Annex 2

Ship Generated Waste Analysis

Content

1 Introduction

Pursuant to article 3 sub-paragraph 7 of the Regulations concerning the requirements that seaports must meet and to article 62 of the Ordinance concerning maintaining order in ports, all ports open to public traffic as well as ports intended for special purposes must establish and implement a port waste management plan. The content of the plan is outline in the annex1 to the Regulations on the requirements that seaports must meet. In particular the plan shall contain an assessment of the needs for port collection facilities regarding the needs of the ships entering the port as well as the type and quantity of collected and processed waste and cargo residues from ships. Therefore it is of importance for the ports to calculate the quantity of waste collected and make an estimate of the waste expected to be collected.
An analysis of the possibility of using several existing waste calculation models and formulas for the Croatian ports has been carried out. The results are presented in this report.

2 Calculation models

With a view to calculating the quantities of waste generated and expected to be generated in the future by ships visiting Croatian ports we intended to use available models. An estimate of the garbage volume should be calculated using a range of factors such as persons on board, anticipated length of voyage, the application of minimization technology, type of ship and ship operational considerations. There are different ways and models to estimate garbage. Two models are discussed here:

- the model developed for REMPEC[1] in the framework of an Assessment of the existing situation and needs of Albania, Croatia and Slovenia regarding port reception facilities for collecting ship-generated garbage, bilge water and oily wastes[2].
- the model which FSI[3] is currently developing.

Both models are **micro-models**, because they try to calculate the total amount of waste bottom-up, from each individual ship and person on board.

[1] REMPEC - Regional Marine Pollution Emergency Response Centre for the Mediterranean Sea
[2] Assessment of the existing situation and needs of Albania, Croatia and Slovenia regarding port reception facilities for collecting ship-generated garbage, bilge water and oily wastes, REMPEC, Activity 1, Final report, February 2004.
[3] FSI - IMO Sub-Committee on Flag State Implementation.

2.1 The REMPEC model

2.1.1 Garbage

The volumes of domestic, maintenance and cargo – associated waste are calculated from the following formula:

$G = G_D + G_M + G_C$ (kg/week)
or
$G = G_D + G_M + G_C / \rho$ (m3/week)

(where ρ=250 kg/ m3 the average density of shipboard garbage)

G = the quantity of garbage received in peak seven day period (kg/week)
G_D = the quantity of domestic solid waste received in a peak seven day period (kg/week)
G_M = the quantity of maintenance solid wastes received in a peak seven day period (kg/week)
G_C = the quantity of cargo associated waste received in a peak seven day period (kg/week)

Quantity of domestic waste
$G_D = G_B + G_P + G_H$

$G_B = N_B * T_B * Q_B * P_B$
where
G_B = quantity of domestic garbage received in peak seven day period from sea-going cargo ships (kg/week)
N_B = number of cargo ships calling at the port in the same period
T_B = average duration of voyage and stay at the port of sea going cargo ships (days)
Q_B = average daily domestic garbage generation rate on sea-going cargo ships (2.0 kg/person and day)
P_B = average number of persons onboard a typical sea-going cargo ship (persons/vessel)

$G_P = N_P * T_P * Q_P * P_P$
where
N_P = number of passenger ships calling at the port in the same period
G_P = quantity of domestic garbage received in peak seven day period from passenger ships (kg/week)
T_P = average duration of voyage and stay at the port this kind of ships (days)
Q_P = average daily domestic garbage generation rate on passenger ships (3.0 kg / person and day)
P_P = average number of persons onboard a typical passenger ship (persons/vessel)

$G_H = N_H * T_H * Q_H * P_H$
where
N_H = number of harbour craft engaged in the port operation
G_H = quantity of domestic garbage received in peak seven day period from harbour craft (kg/week)

T_H = average duration of voyage and stay at the port of harbour craft (7 days)
Q_H = average daily domestic garbage generation rate on harbour chart (1.0 kg/person and day)
P_H = average number of persons onboard a typical harbour craft (persons/vessel)

Quantity of maintenance waste
$\mathbf{G_M = N * T * M}$

N = number of vessels in port during a peak seven-day period (vessels/week);
T = average duration of ships' transit and stay at the port area (days);
M = average quantity of maintenance solid wastes generated daily from a typical vessel (11 kg/vessel-day)

Quantity of cargo – associated waste
$\mathbf{G_C = C_B + C_D + C_C}$

where:
C_B = W_B * 1/123 = quantity of break bulk cargo solid wastes received in a peak seven-day period (kg/week);
W_B = quantity of break bulk cargo received in a peak seven-day period (kg/week);
1 / 123 = break bulk cargo waste generation factor;
C_D = W_D * 1/10,000 = quantity of dry bulk cargo solid wastes received in a peak seven-day period (kg/week);
W_D = quantity of dry bulk cargo received in a peak seven-day period (kg/week);
1/10,000 = dry bulk cargo waste generation factor;
C_C = W_C 1/25,000 = quantity of container cargo solid wastes received in a peak seven-day period (kg/week);
W_C = quantity of container cargo received in a peak seven-day period (kg/week);
1/25,000 = container cargo waste generation factor.

