**Health, Safety and Environmental Management in Offshore and Petroleum Engineering**

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**Module – 01**
**Lecture – 02**
**Drilling operation and consequences**

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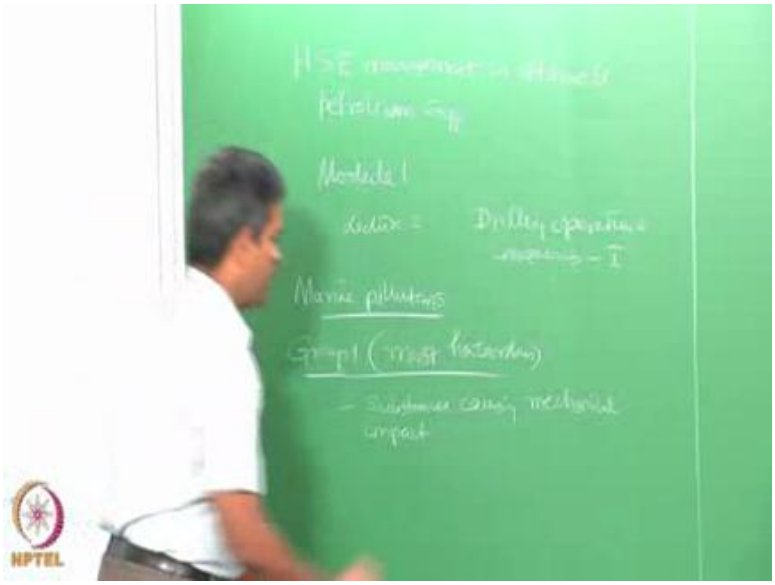


Dear friends, we are now looking at the online course on HSE Management in Offshore and Petroleum Engineering. We are discussing lectures on module one where we are focusing on environmental issues and managing them. Today, we will talk about the second lecture which is going to focus on the consequences arise from drilling operation. Yesterday, we discussed about what are the consequences of marine pollution which is arising from, which is causing the disturbance in the ecological systems. Now, the marine pollutants can be classified into four groups. We can group them into four let us say so there is increase in hard rock hazard this is more hazardous or let us say most hazardous. This includes substances causing mechanical impacts that damage respiratory organs, digestive systems etcetera. So, they include substances causing mechanical impact which can damage respiratory organs, digestive systems etcetera.

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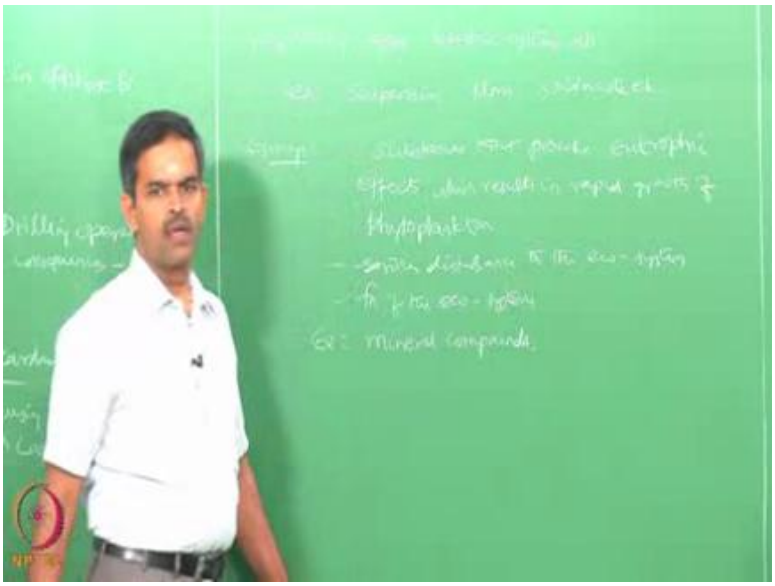

We can give you some examples, let say suspensions, films; solid waste will be included in group 1. Now, group two of pollutants refers to substances that provoke, eutrophic effects, which results in a rapid growth of what we call phytoplankton, so this causes a serious disturbance to the ecosystem and affects various functions of the ecosystem examples can be mineral compounds, organic substances etcetera.

