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Comparative study on the use of the different methods used for cleaning the sea water surfaces

I Voicu, V F Panaitescu, M Turof, M Panaitescu and L G Dumitrescu
Constanta Maritime University, 900663 pC, 104 Mircea cel Bătrân Street, Romania
E-mail: ctionut2009@yahoo.com

Abstract. Sea waters have become extremely polluted with the rise of oil consumption. At the same time, shipowners have been forced to take measures to prevent oil spills, but this has not always been enough to avoid environmental disasters caused by these spills. The purpose of this paper is to determine the effectiveness of the different methods of depollution. For simulate the emergency situation arising from a possible spill we have used the POTENTIAL INCIDENT SIMULATOR CONTROL AND EVALUATION SYSTEM (Pisces II) product of TRANSAS. The simulator is designed to handle real situations such as oil pollution of the sea. The mathematical model used by the simulator is the dispersion oil-water model, taking account all external conditions.

1. Introduction
A significant increase in consumption of petroleum products, led to globalization of environmental problems associated with environmental pollution. The problem of pollution of water areas with oil it is an important thing for the mankind. Emergency oil spills during transportation of oil by water can considerably damage the ecosystem and lead to negative social consequences [1].

The authors study and compare three commonly used methods for depollution of sea and ocean waters when, for various reasons, large quantities of petroleum products are discharged on their surface.

Spills of oil products on water surfaces are classified by the amount of petroleum product discharged as follows:
- minor spills when spillage is less than 7 tonnes;
- average discharges when the amount is between 7 and 700 tonnes;
- major spills when more than 700 tonnes are discharged.

To achieve simulation is used The Simulator for Emergencies Situations PISCES II from Constanta Maritime University - Department of Engineering Science in the Mechanical field and Environment.

The simulator is designed to be used in the preparation process, training and entrainment of staff management from command and operational centers, which perform practical activities for location, limitation and recovery of petroleum products spilled on the sea water surface. The software is designed to simulate the response in the event of discharges of oil on the water surface, so the mathematical model takes into account the authorities' response to the incident, in addition take into account the main physical-chemical processes which affect oil slick, such as: evaporation, dispersion, emulsification and viscosity variation and environmental factors, shoreline, sea currents, weather, sea state, ice and protected areas [2], [3].
2. Comparative study
For the comparative study, the authors made a common scenario in which, at some point, off the Black Sea, the surface of the water reveals the presence of a petroleum product film in the direction 090 ° at a distance of 20.1 km from the Cap Aurora Resort. Following investigations, the oil product was identified as Arabian Heavy Crude Oil, group III.

In order to carry out the four simulations, corresponding to the four methods of removing oil products from the surface of the sea, we use the Simulator for Emergencies Situations PISCES II, where we introduced, for all four simulations as input, the following parameters:

a) hydrometeorological parameters:
- Sea water temperature: 20 °C;
- Air temperature: 20 °C;
- Sea water density: 1,015 kg/m³;
- Speed/direction of the current: 0.1 m/s with 270 °;
- Speed/direction of the wind: 1 m/s with 290 °;
- Sea state: 0 m.

b) physical oil product parameters:
- Density: 8.6 × 10² kg/m³;
- Surface tension: 0.0264 N/m;
- Kinematic viscosity: 2.71·10⁻⁴ m²/s;
- Maximum water content: 70 %;
- Pour point: -28 °C;
- Flashpoint: 36 °C.

2.1. Natural degradation
The simulation is carried out in the context of the natural degradation of the spilled petroleum product, under these circumstances the oil film is transported under the influence of wind and current in the direction 272 °, where it will pollute the shore after about 43 hours, table 1.

