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Article

Use of Hydraulic Fracturing Technology to Extract Shale (Unconventional) Oil and Gas and Predict the Economic Impacts and Negative Repercussions on the Environment

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Abstract: The past few years have witnessed a revolution in the production of oil and gas from unconventional sources and in unconventional ways in the United States of America, as the United States of America was able to extract oil and gas from confined rock reservoirs from which it was not possible to extract oil and gas in economically useful quantities. It used the technique known as hydraulic fracturing, which works to cause tremors inside regular and twisted wells with some catalysts to break the rock layer surrounding the oil or gas and stimulate it to rush upwards. This rock revolution has attracted all countries of the world, which made this industry develop, especially with the discovery of huge reserves of these sources in various countries of the world, which led to the expansion of the production of these sources and took their place in the global energy structure to contribute to diversifying the global energy mix in addition to establishing reliability in extending the life of crude oil and natural gas threatened with depletion in the long term. However, the hydraulic fracturing technique carries with it great risks in environmental pollution, including pollution of groundwater and running water with air and soil pollution on the one hand, and on the other hand, pollution through hazardous chemicals used In this way, as catalysts with the possibility of earthquakes occurring due to rock crushing operations in the interior of the earth, this, in turn, requires following sharp steps and strict policies to reduce the risk of environmental pollution through this technology, taking into account the importance of these sources.

Keywords: hydraulic fracturing technology, economic impacts, negative repercussions

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1. Introduction

Importance of the research

The research is of great importance by addressing the issue of expanding the production of oil and shale gas using advanced technology with hydraulic fracturing operations and the negative and dangerous effects of these methods on the environment.

Research Objectives

The research aims to review the reality and expectations of the future in addition to trying to find solutions for unconventional oil and gas production operations from rock reservoirs (hydraulic fracturing method) while preserving the environment and, at the same time, taking into account the importance of these sources in diversifying the mix of energy sources globally.

Research Problem

The research problem is that reality imposes on us the search for diverse energy sources to meet the increasing energy needs and that shale oil and gas sources are of great importance in extending the life of traditional sources and diversifying the energy mix in global markets, which imposes the necessity of expanding their production, especially for countries that do not have traditional sources in their lands, but the method of producing them using hydraulic fracturing, which cannot be dispensed with, is a harmful, polluting and very dangerous method for the environment.

Research Structure

The research consists of three axes in addition to the abstract, conclusions, and recommendations as follows:

1. Deals with oil and shale gas and hydraulic fracturing technology.
2. Deals with environmental pollution and its relationship to energy sources.
3. The environmental effects of hydraulic fracturing technology.
4. Oil and shale gas and hydraulic fracturing technology.

2. Theoretical framework

Oil and shale gas

Shale oil is meant to be ordinary crude oil that exists in nature in its liquid state. Still, it is surrounded by impermeable solid rocks that do not allow it to flow, and here is the point of difference between shale oil and ordinary crude oil, which exists in nature within a normal environment that allows it to flow and can be extracted by drilling natural oil wells using conventional techniques, while extracting shale oil requires following special and complex methods to break rocks and reach oil reservoirs, so it is called unconventional oil because it cannot be extracted in economic quantities without resorting to industrial catalysts and hydraulic fracturing processes, in addition to its production from unconventional sources, and shale oil is considered light oil and is Its properties vary from one reservoir to another depending on the sedimentary rocks that make up the oil reservoir. The United States of America stands out as the leading country in producing these unconventional resources. There are huge reserves of these resources on a global level. Shale oil production has developed significantly since 2000 until today, as is clear from the following table:

Table 1. The development of global production of unconventional shale oil, actual and future. For the period 2000-2030 million barrels/day

the years	Global shale oil production million barrels/day
2000	0.9
2010	2.6
2019	8.3
2020	7.5
2021	8.4
2025	9.2
2030	9.4

Source: International Energy Agency(IEA), world Energy Outlook, 2006,p92.

International Energy Agency(IEA), world Energy Outlook, 2011, p122.

U.S. Energy Information Administration, Annual Energy Outlook, 2021, p28.

