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Greenhouse Gas Emissions Reduction through a Biogas Plant: A Case Study of Waste Management Systems at FEKA Dairy Farm

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***Abstract*—There are millions of tons of animal waste being produced every year and its disposal is a major problem. A biogas plant with an Anaerobic Digester (AD) nimal waste into vast quantities of methane, whi is a highly promising technology for converting ach may be directly used as an energy source. However, the full benefits of AD have not still been realized in Iran because of the perceived costs involved. To this end, this paper describes AD as an alternative innovative technical approach for animal waste biogas program by using sewage sludge as a raw material. The methane collected is to be used for generating electricity for operating dairy farm equipment. Additionally, the project will reduce greenhouse gas emissions (GHG) and furthermore, it will improve rural environment conditions.**

The objectives of the present paper are:

- **To express the effectiveness of the deep Anaerobic Digester (AD) for a biogas project as a cost-effective means of waste minimization and energy production;**
- **To illustrate and explain GHG reduction criteria for optimal performance of AD;**
- **To explain the benefits of anaerobic digesters for farmers, industry and the general public.**

In order to achieve these objectives, a demonstration of the biogas project at FEKA Dairy near the city of Isfahan, Iran, is described and explained.

Keywords: biogas, anaerobic digester, methane production, dairy farm, animal waste management, greenhouse gas emission.

I. INTRODUCTION

Industrialization in agriculture is an emerging system which is expected to be highly competitive in global markets, since it is more efficient, more responsive to consumer demands, and less receptive to environment pollution. An increase in agricultural industrialization near urban areas, combined with a population explosion in major metropolitan cities in many Iranian provinces has significantly affected the amount of animal waste generated from livestock farms, which is considered an important factor that increases generation of greenhouse gases. The development of biogas projects solves energy problems as well as environmental pollution in Iran.

As a result of this technology, various studies have been conducted to maximize the use of the products of biogas technology. In this study, we focused on industrialization of agriculture in dairy farms as an important variable in generation of GHG. We have also emphasized an important determining factor in significant greenhouse gases associated with air and water contamination, which has caused many dairy farms to take into consideration new plans for manure management in dairy farm projects.

Iran is home to about 1000 dairy farms and the resulting manure is a significant source of methane, a particularly potent GHG with a global warming with a potential 21 times higher than carbon dioxide (CO_2).

Capturing methane through anaerobic digesters of manure allows for its use as an alternative to natural gas in combustion power production, specifically electricity generation.

By installing an anaerobic digester system, in a 7000-cow dairy farm near Isfahan city, greenhouse gas emissions will be reduced as well as resulting in a 99% reduction of global warming potential (GWP). The dairy waste management system at the farm incorporates an AD system that produces biogas and electricity. Anaerobic digesters convert the energy stored in organic materials present in manure into biogas. Biogas can then be fed directly into a gas-fired combustion turbine. Combustion of biogas converts the energy stored in the bonds of the molecules of the methane contained in the biogas into mechanical energy as it spins a turbine. The mechanical energy produced by biogas combustion in an engine, spins a turbine that produces electricity. [5,7]

The present study is to demonstrate innovative technical approaches for animal waste biogas project by using manure as a raw material. The project will reduce the greenhouse gas emissions and, furthermore, will improve rural environment conditions. [2]

The paper is structured into an introduction, materials and methods, results, discussions, and conclusion. The introduction section provides an adequate motivation for the study and stresses the importance of biogas production on dairy farms and focuses on the biogas digesters as a value-adding economic activity in agro-enterprise in Iran.

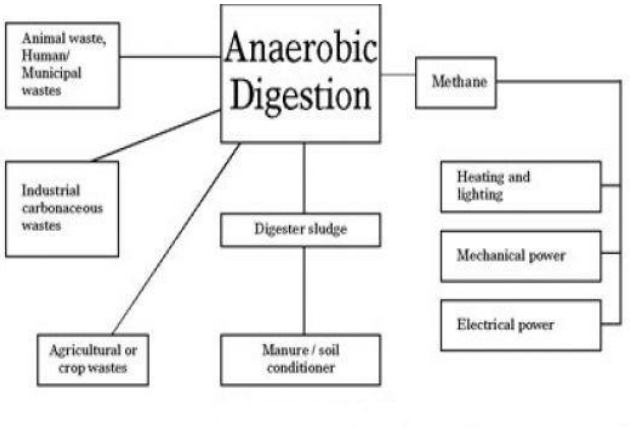

Figure 1. Schematic diagram of the Anaerobic Digestion system

TABLE I. ANALYSIS OF THE MANURE

Parameter	Feb. 2010	
	Value	*Unit*
PH	7.4	mg/l
COD	139	mg/l
BOD	830	mg/l
SO_4	455	mg/l
NO_3	938	mg/l
TVS	62	Kg/m^3
TS in feedstock	16	%
Flow Rate	350	m^3/day

