OFFSHORE PIPELINE RISK AND CONSEQUENCE ASSESSMENT

Iberahin Jusoh

Department of Applied Mechanics
Faculty of Mechanical Engineering
Universiti Teknologi Malaysia

ABSTRACT

There are several modes of transporting oil produced offshore to the processing site onshore. In doing so there are risks that oil spill might happen. In this paper offshore pipeline as a mode of transporting oil from an offshore oilfield to the landfall site is being considered. The study also concerns the impact on the environment from the sources of damage to the subsea pipeline to the landfall site. Mitigative measures in the event of oil spills are also discussed. In addition hazard that are associated with the operational phase of the project are also identified.

1.0 INTRODUCTION

It is well accepted that transporting crude oil via pipeline is more efficient and able to move large amount of fluids under certain amount of time. However, there is also a certain level of risk associated with this mode of transportation. The principal environmental risk arising from the proposed pipeline is a loss of containment of hydrocarbon and the resultant pollution of the marine environment. Basic events that could give rise to such a loss of containment are considered for each phase of the project.

2.0 SELECTION OF ROUTE

Shortest route from the oilfield to the landfall site is the main intent in any installation of offshore subsea pipeline. However not all intended pipeline's corridor on the seabed permit such construction due to several factors such as subsea terrain, offshore installations, marine or ecologically sensitive area, etc. In addition the landfall site that is the nearest direct point to the oilfield may not be the most suitable place to receive oil from the offshore production site. This may be due to several factors such as populated areas, archeological sensitive sites, tourist attraction spot, recreational interest area, etc. The above mentioned factors are examples of reasons that influence the decision in planning routes for transportation of crude oil to landfall site. Thus a study to assess the impact on the environment has to be performed.

Usually, there are several offshore routes and construction techniques proposed and evaluated before the selection could be finalised. Hydrographic survey must be made to evaluate the proposed route, the pipeline should be trenched through the shallow water zones and the beach sands. The pipeline will be buried deeply enough to ensure that it is not exposed by changes in beach profile. Other natural hazards may require study.

3.0 EFFECTS ON THE LOCAL ENVIRONMENT

Environmental impacts arising from the construction and normal operations of the development are likely to occur but are considered to be limited in extent. For a major incident, the opposite is true. It is very unlikely to occur, but if it did, it would be likely to have serious consequences. The major risk of the severe environmental impact arises from an oil spill. Only in the event of a major spill could there be significant consequences. How serious the consequences are depend on many factors including the size of the spill, its location, the time of the year, the weather and the state of the tide. These full effects must be considered in the offshore pipeline spill consequence analysis.

3.1 Effects of Oil Spills

In the case of any offshore oil spill the impacts it will bring to the surrounding as well as on onshore sites and the vicinity must be considered. It is highly probable that a percentage of the spill will reach the shoreline, having a degree of effect on bird and marine life, the local community, industry and tourism. It is well accepted that the degree of environmental damage is proportional to the size and frequency of spills. The depth of pipe as referred to it location on the seabed will effect the rate at which the oil reaches the surface. The oil will become oil in water emulsion that will increase the persistence of the oil slick.

3.2 Effects on Fishing Activities, Tourism and Recreation

The main impact that any spillage would have on open sea activities would be to prevent fishing activities taking place whilst clean up operations are underway. Equipment would be fouled and fishing would have to be temporarily suspended while oil slicks persist. The impact on fish stocks will normally be restricted to eggs and larvae.

Construction operations of offshore pipeline also post a certain level of disruption to fishing activities at the location. During this time numerous vessels will be present in the area. In order to reduce the detrimental effects on fishing activities, close liaison should be maintained with the fishing authority and regulatory bodies. Potential problems should be identified and methods to minimise any negative effects should also be devised. Another problem associated with construction operation in installation of offshore pipeline is construction debris left on the seabed that might affect fishing activities in that location. Therefore disposal of debris at sea must be avoided by all contractors and they must report any accidental losses of objects to the authority. It may be a requirement that such items are recovered.