It is clear from the previous table that global shale oil production reached 0.9 million barrels/day in 2000 developed to reach 2.6 million barrels/day in 2010, and continued to increase until it reached about 8.3 million barrels/day in 2019. Still, it decreased to 7.5 million barrels/day in 2020 due to the effects of the Corona virus, which put the world in an economic crisis that history has never witnessed before. Its negatives were reflected in all aspects of the global economy, especially oil energy markets, with a decrease in global demand for oil. With the introduction of vaccines for the virus, coexistence with the pandemic, and the return of the global economy to a gradual recovery, shale oil production increased in 2021, and the US Energy Agency expects global shale oil production to rise in the coming years to reach 9.4 million barrels/day in 2030. The following chart shows what was mentioned above, as follows:

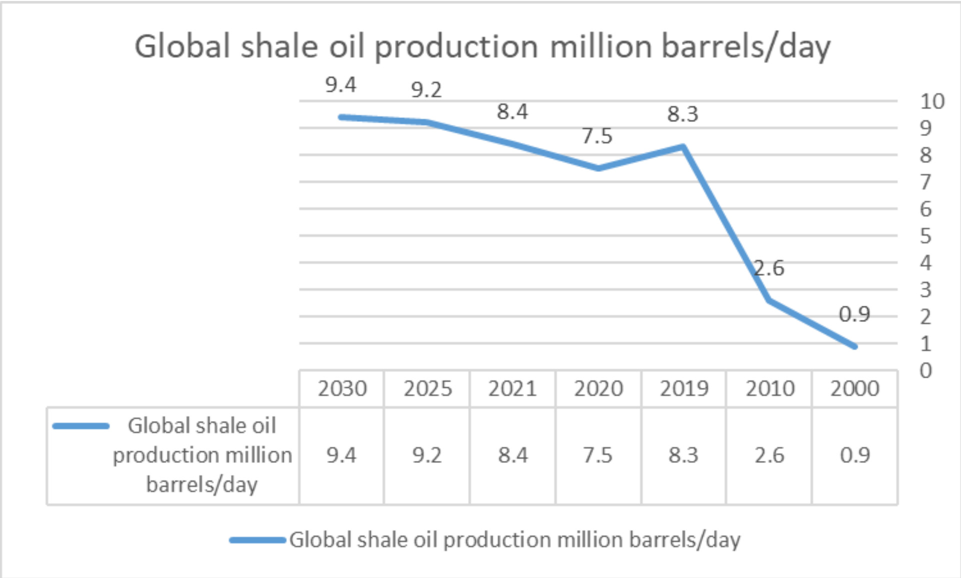


Figure 1. Development of global shale oil production (reality and forecast) for the period 2000-2030 million barrels/day

Source: The chart was prepared based on the data in Table (1).

Shale gas is a natural gas trapped in a sedimentary rock environment containing clay and quartz with some minerals called shale. Shale gas is usually called slate gas and sometimes schist gas in reference to the rocks that surround and trap this gas. The gas that is formed by high temperatures and pressure inside rocks that contain crude oil is also considered shale gas. It is worth noting that these rocks or rock reservoirs that contain gas and do not allow it to flow to the upper layers because they are impermeable are often at a high depth in the earth's interior and cannot produce gas in economic quantities without following stimulating methods with hydraulic fracturing operations. Despite this, some countries in the world have succeeded in producing this gas, especially the United States of America, which is the pioneer of the revolution in fuel production from shale reservoirs. The following table shows the global development in the production of actual and future shale gas for the period 2000-2030, as follows:

Table 2. The development of the global production of unconventional shale natural gas, actual and future, for the period 2000-2030, billion cubic meters

the years	Global shale gas production billion cubic meters
2000	206
2010	460
2019	689
2020	600
2021	695
2025	786
2030	825

Source: International Energy Agency(IEA), world Energy Outlook, 2012, p136.

International Energy Agency(IEA), world Energy Outlook, 2015, p206.

U.S. Energy Information Administration, Annual Energy Outlook, from: https://www.eia.gov

The previous table shows that global shale gas production reached 206 billion cubic meters in 2000 and developed to reach 689 billion cubic meters in 2019. With the outbreak of the Corona pandemic, it decreased to 600 billion cubic meters in 2020. With the gradual recovery of the global economy, shale oil production returned to rise in 2021. The International Energy Agency and the US Energy Agency forecasts indicate that shale gas production will continue to increase in the coming years to reach 825 billion cubic meters in 2030. The following chart illustrates the above:

