JOURNAL OF MARITIME RESEARCH

Vol XIII. No. I (2018) pp 3–7

ISSN: 1697-4040, www.jmr.unican.es

Leopold Matrixes put into effect in SIROCO to study the environmental impact caused by a hydrocabon spilling in The Canary Islands seawater

J.M. Calvilla[1,*], J.R. Bergueiro[2], J.A. González-Almeida[1]

ARTICLE INFO

Article history:
Received 10 October 2017;
in revised form 20 November 2017;
accepted 11 January 2018.

Keywords:
SIROCO, Leopold Matrixes, Canary Islands, hydrocabon spill.

ABSTRACT

The island response systems and operations against ocean pollutants, in Spanish Sistemas Insulares de Respuesta y Operaciones Ante Contaminantes Oceánicos (SIROCO) are made up by a set of integral management tools facing hydrocarbon spilling that allow the research, analysis, planning, mobilization and support for the human means decision making and material resources as an answer to the pollution, in order to prevent or minimise the polluting effect in the hypothetical affected areas by hydrocarbon spilling in The Canary Islands seawater. The results of the implemented simulation models allow the evaluation of the environmental impact through the Leopold Matrixes.

1. Introduction

Operational plans to fight against accidental sea pollution base their success on the caution in advance about random incidental facts, and on the design of an adapted response to every situation, taking into account the environmental features and the available resources (BERGUEIRO, J. R. et al., 2001.)

In order to achieve it, it is required to develop the following actions:

1. Risk identification and diagnostic assessment.
2. Evaluation of the resolution capacity to control the emergency.
3. Emergency organization..
4. Action plans setting-up facing every type of situation.
5. External team coordination.
6. Establishment and operational maintenance plan and staff.

In the fight against pollution, not only in an emergency situation, but also in the planning facing a hypothetical spilling or in the development of eventuality plans, helping tools are essential for the agents to come to a decision. Thus, this design develops the Island Response and Operations System against Ocean Pollutants (SIROCO).

SIROCO is an integral management tool which allows to research, analyse, plan, organise and support the decision making against the contamination in the affected area using monitoring tools, observational studies and oceanography management; the Islands point wise and answer key facing polluting sea agents are modelled.

The virtual technology facing the hydrocarbon spills is researched in this project. It means the software development whose design is based on descriptive equations about the natural processes which affect the spilled substance (crude oil, fuel oil ...) and it is able to simulate its performance. To this effect, different variable processes should be notified to the software, such as those ones related to geographic location, season, wind speed, the air and water temperature and the characteristics of the spilled product.

Besides, the implementation has to be connected to a database which contains the orography of the seafloor, the tidewaters in the area, the swell of the ocean, the prevailing winds and on and

[1]Universidad de La Laguna. Escuela Politécnica Superior de Ingeniería. Sección Náutica, Máquinas y Radioelectrónica Naval. Avda. Francisco la Roche s/n, 38001, Sta. Cruz de Tenerife.

[2]Universidad de las Islas Baleares. Facultad de Ciencias. Carretera de Valldemossa Km.7.5, 07122, Palma de Mallorca. España

[3]Profesor del Área de Construcciones Navales. UD de Ingeniería Marítima, Departamento de Ingeniería Agraria, Náutica, Civil y Marítima. Universidad de La Laguna. Escuela Politécnica Superior de Ingeniería. Sección Náutica, Máquinas y Radioelectrónica Naval. Avda. Francisco la Roche s/n, 38001, Sta. Cruz de Tenerife. E-mail: jagonal@ull.edu.es

*Corresponding author: J.M. Calvilla. E-mail Address: jmcalvi@ull.edu.es

on.

Taking on account all this information, theoretical answers are obtained in advance which allow to get information about the speed, the preview dissemination direction, the force of the evaporation and the most important thing, the formed poison gas course. Furthermore, information about how much of the polluting product will be scattered and dissolved, as well as the quantity to get the coast, the area and its length to get damaged.

This piece of information has a predictive nature though it allows anticipating the system and the moment and taking it into account, so that to take actions aimed to fight the problem. In this way, there is more effectiveness in performance.

