*Dr. sc. Vedran Jelavić, Sveučilište u Dubrovniku, Ćira Carića 4, Dubrovnik*
*Mr. sc. Damir Radan, Sveučilište u Dubrovniku, , Ćira Carića 4, Dubrovnik*

# ECOLOGIC RISKS FROM CRUDE OIL TANKERS IN CROATIAN PART OF ADRIATIC SEA

**Summary**

Project DRUZBA-ADRIA integrated oil terminal Omisalj on the island Krk as loading terminal for crude oil without any previous environmental survey. Such project is extremely environmentaly unfriendly because arriving tankers are unloading ballast water prior to arrival, unloading inert gas at the terminal in Omisalj and departing loaded with crude oil. Ballast water and inert gas dicsharge are evident because there are no facilities for reception and treatment at the terminal. Likelihood of oil spill could be computed based on statistical data about world tankers fleet, crude oil transportation by sea and registered crude oil spills.

*Key words: likelihood of pollution, ballast water, inert gas, crude oil*

# EKOLOŠKI RIZICI TANKERA ZA PRIJEVOZ SIROVE NAFTE U HRVATSKOM DIJELU JADRANSKOG MORA

**Sažetak**

Projektom DRUŽBA-ADRIA naftni terminal u Omišlju na otoku Krku predviđen je kao ukrcajni terminal sirove nafte, bez prethodne studije utjecaja na okoliš. Takav projekt izrazito je rizičan za okoliš jer tankeri *u balastu* dolaze na Omišaljski terminal, ispuštaju balast prije terminala, ispuštaju inertni plin na terminalu i nakon ukrcaja sirove nafte vraćaju se natrag prema Otrantskim vratima. Ispuštanje balastne vode i inertnog plina u okoliš izvjesni su događaji jer na terminalu Omišalj ne postoje prihvatne stanice i postrojenja za tretman inertnog plina ili balastne vode. Vjerojatnost ispuštanja sirove nafte može se izračunati iz dostupnih statističkih podataka o svjetskoj tankerskoj floti, prijevozu sirove nafte morem i registriranim izljevima sirove nafte s brodova.

*Ključne riječi: vjerojatnost onečišćenja, balastne vode, inertni plin, sirova nafta*

## 1. Introduction

The concept of risk has two elements, i.e. the likelihood of something happening and the consequences if it happens [2]. Risk concept, applied in shipping industry and environmental issues became very important element in marine transportation. Oil tankers are potentially the most hazardous ships for marine environment. Beside eventual risk from oil spills, these ships are continiously transporting huge ammount of ballast water on their voyages and discharging inert gas into the air at loading terminals. In the past oil terminal in Omisalj on island Krk served as unloading terminal for oil tankers. In such conditions arriving tankers loaded with cargo used to be considerably risky ships for the environment. On the return voyage under ballast ships were much less dangerous for the environment. After adopting project Druzba Adria oil terminal in Omisalj is supposed to be loading terminal for crude oil, thus becoming ecologicly risky not only from crude oil, but also from ballast water and inert gas. Ballasted tankers are supposed to arrive to the terminal and unload ballast water prior to arrival. During cargo loading operations inert gas from the cargo tanks will be discharged into the air causing direct pollution at the terminal.

## 2. Oil terminal in Omisalj and project *Druzba-Adria*

Oil terminal Omisalj is situated on the north side of island Krk in the bay of Omisalj (Lat: 45°13′N; Long: 14°32′E), containing 4 tanks with capacities of 40.000 $m^3$, 5 tanks with capacities of 72.000 $m^3$ and 3 tanks with capacities of 80.000 $m^3$. Terminal is provided with 4 cargo manifolds each delivering 5.000 $m^3$/h. There are no facilities for storrage and treatment of ballast water and inert gas.

