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65/2015

Impacts of Scrubbers on the environmental situation in ports and coastal waters

For our Environment

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Impacts of scrubbers on the environmental situation in ports and coastal waters

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Summary

As of January 2015, marine fuel with a maximum sulphur content of 0.1% only is allowed in Sulphur Emission Control Areas (SECAs). As of 2020, a 0.5% sulphur limit will apply worldwide. Scrubbers can be used as an alternative to low sulphur fuels.

There are various types of scrubber systems (wet: open/closed, dry). These scrubbers achieve the required emission reduction, but generate wastewater which is discharged into the marine environment. The various scrubber systems differ in their environmental impact through the amount and the components of the wastewater.

The regulations on wastewater quality can be found in the 2009 IMO Resolution MEPC.184 (59). The use of scrubbers causes environmental degradation through short-term and spatially limited pH value reduction, increase in temperature and turbidity as well as pollutant discharge of sometimes persistent materials.

To assess the environmental impact of scrubbers in the German waters of the North and Baltic Seas, the studies of MS Pride of Kent (Hufnagl et al. 2005), MS Fjordshell (Buhaug et al. 2006) and MS Ficaria Seaways (Kjøholt et al. 2012, Hansen 2012) were consulted. The studies report concentrations of wastewater pollutants generated by scrubbers which do not infringe any environmental quality standards set out by the WFD. Cumulative effects have not been considered in the reviewed studies.

German coastal waters are already suffering under heavy pressure for use through shipping, construction material extraction, energy, tourism and discharges from industry and agriculture. The preloads are substantial in some sections of the German coast. The current environmental status of German coastal waters is moderate to poor. The contaminated wastewater adds a further stress factor for marine organisms in the North Sea and Baltic Sea as well as the adjacent catchment areas supporting shipping traffic.

In principle, the use of clean liquid (diesel) and gas (LNG) fuels is preferable to an exhaust gas after treatment for the purpose of sulphur reduction.

Based on legal and regulatory policy considerations, current knowledge indicates that imposing limitations of wastewater discharge generated by scrubbers is the best way to prevent the potential damage which results from their use.

A multilateral approach within the framework of IMO is highly recommended. This can lead to territorial regulation of the discharge of scrubber effluents. The application of protection instruments (APMs) within the framework of PSSAs is particularly important. A short-term strategy could be a discharge prohibition for internal waters and territorial seas as a unilateral measure or in concert with the other EU Member States. However, the prohibition's regulatory content would remain subordinate to a multilateral regulation established within IMO.

Contents

Part A Research, environmental impact assessment and proposed measures

Abbreviations

EEZ	Exclusive Economic Zone
CAS	Chemical Abstracts Service
CEMP	Coordinated Environmental Monitoring Programme
Cd	cadmium
DBT	dibutyltin
EGCS	Exhaust Gas Cleaning System
FFH-D	Fauna Flora Habitat Directive
GES	Good environmental status
GESAMP	Group of Experts on the Scientific Aspect of Marine Environmental Protection
HCH	hexachlorocyclohexane
HELCOM	Helsinki Commission – Baltic Marine Environment Protection Commission
Hg	mercury
ICES	International Council for the Exploration of the Sea
IMO	International Maritime Organization
AA-EQS	annual average – environmental quality standard
LNG	liquefied natural gas
MARPOL	International Convention for the Prevention of Marine Pollution from Ships
MCR	maximum continuous rating
MEPC	Marine Environmental Protection Committee
MSFD	Marine Strategy Framework Directive
NEC	no effect concentration
NBC	North Sea-Baltic Sea Canal
NHT	natural habitat type
SWO	Surface Water Ordinance
OSPAR	OSPAR Commission (Convention for the Protection of the Marine Environment of the North-East Atlantic)
PAH	polycyclic aromatic hydrocarbons
Pb	lead
PCB	polychlorinated biphenyls
PEC	predicted effect concentration
PNEC	predicted no effect concentration
PoK	MS Pride of Kent
PBT	persistent, bioaccumulative and toxic
PSC	Port State Control