Likewise, by means of hydrocarbon spilling simulation models, not only the spill drift is simulated, but also the calculation of the evaporated sections, the risk, the toxicity and its combustion appraisal as well as everything related to the use of barriers or intercepting obstacles for the hydrocarbon containment.

In order to calculate the hydrocarbon spilling strong effect in the coast, defencelessness and inferred restoration of all the surrounding coastal areas susceptible to be affected are defined.

Next, not only the cleaning expenses estimation and the restoration of the affected hydrocarbon coastal environments, but also the economical incidence rate of the spilling in the touristic and fishing sector are tackled.

In the same way, a section is focused to study the evaporated hydrocarbon dissemination in the atmosphere as well as the explosion and poisoning risks and the delimitation of the intervention, alert and safety measures.

Besides, a study about the possible reasons of a spill is included, besides a rough approximation of the amount of the substance that may be spilled and, therefore, affect a specific area. It is also included information about the types of raw fuel and other hydrocarbon mixtures susceptible to be spilled.

In addition to this information, a research about the climatological, orographic and geographic features is included. Depending on the formerly mentioned facts and their results, suitable equipment and techniques to the mentioned risks should have to be considered.

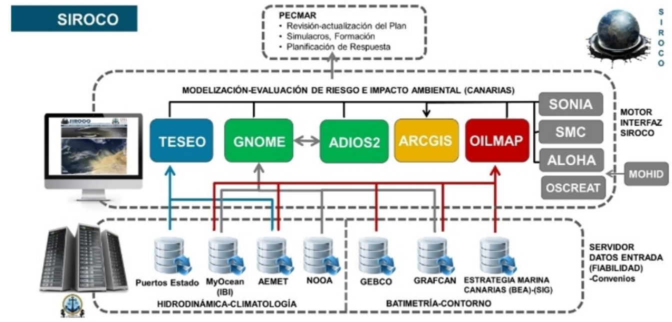
The resulting information about the specific hypothetical raw fuel spilling facts in The Canary Islands waters and in the their surroundings, obtained from the integral numerical patterns in SIROCO, will be crucial data in the revision of the contingent sea contamination specific programme in The Canary Islands (PECMAR).

2. Methodology.

The environmental impact caused by a spillage changes in good part according to whether it occurs in shallow waters where ecosystems are notably sensitive or in deep sea areas.

Aging process decomposes the petroleum in microscopic particles which are eroded because of natural process. In spite of the lacking studies about the spillage impact in the complex ecosystems in deep waters, recent research about the spill consequences of the deep water platform reinforces the idea that a thick oil layer tends to settle in the ocean bottom surface, which

Figure 1: Interface scheme for SIROCO model.

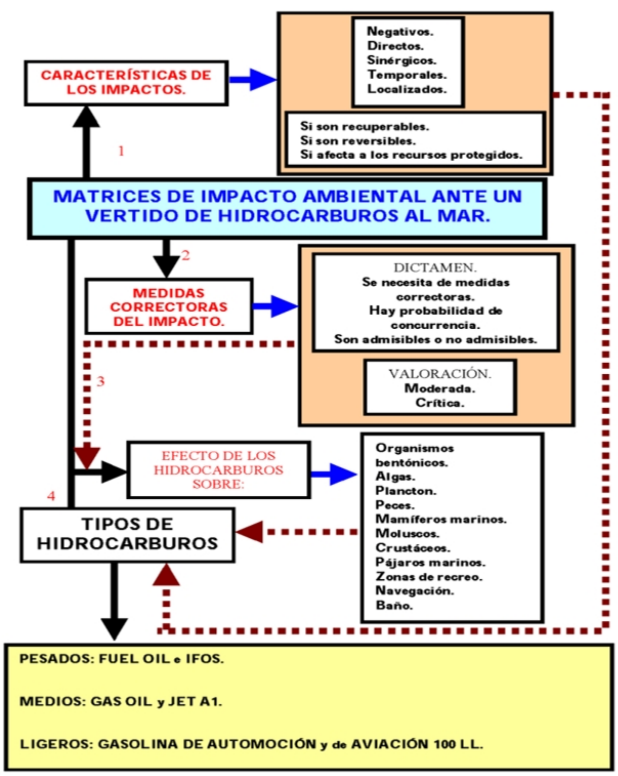


Source: Authors.

provokes the death of the fauna that lives in the sea bed and consequently valuable ecological habitats end up buried and died.