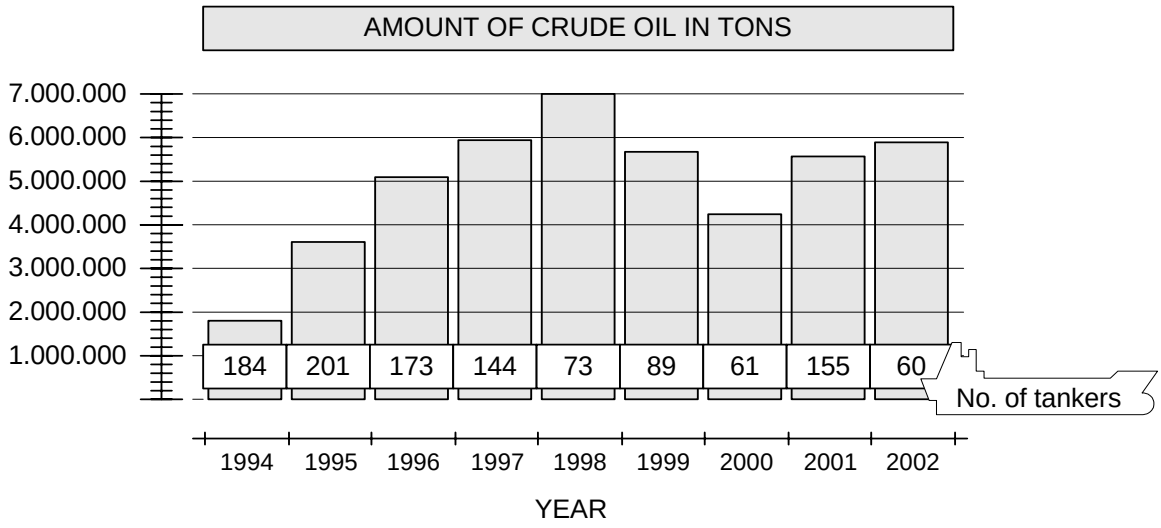


**Fig. 1** Crude oil arrival traffic at Omisalj terminal from 1994 to 2002

**Slika 1**. Promet sirove nafte dopremljene na terminal Omišalj u vremenu od 1994 do 2002

Fig. 1 showes crude oil arriving to terminal Omisalj during 8 years period. It is obvious that different sizes of ships were used for oil transportation. According to number of ships and amounts of crude oil bigger ships were used during years 1998, 1999 and 2000 compared to other periods.

Project *Druzba-Adria* integrated oil terminal Omisalj into 3200 km long pipe line that starts in russian Samara, providing part of the russian crude oil to be exported into the world market. Estimated amount of crude oil would be $5x10^6$t the first year, $10x10^6$t the second year

and $15x10^6$t the third year. Project *Druzba-Adria* is confirmed by high representatives from the folloving governments: Russia, Bjelorussia, Ukraine, Slovakia, Hungary and Croatia.

## 3. Dominant pollutants from crude oil carriers

There are typically three systems harmful for environment recogniesed on oil tankers. These systems are: cargo system, ballast water system and inert gas system.

