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# A NOVEL APPROACH TO USE BIO-GAS IN ENHANCED OIL-GAS RECOVERY (BGEOGR)

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**Abstract-** This research presents a new method to improve oil extraction through the treatment of solid waste and wastewater. Compared to other improved oil recovery methods, this method is more environmentally friendly, more efficient, less costly, and better performing in the long run. It can use throughout elementary, secondary, and tertiary oil recovery, where it increases production during the three recovery stages. This method works to convert oil reservoirs into renewable energy reservoirs after extracting the remaining oil. It can use to equip the oil facility with thermal and electrical power. An algorithm has also been written to inject biogas during the primary and secondary oil recovery. And it is important in increasing production by keeping the reservoir pressure in semi its primary state. This process (BGEOR) also plays an important role in the agricultural sector. This is doing by treating the waste of digestion units to produce plant fertilizer.

**Keywords:** Enhanced oil Recovery (EOR), Renewable Energy, Reservoir Engineering, Fuel and Energy, Derived Fuel, Energy Conversion.

## 1. INTRODUCTION

There are many processes are used to recover oil in the oil fields, these processes aiming to recover the remaining oil after the primary and secondary recovery [1, 2]. whereas a series of EOR processes is applied to oil reservoirs during the production lifetime (each EOR process supersedes the previous process to recover the residual oil. Where the oil recovery processes continue; thus, the cost of these processes increases and they stop when the remaining oil becomes uneconomical, as well as the fluctuation of the price of barrels of oil in the global market) [2, 3].

Water injection is a significant process in increasing oil production. In 1880 John concluded that water finds its way into shallow sandy wells, and its movement through the oil sands increases the rate of oil extraction. The injected water maintains the pressure in the oil trap [4].

Gas injection operations are of great importance in increasing oil extraction. The injected gases differ in the oil extraction processes, either in the form of a composite gas such as ($CH_4$, $N_2$, $CO_2$, Or Flue gas) or an admixture of gases, such as ($CO_2$+$N_2$) The gas injection process maintains the reservoir pressure and reduces the surface tension between oil and water when the gas mix with the oil at miscible pressure [5, 6].

Several analytical and experimental processes of Chemical (Polymer flooding (PF)), Micellar polymer flooding (MPF), alkaline flooding) and thermal (hot water flooding, steam injection, in situ combustion) injections have developed to increase the oil extraction rate. Chemicals like polymer combine with water to improve its viscosity and give it a better efficiency push, thus boosting Sweep Efficiency. The surfactant's job is to lessen the surface tension between the water and the oil, allowing the oil to be pushed deeper into the wellhead. Furthermore, thermal processes decrease oil resistance for movement in porous media since viscosity is inversely related to temperature, resulting in increased mobility [2, 5, 6].

As it is known, a screening parameter are used in EOR processes, the values of these parameters are approximated based on the success of North American projects and are not considered fixed and deterministic. Each EOR method has a limited life which ends when it becomes impractical to recover the oil or, extracting the residual oil becomes uneconomical [2, 7, 8]. This study targets to develop an EOR process with a long-term, economical, environmentally friendly, human-benefit and other significant economic profits.

Methane ($CH_4$) is a multi-use hydrocarbon gas and a source of Bioenergy used in homes, cars, power plants (thermal and electrical), etc. It is also one of the mechanisms of the primary oil recovery and is used in one of the greatest important secondary oil recovery processes. It is used in many EOR methods such as thermal and chemical methods. Because of the high cost of using Methane for such processes, cheaper alternative methods are used such as $CO_2$ or $N_2$ injection or other sources of heat generation that decrease the use of methane in thermal processes (Solar Thermal Enhanced Oil Recovery) [2, 3, 4, 9, 10]. The semi-integrated oil recovery process can be carried out by finding a source to generate methane gas or similar gas in or near the oil fields, especially in the oil fields that are near the cities. This research will be focused on using of Bio-Gas in enhancing oil recovery.

