Environmental Biotechnology
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Lecture-47
Microbially Enhanced Oil Recovery (MEOR)

Welcome to the next lecture of this course environmental biotechnology and in this lecture we will be discussing about microbially enhanced oil recovery.

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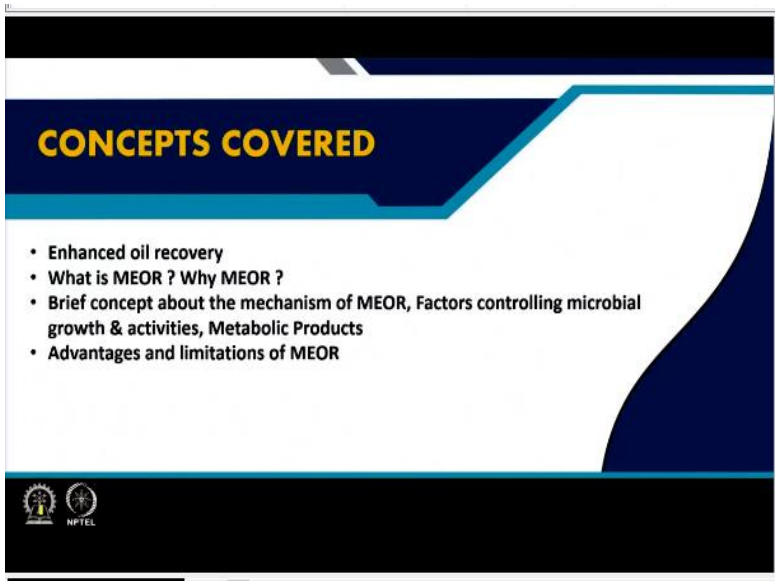

Now the following concepts are going to be discussed in this particular lecture, this will include the enhanced oil recovery, its requirement. Then we will talk about the definition and we will introduce ourselves to the concept of microbially enhanced oil recovery and why do we need such microbially enhanced oil recovery. We will have a brief concept about the mechanism of the MEOR, factors controlling the microbial growth and activities which facilitate the enhanced oil recovery and the metabolic products which are produced by the microorganisms related to this MEOR process and we will also discuss about the advantages and limitations of MEOR.

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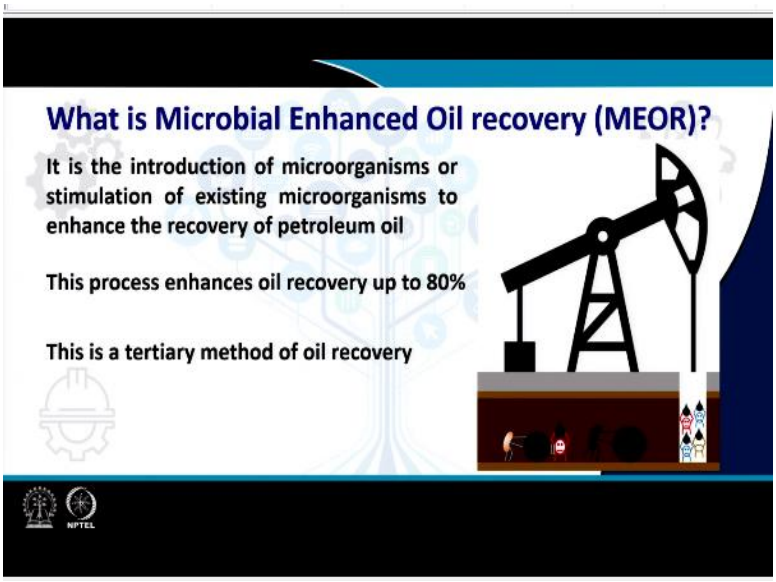

Now to begin with what is microbially enhanced oil recovery? It is the introduction of microorganisms or stimulation of the existing microorganisms to enhance the recovery of petroleum oil from the oil reserves. Now this process can enhance the recovery of petroleum oil up to 80% of the oil reserves and this is considered to be a tertiary method of oil recovery. As you can see that in the underground oil recovery, oil reserves these introduced microbes or the stimulants which are used to enhance the activities of the indigenous microorganisms present over there are utilized to recover the residual petroleum oil.

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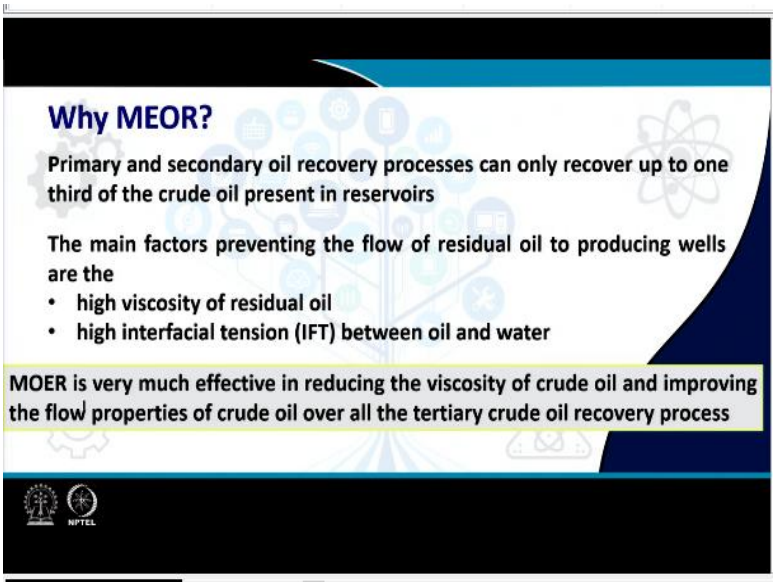

Now why MEOR is required? Primary and secondary oil recovery processes which are mostly the physical and chemical methods they can only recover up to one third of the crude oil present in the reservoirs. And the main factors which are found to be preventing the flow of the residual oil that the remaining oil after the extraction through the primary and

secondary treatments to the product producing oils are basically the high viscosity of the residual oil maybe the tars and other compounds which are having very high viscosity and high interfacial tension or IFT between the oil and the water.