The hydrocarbon spill effect in the ocean environment depends on different factors.

Figure 2: Environmental impact study organizational chart.



Source: Authors.

The environmental impact assessment facing a hydrocarbon spillage is usually quantified by using the Leopold Matrixes (BERGUEIRO, 2004). Possible actions provoking an environmental impact are identified with the matrixes. The line on the left shows a qualitative evaluation of the main environmental impacts, whereas the information on the upper file shows the characterization of the impacts (positive/negative, direct/indirect). In every of the charts there are two numbers separated by a diagonal. Both numbers are fitting an assessment scale ranging from 1 to 10. Numbers 0 is never used because there will always be impacts however few, because when happening a hydrocarbon spill, there will always be an environmental impact, considering that a toxic substance is dumped. On the top left-hand corner, each chart gives a value which shows the probability of a possible impact in a specific area or living organism, in case of a hydrocarbon spill. On the bottom-right hand corner, an assessment is shown also ranging 1 to 10 about the magnitude of the impact.

It should be pointed out that as a starting point in the impact identification, the information about the stock taking of the physical and social means is relevant. These stocks are general ones, that is, they derive from taking on account those components of the physical environment and the areas in the social media susceptible to be affected in the case a hydrocarbon spillage happens in a specific coastal area. The environmental spill is assessed with the Leopold Matrixes and this inventory.

The Figure 2 includes the impacts features and the hydrocarbon effects on benthic organisms, algae, plankton, fish, sea mammals, molluscs, Crustaceans, birds, swimming and recreation areas and navigation. The environmental impact matrixes development base is likewise described in this document.

The impact possible characteristics (negative, direct, synergistic, temporal, located, retrievable, reversible impact and if it affects to protected resources) should be had in mind in order to develop every Leopold Matrix. When it comes to develop the Matrix, it should be also born in mind, which corrective actions for every impact, considering a moderate just as critical assessment and deciding the repairing measures, the coincidence probability and the accuracy of the measures. The mentioned matrixes will show the effects hydrocarbons or their mixture might have on the benthic organisms, algae, plankton, fish, sea mammals, molluscs, Crustaceans, birds, recreation areas and navigation and beaches people usually swim. The oil impact spilled in the sea identification is shown in the Table 1.

Table 1: Matrix: Sea spilled fuel impact identification.

IMPACTS		Negative	Direct	Synergistic	Temporal	Located
Air	Atmospheric pollution	Yes	Yes	Yes	Yes	Yes
	Smells	Yes	Yes	Yes	Yes	Yes
Seafloor	Benthos	Yes	Yes	Yes	Yes	Yes
Seawater	Seawater	Yes	Yes	Yes	Yes	Yes
Marine wildlife	Crustaceans, Molluscs and Fish	Yes	Yes	Yes	Yes	Yes
Aquatic plants	Algaes	Yes	Yes	Yes	Yes	Yes

Source: Authors.

The environmental impact specific features caused by a fuel oil spillage are shown in Table 2.

According to the previous characteristics a series of qualitative risk assessment matrixes have been developed depending on if they are:

- Negative.
- Direct with sinergy or accumulation.

Table 2: Matrix: Sea spilled fuel impact identification.

IMPACTS		Recoverable	Reversible	Protected resources
Air	Atmospheric pollution	Yes	Yes	Yes
	Smells	Yes	Yes	Yes
Seafloor	Benthos	Yes	Yes	Yes
Seawater	Seawater	Yes	Yes	Yes
Marine wildlife	Crustaceans, Molluscs and Fish	Yes	Yes	Yes
Aquatic plants	Algaes	Yes	Yes	Yes

Source: Authors.