### Table 1. Evolution in time of the oil slick in case of inaction.

| Time [hour] | Amount spilled [m³] | Amount floating [m³] | Amount evaporated [m³] | Max thickness [mm] | Slick area [m²] |
|-------------|---------------------|----------------------|------------------------|-------------------|-----------------|
| 0:05        | 809                 | 808                  | 0.1                    | 87                | 15.326          |
| 1:00        | 809                 | 805                  | 3                      | 27.7              | 64.056          |
| 3:00        | 809                 | 792                  | 16.1                   | 14.1              | 124.724         |
| 5:00        | 809                 | 776                  | 32.6                   | 10.4              | 168.443         |
| 7:00        | 809                 | 759                  | 49.4                   | 8.7               | 203.481         |
| 9:00        | 809                 | 743                  | 65.2                   | 8                 | 233.301         |
| 11:00       | 809                 | 729                  | 79.2                   | 7.7               | 259.355         |
| 13:00       | 809                 | 717                  | 91.2                   | 7.1               | 283.359         |
| 15:00       | 809                 | 707                  | 101                    | 6.6               | 304.987         |
| 17:00       | 809                 | 698                  | 110                    | 6.4               | 324.787         |
| 19:00       | 809                 | 691                  | 118                    | 6.2               | 343.614         |
| 21:00       | 809                 | 684                  | 124                    | 6                 | 361.282         |
| 23:00       | 809                 | 678                  | 130                    | 5.9               | 378.699         |
| 25:00       | 809                 | 673                  | 136                    | 5.8               | 394.929         |
| 27:00       | 809                 | 668                  | 141                    | 5.9               | 410.309         |
| 29:00       | 809                 | 663                  | 146                    | 5.8               | 425.592         |
| 31:00       | 809                 | 658                  | 150                    | 5.7               | 439.876         |
| 33:00       | 809                 | 654                  | 155                    | 5.7               | 454.509         |
| 35:00       | 809                 | 650                  | 159                    | 5.5               | 468.408         |
| Time [hour] | Amount spilled [m³] | Amount floating [m³] | Amount evaporated [m³] | Max thickness [mm] | Slick area [m²] |
|------------|---------------------|----------------------|------------------------|-------------------|-----------------|
| 37:00      | 809                 | 646                  | 163                    | 5.5               | 481.174         |
| 39:00      | 809                 | 642                  | 167                    | 5.4               | 494.251         |
| 41:00      | 809                 | 639                  | 170                    | 5.4               | 506.422         |
| 43:00      | 809                 | 635                  | 173                    | 5.4               | 519.381         |
| 43:25      | 809                 | 635                  | 174                    | 5.4               | 522.346         |

Figure 1. The evolution of oil slick in case of inaction [3].

From the initial volume of 809 m³ spilled oil, 21.5% evaporates and the difference, 78.5 %, pollutes the beach of Cap Aurora Resort, figure 1 and table 1. The maximum thickness of the petroleum product film before it pollutes the shore is 5.4 mm and its surface area is 522.346 m².

This depollution method is used when all four conditions are fulfilled concurrently:
- oil product spillage is minor or medium;
- the petroleum product film is located at a considerable distance from shore;
- hydrometeorological conditions are favorable so that the film of petroleum product is not likely to be transported under the influence of wind and current in the direction of the shore;
- the organization of intervention operations and depollution intervention would take longer than the natural degradation of the spilled oil product.

2.2 In-situ burning
This method of in-situ burning it is used when [4]:
- it is necessary to quickly remove large quantities of spilled oil to prevent its spread or impact to sensitive sites or over larger areas;
- oil recovery is limited by available skimming, storage, and handling capabilities;
- the spill occurs in ice-infested waters where mechanical recovery is not effective.

The optimal conditions for considering use of in situ burning method is [4]:
- the spill site is remote or sparsely populated;
- the winds are less than 37 km/h and the waves are less than 0.9 m;
- the oil is a light to medium oil, with an API gravity greater than 32 °API or a density less than 0.864 kg/m³;
- the oil is relatively fresh and has not formed a stable emulsion;
- adequate containment, either natural containment or fire resistant boom, is available in time to conduct the burn within the window of opportunity and there is enough oil to sustain the burn.

For the removal of the petroleum product from the surface of the water using the in situ burning method, the following intervention technique is used, as follows:
- a helicopter equipped with an igniter;
- two tugs used for the transport and handling of the fire boom;
- fire boom.

According to the scenario, at 09.00 hours and 50 minutes after the pollution was detected, the authorities started the procedure of in situ burning of the spilled oil product, table 2.

Figure 2. The evolution of oil slick in case of burning in situ [3].

The oil product is ignite with an igniter mounted on the helicopter. The in situ burning area is 3,196 m², figure 2, and is located near the fire boom, because in this area the oil film has the maximum thickness (the maximum thickness of the oil film is 84.3 mm), in real situation in situ burning area is like on figure 3.

According to the literature, the oil burning rate is 1.6 mm/min.

The fire boom, figure 4, have those characteristics, as follows:
- Producer: Desmi;
- Model: PyroBoom;
- Total height: 0.76 m;
- Standard section length: 200 m;
- Freeboard: 0.28 m;
- Draft: 0.48 m;
- Weight: 13.3 kg/m;
- Operational temperature: -40 °C to 1,315 °C;
- Launch time/section: 40 min.
Figure 3. The evolution of oil slick in case of burning in situ [5].