In the event of oil spill near to the shoreline the tourism and recreational activities will be directly affected. Oil slicks would reach the beach and prevent activities such as swimming, sailing, diving, etc. In short oil pollution would disrupt water sport and cause acrimony among both tourists and local populace, with associated loss of tourist income.

3.3 Effects on Local Community and Natural Habitat

Oil spills will also greatly affect local community in many ways during clean up operations. Oil slicks would at certain point cover hulls of boats, both commercial and leisure crafts. Short term interruption to water sport and other water borne activities could follow.

Oil pollution is always a major threat to birds, particularly to swimming and diving birds. These species are all likely to dive in the oil and become covered, with fatal consequences. Should a spillage of oil occur, its severity will depend on the season, tides, weather, time and size of the spill.

3.4 Other Effects

During pipe-laying operations, there will be effects such as disturbance of the seabed, noise and atmospheric emissions. Significant levels of noise will be produced during dredging and pipe-laying phases. These activities should be subject to close monitoring and study during construction. Potential noise sources are vessel engines and dredging equipment. Both noise and human presence could have a moderate effect on bird life. This will be a particular concern if there is a bird sanctuary near the selected landfall site. Routine emissions that occur during operations are considered to have a negligible impact on local environment. Emission such as exhausts, fuel vapour will have short term, local impacts.

3.5 Potential Impact of Offshore Pipeline

There are numerous potential impacts associated with installation of offshore pipeline to the environment. They could be summarised in Table 1. There are two cases of interactions with environment namely during construction and operation.

These categories are further divided into two categories namely routine events and accidental events. Variables under these categories are as the following;

a. Physical structures
b. Atmospheric emissions
c. Liquid/solid releases
d. Noise
e. Light
f. Human presence

Rating of impacts as referred to in Table 1 are listed as follows:

1 - No impacts
2 - Negligible
3 - Minor
4 - Moderate
5 - Major

Variables that are affected by the installation and operation of offshore pipelines and presented in the matrix of impact analysis are:

i. Air quality
ii. Water quality
iii. Zooplankton
iv. Biofouling
v. Benthos
vi. Fish
vii. Fish farms
viii. Amphibians
ix. Birds
x. Mammals
xi. Flora/Fauna
xii. Ecosystems

Table 1 Summary of Severity of Impact Associated with Offshore Pipeline Prior to Mitigation

	Air Quality	Water Quality	Zooplankton	Biofouling	Benthos	Fish	Fish Farms	Amphibians	Birds	Mammals	Flora/Fauna	Ecosystems
Construction												
1. Routine Events												
Physical Structures	2	3	3	1	4	4	4	3	4	1	4	4
Atmospheric Emissions	2	2	1	1	1	1	2	2	2	1	2	2
Liquid/Solid Releases	2	2	2	1	4	4	3	3	1	1	4	4
Noise	2	2	1	1	1	2	1	2	4	1	1	2
Lights	1	1	1	1	1	1	1	1	2	1	1	2
Human Presence	1	1	1	1	1	2	1	2	4	1	1	2
2. Accidental Events												
Physical Structures	3	2	1	1	1	1	1	2	4	1	4	3
Atmospheric Emissions	2	2	1	1	1	1	1	2	2	1	2	2
Liquid/Solid Releases	2	2	2	1	3	4	3	2	2	1	3	3
Noise	2	2	1	1	1	2	1	2	3	1	1	2
Lights	1	1	1	1	1	1	1	1	2	1	1	2
Human Presence	1	1	1	1	1	1	1	1	3	1	1	2
Operation												
1. Routine Events												
Physical Structures	1	1	1	1	1	1	1	1	1	1	3	3
Atmospheric Emissions	2	2	1	1	1	1	1	2	2	1	2	2
Noise	2	2	1	1	1	2	1	1	3	1	1	2
Human Presence	1	1	1	1	1	2	1	1	3	1	1	2
2. Accidental Events												
Physical Structures	3	2	1	1	1	1	1	2	4	1	4	3
Atmospheric Emissions	2	2	1	1	1	1	1	2	2	1	3	2
Liquid/Solid Releases	2	4	3	1	4	4	4	4	4	1	3	3
Noise	2	2	1	1	1	2	1	2	3	1	1	2
Light	1	1	1	1	1	1	1	1	2	1	1	2
Human Presence	1	1	1	1	1	1	1	1	3	1	1	2

After impact evaluation, mitigative measures were designated for the impact variable having highest scores. The above matrix enables a rigorous and detail considerations of environmental interaction with project activities.