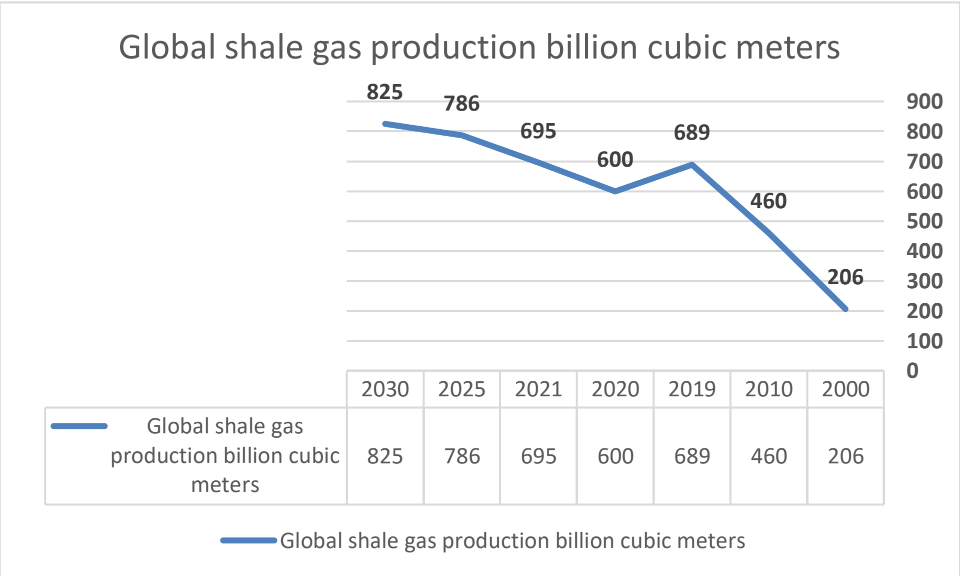


Figure 2. Global developments in shale gas production (reality and future) for the period 2000-2030

Source: The graph was prepared by the researchers based on the data contained in Table 2.

It is worth noting that global reports concerned with energy show the existence of large reserves of oil and shale gas in different countries of the world that can be extracted from a technical point of view, in addition to its expectation that the discovered quantities are much less than what is undiscovered.

Hydraulic fracturing technology

Hydraulic fracturing or fracturing technology, which is used to extract unconventional oil and natural gas sources, consists of drilling wells vertically and then horizontally with the use of water and chemicals in addition to a mixture of sand. This is done to break up and crush rocks to extract the oil and gas trapped inside them. This technology requires pumping large quantities of water, estimated at 7 to 23 million liters of water, which is approximately equivalent to 5 barrels of water for each barrel of oil. These large quantities of water and the mixture of the technology are pushed by huge pumps directed towards sedimentary rock formations in the interior of the earth to create cracks in these rocks and open outlets for the oil or natural gas to exit [1].

Hydraulic fracturing technology is known by the global company Exxon Mobil, which is one of the most important global companies in using this technology, as the process of pumping a mixture of water, sand, and specific proportions of chemicals to create small fractures in the rocks and support the opening of cracks in order to release the buried oil or natural gas to flow into the wellbore. This is only done after building a well with several layers of steel and cement casings to isolate the fluids in the well from other formations, including groundwater, according to studied regulatory and standard foundations. The hydraulic fracturing fluid mostly consists of 98% water and sand and 2% of special additives and chemicals. These proportions are not fixed and vary slightly between increase and decrease according to the location where the well is to be drilled. These additives and materials aim to make the fracturing process safer and more efficient. They reduce friction and protect rock formations, as well as prevent the formation of scales and the accumulation of algae and other benefits that vary from one location to another and according to the type and proportion of additives [2]. In general, the chemicals used in hydraulic fracturing operations mostly include [3]:

1. Gelatinous materials are usually derived from natural seeds such as guar gum which is used to thicken ice cream and other liquids, and the main purpose of these materials is to create viscosity.
2. A crosslinking agent of organic and mineral compounds often based on boron or zirconium, the purpose of which is to increase the viscosity of the gel.
3. Nuts such as enzymes or other materials are used to break the crosslinking bonds when using gel materials.
4. Lubricants, often polymers.
5. Biocides that may be based on chlorine or bromine.

It is worth noting that these materials used in hydraulic fracturing operations are known according to reports from companies operating in this industry. Still, the truth is that there are other chemicals that companies do not announce under the pretext of keeping business secrets, in addition to not wanting to provoke governmental and civil organizations concerned with safety and environmental pollution, as many of the secrets of hydraulic fracturing operations are still unknown except to some workers in this industry in a monopolistic manner.

Despite the success of hydraulic fracturing technology in extracting unconventional resources, it faces many challenges for many reasons, most notably the use of huge amounts of water, especially in light of the general social trend towards preserving water resources in the world. Thus, companies operating in the unconventional oil and gas industry face a challenge represented in balancing operational risks resulting from water shortages or emergency stoppages for the purpose of supplying water, in addition to technical risks related to the water reuse program and the resulting repercussions on the efficiency of the well, as hydraulic fracturing operations are not easy and direct operations, let alone being a risk in itself. They require continuous updating, study, and development, and this is what global companies do, as advanced technological techniques are added from time to time. An example of this is what Halliburton did in 2013 by inventing a new technology for hydraulic fracturing that was developed in cooperation with Chevron. This new technology was known as the "Single-Stroke Multi-Zone Fracturing and Injection System (ESTMZ)." This technology was designed for the purpose of using operations Hydraulic fracturing in deep and very deep water is efficient, as it allows for the injection of huge quantities of fluids and anti-locks very quickly. Halliburton used it to stimulate some wells by injecting 45 barrels of heavy fracturing fluid with 181 tons of anti-locks in a very short time of one minute, using a number of huge pumps with a capacity of 10 thousand horsepower.

