Separation, processing, transformation and final disposal [17]

The wastes should be collected and transported by means of efficient methods; after economically recyclable substance groups are taken, the rest should be converted into harmless forms using appropriate methods.

Major solid waste disposal methods used are as follows:

1) Retrieving
2) Proper storage
3) Burning
4) Composting
5) Pyrolysis

The most common methods among these are retrieving, burning, composting and proper storage. In (Table 6), the distribution of solid waste management technologies in various countries can be seen.

***Table 6**. Distribution of solid waste management technologies percentage in countries [18].*

Country	Proper Storage	Incineration	Composting	Recovery
Australia	82	2,5	----	15,5
Canada	80	8	2	10
Germany	46	36	2	16
France	45	42	10	3
Greece	100	---	---	---
Ireland	97	---	---	3
Italy	74	16	7	3
England	88	6	---	6
U. S.	74	16	2	15
Portugal	85	---	15	---
The Netherlands	45	35	5	15
Spain	64	6	17	13

The distribution of waste disposal methods applications in our country is as in the Figure. As can be seen in the figure, the commonly used method in Türkiye is wild storage method with 57.97 %. In (Table 7), the distribution application of waste disposal methods in our country has been given.

Table 7*. The distribution of waste disposal methods applications in Türkiye [19].*

Disposal Methods	Open Burning	Burial	Pour into the Stream	Uncontrolled Storage	Composting Facility	Proper Storage	Other
(%)	1,37	1,92	0,4	57,97	0,87	33,04	4,44

4 ELAZIĞ PROVINCE SOLID WASTE MANAGEMENT AND STORAGE GAS

With acceleration of migration from rural areas to the urban areas in Türkiye in recent years, Elazığ province has become one of the most populous cities in the East Anatolia Region because of rapid population growth. As in many settlement places of Türkiye, this problem has also reached to serious levels every passing day in Elazığ city centre. Collecting solid wastes, carrying them and disposing them are done efficiently, separating hospital wastes is carried out and they are stored properly.

4.1 Elazığ Population Projection

According to 2009 census, the population of Elazığ city together with provincial towns is 560.000, the city centre population is 375.000. Collecting solid wastes and transporting them are carried out by Elazığ Municipality Sanitation Department. For the resource about Elazığ solid waste collecting, Elazığ Municipality Sanitation Department data were used.

The population of Elazığ was found as 392722 in 2010 due to increase in migration and in population projection this was taken into consideration.

The population growth coefficient is calculated by means following equation:

$$P = \left(\sqrt[a]{\frac{N_y}{N_e}} - 1 \right) 100 \qquad \textbf{(1)}$$

P =Population growth coefficient

a =Duration passing between two population census (year)

N_y =New population value of the settlement place

N_e =Ex population value of the settlement place

By making use of Bank of Provinces, population growth coefficient is calculated as P=2.678 %. According to this, the next ten-year projection of Elazığ province has been found as follows.

Population calculation is done by means of following equation:

$$N_y = N_e * \left(1 + \frac{P}{100}\right)^n \quad \textbf{(2)}$$

Ny = New population value of the settlement place

Ne = Ex population value of the settlement place

P = Population growth coefficient

Target duration of the project has been determined as 10 years, and the population changes within 10 years have been calculated taking 2.678 as population growth coefficient (Table 8)

***Table 8**. Elazığ Population Projection Prediction.*

Duration (year)	Year	Population (person)
0	2010	392722
1	2011	403239
2	2012	414037
3	2013	425125
4	2014	436510
5	2015	448200
6	2016	460203
7	2017	472527
8	2018	485181
9	2019	498174
10	2020	511515

4.2 Province Solid Waste Calculation

Following parameters were taken basically in originating solid wastes related to population. Solid waste originating per capita is 1.20 kg/day. Rate of waste pressing in solid waste proper storage field is 0.65 tonnes/m^3.

Calculations made taking these parameters into consideration show that there will be 1211800 tons or 1743695 m^3 of solid waste during the 10-year period. The calculated solid waste amount is given in (Table 9) and the change in the total waste amount over the years is given in (Figure 3).

