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Origin and Exploration of Petroleum: A Review

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ABSTRACT: Fossil fuels are one of the most valuable as well as most exploited natural resources provided by the Earth. Recent advancements in the technology sector have provided us with cleaner and eco-friendly renewable energy options but still, fossil fuels hold an important position among the global energy sources. Petroleum is one of the major constituents of the fossil fuels family and also the most demanded as well. Petroleum products find applications in diversified fields ranging from the utilization of Aviation Turbine Fuel as a fuel source in aircraft to the use of Liquefied Petroleum Gas as a fuel source in household cooking. This paper deals with the review of the origin of petroleum and the overall process of formation and exploration of oil and Natural Gas. Water deposited sedimentary rocks containing organic substances are the main source for the commercial extraction of Petroleum products such as crude oil and natural gas. The following contents below give an entire overview of the origin and exploration of petroleum.

KEYWORDS: Fossil Fuel, Renewable Energy, Petroleum, Natural Gas, Crude oil.

I.INTRODUCTION

Petroleum is an essential component of the world economy and affects our daily life directly or indirectly. It accounts for almost 3.8% of the global economy [1]. In several parts of the world and majorly in the underdeveloped regions, oil and gas are a survival necessity for a majority of the population living in these areas. From the gasoline and diesel, we use in our cars to the diesel and other fuels used in industries daily as a source of energy to the Aviation turbine fuel (ATF) used by different airlines and even the polymer products we use in our everyday life, petroleum and its derivatives are everywhere [2]. Since the period of the Industrial Revolution, energy has always been a primary factor of focus and production [3]. At present, there are several refineries across the globe for processing crude oil into various finished products used in our day-to-day life.

The world petroleum is derived from a medieval Latin phrase meaning 'rock oil' or 'oil from the earth' [4]. Petroleum collectively includes both liquid hydrocarbons as well as gas phase hydrocarbons called as crude oil and natural gas respectively. Petroleum is the fuel that acted as a major source of energy in the Second Industrial Revolution in the twentieth century [5,6]. The deeper explorations for this highly demanded natural resource often termed 'Black Gold' may lead to faster degradation in the levels and amount of petroleum reserves underneath the earth at an ever-accelerated rate than before. Finding new petroleum reserves and the development of new alternate sources of energy that are both cost-efficient and can meet the huge demand of the worldwide nations is one of the greatest challenges the scientists and engineers across the world are facing in recent times.

Old style writing is observable without any trace of understanding, also Roger Bacon demonstrates in the year 1268 in his treatise named Opus Tertium the absence of conversation at the origin of oil as well as bitumen by Aristotle and the rest of regular scholars [7]. Dual theories in petroleum arose in between the Renaissance. In their 1546 text, De Natura Deorum quae Effluunt ex Terra, Georgius Agricola, a German scholar developed the idea of Aristotle regarding exhalations from deep inside Earth and recommended bitumen, as different minerals, consolidated from sulphur [8]. Different biogenic speculations arose in the mid 19 century recommending that petroleum has gotten straightforwardly from natural remaining parts or refining interaction [9]. In 1936, Alfred Treibs laid out the connection between chlorophyll in biotic creatures and porphyrins in crude [10]. However geochemical proof followed the revelations that less to intermediate oils even still held hydrocarbon divisions along with an optically active [11], there steady isotopes of the carbon of crude sustain an organic fractionation [12], and there the oils contain notwithstanding porphyrins,

heavy group of hydrocarbons which may be followed back to explicit natural precursors [13]. The advancement of the modern abiogenic idea was established during the nineteenth century.

II.SETTLING OF ORGANIC RICH ROCKS

Sedimentary rocks which are water deposited is the source of petroleum that contains enough quantity of the organic substance to produce oil and gases on the commercial scale. When these rocks will be heated, 3 main factors dominate the settling of organic-rich sediments: preservation, dilution, and productivity(Fig. 1) [14-16]. productivity refers to the quantity of organics that are contributed to the sedimentary rocks, whereas Dilution tells the quantity of inorganic substances which is agitated with an organic substituent. once it is accumulated, the organic must preserve, and later it may produce petroleum. after some debate and analysis now it's confirmed, that these are the 3 factors that are inherently co-related in complex ways and in different manners.