The materials and methods section presents the approach utilized in the production of biogas. The results section presents the analysis obtained from measurements. The section on discussion elaborates on the results and reveals the important gap that the current study fills and provides the necessary support to justify investment of energy and resources into the biogas projects. The conclusion section presents concluding remarks on the study.

II. MATERIALS AND METHODS

This study was conducted in June 2010 at FEKA dairy farm near the city of Isfahan. The materials and methods utilized in this experiment are explained as follows:

1. The analysis and quality of the manure which would be the feedstock for anaerobic digesters for biogas production (Table 1) [10];
2. Average composition of biogas (Table 3) [6];
3. Electricity estimation parameters;
4. GHG emissions from power plants in Iran(Table2) [1].

In this study, we also review the current scenario of manure treatment at FEKA dairy farm which was determined by visiting the farm and obtaining the technical report from the engineers on site. Each day the manure is collected from the barns and they are put in the manure depot in the form of piles.

They are kept there about 3 or 4 months and after this period, distributed in thin layers with a loader and air- dried and then sold as fertilizer. The whole other waste including animal manure, waste issued from the dairy farm's milking department, barn, and others are directed by special canals to Lagoon 1. Solid waste will be deposited there and an important portion of waste liquid in this lagoon will be vaporized and the remaining portion is directed by a canal to Lagoon 2. The whole waste (solid and liquid) is kept in Lagoon 1 for about one year.

Uncontrolled anaerobic digestion happens naturally in both lagoons and it is the main source of GHG emissions and also should be added that there is no discharge, output, or mixture system in these lagoons.

The waste (mostly liquid) from Lagoon 2 is directed to the Upflow Anaerobic Sludge Blanket reactor (UASB). This reactor does not have any gas collection system and digests the most of the contaminants. Hence, the output waste from this reactor is led to the aerobic pool in which air is applied at the bottom where the aerobic digestion happens. Also, there is a recycle flow in this part, in which the sludge is circulated through the aerobic digestion cycle in the pool until it is purified. The output of this system is purified water and is used for watering the plants in the area.

The estimation of GHG Emissions (especially methane) from the proposed biogas plant was investigated and the potential of electricity production was calculated. Currently the electricity,

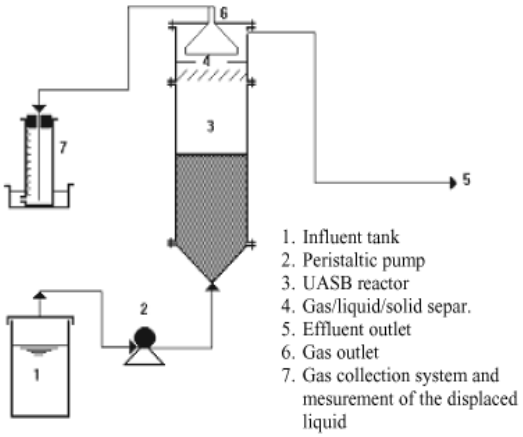

Figure 2. Schematic diagram of the UASB reaction system

which is consumed by FEKA dairy farm, is from the grid using fossil fuel. Thus by producing electricity from such a green source, there will be a huge reduction in greenhouse gas emissions both from the manure management system, and also reliance on electricity from the grid. [9,10]

III. Results and Discussion

From the data obtained by FEKA dairy farm, the estimated reduction of GHG emissions was calculated within the biogas project via the technology of anaerobic digestion as follows:

- The project will result in significant reduction in GHG emissions;
- The project will make use of methane rich biogas for producing electricity;
- The project will act as a clean technology which could be used as a model in dairy farms in other regions of Iran.
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A. Estimation of GHG Emissions

The manure from FEKA dairy farm is kept in lagoons and also in manure depot in the form of piles near the farm. The way of keeping manure has consequences of producing the potential GHG emissions, particularly methane. With the installation of the biogas plant, the GHG emissions will be reduced.