4.0 MITIGATIVE MEASURES

There are three categories of impacts due to oil spills and it could be one or more of the result shown in the following Figure:

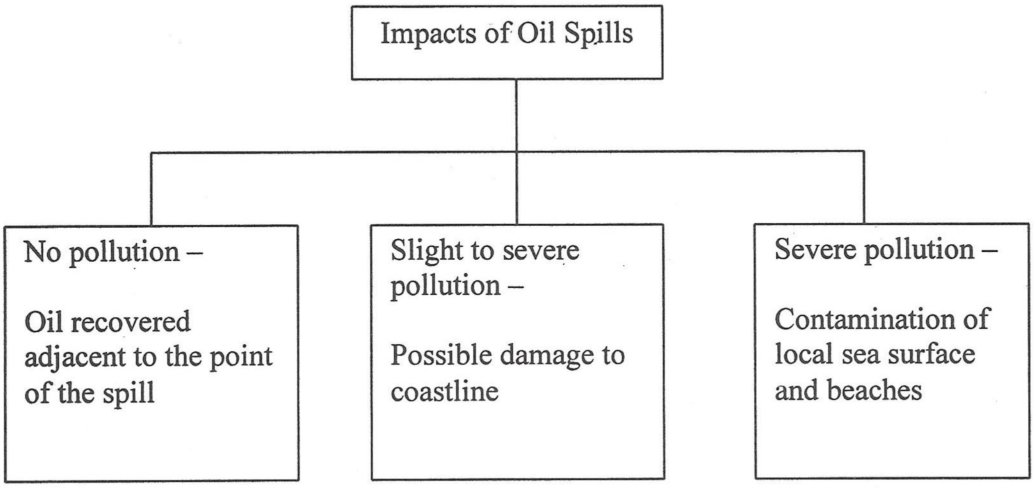

Figure 1 Impacts of Oil Spills

Contingency plan to overcome oil spills effects must be properly devised for all operations. Considerable work must be undertaken to develop a detailed response strategy for any oil spills occurrence within the planned pipeline corridor. Clean-up operation must also be devised in the event of oil slicks reaching the shoreline. The cleaning up operation of the coastal region can be very complicated and difficult if it involves areas that are ecologically sensitive. This also depends on the characteristics and conditions of the beach itself. Sand and pebble beaches, if left to be cleaned by natural wave-action, will be cleaned slowly due to burial but the oil will not create a significant problem to marine life although a tar residue may persist for years.

Dispersants may be used in clean-up operation to treat oil slicks on the sea surface. However, its use must be strictly controlled and should normally not be used in waters shallower than 20 metres or within a mile of the shore. In environmentally sensitive areas these dispersants should not be used. In such a case the clean-up operation would be restricted to booms, scoops, skimmers or other environmentally friendly techniques.

Proper planning must be considered so that all operations are safe and the risk of oil spillage is minimised as low as possible. There should also a comprehensive oil spill contingency plan in place for the above purpose. The availability of manpower, equipment and resources to operate such a plan is equally essential.

Pipeline is known to be the safest way to transport oil and gas worldwide with an average failure rate of 0.6 per 1000 km years for onshore pipeline [2]. Similar data for offshore pipelines indicate that failure rates typically up to one order of magnitude lower, as over most of their length they are far less liable to third party damage. A detailed examination of Concawe (a European oil industry environmental organisation) data shows that for the period 1985 to 1989, approximately ten instances of spillage from pipelines have been recorded each year and of the total, more than half were caused by the external corrosion of accidental third party damage. Therefore the pipeline should be properly wrapped and corrosion protected and trenched wherever possible so that the risk of leaks due to external corrosion is very small. In addition the pipelines should be designed to enable internal inspection using "intelligence pigs" which can detect reductions in wall thickness.