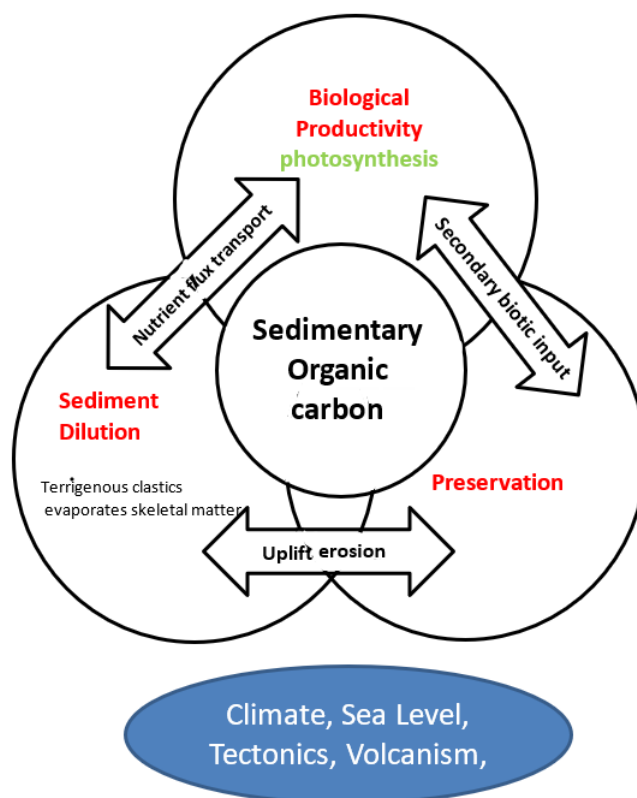


Fig.1. The three main factors: primary productivity, dilution and preservation to find whether biotic rich source rocks are accumulated

Aerobic Cyanobacteria and anaerobic bacteria, land plants, and some algae are all photosynthetic organisms that produce much more organic matter initially by CO₂ fixation. some non-photosynthetic elements like methanotrophic communities depend on the product that is produced by photosynthetic organisms. Many factors like turbidity, CO₂, coastal up-swellings, and many more affect primary productivity. Initial organic matter that was produced by organisms undergoes degradation by other elements during 2nd step of production. heterotrophs in water, rocks are continuously degraded. Some anaerobic organisms also help to degrade the organics in different ways like fermentation and respiration. After some time, some sedimentary organics become lithified rock, and anoxic situation increases the stock of oil-prone organics and enhances the settling of potential rocks as depicted by Fig. 2.

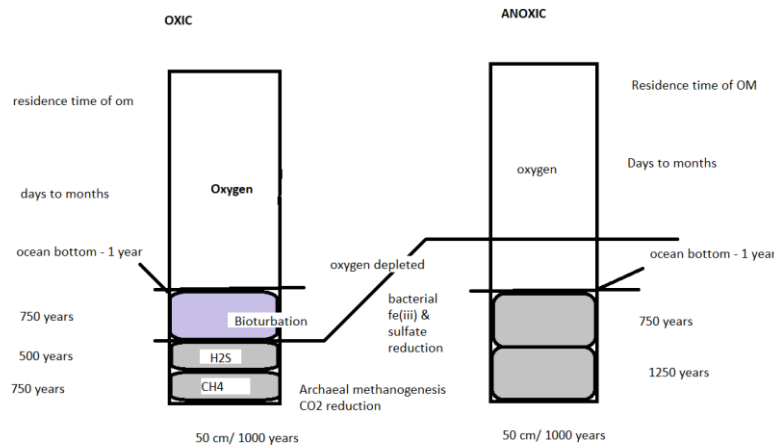


Fig.2.Oxic and anoxic deposition in an environment generally outcome in degraded and well safeguarding of deposited organic substance, respectively

The high amount of organics supply creates the problem of Bio-Oxygen Demands and it may lower the water column. It has been seen in the terrigenous environment with large input materials like swamps and coastal plains. In anoxic aquatic organisms, prevalent organisms are mostly bacteria that use sulfate and provide hydrogen sulfide. Sedimentation influences both factor conservation and concentration of the organics. An organic substance may be eliminated from bio-recycling by instant burial. Sedimentary rocks along with most concentrated organics are dumped under intermediate to the high inpouring of primary organics and low sedimentation rates.

