Quantitative Environmental Risk Analysis for offshore activities: methodology and ideas of improvement for analysis in Brazil

Renata de La Rocque. Autor1, Angela Hayashi. Autor2
Lloyd's Register, Brazil

1. INTRODUCTION

A Quantitative Environmental Risk Analysis (QERA) is part of Environmental Risk Management System and can be described as the process for evaluating how likely it is that the environment might be impacted as a result of exposure to one or more environmental stressors.

Such evaluation involves the identification, prediction, analysis and mitigation of the biophysical, social and others relevant effects prior to major decisions being taken and commitments made.

QERA is quantitatively, meaning the end result is based on calculated environmental damage in the form of restitution time. Through a QERA is possible to identify the environmental hazards and impacts associated to the activity and management measures that have to be taken in place in order to reduce the risk as low as reasonably practicable (ALARP). QERA also provides inputs to emergency preparedness based on oil drift simulations and calculations (shortest oil drift time to shore, largest oil amount to shore, etc.) taking into account the environmental sensibility of the area.

This paper proposes a methodology based on best practices, international standards and methodology recommended by Brazilian Environmental Agency, IBAMA.

2. OBJECTIVES

"Environmental impact assessment, as a national instrument, shall be undertaken for proposed activities that are likely to have a significant adverse impact on the environment and are subject to a decision of a competent national authority." ref. [1]

The main objectives of a QERA are: attendance to regulatory compliance and local authorities' regulations regarding environmental licensing processes; provide available documentation for authorities and general public (communities, fishermen's colony, stakeholders, etc.) with information regarding the risks of oil spill associated to the activity; suggest effective risk-reduction measures related to oil spill; ensure that environmental considerations are incorporated into decision making process; identify procedures and methods for monitoring and mitigating and promote development of sustainable activities.

3. DESCRIPTION OF THE STUDY

The environmental risk analysis will be carried out according to IBAMA's guideline (ref. [2]) and also Norwegian Oil and Gas' guideline for environmental risk analysis as technical basis (ref. MIRA [3].

A QERA is based on the oil spill trajectory resulted from the oil spill modelling, VECs (Valued Ecosystem Component) related to the impacted area and correspondent restitution time.

For estimation of the VECs it is important to consider updated databases for biological resources. Correspondent restitution time shall be estimate using also international references.

Environmental risk shall be calculated and its tolerability evaluated in comparison to environmental acceptance criteria assumed for the activity.

The methodology can be subdivided in six steps of development:

1. Acceptance criteria for environmental damage;

2. Hazardous identification analysis;
3. Oil spill modelling;
4. Vulnerability analysis and identification of the species (VECs) presented in the impacted area;
5. Environmental risk evaluation;
6. Risk tolerability.

3.1 Acceptance criteria for environmental damage

The criterion for determining whether a risk is acceptable or unacceptable is known as acceptance criteria. It is used to express acceptability of the risks associated to the activities by using a limit for acceptable frequency for a given impact on the environment.

Usually the operator defines its own acceptance criteria for environmental damage based on the business' overall acceptance criteria.

To consider an environmental risk tolerable, the restitution time of the VEC shall be insignificant compared to the expected time between the occurrences of the potential environmental damage. In this context, it shall be established what it is assumed to be insignificant.

The proposed criteria shall be technically justified and have its suitability properly evaluated.

3.1.1 Categories for environmental damage

Regarding environmental damage, the risk acceptance criteria adopted considers four categories [3]:

1. Lesser - environmental damage with recovery between 1 month and 1 year.
2. Moderate - environmental damage with recovery between 1 and 3 years.
3. Significant - environmental damage with recovery between 3 and 10 years.
4. Serious - environmental damage with recovery in excess of 10 years.