2.1.2 Oily bilge water and oil residues

$$Q_t = Q_{sl} + Q_m \quad (m^3/day)$$

$$Q_{sl} = \frac{N_1 * P_{sl} * T}{365}$$

$$Q_m = \frac{N_2 * P_m * T}{365}$$

where:
Q_t = Volume of oily wastes from the machinery spaces of ships to be received (m3/day)
Q_{sl} = Volume of oil residues (sludge) to be received (m3/day)
Q_m = Volume of oily bilge water to be received (m3/day)

N_1 = Number of ships calling at the port annually

N_2 = Number of ships without oily bilge water separating and filtering equipment (with only bilge holding tanks) calling at the port on an annual basis

P_{sl} = Oil residues daily production (0.02 x fuel oil daily consumption per day (gr/HP * hr) of voyage (m3/day)

P_m = Oily bilge water production per sailing day from N2 ships calling at the port (m3/day)

T = Average duration of voyage before calling at the port and stay at the port area (days)

2.2 The FSI formulas

The IMO Sub-Committee on Flag State Implementation (FSI), reported the activities of the 17th session: 20-24 April 2009. One of these activities was "WORK ITEM 4.1: TYPES AND AMOUNT OF WASTES – Review of type and amount of wastes generated on board". The result is a set of waste calculation formulas, presented below. The calculation formulas mentioned here are based on empirical values and are estimations only. There is the possibility, that severe deviations may occur depending on the type of ship, application, operation area, size of the crew, environment regulations and many other factors.

The following formula is used for calculation:

$V_{\text{Kind of waste}}$ = Factor x d x P = V dm3 [(dm3 / d x P) x d x P = dm3]

where

V is the volume of the relevant kind of waste in dm3;

d is the duration of journey in days (**at least 30 days**);

P is the number of persons on board.

Glass

V_{Glass} = 1,84 x d x P

Density in t/m³, e.g., ≈ 1,2 for waste glass[1]

Paper, cardboard, cartons

V_{Paper} = 1,05 x d x P

Density in t/m³, e.g., ≈ 0,5 for waste paper

Packaging, plastics

V_{Plastics} = 1,0 x d x P

Density in t/m³, e.g., ≈ 0,2 for plastic containers

Wood

As waste wood normally is a result of cargo residues, no general quantity calculation can be made.

Density in t/m³, e.g., ≈ 0,48 m³ for dunnage, waste wood

[1] Data according to Landesumweltamt NRW (Germany), density table of LAGA kinds of waste.

Metal, scrap

$V_{Metal} = 0,55 \times d \times P$

Density in t/m³, e.g., ≈ 2,0 for iron scrap

$V_{Special\ waste} = 1,84 * d \times P$

Organic waste

$V_{Plastics} = 1,02 \times d \times P$

3 Necessary data

The presented models/formulas are analysed and compared with the present available data. We limited it to domestic waste and ship generated oily liquid waste, because they are the types of waste which are the most suitable for modelling.

3.1 The REMPEC model for domestic waste

The model distinguishes between cargo ships, passenger ships, and harbour craft. For cargo ships the following input is needed:

Factor	**Availability**
N_B = number of cargo ships calling at the port in the same period	yes
T_B = average duration of voyage and stay at the port of sea going cargo ships (days)	yes
Q_B = average daily domestic garbage generation rate on sea-going cargo ships (2.0 kg/person and day)	yes
P_B = average number of persons onboard a typical sea-going cargo ship (persons/vessel)	no, but can be estimated

For passenger ships the following input is needed:

Factor	**Availability**
N_P = number of passenger ships calling at the port in the same period	yes, but no proper distinction between ferries and passenger ships can be made
T_P = average duration of voyage and stay at the port this kind of ships (days)	yes, but not for ferries
Q_P = average daily domestic garbage generation rate on passenger ships (3.0 kg / person and day)	yes, but not valid for ferries
P_P = average number of persons onboard a typical passenger ship (persons/vessel)	no

The model does not take into account that especially large passenger ships have incinerators on board to incinerate (part of) their domestic waste. So probably for those ships the model will over-estimate. Data about (the use of) incinerators

for domestic waste on board of the ships that visit the Croatian ports, are not available.

Unfortunately in the traffic data in the database DOB no distinction can be made between ferries and other passenger ships. Probably ships in Table 1 of the type ro-ro are ferries, and part of the group specified as passenger ships are ferries as well. More than 40 percent of the arrivals of this group of passenger ships concern arrivals of fast passenger ships, which are probably fast ferries. But the remaining 60 percent is a mix of foot ferries, small tourist vessels for day trips, small tourist ships with hotel accommodation[1] and cruise ships. The amount waste produced by a passenger on a ferry is probably much lower than on a passenger ship with hotel accommodation.