So, those parts of the petroleum reserves or petroleum oils remain unrecovered from or through these primary and secondary oil recovery systems. So, microbially enhanced oil recovery system or microbially catalyzed oil recovery system; is very much effective in reducing the viscosity of the crude oil while the oil is still in the oil reserve and improving the flow properties of the crude oil over all the tertiary crude oil recovery methods.

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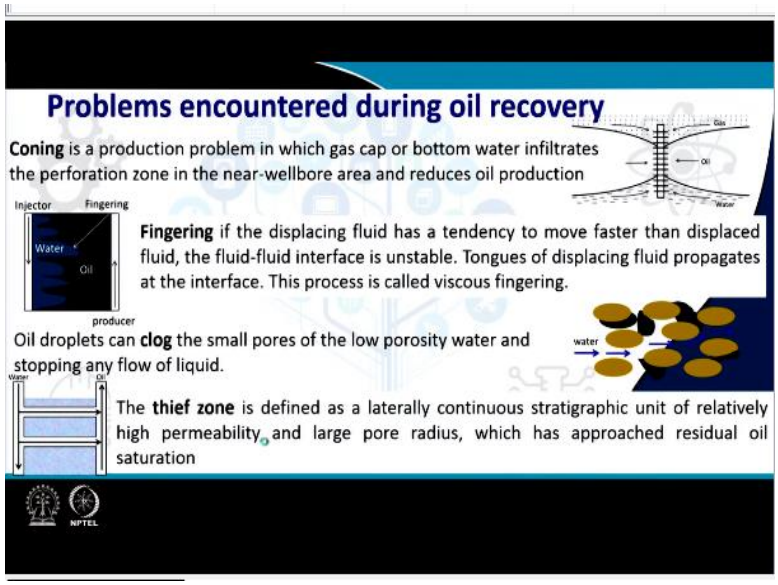

Now what are the problems which are encountered during the oil recovery? The problems are having multiple of kinds; one of them is coning which is a production problem in which the gas cap or bottom water infiltrates the perforation zone in the near well bore area and reduce the oil production. Fingering which is basically the displacing fluid has the tendency to move faster than the displaced fluid and basically the fluid-fluid interface is unstable.

And tongues of displacing fluids propagate at the interface and this process is called the viscous fingering. There are also points like clogging in which oil droplets can clog the small pores in the low porosity water and stopping any flow of the liquid or there could be formation of the thief zone which is defined as the laterally continuous stratigraphic unit of relatively high permeability and large pore radius which has approached residual oil saturation.

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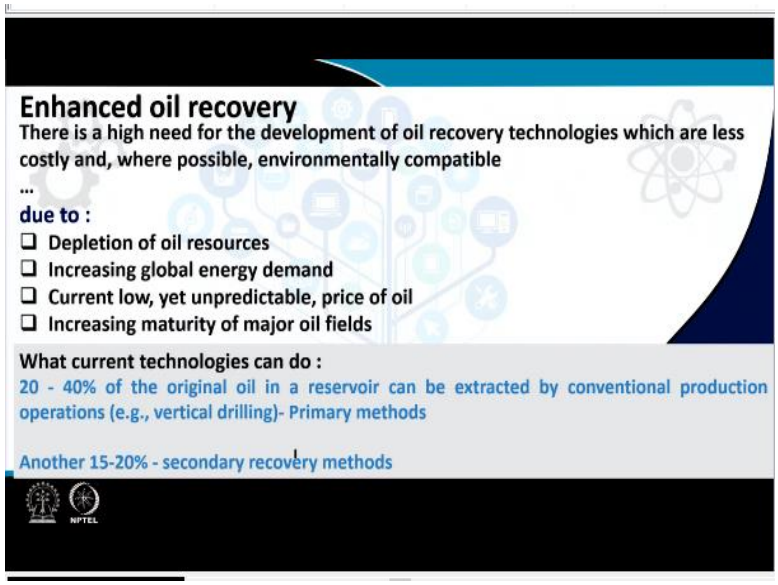

Now, enhanced oil recovery is found to be a very promising approach to recover the residual oils which are left because of the reasons discussed in the previous slide and also after performing the primary and secondary recovery processes. Now, there is a high need for the development of oil recovery technologies which are less costly and where possible, environmentally compatible.

So, we need these and this is particularly true because of the depletion of the oil resources increasing the global energy demands, current low, but unpredictable price of the oil and increasing maturity of major oil fields, where the search for new oil fields and oil reserves are being continued, development of primary and secondary methods are also being done. Utilizing the leftover oil or the residual oil in the oil reserves and developing technologies to recover that oil.

