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Review Article

Evolution of Unconventional Hydrocarbons: Past, Present, Future and Environmental FootPrint

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Abstract

This research was to comprehensively examine the considerable impact of unconventional oil and gas in the oil and gas industry and review the components of accumulation, and integrated analysis of the global resource distribution, the past, present, future revolution, and environmental footprints. A PRISMA systematic review on scientific publications employed to examine unconventional oil and gas. All the literature searches were conducted between June 2020 and October 2021 and the published studies were systematically identified and categorized, respectively. USA is the highest in terms of the number of published articles from across various organization within different nations and accounts for 35% of the overall number of publications per countries studied, China (33%) comes second, and other regions constitute (32%). The regional distribution of recoverable unconventional hydrocarbons across the globe revealed that 23% of the recoverable resources are found primarily in North America, with the others accumulated in Russia (22%), Asia (21%), South America (17%), Africa (13%), and Europe (4%). European countries have had many discussions in attempt to prohibit unconventional oil and gas production activities, due to its possible environmental implications, mainly during fracturing techniques with chemical fluids.

Keywords: unconventional oil and gas; global distribution; environmental footprint

1. Introduction

The global oil and gas exploration market has boomed in recent years, fueled by modern technologies that allow for the exploitation of "unconventional" oil and gas (UOG) resources. UOG may be defined as continuous or quasi-continuous hydrocarbon resources without a natural commercial rate of production. It is usually produced through reservoir stimulation, to improve the permeability of the rock, and, or fluid viscosity, to achieve commercial recovery. There are two significant parameters used to describe UOG distribution, continuous and large oil and gas deposits. They lack natural and continuous commercial output, no clear boundary, and no obvious Darcy flow. Less than 10% porosity and less than 1 μm pore throat size or permeability less than $1x10^{-3}$ μm^2. Geologically, UOG constitutes the conformity of both reservoir and source rocks in basins and sloppy areas that has no clear boundaries or effects of hydrodynamics and minor reserves plenitude. It is important to utilize extensive fracturing in horizontal wells, well pads production systems, nanotechnology for EOR, etc. to recover economic and commercial production. UOG majorly comprise of tight oil and gas, coalbed methane, heavy petroleum asphalt and many more [1].

The assessment of UOG formations illustrates the fact that unconventional resources are accumulated "progressively" in "basin systems" without conventional traps [1, 2]. Cander (2012) formulated a method of defining unconventional oil and gas using viscosity and permeability cross plot, which shows that unconventional resources are those hydrocarbons that can be commercially recovered through the change of the permeability of the rock or viscosity of the fluid and subsequently, permeability-viscosity ratio. The World Petroleum Congress (WPC), American Association of Petroleum Geologists (AAPG), Society of Petroleum Evaluation Engineers (SPEE) in 2007 collectively made a declaration defining UOG as the hydrocarbons accumulated pervasively across a wide area, in which there is no significant hydrodynamic effect. This type of accumulation is known as "continuous-type deposits". The term, unconventional oil and gas is known to be homogenous with continuous-type oil and gas deposits [3]. The history of petroleum geology includes five different occurrences: i) trap and anticline theory (dated from 1885 up to 1930), ii) generation of hydrocarbons from the geology and organic matter of the theory of petroleum system (dated from 1960s-1970s, iii) continental geology of petroleum (2940 – 2000), iv) deep water and marine petroleum geology (from the 1980s to 2000s), and v) continuous deposits and the geology of unconventional oil and gas (from 2000).

UOG by exploration operation differs in geological characteristics from conventional oil and gas (COG) by accumulation pattern. In line with continuous accumulation theories, unconventional geology of petroleum, UOG are progressively accumulated in prevalent areal extent with no obvious gas, oil, and water contacts, the beds of the reservoir have tight properties (4 to 12% porosity, permeability < $1x10^{-3}$ μm^2 and micro and nano-scale pore throats). Horizontal well drilling and hydraulic fracturing are used to produce commercially from these reservoirs. Three different phases exist together as multiphase (i.e. solid, liquid, and gas phase co-exist).

As for the basic concept of UOG geology, a pore throat network on the nanoscale was found initially and the characterization of a nano-scale and micro-scale pore throat formation was published in China, which is contradictory to the

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establishment that there is unconventional in shale and tight sandstone formations [8, 9]. Moreover, continuous-type UOG generations are clearly different in comparison to the conventional trap-type accumulations in several different ways: unconventional and conventional oil and gas are progressively accumulated in petroliferous basins [4-6], unconventional distribution is dominated by no buoyancy procedure, the depths from top to bottom were approximated [2], etc.

Looking at the plentiful UOG, and low recovery factor from conventional reserves, which has been explained by development and exploration operations and world petroleum resource assessment, there is an anticipation, which clarifies that the oil and gas industry will encounter three stages: i) conventional production of oil and gas, ii) co-production of conventional and UOG, and iii) UOG production. The peak oil theory has become invalid since there is a consistent rise in assessments of peak petroleum extraction, because more UOG are being discovered continuously. According to some researchers, the petroleum industries life span could last hundreds years for easy transition to a new era of energy. It has been proven that rather than a termination of the oil and gas industry, because of lack of resources, there will be a smooth replacement by another industry with renewable and eco-friendly energy. The amount of conventional oil resources is equal to the unconventional oil resources available in the world [7].