For harbour craft #the following input is needed:

Factor	**Availability**
N_H = number of harbour craft engaged in the port operation	no, but it can be estimated based on traffic data
T_H = average duration of voyage and stay at the port of harbour craft (7 days)	yes
Q_H = average daily domestic garbage generation rate on harbour chart (1.0 kg/person and day)	yes
P_H = average number of persons onboard a typical harbour craft (persons/vessel)	no

We don't know what is exactly harbour craft on one hand, and on the other hand we have a group of about 170 –210 'other' vessels in the main ports, as can be seen in the table below. This table presents the arrivals per ship type for main ports in 2004 –2008.

Table 1 Arrivals per ship type for main ports, 2004 -2008

	ships					**arrivals**[2]				
ship type	**2004**	**2005**	**2006**	**2007**	**2008**	**2004**	**2005**	**2006**	**2007**	**2008**
oil tanker	139	149	166	172	149	1.236	1.307	1.402	1.309	1.251
chemical tanker	38	47	29	44	38	347	312	303	311	82
bulk carrier	232	244	215	238	226	1.195	1.328	1.368	1.173	1.099
container ship	33	25	26	50	73	97	75	159	260	332
other cargo ship	453	481	513	522	572	1.497	1.502	1.713	1.747	1.896
passenger ship	258	256	263	274	292	13.090	13.355	12.793	12.898	13.480
ro-ro	88	90	82	79	66	9.570	8.947	8.607	8.819	8.681
other	191	188	209	183	167	2.255	2.247	1.915	1.866	1.812
ship not specified	39	28	33	47	0	411	456	411	303	0
	1.471	**1.508**	**1.536**	**1.609**	**1.583**	**29.698**	**29.529**	**28.671**	**28.686**	**28.633**

Maybe this group 'other' can be regarded as harbour craft as far as domestic waste production is concerned. Looking more in detail it becomes clear that in

[1] E.g. typical tourist ships of around 30 GT, with hotel accommodation, carrying around 40 persons on board, during trips of several days along Croatian ports.

[2] Arrivals is defined as days that a particular ship entered a particular port. So, a ferry entering a port 10 times on one day, is counted as one arrival.

2007 the largest groups specified as other vessel where barges with cargo on deck, fishing vessels, supply vessels and tugs, as can be seen in Table 2.

Table 2 Arrivals of 'other' ships per ship sub type for main ports in 2007

Ship sub type	number of ships	number of arrivals
barge-cargo on deck	13	126
barge-liquid bulk cargo in cargo	2	7
barge-solid bulk cargo in cargo	0	0
crane ship	0	0
dredger	6	15
factory ship	1	1
fishing vessel	76	464
motor yacht	0	0
other	24	150
public vessel	3	35
research vessel	0	0
special purpose ship	2	4
supply vessel	11	336
survey vessel	2	39
technical objects	4	18
training ship	2	32
tug	37	639

So, indeed they are partly to be considered as harbour craft, but certainly not all of them.

The general conclusion is that not enough input data for this models are available. Only for cargo ships an estimation could be made.

3.2 The REMPEC model for ship generated liquid oily waste

For the model for ship generated liquid oily waste the following input is needed:

Factor	Availability
N_1 = Number of ships calling at the port annually	yes
N_2 = Number of ships without oily bilge water separating and filtering equipment (with only bilge holding tanks) calling at the port on an annual basis	no
P_{sl} = Oil residues daily production (0.02 x fuel oil daily consumption per day (gr/HP * hr) of voyage (m3/day)	no
P_m = Oily bilge water production per sailing day from N2 ships calling at the port (m3/day)	no
T = Average duration of voyage before calling at the port and stay at the port area (days)	no, but it can be estimated based on traffic data

The database DOB does not contain information about oily bilge water separating and filtering equipment on board. And even if this information was available, it doesn't say anything about the use of this equipment. In Dutch ports many ships

with such equipment do not use it. They just deliver the oily bilge water to the waste reception facilities.

The general conclusion is that not enough input data for this model are available.

3.3 The FSI formulas

The formulas are based on the input of: the duration of journey in days, and the number of persons on board. The formulas are only valid when a journey is at least 30 days. The majority of the journey to Croatian ports as far below the 30 days. The traffic analysis contains a table of Arrivals in all ports per region of origin, which is presented below.

Table 3 Arrivals in all ports per region of origin, 2007 and 2008

		2007			2008	
Previous port along or in:	ships	arrivals	arrivals in %	ships	arrivals	arrivals in %
Unknown	18	169	0,2%	30	52	0,1%
Adriatic Sea	641	4.385	5,0%	644	4.219	4,5%
Croatia	775	81.921	92,5%	794	86.339	93,0%
Mediterranean and Black Sea	622	1.839	2,1%	691	2.018	2,2%
World	207	223	0,3%	165	184	0,2%
Total	**1.804**	**88.537**		**1.799**	**92.812**	

There are no data available on the length of the journey in days and the number of people on board. They can be estimated, but the FSI formulas are only applicable for ships which had a journey of at least 30 day, which can only be the case in ships arriving from the 'World', which is 0,2 till 0,3 percent of all arrivals in Croatian ports. So it can be concluded that this FSI formulas are not useful for the Croatian situation.