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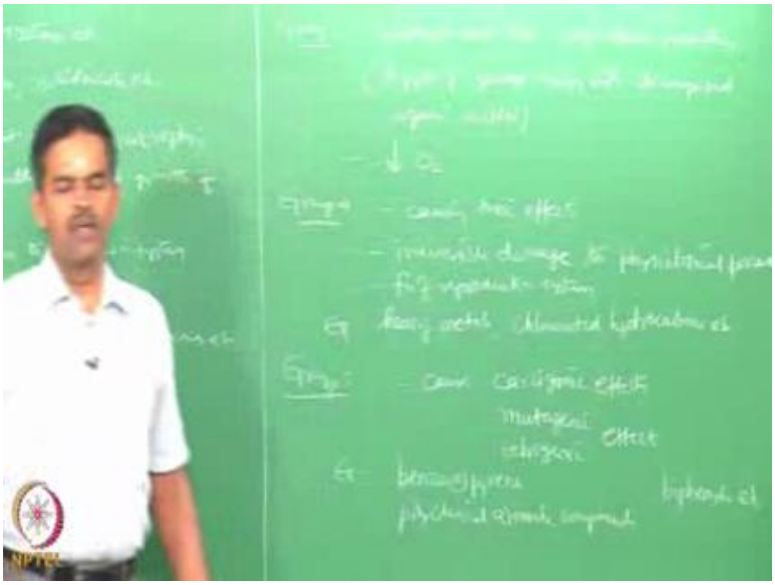

The next group which is group three of pollutants it refers to substances that has saprogenic properties that is it is a high probability of sewage mixing with the

decomposed organic matter that is called saprogenic. The main consequence of this will be it will cause deficiency in oxygen concentration. The next group could be referred to substances causing toxic effects which will cause irreversible damage to physiological processes and it affects functions of reproduction system very badly examples can be heavy metals, chlorinated hydrocarbons etcetera.

The last group could be substances that cause carcinogenic effects, mutagenic effects and tetrogenic effects, examples can be benzopyrene, other polyclinical aromatic compounds, biphenyls concentration etcetera. So, pollutants which come in marine environment which essentially arise from discharges or drilling operations on offshore and oil gas industries can be grouped into five as you see here. So, the most hazardous are the one which actually causes mechanical impact on the systems, which essentially affects the digestive and the respiratory organs, therefore, this causes fatal effects to the mammals or the aquaculture present in marine environment. Of course, the least could be a mutagenic and tetrogenic, effects which are caused by the five biphenolyic acids and the polycyclic aromaic compounds which can also cause some carcinogenic effects on the aquaculture present in marine environment.

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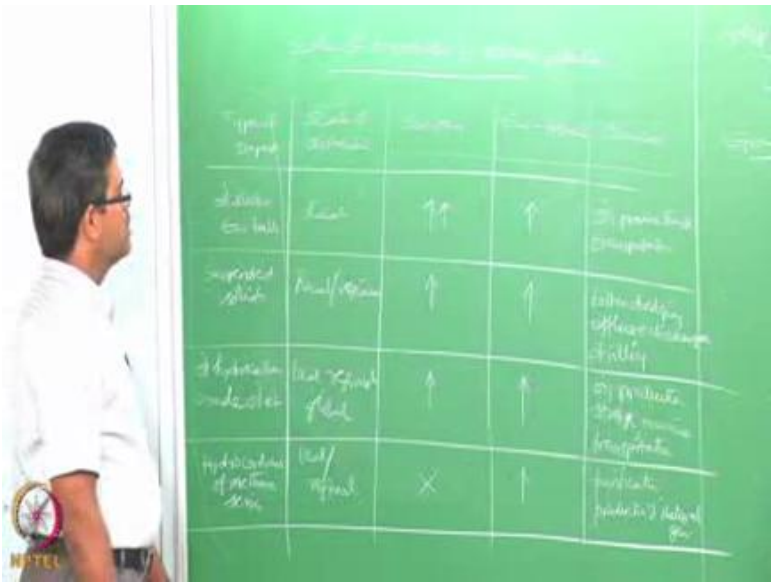

