A Supply Chain Approach for a Sustainable Decommissioning of an Offshore Oil Platform

SALEM Y. LAKHAL *
Faculty of Business Administration,
University of Moncton,
Moncton, NB, postal code: E1A 3E9
CANADA
E-mail: Salem.Lakhal@umoncton.ca

M.I. KHAN
Faculty of Engineering
Dalhousie University,
Halifax, Nova Scotia, postal code: B3J 2X4
CANADA
Email: Ibrahim.Khan@Dal.ca

M. RAFIQUL ISLAM
Faculty of Engineering,
Dalhousie University
Halifax, Nova Scotia, postal code: B3J 2X4
CANADA
Email: Rafiqul.Islam@dal.ca

SOUAD H'MIDA
Faculty of Business Administration,
University of Moncton,
Moncton, NB, postal code: E1A 3E9,
CANADA
Email: Souad.Hmida@umoncton.ca

Abstract: - Oil and gas offshore platform and installations have a limited life of operations. When oil runs out, many terms are used to describe the situation: abandonment, removal, disposal, decommissioning, etc. Even the issue of decommissioning is now at the forefront of deepwater oil drilling for many reason (the enormous costs required for disposal, the increasing number of rigs which required removal, the need to protect the marine environment, legal frameworks), there are very few published researchers studying the problem according to its different facets (legal, environmental, economical etc.). In this paper, we apply the concept of supply chain management to provide feedback for life cycle offshore platforms. Our approach starts from an eco-friendly development of platforms, its exploitation in respect of the environment and an efficient decommissioning taking into account economical and ecological aspects.

Key terms and concepts: Disposition of assets, Sustainability in offshore oil and gas; Green supply chain; Zero-discharges; Marine environment, Decommissioning.

* Corresponding author

1 Introduction

All indications points to the peak years of offshore platform decommissioning, before 2010. It is hard to find an agreement to figure out how many platform offshore oil and gas installations exists. In 2001, Ferreira and Suslick (2001) was comfortable with the number of 7270 oil offshore installations around the world distributed over more than 53 countries. Over 4,000 are situated in the US Gulf of Mexico, some 900 in Asia, some 700 in the Middle East and around 1000 in the North Sea and North East Atlantic (UKOOA, 2005). A 20-year plan for a platform is usual, but it is common to have a life cycle between 30 and 40 years. At the end of this period, baring relocation, platforms are decommissioned. Kaiser (2008) reports, that over the past decade, 136 structures on average have been removed in Golf of Mexico. Figure 1 illustrates a typical life cycle for an oil offshore platform. This figure, adapted from Ferreira et al. (2004) highlights the environmental damages during the life cycle. Because of the business, little emphasis is given on the decommissioning phase (Wood, 2005) in an Oil and Gas Industry. Other operational phases, such as exploration, development and production are well reported and studied (Khan and Islam, 2006; Khan et al., 2006). The decommissioning of offshore oil and gas operations is a complex process and it goes through stages of planning, gaining government approval, and implementing the removal, disposal or re-use of a structure when it is no longer needed for its current purpose.

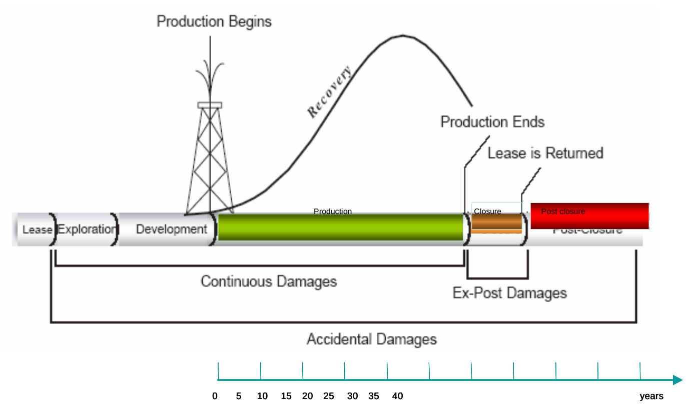

Fig.1 Oil platform life cycle and environmental damages [adopted from Ferreira et al., 2004)

1.1 A brief historical analysis

According to our research it seems that the first recorded offshore platform decommissioning is from the Gulf of Mexico's Outer Continental Shelf 1973. Ever since, platforms have been removed from the OCS at a rate of roughly 100/year, according to data from the US Department of the Interior's Minerals Management Service (Poruban, 2001). Perhaps the most publicised decommissioning case is the Brent spar case. Its owner, Shell U.K. Exploration & Production spent \$36 million in search of a widely acceptable way to dispose of Brent spar and it took two years (between 1995 and 1997) to come up with the principle 'don't dump, re-use or recycle' (Knott, 1998). Izundu (2007) reports that according to the latest UKCS economic activity report by Oil & Gas UK, about 470 installations, 10,000 km of pipelines, 15 onshore terminals, and 5,000 wells await decommissioning. Costs estimates range from £15 billion to £20 billion.