Figure 4. Construction features of fire boom [6].

Table 2. Evolution in time of the oil slick in case of burning in situ.

| Time [hour] | Amount spilled [m³] | Amount floating [m³] | Amount evaporated [m³] | Amount burned [m³] | Amount sunk [m³] | Max thickness [mm] | Slick area [m²] |
|-------------|---------------------|----------------------|------------------------|-------------------|-----------------|-------------------|-----------------|
| 0:05        | 809                 | 808                  | 0.1                    | 0                 | 0               | 87                | 15,329          |
| 0:30        | 809                 | 808                  | 1                      | 0                 | 0               | 43.4              | 42,099          |
| 1:00        | 809                 | 805                  | 3.1                    | 0                 | 0               | 27.6              | 64,131          |
| 1:30        | 809                 | 803                  | 5.7                    | 0                 | 0               | 21.5              | 81,970          |
| Time [hour] | Amount spilled [m³] | Amount floating [m³] | Amount evaporated [m³] | Amount burned [m³] | Amount sunk [m³] | Max thickness [mm] | Slick area [m²] |
|------------|----------------------|----------------------|------------------------|-------------------|-----------------|-------------------|-----------------|
| 2:00       | 809                  | 800                  | 8.9                    | 0                 | 0               | 18                | 97,867          |
| 2:30       | 809                  | 796                  | 12.4                   | 0                 | 0               | 15.7              | 112,051         |
| 3:00       | 809                  | 792                  | 16.1                   | 0                 | 0               | 14.2              | 124,903         |
| 3:30       | 809                  | 788                  | 20.1                   | 0                 | 0               | 13.1              | 136,636         |
| 4:00       | 809                  | 784                  | 24.2                   | 0                 | 0               | 12.1              | 147,926         |
| 4:30       | 809                  | 780                  | 28.4                   | 0                 | 0               | 11.2              | 158,205         |
| 5:00       | 809                  | 776                  | 32.6                   | 0                 | 0               | 10.5              | 168,378         |
| 5:30       | 809                  | 772                  | 36.8                   | 0                 | 0               | 9.9               | 177,692         |
| 6:00       | 809                  | 767                  | 41.1                   | 0                 | 0               | 9.4               | 186,544         |
| 6:30       | 809                  | 763                  | 45.3                   | 0                 | 0               | 9.1               | 195,180         |
| 7:00       | 809                  | 759                  | 49.4                   | 0                 | 0               | 8.8               | 203,195         |
| 7:30       | 809                  | 755                  | 53.5                   | 0                 | 0               | 8.4               | 211,505         |
| 8:00       | 809                  | 751                  | 57.5                   | 0                 | 0               | 8.3               | 218,780         |
| 8:30       | 809                  | 747                  | 61.4                   | 0                 | 0               | 8                 | 236,527         |
| 9:00       | 809                  | 743                  | 65.1                   | 0                 | 0               | 38.6              | 175,252         |
| 9:30       | 809                  | 742                  | 66.9                   | 0                 | 0               | 77.9              | 56,897          |
| 10:00      | 809                  | 678                  | 67.4                   | 63.5              | 0               | 70.2              | 43,841          |
| 10:30      | 809                  | 378                  | 67.9                   | 265               | 97.1            | 40.5              | 42,012          |
| 11:00      | 809                  | 49.9                 | 68.1                   | 464               | 227             | 23.4              | 23,642          |
| 11:30      | 809                  | 18.3                 | 68.3                   | 495               | 227             | 9.3               | 16,299          |
| 12:00      | 809                  | 10.6                 | 68.3                   | 503               | 227             | 5                 | 8,992           |
| 12:30      | 809                  | 6.6                  | 68.4                   | 507               | 227             | 2.2               | 2,494           |
| 12:55      | 809                  | 0                    | 68.4                   | 513.6             | 227             | 0                 | 0               |

After three hours from ignition of the spilled oil product, the authorities involved in the depollution process managed to remove all the quantity of petroleum products, table 1, so from the initial volume of 809 m³ spilled oil, 8.45 % evaporates, 63.49 % burnes and 28.06 % sank.