Let us now understand what are the scales of the distribution of these marine pollutants or their components in sea. Let us divide this in to about five columns. Let us talk about the type of impact scale of distribution a let us say qualitative index. Let us then divide

this into subdivision of three if you want to see the effects which can be sanitary and hygienic effects, it can be ecology and fisheries effect. Let us see what are the sources which they come from. Let us say oil sleeks, tar balls, they are present in the local level. The sanitary are hygienic impact caused by them is significantly high. The eco fishery disturbance caused by these pollutants is high. They essentially come from oil production and of course, transportation.

The second source could be suspended solids. They have both the impacts; they are present local and regional. They have considerably a higher impact on the sanitary and hygiene part of it. They also have a significant impact in the eco fisheries. They essentially come from dredging, effluent discharges, drilling. The third level could be oil hydrocarbons, crude oil etcetera. They have both local regional and of course, the global effect as well they are present significantly higher in the sanitary and level or hygienic disturbance in ecosystems they also affect ecology and fisheries and they essentially come from oil production storage and marine transportation.

Next could be next type of impact could be hydrocarbons of methane series, they have local and regional impact they do not have a sanitary impact or a hygienic impact essentially, but they do have eco disturbances in fisheries. They essentially come from purification and production of natural gas; let us say purification production of natural gas. So, if you look at the different type of impact caused by pollution caused in marine industry essentially the source of these arise from oil and gas sector alone. And they have significant impact both regional local and global level and they have representative influences in the hygiene part of it in the eco fishery part of it as well as the ecosystem disturbance which is being caused by the set of pollutants which essentially arise from oil and gas production activities.

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Let us quickly see or try to identify the important consequences which arise from marine pollutants. One major issue which has been referred in the literature is it is very difficult to estimate the consequences of marine pollution as it is a very complex task why it is complex, due to one hazardous property with pollutants are mixed in nature. Their volume as input to ocean is very difficult to quantify. Three - it is rather difficult to estimate the scale of distribution though we have qualitatively indicated that it is local, regional and global their qualitative statement to quantify them is rather difficult to establish.

Fourthly, if it is difficult to know the pattern of the behavior in affecting ecosystems; it is also difficult to establish stability of their compositions. So, if you really wanted to know the quantified values of these pollutants or contaminates in surface water of sea has taken from various research papers, I will give you some indicating numbers just to have an idea on what concentration these level of contaminants are present in surface waters.

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Let us say level of contaminants in sea surface water. We will express this in mu gram per liter as the unit. Let us try to look at the ecological zone which arise essentially from various sources let us say oil hydrocarbons is one primary source the second could be chlorinated hydrocarbon, which are the sources what we saw in last day discussion. And of course, third could be essentially the metals or metallic compounds which we classify them as let us say mercury, lead and cadmium. Let us look these effects individually because they are of keen interest to us in terms of modeling them later for risk assessment.

The ecological zone of the geographical distribution of sea surface can be divided into various sectors. Let us call this as one as south zone, the next could be ocean pelagic area, then third could be the enclosed area or an open waters, and fourth of course, could be coastal zone. So, here it is 0.01 to 1. I am giving the indicating numbers in terms of mu gram per liter. Same 0.1 to 1 and here it is very, very high on the coastal side. Similarly, look at the chlorinated hydrocarbons, it is ten power minus 3 to 10 power minus 4 very low, 10 power minus 3 to 10 power minus 2, 10 power minus 2 to 10 power minus 1, and it is from 10 power minus 1 to 1. So, the focus is on the coastal zones so far for both these kinds of contaminants.

If you look at the metal part of it 10 power minus 4 to 10 power minus 2, same here; 10 power minus 3 to 10 power minus 2, 10 power minus 2 to 1, sorry 10 power minus 1 that

is 0.1. Look at the lead concentration 10 power minus 3 to 10 power minus 2 same here for ocean pelagic area 10 power minus 3 to 10 power minus 1 and 10 power minus 2 to 1. If you look at the cadmium concentration 10 power minus 4 to 10 power minus 2 same here 10 power minus 3 to 10 power minus 1. Whereas, here 10 power minus 1 to 10 power minus 2.