Because as I mentioned that a large proportion of the petroleum oil still remain in the oil beds or the oil reserves after the secondary treatment is even done. Now what the current technologies can do? That is the physical and chemical technologies which are basically the primary and secondary methods. 20 to 40% of the original oil, petroleum oil present in the reservoir can be extracted by conventional production operations.

That is called vertical drilling and it is basically the primary method. Another 15 to 20% can be recovered by secondary recovery method. So, total around 55 to 60% of the oil present in the oil reserves can be recovered through conventional primary and secondary methods. So,

there could be high possibility or there is a high possibility that 40 to 50% of the petroleum oil still remains unrecovered in the petroleum reserves.

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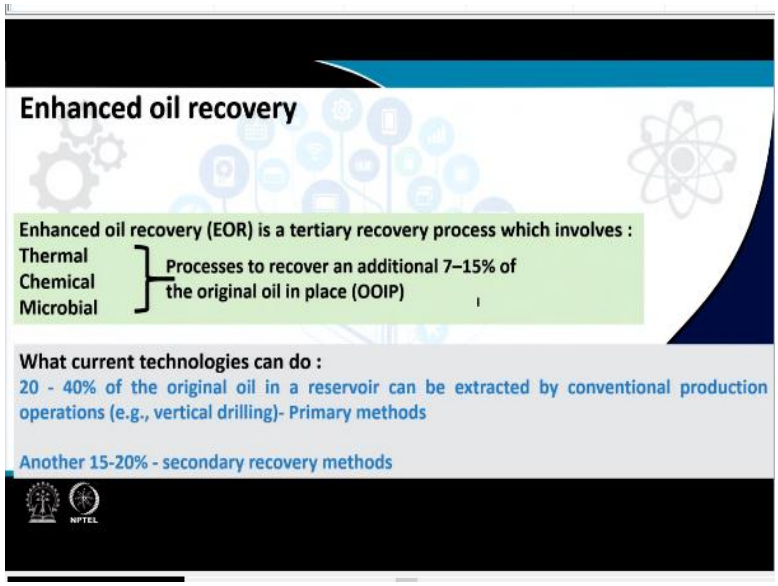

Now enhanced oil recovery is the tertiary recovery process which involves both thermal, chemical and microbial processes to recover the additional 7 to 15% of the original oil in place are OOIP.

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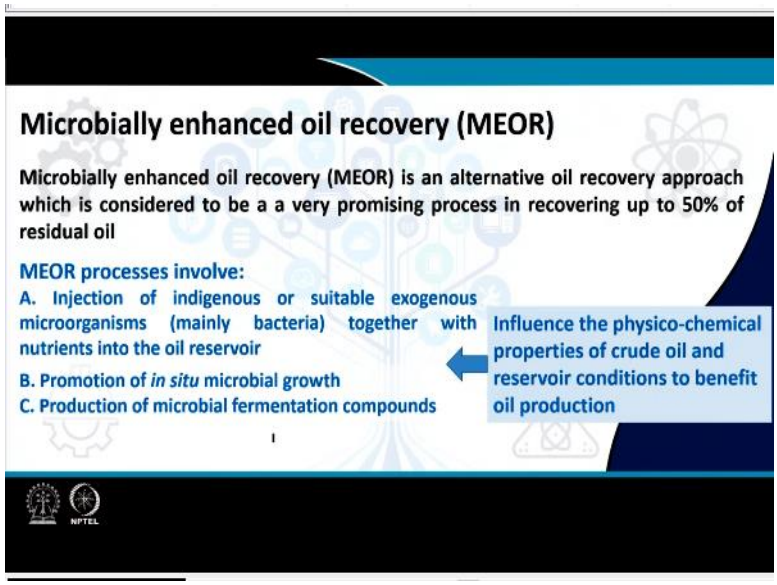

Now microbially enhanced oil recovery is an alternative to the oil recovery approach along with the chemical and the thermal processes which is considered to be a very promising process in recovering up to 50% of the residual oil and this MEOR processes involved injection of indigenous or suitable exogenous microorganisms mainly bacteria, sometimes

some archaea are also found to be very important in facilitating the desirable reactions together with the nutrients into the oil reservoirs.

Now the selection of the nutrients are very critical because these are the nutrients which the microbes would like to utilize during the process which will possibly facilitate the recovery of the oil from the underground oil reserves. Promotion of in situ microbial growth because the reservoirs they themselves are having huge microbial communities and many of those microbes could be suitable or useful for facilitating this microbial oil recovery process.

So, addition or injection of suitable nutrients to facilitate the; promotion of such microorganisms are considered as in situ microbial activities. Essentially the entire process would rely on in situ microbial activity most of the cases, but sometimes we add exogenous organisms or sometimes we add nutrients to encourage or promote the in situ organisms and in situ microbial growth and activities.

And also production of microbial fermentative products and other metabolites which help or which facilitates this oil recovery process. So, the ultimate goal of this is to influence the physicochemical properties of the crude oil and reservoir conditions or characteristics to benefit the oil production. So, that the oil moves close to the oil recovery wells and it is possible to recover the oil from the reservoirs.

