SELF-CLEANING CAPACITY OF SEA COASTS IN CASE OF OIL POLLUTION

Kuznetsov A.N., Fedorov Yu.A.  
Southern Federal University,  
Rostov-on-Don, Russia

Fattal P., Ebner F.  
University of Nantes,  
Nantes, France
Objectives

The objective of the research is to evaluate:

• the rates of spilled fuel oil natural destruction on geographically different sea coasts;

• their relationship with principal environmental factors such as climatic and hydrological conditions, coast exposure and geomorphology, sediment types, intensity of biogeochemical cycles etc.
Study areas: geographically different oiled sea coasts

- Tanker "Erika" accident, December 1999
- Tanker "Prestige" accident, November 2002
- Tanker "Volgoneft-139" accident, November 2007

For this research, several geographically different sites were chosen in Russia, France, and Spain. The duration of the observations ranged from 6 to 15 years.
Materials and methods

• 24 expeditions were carried out;

• 320 samples of oil slicks and 48 sediment cores up to 50 cm thick divided into 178 samples were taken, described and analyzed.

• The samples were analyzed with the use of thin layer chromatography, infrared and ultraviolet spectrophotometry, luminescent and gravimetric methods in order to determine separately the concentrations of three groups of petroleum components:
  – the aliphatic, naphthenic, mono- and di-aromatic hydrocarbons (HC);
  – the polycyclic aromatic hydrocarbons (PAH);
  – the asphaltic components (AC): the resins and the asphaltenes.
Field study on the Atlantic coast of France and in the Loire River estuary, 1999 to 2014

In France, the observations were carried out on the coasts of the Le Croisic peninsula and the island of Noirmoutier polluted by fuel oil from the broken tanker “Erika” in December 1999. We also studied the Loire River estuary contaminated in consequence of an accident at an oil refinery in Donges in March 2008. Here you can see that even 15 years after the tanker “Erika” accident the traces of spilled fuel oil were still present on the contaminated coasts, although their number and size had decreased considerably due to self-cleaning process.

In Spain, the studied sector covered the north-western coast of Galicia polluted by fuel oil from the broken tanker "Prestige" in November 2002.
Field study in the Strait of Kerch and in the area of Novorossiysk, 2007 to 2016

In Russia, the observations were carried out in the Strait of Kerch contaminated by fuel oil from the broken tanker "Volgoneft-139" in November 2007, and in the area of major petroleum seaport of Novorossiysk on the Black Sea coast.
Natural transformation of composition of spilled fuel oil

The comparative analysis of temporal changes in the composition of fuel oil traces reveal a steady decrease in the percentage of relatively labile aliphatic, naphthenic, mono- and di-aromatic hydrocarbons due to their natural destruction. At the same time, the residual percentage of conservative asphaltic components rises. That is why we use the ratio of the relatively labile hydrocarbons content to the conservative asphaltic components content as a simplified indicator of the oil pollution transformation level.

**Strait of Kerch coast (Russia)**

- Number of days: 0, 7, 40, 270, 665, 1025, 1150
- Percentage:
  - Saturated, mono- and di-aromatic hydrocarbons: 65, 60, 57, 51, 45, 46, 47
  - Asphaltic components: 21, 14, 14, 14, 14, 14, 15
  - Polycyclic aromatic hydrocarbons: 15, 15, 15, 15, 15, 15, 15

**Atlantic coasts of France**

- Number of days: 0, 1825, 2555, 2870, 3240
- Percentage:
  - Saturated, mono- and di-aromatic hydrocarbons: 65, 36, 51, 58, 63, 63
  - Asphaltic components: 20, 16, 14, 14, 13, 17
  - Polycyclic aromatic hydrocarbons: 14, 14, 14, 14, 14, 14

**Atlantic coasts of Spain**

- Number of days: 0, 6, 730, 1460, 1775, 2145, 2515
- Percentage:
  - Saturated, mono- and di-aromatic hydrocarbons: 64, 61, 54, 48, 49, 47, 56
  - Asphaltic components: 23, 14, 14, 13, 12, 16, 16
  - Polycyclic aromatic hydrocarbons: 14, 14, 14, 14, 14, 14
Temporal changes in the ratio of hydrocarbons content to asphaltic components content (HC/AC) in the fuel oil slicks found on the sea coasts

\[(HC/AC)_t = (HC/AC)_0 \cdot e^{-kt}\]

\[T = \ln 2 \div k\]