III.PRODUCTION AND EXPULSION OF GAS AND OIL

In catagenesis, kerogen is cracked and bitumen is produced. Carbon-Sulphur and Carbon-Oxygen bond breaks in the initial stage of the process that is very rich in polar compounds, with extra heat Carbon-Carbon bond break within polar compounds and produce kerogen and fluid rich in hydrocarbon. On applying thermal stress, kerogen produces primarily wet gases (C1-C6) and condensate. Under more thermal alteration metagenesis may take place. In oil production both temperature and time are judgmental since it's a kinetic process [17] some good models describe the composition of fluid of the outcome products.

Thermogenesis describes the generation of petroleum, geo-catalysis contains reactive mineral zone, and trace elements [18, 19]. It's very difficult to imagine how the inorganic substances would remain activated. Petroleum is poured out into mineral pore space after kerogen production. This oil is very rich in saturated hydrocarbons and aromatics concerning bitumen. Expulsion model idea is based on the interaction of produced yield with the kerogen have achieved. As they had the things to judge composition between bitumen and expelled oil that is dependent on the kerogen varieties and quantity.

IV. COMPOSITIONAL CHANGE IN THE RESERVOIR

Petroleum composition is variable. It varies with the alteration of circumstances. With an increment of temperature-depth of burial also get increased which leads to thermal maturation. In this phenomenon, heavy molecules are cracked by the thermal effect into small ones and to get the lighter fraction, enhance the oil passage to reduce the densities in the series from oil, to lighter ones, to wet and eventually converted to dry gas. Parallel reaction in the cyclization and aromatization provides the hydrogen and it leads to increment of hydrogen. When the molecules start losing hydrogen at the same moment, oil is becoming light. Eventually, these molecules get precipitated as asphaltenes which are known as "natural deasphalting".

Solvent deasphalting unit in the refinery is just analogous to it, SDU is done just to improve the quality and up gradation of primary phase product, by reducing the traces of sulphur, some metals, and nitrogen.

V. BIOGENIC ORIGIN

Biogenic origin is currently accepted on a very high scale for high carbon material in petroleum. The inorganic phenomenon leads to a racemic mixture, optically active components in the oil, some naphthenes give high support. These are chemical fossils that are components with some characteristic figure, those compounds contain isoprenoids, hopanes, porphyrins, etc. The scarcity of thermodynamic equilibrium in the compounds and the very close and dense association of petroleum concerning sedimentary rocks generated in an aqueous medium supports low-temperature origin. The proof supports the biological source that produces petroleum [20].

VI. THERMAL GENERATION

Organisms generate a very large quantity of organics along with protein, carbohydrates, and many more things. After the life-ending, some part of this organics may deposit in aquatic surrounding with varieties of compounds with variable stabilities range. Survival depends on many factors, specifically the oxidation and reduction nature of the system. Sediments accumulated in oxygenated surrounding contains approximately 4 wt% organics and anoxic sediments may cross 20 wt% organics, the latter accounts for 50 wt% and more by volume of rock. The generation of petroleum requires more than the accumulation of bitumen that is in sediments. Organism and some sediments are in the range of C₂-C₁₀, these hydrocarbons may lead to half of the crude. Remaining compounds are also reported in crude oil. Continuously thermal operation on organics in decreasing environments produce eventually to final products one of them is rich in hydrogen and another one is a poor product. At the minimum temperature, the organic component progress along this way and generates high molecular weight and solvent immiscible components known as "kerogen" that becomes highly aromatic and rich in carbon. Whereas lower molecular weight organics are bitumen which is rich in hydrogen and finally progresses through a fraction of the crude oil.

VII. PETROLEUM EXPLORATION

From the study of the origin of petroleum, it is very clear that petroleum is present in the rock layers underneath the earth's surface and must be explored using suitable methods to achieve the maximum extraction of the natural resource. The petroleum is trapped in the porous rocky layer known as the reservoir rock which is above the source rock layer. The source rock layer is the shale rock layer or lime mudstone which is abundant in organic matter and is the primary source of petroleum [21].