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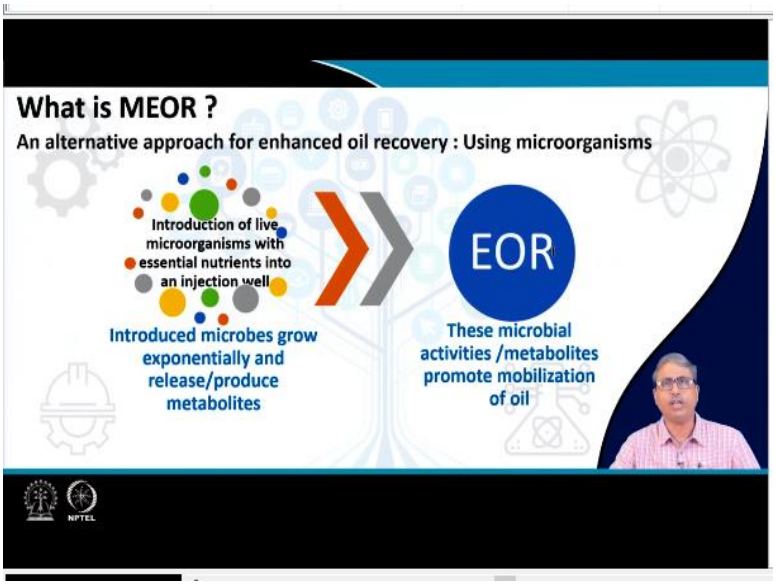

Now what is MEOR? As we have possibly understood by this time that this is a microbially mediated process number 1 and also number 2 it helps in recovering the petroleum oil from

the underground oil reservoirs. Now basically it is an alternative approach for enhanced oil recovery using microbes as there are thermal and other chemical methods as enhanced oil recovery process.

Now the introduction of the live microbes mainly bacteria and archaea with essential nutrients are initially done, so we use injection wells and these injection wells are used to pump in the microorganisms a desirable catalytically relevant microorganisms and essential nutrients to facilitate the desirable chemical reactions. Now these introduced microbes grow exponentially and release or produce the metabolites including biosurfactant gas and many other things.

Now, these activities of microbes, so, it is the products of the microbes and the activities of the microbes which are found to be responsible for enhanced oil recovery. Now these microbial activities which are basically promoted or enhanced due to the injection of the organisms from the external sources through the injection oil or through the injection of the nutrients or may be both. So, these microbial activities or metabolites promote the mobilization of the oil resulting into the enhanced oil recovery.

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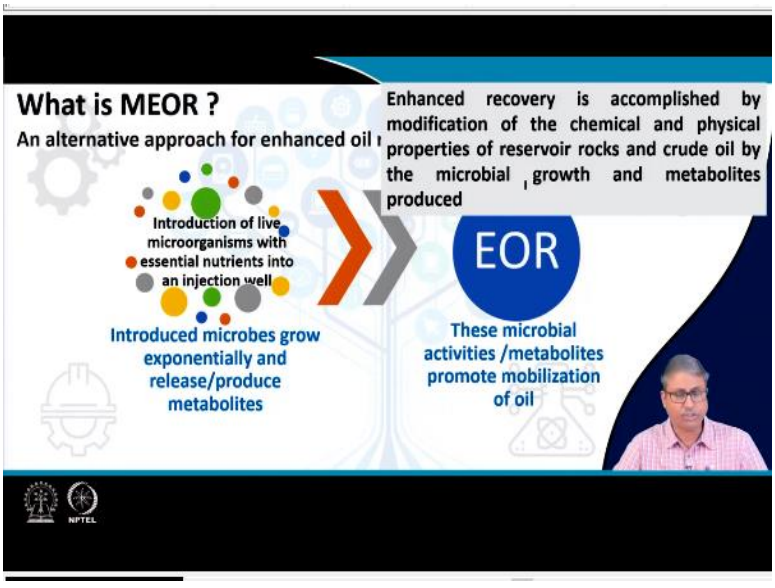

Now the enhanced recovery is accomplished by modification of the chemical and physical properties of the reservoir rocks and the crude oil by microbial growth. Because we have already seen that coning and clogging and formation of thieve zones and there are multiple constraints which are found to be important and actually those are responsible for the residual oils is still remaining there even after the secondary oil recovery processes.

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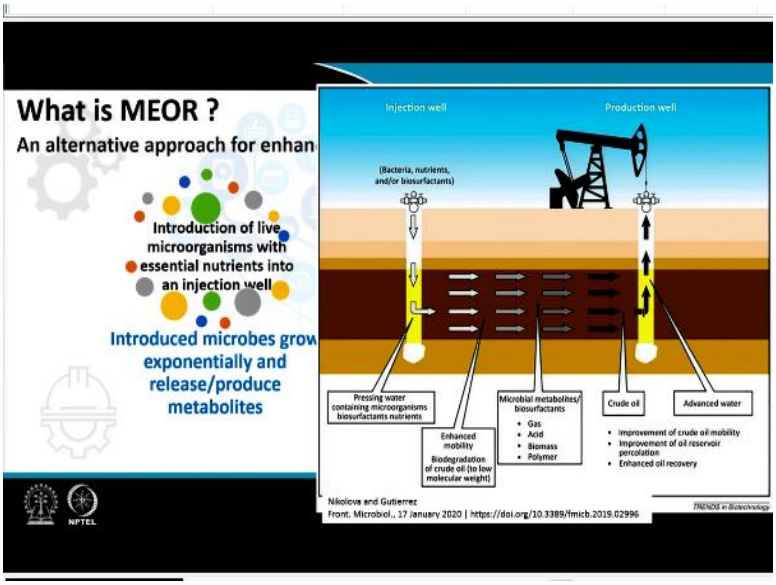

So, this picture in this case is depicting some of these ideas that how the injection well can actually be used to inject the bacteria and other nutrients and sometimes the biosurfactant molecules and the pressing water along with this bacteria, nutrients and biosurfactant allows this to react to the oil reserve zone and as it moves on so enhanced mobility of the oil molecules takes place. Now the microbially produced metabolites over here including the biosurfactant, the different gas, different acid, biomass and polymer are also responsible for facilitating this process.