## 2. REFUSE-DERIVED FUEL

Bio-Gas is produced through the treatment of solid waste, industrial waste and others important processes in the generation of energy (thermal and electrical). The uses of bio-gas reduce utilizing of fossil fuels. the preservation of a safe environment free from the waste accumulation or the burning of accumulated waste to remove of them, which lead to environmental pollution does not praise his punishment and the pollution of the gases and gases resulting from burning waste lead to global warming. Through the establishment of industrial digesters of control and treatment solid waste using anaerobic fermentation, bio-gas can be produced in weeks instead of years, and sewage is used to dilute waste by feeding digesters. The presence of anaerobic decomposition bacteria is worked on rot and dissolve waste (organic and other biodegradable materials), Where the gases emit (Bio-Gas) as a result of decomposition. by knowing the conditions necessary for the decomposition process can be controlled in the digestion to increase or reduce the decomposition process to generate bio-gas. The bio-gas composition varies depending on the digestion process and the type of waste used to generate the bio-gas. Bio-gas consists of 50-75% Methane and 50-25% Carbon dioxide, 0-10% Nitrogen, 0-1% Hydrogen, 0-3% Hydrogen sulfate and 0% Oxygen [11]. Organic waste is considered an important element for the generation of pure bio-gas. The greater proportion of organic matter in waste mix, the more bio-gas purity is.

These industrial digesters are characterized by the possibility of being established near residential areas or near the oil fields close to residential areas, therefore waste does not need to be moved for a long distance. These digesters do not need a large area of land. There are several uses for waste gas (Bio-Gas) in power generation (thermal and electrical), and as fuel in machinery and domestic use (cooking gas) [12, 13]. Among the most critical uses of bio-gas in the oil sector is used in enhanced oil recovery. Bio-gas is distinguished because it is considered one of the components of the reservoir fluid mixture (That is, the injection of bio-gas to increase oil recovery, does not result in chemical reactions with crude oil which lead to a change in the composition of crude oil or the formation of other undesirable compounds).

## 3. BIO-GAS AND RESERVOIR FLUIDS

By reviewing the origin of the crude oil and the formation conditions, many things can be understood to find suitable solutions to some oil problems. Decomposition of the organic materials and the remains of organisms (animals and plants) that had extinct and deposited under the layers of the earth in isolation from the air, due to the presence of anaerobic bacteria, high pressure and high temperature. In general, the crude oil is emigrating and then trapping in sandstone or carbonate traps to form an oil reservoir [14-16].

The Bio-gas is found as an integral part of the reservoir fluid and can be represented by:

$$OM + SM + OC \xrightarrow[P_H + T_H]{anaerobe} MOH\left(+BG\right) + MOG\left(BG + OG\right) + OC$$

Biogas is found in a reservoir fluid either as a gas cap or mixed with a hydrocarbon mixture or both. Therefore, Biogas is considered an integral part of reservoir fluids. So, Bio-gas is considered one of the most crucial mechanisms for crude oil recovery, such as gas cap drive, solution gas drive and gravity drain. The oil extraction process led to a decline in the content of the reservoir and subsequently decrease pressure; and to maintain production pressure; secondary recovery is performed (W.I. and G.I.). When these processes become exhausted for extracting the remaining oil, EOR processes are used.

## 4. BIO-GAS ROLES IN OIL RECOVERY PROCESSES

The establishment of dig-esters near the residential cities for a handle of solid waste and industrial waste and sewage water for bio-gas generates is important in the work of oil fields reclamation companies, especially fields near these cities to increase the rate of oil extraction. One of the most important uses of bio-gas is increasing the rate of oil production, where bio-gas is injected into the gas cap to compensate the reservoir contents to maintain the reservoir pressure from dropping as a result of the reservoir fluid extraction, as shown in Figure 1.

For efficient production continues, the injection process of Bio-Gas may apply to a reservoir at the primary and secondary recovery. Characterized this type of gas is compatible with the reservoir fluid under all conditions. The reason is because it is a part from the reservoir fluid composition. Also, the miscibility speed of bio-gas with oil in the displacement processes or injection processes in the reservoirs have enough pressure to mix bio-gas in reservoir oil. And that reduces the oil viscosity and increase the oil mobility in the porous medium to the well-bore, as shown in Figures 2 and 3.