PSSA	Particularly Sensitive Sea Areas
QSR	Quality Status Report
REACH	European Directive on the Registration, Evaluation, Authorisation and Restriction of Chemicals (Regulation EC No. 1907/2006)
SECA	Sulphur Emission Control Area
TBT	tributyltin hydride
TeBT	tertrabutyltin
TEQ	toxic equivalents according to the 2005 WHO toxic equivalency factors
TPT	triphenyltin
TWC	Trilateral Wadden Sea Cooperation
UQN	environmental quality standard
US EPA	United States of America Environmental Protection Agency
WHG	Federal Water Act
WFD	Water Framework Directive
MAC-EQS	maximum allowable concentration – environmental quality standard

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1 Introduction and aim of the project

Ship emissions are regulated internationally by the IMO (International Maritime Organization) and must comply with the limits prescribed in Annex VI of MARPOL in particular. In order to reduce sulphur emissions, worldwide limits on the sulphur content of marine fuel are established. Additional Emission Control Areas / ECA can be designated.

As a result of the implementation of the revised Annex VI of MARPOL in January 2015, marine fuel with a maximum sulphur content of 0.1% only is allowed in Sulphur Emission Control Areas (SECAs) (Table 1). As of 2020, or alternatively as of 2025 depending on the availability of fuel, a 0.5% sulphur limit will apply worldwide.

As an alternative to low-sulphur fuels, exhaust gas aftertreatment units called scrubbers can be utilised to reduce air pollutant emissions to an appropriate level.

Table 1 Overview of sulphur limits in accordance with MARPOL VI, source: IMO

<table>
<tr><th>Start of the limit value regulation</th><th>SO_x Emission Control Area (SECA)</th><th>SO_x worldwide</th></tr>
<tr><td></td><td>1.5%</td><td rowspan="2">4.5%</td></tr>
<tr><td>March 2010</td><td rowspan="2">1.0%</td></tr>
<tr><td>2012</td><td rowspan="3">3.5%</td></tr>
<tr><td>2015</td><td rowspan="4">0.1%</td></tr>
<tr><td>2018</td></tr>
<tr><td>2020</td><td>0.5%</td></tr>
<tr><td>2025</td><td>Alternative start of the 0.5% limit</td></tr>
</table>

The German coastal waters of the North Sea and Baltic Sea have already been designated as SECAs since 2006 and 2007, respectively. The shipping industry has since responded to the stringent limits mostly by buying higher quality fuel. Only a few operators have decided to install pollution control systems (EGCS). The development of alternative fuels such as gas engines / dual fuel engines was also imposed.

Fuels with the required low sulphur levels are significantly more expensive than those previously used. This serves as a great incentive to install pollution control devices as a cheaper alternative in order to achieve the required emission limits.

The aim of this report is to present the current state of research on the environmental impact of scrubbers and, based on the assessment, of possible environmental damage from their use.

This report exposes the already obvious need for action and proposes regulations to avoid or minimise environmental impacts.

The biological evaluation in this study was accomplished with the help of INASEA, Bremen.

Estimates of quantities of waste water using sample vessels on sample routes along the German coastal waters were determined with the support of the Bremen University of Applied Science (FH), Prof. Dr. A. Kraus.

The authors of Section B: Legal decrees for the regulation and requirements for the use of ship-based treatment units (scrubbers) are Dr. Till Markus and Lutz Philipp Helfst of the University of Bremen, Research Centre for European Environmental Law (FEU).

2 Exhaust Gas Cleaning Systems in shipping

Since the revision of Annex VI of MARPOL, a number of manufacturers have developed Exhaust Gas Cleaning Systems (EGCS) based on experiences with onshore industrial facilities and adapted them for marine purposes.

The use of scrubbers allows for compliance with the sulphur emission limit of 0.1% even when fuels containing up to 3.5% sulphur are being burned.

2.1 Operating principle of scrubbers

The cleaning effect results from the fact that the combustion exhaust gases from the engine are passed through a purification medium. This can be sea water, fresh water or dry granules. The majority of the exhaust constituents is dissolved or reacts chemically with the ingredients of the water or the granules and is removed from the exhaust gas stream.