And finally the crude oil is released and it is coming close to the well head from where it can be pumped outside and this is called the production oil. So, the oil can essentially be recovered. So, the nutrients which are or the biosurfactant type of compounds which are introduced into the oil reserve they facilitate the reactions which actually allow the mobilization of the crude oil towards the oil recovery of the production well. So, that the; well can actually pump out the oil.

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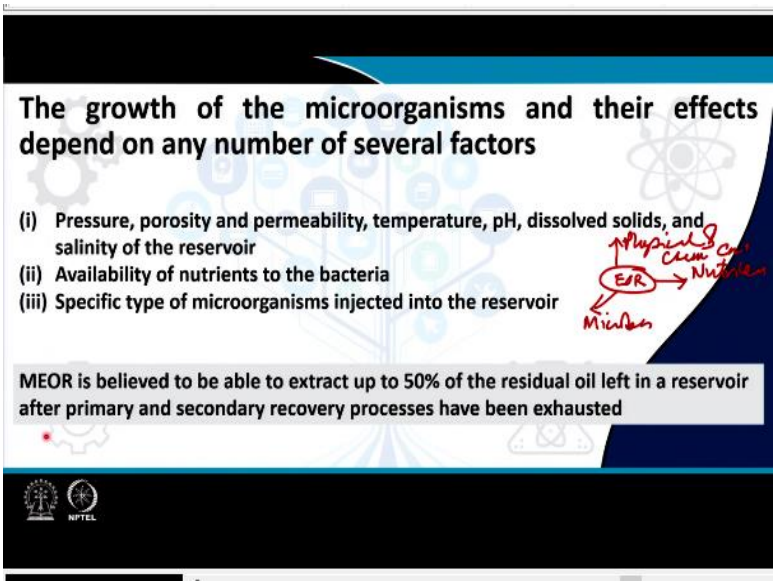

Now the growth of the microbes which are responsible for these processes and their effects depend on a number of factors which includes the pressure, porosity and permeability temperature, pH, dissolves solid and salinity of the reservoir. So, as like any environmental biotechnology process we have already learned that the physical, chemical and the nutrient conditions are very important along with the catabolic properties of the microorganisms.

So, these are the physical boundaries like the physical pressure, porosity, permeability, temperature and also the pH availability of different nutrients, the conductivity of the environment etcetera are very important. Availability of the nutrient is of course very important because the microbes other than the petroleum oil because petroleum oil will be utilized by some of these or many of these microbes as the source of carbon and energy.

But you need to provide them phosphate and nitrate and all the nitrogen phosphorus sources and specific type of microorganisms which are injected into the reservoirs. These are also because the microorganisms are again the very important catabolic instrument or catabolic component of the entire system. So, again it is a kind of a 3, vector situation where you have the nutrient you have the process where we have this oil recovery process if we consider the EOR enhanced oil recovery.

Of course it will have the appropriate microbes but it will also have the nutrients and the physical and chemical conditions. So, all 3 factors they actually they are found to be responsible or they are the primary factors controlling the enhanced oil recovery process. Now MEOR is believed to be able to extract up to 50% of the residual oil which is left in the

reservoir even after the primary and secondary recovery processes have been exhausted. So, once the primary and secondary oil recovery processes are done and they found that it is no more suitable even for the secondary oil recovery, oil extraction procedure.

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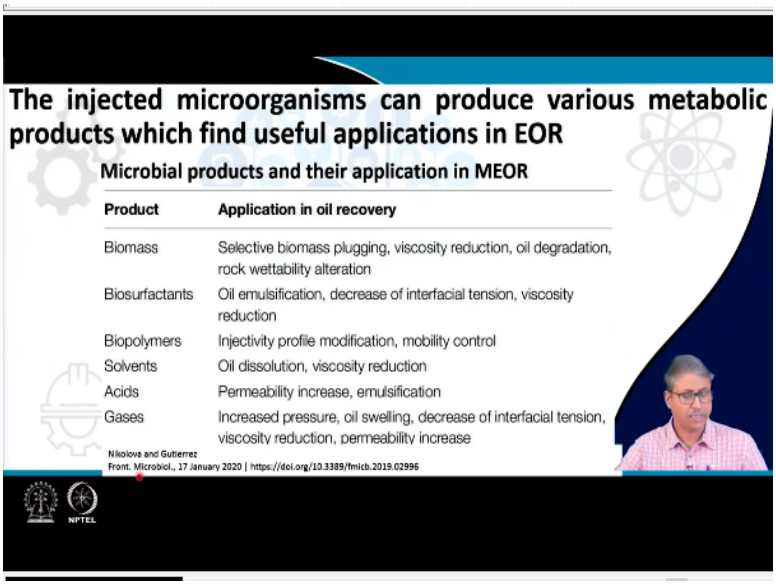

Then this microbially enhanced oil recovery or this enhanced oil recovery processes are done. Now the injected microbes can produce various metabolic products which are found to be very useful for the enhanced oil recovery and these include the biomass itself because the selective biomass plugging, viscosity reduction, oil degradation, rock weathering or rock wettability alteration. All these are responsible by this biomass. The gross biomass which is produced over there they are also responsible for bringing out certain changes which are desirable for the oil recovery.