So, the focus one can see easily from this comparative statement that the level of contaminants in different sources which arise from oil hydrocarbons chlorinated hydrocarbons or metallic or metallic compounds found dissolved because essentially they arise from drilling and production activities and offshore. They all focus essentially on the coastal areas, which cause a very serious ecological disturbance or ecosystem disturbance to the marine environment. Therefore, ladies and gentlemen, the anthropogenic impact on ocean environment causes cumulative impact on oil and gas production facilities backwards.

You will also notice in both these comparative discussions, we also saw that the contaminations or the pollution caused by most of the activities sourced from the oil and gas industry production systems are essentially in local level. It means the marine pollution is considered to a leading factor for anthropogenic impact on marine ecosystems. Interestingly, the literature says that offshore activities contribute close to 5 percent of the overall pollution in ocean environment. Now, to understand the impact caused by the exploration production of hydrocarbons on marine environment it becomes important to revisit various stages of oil and gas production and exploration. We must try to understand what are the various stages involved in oil and gas production exploration then let us try to connect the sources of these pollutants or contaminants with each stage of oil and gas production systems.

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Let us talk about stages of oil and gas production. Of course, it includes exploration also, because without exploration you cannot produce or then say generous oil and gas development. The first stage is what we call G and G stage, which stands for geological and geographical survey. So, it is actually a survey level. This stage is very vital to estimate the potential of oil and gas reserve present in a specific sector for its commercial viability.

The next stage could be the exploration stage it is again an important stage because in this stage you identify the location for replacement you also do what we call exploratory drilling one can do plugging of the well or what we call well killing also if you do not find the yield of the well this commercially viable. The third stage could be developmental production this is also an important stage because here you do platform commissioning. You also do lot of pipe link we also do production drilling in this case and of course, we do maintenance of all these three as well in this stage.

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The fourth of course, is very precarious which is the decommissioning stage this is of course, the final stage in oil and gas development field which includes removal of any oil production platform, well plugging, when the well is completely drained off. Now, let us quickly see at each stage what would be the impact of these stages on the overall marine pollution. So, impact caused at each stage on let us say marine ecosystem. Let us divide the stages let us say G and G, the exploration, development and production, decommission.

Let us quickly see what are the activities which takes place during these stages. Then we will see what are the consequences caused by these activities on the marine ecosystem. We do size mix service in this stage during survey. We also do lot of test drilling. What would be the nature of impact caused during these stages? One it could have a great interference with fisheries. There will be a significance interference with fisheries and aquaculture which causes impact on water organisms. The second could be there could be lot of sediment re-suspension which increases what we call the turbidity so that is one of the important impact caused during the test drilling operation. During exploration, we also do what is called replacement. During exploratory drilling, so it can cause discharge of pollution or I should say discharge of various groups of pollutants. It also has great interference with fisheries because of the noise, because of the vibration caused, during the commissioning during production operation even during exploration stage.

When you now come to the full fledged development and production stage, then we also do platform placement we do pipe link etcetera. They have physical disturbance to the ecosystem. They also do operational discharges, they also do accidental oil spill etcetera. During decommissioning stage people work at platform removal plugging of wells so during this people also land up in operational discharges lot of residual remains of the abundant platforms causes physical disturbance. And most importantly the third point, I am writing it here explosives which are used for decommissioning causes serious impact on marine organisms. So, friends different stages of oil and gas field development has different levels of impact caused on the marine ecosystem because of various activities which has been undertaken during different stages of oil and gas field development.