1.2 Oil and gas offshore exploration and environmental issues

The main source of pollution in the oil and gas exploration is the drill cuttings (the collective name for drilling mud, specialty chemicals, and fragments of reservoir rock) being deposited onto the seafloor. For example, in North Sea this drill cutting was estimated in 1996 to by by 7 million m^3 in 2004 (De Groot, 1996), but this amount is updated to 12 million m^3 in 2000 (OLF, 2000). It is clear that the drill cutting is a complex mixture having adverse impact on the environment (Breuer et al., 2004). However, there are no two drill cutting piles that are the same. Each represents a unique combination of sediment characteristics, contaminants and benthic community and each is affected by the local hydrodynamic regime. However, the constituents found in drill cuttings piles include heavy metals, barite, bentonite, speciality chemicals, hydrocarbons, organic contaminants and radioisotopes. Available information on drill cuttings accumulations mainly focuses on three chemical groups: hydrocarbons, heavy metals, and to a lesser degree, radionuclide. Although there is uncertainty as to the extent to which oil concentrations reduce over time it appears that most oil is dispersed during initial deposition. Thereafter, further degradation of oil in the pile will be very slow. In the case of drill cuttings piles which contain a number of potentially hazardous chemicals, synergistic effects from multiple contaminants should also be considered. Grants and Briggs (2002) conducted a toxicity study of sediments from around a North Sea oil platform. They concluded that the sediment around the platform is very toxic. Dichloromethane extracted of sediments from close to platform are very toxic to Microtox even after removal of element sulphur. Breuer, Shimmield and Peppe (2008) arrived to similar conclusion by studding the Microbially mediated diagenetic reactions taking place in the organic-rich cuttings and the results were a rapid removal of O2 within the top few millimeters and creating a more compacted redox zone and an O2 demand of 19 19 mmol m^{-2} d^{-1}. This process then slows the degradation of hydrocarbons resulting in highly elevated concentrations accumulating within the pile.

Instead to be degraded metals from the cutting pile that are released into the porewaters and migrate either upward to the overlying water (Ba, Mn, and Fe). The conclusion is the pile is a contaminated site due to the elevated solid phase metal concentrations observed in the cuttings pile compared to the surrounding environment.

The toxic wastes extended as far as 600 m from the platform. Around 100 to 300 m from the platform sediments caused 100% mortality of *Corophium*. Marsh (2003) studied the archived drilling records of the drill cuttings oil at the North West Hutton Platform and he conclude that a least 130 chemical products were used. He adds that safety and toxicity information is generally sparse even for the better-reported products. Furthermore, the obstacles facing researchers or a journalist wishing to obtain data on the safety and (eco-) toxicity is: many data are easily available: many websites charge registration fees. Information may also be commercially confidential, even for products no longer in use. There is no a standardised international legacy database on all the chemical products which are, or have been, used on oil platforms.

In offshore oil and gas operations, many different types of platforms are used. They are namely; steel jacketed platform (shallow water), concrete gravity structure, steel gravity structure, floating production system, steel jacketed platform (deepwater), compliant tower and tension leg platform. Pictorial sketches of different oil platforms are shown. They range from small shallow structure to heavy structure for deepwater. Submersible rigs are used in shallow water, generally ranging up to 25m (UKOOA 2005). In the fully blasted position, the rig hull on the seafloor serves as foundation support for drilling operations and resists environmental loads caused by waves, winds and currents.

This paper examines the decommission phases of offshore oil and gas platforms. A brief overview of historical perspective of offshore platform decommissioning, environmental issues and types of platforms is presented in the introduction section. Data collection, waste estimation, sustainability evaluation procedures are discussed in Section 2. The platforms decommission practices, their limitations and state of sustainability are addressed in Results and Discussion. New guidelines and model namely 'Olympic green supply chain' are presented in this section.