3.4 Conclusion

Despite the fact that both micro-models contain a lot of valuable empirical knowledge, there are not enough data available to feed this models and make a realistic calculation of waste to be expected in ports.

4 The available data

Let's try it the other way around and look what data we have. The following data are available for this study:

- quantities of waste to be delivered by ships, according their pre-arrival waste notification
- quantities of collected waste provided by Port Authorities and waste collecting companies
- results of the calculation using the REMPEC models, carried out by Environmental Protection Engineering SA in 2004.

4.1 Quantities of waste to be delivered by ships, according their pre-arrival waste notification

The Ministry presented us also waste statistics based on the pre-arrival forms of 2007 and 2008. This data are presented below. The data of Dubrovnik are missing.

Table 4 Volumes of waste expected in Croatian ports according pre-arrival waste notifications in 2007

Pre-arrival notifications **2007** m3	Oily waste			Garbage			Cargo-related waste	Cargo-residues
	sludge	bilgewater	other	food-waste	plastic	other		
Pula				89	60	82		2
Rijeka	540	450	202	137	199	178	742	329
Zadar	84	73	7	94	143	192		
Sibenik	15	41	9	37	50	54		
Split	32	39	4	669	448	452	0,2	
Ploce				97	113	138		
Dubrovnik								
Total	**671**	**603**	**222**	**1.123**	**1.013**	**1.096**	**0,2**	**331**

Table 5 Volumes of waste expected in Croatian ports according pre-arrival waste notifications in 2008

Pre-arrival notifications **2008** m3	Oily waste			Garbage			Cargo-related waste	Cargo-residues
	sludge	bilgewater	other	food-waste	plastic	other		
Pula	14	12	4	130	108	132		
Rijeka	374	242	56	117	271	374	780	850
Zadar	20	24	79	85	166	189	1026	70
Sibenik	36	63	2	54	70	112		
Split	61	64	14	570	498	432		
Ploce	28	37	3	129	158	106	32	0
Dubrovnik								
Total	**534**	**443**	**158**	**1.085**	**1.270**	**1.345**	**1.837**	**919**

The quantities presented in this table are quit low compared to the data in the two tables above. The difference can probably be explained by the fact that ferries and ships below a Gross Tonnage of 150 (tankers) or 300 (other ships) usually do not send a pre-arrival form.

The waste statistics of the Ministry also contain information about the number of arrivals and the number of arrived ships that intended to deliver waste, as can be seen in the table below. On average 72 percent of the arrived ships intended to deliver waste. If this data would be available for annex V and annex I separately, it was of more value, because the percentage of ships delivering

annex V waste is usually much higher than that of ships delivering annex I waste in the ports, mainly due to the fact that annex V can have an unpleasant smell.

Table 6 Arrivals and expected waste deliveries according pre-arrival waste notifications and arrivals in main ports according DOB in 2007

Pre-arrival notifications 2007	Arrivals	Deliveries	% delivering ships	Arrivals in the main ports according DOB
Pula	417	194	47%	1.770
Rijeka	1.231	687	56%	3.677
Zadar	533	320	60%	6.145
Sibenik	308	176	57%	1.002
Split	1.405	813	58%	10.950
Ploce	1.130	602	53%	1.132
Dubrovnik				4.010
Total	**5.024**	**2.792**	**56%**	**28.686**

Because not all ships that have to send a pre-arrival notification do it, in particular smaller ships the number of arrived ships based on this notifications is always lower than the real number of arrivals (according DOB), as can be seen in the same table. In fact in 2007 only 20 percent of the arrived ships sent a pre-arrival notification (Dubrovnik is excluded).

So for a calculation of the total amounts of waste to be expected, this data are less suitable.

4.2 Quantities of collected waste provided by Port Authorities and waste collecting companies

The data in the table below are obtained from the Port Authorities, and compared and completed with data other sources, mainly from waste collecting concession holders. Some remarks:

- the quantities of waste are not specified properly in some ports. Only Pula presents more specified data for annex V (both ship-bound waste and cargo-related waste).
- data of other years are available, but not complete, so we chose 2007 to present here.
- amounts of waste are not presented in the same units – sometimes in cubic metres, sometimes in tons.
- the quantities of waste delivered by each individual ship are not available.
- it is unclear how different types of liquid oily waste is named. One would expect that the quantity of bilge water (containing mainly 90 percent water and 10 percent oil) is higher than the quantity of used oil. In the ports from Zadar to the south, it is as we expected, but in Rijeka and Pula we have some doubts. Also the fact that sludge (talog) is missing in this data, is strange, because sea going ships normally 'produce' two kinds of sludge: sludge form bilgewater separation on board and sludge from purification of heavy marine fuel.
- the amount of collected solid waste in Split is not clear, because the volume of the collected garbage is reduced 4 times by a press-container. We understood that the estimation of the collected volume is done after it is pressed. If so, the original volume was 32.000 m^3, which is more than in all other ports together.

