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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 environmentally 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 discharge 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 continuously transporting huge amount 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 ecologically 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 m³, 5 tanks with capacities of 72.000 m³ and 3 tanks with capacities of 80.000 m³. Terminal is provided with 4 cargo manifolds each delivering 5.000 m³/h. There are no facilities for storage and treatment of ballast water and inert gas.

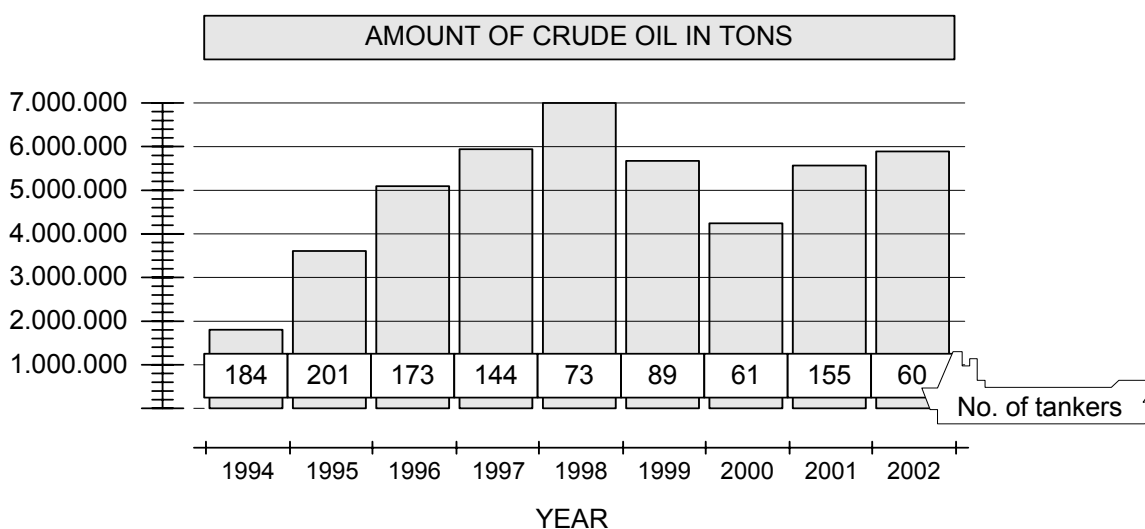


Fig. 1 Crude oil arrival traffic at Omisalj terminal from 1994 to 2002

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

Fig. 1 shows 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 5x10⁶t the first year, 10x10⁶t the second year and 15x10⁶t the third year. Project *Druzba-Adria* is confirmed by high representatives from the following governments: Russia, Bjelorussia, Ukraine, Slovakia, Hungary and Croatia.

3. Dominant pollutants from crude oil carriers

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

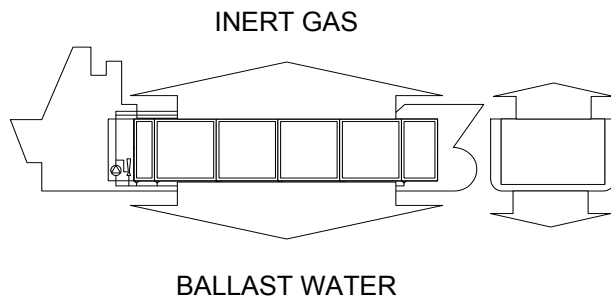


Fig. 2 Certain sources of pollution

Slika 2. Izvjesni onečišćivači okoliša

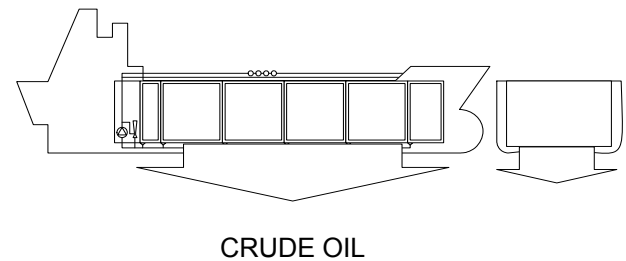


Fig. 3 Probable sources of pollution

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 pollutants, while crude oil may occasionally 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. Amount 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 available statistical data. Likelihood of pollution from different types of oil tankers is based on structure of tanker fleet and registered 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 voyages under cargo per tanker, per year.

$$\bar{n}_{CGO} = m_{WORLD}/m_{FLEET} = 7.846 \quad (4)$$

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

$$n_{CGO} = \bar{n}_{CGO} \times n_{FLEET} = 29754 \quad (5)$$

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 (tons)	SHIP'S TYPE					Total (tons)
	Double bott.	Double hull	Double side	No nformation	Single hull	
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 (tons)	SHIP'S TYPE					Total
	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 (tons)	SHIP'S TYPE					Total
	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].

$$n_{SPILL} = 329 \quad (6)$$

Probability of tanker oil spill.

$$P_{SPILL} = n_{SPILL} / n_{CGO} = 0.01105151 \quad (7)$$

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

$$m_{SPILL} = 1.1 \times 10^5 \text{ t} \quad (8)$$

Average ammount of oil per spill.

$$\bar{m}_{\text{SPILL}} = m_{\text{SPILL}} / n_{\text{SPILL}} = 334 \text{ t} \quad (9)$$

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 (tons)	SHIP'S TYPE					Total
	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 m_{SPILL} is taken from the period 1990 – 2000 because 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 ($P_{\text{SPILL,TYPE}}$)**Tablica 6.** Vjerojatnosti pojedinih tipova onečišćenja s tankera za različita operativna stanja ($P_{\text{SPILL,TYPE}}$)

	$P_{\text{SPILL,TYPE}}$			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.

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

Table 7 Total probability of typical oil spills for different tanker operational conditions ($P_{\text{TOTAL,SPILL,TYPE}}$)**Tablica 7.** Ukupna vjerojatnost pojedinih tipova onečišćenja s tankera za različita operativna stanja

	$P_{\text{TOTAL,SPILL,TYPE}}$			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 ($P_{\text{TOTAL,SPILL,TYPE}}$), 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, with all ships built under the same standards, thus making every statistical analysis much easier.

4.3 Oil spill expectations through project *Druzba-Adria*

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

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

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

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

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_{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_{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 amount of spilled oil through the project *Druzba-Adria* for different number of tanker arrivals in the first year of traffic

Tablica 9. Očekivana količina izlivena 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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