As observed, low air permeability and low porosity are the main characteristics of unconventional resources, and these are the reasons why their exploitations require advanced technologies to improve reservoirs' permeability or fluid viscosity. As of 2015, the yearly production of unconventional oil constituted to about $3.7x10^8$ t, which represents 9% of the yearly global oil production. In addition, in 2015 the global production of the unconventional gas stood at 8273×10^9 m^3, which accounts for 42% of the total global natural gas (NG) production. The US takes global lead in the production of tight oil. The number of US yearly tight oil production in 2015 adds up to $2.59x10^8$ t, which accounts for 45% of its yearly oil production. The unconventional gas was $4,500x10^8$ m^3, which accounts for 50% yearly gas production. The production of tight oil was $1800x10^4$ t in 2000. In 2008, there was an increase in tight oil production to $2.1x10^8$ t [10] and this is majorly because of advances in multistage horizontal well hydraulic fracturing technology. In the production of shale gas, this application is also very common. In 2008, production from conventional reservoirs decreased from its peak of $5.7x10^8$ t. But in 2015, progress production of tight oil gave rise to 2^{nd} peak oil of $5.7x10^8$ t. Production from tight oil has since sustained the increase in production. In the global supply of oil and gas, UOG resources have made a huge impact consequentially, in the structure of demand [2]. UOG resources may be described as an alternative conventional petroleum [10, 11].

The exponential growth in UOG development in recent years has given rise to extensive switch in demand-supply system, technique for recovery, and many technologies in the oil and gas industry. Thus, it is highly recommended to comprehensively examine the considerable impact of UOG in the oil and gas industry and to review the UOG components of accumulation, and integrated analysis of the UOG resource global distribution, the past, present, future revolution, and environmental footprints [10-13]. However, tight gas production is 0.46×10^{12} cm^3, shale gas production is 1.7×10^{12} cm^3, and coalbed methane production is 0.32×10^{12} cm^3. On the contrary, in the same year, there was about 20% total global oil production of the unconventional oil which is about is 4.8×10^8 t, according to the World Energy Outlook Report 2009 [10, 14].

The most difficult challenge that the energy industry must deal with, is the development of proper geological models to fit with the exploration and production of unconventional hydrocarbons [22]**.** Nevertheless, China increased the production of unconventional oil to about 60% between 2000-2010 [13].

Lengthy horizontal wells, between 3,000 to 10,000 ft, along with multistage hydraulic fracturing are essential to produce commercially from unconventional reservoirs. The closeness of the fractured points causes tensile intrusion with improved permeability. This is a result of some mechanical movements including stress from fractures, movements towards slipping fractures, and multiple hydraulic fractures geometry. There is the complexity of transient flow characteristics in these types of the wellbore. Diffusion may be a significant benefactor in producing from an unconventional reservoir [15].

Generally, hydrocarbon resources that are not classified as conventional are usually known as unconventional oil and gas. For instance, any tight base formation containing oil and or gas may be classified as UOG since they have low permeability when compared to the conventional formations. Unconventional oil and gas have played an increasing important role in the oil and gas production and this was possible through coal bed methane (CBM), tight gas, oil sand, commercial production and increased growth in the production of tight oil and shale gas because of the US shale gas revolution [7, 16].

This study analyses some of the features of systematic review of the scientific publications employed to examine the UOG, past, present revolutions, environmental footprint, and future forecasting. A literature's systematic review ensures that published studies are identified and categorized [17]. Information was examined and sorted and relationships across the literatures were identified and were used to draw conclusions concerning the topic of the study.

2. Research Methodology

2.1. Search Strategy

A systematic review of any research study can be organized and properly arranged in such a manner that makes it easy to be identified during a future literature search thereby bringing notice to papers that have been published. Systematic review uses a method that can be used for repetition, identification, and thorough research of literatures [17].

This systematic review was done in 2021, through the use of PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) checklist for a comprehensive review on unconventional oil and gas. Three digital databases (One Petro, ScienceDirect, and Google Scholar) were reviewed in October 2021. Google Scholar was utilized to search for grey literature. The keywords were: unconventional oil and gas global distribution, past and present revolutions, environmental footprint, future forecast unconventional resources, unconventional reserves. The literature collected was entered in a reference management software and duplicates were immediately removed.

2.2. Combining Search Terms

All the literature searches were conducted between June 2020 and October 2021 using keywords for only studies that were published between 2000 and 2021. Search terms were incorporated utilizing Boolean operators that allow standard search and free text terms to be used together. The Boolean operator used in this paper was "AND", which was utilized in joining different keywords together. The keywords were applied in article titles, abstracts, and keywords between the years 2000-2021.

2.3. Inclusion and Exclusion Criteria

This research was carried in order to examine the unconventional oil and gas global distribution, the past and present revolution, environmental footprint, and future forecasting. The deadline established as the end date for searching literatures was April 2021, as one of the criteria to end the search of publications. The following are the keywords that were used:

1. Unconventional oil and gas
2. Unconventional oil and gas "AND" Global distribution
3. Unconventional oil and gas, past, present and future revolution
4. Unconventional oil and gas environmental footprint
5. Unconventional oil and gas future forecasting

Applicable literature reviews were retrieved and assessed for actual significance. Consequently, the exclusion criteria were also used to narrow the findings. At the start of the review, the following exclusion criteria were chosen and explicitly specified:

- Criterion 1: Literatures that were published in just about any language that is not English.
- Criterion 2: Articles that were not published in one of the three databases under consideration ScienceDirect and OnePetro and Google Scholar.
- Criterion 3: Articles that did not contain some of the search terms' keywords.

The three criteria were used throughout the entire research according to articles chosen to be thoroughly read. Due to linguistic constraints, only English-language articles was reviewed. This showed that 27 papers were found in ScienceDirect, 15 in OnePetro, 12 in Google Scholar and 54 in total. After checking the papers that were gotten, 61 were removed due to criterion C3, leaving out only a final sample of 54 papers (Figure 1).