The criteria shall be satisfied for all categories for the risk level to be acceptable. If the environmental risk exceeds the acceptance criteria, the activities are not acceptable and must be changed focusing on probability reduction measures rather than consequence reduction measures. [4]

3.2 Hazardous identification analysis

The hazardous identification analysis shall select all scenarios with potential to harm the environment and recommend risk reduction measures whenever necessary.

For oil spills related to offshore petroleum business, this can include the following scenarios [3]:

- Blowout;
- Process Leaks;
- Pipeline Leaks;
- Pipeline Rupture;
- Leakage from storage tanks;
- Leak from bottom frames;
- Leaks in loading and unloading operations;
- Oil Tanker Accidents.

There are some methodologies used to perform hazardous identification analysis and the best technique applicable for the activity shall be chosen to perform the analysis. Some of the techniques to perform hazard identification are:

- HAZID – Hazardous Identification
- ENVID – Environmental Hazard Identification
- HAZOP – Hazard and Operability

3.2.1 *Accidental scenarios frequency*

The frequency of occurrence for each accidental scenario that could cause environmental damage shall be quantitatively estimated, based on references and databases. In some cases, with complex initiating events, specific fault trees can be built and evaluated.

It is also stated that all accidental scenarios that might occur after each initiating event need likewise have their frequency of occurrence assessed.

Each event considers the failure of the respectively safety systems actuated. These safety systems' probability of failure or unavailability need to be evaluated through a Fault Tree Analysis with equipment counting (e.g. flanges, valves, vessels, pumps, etc.).

The failure rates shall be originated from recognized databases such as AIChe, OREDA, etc.

Any database to be used in the probability calculation need to comply with the following requirements [4]:

- The failure and accident data applied shall be suitable in relation to the context of the study and the method, model(s) and tool(s) used;
- The data shall be consistent with applicable operations and phases;
- Any trend in data used need to be substantiated.

Similarly, all analytical models and computer codes to be used shall be appropriate and have a resolution adapted to the purposes of the analysis. The models shall also observe requirements related to input data, assumptions, etc. Moreover, the need for sensitivity analysis also has to be considered.

3.3 *Oil spill modelling*

The oil spill modelling aims to identify the probability of damage to coastal areas and vulnerable species.

The modelling allows understanding the behaviour of the oil's slick into the sea, resulting in the identification of its trajectory, dispersion over time and if slick's displacement will reach the coast / shore or sensitive areas. The modelling also allows identifying how long and in what quantity the oil's slick could reach the VECs associated to the vulnerable area.

The results from the modelling indicate the amount of oil throughout the water column and the advance of the oil's slick in the water surface.

The modelling shall consider the type of oil (e.g. crude oil, maritime diesel fuel), project's phase (piping installation, operation, supply vessels, FPSO, rig), vessels involved in the activity and oil volume ranges required by the local legislation.

As species can have different vulnerability categories depending of the season, the modelling also needs to consider parameters per seasons.

3.3.1 *Available tool for oil spill modelling*

To understand the behaviour and trajectory of the oil spill, specific software is required to perform the modelling of the oil spillage into the sea.

<u>Considerations for modelling:</u>

- Updated database for wind, current and other relevant input to the oil spill trajectory model;
- As required by Brazilian legislation, the modelling shall consider three different volumes per unit (small, medium and worst case volume [6];
- The resolution for wind and current data shall be specified.

<u>The following results are expected to be obtained by the oil spill modelling:</u>

- Oil spill extension with probabilities by square kilometres;
- Oil spill extension with quantities of oil by square kilometres;
- Oil slick trajectory.

Software suggested: OSCAR

OSCAR OS3D, by Sintef, is a state of the art model and simulation tool for predicting the fates and effects of oil released during an accidental release of oil, either from a platform or a vessel. OSCAR provides insight in the behavior of oil during an accident and captures the effects of contingency and response, allowing for contingency analysis and planning as well as hind- and forecasting.

The model accounts for weathering, the physical, biological and chemical processes affecting oil at sea. Many of these processes are strongly coupled with laboratory activities at SINTEF on oil weathering. Contingency and response strategies provided ranges from mechanical collection of oil to dispersant application on surface and in water.