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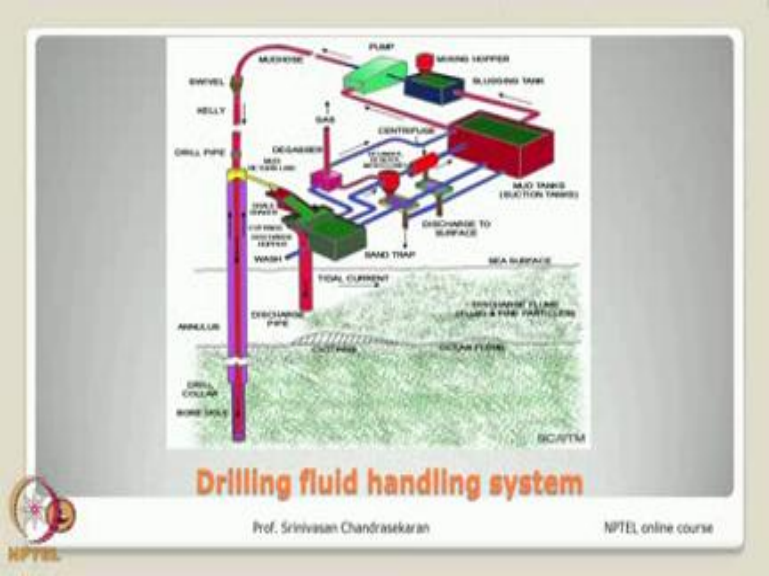


Now, please look at the screen. We are explaining here a drilling fluid handling system. So, if you look at the screen the sketch shows a typical drilling fluid handling system. In this system, you can see this is my drilling pipe, which is shown in red color here, which is actually the bore hole which is connected through the Kelly and swivel which comes from actually the swaging tank and the mixing hopper. Because I need to also have the drilling mug which should be collected back and the ones we pushed inside for having gravity discharge. If you look at the sea surface and look at the ocean floor there will be lot discharge flumes in terms fluid and fine particles deposited here of course, the solid and metal cuttings and heavy density materials will be deposited on the ocean floor as you see here.

You can see the drilling handling system is a multi-complicated task which has got electromechanical systems which is being shown in the figure here. And also carefully see the sand being trapped during the whole operation and the discharge which is being collected till the drilling operation is sent back to the sea either is the sand trap line or the discharge pipeline. So, these are the two points where the maximum concentration of pollutants reaches the ocean bit or the marine environment. Therefore, inherently a drilling fluid handling system cannot have a non or a pollution free operation because there are certain feedback systems available in the whole mechanism which is contributing to the majority of the contaminants present in the ocean environment.

Now, let us see a typical drilling fluid handling system has got various complexities involved in drilling operation which of course, results in high probability of pollution to marine environment. Now, therefore, it is important for us to note that every care though it is been taken that the drilling system is designed efficiently consequences do arise because drilling fluid handling system by itself is an integrity system which discharges pollutants directly in marine environment. In addition to this, there are accidental cases which can either be predicted or avoided even though the whole effort is towards reducing the consequences of such events, but of course, we all know from the previous history drilling accidents cannot be predicted and they are highly unexpected activity during drilling operation.

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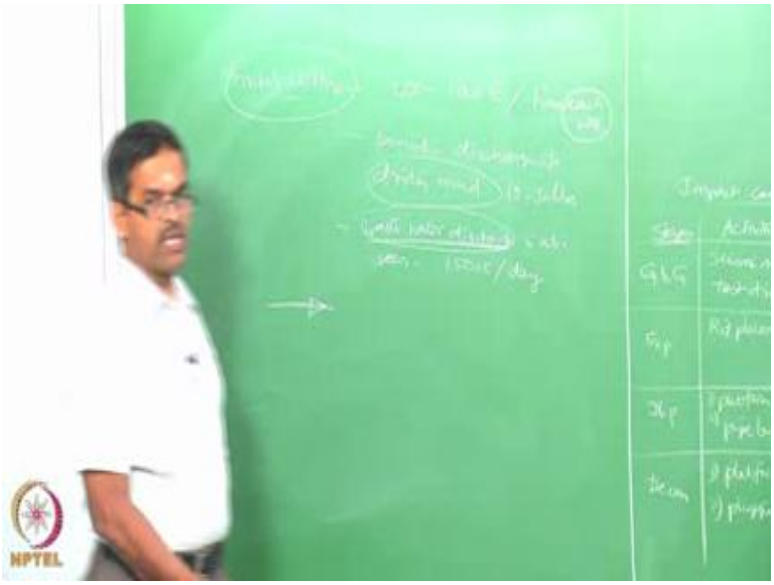