Also, the author thinks that the bacteria found in bio-gas are working to complete the unfinished organic matter decomposition and break down long-chain hydrocarbon compounds into compounds with smaller chains (in other words, heavy oil diluting). Bio-gas can be pumped back again into the reservoir, when it comes out as an associated crude oil gas or during the recovery process. This procedure be done by a bio-gas isolation unit and then the isolated-gas from the crude oil is connecting to the bio-gas injection pipe-network, as shown in Figures 1-3. When the crude oil runs out, bio-gas can extract and used in power generation (thermal and electrical). Bio-gas can also be upgraded to produce pure methane.

In the thermal processes (combustion - steam stimulation - hot water drive - steam flooding) that used for extracting heavy oil, the bio-gas can use as fuel burned to heat water and generate steam, which injected into a reservoir to dissolve the heavy oil and increases the oil mobility in the porous medium, as in Figure 4. Bio-gas can also be used in the combustion process to form a thermal forehead to dissolves heavy oil and to ease it is movement through the porous medium. Due to thermal cracking, it also dilutes the heavy oil of the long hydrocarbon chains which lead to increases the phase-oil mobility.

It is worth mentioning that this occurs during the combustion phase; the non-pure biogas that has the siloxanes resulting from disintegrating materials found in detergents and soaps; the silicon releases; which reacts with oxygen or other compounds; to form deposits that contain silica ($SiO_2$) or Silicate (SixOy) [17, 18]. Therefore, Bio-gas must be upgraded to obtain a pure bio-gas free of Siloxanes and other substances such as zinc, phosphorus, sulfur, and calcium.