Production of the biosurfactants; these are found to be very, very important for this because of this their property for oil emulsification, decrease of interfacial tension, viscosity reduction. So, biosurfactant is possibly one of the most important factors that could facilitate enhanced oil recovery. Biopolymers which are responsible for facilitating the injectivity profile modification, mobility control, different solvents which will allow the dissolution of the oil or viscosity reduction again.

Different acids which are produced by the microbes will help in the permeability in enhancing or emulsification process and different gases which are produced by the microbes. Increased pressure, build up pressure, built up is very important, so that the entire thing will be pushed towards the oil well and you already have a high pumping system working on

there, oil swelling, decrease of inter facial tension, viscosity reduction and permeability enhancement.

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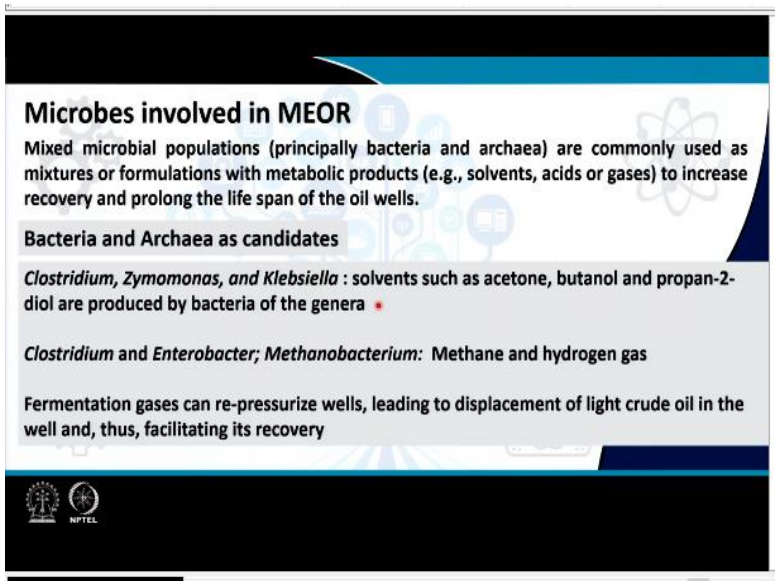

Now what are the microbes involved in the MEOR? It is basically a job done by mixed microbial populations, both bacteria and archaea. And there are number of formulations and number of organisms, their metabolic products including the solvents acid, gases, biosurfactant have been reported to increase the recovery and extend the life span of the oil wells. What are these?

So, the bacteria and archaea which are found to be the potent candidates for these are Clostridium, Zymomonas and Klebsiella; they produce different solvents such as the acetone, butanol and propane-2-diol which are produced by these bacteria. Clostridium and Enterobacter, Methanobacterium are also responsible for producing methane and hydrogen gas. These fermentation gases can repressurize the wells leading to the displacement of the light crude oil in the well and thus facilitating its recovery.

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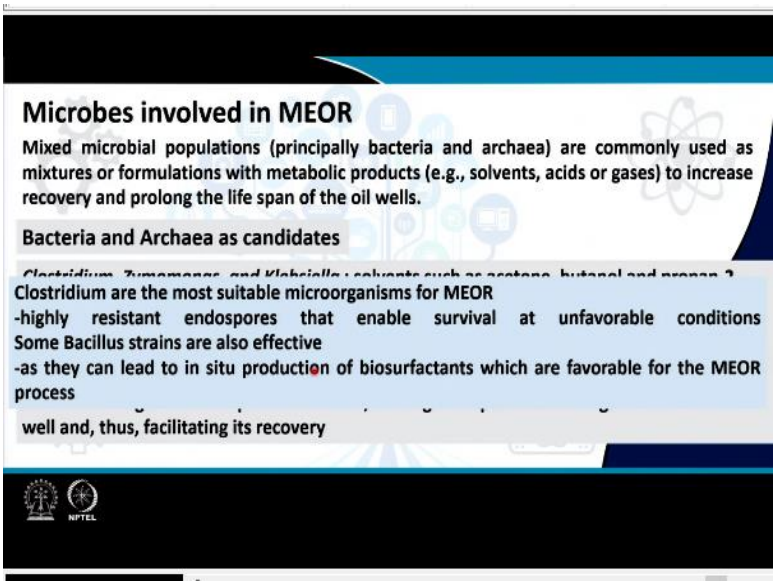

Clostridium is found to be one of the most suitable microorganisms for the MEOR. If we are asked to identify one of the most suitable candidate it is the clostridium, it is because they are highly resistant particularly they are able to produce the endospores that enable them to survive at unfavorable conditions, some of the bacillus strains are also found to be very effective because they can produce biosurfactant and that production of the biosurfactant can lead to incident production of biosurfactant which favours the MEOR process.