TABLE II. GHG Emissions from Power plants in Iran depending on its kind in 2005 Unit: gr/KWh

Type of power plant	CO_2
Steam Turbine	621.536
Gas Turbine	787.056
Combined Cycle	472.834
Diesel	778.162
Hydro	6.595
Average	560.249

The average amount of biogas produced from the total volatile solid (TVS) of the cow manure is 0.2 m^3/ kg TVS [3]. The production of total volatile solids at FEKA dairy is 21,700 kg/day. Equation (1) is the feedstock for anaerobic digesters for producing of biogas:

$$\text{Production} = \text{flow rate} * \quad . \qquad (1)$$

The potential of biogas production in one year will be obtained by using equation (2):

$$\text{Biogas/year} = \text{production} * 0.2 * 365 \qquad (2)$$

The biogas production was calculated to be 1,584,100 m^3 per year. By assuming that the average methane percentage in biogas is about 57.5%, the methane production per year will be 902,937 m^3/year. [6,8] Considering that the density of methane is 0.717 kg / m^3 (gas, 0°C), the methane production per year will be 647,405 kg/year or 647 tons per year and is equivalent to 13,587 tons CO2 per year (methane is 21 times more potent than CO2). This methane can be the best source for electricity production in the biogas plant. Furthermore, we should take into consideration that more than 80 percent of electricity production is currently from fossil fuels in Iran, which is significantly carbon intensive and is one of the main sources of GHG emissions. If we use this potential to produce electricity from such sources, then GHG emissions will be reduced considerably in Iran. [4]

TABLE III. Average composition of biogas

Gases	Percentage %
Methane (CH_4)	40-75
Carbon Dioxide (CO_2)	25-40
Nitrogen (N)	0.5-2.5
Oxygen	0.1-1
Hydrogen Sulphide (H_2S)	0.1-0.5
Carbon Monoxide (CO)	0.1-0.5
Hydrogen (H)	1-3

Using the proposed biogas project with the technology of anaerobic digester system, a huge amount of methane gas can be used for electricity production. Assuming that the methane heating value is about 37.78 MJ/ m^3 [6] and considering the conversion factor of 1KWh= 3.6 MJ, then the capacity of electricity generation will be 1.1 MW.

Assuming that the average emissions from using fossil fuels for electricity production in Iran is 560.249 gr/KWh (Table 2)[1], the CO_2 reduction in emissions will be 5308.820 tons of CO_2/year.

B. Total Emission Reduction Scenarios

Considering the biogas plant in FEKA dairy farm, there is a potential reduction in GHG emission from the following parts:

- Emission reduction by purging the natural anaerobic digestion of the manure in the lagoons;

- The 1.1 MW potential of electricity production from green sources instead of fossil fuels, so the consumption of fossil fuels will be reduced and there will be a GHG emissions reduction.

It is important to recognize that the emission reduction from the first part is 13,587 tons of CO2/year and from the second part is 5308.820; thus the total emission reduction will be 18895.820 tons of CO2 per year.

IV. Conclusion

The current study addressed animal waste management and engineering aspects of alternative sources of energy production, with an emphasis on biogas as a highly promising technology for converting animal waste into vast quantities of methane, which may be used directly as an energy source through utilization of animal manure for ensuring environmental safety. Biogas development through anaerobic digester (AD) would influence the activities of agricultural, water, soil, and electrical sectors more in the future as the need for animal waste utilization, management, and using sustainable energies increase.

As with any development, the sustainable use of animal manure resources would not be without difficulties; but, it would open up an opportunity for technological developments in Iran.

Biogas has an important role in society's drive for sustainable development. In addition, the sludge as a raw material involved in its production tends to be derived from renewable resources.

Environmental safety and sustainable development through animal waste utilization, aim to ensure that the development needs of the present do not compromise the needs of future generations in Iran. It is also important to emphasize that in order for biogas utilization to make a meaningful impact on developing countries like Iran, suitable biomass processes should be developed on a much wider scale; Iran should also begin to pull their meager resources and industrial expertise in a cooperative and integrated manner and improve activities suitable for the biogas dairy farm-scale applications.

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