



Review article

Valorization of Household Waste via Biogas Production in Algeria since 1938: Inventory and Perspectives ¹

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Abstract

Energy is an important factor in Algerian's economy, the recent Algerian's economy crisis is due to the fall of the oil incomes of 70% in less than two years, which made the country lose half of its external receipts and causing an important deficit of its trade balance. The fossil fuel reserves will not last eternally (some 40 to 50 years) and the human activity causes a significant change of the climate, which has actually important repercussions. The need to find an alternative and renewable source of energy is becoming increasingly important for the sustainable development. However, Algeria is a country rich in solar and biomass layer; according to the National Waste Agency, more than 28,219 tones of municipal solid waste are generated per day. Energetic valorization of municipal solid waste (MSW) seems to be an alternative solution for sustainable development of Algeria, which the biogas constitutes a considerable source of renewable energy. This paper presents an overview for the status of this technology in Algeria including the increasing of the interest in methanization since 1938. Also in this study, is referred the first experience of Tamanrasset (southern of Algeria) in the field of biogas production.

Keywords: Biogas, Methane, Municipal Solid Waste, Renewable Energies, Methanization, Valorization.

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INTRODUCTION

Algeria has created a green momentum by launching an ambitious program to develop renewable energies and promote energy efficiency. This program leans on a strategy focused on developing and expanding the use of inexhaustible resources, such as solar energy in order to diversify energy sources and prepares Algeria of tomorrow. Through combining initiatives and the acquisition of knowledge, Algeria is engaged in a new age of sustainable energy use. The program consists of installing up to 22000 MW of power generating capacity from renewable sources between 2011 and 2030, of which 12000 MW will be intended to meet the domestic electricity demand and 10 000 MW destined for export. This last option depends on the availability of a demand that is ensured on the long term by reliable partners as well as on attractive external funding. In this program, renewable energies are at the heart of Algeria's energy and economic policies: It is expected that about 40% of electricity produced for domestic consumption will be from renewable energy sources by 2030. Algeria is indeed aiming to be a major actor in the production of electricity from solar photovoltaic and solar power, which will be drivers of sustainable economic development to promote a new model of growth. The national potential for renewable energy is strongly dominated by solar and biomass energies. Algeria considers these sources of energy as an opportunity and a lever for economic and social development, particularly through the establishment of wealth and job-creating industries. The potential for wind, geothermal and hydropower energies is comparatively very small. This does not, however, preclude the launch of several wind farm development projects and the implementation of experimental projects in geothermal energy (Ministry of Energy and Mines, 2011).

In this paper we interest to the technology of biogas, which consists in managing rationally polluting and unhealthy waste, producing energy with lower costs for cooking, heating and lighting, as well as the production of residues being able to be used for the fertilization of the agricultural or forestry lands. Biogas seems consequently an economic solution, decentralized and ecological for pollution's problems, through providing energy autonomy and sustainable development to the isolated regions and wedged as the city of Tamanrasset.

Solar energy potential in Algeria

Due to its geographical location, Algeria holds one of the highest solar potentials in the world. It is valued at more than 3300 hours of sunshine per year and 05 KWh of daily energy received on a horizontal surface of 01 m² on most of the country (Sonalgaz, 2008). The climate is largely favorable for solar energy exploitation. The objective of the strategy for developing renewable energies in Algeria was reaching to achieve, by 2015 a share of these energies in the national electricity balance that would be 6%. The total solar irradiation of the city of Tamanrasset presented in figure 2, is measured and predicted by using the model "Third order Angström type correlation" (Benkhelifa, 2012).