The sulphur dioxide from the exhaust gas dissolves in water to form sulphurous acid (H_2SO_3). This sulphurous acid decomposes in solution into bisulphite/sulphite (HSO_3^-/SO_3^{2-}). To a large extent, sulphite is oxidised with the oxygen from the seawater into sulphite (Karle & Turner 2007, p. 13).

$$SO_2^* + H_2O \rightleftarrows H^+ + HSO_3^-$$

$$HSO_3^- \rightleftarrows H^+ + HSO_3^{2-}$$

$$SO_3^{2-} + {}^1/_2O_2 \rightleftarrows SO_4^{2-}$$

The natural buffering capacity of seawater is used to neutralise the acid ions formed in this process. The washwater obtained from the scrubbing process has a very low pH value (pH 3).

The buffer capacity of seawater depends on its physical and chemical composition (temperature and salinity).

Seawater is usually slightly alkaline with a pH of 7.5 - 8. The uninfluenced alkalinity of seawater in the North Sea, for example, is normally constant and relatively high at 2,300-2,600 µmol/l[1]. Coastal waters, harbours, rivers and their estuaries, however, are affected by the drainage areas of the rivers and have a larger chemical spectrum (Table 2).

The Baltic Sea has a low salinity due to its location and the inflow of fresh water. The alkalinity in the northern part of the Baltic Sea is 700-1,300 µmol/l while in the southern part it measures 1,650-1,950 µmol/l.

[1] When using water, a ratio of 1l = 1kg can be assumed. Deviations in salt water can be up to 3%.

Table 2 Physical and chemical composition of marine, brackish and freshwater (Karle & Turner 2007, p 11)

	Seawater/ North Sea	Baltic Sea	Estuaries	Freshwater
T (^{0}C)	5 -15 [a]	0 – 20 [c]	1 – 20	0 - 20
Salinity (PSU)	32 – 37 [a]	3 - 9 [d]	0.5 – 17 [a]	0 – 0.5 [a]
Alkalinity (µmol*kg^{-1})	2,300 – 2,600 [b]	700 – 2,000 [d]	0.1 – 5,000 [b]	0.1 – 5,000 [b]

[a] Office of Naval Research (www.onr.navy.mil/focus/ocean/water/salinity1.htm)

[b] W. Stumm and J. Morgan, Aquatic Chemistry, 3rd ed. 1996

[c] HELCOM (www.helcom.fi)

[d] FIMR (Perttilä et al., 2006)

Scrubbers generally work with low alkalinity as well; however the cleaning performance is reduced and must be compensated.

The required amount of washwater increases with the decreasing pH level of seawater and higher water temperature (Karle & Turner 2007, p. 16). To improve the cleaning performance in waters with low buffering capacity, either the amount of washwater is increased (open systems) or a buffering substance, usually sodium hydroxide, is added (closed systems).

The sulphate, sulphite and bisulphite ions then react to a mixture of sodium sulphate, -sulphite and -bisulphite.

$NaOH + H_2O \rightleftarrows Na^+ + OH^- + H_2O$

$2Na^+ + SO_4^{2-} \rightleftarrows Na_2SO_4$ (sodium sulphate)

$Na^+ + HSO_3^- \rightleftarrows NaHSO_3$ (sodium bisulphite)

$2Na+ + SO_3^{2-} \rightleftarrows Na_2SO_3$ (sodium sulphite)

Depending on the calcium content of the applied washwater, sparingly soluble calcium sulphate ($CaSO_4$) is formed in addition to the easily soluble sodium sulphate.

2.2 Types of scrubbers

Scrubbers are divided according to two principles into wet and dry systems.

Wet scrubbers use ambient water (sea water) or water processed on board (fresh water) as cleaning media. Manufacturers use different construction systems for the scrubbing process. However, the principle is always the same: the exhaust gas is brought into contact with the water to initiate the cleaning process. The larger the surface of the water as a reaction surface, the more efficient the scrubbing process. For this purpose, washer nozzles or washing cascades are used in different variations and combinations (ABS 2013).

The resulting temperature drop in the exhaust stream leads to the condensation of unburned hydrocarbons and larger particles are precipitated.

The resulting wastewater is passed through a water purifier which eliminates the particles and partially oily residues. This scrubber residue, or scrubber sludge, contains particles, ash and heavy metals. The exact composition of the scrubber sludge is determined mainly by the fuel composition and the combustion process. The sludge also contains insoluble calcium sulphate left over from the cleaning process.

Scrubber sludge must be stored on board in a separate tank. It shall not be dumped at sea and must be dispensed in appropriate collection systems in the port (Annex VI of MARPOL, Reg. 16, 2.1). Table 3 shows the amount of scrubber sludge generated by ship operation.