2 Methodology

For the purposes of this research, information about the lifecycle of OOGOs and its different activities was collected through review of government documents and reports, and published papers, such as CNSOPB activities reports (CNSOPB, 2005), Khan and Islam (2003; 2006), and EPA (2000). Severe limitations were encountered in finding information about quantitative data, such as amount of waste generation, amount of emissions, and use of toxic compounds. To overcome this restriction, different types of waste generation were estimated following the methodology of EPA (2000).

Total amounts of drilling wastes, such as drilling cuttings, drilling fluids, and releases of oils were estimated for the four different types of wells used for exploratory and development drilling in shallow and deep waters. Drilling wastes have consequently been estimated using Equations 1 through 8 specified below [source: (EPA, 2000)].

The dry drill cuttings volume is estimated based on Equation 1. In this estimation, the dry drilling cuttings are equivalent to gage hole volume plus washout.

Drilling hole volume (ft^3) = {length (ft) × π [diameter (ft)/2]2} × (1 + washout fraction of 0.075) (1)

Drill cuttings (bbls) = hole volume (ft3) x 0.1781 bbls/ft3 (2)

Drill cuttings (lbs) = drill cuttings (bbls) x 910 lbs/bbl (3)

Waste Components are estimated following Equations 4 and 5. The algebraic calculation of lbs of waste components in the given drilled

Total Wastes (TW) = (base fluid) + (water) + (barite) + (drill cuttings) (4)

TW = (RF × TW) + {[RF × (WF/SF)] × TW} + {[RF × (BF/SF)] × TW} + (DF × TW) (5)

where:

TW = total waste (whole drilling fluid + dry cuttings) in lbs

RF = retort weight fraction of synthetic base fluid

WF = water weight fraction from drilling fluid formulation

SF = synthetic base fluid weight fraction from drilling fluid formulation

BF = barite weight fraction from drilling fluid formulation

DF = drill cuttings weight fraction, calculated as follows:

DF = 1 - {RF x [1 + (WF/SF) + (BF/SF)]} (6)

TW = drill cuttings (lbs) (7)

In order to calculate TW, Equations (4) and (5) are first used to calculate DF (Equation 6). Then TW is calculated following Equation 7. Input data to estimate the emissions of OOGOs are shown in Table 1. These data have been gathered from different sources such as EPA (2000) and Wenger et al., (2004). In this estimation, 10.2% (wt./wt) standard (baseline) solids control have been taken into account (EPA, 2000). The whole drilling fluid volume is estimated following Equation 8.

Whole SBF volume (bbls) = synthetic base fluid (bbls) + water (bbls) + barite (bbls) (8)

The formation oil in whole mud discharged is 0.2% (vol.), which is calculated based on Equation 8.

Formation oil (bbls) = 0.002 x whole SBF volume (bbls) (9)

The concept of Olympic framework is developed by Lakhal et al. to study the green supply chain of a refinery. This concept could be relevant for the offshore platform life cycle. However, this paper we will adapt it and apply it for the decommissioning phase. In the case of green supply chain analysis, the methodology used follows the work of Lakhal et al. (2005; 2007). In this study, the "Olympic" green supply chain method is used to achieve the following five "zeroes", corresponding to the five circles of the Olympic logo: (i) zero emission (air, water, solid wastes, soil, toxic wastes, hazardous wastes; (ii) zero resource wastes; (iii) zero wastes in activities (energy, materials, human); (iv) zero use of toxics; and (v) zero waste in product life-cycle in case of OOGOs.

3. Results and Discussions

Major steps of offshore oil and gas operations are seismic, drilling, production, transportation and decommissioning. The complete supply chain of offshore operation is shown in Figure 2. The main focus of this research is the decommission phase of the offshore supply chain. The input and output of every phase are also shown in this figure. There are three major input and 6 types of wastes outputs are identified. Current practices of offshore platform decommissioning are discussed in the following subsection.

3.1. Current Practices

The present decommissioning practice is considered as the only 'environmentally appropriate' way to remove offshore oil and gas platform. Actually, decommissioning operations take several of months, but the whole process can take as long as three years. To complete the process, the operator of an offshore oil and gas installation has to plan, gain government approval and implement the removal, disposal or re-use of a structure after completion of production. There are three stages in the decommissioning process: planning, permitting, and implementation. The major stages of offshore platform decommission can be summarised as follows (UKOOA, 2005).