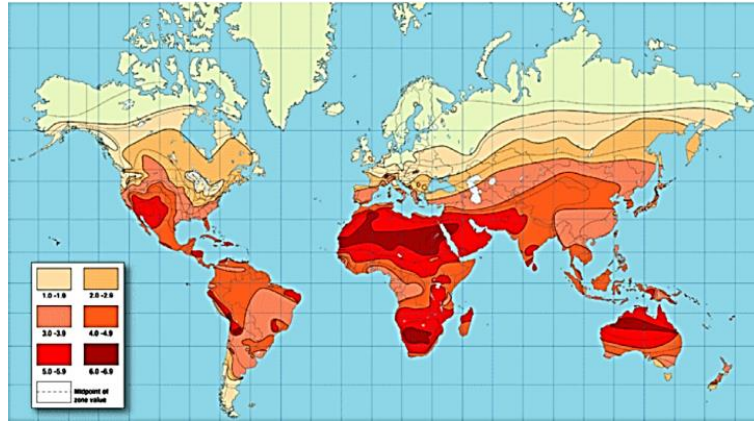


Figure 1. Solar insolation Map of the World (Adel, 2012)

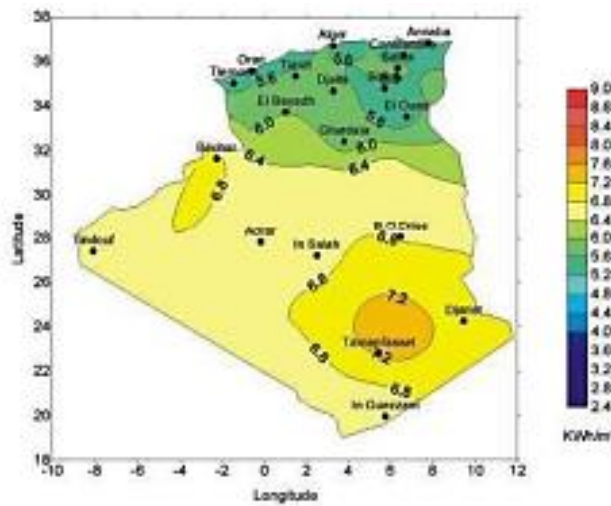


Figure 2. Annual average of the total solar irradiation received on the latitude of the site (Nia et al., 2013)

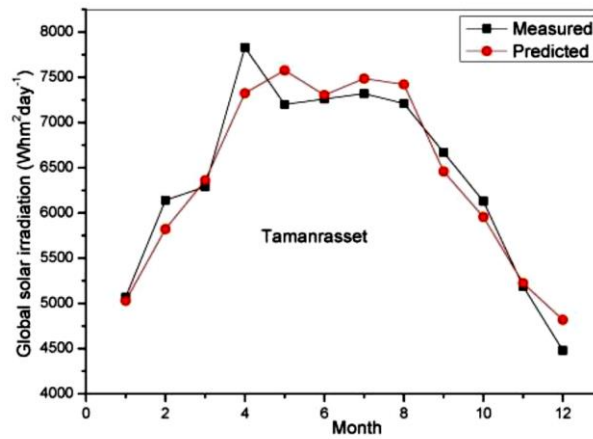


Figure 3. Global solar irradiation measured and predicted with the model “Third order Angström type correlation” for Tamanrasset city (Benkhelifa, 2012)

Since the graphic of figure 3 of (Benkhelifa, 2012), the values of total solar irradiation measured and predicted for the city of Tamanrasset are in conformity. The coefficient of R^2 is higher than 0.91 and the irradiation solar peak occurs from May until July.

Situation of municipal solid waste in Algeria

The management of solid waste in Algeria proves to be a huge problem considering the enormous quantity of household wastes produced each year through the Algerian territory. According to the National Waste Agency (AND), Algeria produces 10.3 million tones of MSW each year or 28,219 tones per day, with a collection coverage of 85% in urban areas, 60% in rural areas, a rate of 0.9 kg/inhabitant/day for urban zones and 0.6 kg/inhabitant/ day for rural zones.