Table 3 Quantities of scrubber sludge, source: Tomas Nilsson, Consultant, Environment, COWI AB, 2014 Scrubbers What do they mean to ports?, example of Alfa Laval, BPO Environmental Seminar on sewage from passenger ships in port waste from scrubbers training on SDM, 5 March 2014, Gdańsk, Poland

	Number of engines	Total installed capacity in MW	HFO t/a	Sludge t/a
Container	1	8	5 800	1
Tanker	1	13.74	5 925	6
Ro-Ro	4	24.8	17 534	14

2.2.1 Open wet scrubbers (open loop)

In open systems seawater is pumped directly into the purification levels. Each manufacturer has developed its own system of how the exhaust gas is mixed with the water.

After the separation of oily solids the wastewater from the scrubbing process is diluted with seawater until it meets the adequate pH limits for wastewater discharges (see Chapter 3, Table 7). Depending on the environmental conditions, sludge from open scrubbers also contains suspended solids of the surrounding water. In areas with a high level of suspended solids, sludge can contain a large amount of such residues (ABS, 2013).

2.2.2 Closed wet scrubbers (closed loop)

Closed systems use treated washwater which is run in a circuit independent of the ambient water. To keep the buffer capacity of the water constant, it is supplemented with an alkaline solution, usually sodium hydroxide (NaOH). The enrichment of the processing water with sodium hydroxide solution requires a 20°C - 60°C tempered tank for NaOH and a monitoring unit that adds NaOH corresponding to the pH of the cleaning water (DNV 2009). The amount of required solution varies according to Kjøholt et al. (2012) between 1 - 15 l/MWh and depends primarily on the sulphur content of the applied fuel (Table 4). Besides sodium hydroxide (NaOH), other buffering substances can be used, such as magnesium oxide on the "Liberty of Seas" (Annex II).

Table 4 Required amount of sodium hydroxide solution to achieve the desired sulphur removal efficiency, based on Table 3-3 of Kjøholt et al. 2012

% of eliminated sulphur	NaOH consumption (in litres, 50% solution/MWh)
2.9	11
2.4	8
1.4	4
0.9	1

After the cleaning process, the washwater is treated and pumped back into the cleaning process. The water treatment can occur either purely mechanically or supported by aggregates. These additives are chemically active substances (e.g. aluminium III sulphite) that promote the flocculation of water components so that a higher purity of the recycled water is achieved.

The generated solids are exhausted at the lower end of the cleaning unit called the swamp. This watery mixture is passed through a separator or hydrocyclone exactly as it would in an open system. The resulting solids are stored as scrubber sludge in a special tank. The separated wastewater, known as bleed-off, is diluted in a Bleed-Off Treatment Unit (BOTU) until it corresponds to the adequate pH limit for water discharge and can be discharged into the sea. The stream flow rate resulted from the bleed-off is approximately 0.1 - 0.3 m^3/MWh (Kjøholt 2012, Wärtsilä 2012). This amount of water is constantly replaced by fresh water during the process.

Closed systems can be equipped with so-called Holding Tanks so that they can function for a certain amount of time without discharge into the sea during the so-called "zero emission mode".
A series of tests on the DFDS ferry Ficaria Seaways 2012 showed that they could run for 6 hours without discharge due to the size of their washwater tank.

2.2.3 Hybrid systems

Hybrid systems combine the open and closed wet system. Seawater is used as washwater, which can be pumped directly into the sea in open mode. If necessary, it can be operated in closed mode with the addition of a buffering solution and without discharge of wastewater. The wastewater is collected in holding tanks and released in the port or into the open sea later on.

2.2.4 Dry system

As a special cleaning medium, limestone granules in special packed bed absorbers can be used instead of seawater (Steinbeis n.d.). The cleaning performance is equivalent to wet scrubber systems.

The supply and disposal of limestone granules can take place only in port. This system has been installed in two ships (MS Timbus, MS Oceanex); a further ship is under construction at the Flensburg Shipbuilding Company.

Table 5 shows a selection of currently available emission control systems for marine utilisation as well as their manufacturers.