OSCAR supports doing statistical or stochastic modelling, providing insight in how a typical oil spill scenario behaves under a wide range of weather or seasonal conditions.

The Figure 1 presents an example of oil spill modelling using OSCAR and their typical inputs and outputs.

Typical input	Typical output
Potential discharge event	Statistical maps showing distribution of oil in all compartments (water column, surface, stranded on shoreline)
Discharge frequency, leak rates and duration distribution for blowouts	Fastest arrival to shore
Presence and distribution of VECs	Highest amount of oil to shore
Oil type	Damage calculations on VECs
Weathering data	Restitution time
Wind data	Fastest arrival to shore
Current data	-

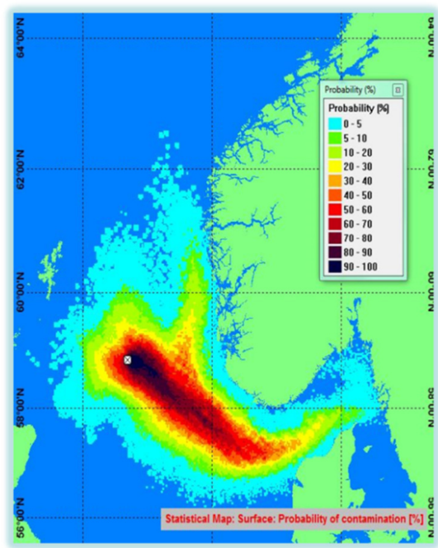

Figura 1 – Representative figure of oil spill modelling using OSCAR

3.4 Vulnerability analysis and identification of the VECs presented in the impacted area

Vulnerability analysis is performed considering impacted area obtained by oil spill modelling and respective VECs presented.

Classification of environmental vulnerability is based on sensitivity of the species to oil pollution. The sensitivity depends on the species life stage, so species can have different vulnerability categories depending of the season.

3.4.1 Vulnerable area

The vulnerable area is represented by the region reached by the oil slick (identified by the oil spill modelling). The level of impact depends of factors as: oil characteristics, volume of oil leaked into the sea, behaviour of the slick into the sea (part of the oil will evaporate and part will dislocate) and environmental sensibility of the VECs identified.

After identifying vulnerable area, is necessary to do a mapping of the VECs to allow posterior risk calculation through restitution time of VECs.

3.4.2 Identification of the VECs associated

The VECs are defined as a resource or an environmental property that has at least one of the characteristics presented in the list below. Table 1 listed areas of special value that shall be identified.

i) Important (not just financially) for the local population;
ii) Have a national or international interest; or
iii) Ecological importance – if it is modified from its current state, it will have an impact on how the environmental impacts of the measures under consideration, and for the mitigation measures that will be selected.

Table 1 – Special value areas

Value areas	Examples
Ecological	Coral reefs, saltmarshes, estuaries, fish spawning areas, bird breeding/feeding and roosting areas, mangroves, seagrass beds.
Recreational	Tourist areas, bathing beaches, watersports.
Commercial	Water intakes, shipyards/ports, fish farms and maricultures.

The identification of the VECs provides basis for the calculation of the environmental risk and for the estimative of the restitution time used to evaluate risk tolerability.

The two main types of VECs regarding its location are presented below:

- Biological communities (movable): seabirds, marine mammals, fishes, planktons, chelonians and cetaceans.
- Ecosystems (fixed): beaches, rocks, reef corals, mangroves and everglades.

Both of them shall be identified in the analysis according to the local characteristics.

3.4.3 Environmental damage and restitution time

Environmental damage is expressed as restitution time. Restitution time is the time that a VEC takes to recover itself from damage, and it is possible to say that an impacted ecosystem or biological community have recovered themselves when their biological processes are functioning normally as before the oil spill.