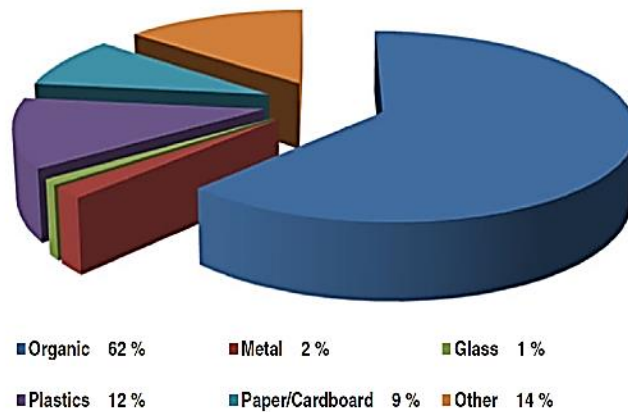


Figure 4. MSW composition in Algeria (Gourine, 2010)

Municipal solid waste management in Algeria

The process of solid waste management and its energetic valorization are based on the classification of solid waste according to their composition, its categories and physicochemical characteristics. Currently, the elimination of produced waste is the solution applied to 97% in Algeria, which the solid waste is treated as follows: on a side disposed in open dumps (57%), eliminated by incineration in the open air in public dumps or municipal uncontrolled ones (30%), and controlled dumps and landfill (10%). On the other side, the quantities destined for recovery are too low: only 2% for recycling and 1% for composting (Boukelia and Mecibah, 2012).

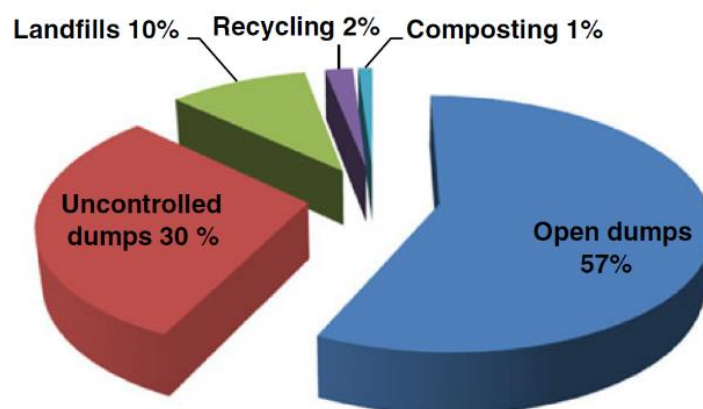


Figure 5. MSW management in Algeria (Gourine, 2010)

Involvement of the production of biogas to sustainable development of Algeria

Methanization is an effective mode of processing organic waste, economic and easily exploitable. This process reduces the recourse to fossil energies in the areas where the installation of natural gas and electricity is very expensive, as well as the production of a clean energy, which is biogas. In addition, this process contributes to the depollution of the organic loads, without forgetting another advantage and not the least: the production of rich manures, which can be used as an organic soil conditioner on agricultural ground poor in organic matter and for the launching of programs of afforestation intended to the reconstitution of the forest heritage. Simply, it would be necessary to target the substrates and the sites most adapted for the installation of digesters allowing a production and an optimal exploitation of biogas in Algeria.

Increasing of the interest in biogas in Algeria

Algeria is firmly committed to the promotion of renewable energy in order to provide comprehensive and sustainable solutions to environmental challenges and to the problems regarding the conservation of the energy resources of fossil origin. Algeria also plans to install some experimental size units to test the various technologies in renewable energies such as biomass, geothermal energy and desalination of brackish water.

In Algeria, the first achievements of biodigestion were carried out about the end of the Thirties, under the impulse of two teachers of the National school of agriculture of Algiers (El Harrach), Isman and Ducellier, which deposited a patent in 1938 in the United States about a system for producing a pulsating circulation in apparatus containing gas-evolving products (Isman and Ducellier, 1939). That work has been considered as the beginning of the biogas production mastery not only in Algeria but also in the whole world.

In addition, they constructed the first digester (Fig. 6). Based on their patent, many agricultural installations were equipped with gas digesters of manure, and that various equipment of valorization of biogas had developed.