Hydrocarbons in their natural state are present in the pores of the rocks found in the reservoir rock layer. The size of the pores is in the order of microns but the exact size may vary from place to place and the size of pores found in the conventional petroleum reservoir is also more (usually in the multiple of ten microns) than that found in the non-conventional sources (usually half a micron) [22]. This petroleum is formed in the source rock bed from the organic deposits present by the process of biogenic decay or due to thermogenic maturation of the organic matter present in the deeper source rocks. This conversion process of raw organic matter to petroleum is very time-consuming and also depends upon the right temperature and pressure which are usually very high at such great depths below the earth's surface. The petroleum formed then slowly migrates through the porous silt layer and finally reaches the reservoir rocks and gets deposited there for years. It is usually seen that if the organic material is largely comprised of plant origin and the depth of the reservoir is greater, the petroleum product is very much rich in natural gas whereas if the organic matter is of animal origin and the depth of the reservoir is shallow, the petroleum, product obtained is dominated by crude oil which is in a liquid state [23].

Hydrocarbons are the main constituent of petroleum. Because of their lower specific gravity than water, the petroleum tends to migrate upwards to the reservoir rocks from the source rocks through the intermediate porous silt layer, which provides a good passage for the petroleum to migrate upward. The layers inside the earth's surface are not flat or perfectly horizontal due to continuous tectonic plate movement. Thus, they tend to form bends and faults which create geometrically isolated and well-sealed structures known as traps in the reservoir rock layer where finally the petroleum gets stuck and remains there for several years. The primary objective behind performing any drilling operation is to dig into these traps where a potential amount of petroleum and natural gases are suspected to be present.

The data obtained by IEA, oil need continuously increase till 2040. The US predicts an 80% increment in global transportation by 2025. The natural gas requirement is approximately 45% by 2040. In a progressive economy, about 80 % of age gas demand is taking place, led by the country China and many more countries in the Asian continent [24].

It is determined that by 2040, oil, coal, and gas will contribute more than 75 % of energy globally. consumption of oil will enhance in upcoming decades. There are many more sectors excluding vehicles where oil is demanding towards 105 mmb/d, by 2040 [25].

VIII. EXPLORATION STEPS

The exploration operation for any new petroleum reservoir takes place in a series of concurrent steps. They are to be done in a specific sequence one after the other and each step must be done accurately and precisely to make the exploration operation a success and that the company makes the maximum possible profit from the adequate amount of petroleum it recovers from that particular reservoir.

ANALYSIS, SEARCH, AND SELECTION OF SUITABLE DRILLING LOCATION:

The first and foremost job of any exploration team is to search for the ideal drilling location which contains a good amount of crude oil or natural gas. This task is predominantly taken by the group of geologists. The team uses the concepts of geology, geophysics, and seismic waves to detect the position, thickness, and density of various layers underneath the earth's surface and detect the particular location or the locations where these traps with petroleum reserves might be present. These are the sites where later the drilling operation will take place for the main exploration purpose. Also, factors like a well porous silt layer, well-sealed traps, and thick and organic matter-rich source layers are kept into consideration for locating a profitable drill point.

Oil quantity in volumes is only obtained and generated from the reservoir, and the data average recovery factor is around 30% in the industrial norm. nowadays, a lot of new technology of extraction may enhance it to 50 %.

IX. DRILLING

Once the exploration job is done by the team of geologists and the location of the traps is confirmed, initiating the drilling operation is the next mode of action for the exploration team. As the reservoirs can be found in any kind of geographical location with any kind of geological properties of the landscape, the wells must be drilled very specific to the type of reservoir considering all the location constraints as well. Drilled wells can be classified as an exploratory well, the discovery well, development well, and infill well depending upon the purpose for which the well is dug. A well that is drilled for discovering a new petroleum reservoir is known as an exploratory well. Well drilled for discovery is known as the discovery well.

The drilling of well is an operation that employs the use of various small equipment so connected that they together form a complex and long structure. The structure known as the drilling rig is the assembly of sub-components connected like drill string and drill bit. The drilling operation involves an appreciable cost hence the components must be selected judiciously and the operation is to be carried out carefully and must be specific to a specific well or reservoir.

The drilling rig may vary from small to large, maybe mobile or fixed depending on the type and location of exploration operation, material to be extracted, and geological features of the location where the exploration operation is being carried out. During the drilling operation, a special chemical mixture known as drill mud is circulated into the drill hole through the drill string which serves various purposes such as lubricating and cooling the drilling pipes, stabilizing the hole, and preventing the flow of formation fluids into the wellbore. The main objective of the drilling mud is to increase the efficiency and cost-effectiveness of the entire process.