Modern pipelines that are continuously welded are immensely strong and able to resist dragging from fishing nets, anchors, etc. It is found out that occurrence of mechanical failures are very rare.

The installation of pipeline to a certain extent will disturb benthic organisms, which are incapable of moving away from the area of operations. There will be some animals that cannot reach the surface following the burial of the pipeline. Following that, there will be some suspended materials causing temporarily localised impact on water column organisms. However, once the operation is completed little or no evidence will be available to suggest a pipeline has been laid and ecology recovery of the disturbed area is also likely to be rapid.

5.0 CONSEQUENCES ANALYSIS

Each incident or event has certain consequences. Similar to onshore pipeline consequence analysis [1], offshore pipeline installation and operation could lead to a single or multiple consequences. These consequences are presented in Figure 2 and 3. Detailed strategy and careful consideration should be included during planning and execution of all stages of pipeline construction and operation phases so that minimum risk and consequences may be achieved.

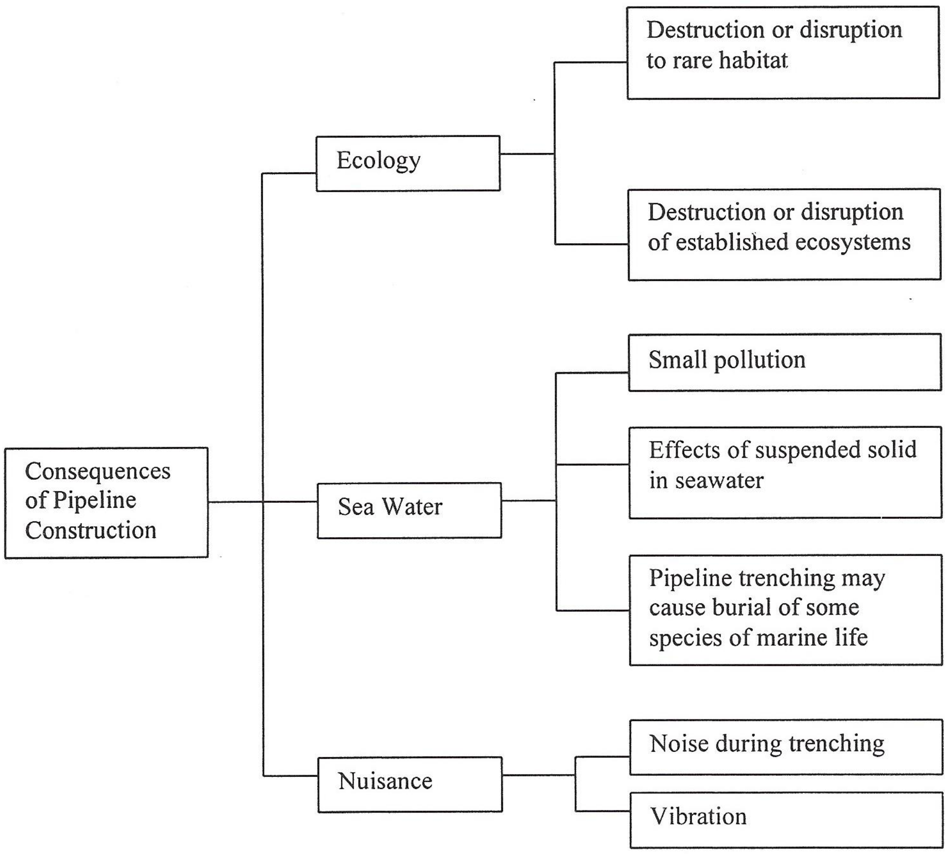

Figure 2 Consequences of Offshore Pipeline Construction

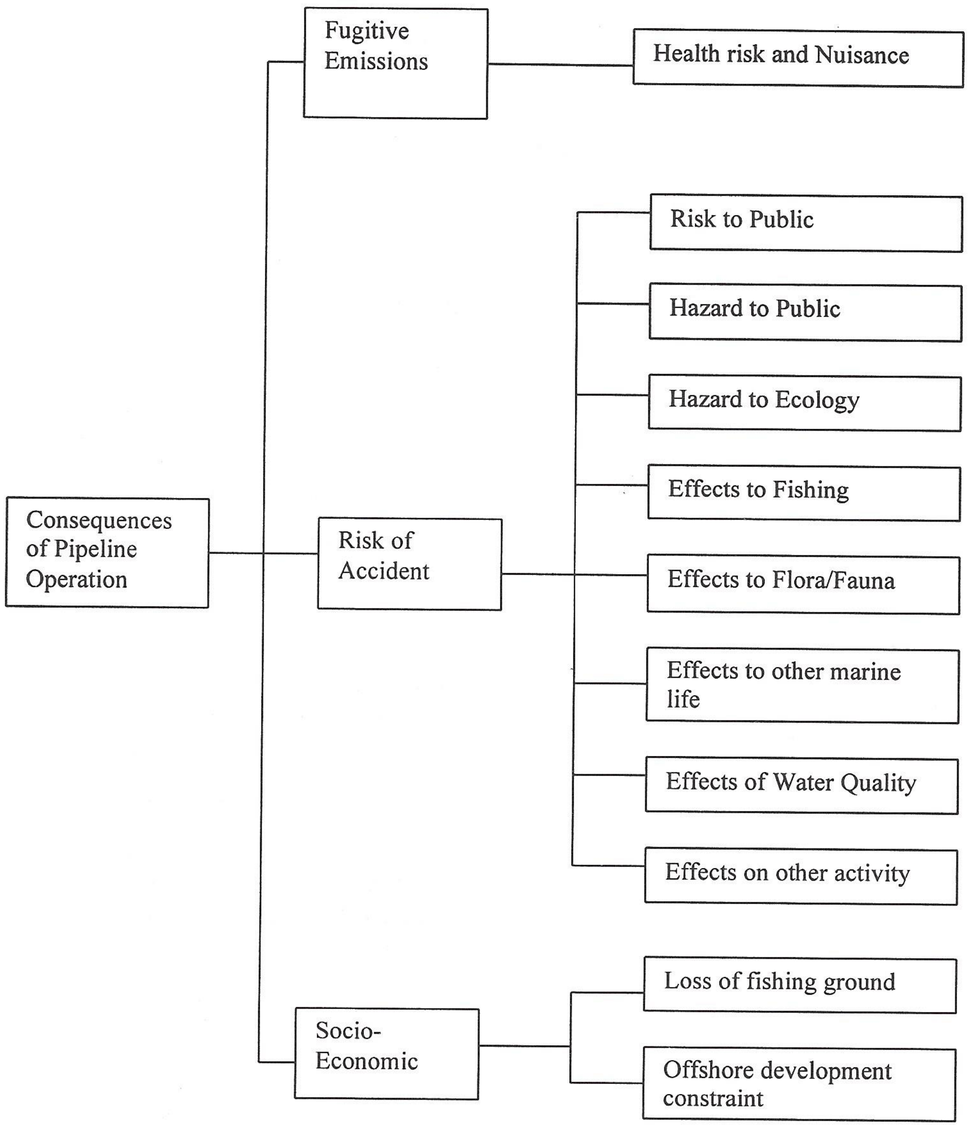

Figure 3 Consequences of Offshore Pipeline Operation

6.0 HAZARD IDENTIFICATION

The principal environmental risk arising from the proposed pipeline is a loss of containment of hydrocarbons and the resultant pollution of the marine environment. Basic events that could give rise to such losses of containment are considered for each phase of the project. The environmental impact assessment of routine aspects of the operation of the pipeline is considered in earlier Sections.

6.1 Hazards Peculiar to Pipeline Phases

There are several types of hazards associated with several phases of offshore pipeline namely hazards during installation phase, commissioning phase, operating phase and decommissioning phase. These categories of hazards are presented in Figures 4 to 7.