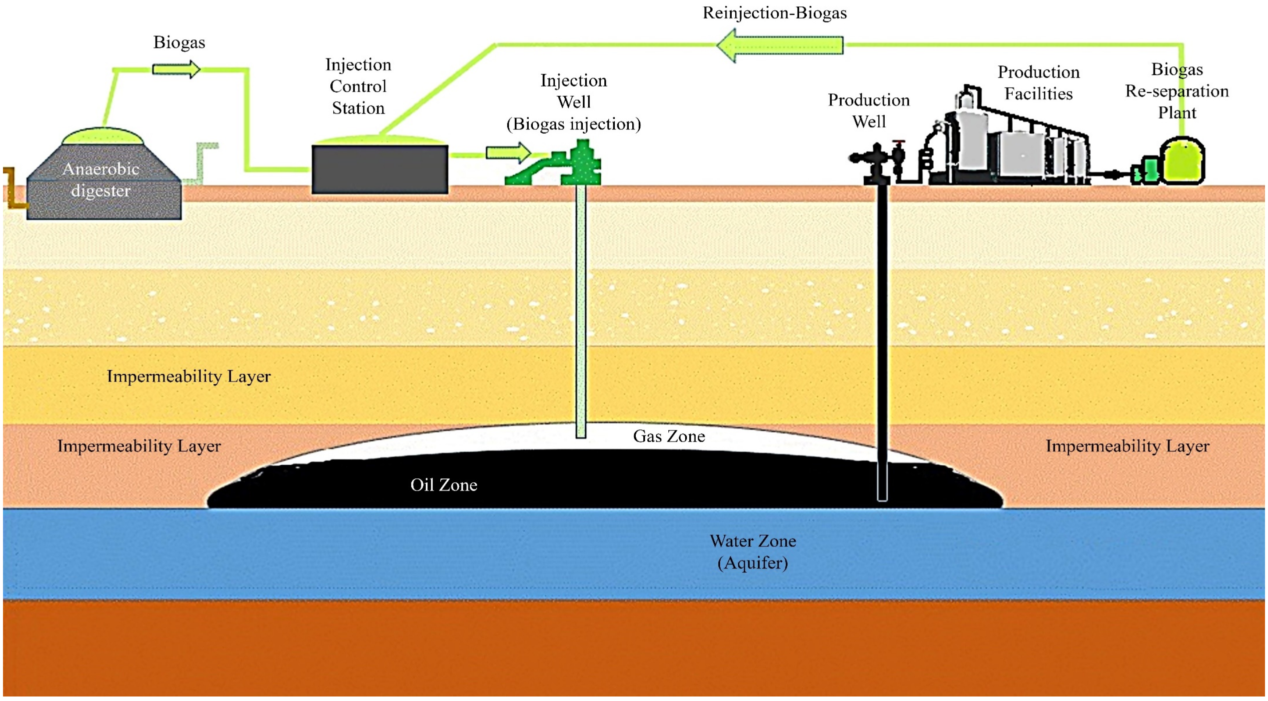


Figure 1. Diagram of Bio-gas injection into gas cap

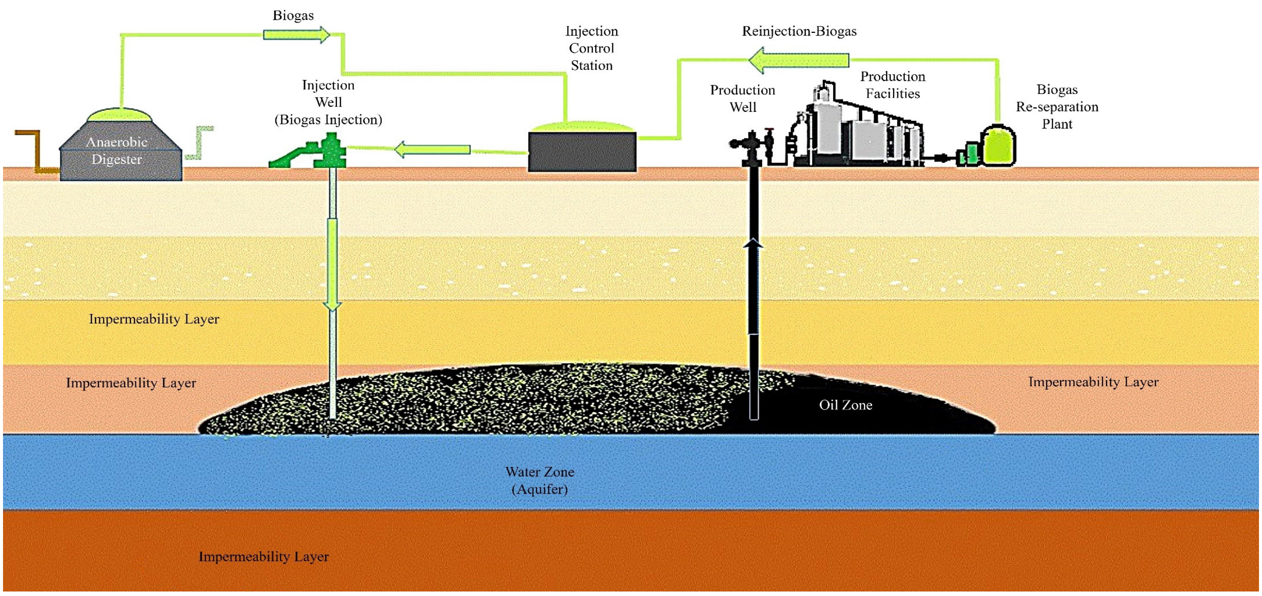


Figure 2. Diagram of miscible displacement process of oil by bio-gas

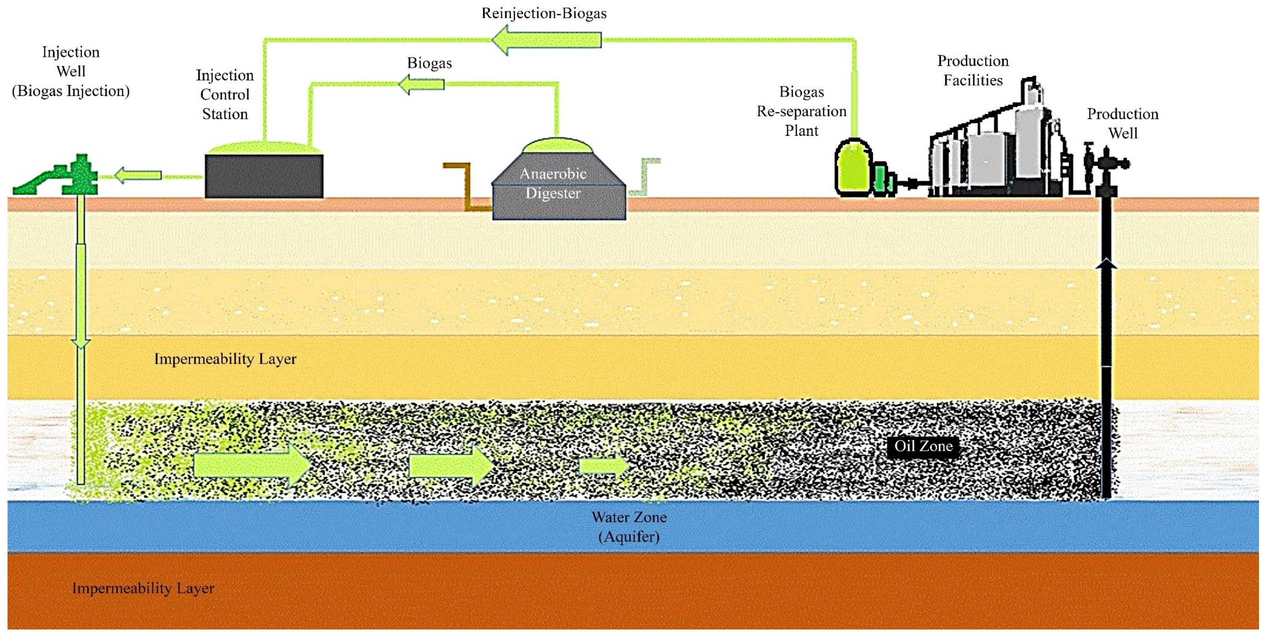


Figure 3. Diagram of Bio-Gas injection process into the high-pressure reservoir

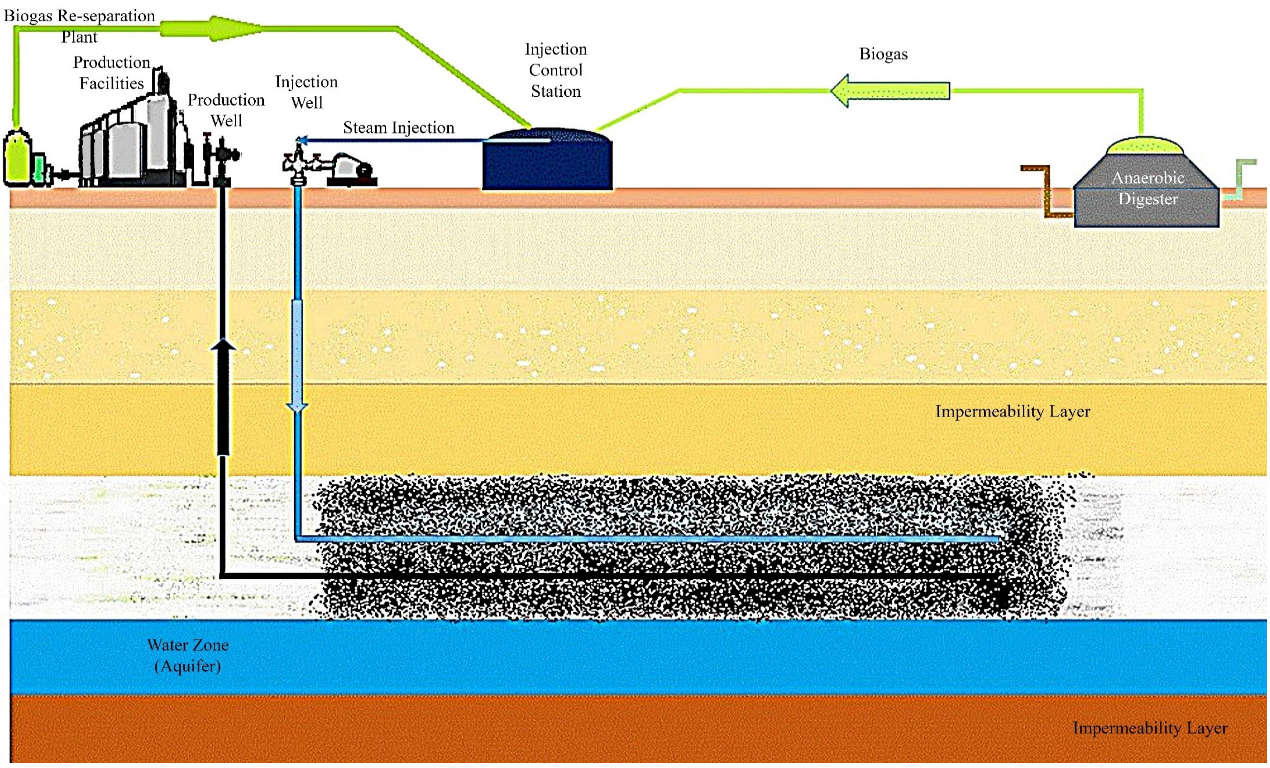


Figure 4. Diagram of a thermal process (steam flooding, steam stimulation or hot water drive)

## 5. A PLAN OF THE BIO-GAS INJECTION PROCESS DURING PRIMARY AND SECONDARY RECOVERY LIFE

Assume we have an oil reservoir with pressure prior to extraction ( $P_i$ ) and a build bio-gas injection system. Upon extraction, we assume the primary extraction pressure ( $P_{i0}$ ) in the bottom of an oil production well; where ( $P_i = P_{i0}$ ); and ( $P_S$ ) at the top of an oil production well. To maintain the production pressure, biogas injecting according to the following mechanism.