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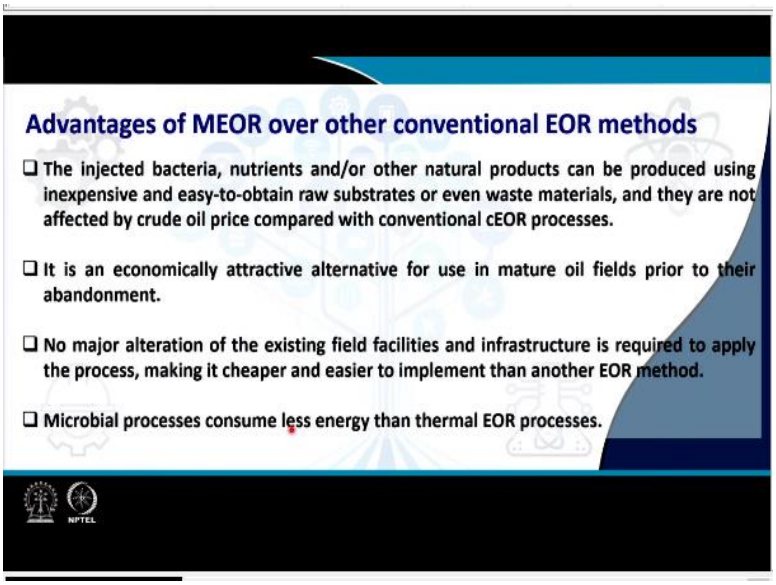

Now we will discuss about the advantages of the MEOR over other conventional EOR methods. First and foremost the injected bacteria, nutrients and other natural products can be produced using inexpensive and easy to obtain raw substrates or even waste materials and they are not affected by crude oil price compared to conventional chemical EOR processes. It

is an economically attractive alternative for use in natural or mature oil fields prior to their abandonment.

So, many a times we see that oil fields which are going to be abundant very soon because of the secondary extraction is already going to be done by this time. So, adoption of this microbially enhanced oil recovery processes are found to be economically a viable alternative. No major alteration of the existing field facilities are required and infrastructure is also minimal because most of the cases these wells are already present there to apply the process making it cheaper and easier to implement than other EOR processes.

So, the infrastructure cost and the investment point of view the things are more acceptable. Microbial processes consume less energy than thermal EOR process. Of course they consume less energy, so even we produce the biomass externally and try to engineer inject those biomass then also we found that making those biomass externally are still cost effective and energy effective.

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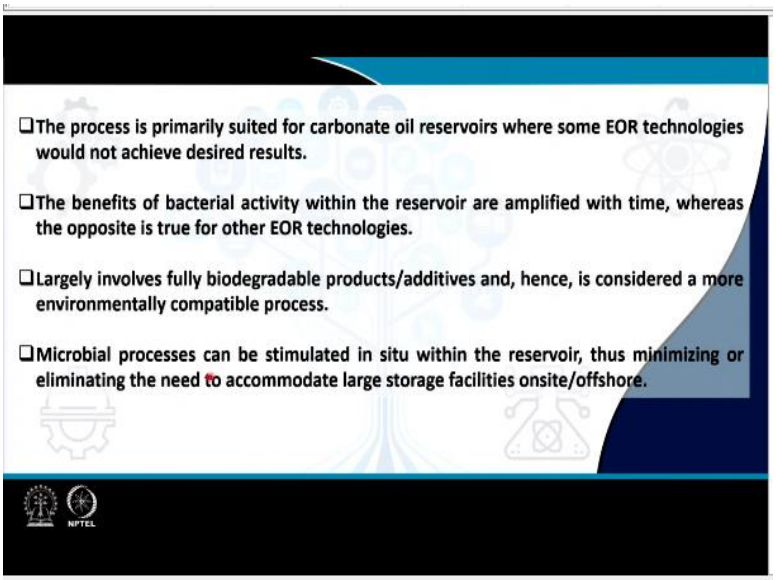

In addition to this there are multiple other advantages like the process is primarily suited for carbonate oil reservoirs where some EOR technologies could not achieve desired result. So, it has some competitive advantages over thermal or physical or chemical methods. The benefits of bacterial activity within the reservoir are amplified with time whereas the opposite is true for the thermal or chemical processes because as microbes they continue their growth and activity.

So, the process goes on, so eventually compared to the thermal and chemical processes whether the chemicals might be depleted. There is no chance of that because the microbes will grow on and they will continue working on these petroleum residues and they will help the oil to move towards the production well. Largely involves fully biodegradable products additives and hence it is considered to be more environmentally compatible process.

And microbial processes can be stimulated in situ within the reservoir thus minimizing on elevating the need for accommodating large storage facility on site or offshore. So, as I mentioned earlier that in situ microbes can be also stimulated. So, just by pumping the desired nutrients we can achieve in situ MEOR and that might be found to be more useful sometimes.