Table 5 Selection of emission control systems for marine utilisation

Name	Manufacturer	Short description (type, technical details)
LMB-EGS	Saake	Open EGCS, VentSep before wet cleaning stage, separated solids, easier storage on board, 2 - 16 MW
Hamworthy Krystallon	Wärsilä/Moss	Hybrid ECGS, 1 - 100 MW
Clean Marine	Clean Marine	Hybrid ECGS, Advanced Vortex Chamber technology (AVC) with high particle separation rates
DryECGS	Couple Systems	Dry scrubber
DuPont™ BELCO®	DuPont™ Marine Scrubbing Systems	Open, closed and hybrid EGCS
GTM R15	Green Tech Marine	Hybrid EGCS, relatively small structure
MES EcoSilencer®		Open EGCS for large installations
CSNOX™	Ecospec	Ultra Low Frequency (ULF) Unit – pH value increase, no active substances needed
Pure SOx	Alpha LAval	Hybrid system up to 21 MW, energy demand approximately 1.5 % of engine power

2.3 Cleaning performance and energy consumption of scrubbers

In assessing the cleaning performance, available studies are focused on efficiency in terms of SO_x, particulate matter (PM) and nitrogen oxides (Table 6). The scrubber technology does not remove any nitrogen oxides, or only to a very small degree, and no CO_2.

Table 6 Cleaning performance of various systems in terms of SO_x (sulphur oxides), PM (particulate matter), NO_x (nitrogen oxides) and CO_2 (based on Tables 3-1 and 3-2 from Kjøholt, 2012)

	Mode	Cleaning performance (%)	Notes
SO_x	Seawater	> 90	In uninfluenced seawater
	Freshwater	> 90	Addition of buffering substances
	Seawater-freshwater conversion	> 90	Addition of buffering substances
PM	Seawater	70 – 90	2 providers, 90% removal efficiency of visible particles (50% of the total mass)
	Freshwater	65 – 95	2 providers
	Seawater-freshwater conversion	60 - > 90	3 manufacturers, smallest cleaning performance of 60% can be improved by process optimisation, but increases the exhaust gas back pressure. Cleaning performances over 90% are achieved through larger cleaning units, higher water flow rate and by adding more NaOH

The wastewater resulted from waste gas purification has a very low pH. According to IMO regulations MEPC 184/59 Annex 9, hereinafter referred to as 'Guidelines 2009', it is not to be discharged without preconditions (see Chapter 3).

According to Wärtsilä (2012, p.15), energy consumption represents about 0.5% of the main engine power. In closed mode (closed loop), the energy demand increases by about 2% due to the consumption of sodium hydroxide (Kjøholt et al., 2012, p. 42).

Shortly before the introduction of the last stage of Annex VI of MARPOL in SECAs (Table 1), the utilisation rate of emission control systems is very low. However, the financial incentive to use ECGS instead of low sulphur fuels is quite high. Manufacturers have calculated that investment costs are redeemed after two years if the ships stay within SECAs for 90% of their operating time (Twentyfour7 01/2013).

The industry association EGCSA estimates investment returns in less than 5 years for an operating time of 60% within SECA. A pay-back period of 6 years is estimated for operation exclusively outside of ECAs.

The global sulphur limit of 0.5% will apply as of 2020. It is expected that scrubber technology will be considered by many ship operators as an alternative to the use of low-sulphur fuel by that time.

A number of ship operators are already considering the installation of scrubbers in ships under construction or are planning to retrofit existing ships (DNV GL; as of March 2014).

Advantages and disadvantages of different types of gas scrubbers from an environmental perspective

- Advantages

Closed scrubbers: small quantities of wastewater, good control of pollutants in the marine environment, possibility to function without water discharge for a limited time, cleaning performance independent of sea water

Open scrubbers: no additional hazardous substances on board

Dry scrubbers: no water uptake and no discharge into the sea, cleaning performance independent of sea water

- Disadvantages

Closed scrubbers: complex handling of leach on board, possible use of active substances without ecotoxicological examination

Open scrubbers: very high water flow rate, achieving the desired cleaning performance in water with low alkalinity is uncertain, larger flow of polluting wastewater constituents due to high volumes of wastewater

3 Regulation of wastewater constituents

The United Nations and its organisations (IMO / FAO / UNESCO / WMO / WHO / IAEA / UN / UNEP) are advised on issues of marine environmental protection by a panel of scientific experts (GESAMP). Based on the recommendations of the GESAMP, limits were established for wastewater generated by scrubbers (GESAMP 2008) and were implemented, together with Resolution MEPC.184 (59) 2009, as "2009 Guidelines for Exhaust Gas Cleaning Systems" on July 1, 2010.