2.3. Concentration and collection of the petroleum product on the water surface
For the implementation of the method of concentration and collection of the petroleum product on the surface of the water, the following intervention technique is used, as follows:
- a helicopter, used to monitor the oil film;
- three tugs for the transport of two skimmers, the collecting tank and the boom at the intervention site. Two of these are used to handle the boom and the third tug is used to operate the two skimmers, respectively the collector tank;
- a 1,000 meter long boom, which is used to concentrate petroleum products to efficiently recover the spilled oil;
- the two skimmers are used for the recovery of the spilled oil product, which are located in such a way as to collect a maximum quantity of petroleum product;
- a collecting tank, which is located behind the boom and near the skimmers, used to store the oil product collected by the skimmers.

At 4 hours and 45 minutes from the pollution, all the equipment is ready for intervention, the film of the oil product being at 246 m from the boom.

After 2 hours and 30 minutes from the beginning of the discharge operation, the authorities involved in the depollution process remove the entire quantity of petroleum product, so from a volume of 809 m³ spilled oil product, 4.69 % was evaporated and 95.31 % was recovered.
Table 3. Evolution in time of oil slick in case of using the method of concentrating and collecting the petroleum product on the sea water surface.

| Time [hour] | Amount spilled [m³] | Amount floating [m³] | Amount evaporated [m³] | Amount recovered [m³] | Max thickness [mm] | Slick area [m²] |
|-------------|---------------------|----------------------|------------------------|----------------------|-------------------|-----------------|
| 0:05        | 809                 | 809                  | 0.1                    | 0                    | 86.8              | 15.349          |
| 0:15        | 809                 | 809                  | 0.4                    | 0                    | 65.1              | 27.970          |
| 0:30        | 809                 | 808                  | 1.0                    | 0                    | 43.6              | 42.065          |
| 0:45        | 809                 | 807                  | 1.9                    | 0                    | 33.3              | 53.784          |
| 1:00        | 809                 | 805                  | 3.1                    | 0                    | 27.3              | 64.098          |
| 1:15        | 809                 | 804                  | 4.3                    | 0                    | 24.4              | 73.517          |
| 1:30        | 809                 | 803                  | 5.7                    | 0                    | 21.7              | 82.224          |
| 1:45        | 809                 | 801                  | 7.2                    | 0                    | 19.8              | 90.409          |
| 2:00        | 809                 | 800                  | 8.9                    | 0                    | 18.4              | 98.044          |
| 2:15        | 809                 | 798                  | 10.6                   | 0                    | 16.8              | 105.314         |
| 2:30        | 809                 | 796                  | 12.4                   | 0                    | 15.6              | 112.184         |
| 2:45        | 809                 | 794                  | 14.2                   | 0                    | 14.8              | 118.620         |
| 3:00        | 809                 | 792                  | 16.1                   | 0                    | 14.2              | 124.993         |
| 3:15        | 809                 | 790                  | 18.1                   | 0                    | 13.6              | 131.060         |
| 3:30        | 809                 | 788                  | 20.1                   | 0                    | 13.1              | 137.040         |
| 3:45        | 809                 | 786                  | 22.1                   | 0                    | 12.5              | 142.529         |
| 4:00        | 809                 | 784                  | 24.2                   | 0                    | 12                | 148.129         |
| 4:15        | 809                 | 782                  | 26.2                   | 0                    | 11.4              | 153.535         |
| 4:30        | 809                 | 780                  | 28.3                   | 0                    | 11                | 158.914         |
| 4:45        | 809                 | 778                  | 30.4                   | 0                    | 10.7              | 163.922         |
| 5:00        | 809                 | 741                  | 32.5                   | 35.5                 | 10.4              | 161.907         |
| 5:15        | 809                 | 647                  | 34.5                   | 127                  | 27.4              | 143.096         |
| 5:30        | 809                 | 549                  | 36.0                   | 224                  | 45.4              | 97.708          |
### Table 1: Spilled Oil Products from Sea Water Surface

| Time [hour] | Amount spilled [m³] | Amount floating [m³] | Amount evaporated [m³] | Amount recovered [m³] | Max thickness [mm] | Slick area [m²] |
|------------|---------------------|----------------------|------------------------|----------------------|-------------------|-----------------|
| 5:45       | 809                 | 462                  | 36.8                   | 310                  | 61.2              | 45.748          |
| 6:00       | 809                 | 370                  | 37.1                   | 401                  | 61.8              | 21.773          |
| 6:15       | 809                 | 292                  | 37.3                   | 479                  | 54.3              | 19.897          |
| 6:30       | 809                 | 210                  | 37.6                   | 561                  | 45.7              | 17.961          |
| 6:45       | 809                 | 150                  | 37.7                   | 621                  | 38.6              | 15.612          |
| 7:00       | 809                 | 75.6                 | 37.9                   | 695                  | 26.4              | 10.826          |
| 7:15       | 809                 | 11                   | 38                     | 760                  | 11.8              | 4.162           |
| 7:20       | 809                 | 0                    | 38                     | 771                  | 0.1               | 1.019           |

![Image](RO-BOOM-1500.png)  
**Figure 6.** Heavy-duty containment boom, RO-BOOM 1500 [7].