- Located and casual.
- Recoverable.
- Reversible.
- Affecting protected resources.
- In want of correcting measures.
- Concurrence posibility.
- According to if they are admissible.
- Depending on whether their assessment is moderate or not.

The previous criteria factors have been determined by:
- The Air:

In the event that there is a fire in the hydrocarbon unloading processes from an oil tank to oil pipeline considering air pollution and smells.

- Benthos (Seafloor)

In the case of part of hydrocarbon, highly aged and mixed with suspended particles which can be harmful when coming in contact with the benthos.

- Sea water in the strict sense and marine life such as fish, Crustaceans and molluscs.

- Sea plants (algae).

The identifying matrixes of the fuel spilling impact correcting measures are shown in the Table 3.

Table 3: Identification of the oil fuel spilled in sea water.

IMPACTS		DICTUM			ASSESSMENT
		Corrective action	Probability	No admissible	Moderate
Air	Atmospheric pollution	No	Yes	Yes	Yes
	Smells	No	Yes	Yes	Yes
Seafloor	Benthos	Yes	Yes	Yes	Yes
Seawater	Seawater	Yes	Yes	Yes	Yes
Marine wildlife	Crustaceans, Molluscs and Fish	Yes	Yes	Yes	Yes
Aquatic plants	Algaes	Yes	Yes	Yes	Yes

Source: NOAA (2001).

3. Results and Discussion.

By virtue of what it is set out in the methodology, impact assessment matrixes (Leopold Matrixes) have been thrown according to the hydrocarbon conditions. The case system research results are the ones based on the hydrocarbons producing the impact:

- Hydrocarbon spilled on the surface of the sea.
- Dispersed and emulsified hydrocarbons.
- In condition of air suspended particles.
- Burning causing dioxide and monoxide carbon.
- Producing sulphurous anhydride in their combustion.
- Causing a diminution in the light leak and of the oxygen in the water due to the floating in the sea hydrocarbon layer.
- Being settle out on the marine benthos.
- Hydrocarbon mixtures, scattering ones (if used), or the products formed from the hydrocarbon biodegradation process whose mechanism of injury is toxicity in the sea.

.

The living beings for whoever or whatever the different Leopold matrixes have been developed are:

- Marine mammals.
- Sea birds living in the affected area.
- Fish.
- Molluscs and Crustaceans.
- Benthic organism.
- Seaweed and plankton.

. Besides, it has been studied the influence on:

- Sport diving.
- Sport fishing.
- Recreational areas.
- Sailing.
- Swimming.

Next, identification of environmental impacts based on Leopold Matrixes (Table 4, Table 5, Table 6, Table 7) are presented together with its analysis that have been developed for a Fuel-Oil spill. The description can be visualized in the accompanying epigraph. The results of the implemented Leopold Matrix allow the evaluation of the environmental impact.

Table 4: Leopold Matrix (Type A) of the fuel oil spilling impact: Benthic organisms, Algaes, Plankton, Recreational areas, Fish, Sailing and Swimming.

	Fuel Oil on sea surface	Emulsified Fuel Oil	Dispersed Fuel Oil	Dispersants	Combustion gases and particles		
					Suspended solids	Carbon monoxide	Sulfur dioxide
Benthic organisms	2/7	2/7	2/7	2/7	1/1	1/1	1/1
Algaes	5/8	6/8	7	8/8	1/1	1/1	1/1
Plankton	5/8	8/9	8/9	9/9	1/1	2/3	2/3
Recreational areas	9/9	8/8	8/8	8/7	9/8	9/9	9/9
Fish	6/8	7/8	8/8	8/8	1/1	1/1	1/1
Sailing	8/3	4/3	4/3	3/3	9/9	9/9	9/9
Swimming	9/9	9/9	9/9	9/9	9/9	9/9	9/9

Source: Authors.

Table 5: Leopold Matrix (Type A) of the fuel oil spilling impact: Molluscs, Crustaceans, Sea birds, Land birds, Sea mammals, Diving and Underwater Fishing.