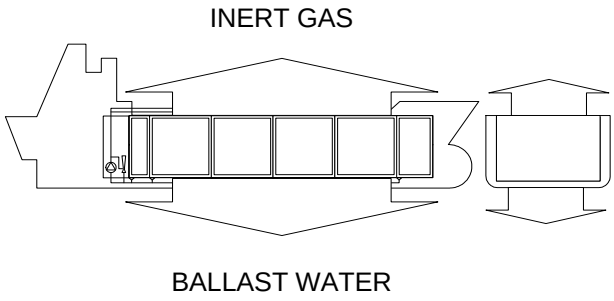


**Fig. 2** Certain sources of pollution

**Slika 2**. Izvjesni onečišćivači okoliša

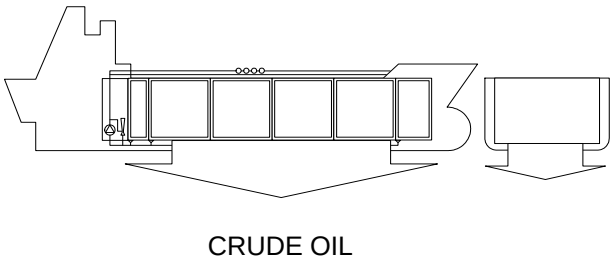


**Fig. 3** Probable sources of pollution

**Slika 3**. Mogući onečišćivači okoliša

Figures 2 and 3 are presenting dominant sources of pollution on oil tankers. Ballast water and inert gas are certain polutants, while crude oil may ocasionaly enter into the sea. Considering environmental risks it is very important to distinguish cargo loading terminals from cargo unloading terminals. Ships that are arriving to loading terminals are ballasted and inerted. For cargo loading purposes ballast water is pumped out into the sea and inert gas is released into the air. Amount of ballast water depends on ships` size, while composition of ballast water depends mainly on ballasting region and ballast water treatment. Ammount of inert gas, which is very toxic for humans and environment, depends on size of the cargo tanks. Every voyage from ballasted ship is therefore accompanied by evident risk from ballast water and inert gas discharge and probable risk from crude oil incident.

## 4. Likelihood of crude oil spill in Croatian part of Adriatic Sea from transportation of oil through the project Druzba-Adria

Likelihood of different oil spills ($P_{SPILL}$) could be computed from availlable statistical data. Likelihood of pollution from different types of oil tankers is based on structure of tanker fleet and rgistered oil spills. Such approach is conservative, but adequate, because there are no reliable data about participation of different ship types in oil transport and oil pollution incidents. Prognoses for oil spill in Croatian part of Adriatic sea are based on quantity of oil to be transported and structure of tanker fleet. In this paper quantity of oil proposed by project Druzba –Adria will be considered. Likelihood of oil spill, based on two factors, such as **ship type** and **spill type** is calculated as follows:

World total number of tankers.

$$n_{FLEET} = 3792 \quad (1)$$

World total tonnage of tankers.

$$m_{FLEET} = 293128310 \text{ t} \quad (2)$$

World total oil transportation carried by sea per year [x].

$$m_{WORLD} = 2.3 \times 10^9 \text{ t} \quad (3)$$

Average number of woyages under cargo per tanker, per year.

$\bar{n}$CGO = mWORLD/mFLEET = 7.846 (4)

Total number of woyages under cargo of the world tanker fleet.

nCGO = $\bar{n}$CGO x nFLEET = 29754 (5)

## 4.1. Likelihood of oil spill based on ship`s type

**Table 1** Contribution of different types of tankers in the world tanker fleet by tonnage [5]

**Tablica 1.** Udio pojedinih tipova tankera u ukupnoj nosivosti svjetske tankerske flote [5]

| Size | SHIP`S TYPE | | | | | **Total** |
|---|---|---|---|---|---|---|
| (tons) | Double bott. | Double hull | Double side | No nformation | Single hull | (tons) |
| 5-20000 | 1203120 | 3951035 | 70488 | 3164639 | 3071362 | **11460644** |
| 20-60000 | 4307083 | 19630152 | 1308006 | 105578 | 15985129 | **41335948** |
| 60-80000 | 578937 | 5855438 | 1249721 | | 7396864 | **15080960** |
| 80-120000 | 1161870 | 29872285 | 5596242 | | 18530011 | **55160408** |
| 120-200000 | 1234527 | 25674700 | 1500974 | | 11172412 | **39582613** |
| 200000 + | 243850 | 65240435 | 2025795 | | 62997657 | **130507737** |
| **Total** | **8729387** | **150224045** | **11751226** | **3270217** | **119153435** | **293128310** |

**Table 2** Contribution of different types of tankers in the world tankers fleet by number [5]

**Tablica 2.** Udio pojedinih tipova tankera u ukupnom broju tankera svjetske tankerske flote [5]

| Size | SHIP`S TYPE | | | | | **Total** |
|---|---|---|---|---|---|---|
| (tons) | Double bott. | Double hull | Double side | No information | Single hull | |
| 5-20000 | 124 | 362 | 6 | 495 | 197 | **1184** |
| 20-60000 | 114 | 497 | 30 | 4 | 449 | **1094** |
| 60-80000 | 9 | 85 | 19 | | 113 | **226** |
| 80-120000 | 11 | 299 | 60 | | 202 | **572** |
| 120-200000 | 9 | 173 | 10 | | 78 | **270** |
| 200000 + | 1 | 217 | 7 | | 221 | **446** |
| **Total** | **268** | **1633** | **132** | **499** | **1260** | **3792** |