2.4. The included studies

While simple search on OnePetro with the keyword "unconventional oil and gas" between 2000 and 2020 returned over 18,000 results, advanced search with an exact phrase "global distribution" returned 35 results. After searching OnePetro, ScienceDirect and Google Scholar, 352 relevant papers were retrieved. A total of 223 papers were collected, after duplicates were removed and full texts were assessed, and 115 studies were left for the final analysis. After the application of the exclusion criteria, 54 papers were then reviewed and categorized (Table 1).

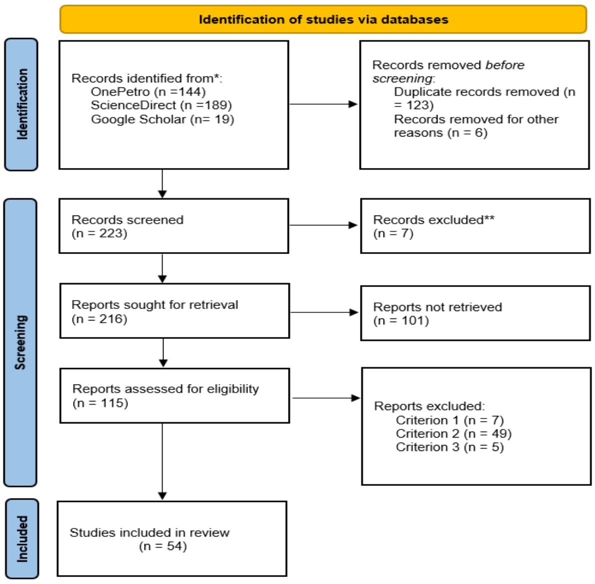

Fig. 1. PRISMA flowchart for selecting included studies.

Table 1. Characteristics of the included studies.

N/N	Author	Year	Country	Research Area	Title
1	Zou, C., et al	2013	China	Petroleum Exploration and Development	Concepts, characteristics, potential and technology of unconventional hydrocarbons: On unconventional petroleum geology
2	Zou, C., et al	2012	China	Petroleum Exploration and Development	Nano-hydrocarbon and the accumulation in coexisting source and reservoir
3	Etherington, J.R. and J.E. Ritter	2008	Canada	Reserves Evaluation	The 2007 SPE/WPC/AAPG/SPEE Petroleum Resources Management System (PRMS)
4	Caineng, Z., et al	2013	China	Petroleum Exploration and Development	Geological concepts, characteristics, resource potential and key techniques of unconventional hydrocarbon: On unconventional petroleum geology
5	Zou, C.N., et al.	2013	China	Petroleum Geology	Continuous hydrocarbon accumulation over a large area as a distinguishing characteristic of unconventional petroleum: The Ordos Basin, North-Central China
6	Caineng, Z., et al	2014	China	Petroleum Exploration and Development	Conventional and unconventional petroleum "orderly accumulation": Concept and practical significance
7	Chengzao J., et al.	2012	China	Petroleum Exploration and Development	Unconventional hydrocarbon resources in China and the prospect of exploration and development
8	Zou, C.	2017	USA	Petroleum Geology	Unconventional petroleum
9	Caineng, Z., et al	2010	China	Petroleum Geology	Geological features, major discoveries and unconventional petroleum geology in the global petroleum exploration
10	Hongjun, W., et al.	2016	China	Petroleum Exploration and Development	Assessment of global unconventional oil and gas resources

11	Caineng, Z., et al.	2015	China	Petroleum Exploration and Development	Formation, distribution, potential and prediction of global conventional and unconventional hydrocarbon resources
12	Dong, Z., et al.	2015	USA	Reserves Evaluation	Probabilistic estimate of global coalbed-methane recoverable resources
13	Chengzao, J.	2017	China	Petroleum Geology	Breakthrough and significance of unconventional oil and gas to classical petroleum geology theory
14	Biewick, L.R.	2014	USA	Petroleum Geology	Map of assessed tight-gas resources in the United States
15	Holditch, S.A.	2006	USA	Petroleum Technology	Tight Gas Sands
16	Guangming, Z.	2008	China	Petroleum Exploration and Development	Speculations on the exploration and development of unconventional hydrocarbon resources
17	Torreglosa, J.P., et al.	2016	Spain	Reserves Evaluation	Control strategies for DC networks: A systematic literature review
18	Clark, A.J.	2009	USA	Petroleum Exploration and Development	Determination of recovery factor in the Bakken formation, Mountrail County, ND
19	Meddaugh, W.S., et al	2013	Bahrain	Reserves Evaluation	The Wafra Second Eocene heavy oil carbonate reservoir, Partitioned Zone (PZ), Saudi Arabia and Kuwait
20	Brannon, H., et al.	2007	USA	EOR	Modern Fracturing: Enhancing Natural Gas Production
21	Feiyu, W., et al.	2013	China	Petroleum Exploration and Development	Evolution of overmature marine shale porosity and implication to the free gas volume
22	Hisseine, O.A. and A. Tagnit-Hamou	2020	Canada	Applications	Development of ecological strain-hardening cementitious composites incorporating high-volume ground-glass pozzolans
23	Goraya, N.S., et al.	2019	India	EOR	Coal bed methane enhancement techniques: A review
24	Chew, K.J.	2014	UK	Outlook	The future of oil: unconventional fossil fuels
25	Makogon, Y.F. et al.	2007	USA	Natural Gas Hydrates	Natural gas-hydrates—A potential energy source for the 21st Century
26	Wood, W.T., et al.	2008	USA	Natural Gas Hydrates	Gas and gas hydrate distribution around seafloor seeps in Mississippi Canyon, Northern Gulf of Mexico, using multi-resolution seismic imagery
27	Takahashi, H. et al.	2001	USA	Natural Gas Hydrates	Exploration for natural hydrate in Nankai-Trough wells offshore Japan
28	Kvenvolden, K.A.	2000	USA	Natural Gas Hydrates	Natural gas hydrate: Background and history of discovery
29	Honoré, A.	2014	UK	Outlook	The outlook for natural gas demand in Europe.
30	Bhutto, A.W. et al.	2013	Pakistan	Applications	Underground coal gasification: From fundamentals to applications
31	Warpinski, N.R., et al.	2009	Canada	Hydraulic Fracturing	Stimulating Unconventional Reservoirs: Maximizing Network Growth While Optimizing Fracture Conductivity
32	Joshi, S.	2007	USA	Petroleum Exploration and Development	Horizontal and Multilateral well technology
33	Butler, B., et al.	2017	USA	Petroleum Exploration and Development	Study of Multilateral-Well-Construction Reliability
34	Market, J., et al.	2010	Italy	Petroleum Exploration and Development	Logging-While-Drilling in Unconventional Shales
35	Bellani, J., et al.	2021	India	Outlook	Shale gas: a step toward sustainable energy future.
36	Montgomery, C.T. and M.B. Smith	2010	USA	Hydraulic Fracturing	Hydraulic Fracturing: History of an Enduring Technology.
37	Gao, C. and C.M. Du	2012	USA	Hydraulic Fracturing	Evaluating the Impact of Fracture Proppant Tonnage on Well Performances in Eagle Ford Play Using the Data of Last 3-4 Years
38	Cipolla, C.L., et al.	2011	UAE	Petroleum Exploration and Development	Seismic-to-Simulation for Unconventional Reservoir Development
39	Bybee, K.	2010	USA	Petroleum Exploration and Development	Evaluating Stimulation Effectiveness in Unconventional Gas Reservoirs
40	Caineng, Z., et al.	2009	USA	Reserves Evaluation	Global importance of “continuous” petroleum reservoirs: Accumulation, distribution and evaluation.
41	Zhao, Z., et al.	2011	China	Petroleum Geology	Geological exploration theory for large oil and gas provinces and its significance.
42	Tong, X., et al.	2018	China	Reserves Evaluation	Distribution and potential of global oil and gas resources.
43	Haider, W.H.	2020	Saudi Arabia	Reserves Evaluation	Estimates of Total Oil & Gas Reserves in The World, Future of Oil and Gas Companies and