One of the major developments and expansions in hydraulic fracturing technology is what Schlumberger did, which was considered the largest hydraulic fracturing operation of its kind in Europe. A well was drilled to a depth of 4641 meters in a Permian sandstone reservoir, and then a 1000-meter-long side trunk was drilled from it at a real depth of 3650 meters, and 1200 tons of anti-lock materials and 35,000 barrels of fracturing fluids were injected, i.e., more than 5.5 million liters. This shows the size of the large operations that are being carried out using this technology and the developments that are being added to it [4].

Such extensive operations using hydraulic fracturing technology have raised many concerns and drawn the attention of governmental and civil organizations, especially environmental organizations, to call for stopping these operations or placing them under supervision as an option to limit them, as there must be negative effects reflected on the environment, especially with the continuous efforts of companies operating in the United States of America that aspire to increase profits by increasing production from unconventional oil and gas sources, not to mention the economic, political and social goals.

The following figure shows the drilling of a well using hydraulic fracturing technology:

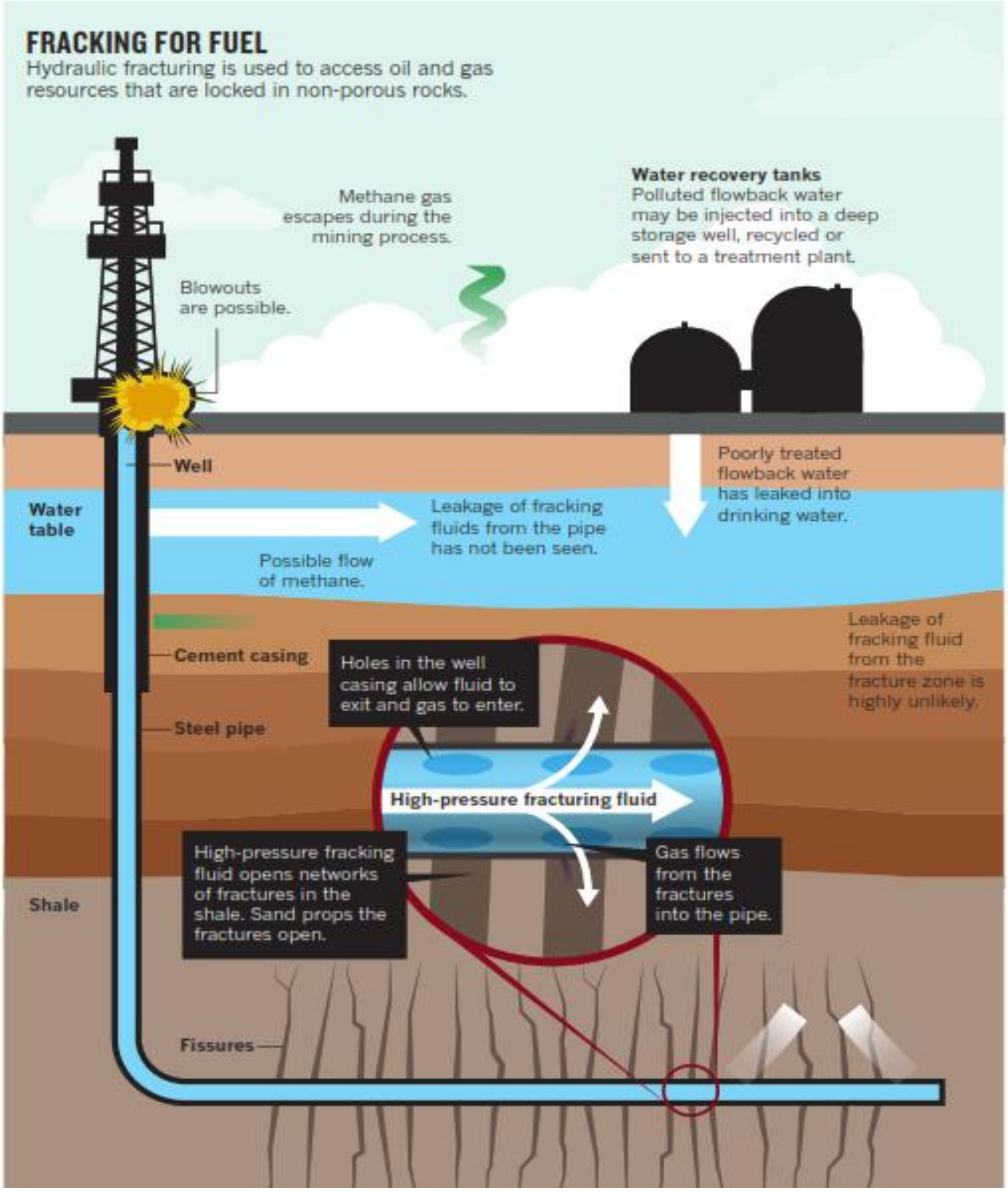


Figure 4. The process of drilling a well to extract shale gas using hydraulic fracturing technology

Source: Jamal Qasim Hassan, Shale Oil and Gas and Their Impact on Global Oil Markets, Arab Monetary Fund, 2015, p. 3.

The importance and economic necessity of hydraulic fracturing technology

There is no disagreement about the great importance of unconventional oil and gas sources, especially shale oil and gas. Had it not been for the invention of hydraulic fracturing technology, these sources would not have taken their place in the global energy balance. Many economists, politicians, and a number of governments who are interested in energy affairs believe that hydraulic fracturing technology is an important and necessary global development to achieve a great deal of security in obtaining energy source supplies and diversifying the mix of energy sources in global energy markets. Here, hydraulic fracturing technology takes its importance from the importance of energy sources that represent the lifeblood and the main tool for the wheel of development in the world, which cannot be dispensed with, not to mention what America, which is the main adopter of this technology, has found in achieving its political and economic goals and achieving profits by strongly delving into the industry of unconventional oil and natural gas sources of energy with the capabilities it enjoys from the reserves of these sources. In general, we can show the importance of hydraulic fracturing technology, which is derived from the importance of unconventional shale oil and gas sources, as follows:

1. The achievement of hydraulic fracturing technology has achieved an unconventional revolution, Represented by the production of oil and natural gas from sources and sites that could not be produced.
2. Unconventional oil and natural gas produced by hydraulic fracturing technology have taken an important place in the global energy balance.
3. This technology has achieved huge profits for companies and countries that adopt it to enter the unconventional sources industry.
4. Some countries find their political and economic goals achieved by resorting to this industry that depends on this technology in addition to entering the global energy markets as a strong competitor.
5. There is a great need for unconventional energy sources to diversify the global energy mix and achieve a degree of security in the supply of supplies to global markets.
6. Extending the life of fossil sources.

3. Results and Discussion

Environmental pollution and its relationship to energy sources

Environmental pollution

Although the word environment is a common word, especially in recent years, its meaning and concept have been linked to the type of relationship between it and its users on the one hand and the other hand, between it and various human activities, the general characteristic of the environment remains a reference to the surroundings around something. This thing may be a living being, such as a human or an animal, or it may be non-living, such as an inanimate object. Thus, the environment represents the framework in which a person lives and from which he obtains the requirements and components of his life [5].

The environment was defined at the United Nations Conference held in Stockholm as the balance of material, social, and climatic resources in a specific place and time to satisfy the diverse needs of man [6].

To define the concept of the environment in light of its many ramifications and connections, and with a focus on the economic point of view, it is necessary to pay attention to its following aspects [7]:

1. The biological aspect: This aspect is related to the spatial entrance and includes all of the lower air layers, the upper water layers, and the surface layers of the earth, which are represented by the atmosphere, the hydrosphere, and the terrestrial envelope, and that this aspect represents the place where life appeared on this planet.
2. The social aspect: This aspect represents the result of the accumulation of human work over a long period of civilization, which is embodied in various factors, including legal, intellectual, and social norms, which are homogeneous and linked through a group of political, cultural, social, and administrative relationships and systems from the formation of man on the first side, and that it is a legacy from multiple generations to future generations.
3. The technical aspect: This aspect is related to all human work within the boundaries of the biosphere aspect, meaning that it is represented by everything

that man has built in his surroundings, from cities, buildings, landmarks, roads, factories, ... etc., and this is called the changes represented by human capital.