By the other hand as ecosystems are naturally in a constant state of flux, it is impossible to say whether an ecosystem that has recovery from an oil spill is the same as, or different from, that which would have persisted in the absence of the spill. In other words, restitution time is the time that a population of a certain VEC takes to get back to an expected level.

The restitution time will depend on the VEC's sensitivity to oil pollution. The sensitivity to oil pollution depends on the species life stage, so species can have different vulnerability depending of the season. Table 2 presents consequences related to restitution time of the VECs, which can be described as environmental damage categories.

Table 2 - Environmental damage categories

Categories	Restitution time
Lesser	< 1 year theoretical restitution time
Moderate	1 – 3 years theoretical restitution time
Significant	3 – 10 years theoretical restitution time
Serious	> 10 years theoretical restitution time

There are several factors which have direct influence in the damage and recovery times. Recovery times in consequence of an oil spill can vary from days to years.

The restitution time shall be identified for each VEC existed in vulnerable area.

3.4.3.1 Issues faced when performing QERA studies for activities in Brazil

- Difficulties regarding environmental database;
- Much time for environmental risk calculation.

Normally, database presents general information about species presented in the coast area and biological researches and articles for the area in study.

3.5 Environmental risk evaluation

Environmental risk (ER) shall be calculated for each VEC, considering volume of oil spill and phase of the project.

The ER's value represents the damage that each VEC is exposed in case of an accident with oil spill. The ER can be calculated through the following formula.

$$ER_{\text{VEC}} = \left(\sum_{i=1}^{n} fi\right) * p(x) \tag{1}$$

ER = Environmental Risk
n = number of accidental scenarios
$\left(\sum_{i=1}^{n} fi\right)$= total frequency of accidental scenario
p(x) = probability of VEC be touched by oil

<u>Step 1: Calculation of total frequency by volume</u>

1. Identify all scenarios with probability to lead to an oil spill and separate them per volume range;
2. Identify the frequency of occurrence of all accidental scenarios associated;
3. Sum of all contributions of frequencies of all accidental scenarios by volume range to obtain the total frequency by volume.

<u>Step 2: Probability of VEC be touched by oil</u> $p(x)$

The probability results come from oil spill modelling and also shall be considered per volume range.

3.5.1 Environmental Risk calculation by volume range

The total ER per VEC is the sum of all ER's contributions per different volume ranges. The Table 3 presents how to calculate the ER total for each VEC that might be touched by any volume of oil.

Table 3 - Environmental Risk per VEC

	ER per volume			**ER total**
	volumes			
VECs	8 m3	200 m3	VPC	
VEC1	ER $_{\text{VEC1(8m3)}}$	ER $_{\text{VEC1(200m3)}}$	ER $_{\text{VEC1(VPCm3)}}$	ER $_{\text{VEC1(8m3)}}$ + ER $_{\text{VEC1(200m3)}}$ + ER $_{\text{VEC1(VPCm3)}}$
VEC2	ER $_{\text{VEC2(8m3)}}$	ER $_{\text{VEC2(200m3)}}$	ER $_{\text{VEC2(VPCm3)}}$	ER $_{\text{VEC2(8m3)}}$ + ER $_{\text{VEC2(200m3)}}$ + ER $_{\text{VEC2(VPCm3)}}$
VECn	ER $_{\text{VECn(8m3)}}$	ER $_{\text{VECn(200m3)}}$	ER $_{\text{VECn(VPCm3)}}$	ER $_{\text{VECn(8m3)}}$ + ER $_{\text{VECn(200m3)}}$ + ER $_{\text{VECn(VPCm3)}}$

Calculate ER is quantifying the environmental impact associated to an accident with oil spill. From this point, ER shall be evaluated in terms of acceptance criteria and risk tolerability and if necessary, risk-reducing measures should be suggested.

Due to the lack of detailed information about VECs existed in Brazilian coast area, the formula suggested by IBAMA for calculating Environmental Risk is too conservative. Raising reliability of database is possible to have more precise results (treated on Chapter 4 – ideas of improvement).