**Table 3** Number of voyages under cargo per year depending on ships` type and ships` size

**Tablica 3.** Godišnji broj putovanja u teretu prema tipovima i veličinama brodova (Tabl. 2 x $\bar{n}_{CGO}$)

| Size | SHIP`S TYPE | | | | | **Total** |
|---|---|---|---|---|---|---|
| (tons) | Double bott. | Double hull | Double side | No information | Single hull | |
| 5-20000 | 972,952766 | 2840,39437 | 47,07835964 | 3883,9647 | 1545,7395 | 9290,12964 |
| 20-60000 | 894,4888332 | 3899,65746 | 235,3917982 | 31,385573 | 3523,0306 | 8583,95424 |
| 60-80000 | 70,61753947 | 666,943428 | 149,0814722 | | 886,64244 | 1773,28488 |
| 80-120000 | 86,31032601 | 2346,07159 | 470,7835964 | | 1584,9714 | 4488,13695 |
| 120-200000 | 70,61753947 | 1357,42604 | 78,46393274 | | 612,01868 | 2118,52618 |
| 200000 + | 7,846393274 | 1702,66734 | 54,92475292 | | 1734,0529 | 3499,4914 |
| **Total** | **2102,833397** | **12813,1602** | **1035,723912** | **3915,3502** | **9886,4555** | **29753,5233** |

Number of tanker oil spills per year [4].

$$nSPILL = 329 \quad (6)$$

Probability of tanker oil spill.

$$PSPILL = nSPILL / nCGO = 0.01105151 \quad (7)$$

Total ammount of oil spills from the tankers per year [4]

$$mSPILL = 1.1 \times 105\ t \quad (8)$$

Average ammount of oil per spill.

$$\bar{m}SPILL = mSPILL / nSPILL = 334\ t \quad (9)$$

**Table 4** Probability of voyage under cargo depending on ships` type and ships` size

**Tablica 4.** Vjerojatnost putovanja u teretu prema tipovima i veličinama brodova (Tabl. 3 / $n_{FLEET}$)

| Size | SHIP`S TYPE | | | | | **Total** |
|---|---|---|---|---|---|---|
| (tons) | Double bott. | Double hull | Double side | No information | Single hull | |
| 5-20000 | 0,032700422 | 0,09546414 | 0,001582278 | 0,130538 | 0,0519515 | **0,31223629** |
| 20-60000 | 0,030063291 | 0,1310654 | 0,007911392 | 0,0010549 | 0,1184072 | **0,28850211** |
| 60-80000 | 0,002373418 | 0,02241561 | 0,005010549 | 0 | 0,0297996 | **0,05959916** |
| 80-120000 | 0,002900844 | 0,07885021 | 0,015822785 | 0 | 0,05327 | **0,15084388** |
| 120-200000 | 0,002373418 | 0,04562236 | 0,002637131 | 0 | 0,0205696 | **0,07120253** |
| 200000 + | 0,000263713 | 0,05722574 | 0,001845992 | 0 | 0,0582806 | **0,11761603** |
| **Total** | **0,070675105** | **0,43064346** | **0,034810127** | **0,1315928** | **0,3322785** | **1** |

Estimation of mSPILL is taken from the period 1990 – 2000 becase at the beginig of that period expansion of double hull tankers started, together with implementation of new rules and regulations. Today, number of double hull tankers and single hull takers in the world fleet is almost equal. Although amount of oil spills from the period 2000 – 2003 is much smaller than the ammount from the former period it is too early to take it into cosideration.