Interestingly, the mud cuttings, which arise during drilling operation, contain dry mass which is about 200 to 1000 tons from a single well. So, the metal cuttings which arise essentially from drilling operation contain approximately 200 to 1000 tons from each well. There is also a periodic discharge of drilling mud, which is about 15 to 30 pounds from each well. In addition to this you have waste water discharge is also seen as one of the pollutant which is about 1500 metric ton per each day which is a waste water discharge. So, three sources metal cuttings, drilling mud and waste water discharge; put together they add to a good substantial volume from each well. Think about, multiple wells think about interconnected wells and let us see what is this typical volume of discharge and what do they actually contain.

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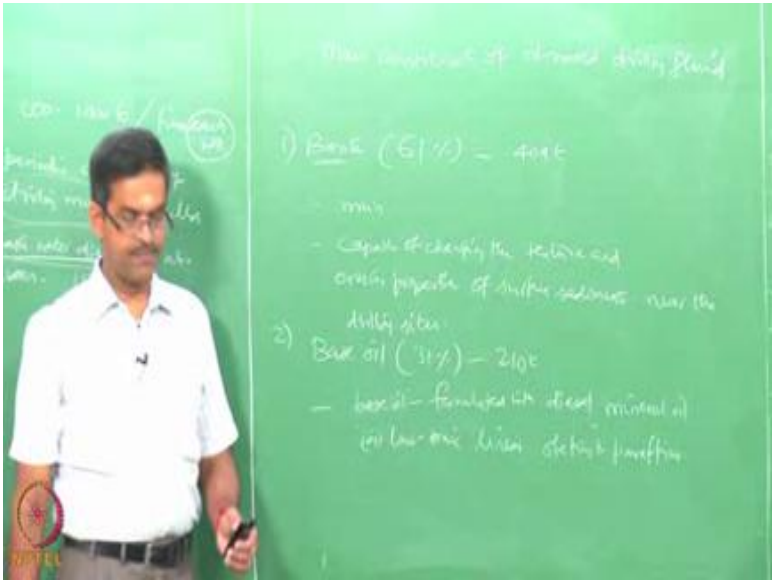

Let us quickly now see what are the main constituents of a drilling or oil based drilling let us be very specific. The foremost contain what we say the barite, which is about 61 percent. If you look at the quantity, it is about 409 tons; this is one of the main constituents of the drilling mud. The important difficulty or the characteristic of this constituent is it is capable of changing the texture and erosion properties of the surface sediments near the offshore drilling sites.

The second component is the base oil, which is about 31 percent. If you look at the quantity is approximately 210 tons. The base oil which is commonly used nowadays is formulated with diesel the base oil is essentially formulated with the diesel or mineral oil

or oil with more toxicity or low toxic leaner olefins and paraffins. The olefins and paraffins present in the base oil are often referred synthetics although some of them may be derived from distillation of crude oil; some of them are chemically synthesized from smaller molecules.

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The third component is emulsifier, which is about 2.2 percent in terms of quantitative value; it is about 15 tons. The main difficulty with emulsifier is it can cause emulsification blockage, it can cause emulsion blockage. The moment emulsion blockage is caused it will result in increased viscosity. And therefore, the mobility of crude oil will be affected. The other constituents who also come in different percentage will be filtrate agent, which is about 1.8 percent in quantitative terms it is about 12 tons. Line which may be about 0.25 percent in quantitative terms, it is about 2 tons. Viscosifier which is about 0.4 percent; it is about 2 tons. Each of these components present in the base oil or present in essentially the drilling fluid has at least one severe technological consequence. The drilling discharges also contains heavy metals are present in drilling discharges, which also have a very serious impact on the marine ecosystems.