					SMART Investments by E & P Companies in Renewable Energy Sources for Future Energy Needs
44	Meyer, R.F., et al.	2007	USA	Petroleum Geology	Heavy oil and natural bitumen resources in geological basins of the world: Map showing klemme basin classification of sedimentary provinces reporting heavy oil or natural bitumen
45	Li, C. and T. Huang	2016	China	Natural Gas Hydrates	Simulation of gas bubbles with gas hydrates rising in deep water.
46	Caineng, Z., et al.	2018	China	Petroleum Exploration and Development	Theory, technology and prospects of conventional and unconventional natural gas.
47	Borja, Á., et al.	2011	Spain	Environment	Implementation of the European Marine Strategy Framework Directive: a methodological approach for the assessment of environmental status, from the Basque Country (Bay of Biscay)
48	VijayaVenkataRaman,S. et al.	2012	India/Croatia	Environment	A review of climate change, mitigation and adaptation
49	Pryor, S.C. and R. Barthelmie	2010	USA	Environment	Climate change impacts on wind energy: A review
50	Roos, I., et al.	2012	Estonia/Lithuana	Environment	Greenhouse gas emission reduction perspectives in the Baltic States in frames of EU energy and climate policy
51	Zhao, J., et al.	2017	China/Malaysia	Environment	Opportunities and challenges of gas hydrate policies with consideration of environmental impacts.
52	Retief, F.	2007	South Africa	Environment	A performance evaluation of strategic environmental assessment (SEA) processes within the South African context
53	Ye, J.-l., et al.	2018	China	Petroleum Geology	Preliminary results of environmental monitoring of the natural gas hydrate production test in the South China Sea
54	Moridis, G.J., et al.	2010	USA	Petroleum Exploration and Development	Challenges, uncertainties, and issues facing gas production from gas hydrate deposits

3. Results and Discussion

3.1. Yearly Frequency of Article Publications

This analysis considered publication period from 2000 to 2021, and the earliest mention of an article meeting the requirements for conducting this investigation was published in 2000 (Figure 2). The data suggest that 19 publications were published during the first 10 years studied upon this subject, corresponding to an average of 1.9 papers in a year for this period of time. The most significant contribution to the topic occurred from 2011 and 2021 accounting for 64.82% of all papers published and an average of 3.2 papers each year. A distinguishing aspect of this time frame is that the most publications were produced between 2010 and 2014, totaling 24 papers, which is more than the number for the years between 2000 and 2009. In 2010 and 2013, the pace of development in publishing was higher compared to the other years.

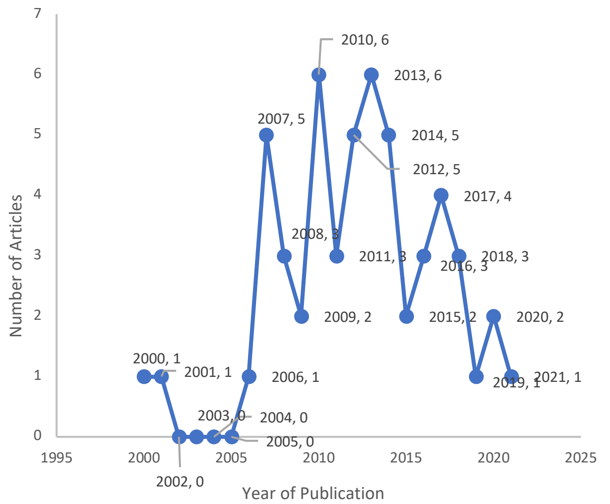

Fig. 2. Number of articles published per year.