- sometimes waste collected in the port area but not from ships is included in the presented quantities.

Table 7 Quantities of ship waste collected in major Croatian ports (State Port Authorities and Pula) in 2007

2007 in m^3, unless declared otherwise	Pula	Rijeka	Zadar	Sibenik	Split	Ploce	Dubrovnik	Tota
ship-generated – annex I								
bilge water	4,14	186	302,4	179,6	970,2		93,4	1.73
used oil / waste oil	17,61	537,43	3,5	1,3	107,6			
solid waste – annex V								
food waste	45	212,5						
plastic	60	417						
other	145	818,1	730	504	8.022	506,1	6.769	17.49
oily rags, oil filters, absorbents	0,78		550 kg				40kg	
solvents	0,35							
packing	4							
(oil) contaminated packing	0,625			2 tons				
cargo-related – annex I and V								
otpad od tereta (dunnigs, lining, strapping etc)	45			10				5
metals	617,2			1,7 tons				61
others (antifriz, edible oil etc)	1,7		720 kg		1,84 kg	0,18		

Opmerking [JS1]: Darko wrote 549+10,19 m3 in table 1 of his work Volume of ship generated oily waste.

Table 8 Quantities of ship waste collected from Jadrolinija in major Croatian ports and small northern ports

Collected from Jadrolinija in main ports in 2007 in m^3	Pula	Rijeka	Zadar	Sibenik	Split	Ploce	Dubrovnik
ship-generated – annex I							
bilge water + used oil		170+500	258	144	757		78
solid waste – annex V							

We don't know yet whether the quantities in table 4 are inclusive Jadrolinija or not.

This data are not suitable for further analysis, due to the poor specification, the lack of consistence in classification of liquid oily waste, and the fact that data on a detailed level (per ship per arrival) are not available. But the data give a good overall view of the quantities per year per port. The quantities liquid ship-generated oily waste (bilgewater and used oil) and that of domestic waste (food waste, plastic and other) are totalised per port in the table below for the year 2007.

Table 9 Summary of Table 7 and Table 8

2007, in m³	Pula	Rijeka	Zadar	Sibenik	Split	Ploce	Dubrovnik	Total
Total annex I ship-generated	22	1.393	564	325	1.835	0	174	4.313
Total annex V domestic waste	250	1.448	730	504	8.022	506	6.769	18.229

The highest quantities of oily liquid waste are collected in Split and Rijeka. The highest quantities of domestic waste are received in Split and Dubrovnik.

4.3 Results of the calculation using the REMPEC models

In the REMPEC report the authors had at that time additional data obtained by field work. The outcome of the calculation is summarised in the next table. This calculation is probably done in 2003[1].

Table 10 Results of the calculation using the REMPEC models

in m³	Pula	Rijeka	Zadar	Sibenik	Split	Ploce	Dubrovnik	Total
Total annex I ship-generated		6.162	4.868		8.067	4.375	800	24.271
Total annex V garbage		1.446	2.234		6.278	854	1.417	12.229

5 Macro-approach

In situations like this, where not sufficient data on waste are available, a good start is a macro-approach. With experiences from ports in other countries we calculated multipliers, which make it possible to estimate the volume of waste to be collected in the ports. Of course it is a very rough estimation, because it ignores the specific circumstances of the investigated port. We could use some data of the Dutch ports Den Helder[2], Zeeland Seaports[3] and Rotterdam[4] of the years 2006 or 2007. With this data we calculated the volume of waste delivered in the ports per arrival. The results are presented below.

Table 11 Average volume of delivered waste per arrival in Dutch ports in 2006 of 2007

in m³	Den Helder	Zeeland	Rotterdam
average amount of annex I per arrival in	0,590	0,58	1,473
average amount of annex V per arrival	0,271	0,14	0,913

[1] Source: Assessment of the existing situation and needs of Albania, Croatia and Slovenia regarding port reception facilities for collecting ship-generated garbage, bilge water and oily wastes, REMPEC, Activity 1, Final report, February 2004.
[2] Draft Waste Management Plan Den Helder February 2009.
[3] Waste Management Plan Zeeland Seaports 2007.
[4] Data sheets provided by Ron van Gelder, Havenbedrijf Rotterdam NV.

We used the average factor of both smaller ports as **multipliers**, because they are more comparable with Croatian ports than the port of Rotterdam which receives mainly larger ships. The amounts of waste are estimated by multiplying the traffic in the main ports with this multipliers for annex I and annex II waste. The result is presented in the table below.