## 4.2. Likelihood of oil spill based on spill`s type

**Table 5** Number of typical oil spills for different tanker operational conditions

**Tablica 5.** Broj karakterističnih tipova onečišćenja za različita operativna stanja tankera [4]

| | Number of oil spills | | | Total |
|---|---|---|---|---|
| | < 7 tons | 7-700 tons | > 700 tons | |
| **OPERATIONS** | | | | |
| Loading/Unloading | 2772 | 301 | 17 | **3090** |
| Bunkering | 542 | 25 | 0 | **567** |
| Other operations | 1167 | 47 | 0 | **1214** |
| Total | 4481 | 373 | 17 | **4871** |
| **ACCIDENTS** | | | | |
| Collisions | 164 | 260 | 87 | **511** |
| Groundings | 222 | 203 | 107 | **532** |
| Hull failures | 563 | 77 | 44 | **684** |
| Fires & explosions | 150 | 16 | 19 | **185** |
| Toatal | 1099 | 556 | 257 | **1912** |
| Other | 2221 | 165 | 38 | **2424** |
| Toatal | **7801** | **1094** | **312** | **9207** |

**Table 6** Probability of typical oil spills for different tanker operational conditions ($P_{SPILL.TYPE}$)
**Tablica 6.** Vjerojatnosti pojedinih tipova onečišćenja s tankera za različita operativna stanja ($P_{SPILL.TYPE}$)

| | $P_{SPILL.TYP}$ | | | Total |
|---|---|---|---|---|
| | < 7 tons | 7-700 tons | > 700 tons | |
| **OPERATIONS** | | | | |
| Loading/Unloading | 0,30107527 | 0,032692517 | 0,0018464 | **0,3356142** |
| Bunkering | 0,05886825 | 0,002715325 | 0 | **0,0615836** |
| Other operations | 0,12675138 | 0,005104812 | 0 | **0,1318562** |
| Total | 0,48669491 | 0,040512653 | 0,0018464 | **0,529054** |
| **ACCIDENTS** | | | | |
| Collisions | 0,01781253 | 0,028239383 | 0,0094493 | **0,0555012** |
| Groundings | 0,02411209 | 0,022048441 | 0,0116216 | **0,0577821** |
| Hull failures | 0,06114913 | 0,008363202 | 0,004779 | **0,0742913** |
| Fires & explosions | 0,01629195 | 0,001737808 | 0,0020636 | **0,0200934** |
| Toatal | 0,1193657 | 0,060388835 | 0,0279135 | **0,2076681** |
| Other | 0,2412295 | 0,017921147 | 0,0041273 | **0,2632779** |
| Toatal | **0,84729011** | **0,118822635** | **0,0338873** | **1** |

Total probability of typical spill types from tankers.

$$P_{TOTAL,SPILL.TYPE} = P_{SPILL} \text{ x } P_{SPILL.TYPE} \quad (10)$$

**Table 7** Total probability of typical oil spills for different tanker operational conditions ($\boldsymbol{P}_{TOTAL,SPILL.TYPE}$)

**Tablica 7.** Ukupna vjerojatnost pojedinih tipova onečišćenja s tankera za različita operativna stanja

| | $\boldsymbol{P}_{TOTAL,SPILL.TYPE}$ | | | Total |
|---|---|---|---|---|
| | < 7 tons | 7-700 tons | > 700 tons | |
| **OPERATIONS** | | | | |
| Loading/Unloading | 0,00332734 | 0,0003613 | 2,0406E-05 | **0,003709** |
| Bunkering | 0,00065058 | 3,001E-05 | 0 | **0,0006806** |
| Other operations | 0,00140079 | 5,642E-05 | 0 | **0,0014572** |
| Total | 0,00537871 | 0,0004477 | 2,0406E-05 | **0,0058468** |
| **ACCIDENTS** | | | | |
| Collisions | 0,00019686 | 0,0003121 | 0,00010443 | **0,0006134** |
| Groundings | 0,00026648 | 0,0002437 | 0,00012844 | **0,0006386** |
| Hull failures | 0,00067579 | 9,243E-05 | 5,2815E-05 | **0,000821** |
| Fires & explosions | 0,00018005 | 1,921E-05 | 2,2806E-05 | **0,0002221** |
| Toatal | 0,00131917 | 0,0006674 | 0,00030849 | **0,002295** |
| Other | 0,00266595 | 0,0001981 | 4,5613E-05 | **0,0029096** |
| Toatal | **0,00936384** | **0,0013132** | **0,00037451** | **0,0110515** |