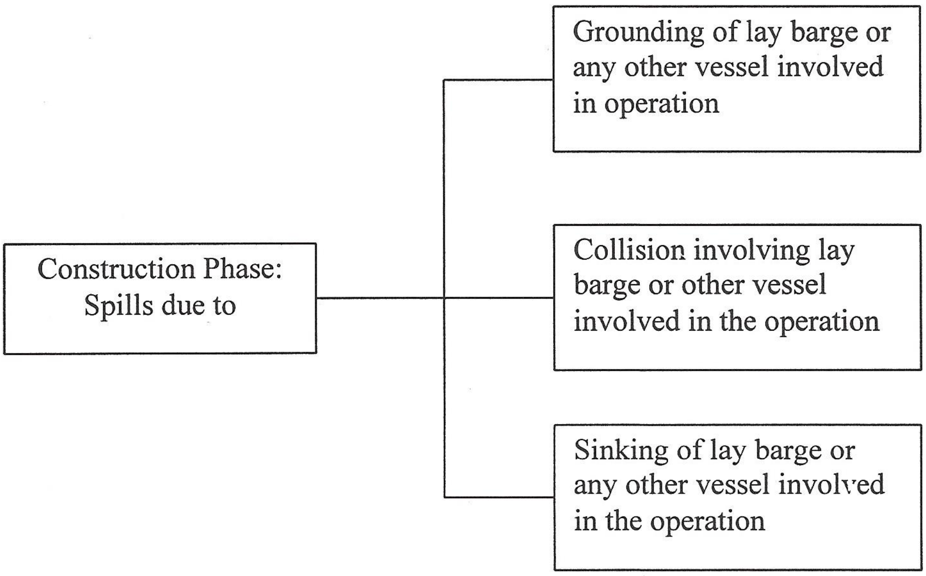

Figure 4 Hazards Associated with Installation Phase

The above hazards are not significant in this study because in the event of collision or sinking of barges or vessels at worst they would result in the release of a few tonnes of fuel oil and highly localised damage to the benthic community.

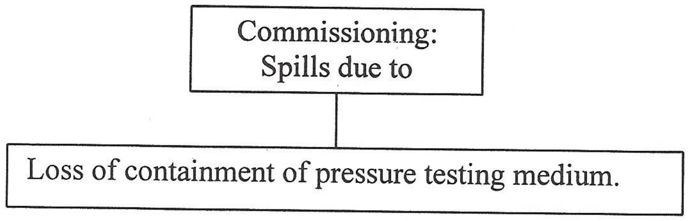

Figure 5 Hazards Associated with Commissioning Phase

This hazard is insignificant in the term of this study since the toxicity of the pressure testing medium (water + inhibitor) is negligible.