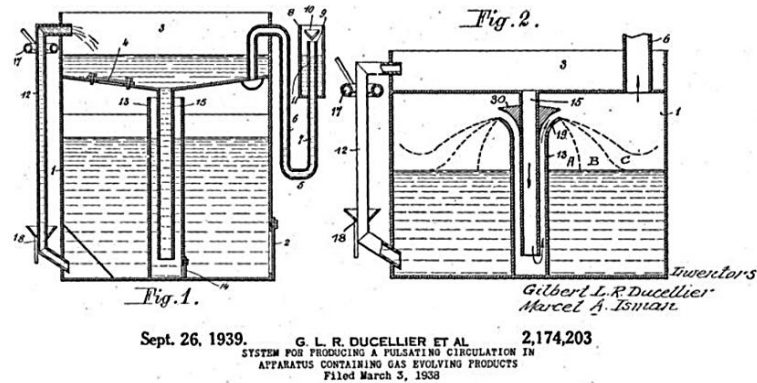
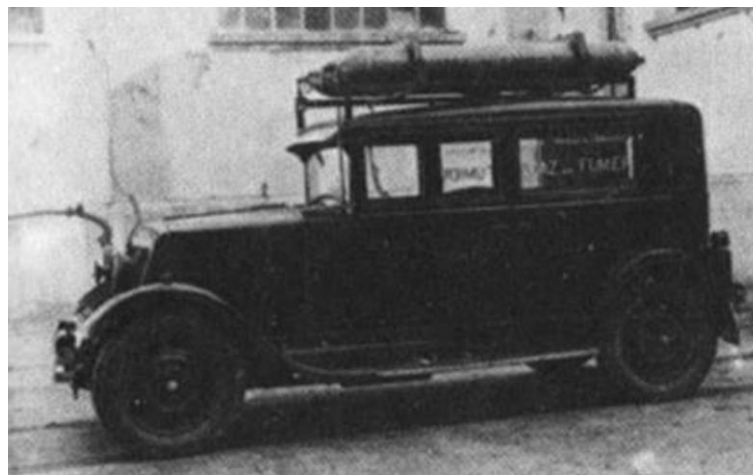


Figure 6. The first digester constructed in Algeria (Isman and Ducellier, 1939)



La première voiture expérimentale de l'Institut agricole d'Algérie.

Figure 7. The first experimental car with biogas in Algeria (Adler, 2015)

In 1948, and in Algeria, the first experimental car with biogas at Africa level (Fig. 7). In 1949, an engine was developed of 08 tanks of 40 m³, supplied with 260 tons of manure (05 cattle, 12 horses and 25 pigs), and production of almost 30,000 m³ a year of biomethane until The Sixties (Adler, 2015). Biogas was developed in kitchen of boarding schools (200 pupils), for the needs of the laboratory and 02 tractors.

After the discovery of less expensive fuels at the end of the Forties, the activities in the field of bio methanization decreased very quickly. A little interest was given to this technology despite the

important resources and the successful applications that have been made by the National Institute of Agronomy (El Harrach) and the CDER, through the establishment of two experimental plants, in Bechar and Ben Aknoun, in 1986 and in 2001, for the study of biogas production from cow dung. Since, very few digesters were developed. However, we must note the efforts of the Algerian government in these last years to develop this technology by upgrading the landfill of Ouled Fayet, which has been put into operation in 2011 (Tabet Aoul, 2011). The project's main objective is the capture of the landfill's gas, which contains 50% of methane (CH₄); the expected amount of emission reduction is 83,000 tones equivalent CO₂/year.

In addition to biomass, power projects are at the feasibility study stage such as the Sonelgaz's biomass power project in the Oued Smar site, which has an installed capacity of 02 MW that can reach a peak of 06 MW from the discharge of this site, and the energy recovery plant of biogas generated in the landfill of Batna. The sewage treatment plant of wastewater of Baraki, equipped with sophisticated processes, was put on test since the month of January 2007 with capacities for treatment of 250,000 m³ a year. Currently in Algeria, it is one of the rare stations to make function its boilers by its own biogas (Zemmouri, 2011).