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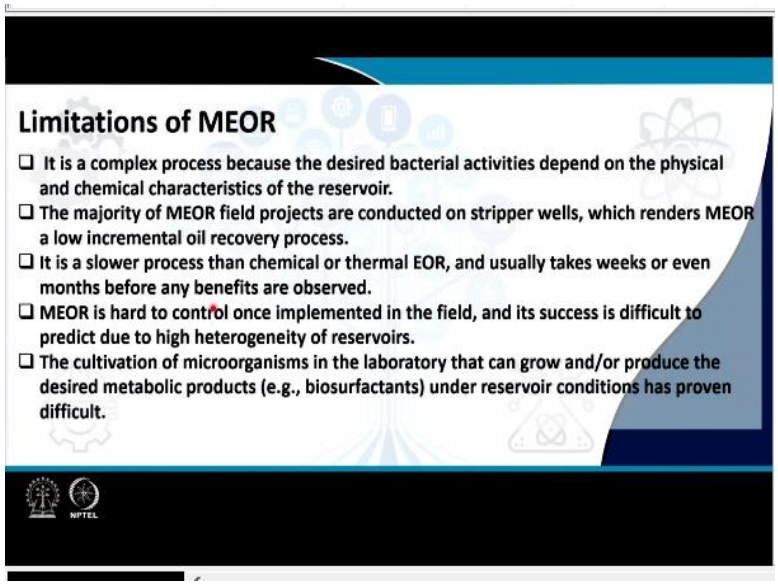

However, in spite of having many advantages there are certain limitations of the MEOR which include number 1 it is a complex process because the desired bacterial activities depend on physical and chemical characteristics of the reservoir that I have already mentioned. So, maintaining those desirable conditions, so that the microbial catabolic activities are allowed at the desirable rate and desirable extent, that is a very important criteria.

The majority of the MEOR field projects are conducted on stripper wells; which renders MEOR a low incremental oil recovery process, it is a slower process than chemical or thermal EOR and usually takes weeks or even months before any benefits are observed. So, those kinds of lag periods are to be allowed. And MEOR is hard to control once implemented

in the field. And its success is difficult to predict due to the high heterogeneity of reservoirs. So, only in cases where the reservoirs geological structures and hydrogeological parameters are very well studied well organized data are available.

There these kinds of implementations are found to be prone to be more successful. The cultivation of the microorganism in the laboratory that can grow and or produce the desired metabolic products like with biosurfactant particularly under reservoir conditions has proven difficult because of the intrinsic reluctance of most of these microbes to be cultivated in the laboratory. So, producing the biosurfactant by the indigenous microorganisms often found to be not successful in the laboratory because these organisms are not cultivable.

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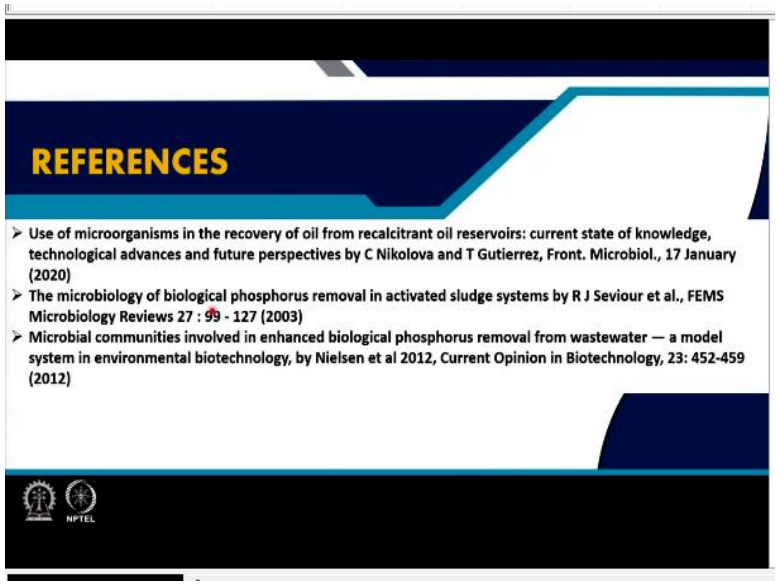

So, for this particular part of the lecture we will use these following articles.

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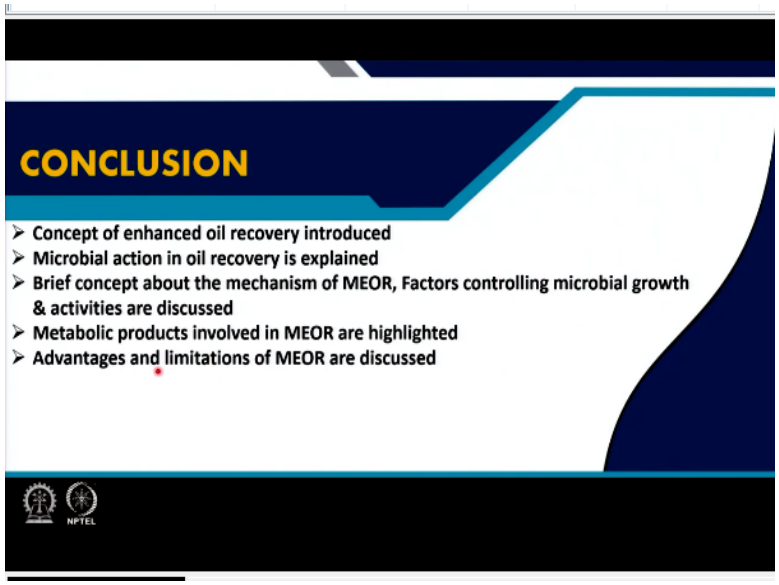

And in conclusion the concept of enhanced oil recovery is introduced, microbial action in oil recovery is explained and a brief concept about the mechanism of MEOR, factors controlling microbial growth and activities are discussed, metabolic products which are involved in MEOR are highlighted and finally the different advantages and limitations of MEOR are also discussed. Thank you.