The deepest petroleum well drilled was Bertha Rogers No. 1 around 31,441 feet around 9583 m, in Oklahoma in 1974. Wildcat, a petroleum well is drilled for new oil discovery, so it is known as the discovery well. It was drilled between producing wells to enhance the productivity that is nothing but only infill wells [26].

There is much complex equipment in the drilling phenomenon that is known as DRILLING RIG, in which drill string is the most important. These are the combined form of many devices including drill bits at the last. Drilling rigs can be either offshore or land. Land rigs are rigs that vary from small to intermediate(basic) to large ones for different objective purposes, whereas offshore can be fixed or movable.

Fixed rigs are also classified as jack-up rigs, in which shallow waters are up to around 350 feet. In the case of mobile offshore rigs which are generally considered in relatively deep water around 3500 feet and for drill-hips it is up to

10000 feet. During drilling, a mixture known as the drilling fluid is passed through the drill string into the pore to ensure that the holes are stable.

X. DEVELOPMENT OF AN EXTRACTION FIELD

When the discovery of a petroleum reserve is confirmed by drilling and exploration, the immediate next priority is to evaluate the volume, productivity, physical properties, and other important parameters of the petroleum from the well with the use of samples collected. Simulations are also performed to better understand the flow behavior and other important factors of the fluid in the well. After figuring out all these parameters, a plan to develop a petroleum extraction unit is carried out. The development of the field depends on various factors both from the profit and environmental points of view. The major product to be extracted, the extent of extraction, the geographical properties of the drilling location, the environmental factor, the consumer demand scenario, the side products to be extracted, and the capacity of the petroleum reserve are some of the important factors kept in mind during the development process.

Development of extraction unit includes mainly the design, building of oil and gas processing systems, pipelines, infrastructural plan for production, storage, depositing facilities, as well as essentially the extensive drilling of petroleum production wells. The modeling of the reservoir and optimizing the construction of the field, i.e., judicious selection of the number of wells which are to be drilled, how much apart they must be from each other, and how much deep the wells are to be dug for maximum extraction of petroleum with the optimum investment are altogether considered as an important factor to be kept in mind during the planning of the development of oil or gas field.

Also, onshore oil fields vary greatly from offshore oil fields because additional restrictions such as the level of water from the sea bed, wind, water currents, tides, seasonal storms, and cyclones are to be considered in the initial modeling and simulation of the reservoir and the oil or gas field.

In all the oil and gas industries across the globe, a vital component of their total investment is being used up for drilling and development of a sustainable oil field that produces petroleum for at least a few decades. Hence, all the prerequisites are checked thoroughly and the modeling and simulations are also done very precisely keeping into consideration all the necessary factors and restrictions so that an efficient field can be set up with well-optimized inputs and the maximum output possible.

A huge important data gathering generally gets affected upon the execution of improvement well after the recognition of all wells. In the USA, according to the WTRG, the rate of success of the wells enhanced from 77% to 90%, in the year 1974 to 2012. These development wells are drilled to get hydrocarbons; these are discovered based on successful exploration.

In the last two decades, there are several deeper offshore which is about 1000m water depth, in many areas like Brazil's pre-salt reservoirs the UDW, there are too many deep wells which was drilled.

XI. EXTRACTION AND YIELD

The last step of the exploration of petroleum is the extraction of petroleum from the field and sending it to nearby or distant refineries through pipeline networks and other modes of transport. Many times, the crude oil obtained from the field is directly sold in the international market to the oil deficient countries without any processing or with minimal processing.

Also, an important factor nowadays is the paperwork, legal agreements, and contract between the company and the landlord or the government for privately owned and public properties respectively. The area is given to the company for a particular duration of time stated in the contract note. If the company couldn't find any oil or gas and the contract becomes invalid, the company has to incur a huge loss. So, the companies are very careful about the total geological aspect of the drill site.

Conventional reservoir hydrocarbons can be extracted from the field for a few decades, even extending up to 50 years or more for giant reservoirs. But in the case of unconventional reservoirs, the production rate and duration vary from place to place due to several anomalies, and sometimes, the extraction is either very costly and labor-intensive or not possible at all due to the strict laws followed by the particular nation.