	Fuel Oil on sea surface	Emulsified Fuel Oil	Dispersed Fuel Oil	Dispersants	Combustion gases and particles		
					Suspended solids	Carbon monoxide	Sulfur dioxide
Molluscs	2/3	8/8	8/8	9/9	1/1	1/1	1/1
Crustaceans	2/3	8/8	8/8	9/9	1/1	1/1	1/1
Sea birds	9/9	7/5	7/5	7/5	8/7	8/8	9/9
Land birds	9/9	7/5	7/5	7/5	8/7	8/8	9/9
Sea mammals	7/8	7/7	7/7	7/7	8/8	9/9	9/9
Diving	3/4	9/7	9/7	8/8	1/1	1/1	1/1
Underwater Fishing	3/4	9/9	9/9	9/9	1/1	1/1	1/1

Source: Authors.

References

Bergueiro, J. R. (2001). La Gestión de los Derrames de Hidrocarburos en el Mar. *Área de Ingeniería Química.* Facultad de Ciencias. Universidad de las Islas Baleares. Palma de Mallorca.

Bergueiro, J. R. (2004) Gestión integrada de zonas costeras ante vertidos de hidrocarburos en el mar. G. I. L. B. A. *Área de Ingeniería Química.* Facultad de Ciencias. Universidad de las Islas Baleares. Palma de Mallorca.

Table 6: Leopold Matrix (Type B) of the fuel oil spilling impact: Benthic organisms, Algaes, Plankton, Recreational areas, Fish, Sailing and Swimming.

	Light penetration in seawater	Dissolved Oxygen in Water	Fuel Oil on Benthos	Dissolved Fuel Oil	Toxic Products-Fuel-Oil degradation	Synergistic effect-Fuel-Oil degradation	Toxic Products-Dispersants degradation
Benthic organisms	6 / 5	9 / 9	9 / 9	1 / 1	6 / 5	5 / 5	6 / 5
Algaes	9 / 9	9 / 9	7 / 7	3 / 5	7 / 6	6 / 6	6 / 7
Plankton	9 / 9	9 / 9	5 / 4	3 / 4	5 / 5	3 / 5	4 / 4
Recreational areas	1 / 1	1 / 1	3 / 3	1 / 1	2 / 2	4 / 4	4 / 5
Fish	8 / 9	8 / 9	8 / 8	6 / 5	7 / 8	8 / 7	7 / 6
Sailing	1 / 1	1 / 1	1 / 1	6 / 5	2 / 2	2 / 1	2 / 1
Swimming	1 / 1	1 / 1	1 / 1	1 / 1	9 / 8	9 / 8	9 / 8

Source: Authors.

Table 7: Leopold Matrix (Type B) of the fuel oil spilling impact: Molluscs, Crustaceans, Sea birds, Land birds, Sea mammals, Diving and Underwater Fishing.

	Light penetration in seawater	Dissolved Oxygen in Water	Fuel Oil on Benthos	Dissolved Fuel Oil	Toxic Products-Fuel-Oil degradation	Synergistic effect-Fuel-Oil degradation	Toxic Products-Dispersants degradation
Molluscs	9 / 9	8 / 8	8 / 8	7 / 8	8 / 8	6 / 7	6 / 5
Crustaceans	9 / 9	8 / 8	8 / 8	7 / 8	8 / 8	6 / 7	6 / 5
Sea birds	3 / 3	3 / 3	1 / 1	1 / 1	3 / 2	3 / 2	3 / 2
Land birds	3 / 3	3 / 3	1 / 1	1 / 1	2 / 2	1 / 2	1 / 2
Sea mammals	2 / 2	3 / 3	1 / 1	2 / 1	2 / 2	2 / 2	2 / 2
Diving	9 / 9	2 / 3	1 / 1	1 / 1	2 / 2	2 / 2	2 / 2
Underwater Fishing	9 / 8	2 / 3	3 / 2	2 / 2	2 / 2	2 / 2	3 / 2

Source: Authors.

NOAA. (2001). Hábitats Costeros Característicos: Selección de Alternativas para Responder a Derrames de Petróleo. Administración Nacional Océanica y Atmósférica. Servicio Nacional Oceánico de NOAA Oficina de Atención y Restauración. División de Atención a Materiales Peligrosos.