***Table 9**. Amount of Waste for the Coming Years, Depending on the Population.*

Duration (years)	Years	Population	The amount of waste per Capita (kg/person-day)	The amount of waste (tons/day)	Total (tons/year)	The amount of waste (m^3/year)	Total (m^3)
0	2010	392722	1.20	471	171915	264484	264484
1	2011	403239	1.20	483	384210	271223	535707
2	2012	414037	1.20	496	529250	278523	814230
3	2013	425125	1.20	510	710400	286384	1100614
4	2014	436510	1.20	523	901295	293684	1394298
5	2015	448200	1.20	537	1097300	301546	1695844
6	2016	460203	1.20	552	1298780	309969	2005813
7	2017	472527	1.20	567	1505735	318392	2324205
8	2018	485181	1.20	582	1718165	326815	2651020
9	2019	498174	1.20	597	1936070	335238	2986258
10	2020	511515	1.20	613	2159815	344223	3330481

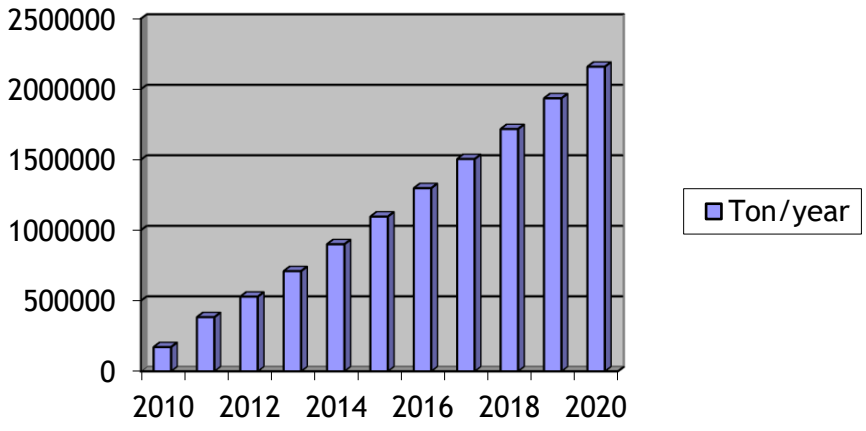

***Figure 3**. Variation of total waste amounts by years.*

4.3 Elazığ Solid Waste Proper Storage Field

The solid waste proper storage field of Elazığ is approximately 31 km far from the city centre of Elazığ. The size of the field allocated is 130 hectares. There is waste cell container in the plant. Due to the necessity that the medical wastes should be controlled, sterilization, proper storage and disposal method are used.

4.4 Elazığ Storage Gas Projection

Generating of gas in the solid waste storage field begins nearly after 2 and 6 months. Normally, it is accepted that there is one year between the dates when the solid waste is started to be stored and gas production starts.

During filling up the solid waste proper storage field, especially after completing the final cover, anaerobic reaction starts because there is no access of air into this layer. As a result of this reaction, the organic substances beak into pieces and gases such as CO_2 (carbon dioxide), H, CO, H_2S (hydrogen sulphur) and CH_4 (methane) occur. In order to dispose these gases, gas collecting chimneys are fixed in the solid waste proper storage field. Via gas collecting wells, the gases which will be collected are burned by means of portable gas burning gadgets.

In order that the gas generating potential of Elazığ solid waste storage plant can be calculated, [20] correlation has been used:

$$\mathbf{Gt} = 1{,}868 \times Co \times (0{,}014 \times T + 0{,}28) \times (1\text{-}10^{-kt}) \quad \mathbf{(1)}$$

Gt: The gas volume generated within t time per tonne (m^3/tonne)

Co: The organic carbon content in 1 tonne of waste (kg/tonne-waste). These values are for domestic wastes. They are between 170 and 220, and changes according to carbon content of the waste

T: Temperature (°C). The Temperature values for solid waste storage fields change between 30°C and 35°C.

k: Reduction fixed value. This value is taken as 0,035 – 0,04 for decaying of the organic substances in solid waste proper storage fields for 10-25 years.

t: Duration (year)

Co: 170 kg/ton-waste

T: 30°C

k: is taken as 0,035.

Stored gas projection has been done for the acceptance that the solid waste will be properly stored between the years 2010 and 2020. The calculated gas generating potential is given in (Table 10) and stored gas according to the years is given in (Figure 4).