Hydrocarbons may be obtained in 15 and 30 years of time ranges but sometimes it extends up to more than 50 years for "giant fields".

During primary recovery, hydrocarbon normally flows under the oilfield base, and underground strain in the oil well pushes to the surface, from this phenomenon around 5 % to 15b% of oil is to be drawn out. In the tertiary phase, the

injection may be compulsory to withdraw around 5 to 15 % of the crude oil. The amount of the reserve in North America, along with new advanced technology, for the horizontal drilling and hydraulic stimulation of the reservoir rocks, gives the justification that in 2012, the USA and Canada generated 275 million m³ [27].

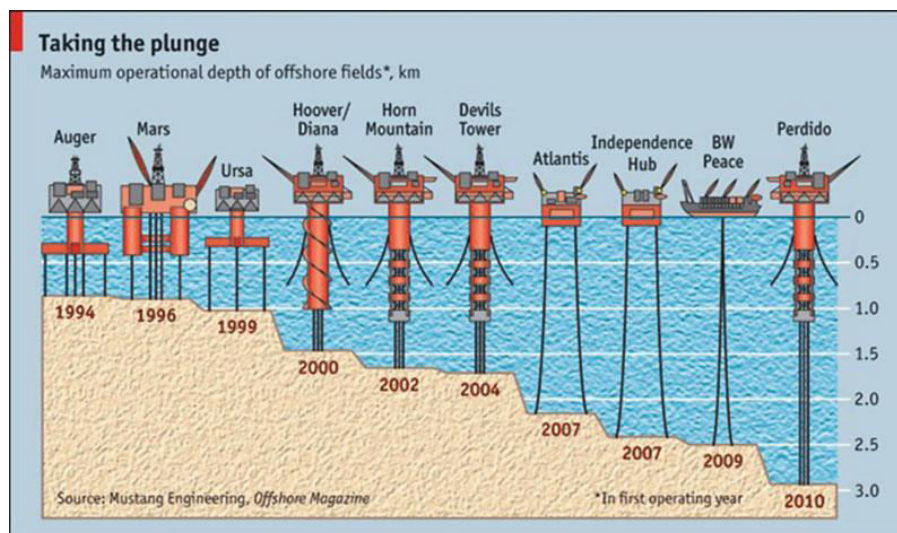


Fig. 3 The above figure differentiates between unconventional and conventional gas accumulations that are basin-centred [28]

XII. ABANDONING THE FIELD

This is the final fate of almost any oilfield the field abandonment and dismantling of the oil rig structure. Abandonment is the end stage in an upstream life cycle. When the rate of production of the crude oil or gas becomes non-economical and now there is no scope for commercial extraction, reservoir abandonment is the only option left. Before abandoning the oil field, the oil companies must: Dismantle and remove all the facilities such as the platforms. There are special vessels that remove offshore platforms which must be requested and entered into action. The removal of surface facilities should be at least a few meters below the seabed otherwise they will be remained as an artificial reef on the ocean bed after the conditions of free hydrocarbon are reached.

A safe state of the well must be ensured, i.e., the well must be closed and sealed off permanently in such a manner that no more hydrocarbons can exit from the well surface. Preserving the residual reserves of hydrocarbons in the exploration field is also a key point to be remembered. The company must ensure the cleaning, depolluting, and rehabilitation of the site so that the site is restored to its original condition in a precise manner.

XIII. CONCLUSION

This review paper aimed is at focusing on the entire process of formation and extraction of petroleum from conventional points or regions. In situ combustion, or burning some of the reservoir oil in place, is an alternative technique for heating a reservoir. To support the combustion, a lot of compressed air needs to be fed into the oil zone. The ideal temperature for combustion is 500 °C or 930 °F. Oil production is aided by the hot combustion products flowing through the reservoir. The usage of in situ combustion is not very common.

There are much ongoing current research and development going on in the field of clean energy which could potentially replace petroleum as the main source of energy but it can be easily said that despite all these efforts, this is very much unlikely that petroleum will cease to play the central role in the worldwide energy supply market for at least another four decades. Yet, meeting this sped-up development rate without further ado implies that the conventional oil projects must twice their quantity from their ongoing low levels. This also indicates several existing environmental issues will rise in intensity and new concerns will also begin to come into the news.

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