Table 12 Result of multiplication of the number arrivals in Croatian ports with multipliers

in m^3	multiplier	Pula	Rijeka	Zadar	Sibenik	Split	Ploce	Dubrovnik	To
Total annex I ship-generated	0,59	1.035	2.151	3.595	586	6.406	662	2.346	16.7
Total annex V domestic	0,21	364	756	1.263	206	2.251	233	824	5.8

5.1 Comparison

In the next table the real data are compared with the outcome of the REMPEC-calculation and our macro-model.

Table 13 Comparison of the collected volumes with calculations of REMPEC and the macro-model

in m^3	Pula	Rijeka	Zadar	Sibenik	Split	Ploce	Dubrovnik	Total
Total annex I ship-generated waste								
Collected quantities in 2007	22	1.393	564	325	1.835	0	174	4.313
Calculated quantities (REMPEC)		6.162	4.868		8.067	4.375	800	24.271
Macro-model (multiplier 0,59)	1.035	2.151	3.595	586	6.406	662	2.346	16.782
Total annex V domestic waste								
Collected quantities in 2007	250	1.448	730	504	8.022	506	6.769	18.229
Calculated quantities (REMPEC)		1.446	2.234		6.278	854	1.417	12.229
Macro-model (multiplier 0,21)	364	756	1.263	206	2.251	233	824	5.897

Regarding annex I waste the real quantities are much lower than both models estimate. So potentially there is much more liquid oily ship-generated waste to be collected in all ports. The REMPEC model seems to over-estimate the quantities, especially in Ploce and to a lesser extent in Rijeka. A total processing capacity of 10 m^3 per hour for this types of waste will be enough[1].

Regarding annex V waste both models under-estimate, and the estimation of the macro-model is much to low in Rijeka, Sibenik, Split, Ploce and Dubrovnik. This is caused by the fact that Croatia has many arrivals of passenger ships. So far,

[1] 16.782 m^3 to be processed in 260 workingdays of 8 hours results in 8 m^3 per hour.

we could not calculate any realistic multiplier for passenger ships, because specific data are not available.

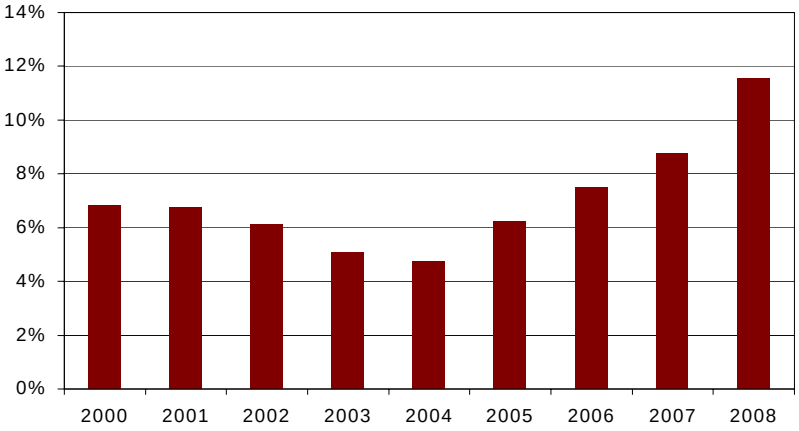
6 The effect of the introduction of an indirect payment system

The introduction of an indirect payment system according Directive 2000/59/EC on port reception facilities for ship-generated waste and cargo residues will certainly influence the volumes of waste collected in Croatian ports. We obtained detailed data of the Port of Rotterdam, which enabled us to make some calculations for ship-generated annex I waste and annex V waste. The Directive does not prescribe indirect payment for cargo-related waste.

6.1 Ship-generated annex I waste

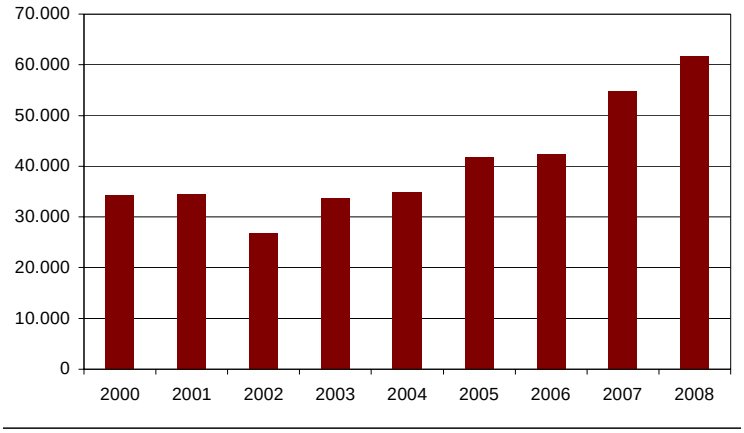
The next three figures show the data concerning ship-generated annex I waste in the years 2000 till 2008. The indirect payment system (of at least 30 percent indirect) was introduced in 2005. Before the introduction only 6 percent of the arriving ships delivered waste. after introduction this number grew strongly to almost 12 percent, as can be seen in Figure 1.