It can be said that there is a rarity in the world of a clean, pollution-free environment due to the ease of pollution transmission from one area to another, in addition to the extreme difficulty in containing it, especially in light of the prevailing economic system that depletes non-renewable resources and relies on unclean fuels as easy sources of energy and causes chemical changes in the earth and distorts ecosystems to produce damage that is difficult to repair for both the earth, water and air. However, the problem revolves around the degrees of damage caused by pollution, and the extent of the danger of this pollution to living organisms varies from one pollutant to another. Pollution has been defined as any substance that leads to changes or manipulations in the properties or components of the environment by increasing or decreasing, which causes harm to living organisms, regardless of the nature or type of pollutant, whether chemical, physical, or otherwise. Pollution has also been defined from the point of view of the National Academy of Sciences as any harmful and undesirable change in the chemical, physical, or biological properties of air, water, or soil that has harmful effects on human health and other organisms [8].

In light of the above, we can define pollution as any direct or indirect human intervention through activities and the introduction of solid, liquid, or gaseous materials or the creation of noise, vibrations, heat, or other, which leads to negative changes in the nature of the components of the environment and results in an imbalance in its balance and thus a negative and health impact on living organisms in general and humans in particular. Accordingly, attention is directed towards caring for the environment and pollution issues despite the slow interaction with this matter, in light of the global focus on the priority of caring for industry at the expense of the environment. Still, the interest in the issue of environmental pollution was taken into consideration in the late sixties in developed countries through a number of organizations that expressed their concern about environmental pollution that has become a threat to human health, and interest in the environment. Its pollution became an international issue when the world witnessed its danger in recent years, accompanied by the rise of voices to preserve the environment and raised many environmental problems on a global level.

The relationship between energy sources and the environment and pollution

Day after day, new and different challenges emerge to make the world face a complex confrontation to protect the environment on the one hand and, on the other hand, to increase long-term economic growth rates. As is clear, achieving economic growth is based mainly on meeting its requirements by increasing the consumption of energy sources. Here, the complex and complex problem is created, which revolves around increasing the consumption of energy sources, especially oil, while maintaining a clean environment. Increasing energy use rates, whether in transportation, manufacturing, or one of the multiple stages of use, will affect the environment and increase pollution rates in different ways. Thus, the inverse relationship between the level of environmental cleanliness and energy use rates becomes clear.

Most countries in the world, or all of them, want to achieve high economic growth rates and, at the same time, do not want to pollute their environment, i.e., they do not want to achieve high pollution rates. This in itself imposes a complex problem, as a change in one of them cannot be easily modified, and requires a long period and high costs for society. This, in turn, means that each country must achieve balanced rates between energy consumption and environmental cleanliness and determine an optimal and acceptable level of pollution resulting from the use of energy sources. Here come energy sources. Fossil fuels are considered the most important energy source on the global level, and achieving economic growth rates on the global level depends on them fundamentally.

Accordingly, they play a major role in polluting the environment, especially with the continuous global effort to increase production processes and use new techniques, technologies, and methods.

Environmental impacts of hydraulic fracturing technology

After reviewing the reality of the expansion in the production of oil and shale gas at a high level through increasing hydraulic fracturing operations and addressing future expectations until the year 2030, which indicate a continuous increase in the production operations of these sources, here we shed light on the damages of this on the environment as follows:

Water pollution

The huge amount of water required to be used in the extraction of oil and gas from unconventional sources is one of the main issues that attracts attention. Here, hydraulic fracturing technology comes to the forefront, as concerns are raised about many issues in this regard, including the problem of water scarcity and the depletion of large quantities of it, which may disturb the water environmental balance in some areas. Another issue is the question of the possibility of polluting groundwater, as hydraulic fracturing technology penetrates the groundwater layers, and with what this technology includes of special chemicals and liquids, significant pollution can occur in groundwater, in addition to many environmental pollution problems associated with water.

In general, the issue of potential groundwater pollution associated with productive drilling operations in oil and gas projects is not specific to unconventional resource extraction operations, as conventional drilling operations for productive oil and natural gas carry the same risks of groundwater pollution when penetrating water-bearing layers. This is done despite the use of protection methods and safety techniques and the rapid disposal of wells after drilling these layers in order to isolate them from the effects of chemicals used with drilling fluids.

However, the hydraulic fracturing technique carries a much higher risk of groundwater pollution than conventional well drilling. This has been confirmed by studies and research in this field, as many cases of water pollution have been recorded in the United States of America, accompanied by an increase in hydraulic fracturing operations, especially with methane gas. Many private wells that residents depend on for drinking have been contaminated with methane gas and a number of chemical pollutants, to the point that the pollution has reached the point of setting fire to some of the water in these wells. The matter was not limited to this, as the pollution has reached the point of recording clear pollution in the drinking water of residential areas, to the point that some residents were able to set fire to tap water. Some samples have shown The contaminated drinking water was tested and found to contain the same chemicals used in hydraulic fracturing operations [9].