Different decommissioning options are developed, assessed and selected balancing environmental factors, cost, technical feasibility, health and safety and public acceptability factors

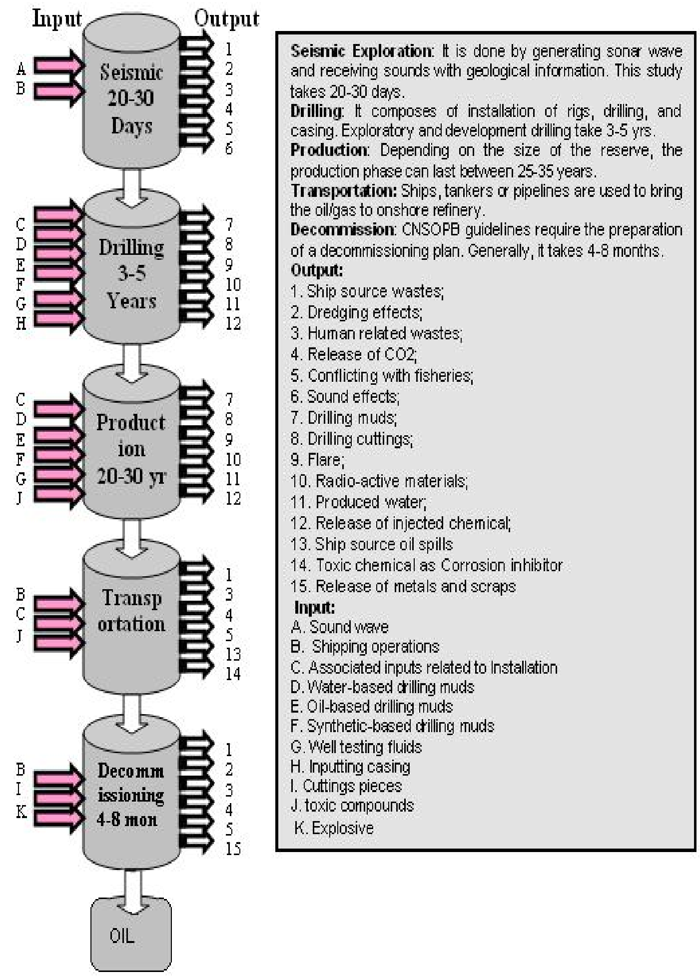

Fig. 2: Supply chain of offshore oil and gas development

- The operator applies to the government to cease production having proved the reservoir is no longer viable. The government grants a Cessation of Production permit or 'COP'. The wells are then securely plugged deep below the surface;
- The operator gains government approval to proceed with its recommended decommissioning option and offshore operations begin to remove all or parts of the structure to shore;
- The parts of the structure removed to shore are then re-used, recycled or disposed of.

Detailed phases of offshore operations are presented in Figure 2 showing different components of decommissioning and suggesting that oil and gas processing equipments and piping are completely removed. The decommissioning process considers the total pipelines run from all platforms either to shore or to other platforms that collect the oil or gas. They are generally shipped to shore for disposal.

The deck and jacket of a rig are most concerning parts for disposal. There are strict legal framework of national, regional and international regulations govern how operators decommission disused offshore facilities

(UKOOA, 2005). Under current regulatory requirements, more that 90 per cent of the structures are needed to completely remove. The removed portions are reused as a platform or disposed onshore. At present, a more flexible and phased approach is used. It suggests immediate and total removal of offshore structures (mainly platforms) weighing up to 4,000 tons in the areas with depths less than 75 m and after 1998 - at depths less than 100 m. The rest, 10 per cent, which comprise the very large and heavy steel or concrete installations, are allowed to partially removing which is known as toppling.

In deeper waters, removing only the upper parts from above the sea surface to 55 m deep and leaving the remaining structure in place is allowed (Patin, 1999). The removed fragments can be either transported to the shore or buried in the sea. This approach considers the possibility of secondary use of abandoned offshore platforms for other purposes.

At present, the platform decommissioning alternatives fall into four general categories: complete removal, partial removal, toppling, and leave-in-place. Some of the study's decommissioning alternative is to leave partial or platform on site. It is to develop artificial reefs, which provides substrate for marine organisms.