Figure 1 Percentage of ships that delivered ship-generated annex I waste in the port of Rotterdam



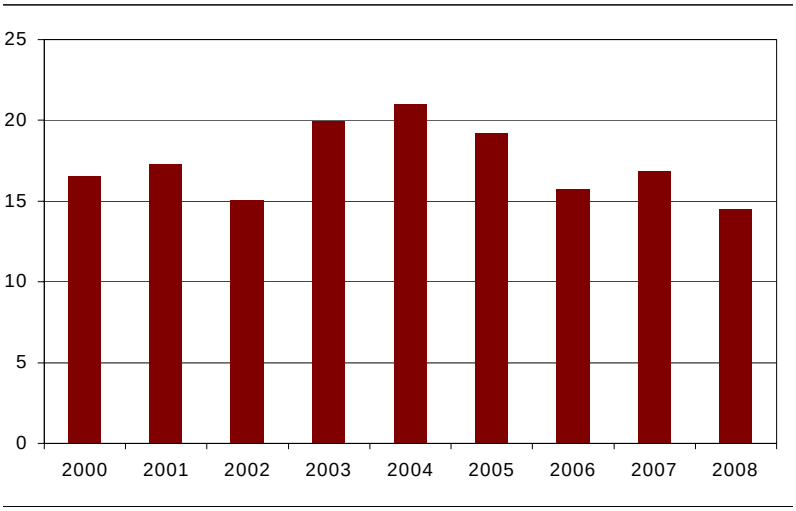
Also the total volume of collected ship-generated annex I waste almost doubled, see Figure 2.

Figure 2 Total volume in m3 of ship-generated annex I waste in the port of Rotterdam



The next graph shows that that average volume did not show a particular trend. It fluctuated between 15 and 21 m^3. Note: this average is calculated through dividing the total volume by the number of ships that delivered annex I waste. The multiplier in par. 5.1 is calculated through dividing the total volume by the total number of arrivals.

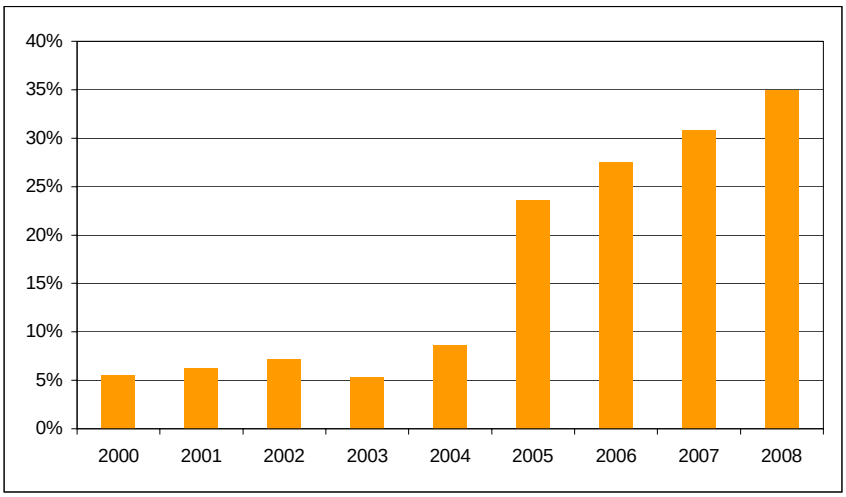
Figure 3 Average volume in m3 of ship-generated annex I waste in the port of Rotterdam



6.2 Ship-generated annex V waste

Regarding the ship-generated annex V waste the picture is quite different. The number of waste delivering ships increased enormously from around 6 percent to 35 percent in 2008 (Figure 4).

Figure 4 Percentage of ships that delivered ship-generated annex V waste in the port of Rotterdam



But the total volume did not grow that strong, is can be seen in the next graph. So the volume delivered per ship must be getting lower.

Figure 5 Total volume in m^3 of ship-generated annex V waste in the port of Rotterdam