Academic studies on biogas in Algeria

Since the end of the year 2001, this sector of bioenergetic production is revitalized again with Biomass Division for the innumerable advantages, which it has. The conception and the installation of an experimental digester with a capacity of 800 liters (Fig. 8). Using cow-dung manure, the digester allowed producing 26,898 m³ of biogas during 77 days. The average composition of produced biogas is 61% of methane and 35, 65% of carbon dioxide (Igoud, 2002).



Figure 8. Experimental dispositive (Igoud, 2002)

In 2007, S. Kalloum (Kalloum et al., 2007) studied the anaerobic digestion of household wastes (waste of kitchen) and more particularly the influence of the pH on the biogas yield. The got results made it possible to show the possibility of producing a significant amount of flammable biogas for a

short time for the digester with adjusted pH. In the same year, Hadri (Hadri et al., 2007) constructed and realized a solar digester at the Research Unit in Renewable Energies in Saharan Medium of Adrar (Fig. 9). In this work the digester having a capacity of 11 liters, which the lid is a solar panel being used to supply the digester in calorific energy necessary to maintain a temperature favorable to the methanization.

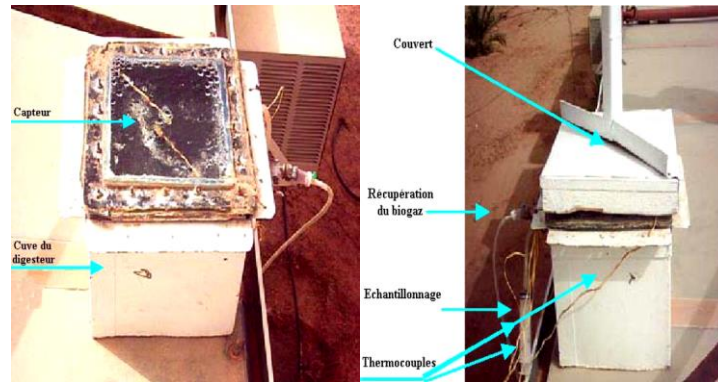


Figure 9. Solar digester of batch type without and with lid (Hadri et al., 2007)

In 2008, Nuri Azbara (Azbara et al., 2008) investigated the feasibility of using chemical pretreatment to improve the anaerobic biological degradation of industrial effluents containing high concentrations of phenolic compounds.

In 2009, Derbal (Derbal et al., 2009) developed an anaerobic digestion model no. 1, and model of international water association was applied to a full-scale anaerobic co-digestion process for the treatment of the organic fraction of municipal solid waste along with activated sludge wastes originating from a municipal wastewater treatment plant. This operation was carried out in a digester of 2000 m³ in volume. The aim of this study is to compare the results obtained from the simulation with the experimental values.

In 2012, Abderezzak (Abderezzak et al., 2012) developed an Excel-based spreadsheet and database program with visual basic that can help to find the optimal scenario to valorize the biogas. Finally, this scenario chosen must take into account social and environmental impacts. Bensmail and Touzi (L. Bensmail and A. Touzi, 2012) in turn, interested to the energetic valorization of the biomass, especially to the contribution of the biogas production to sustainable development. In the same year, a research realized in Adrar by Tahri (Tahri et al., 2012) consists in studying the production of biogas by codigestion of organic waste of slaughterhouse and poultry.

In 2014, Kalloum (S. Kalloum et al., 2014) works on the stability and the progress of the reaction from solid substrate to biogas as a final product, by the installation of batch digestion experiments. The substrate chosen in this study was slaughterhouse waste from Adrar city (southwest of Algeria). The inoculation was made by sludge issued from wastewater treatment plant. Maamri and Amrani (S.