3.2. Article Distribution by Country

In terms of the number of articles from across various organization within different nations (Figure 3), out of the 54 papers chosen, 18 were conducted in China, 19 in the United States, 3 in Canada, 3 in India, 2 in the UK, 2 in Spain and 1 paper in each of the other countries. USA had the highest percentage, accounting for 35% of the overall number of publications per countries studied, China (33%) came second, and other regions constituted 32% (Figure 4).

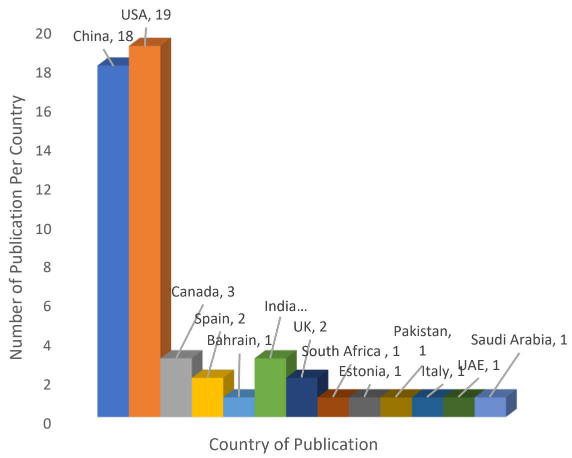

Fig. 3. Number of articles published per country.

3.3. Distribution of Recoverable Resources per Region

Figure 5 depicts the regional distribution of recoverable UOG across the globe. As can be seen in Figure 6, 23% of the recoverable resources were found primarily in North America, with the others accumulated in Russia (22%), Asia (21%), South America (17%), Africa (13%) and Europe (4%). Table

2 and Table 3 illustrate the regional distribution of recoverable unconventional resources according to USGS report. Tight oil, oil shale, oil sand, and heavy oil resources around the world were approximately $412x10^9$ t. There was a large quantity of heavy oil that was majorly deposited in Middle Ease, and South America. Oil sand, which is also called natural bitumen, was enormously deposited in Canada. USA, Asia and Russia have the majority of tight oil formations. Oil shale, with depositions of about $150x10^9$ t were majorly deposited in the United States.

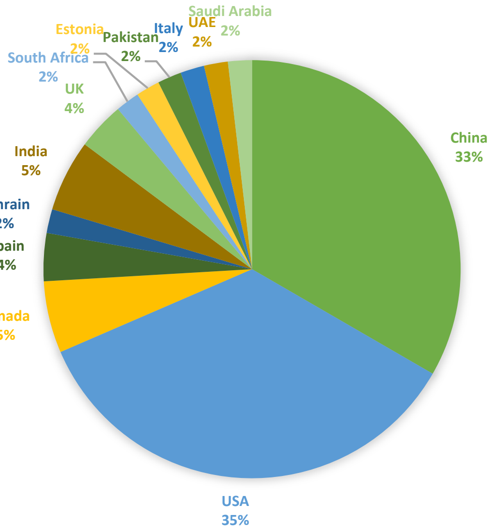

Fig. 4. Percentage (%) of articles published per country.

Recoverable tight gas resources were about $210x10^{12}$ m^3, which were majorly accumulated in North America, Latin America, and Asia Pacific. CBM was about $256x10^{12}$ m^3 recoverable resources and were accumulated majorly in Russia, North America and Asia Pacific. Recoverable resources of shale gas were around $457x10^{12}$ m^3 with dominant regions North America, Asia Pacific, Middle East and North Africa. The gas hydrate resources were approximately $3000x10^{12}$ m^3 around the globe.

3.4. Unconventional Oil
This work assessed the three major sources of unconventional oil. This was done with a geological overview of each resource, making mentions of the major techniques of extraction and production.

3.4.1. Tight Self-Sourcing Oil
Tight self-sourcing oil plays accumulates whenever oil-prone source rock of extremely low permeability (limestone, mudstone, chert or shale,) matures thermally, but hydrocarbons accumulated will remain largely in place because of restricted full mobility. The oil can be recovered from the source rock, from interbeds with more pores, e.g. siltstone in a shale source, or from tight porous rocks that has close contacts with the source rock. The petroleum is commonly light oil. Such plays were discovered so many years ago, and the recovery was quite minor, but recently, high prices of oil, advances in hydraulic fracturing and horizontal drilling attracted investors. Tight self-sourcing oil is the most interesting unconventional oil to be commercially produced. This is because the conditions of occurrence are more convenient across the world while the geology of many extra-heavy oil and oil sands accumulations are rare [10, 11].

Shale oil can be recovered by the means of low temperature carbonization. Shale oil in its case exhibits the first production rate between 250 and 2,000 BOPD [18]. Oil shale is said to be the combustible shale with high organic matter content and high ash content. The oil content of oil shale is more than 3.5% and the calorific value more than 4.18/MJ·kg^{-1} [18].

3.4.2. Oil Sand Bitumen
Oil sand occurs naturally in a mixture of water and bitumen, retained in rock sand or sandstone with little amount of mineral clay and fewer times, limestone. In defining bitumen, its density is more than 1.00 (< 10 degrees API) and its viscosity more than 10,000 cp. Bitumen is asphaltic and very sticky degraded petroleum, solid at 11 ºC. It is either heated or upgraded to synthetic crude oil (SCO) after recovery, diluted to minimize the viscosity and transported through pipelines to refineries. It is either mined or produced *in situ*. In Canada, oil-sand mining is on the average of 11% bitumen and 4% water by weight. It is averagely 2 t of oil sand (~ 1 m^3) contains 1 bbl of bitumen, which produces up 0.85 bbl SCO. Oil sand extraction is very productive, because more than 90% of bitumen can be recovered from oil sand accumulations in most regions. It has a considerable rate of recovery than many conventional light oil resources, which is hardly more than 50%. Canadian *in situ* oil sand extraction can reach 80% [10, 11].