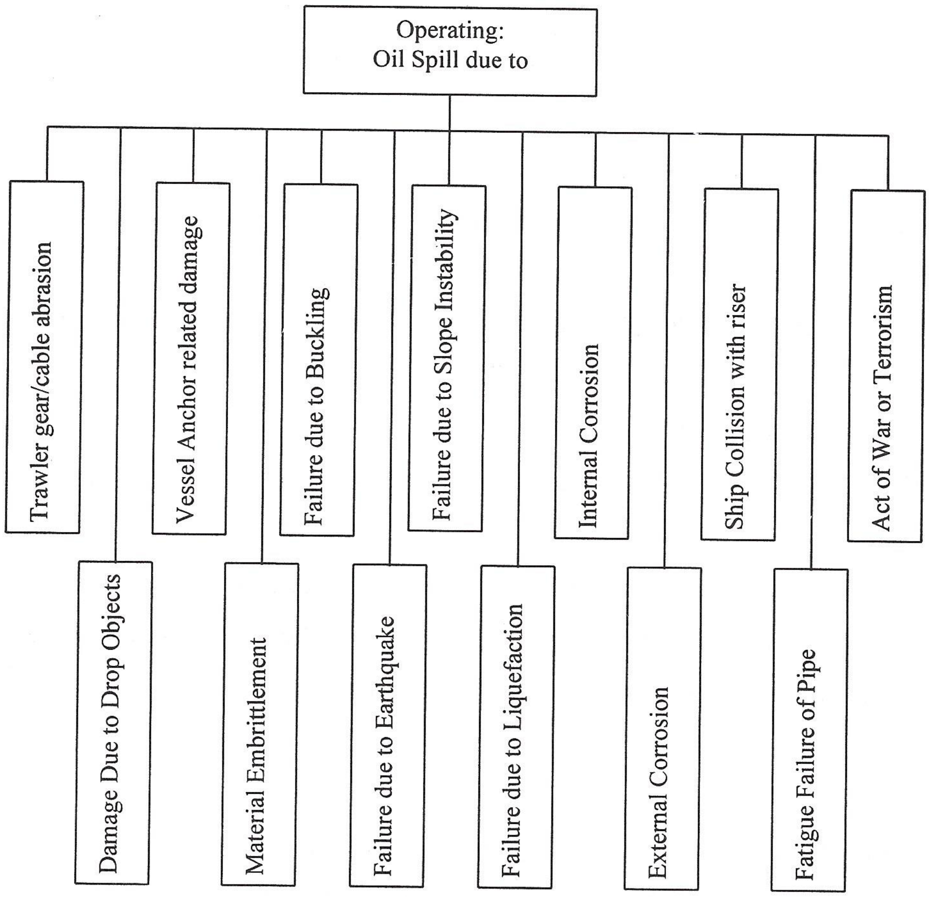

Figure 6. Hazards Associated with Operating Phase

Significant hazards listed in Figure 6 are further quantified in Section 7.0. Its likelihood of occurrence and related spills size is also estimated.

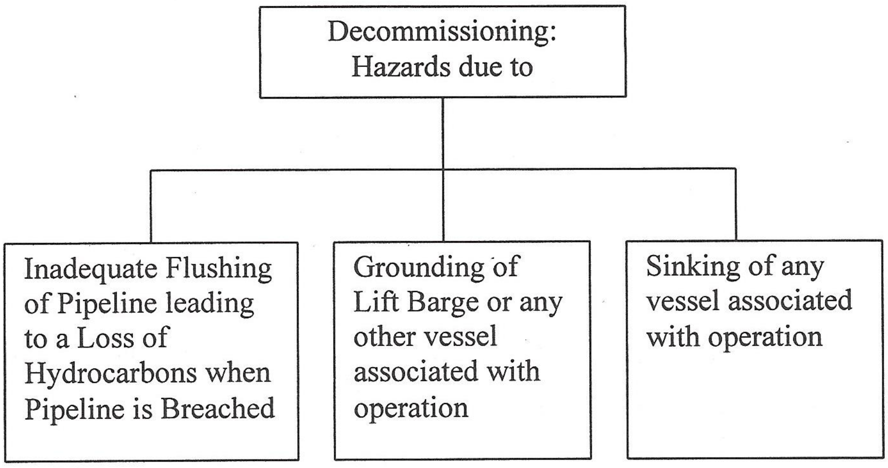

Figure 7 Hazards Associated with Decommissioning Phase

Decommissioning strategy for any pipeline development must be properly considered so that no or minimum pollution to environment takes place.

7.0 HAZARD QUANTIFICATION

7.1 Oil Spill Hazard Frequency

The published figure for the risk of breach of North Sea pipelines of larger than 20 inches diameter (from all hazards) is $6x10^{-4}$/kmyear [2]. On the other hand, the figure for the Gulf of Mexico indicates that eighty percent of pipeline failures occur in the twenty percent of pipeline that lies in the near platform/shore region [2]. This gives a ratio of (risk near platform/shore):(risk in open sea) of 16:1.

Then;

20 x (risk near platform/shore) + 80 x (risk in open sea) = 100 x ($6x10^{-4}$)

320 x (risk in open sea) + 80 x (risk in open sea) = 100 x ($6x10^{-4}$)

Gives;

Risk of spill in "close" to platform/shore portion of pipeline = 2.4×10^{-3}/kmyear.

Risk of spil in the "open sea" portion of the pipeline = 1.5×10^{-4}/kmyear.