Atlantic coasts of France and Spain

Strait of Kerch coast (Russia)

Black Sea coast in the area of Novorossiysk

1 - large accumulations; 2 - weathered crusts 2 to 5 cm thick; 3 - weathered crusts 5 to 10 cm thick; 4 - weathered films; T – average half-periods of oil pollution natural transformation (the indexes correspond to the numbers in the legend).
<table>
<thead>
<tr>
<th>Polluted sites</th>
<th>Part of littoral zone</th>
<th>Forms of fuel oil traces</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Western coast of France, Croisic Peninsula and Noirmoutier Island, large</td>
<td>upper</td>
<td>Films</td>
<td>Crusts 2 to 5 mm thick</td>
</tr>
<tr>
<td>granitic tidal flat passing into low granitic cliffs and dunes</td>
<td></td>
<td>1073 (5)</td>
<td>1368 (7)</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td>1137 (4)</td>
<td>1440 (7)</td>
</tr>
<tr>
<td>Loire River estuary, muddy coast with reeds and protection embankment</td>
<td>upper</td>
<td>426 (4)</td>
<td>759 (2)</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td>-</td>
<td>838 (2)</td>
</tr>
<tr>
<td>North-Western coast of Spain, Cape Finisterre, high granitic cliffs</td>
<td>above high tide level</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>surrounding a bay with sand beach and dune</td>
<td>upper</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>middle</td>
<td>-</td>
<td>1428 (2)</td>
</tr>
<tr>
<td>Strait of Kerch, the Black Sea side, Tuzla dam made of limestone blocks</td>
<td>upper</td>
<td>440 (3)</td>
<td>733 (2)</td>
</tr>
<tr>
<td>with narrow sand beaches</td>
<td>middle</td>
<td>659 (14)</td>
<td>834 (7)</td>
</tr>
<tr>
<td></td>
<td>lower</td>
<td>612 (2)</td>
<td>782 (5)</td>
</tr>
<tr>
<td>Strait of Kerch, the Sea of Azov side, low clay cliff with protection</td>
<td>upper</td>
<td>504 (5)</td>
<td>-</td>
</tr>
<tr>
<td>embankment, large sand beach, rock groynes</td>
<td>middle</td>
<td>551 (3)</td>
<td>723 (2)</td>
</tr>
<tr>
<td></td>
<td>lower</td>
<td>567 (4)</td>
<td>739 (2)</td>
</tr>
<tr>
<td>Area of Novorossiysk seaport, the Black Sea coast, high flysh cliffs with</td>
<td>upper</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>pebbly and gravel beaches and spits</td>
<td>middle</td>
<td>291 (2)</td>
<td>846 (20)</td>
</tr>
<tr>
<td></td>
<td>lower</td>
<td>259 (3)</td>
<td>-</td>
</tr>
</tbody>
</table>
Dependence of the rate of an oil slick natural transformation on its thickness

The results of regression analysis of the set of data on 162 samples of oil slicks taken on the Russian, French and Spanish coasts show that the half-period of a fuel oil slick transformation ($T$) significantly ($r = 0.86$) depends on its thickness ($h, \text{ mm}$) according to the equation:

$$T_i = T_1 \cdot h^{0.408},$$

where $T_i$ is the half-period of transformation of an oil slick $i$ mm thick, $T_1$ is the half-period of transformation of an oil slick of 1 mm thick. The exponent of $h$ is statistically significant.
Results of regression analysis of the influence of geographical factors on the rates of spilled oil transformation

<table>
<thead>
<tr>
<th></th>
<th>Quantitative parameters of geographical factors of oil pollution transformation expressed in points of 5-point scale</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$I$</td>
</tr>
<tr>
<td>Partial correlation coefficients</td>
<td>-0.47</td>
</tr>
<tr>
<td>Multiple regression coefficients</td>
<td>-0.05</td>
</tr>
<tr>
<td>Standard deviation of the multiple regression coefficients</td>
<td>0.07</td>
</tr>
</tbody>
</table>

$$k = 4.96 - 1.04S + 0.17ESI - 0.05I + 0.09W$$
Mapping of sea coasts by their capacity to destruct the spilled oil
We are very grateful for financial support of our scientific and academic cooperation to RFBR, the CNRS and the Ambasy of France in Russia

Thank you for your attention !!!