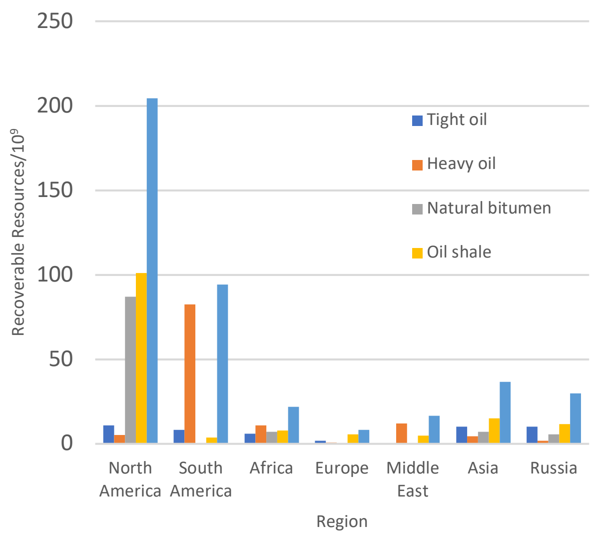

Fig. 5. The distribution of global recoverable unconventional oil.

Table 2. Distribution of recoverable unconventional oil resources per region.

Region	Tight oil	Heavy oil	Natural Bitumen	Oil shale	Total recoverable
Africa	5.9	11	7.1	7.8	21.8
Asia	10.1	4.5	7	15.2	36.8
Europe	2	0.7	0.03	5.6	8.4
Middle East	0.01	11.9	0	4.7	16.5
North America	10.9	5.4	87	101.1	204.4
Russia	10.3	2	5.5	11.8	29.7
South America	8.1	82.4	0.02	3.9	94.4
Grand Total	**47.31**	**117.9**	**106.65**	**150.1**	**412**

* All the numbers expressed in 10^9 tonnes.

Table 3. Distribution of recoverable unconventional gas resources per region

Region	Tight Gas	Coalbed Methane	Shale Gas	Total recoverable
North America	39	85.3	109	233.3
Latin America	37	1.09	60	98.09
Europe	12	8	16	36
Russia	26	112	18	156
Middle East and North Africa	23	0	72.1	95.1
South Africa to the Sahara	22	1	8	31
Asia Pacific	51	49	174.4	274.4
Total	**210**	**256.39**	**457.5**	**412**

* All the numbers expressed in 10^{12} m^3.

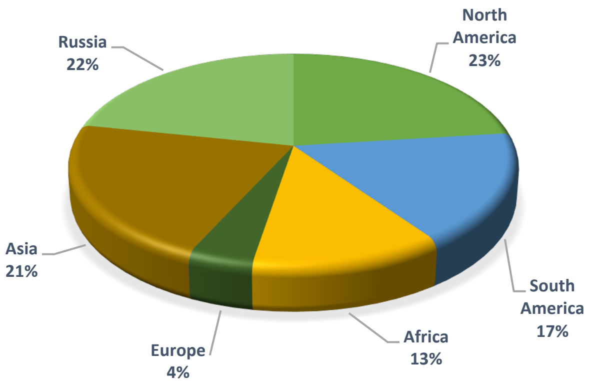

Fig. 6. Percentage (%) of recoverable unconventional oil per region.

3.4.3. Heavy and Extra-Heavy Oil

In as much as there is no general definition for heavy and extra-heavy oil, the commonly accepted consensus for the characteristics listed below in-reservoir values:

1. For a heavy oil, its density ranges between 0.934 and 1.00 g cm^3 (20◦ to 10◦ API gravity) and its viscosity between 100 and 10,000 cp.
2. For an extra-heavy oil, its density is greater than 1.00 g cm^3 (< 10◦ API gravity) and its viscosity ranges between 100 and 10,000 cp.

Extra heavy oil has a density that is in the same range with bitumen, but lower viscosity with mobile liquids below reservoir conditions. In Venezuela, large extra heavy oil accumulations are discovered as liquids at 15 ºC and not 48-55 ºC of Alberta deposits, which would be solid and not liquid. The top ten regions of global heavy oil resources are the Venezuelan Basin, the Arabian Basin, Tampico Basin, San Joaquin Basin, Maracaibo Basin, Yucatan Basin, Ventura Basin, the Northwest Germany Basin, the Morondava Basin and the Sumatran Basin [11, 19].

3.5. Unconventional Gas

Unconventional gas can be discovered at different phases. Shale gas systems are sometimes mixed. Some exists as free gas and others, adsorbed on kerogen or clay deposits. For coal seam gas reservoirs, majority of the gas are adsorbed on the surface of coal. Little amounts occur as free gas. Few spectators suggest that reservoirs, whereby gas is discovered as free gas, should not be defined as unconventional, and this excludes tight gas. Others suggested that only reservoirs that also act as source rocks, whereby few gases are adsorbed on the organic matter, should be classified as unconventional gas reservoir. This makes a lot of sense because technological advances in tight reservoirs in recent years have made it difficult to define the difference between conventional and unconventional reservoirs. Although, tight, shale and coal seam reservoirs have common characteristics, since the diameter of the micropore via which gas flows to the wellbore is 1μm. Tight gas, shale and coal seam reservoir use similar technology for recovery.