The $\left[\left(P_{iO} - P_{iS}\right)_r\right]_i = P_P$ is Pressure difference during primary recovery at the beginning of each production period, $i = 1, 2, 3, ..., n$ as production periods during primary, secondary recovery or both them (i.e., the primary and secondary recovery processes can be one process that takes place during different production-time periods depending on the pressure of the reservoir and the quantity of oil recovered per day). The $r = 1, 2, 3, ..., m$ are Time Periods during each production period.

The $P_p$ can be changed in the initial of each production period, to suit the production pressure rate and the oil reservoir capacity on the production, either to increase the oil recovery or reduce it. This mechanism can be used during elementary and secondary recovery.

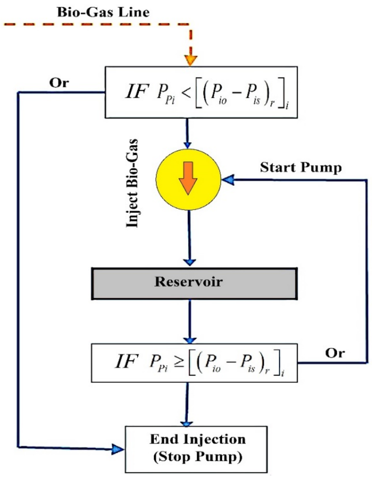


Figure 5. Schematic diagram of bio-gas injection control system

The advantages of this type of injection mechanism are manifested by the production of the largest possible quantity of crude oil during the primary recovery because it works to keep the reservoir almost in its state of primary activity, which leads to the long life of the primary recovery. It can also continue until secondary recovery. This injection mechanism can update at the secondary recovery stage to inject bio-gas and water depending on the recovery rate and reservoir type (containing aquifer). Bio-gas can be injected by 50% and water by 50% and at a rate of (1-5) barrels (50% bio-gas + 50% water) per (1-5) barrels of reservoir liquid. The gas or oil layer is injected with bio-gas, if the reservoir pressure is sufficient to keep the bio-gas in liquid condition, and water injects into the water layer. This method increases the longevity of the secondary recovery and extracts the largest possible amount of crude oil.