![Image](Terminator.png)  
**Figure 7.** High capacity self-adjusting weir skimmer [8].

The following emergency equipment, required to limit and recovery the spilled oil products from sea water surface, have those characteristics, as follows:

- heavy-duty containment boom, RO-BOOM 1500, 1,000 m, figure 6, which has the following characteristics:
  - Producer: Ro-Clean Desmi;
  - Model: RO-BOOM 1500;
  - Standard section length: 200 m;
  - Width: 1.30 m;
  - Freeboard: 0.50 m;
  - Draught: 0.7 m;
  - Launch time/section: 40 min;
  - high capacity self adjusting weir skimmer, figure 7, which has the following characteristics:
  - Producer: Ro-Clean Desmi;
  - Model: Terminator;
  - Recovery rate: 170 m³/hour;
  - Weight: 162 kg;
  - Recovery radius: 20 m.
3. Conclusions

In case of natural degradation, the fate of oil in the sea water largely depends on mechanical (wave, wind), physical (temperature, UV) and chemical (pH, dissolved oxygen and nutrient concentration) factors which may differently influence its natural transformation (oil weathering) and bio-degradation [9].

At an early stage light fractions of oil are naturally removed, but heavy fractions are instead dispersed or dissolved and only a small portion may be removed by the process of biodegradation.

On water, oil is spreads very rapidly (within hours) into very thin film oil that are too thin to burn. The oil may also emulsify and evaporation can remove the burnable components, making oil burning difficult or unachievable beyond the first 12 - 24 hours after it is spilled. Thus, burning in-situ is primarily considered an option for incidents with a continuous release source.

The main advantage of using in-situ burning is that large volumes of oil can be removed rapidly from the surface of the water under ideal conditions.

A second advantage of in-situ burning is its relatively high burn efficiency. Studies have shown that between 90 % and 99 % of the spilled oil volume, boomed and maintained at the required thickness, can be removed by burning under normal conditions.

A third advantage is that burning reduces the amount of oily wastes for collection and disposal. In-situ burning can be more efficient than mechanical recovery under similar spill conditions because recovery devices for example skimmers and temporary storage, are not necessary in case of in-situ burning. So this method of depollution is cheaper.

The most common method of depollution remains the method that uses mechanical means, as it is often the only method that can be applied because most of the time the pollution occurs in the area of the ports or near the shore and the quantities of petroleum products are not large. So this method is most appropriate to use.

4 References

[1] Mansurov Z A, Lesbaev B T, Prikhodko H G, Kazakov Yu V and Ualiyev Zh 2013 Burning oil layer on the surface of water Eurasian chemico-technological Journal 15(2013) 275-281
[2] Voicu I, Dumitrescu L G, Panaitescu F V and Panaitescu M 2017 Studies on the oil spillage near shoreline IOP Publishing, IOP Conf. Series: Materials Science and Engineering 227(2017) 012135
[3] ***, PISCES29-PL Specifications, ver. 1.0. 2008.
[4] In situ-Burning, A Decision maker s Guide to In-situ Burning , Regulatory Analysis and Scientific Affairs Publication number 4740 april 2005, American Petroleum Institute
[5] https://www.elastec.com/products/floating-boom-barriers/fire-resistant-oil-boom/hydro-fire-boom
[6] http://www.desmi.com/UserFiles/file/oil%20spill%20response/Product%20brochure/Pyroboom.pdf
[7] http://pdf.directindustry.com/pdf/desmi-pumping-technology-s/ro-boom-1500-heavy-duty-oil-containment-boom/21088-419147.html
[8] http://pdf.directindustry.com/pdf/desmi-pumping-technology-s/terminator-high-capacity-self-adjusting-weir-skimmer/21088-419089.html
[9] Nikolopoulou M and Kalogerakis N 2010 Biostimulation strategies for enhanced bioremediation of marine oil spills including chronic pollution In Timmis K N (ed) Handbook of hydrocarbon and lipid microbiology (Berlin: Springer-Verlag Berlin) pp 2521-2529