Maamri and M. Amrani, 2014) in turn, studied thermophilic anaerobic digestion of waste activated sludge (WAS) using cattle dung inoculums. The results showed that WAS mixed with cow dung is an effective feedstock for biogas production, giving a high cumulative biogas yield. The simpling of WAS was done in the urban wastewater treatment plants in Boumerdes, Algeria. In addition, Djaafri (M. Djaafri et al., 2014) interested in improving the efficiency of biogas production with readily biodegradable substrates. The substrate chosen for this study consists of organic waste, high in sugar and cooked foods rich in starch issued from African university campus in Adrar city.

In 2015, Fedailaine (M. Fedailaine et al., 2015) studied the modeling of bio-kinetics of anaerobic digestion on several aspects such as microbial activity, substrate degradation and methane production. For this, they developed a mathematical model based on mass balances on biomass, the organic substrate and biogas. Siboukeur (H. Siboukeur et al., 2015) have made, in the same year, a microbiological study of the anaerobic digestion of sludge from the purifying plant wastewater from the city of Touggourt, which is southeast of Algeria. Ghouali (A. Ghouali et al., 2015) presented a study on an optimal control law policy for maximizing biogas production of anaerobic digesters. In addition, Mebarki (B. Mebarki et al., 2015) developed a theoretical estimation of the production of biogas from the landfill of Batna city (Algeria) and its electrical conversion by a SOFC.

In 2016, Mameria (A. Mameria et al., 2016) have made a numerical investigation of counter-flow diffusion flame of biogas–hydrogen blends: Effects of biogas composition, hydrogen enrichment and scalar dissipation rate on flame structure and emissions. This study addresses numerically the influence of several operating conditions on the structure and NO emissions of a biogas diffusion flame.

In 2017, Dahou and Touzi (M.A. Dahou and A. Touzi, 2017) have developed the effect of Alkaline pretreatment on the production of biogas from the sludge of the Lagoon Station of Adrar City.

In 2018 and in the context of sustainable development in Algeria, (I. Belkaid et al., 2018) studied the characterization of three different sewage sludge of the Water and Sanitation Society of Algiers (SEAAL) for reuse among others manages: (i) Baraki Wastewater Treatment Plant which received an average of 63400 m³/day in 2013 and produces 12 tons of sludge which treatment is carried out by anaerobic digestion at 35°C. (ii) Beni-Messous Wastewater Treatment Plant: 33400 m³/day and produced 9 tons of sludge in 2013. (iii) Reghaia Wastewater Treatment Plant: 62300 m³/day in 2013 and produced 10 tons of sludge without treatment. Blkaid et al. stated that (i) the contents of fertilizing elements and metallurgical trace elements of the sludge quite vary from one station to another. (ii) The agronomic value of the sludge generally respects the mineralization criteria because of better conservation of the organic matter during the wastewater treatment process.

In the framework of the biogas quality enhancing for use as a fuel, (Mokrane et al., 2018) investigated numerically the effect of the biogas composition on the emissions of CO and NO_x in an SI

engine. They found that increasing CO₂ in the biogas lowers NO_x emissions significantly, whereas, CO was found to be very low, and appears only at high CH₄ concentration. A biogas with (CH₄: 60 %, CO₂: 40 %), burning at about ($\phi = 0.9$), i.e. slightly lean mixture, and advanced spark timing (between 10 to 20°.) seems to be a very a realistic combination in terms of biogas composition, stoichiometry and spark timing. They recommended that, to accomplish some upgrading, in case of biogases with low CH₄ percentage, to get it up to 60 %.

Agricultural wastes

Farms often generate large amounts of organic wastes (from animals or from vegetation). Those wastes can be converted to energy in order to respond at least the local energy needs for farms exploitation. In fact, animal manure from livestock is at the origin of the first biogas installations in agricultural farms. Mixed with other green wastes, they can produce in addition to biogas, a very good organic fertilizer for agricultural activities (IRENA, 2015). As an example cited by (Akbi et al., 2017) poultry farming generates considerable amounts of waste as liquid manure (1,314,000 tones/year) and solid manure (125,000 tones/year), (TTZ BREMERHAVEN, 2011) those amounts are able to generate about 100 GWh of electricity.