Table 2 presents details decommissioning scenarios of different components of offshore platform. Considering some different alternatives, the decommissioning of a given platform will follow up to 160 scenarios: 2x5x2x4x2. An example of scenario that could be recommended is the shaded one A,C,B,C,A. This one is privileged Ekofisk Group in the Ekofisk Area (the Norwegian Offshore area). The selection criteria may be technical, safety, environmental, social and economic aspects of each Disposal Alternative, as well of the needs of other users of the sea and the physical and operational limitations. Knowing how much material to handle in a decommissioning operation will help estimate the operations cost. Some cost estimation models are based on the weight of the structure. Each platform is unique, but we may define a common offshore platform in the middle of the size range (Ekins et al. 2006).

3.2. Sustainability of Current Practices

At present, it is considered that the best solution of offshore platforms is to cut the structures into small manageable pieces, lift them onto barges and bring them back to shore for reuse, recycling or disposal (Khan and Islam, 2003; UKOOA, 2005) . This is also considered as the 'only environmental way' to handle the abandoned structures. This process is often a dangerous, lengthy, costly and weather sensitive procedure (Patin, 1999; UKOOA, 2005). However, there are better alternatives to obtain ecological economic benefit. The enormous structures can be utilized as a fish shelter/habitat and artificial reefs. However, the industry is currently not considering this alternative, sponsoring instead a number of different projects to develop new technologies which would cut down the time spent offshore by lifting larger pieces of the structure in one go and floating them back to shore. The industry is keen on speeding up the time taken to remove a structure rather than developing of a sustainable technique.

The ecological, safety and risks and economic issues of present practices are considered. In the decommissioning phase an offshore operation has to submit the environmental impact assessment of decommissioning process. Most it is reported that there is no significance environmental impact due to decommissioning process. However, if the structures utilize in a sustainable way, such as development of artificial rigs, fish shelter than the ecological consequences is much more acceptable than present practices. The structure dismantling is much more labour-intensive, and involves complex and potentially hazardous operations. The risk analysis suggests that the probabilities of fatal injuries are higher. If the same structure is utilized for artificial rigs than the risk factor is six times less than present practices.

On-shore dismantling also involves potential exposure to the LSA scales, asbestos etc. and therefore requires strict health and safety controls throughout. The dismantle process also involves much greater engineering complexity of rotating the rig and dismantling. It is reflected in the different initial cost estimates - £12 million for deep water disposal and £46 million for horizontal dismantling (UKOOA, 2005).

After decommissioning offshore platforms a large amount of wastes are transported to onshore. There are established onshore techniques for cleaning drill cuttings. Generally, onshore facilities treat solids using techniques such as grinding, direct thermal desorption, and indirect thermal desorption. Emerging solids treatment techniques, such as micro-emulsion, supercritical extraction using liquid natural gas or liquid carbon dioxide, are considered as alternatives (Khan and Islam, 2008; Veil, 1988, 2002). At present, offshore wastes, such as cuttings, only go for onshore disposal when solid and water treatment rates and the potential for reuse of recovered oil are economically feasible. As mention in section 3.2, the current practices are not environmentally friendly. Therefore, alternative wastes management is suggested which is presented in Figure 3. In this alternative management, it not only suggested for wastes treatment, but it also proposed to beneficial reuse and disposal.

Table 2: Decommissioning scenarios

<table>
<tr><th>Entiti</th><th colspan="5">Disposal Alternatives</th></tr>
<tr><td>I TOPSIDES</td><td colspan="2">A
Jacket Topsides: Lift and transport to shore for recycling
Tank Topsides: Lift and transport to shore for recycling</td><td colspan="3">B
Jacket Topsides: Lift and transport to shore for recycling
Tank Topsides: Remove at shore & recycle after tow shore on substructure</td></tr>
<tr><td>II SUBSTRUCTURES</td><td>A
Jacket: Reef ir place
Tank: Reef ir place</td><td>B
Jackets: Reef at Tank.
Tank: Reef in place</td><td>C
Jackets: Recyc onshore
Tank: Leave in-place</td><td>D
Jackets: Recycle onshore
Tank: Refloat and deposit in deep water</td><td>E
Jackets: Recycle onshore
Tank: Refloat and recycle</td></tr>
<tr><td>III PIPELINES</td><td colspan="2">A
Remove to shore for recycling of materials</td><td colspan="3">B
Leave buried in-place</td></tr>
<tr><td>IV CUTTINGS</td><td>A
Slurrification and reinjection</td><td>B
Remove to shore for disposal</td><td>C
Leave in-place</td><td colspan="2">D
Cover with gravel</td></tr>
<tr><td>V SEABED</td><td colspan="2">A Remove debris</td><td colspan="3">B Leave debris in-place</td></tr>
</table>