***Table 10**. Gas Potential of Waste Storage Area for the Years.*

Year	Annual waste ton/year	Total waste ton/year	Total Gas m^3/hour	Gas m^3/year	Total Gas m^3/year
2010	171915	171915	337,7806	2958958	2958958
2011	176295	384210	658,0132	5764196	14198094
2012	181040	529250	962,7738	8433898,49	25182936
2013	186150	710400	1253,977	10984841,5	36167777
2014	190895	901295	1531,956	13419938	49587715
2015	196005	1097300	1798,997	15759215	65346930
2016	201480	1298780	2055,225	18003773	83350703
2017	206955	1505735	2302,72	20171824	103522527
2018	212430	1718165	2541,808	22266241	125788768
2019	217905	1936070	2773,142	24292725	150081493
2020	223745	2159815	2558,422	22411774	172493267
2021			2360,327	20676462	193169729
2022			2177,57	19075513	212245242
2023			2008,964	17598524	229843766

In the solid waste disposal plant of Elazığ, the gas can be released to atmosphere after it has been collected (passive system); or, can be burned after it has been collected under control (active system). Disposing the collected gas by burning so eliminating the potential hazard or preventing the danger as much as possible is very important in terms of environment.

As burning options, central burning unit or portable independent burning units are used. For a central burning unit, installing a gas collecting network from gas

collecting wells to the burning unit and establish interval collectors in specific parts are necessary.

The working principle of the burning unit is based on the principle of collecting gas by means of collectors and collecting wells by creating pressure difference and then burning it.

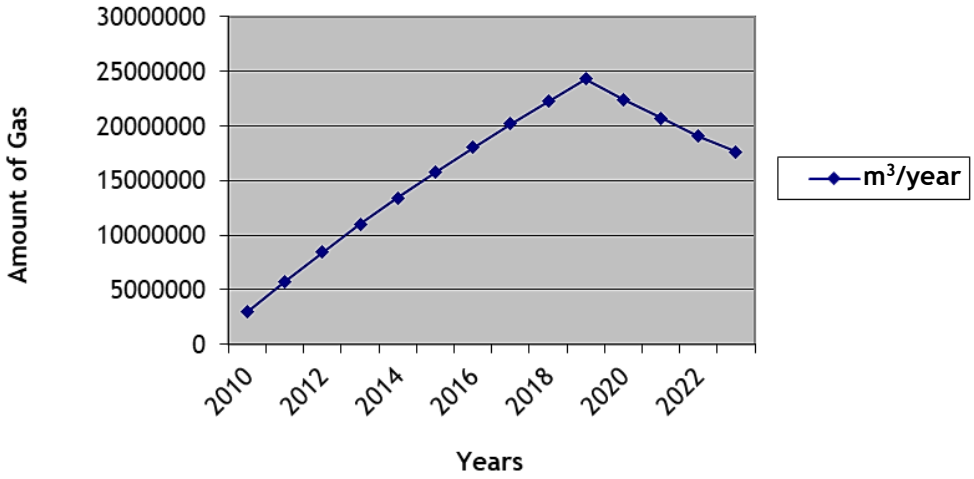

***Figure 4**. Change of Storage Gas According to Years.*

5 RESULT

The garbage gas occurring in airless means in the solid waste proper storage fields should certainly be disposed by burning or with the aim of energy production. For this, it is important that an active stored gas system should be established in garbage fields. Every kind of activity towards eliminating the negative effects of stored gas on human health and environment or decreasing its effects is considered in the context of this method.

As seen in the activities in proper storage fields of Elazığ province, it is possible to eliminate the negative effects of storage gas on environment and human health besides making the generated gas economic achievement by utilizing it. Under all these conditions, and as in the example of Elazığ, it has turned out that storage gas management is very important and necessary.

The electric potential of storage gas generated in the proper storage fields has an important potential from the perspective of energy obtaining. Therefore, it

is essential that the local governments search the gas generation in the storage fields and electric production potential and provide contribution to economy.

Taking into account the capacity and emission output of the landfill, contribution to the economy can be made by using the appropriate system (using an internal combustion engine, gas turbine or steam turbine) to generate electricity.

Conflict of Interest

There is no conflict of interest between the authors.

Authors contributions

Halit Lutfi YÜCEL collected the data and evaluated it. Cengiz YILDIZ conceptualized the research. Zeki ARGUNHAN wrote the research article. Finally, Cengiz YILDIZ corrected the mistakes in the article.

Statement of Research and Publication Ethics

The study is complied with research and publication ethics.

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