3.5.1. Shale Gas

Shale gas resource deposits is a self-contained hydrocarbon reservoir in which the accumulated gas is trapped in the source rock. Most of the shale gas system that is under economic production in the US are thermogenic. Thermogenic gas happens when a primary thermal cracking of the organic compound inside the gas phase. Secondary gas cracking of organic compound leftover liquid also takes place. The types of hydrocarbons accumulated in a reservoir are determined by thermal maturity. Gas extracted in a thermogenic system will be generally dry. Hydraulic fracturing is remarkably effective for mineralogy and marine accumulated shales. Depositions that are not marine, such as lacustrine and fluvial, have more clay, very ductile, and less effective in hydraulic fracturing. Onlap (Transgressive systems) are categorized according to their high total organic carbon and quartz with less clay. Shales accumulated at the course of transgression do not only have efficiency for hydraulic fracturing, but they also have high hydrocarbon recovery factors. On the other hand, regressive formations are categorized by low total organic carbon, quartz and contain high clay. Shales accumulated during regression respond less to hydraulic fracturing and possess high hydrocarbon recovery. Therefore, the depositional environment for shale may be significant including pay thickness and reservoirs pressure [10-11, 20-21].

3.5.2. Coal Seam Gas

Coal seam gas, also called coalbed methane, natural gas from coal and coalbed gas, is a gas that is rich in methane and exists in coal seams. Approximately 90% of the gas is adsorbed on the surface of the coal leaving the remaining dissolved in the aquifer or as free gas in the fractured rocks and pore spaces, unlike shale gas that occurs in self-contained source rock. Coal seam gas is sweet gas that contains greater than 90% of methane (including CO_2, N_2 and ethane). There is a need for little or no technology to process meaning that it can be immediately used in power stations and filling stations. However, it has a low calorific value, due to the absence of natural gas liquids (NGLs) [10, 12, 14].

Coalbed Methane mirrors methane and is the only adsorbed gas in the coal and effectively underlines that it is the essential constituent of the gas adsorbed in the coal. Specifically, it centers on the "clean" and "pure" constituent of the coalbed gases. Subsequently, the relative wealth of methane as an essential part of the coalbed gas makes it an appealing fuel [22-23].

3.5.3. Tight Gas

Tight gas, commonly known as 'deep gas' or 'basin-centered gas', is not restricted to regional prevalent resource play depositions, but also exists in conventional traps. The most efficient tight gas reservoir is heterogeneous with sweet spots and high permeability and porosity that maybe sedimentological or origin structure. In North America, majority of the efficient tight gas resources comprise thick-stacked sandstones that permits hydraulic fracturing up to the entire length. The natural gas accumulated in tight sandstone and rock structures is generally known as tight gas [24].

3.5.4. Natural Gas Hydrate

There has been a lot of progress in the last fifty years in investigations on natural gas hydrates (NGHs) in 79 nations. More than 100 wells have been drilled in developing NGHs. There is a line of projects for further research, productions of natural gas from NGHs, the sediments of NGHs are discovered everywhere throughout the world in deep water and in the Arctic [25]. Recently, countries within Asia and North America are very active in the research of NGHs [26]. NGHs are majorly found around continental edge of northern Gulf of Mexico. Advanced drilling information, seismic reflection is sufficient for the investigation of NGHs in Nankai-Trough seaward. Japan is also underway with NGH exploitation [27]. NGHs assemble in Arctic zones are linked with permafrost in Canada, Russia, and northern Alaska. It is assumed that Coastal NGHs in West Siberian Basin are also abundant in other part of permafrost areas in northern Russia. Canada completed a project to obtain methane from NGH zones under the ground in year 2002, it was utilized by America, Japan, India and German. In 2008, a project on practical production was carried by Japan and Canada. As presently identified, the foremost common NGHs on earth contain primarily methane series [28- 29].

3.5.5. Underground Coal Gasification

Underground coal gasification (UCG) is a process during which coal in-situ changes into a vaporous product, that is generally known as synthetic gas or syngas, through similar concoction responses that happen in surface gasifiers. Gasification changes hydrocarbons into synthetic gas (syngas) at raised pressures and temperatures and can be utilized to make numerous products (liquid fuels, electric power, synthetic gas, chemical feedstock). Also, gives various chances for the control of contamination, particularly regarding discharges of sulfur, nitrous oxides, and mercury**.** UCG is a promising alternative for the future utilization of unexploited coal. Most of the new technologies of UCG use a surface reactor for gasification, for example entrained stream, fluidized bed and moving bed. These processes mainly differ from each other on the gas stream configuration, process conditions, coal molecule size, and ash handling [30, 47]**.** There has been considerable advances and developments of technologies since the 1990 for various applications in UOG exploitation, raising global oil and gas production to almost $70x10^8$ t. This includes technologies for petroleum systems evaluation, advances in seismic resolutions, numerical simulation, reservoir characterization, inroads in horizontal drilling, multilateral drilling and extended reach well drilling [8, 9, 24], [31-34], [36-39], [48].