3.3. Onshore Wastes Management

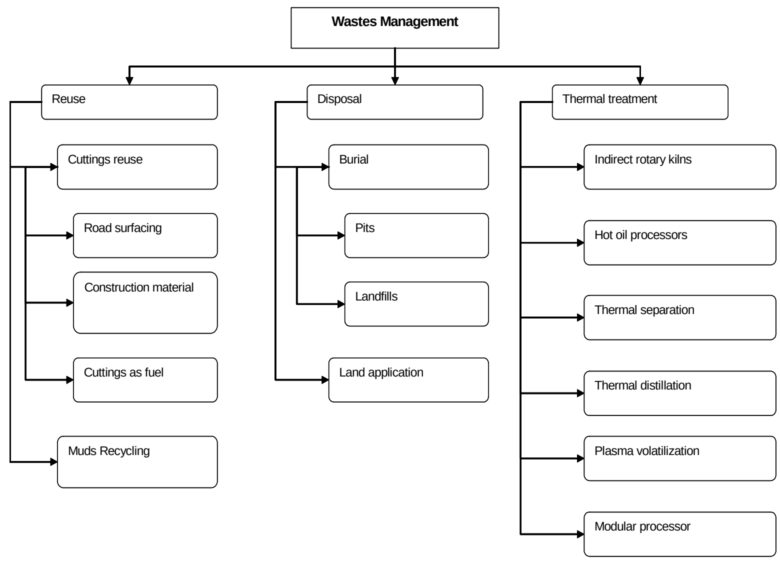

Fig.3 Flow-chart of overall onshore wastes treatment

3.4. Alternative Offshore Use: Artificial Reefs from Oil Rigs (AROR)

The Artificial Reefs from Oil Rigs (AROR) model is proposing to use these rigs as artificial rigs. The main objectives of the AROR are to utilize the abandoned structures for fisheries yield and production, for recreational activities, to prevent trawling, to repair degraded marine habitats, and overall economic and for the social benefit (Baine, 2001). The artificial reefs have been used for coastal management (Baine, 2001). For establishing a reef different shapes of structures are made with concrete, rocks, used tiers, vessels, plastics, wood, and steels. Popular prefabricated concrete structures are also often utilized for making an artificial reef. Targeting specific desired organism to inhabit particular materials can be included. For example: to develop an oyster bed, the natural shells are collected and can be attached to the oilrigs. Sessile organisms such as, algae, sponges, gorgonians, and other benthic organisms, will then become attached to the deployed structure or in this case on the rigs. In the benthic environment, space and shelter are very limited. These structures therefore, provide shelter for many marine organisms and protect them from predators. Right after deploying the artificial rigs, few organisms will begin to grow in association with other fauna and flora, symbiotic and predatory relationships. As a result a reef-based food chain will develop, with the AROR providing food sources for comparatively large organisms, as well as recreational species, such as crabs, larger fish species, and lobster.

According to (Dybas, 2005) oil companies can save between $400 and $600 million per rig by converting them into artificial reefs instead of offshore decommissioning.

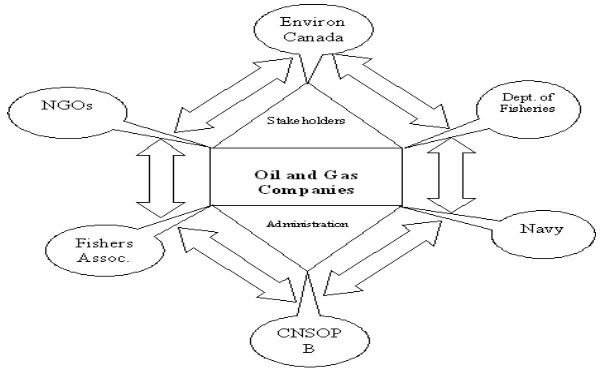

Fig.4 Implanting agencies of sustainable management models (the Canadian context)