Bio-economic and environmental management waste model challenge in sustainable development of Tamanrasset city: from waste to biogas energy

Knowledge and scientific research is the important prerequisites for sustainable development particularly in developing countries such as Algeria, and especially in the southern regions. Knowledge in engineering systems optimization model OptiWaste, which integrate life cycle assessment (LCA) (M. Münster et al., 2015) is an important tool for waste companies and national authorities to avoid suboptimal environmental solutions. However, in Algeria collaboration between municipalities, households, private production sectors, is far from being a reality (A. Youb et al., 2014). So, one of the most important action in Tamanrasset region (Southern of Algeria), was the establishment of an effective cooperation on April 2015 (K. Benaissa et al., 2017(a),(b)), between Sciences and Environment research laboratory at Tamanghasset Centre University and Direction of Environment to put-up the first biogas digester (Fig. 10) as an alternative energy strategy. Indeed, reduction in waste volume, production of bio-fertilizer and valuable soil conditioners it is known. That biogas process is an environment friendly, economic and an alternative means to fossil fuel. Today economy and technologies largely depend upon energy resources that are renewable as well as eco-friendly (P. Merlin Christy et al., 2014).

In fact, the Biogas Digester of Tamanrasset City (BDTC) with a capacity of 15m³, it is a batch type, with Chinese fixed dome (Fig. 11). The BDTC is designed to produce almost three (3) cylinders of methane with 47m³ of volume per month, from fermentable household waste, dromedary dung and

sewage sludge water as microbial inoculum bio-resources for enhanced biogas production and bio-economy approach (K. Benaissa et al., 2017(a),(b)).

It is made up mainly of an enclosure of digestion, impermeable and underground, which offers an anaerobic environment and a maintenance of moisture. It thus supports the methanization of a biomass biodegradable, fluid and locally available (household waste and excrements of dromedary) for biogas production. Its supply, is from the storing reservoir, is ensured by the effect of gravity. As for its partial draining. The daily supply of the digester in biomass ensures the continuity of methanization process, further than an average of temperature of digestion about 30 °C (K. Benaissa et al., 2017(a),(b)).



Figure 10. Biogas digester with a capacity of 15m³ installed at Tamanrasset city (Southern of Algeria) (K. Benaissa et al., 2017(a),(b))

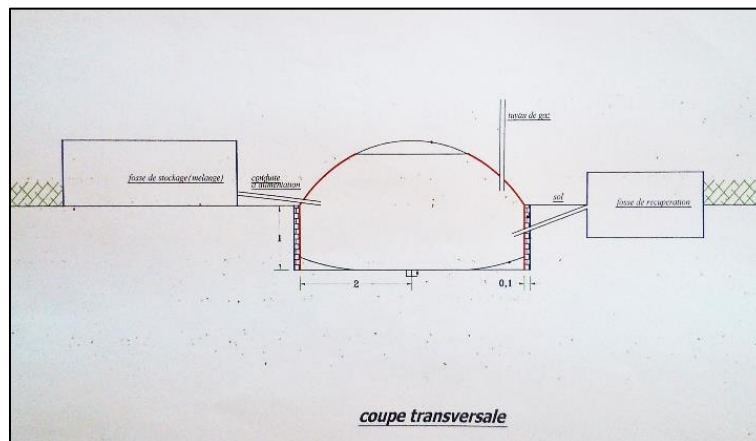


Figure 11. The BDTC plan : transverse section

Conclusions

The Algerian's economy is in an alarming situation. The waste management did not yet take his part of interest by the Algerian government. Algeria has a very considerable solar layer, and an enormous quantity of fermentable household waste, which these goods are not exploited yet amply.

Growth must be mastered and taking into account development consequences. We must no longer consider our goods under the sole view of immediate consumption, but also through recovery and recycling and giving these goods many lives and uses. To take up this challenge requires an immediate awakening and a significant modification of citizen behaviors and our environmental strategy.

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