3.6. Global Unconventional Oil and Gas Distribution

UOG deposits are largely distributed in certain negative tectonic structures as basin centers and slopes with "continuous" and "quasi-continuous" accumulations, are enriched in local areas, and they are different from conventional resources dominated by second-order structural zones. There can be an extension of exploration to an entire basin. UOG are distinguished various amount of plenitude and large accumulation area. Source rocks that behave like reservoirs, spreading wide, they have no obvious traps (and no trap most times), and are continuous reservoirs, resulting in large deposits of UOG without clear boundary layers, with a possibility of forming oil and gas regions and units. For instance, shale oil and gas behave as reservoir rocks and also source rocks, with no clear boundary traps or gas-water contacts [40-44]. Unconventional oil is particularly prevalent in foreland basins. It possesses recoverable resources of about $2,556x10^8$ tons. The world's foreland basins account for 58% of the total. In that order, craton basins, passive continental margin, rift basins, fore-arc and back-arc basins have $720x10^8$ tons, $481x10^8$ tons, $474x10^8$ tons, $128x10^8$ tons, and $63x10^8$ tons of unconventional oil, respectively. They make up 16%, 11%, 11%, 3%, and 1%, respectively. The majority of heavy oil is found in the East Venezuela foreland basin, the Maracaibo foreland basin, the Tampico basin, and the Arab passive continental margin basin. The Alberta foreland basin and the East Siberia craton basin have the highest concentrations of oil sands. Tight oil is mostly found in the Neuquén foreland basin, the Williston craton basin, and the West Siberia rift basin. The Piceance foreland basin, Volga-Ural foreland basin, Uintah foreland basin, Dnepr-Donetsk foreland basin, Paris craton basin, West Siberia rift basin, and Arab passive continental basin are the most common locations for oil shale.

Foreland, craton, rift, passive continental margin, and back-arc basins are the most common locations for unconventional natural gas deposits. Foreland basins with the most accumulation have an unconventional natural gas recoverable reserve of around $125x10^{12}$ m^3, accounting for 55% of the world's total. Unconventional gas resources in craton basins, rift basins, passive continental margins, and back-arc basins are $58x10^{12}$ m^3, $26x10^{12}$ m^3, $16x10^{12}$ m^3, and $1x10^{12}$ m^3, respectively [10, 12, 14]. It contributes for 26%, 11%, 7%, and 1% of the total, respectively. The Zagros foreland basin, Appalachia foreland basin, Gulf foreland basin, Triassic-Ghadames craton basin, Cunning craton basin, West Siberia rift basin, and mid-Arab passive continental margin basin are the most common locations for shale gas. Coalbed gas is primarily found in the Alberta foreland basin, the East Siberian craton basin, and the Kuznetsk rift basin. Tight gas is primarily found in the Appalachia and Alberta foreland basins [44].

3.7. Legislation

European countries have had many discussions in attempt to prohibit hydraulic fracturing due to its possible environmental implications. Recently, Spain discussed about a legislation on Climate Change and Energy Transition, which would prohibit fracking and in February of 2019, in order to adapt to climate change policies, the Council of Ministers of Spain put it to law. In 2019, UK halted fracking process using a moratorium, because of reports and studies that were made and found that fracking operations can be linked with earthquakes. Nevertheless, the factor that led to this decision was said to be high amount of money spent compared to the failure of energy return. UK may have made a difficult decision, but France was the first to decide the ban of all oil and gas explorations and exploitations by 2040. Under this decision no new licenses will be given, and no renewals will be done. Also, halting funding guarantees of energy projects that have to do with fracking and flaring is a thought. However, an interesting fact, without being a law, was that, on September 1 of 2019, Pope Francis, published a message calling the believers to turn themselves to clean energy and leave fossil fuels dependence behind. What followed was that many religious institutions stopped investing in fossil fuels (Global Catholic Climate Movement, 2019) [45-47].

3.8. Environmental Footprints

The nature of these resources is the primary cause for the elevated environmental footprint of unconventional oil and gas. They are difficult to extract because they are deposited in formations that are relatively tight or have limited permeability, preventing them from flowing to the surface. As a result, drilling and other production activities can be more invasive and have a greater environmental impact, not only because of the vast number of drilling rigs, that is greater than in conventional drilling, but also because of the utilization of fracturing fluids, which contain chemicals such as benzene, toluene, formaldehyde, or hydrochloric acid. These substances might readily enter freshwater aquifers and pollute water supplies throughout the vicinity. Concerns regarding the future of wind and solar energy have been raised, because natural gas has become more affordable, at least in the United States. Many nations will develop shale gas resources in the near future, but none will have a perfectly functioning, unsubsidized renewable energy market [47, 48].

Another great environmental concern is the impact of CBM exploitation methods, which release waste gas and wastewater. There were studies that proposed first to filter the water and then the waste gases. According to many scientists, the treat of surface and ground water will affect residential land and hydraulic fracturing. Moreover, during the NGH exploitation, there are environmental impacts such as green gas effect, marine ecological deterioration and submarine landslide that impel the scientists to develop new techniques to minimize them [23, 30]. According to UN Environmental Program, methane hydrates (MHs), are found primarily in two types of cold environments, deep in the ocean in deep water continental margins and beneath the permafrost in Arctic regions. In recent years, the attention of science and the political network to environmental change has increased [49, 50]. NGHs can be identified with natural dangers on the grounds that their separation could influence the ocean or dependability and discharge methane (and related gases) into the water segment [49, 50].

It was speculated that ocean warming causes the release of seafloor methane to the ozone layer, which in turn leads to global warming. Several researchers have suggested the hypothesis of ‘‘clathrate gun’’ in the nature.. Nowadays, there are increasing concerns that CH_4 venting from seafloor may cause a common global warming. Likewise, many scientists believed that large volume of GHs can cause geohazards such as earthquakes, subsidence, marine ecosystem changes, landslides and possibly global warming [51- 54].

4. Conclusions

The current review aimed to establish a study that is focused on unconventional oil and gas, putting forward interpretation with emphasis on the articles that were published between 2000 and 2021.

USA was the highest in terms of the number of articles from across various organization within different nations and China came second. The analysis of the data revealed that there is 23% of the recoverable unconventional resources in North America, with the others accumulated in Russia (22%), Asia (21%), South America (17%), Africa (13) and Europe (4%).

However, some UOG production activities, such as drilling, can be invasive and may have an environmental impact, because of the utilization of fracturing fluids, which contain chemicals such as benzene, toluene, formaldehyde, or hydrochloric acid.

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