Therefore, the conversion of AROR as well as other proposed models an economically profitable and can be implemented with coordination of other governmental agencies and NGOs. Figure 4 shows the implementing of offshore rigs to reef. In coordination with Environment Canada, Department of Fisheries, Navy, Offshore Petroleum Board, Fisheries Association and Non-Governmental Organizations AROR project can be implemented. The abandoned rigs can be kept in their original sites to establish a reef community or it can be transported to another planned site giving a choice of type of seafloor conditions, for example sand or muddy bottom or shallow or deep water areas. It is reported that wherever artificial reefs are established benthic communities become productive. For example the sand and mud habitat areas may not be as diverse as an original reef community but often they can produce the productive benthic flora and fauna in establishing AROR.

It has been reported that the deployment of an artificial reef structure on the seabed has an immediate positive impact on habitat restoration (Wilding and Sayer, 2002). According to different studies it has been observed that algae begins to grow immediately, sessile organisms start to settle, drifting plankton acquires substances that provide shelter, reef associated fish start to increase with the growing of their food components(Wilding and Sayer, 2002). By establishing armors, a totally new reef based community will be developed enhancing the fisheries as well as ecosystem productivity. The AROR is one of the most effective ways of managing abandoned rigs in the context of ecosystem improvement. Figure 4 shows implementation of an artificial rig from disused offshore oil and gas platform.

3. Concluding remarks

Decommission of offshore oil and gas platforms is the last phase of offshore operations. This paper examines the present status of offshore structure decommissioning process as a part of whole lifecycle of offshore oil and gas development. Different decommissioning activities are studied and it is found that every activity is associated with gaseous, liquid, and solid wastes. Sustainability of current practices, which is presently considered as the best environmental way of solving the problem, are also analyzed. It is found that current practices cause ecological, health and safety and economically imbalance and are not sustainable. To achieve ecological and economic sustainability an alternative management technique, Artificial Reef from Oil Rig, is possessed. This management technique will not only minimize the cost, but will also bring ecological benefit such as marine productivity, improvement of fisheries habitat, restoration of biodiversity. The study also identified inefficient resource utilization in the form of energy, human, and materials, and toxic compound usage in different processes of the production lifecycle.

References

Baine, M. (2001). Artificial reefs: A review of their design, application, management and performance. *Ocean & Coastal Management* **44**, 241-259.

Bansal, K. M., and Sugiarto (1999). Exploration and Production Operations – Waste Management A Comparative Overview: US and Indonesia Cases. *In* "SPE54345, SPE Asia Pacific Oil and Gas Conference", Jakarta, Indonesia.

Breuer, E., Shimmield, G., and Peppe, O. (2008). Assessment of metal concentrations found within a North Sea drill cuttings pile. *Marine Pollution Bulletin* **In press**.

Breuer, E., Stevenson, A. G., Howe, J. A., Carroll, J., and Shimmield, G. B. (2004). Drill cutting accumulations in the Northern and Central North Sea: a review of environmental interactions and chemical fate. *Marine Pollution Bulletin* **48**, 12-25.

CNSOPB (2005). "Activity Report 2005." Canada-Nova Scotia Offshore Petroleum Board, Halifax, Nova Scotia, November 5, 2004.

De Groot, S. J. d. (1996). Quantitative assessment of the development of the offshore oil and gas industry in the North Sea. *ICES Journal of Marine Science* **53**, 1045-1050.

DOE (2005). The Drilling Waste Management Information System, Fact Sheet - The First Step: Separation of Mud from Cuttings, Argonne National Laboratory, Natural Gas & Oil Technology Partnership program.

Dybas, C. L. (2005). Marine Life Complicates Removal of Old Oil Rigs. *In* "The Washington Post ", pp. A10, Washington.

EIA (2002). "Energy Information Administration International Energy Annual 2002," 1000 Independence Avenue, SW, Washington, DC 20585.

Ekins, P., Vanner, R., and Firebrace, J. (2006). Decommissioning of offshore oil and gas facilities: A comparative assessment of different scenarios. *Journal of Environmental Management,* **79**, 420-438.

EPA (2000). "Development document for final effluent limitations guidelines and standards for synthetic-based drilling fluids and other non-aqueous drilling fluids in the oil and gas extraction point source category." United States Environmental Protection Agency. Office of Water, December 2000, Washington DC 20460, EPA-821-B-00-013.