With combinations of elements contained in tables 4 - Probability of voyage under cargo depending on ships` type and ships` size and 7 - Total probability of typical oil spills for different tanker operational conditions ($\boldsymbol{P}_{TOTAL,SPILL.TYPE}$), it is possible to compute different probabilities based on ship types and spill types. There are 676 possible combinations and therefore it is important to focus only on particular type of the tanker

regarding size and hull structure. The reason for huge number of combinations is heterogeneous structure of tanker fleet, including even 5 different types of the ships. After year 2015 tanker fleet is supposed to be homogeneous, wit all ships build under the same standards, thus making every statistical analyses much easier.

4.3 Oil spill expectations through project *Druzba-Adria*

Different ammounts of oil are supposed to be carried from oil terminal in Omisalj as a result of the project *Druzba-Adria.*

1. year - $m_{\text{DRUŽBA-ADRIA}} = 5 \times 10^6$ t (11)

2. year - $m_{\text{DRUŽBA-ADRIA}} = 10 \times 10^6$ t (12)

3. year - $m_{\text{DRUŽBA-ADRIA}} = 15 \times 10^6$ t (13)

Possible number of tanker arrivals ($n_{\text{DRUŽBA-ADRIA}}$) based on former traffic of the terminal could be: 58, 78, 100, 118, 136 or 158 arrivals.

Expected number of spills ($n_{\text{SPILL,DRUŽBA-ADRIA}}$) for the first year of the project is based on $P_{\text{SPILL}}$, and computed as follows:

$$n_{\text{SPILL,DRUŽBA-ADRIA}} = P_{\text{SPILL}} \times n_{\text{DRUŽBA-ADRIA}} \quad (14)$$

**Table 8** Expected number of oil spills through the project *Druzba-Adria* for different number of tanker arrivals in the first year of traffic

**Tablica 8.** Očekivani broj izljeva projektom *Druzba-Adria* za različiti broj brodova u prvoj godini prijevoza

| NUMBER OF TANKERS $n_{\text{DRUŽBA-ADRIA}}$ | PROBABILITY OF SPILL $P_{\text{SPILL}}$ | EXPECTED NUMBER OF SPILLS $n_{\text{SPILL,DRUŽBA-ADRIA}}$ |
|---|---|---|
| 58 | 0.01105151 | **0,640987713** |
| 78 | 0.01105151 | **0,862017959** |
| 100 | 0.01105151 | **1,105151230** |
| 118 | 0.01105151 | **1,304078451** |
| 136 | 0.01105151 | **1,503005672** |
| 158 | 0.01105151 | **1,746138943** |

**Table 9** Expected ammount of spilled oil through the project *Druzba-Adria* for different number of tanker arrivals in the first year of traffic

**Tablica 9.** Očekivana količina izlivene nafte projektom *Druzba-Adria* za različiti broj brodova u prvoj godini prijevoza

| NUMBER OF TANKERS $n_{\text{DRUŽBA-ADRIA}}$ | EXPECTED AMMOUNT OF SPILLED OIL (tons) $m_{\text{SPILL,DRUŽBA-ADRIA}}$ |
|---|---|
| 58 | **213,76** |
| 78 | **287,90** |
| 100 | **369,07** |
| 118 | **435,5** |
| 136 | **502,00** |
| 158 | **583,16** |

## 5. Conclusion

Oil tankers are environmentally very specific ships because of continuous pollution from cargo and ballast tanks. Inert gas and ballast water is mostly discharged without any previous treatment. Hazard of inert gas is well known while hazard of ballast water depends on the origin of the water. Oil discharges are results of incidents and therefore subject of probability. Even probabilities of oil spills sometimes seem to be low, incidents happen in our neighborhoods and our homes. Bigger incident in Croatian part of Adriatic Sea would cause catastrophe for tourism, fishing and other industries. With signing project *Druzba-Adria* Croatian Government signed to deal with consequences from probable oil spill risk and certain risks from ballast water and inert gas. It is really questionable if *we* have enough technical, organizational and political power to afford such risk.

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