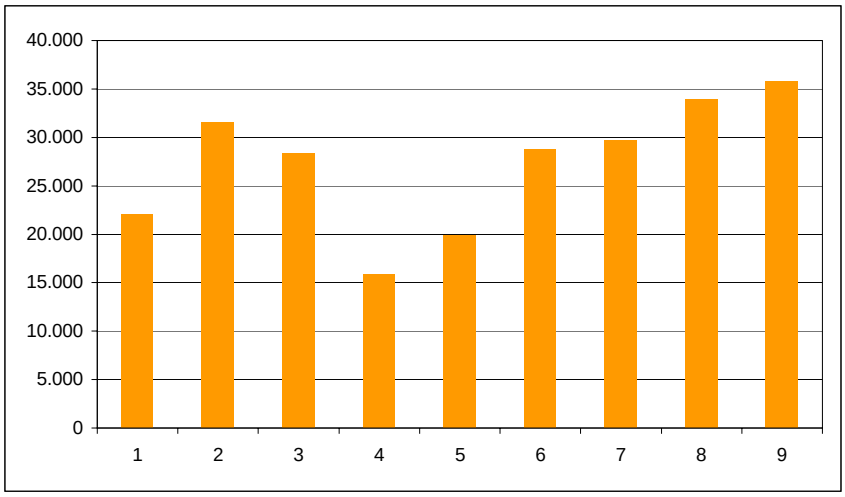
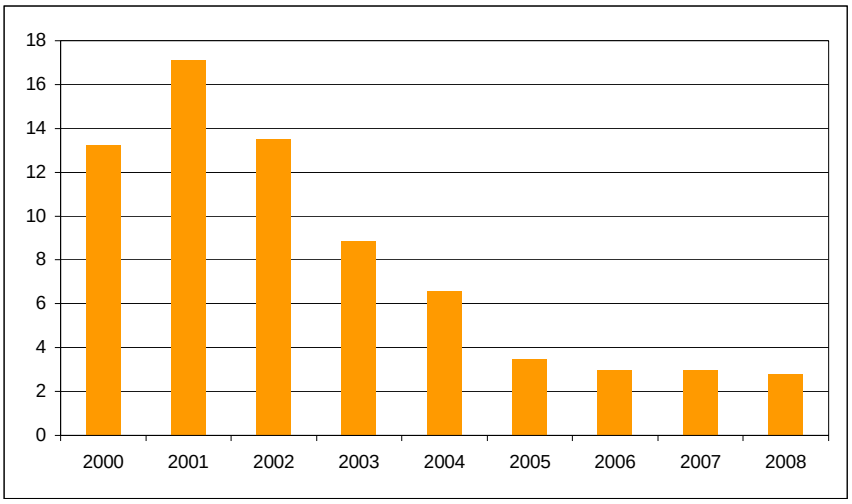


Figure 6 shows that indeed the average volume of annex V waste per ship declined strongly, from around 15 m^3 in the years 2000 – 2002, till 3 m^3 in the years 2006 – 2008. Remarkable is that this decline started already before the introduction of the indirect payment system in 2005.

Figure 6 Average volume in m^3 of ship-generated annex V waste in the port of Rotterdam



7 Conclusions and recommendations

- it is not possible to use existing waste micro-models due to lack of input data.
- an rough estimation can be made, using experiences of ports in other countries,
- the real quantities of annex I waste are much lower than the outcome of our estimations.
- both the calculation carried out by REMPEC the macro-model for annex I waste give a rough estimation of the potential amount of this types of waste, however the REMPEC models seems to over-estimate for some ports.
- To estimate the volume of annex V is more difficult, because it is strongly influenced by (large) passenger ships. And we don't have specific multipliers for ports comparable to Croatian ports with a high passenger traffic. It would be of great help if we could obtain data of e.g. Greek ports, because they have more similarity with the Croatian ports – also many ferries and other passenger ships.
- the effect of the introduction of an indirect payment system according to the Directive 2000/59/EC on port reception facilities for ship-generated waste and cargo residues should not be over-estimated. Probably the volume of ship-generated annex I waste (liquid oily waste) to be collected will grow significantly, but the volume of ship-generated annex V waste (domestic waste) not. Looking at the Dutch experiences in Rotterdam, it is clear that more ships are delivering annex V, waste, but in smaller quantities. The total amount hardly grew. In Croatia the collection of annex V waste is organised in every main port, at least for the first day after arrival. For annex I the total volume increased in The Netherland after the implementation of the indirect payment system. In Croatia this will happen also. The current prices for annex I waste are high, in compared to the prices in ports of other

countries, so as soon as in indirect payment system will be implemented, there is less incentive to keep waste on board and discharge it elsewhere. How strong this effect will be, depends on the service level of the waste collectors, but even more on the way the indirect payment system will be implemented. Will it be a system with only 30 percent or 100 percent indirect payment? Experiences in Sweden learn that a 100 indirect system even 'attracts' waste from ports in other countries which have a partly indirect system[1].

- the effect of the introduction of an indirect payment system according to the Directive 2000/59/EC on the volumes of annex V waste will not be so strong, because in most Croatian ports waste delivery (at least on the first day of stay in the port) is already compulsory, and in some ports the price is not related to the quantity, which is an incentive to deliver all solid waste on board.

To gather basic data of ship waste in Croatia as a starting point for a waste forecast, it is strongly recommended to introduce a harmonised waste delivery receipts and store all obtained data on this receipts in a database, to be able to develop realistic multipliers/factors for waste modelling. This will be a solid basis for a review of the waste collection and processing capacity which is desired in the Port waste recep

[1] Implementation of the Ships' Waste Directive in Sweden, presentation of Per Olson held on the Port Reception Facilities INFRA 11829 meeting of the European Maritime Safety Agency in May 2005.