3.6 Risk tolerability

For evaluation of risk tolerability is necessary to analyse the relation between restitution time of the VECs and environmental damage in terms of years.

Environmental risk is consider tolerable if the restitution time of the VECs are insignificant related to expected environmental damage recurrence in numbers of years.

4 RESULTS – IDEAS OF IMPROVEMENT

The methodology presented follows IBAMA guideline and also best practices used around the world, but at the same time, there are ways of improving the quality of results and the way the studies are performed nowadays in Brazil.

Table 4 present suggestions for improvement regarding issues normally found when performing environmental risk analysis studies.

Table 4 – Ideas of improvement

TOPIC	Environmental damage and restitution time (item 3.4.3)
CURRENT SITUATION	- Difficulties regarding environmental database available in Brazil. - Available database presents general information about which species exist in the coast area, with no quantities and no distribution of the species. - Restitution time is estimated based on historical data and researches already made for each VEC presented in Brazil.
DIFFICULTIES	- Distribution of the species all over the coast area (population distribution per area); - Characteristics per season; - Quality of the maps; - Extension of files.
IDEAS OF IMPROVEMENT	
SHORT TERM	1. Correlation table between VECs existed in Brazilian coast and their restitution time based on technical articles and researches related to VECs.
MEDIUM TERM	2. Improve quality of database existed in Brazil. 3. Mapping all VECs existed in Brazilian coast considering their particularities per season. 4. The idea is to have information referred to VEC cell by cell and make the intersection of modelling and VECs presented. 5. Restitution time can be calculated through software MIRANDA(*) or similar.
BENEFITS	1. More reliable result for quantitative environmental risk. 2. Optimization of time required to perform a QERA. 3. Better understanding about the impacts per species. 4. More reliable study allowing improving the emergency response plan associated to the activity and also the development of an action plan with focus on affected species.

Table 4 separates the ideas of improvement in two categories: short and medium term. Short term is simpler and faster to be implemented, does not required too much energy on it, but also present smaller benefit comparing with medium term idea. Medium term means that the idea requires reliable database information and some time to be implemented, but also provides a better benefit related to more reliable results.

4.1 MIRANDA SOFTWARE (*)

MIRANDA is developed to calculate environmental damage based on OSCAR exported UTM files.

Effect, damage keys and marine resource occurrences are hard coded into MIRANDA. Any changes to these elements due to change in premises will result in the need to re-code MIRANDA.

MIRANDA is current in use for environmental studies in LRC Norway and can be adjusted to be used in Brazil or other Country if required information is available.

5 CONCLUSIONS

Due to the lack of detailed information about VECs existed in Brazilian coastal area, the results found through IBAMA's suggested formula are too conservative. The objective of the work is giving the possibility to raise reliability and have more precise results.

This work presents a current methodology to perform a QERA attending IBAMA and following best practices applied in worldwide offshore industry. An accurate QERA requires precise and detailed environmental data, which is a point of difficulty on studies performed for Brazilian coast.

Some improvements points were listed (Chapter 4) as a way of getting more reliable results for a QERA.

6 REFERENCES

[1] International Association for Impact Assessment, "What is an impact assessment?", October 2009, www.iaia.org

[2] Instituto Brasileiro de Meio Ambiente, "Termo de Referência CGPEG/DILIC/IBAMA n°01/09", IBAMA, Brazil, 2009

[3] Oljeindustriens Landsforening, "Metode for Miljorettet Riskoanalyse (MIRA)", 2007

[4] Norwegian Technology Standards Institution, "NORSOK standard Z-013: Risk and emergency preparedness analysis, rev.2", 2001

[5] Petroleum Safety Authority, "Guidelines Regarding the Management Regulations", PSA, Norway, 2014

[6] Conselho Nacional do Meio Ambiente, "Resolução 398", CONAMA 2008