The next component could be calcium chloride, which is about 3.35 to 4 percent which in terms of let us say 22 tons. Calcium chloride is actually a common soluble salt used in drilling and completion stages; this is generally available in powder pallet or in grains form calcium chloride is highly hygroscopic, and therefore, appropriate protection to this

particular component is very important. So, based upon the constituents present in oil based drilling fluid, one can always make out what would be the pollution which is caused by this due to produced waters during drilling. The produced waters during drilling operation contains dissolved salts and organic compounds; along with this of course, oil hydrocarbons, metal traces and other suspended solids are also present which makes the composition completely complex.

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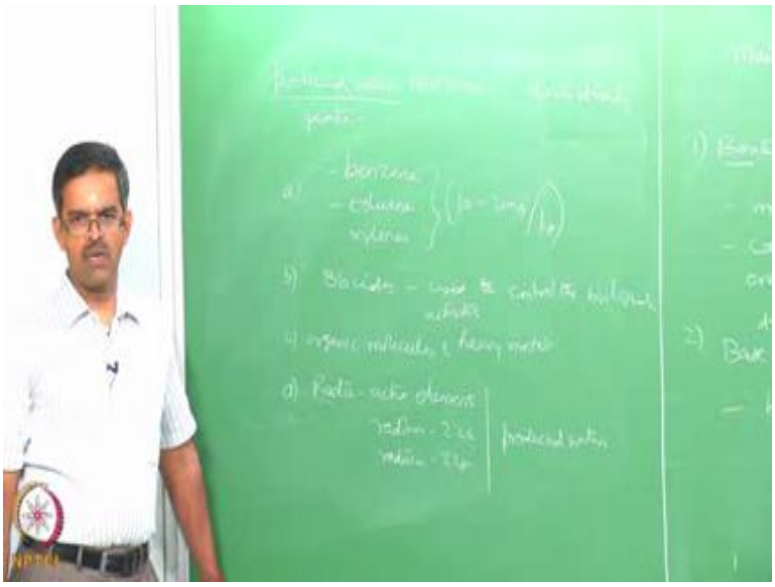

To have an idea the produced waters that arise from drilling, during drilling operation generally contains benzene, toluene and xylenes their concentration will be about 10 to 40 milligrams in every kg in total. In addition to this, we also have biocides these are present in produced waters essentially biocides are used to control the biological activities with limited efficiency it also contains. Of course, organic molecules in heavy metals, they are one of the important sources of the marine pollution interestingly the chromatographic analysis of discharged water in Gulf and Mexico showed very high and relative stable compounds of phenyl and its Alcaide homodudes in the drilling discharge.

In addition, radioactive elements like radium 226 radium 228 are also seen in produced waters. The radioactive elements though they are in a very lower level concentration seen in discharge waters they are become a main focus of pollution analysis or marine waters these days. During contact with sea water these radio elements interact with sulphates

and precipitates to form radioactive scale they increase the radioactive risk of local or regional areas of the produces waters, it also affects the marine life very significantly.

So, there is one alternative by which you can control them, because nowadays if you look at the drilling fluid design people are going for organic based drilling fluids. People avoid emulsifiers and toxic agents as additives in drilling fluids that is fine to some extent one can control the concentration of pollutants present which arise essentially from the drilling discharge which the major contribution of disturbances in marine ecosystem. The one which you cannot avoid which we will discuss is going to be the drilling accidents. Of course, during drilling accidents you encounter lot of unprecedented events which results in oil spill which also causes lot of marine eco disturbances which arise essentially from the oil and gas production activities which we will discuss in the next lecture.

So, our friends, in this lecture, we discussed very interestingly what are the constituents present in a drilling mud or a drilling fluid. What are the various stages of operation of drilling and each operation stage or production stage, how do they contribute to the marine ecosystem disturbances, what are the typical concentrations present in local, regional and global level qualitatively and quantitatively, in what volume what percentage they have been present. What are the different stages of exploration production etcetera, and how do they physically disturb the marine ecosystems.

I would also request you to go through the additional literature support given in the NPTEL website. Look at the papers and test books referred in the NPTEL website. To know more information in terms of authentic statements given by the various researchers and authors in the textbooks about the data what we discussed in the black board. See you in the next class bye.