In addition to the above mentioned possibility of groundwater pollution due to the use of hydraulic fracturing technology, another environmental problem arises, which is the return water, which is the water that is extracted from the wells after drilling and fracturing operations, as a quarter or a third of the volume of water used in fracturing operations returns and is either extracted for treatment (rarely) and reused or disposed of (often), as the reuse of this (return) water carries with it major negatives on the efficiency of the productive well and on the costs of the project in general, and the return water is often brackish because it touches the rocks and sediments in the ground, not to mention its mixing with the salty and impure water that is trapped in the pores of the rocks, and on the other hand, this return water is loaded with large quantities of impurities, and the most dangerous of these impurities is heavy metals, which sometimes include a significant portion of radioactive materials despite their weak concentration, and the disposal of this water is what constitutes the major environmental problem, as the danger lies in illegal discharge operations, which raises controversy, in addition to the fact that this water represents a disaster Environmental in itself [10].

Pollution through the use of dangerous chemicals

Despite the rising voices of governmental and civil organizations demanding that international companies that use hydraulic fracturing technology disclose the chemicals used with the fracturing fluid, companies refrain from full and explicit disclosure in this regard. They are content to respond that they do not use dangerous materials and that they take into account protection and safety systems and hide many of the secrets of this technology under the title of keeping business secrets and not disclosing technology methods, what raises doubts about this matter are some environmental studies and research issued by environmental protection organizations in the world that recorded the discovery of highly toxic and very dangerous materials used by companies in hydraulic fracturing technology.

In a study on shale gas, it was found that carcinogenic and toxic chemicals were used in hydraulic fracturing technology, and these materials are as follows [11]:

1. Hydrochloric acid: It is the same substance used in car batteries, and it is considered highly dangerous as it burns or reacts with all organic materials and a large part of mineral materials. If it comes into contact with the human body, it causes severe burns.
2. Hydrofluoric acid: This acid has the same properties as hydrochloric acid but to a lesser degree, and therefore, it carries the same danger but in lower proportions.
3. Benzane C_6H^6: It is considered one of the carcinogenic substances according to many studies and research that confirmed this, and this, in turn, prompted the World Cancer Research Center to classify benzane as a carcinogenic substance in the first degree, especially for leukemia, and some research has concluded that 5% to 18% of leukemia cases are caused by exposure to benzene gas during work. 4- Toluidine C_7H_8: It is also a dangerous substance as it can cause many diseases of the central nervous system and lung infections if inhaled or swallowed with food or water. It leads to severe inflammation and burns in the digestive system; in addition to being classified as a carcinogenic substance, if it spreads to a specific organ and takes hold of it, it will cause cancer as benzene does.

Air and soil pollution

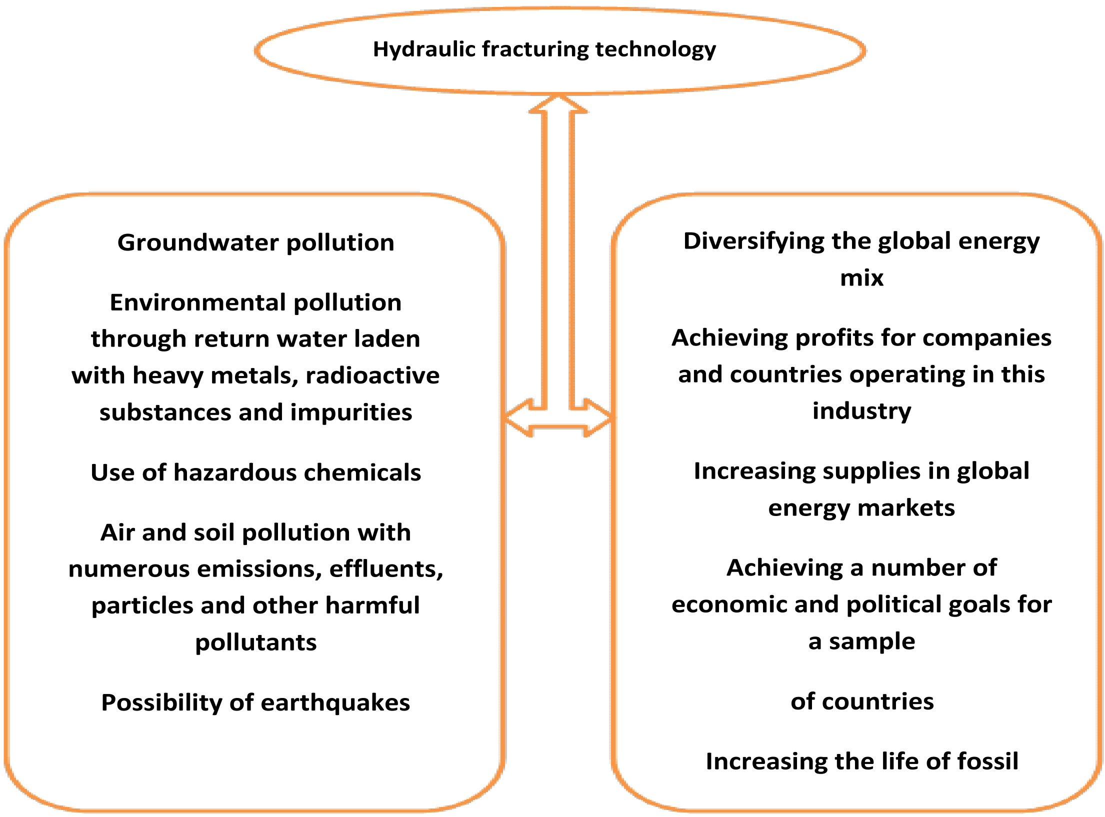
No manufacturing process is free from environmental pollution, but the extraction of unconventional oil and natural gas sources using hydraulic fracturing technology leads to widespread air and soil pollution, and in general, pollution is represented by the following:

1. Emissions and pollution from drilling equipment and trucks (particles, noise, nitrogen oxide, etc.).
2. Emissions resulting from various treatment processes in the project and transportation.
3. Emissions consisting of chemical vapors from sewage pond areas.
4. Emissions and pollution resulting from leakage of drilling and fracturing fluids.
5. Emissions resulting from fuel-burning operations to operate drilling equipment, which then emits CO_2, methane gas, and other emissions, as drilling equipment in this huge technology consumes large quantities of fuel.

Hydraulic fracturing technology and the occurrence of earthquakes [13]

The hydraulic fracturing technique depends on pumping a mixture of fluids and special materials under high pressure to create cracks and fissures in the rocks, which in turn affects the geological characteristics of the oil and gas reservoirs in the rock layer and the entire area where the project is located. In this regard, a number of earthquakes were recorded in areas where hydraulic fracturing operations were carried out. These earthquakes were of the small and medium type, specifically in the United States of America, such as Arkansas, Colorado, Ohio, Texas, and Virginia. The Earthquake Study Center linked these earthquakes to oil and gas extraction operations using hydraulic fracturing technology.

Some studies by the American Geological Observatory also showed a relationship between pumping fluids into wells and seismic activity. The center also indicated that the number of earthquakes that occur in the world during one year is very large and is estimated at several million. Still, most of them are of the type that cannot be felt because they are very weak or occur in remote and unpopulated areas. An increase in the number of earthquakes has been observed in the United States of America, especially in the central and eastern regions, accompanied by an increase in the operations of the non-oil and gas industry. Traditionally, studies have shown that hydraulic fracturing technology produces a large number of earthquakes, estimated at thousands. Still, only some of them are felt on the surface of the earth, as most of them are very weak or microscopic. In general, any process that creates pressure in the interior of the earth is likely to lead to the risk of earthquakes (such as dam construction operations and deep mining operations). Scientists at the US Geological Observatory have clearly explained that the areas in which the increase in earthquakes that are felt coincided with the processes of disposing of fluids extracted from hydraulic fracturing operations and pumping them into deep wells.



4. Conclusion

1. The process of extracting and producing unconventional sources of oil and natural gas, especially shale oil and gas, cannot be done efficiently and economically without resorting to hydraulic fracturing technology at present.
2. Unconventional shale oil and gas sources represent important and necessary sources for diversifying the energy mix in global markets, and this industry is a necessity for some countries, such as the United States, as it achieves its economic and political goals.

3. Hydraulic fracturing technology poses a great risk to the environment.
4. Despite following the means of protection in work and environmental safety technology, the occurrence of environmental pollution of various types accompanies hydraulic fracturing operations.

5. Recommendations

1. Issuing laws obligating companies working in hydraulic fracturing technology not to use hazardous chemicals or materials classified as causing cancer and monitoring companies in implementing this.
2. Paying more attention to the issue of water and its pollution, as it requires issuing strict laws obligating companies to treat this water before disposing of it.
3. Accurate programs must be followed in directing hydraulic fracturing to achieve the greatest degree of safety by preventing cracks from reaching groundwater reservoirs.
4. Work on increasing scientific research in the field of technological techniques specific to this industry in order to reach environmentally friendly extraction methods in the future.
5. Setting specific limits for companies' expansion in hydraulic fracturing operations in a way that preserves the environment from the risks of pollution.
6. Developing policies that encourage reducing the consumption of fossil fuels, especially shale, and resorting to the consumption of clean energy sources.

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