Ferreira, D., Suslicka, S., Farleyc, J., Costanzac, R., and Krivovc, S. (2004). A decision model for financial assurance instruments in the upstream petroleum sector. *Energy Policy* **32**, 1173-1184.

Ferreira, D. F., and Suslick, S. B. (2001). Identifying potential impacts of bonding instruments on offshore oil projects. *Resources Policy* **27**, 43-52.

Grant, A., and Briggs, A. D. (2002). Toxicity of sediments from around a North Sea oil platform: are metals or hydrocarbons responsible for ecological impacts? *Marine Environmental Research* **53**, 95-116.

Izundu, U. (2007). UK decommissioning issues. *Oil & Gas Journal* **105**, 15.

Kaiser, M. J. (2008). Modeling regulatory policies associated with offshore structure
removal requirements in the Gulf of Mexico. *Energy* **33**, 1038-1054.

Khan, M. I., and Islam, M. R. (2003). Wastes Management in Offshore Oil and Gas: A Major Challenge in Integrated Coastal Zone Management. *In* "CARICOSTA 2003 -1st International Conference on Integrated Coastal Zone Management ICZM" (L. G. Luna, ed.), University of Oriente, Santiago du Cuba, Santiago du Cuba, May 5-7, 2003.

Khan, M. I., and Islam, M. R. (2006). Achieving True Sustainability in Technological Development and Natural Resources Management. *Nova Science Publishers, New York, USA,* **in press**.

Khan, M. I., and Islam, M. R. (2008). "Petroleum Engineering Handbook: Sustainable Operations," Gulf Publishing Company/Ed., Austin, Texas.

Khan, M. I., Lakhal, S. Y., Satish, M., and Islam, M. R. (2006). Towards Achieving Sustainability: Application of Green Supply Chain Model in Offshore Oil and Gas Operations. *Int. J. Risk Assessment and Management* **6**.

Knott, D. (1998). 20/20 hindsight over Brent spar. *Oil & Gas Journal* **96**, 31-32.

Lakhal, S. Y., H'mida, S., and Islam, R. (2005). A Green Supply Chain for a Petroleum Company, Proceedings of 35th International. *In* "Conference on Computer and Industrial Engineering, Istanbul, Turkey (June 19-21, 2005)," Vol. 2, pp. 1273-1280. Computers & Industrial Engineering Journal.

Lakhal, S. Y., H'Mida, S., and Islam, R. (2007). Green Supply Chain parameters for a Canadian Petroleum Refinery Company. *International Journal of Environmental Technology and Management, IJETM* **7**, 56-67.

Marsh, R. (2003). A database of archived drilling records of the drill cuttings piles at the North West Hutton oil platform. *Marine Pollution Bulletin* **46**, 587-593.

OLF (2000). "Physical, Chemical, and Biological Characterisation of
Offshore Drill Cuttings Piles," 10 May 2000.

Patin, S. (1999). "Environmental impact of the offshore oil and gas industry," EcoMonitor Publishing, East Northport, New York.

Poruban, S. (2001). Platforms, producers, and the public. *Oil & Gas Journal* **99**, 15-15.

Post_Note (1995). "OIL 'RIG' DISPOSAL, P.O.S.T. Note: 65."

Schroeder, D. M., and Love, M. S. (2004). Ecological and political issues surrounding decommissioning of offshore oil facilities in the Southern California Bight. *Ocean & Coastal Management* **47**, 21–48.

UKOOA (2005). <http://www.ukooa.co.uk/issues/decommissioning /background.htm>. Accessed: April 22, 2006.

Veil, J. A. (1988). " Data Summary of Offshore Drilling Waste Disposal Practices, prepared for U.S. Environmental Protection Agency." Engineering and Analysis Division, and U.S. Department of Energy, Office of Fossil Energy.

Veil, J. A. (2002). Drilling Waste Management: past, present and future. *In* "Annual Technical Conference and Exhibition, San Antonio, Texas, 29 Septermber-2 October". Waste Management Practices in the United States," prepared for the American Petroleum Institute, San Antonio, Texas.

Wilding, T. A., and Sayer, M. D. J. (2002). Evaluating artificial reef performance: approaches to pre-deployment research. *ICES Journal of Marine Science* **59**, S222-S230.

Wood, D. A. (2005). MANAGING PORTFOLIOS: The impact of petroleum asset life cycles. *Oil & Gas Financial Journal,* **August 1**.