## 6. BIO-GAS FEATURES IN THE OIL FIELDS

1. The oil recovery can be Improved by increasing the life of oil recovery operations.
2. Bio-gas can be generated in abundance by establishing industrial digesters for waste and sewage treatment, which contributes to maintaining a clean environment free of pollution. And these digesters do not need large areas for construction as sanitary landfills.
3. Bio-gas can be used to generate electricity to equip the buildings and oil stations.
4. It is a Flammable pure gas can be used as cooking gas and compressed in a capsule as a liquid.
5. Bio-gas can be upgraded to obtain pure methane.
6. After the completion of the oil extraction processes, bio-gas can be extracted and used for power generation (thermal-electrical), where it is considered a one of renewable energy source.
7. Bio-gas can be re-injected into the reservoir when it exits with the oil.
8. Bio-gas contains volatile bacteria that analyze non-decomposing organic matter or speed up decomposition or complete decomposition process.
9. A fluid of bio-gas acts as a solvent for semi-liquid or solid hydrocarbon compounds and acts as a dilute for liquid hydrocarbon compounds.
10. An inexpensive renewable energy source and its investment in the energy field (thermal and electrical) is very practical and profitable.

## 7. RESULTS AND DISCUSSIONS

1. Biogas has the most harmonic chemical and physical properties with reservoir fluids (gases and hydrocarbon compounds) compared with other gases used to improve oil recovery.
2. Its multiple uses and its generation methods make it the optimal and cheapest material in the remaining oil extraction processes compared to carbon dioxide, nitrogen and HC gases.
3. Oil companies should have an effective role in preserving the environment from pollution and serving civil society.
4. Bio-gas injection into the oil reservoirs can be described by the return of decomposing bacteria to accomplish and treatment the last of the previous decomposition process (in other words complete the oil formation image).
5. Bio-gas enhanced oil recovery (BGEOR) achieves long-term oil recovery. Since it is part of the combination of reservoir fluid because they (Bio-gas & reservoir fluid) are as a result of the decomposition process of organic matters and sediments, so it can use in most hydrocarbon reservoirs.
6. When using bio-gas in thermal processes (Combustion), the bio-gas must be upgraded to avoid the sediments that reduce the layer permeability.

## 8. CONCLUSION

1. BGEOR is one of the most vital processes for treating waste of oil cities epically cities that are near oil fields. Therefore, it is considered the most environmentally friendly project.
2. It can be operated in oil sites without a hypothetical lifespan and even before the start of oil operations because it has an economic and environmental benefits. Also, it is possible to direct injection at the beginning of the primary oil recovery and until the last amount of oil is extracted.
3. It is considered a source for generating electrical energy within the institution and oil fields. Also, it considers a source of thermal energy to generate the necessary steam in thermal processes to improve oil extraction.
4. The injected biogas can be reused after the oil is depleted as a vital energy source, Where the oil reservoir turns into a biogas reservoir.
5. Reclamation project implementation has very large financial and environmental returns. Waste of digestive units can also be treated in special plant fertilizer production units to support the agricultural market.

The following suggestion are also obtained:

• Designs 2-cores, each one containing a homogeneous porous medium of sandstone and carbonate. Water injects into cores to saturate mediums. Then, a specific type of oil injects into cores, its density, specific gravity, molecular weight, volatile and intermediate compounds are known, to displace water and saturates the porous mediums. Then, the bio-gas injects into cores and observes the changes (change time, oil concentration, bio-reaction) with a study of the temperature effect on the progress Process. Repeats the previous steps with other types of oil and observes changes with temperature.
• Bio-gas injects into cores then calculate the oil recovery rate and efficiency.

## NOMENCLATURES

### 1. Acronyms

| | |
|---|---|
| BGEOR | Bio-Gas Enhanced Oil Recovery |
| PF | Polymer Flooding |
| MPF | Micellar Polymer Flooding |
| W.I. | Water Injection |
| G.I. | Gas Injection |
| OM | Originic Materials |
| SM | Sedmentary Materials |
| OC | Other componunts |
| BG | Bio-Gas |
| OG | Other Gases |
| MOH | Mixture of Hydrocarbons |
| MOG | Mixture of Gases |
| Anaerobe | Anaerobic Organism |

### 2. Symbols / Parameters

$P_H$: High Pressure
$T_H$: High Temperature
$P_i$ : Reservoir Pressure prior production (psi)
$P_{i0}$ : The primary pressure at the bottom well production (psi)
$P_S$ : The pressure at the top well production (psi)
$P_p$ : Production pressure (pressure difference between $\left(P_{iO} - P_{iS}\right)$) (psi)

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