Note: "Close" in this instance is defined as within 5 km. The seaward 60 km of the pipeline may be considered as "open sea" excepting the 5 km immediately adjacent to the platform, which is close to the platform. The landward 60 km of the pipeline is considered as "close to shore".

7.2 Corrosion Hazard Frequency

Taking onshore pipeline corrosion rates as a model for offshore pipelines then the hazard rates due to corrosion are derived as follows [3],

Total pipeline population for the period 1983-1987 = 87.6 x 10^3 kmyear

Number of spill due to internal corrosion = 5

Therefore hazard rate due to internal corrosion = $\frac{5}{87.6 \times 10^3}$ = 5.7 x 10^{-5}/kmyear

Number of spill due to external corrosion = 9

Therefore hazard rate due to external corrosion = $\frac{9}{87.6 \times 10^3}$ = 1 x 10^{-4}/kmyear

With suitable management, that is careful design and material selection and the use of an appropriate Inspection, Repair and Maintenance (IRM) program this hazard may be reduced to an insignificant level.

7.3 Seismic Hazard

The presence of any geological fault must be carefully studied to investigate the risk of seismic hazard to that pipeline system. It is very important that sufficient data be made available in order to support the decision for the final route of the pipeline. Availability of sufficient seismic data for offshore and onshore fault enables more accurate selection be made.

7.4 Oil Spill Size

It is known that the worst case in pipeline oil spill is in the case of total pipeline rupture. The size of spill is given by the following relationship;

Spill size = 60 minutes pipeline throughput + 50 tonne depressurisation losses.

Say, daily pipeline throughput = 100,000 barrel/day

Mass of 1 barrel = 153 kg

Therefore spill size = $\left(\frac{100{,}000}{24} \times \frac{153}{1000}\right) + 50 = 685$ tonne

Typical spill sizes for oil pipelines are 10 – 30 barrel involving some 4 tonne of oil [2].

7.5 Oil Spill Vector

Spill vector is modelled based on Beufort scale 12 or 80 knots (nautical miles per hour) as a maximum.

Hence wind speed = 80 x (3/100) x 24
= 57.6 nm per day maximum drift effect

Residual currents = 1.5 nm per day

Note: 1 nm = 6080 feet.

Tidal currents = 1.0 m/s
= 1.0 x 39.37 inches per second
= 39.37 x 60 x 60 x 6080 x 12
= 2.0 nm per hour

Tides will run for approximately 6 hours per day, i.e. maximum effect from tides will be 12 nm per day. Therefore resultant drift of 71.0 nm per day is achieved.

8.0 CONCLUDING REMARKS

The pipeline route from the oilfield to the landfall sites raises many environmental issues. This study indicates the important issues of pollution control and how it should be tackled. Pollution control matters are of great concern in such a sensitive area to both environment and the local people. It should be realised that the best pollution control measures should be incorporated in the final design and operating procedures to protect the area's natural resources.

The environmental impact analysis indicates that the offshore pipeline can be constructed in such a way that it does not cause unacceptable impact on the area's tourism, fishing and conservation interests.

The expected spill frequency is 2.4 x 10^{-3}/kmyear for those portions of the pipeline close to the platform or the shore and 1.5 x 10^{-4}/kmyear for that portion of the pipeline that is in the open sea.

It is estimated that for a pipeline with a daily throughput of 100,000 barrel/day the worst oil spill will give rise to a spill of 685 tonnes and further 50 tonnes being loss during the depressurisation of the pipeline. It is estimated that in the worst scenario the oil slicks could drift up to 71 nm perday.

REFERENCES

1. Jusoh, I., 1998; '*Onshore Pipeline Risk and Consequence Assessment*', Jurnal Mekanikal. Fakulti Kejuruteraan Mekanikal. Universiti Teknologi Malaysia.
2. SINTEF, 1987; '*Reliability Evaluation of SubSea Pipelines*', SINTEF Report, Norway, 1987.
3. Rudolp, E.K., et al, 1989: '*Performance of Oil Industry Cross Country Pipelines in Western Europe*'. CONCAWE Report. No. 9/89.