The Guidelines 2009 highlighted the limited data base regarding the constituents of the wastewater and their potential environmental effects, and there are calls for further investigation (Resolution MEPC.184 (59) 2009, Appendix III).
A future revision of the Guidelines 2009 is therefore very likely.

The limits outlined in the Guidelines 2009 are based on a standardised flow rate of 45 t/MWh (Table 7).

Dilution of the pH value prior to outlet is permitted. All other concentrations must comply with the limits in their undiluted state.

Table 7 Discharge requirements in accordance with MEPC 184 (57) 2009: Guidelines for Exhaust Gas Cleaning Systems

Components	Limit	Criteria
pH value	Min. 6.5, max. 2 pH units per inlet	Measuring the value after the dilution unit
PAHs (Polycyclic Aromatic Hydrocarbons)	Max. 50 µg/l PAHphe (phenanthrene equivalents) to the inlet value (for a flow rate of 45 t/MWh)	Measurement in the inlet and outlet of the EGCS, before dilution unit
Turbidity / dissolved particles	Max. 25 FNU (formazine nephelometric units) or 25 NTU (nephelometric turbidity units)	Measurement in the outlet of the EGCS, before dilution unit
Nitrates	Max. 60 mg/l for a standard flow rate of 45 t/MWh	Values for nitrates must correspond to a min. 12% reduction of NO_x

According to Resolution MEPC 184 (59) 2009, 10.4 the following also apply:

- monitoring the oil content of the wastewater indirectly via the PAH content,
- residues from emission control systems are to be disposed of on land at appropriate containment facilities,
- storage and dispensing of residues from cleaning equipment shall be recorded in a protocol indicating the date, time and place.

4 Quantity and constituents of the scrubber effluent

The components of the exhaust gas vary depending on the quality of the fuel used, completeness of combustion, contamination of the seawater used, and cleaning efficiency of the scrubber. They may also be influenced by process additives supplied.

Seawater contaminations may include PAHs, heavy metals, fluctuating pH values and, particularly in the coastal area and ports, elevated temperatures.

The temperature of the wastewater introduced is increased by the passage of the hot exhaust gas. No temperature limits are defined pursuant to MEPC 2009 Directive, but temperature must be recorded (Res. 184 (59) 2009, Chap. 10.1.1).

There are a few publications on wastewater constituents from ship scrubbers, e.g. of Marintek with measurements on the MT Fjordshell (Buhaug et al. 2006), BP Marine/Krystallon on the MS Pride of Kent ferry (Hufnagl et al. 2005) and the MS Ficaria Seaways DFDS ferry (Hansen 2012, Kjøholt et al. 2012). Table 8 shows the assignment of the authors to ships and scrubber systems, which will be discussed below.

Table 8 Publications on various scrubbers; FW-freshwater, SW-seawater

	Ship	Scrubber
Buhaug et al. 2006	MS Fjordshell	Open (SW mode)
Hufnagl et al. 2005	MS Pride of Kent	Open (SW mode)
Hansen 2012 Kjøholt et al. 2012	MS Ficaria Seaways	Hybrid (SW and FW mode)

The measurements of both Hansen (2012) and Kjøholt et al. (2012) were carried out on the hybrid ECGS of MS Ficaria Seaways. The results of these investigations differ in part widely.

HFO with a 2.7% sulphur content was used as a fuel in Buhaug's test (2006). The tests were carried out in open and closed mode. However, the study has only measurement results for wastewater constituents for the metals contained in Table 9 and in part for PAHs in open mode without washwater treatment.

Table 9 (p. 20) summarises the results of the studies of Buhaug et al. (2006), Hansen (2012) and Kjøholt et al. (2012).

4.1 Heavy metals

Hansen (2012, p. 25) provides a direct correlation between the concentrations of vanadium, nickel, copper and zinc in wastewater and fuel consumption. Kjøholt et al. (2012) show, in addition, a connection between vanadium and nickel content in washwater and fuel sulphur content.

The surprisingly large increase in copper and zinc contents in washwater as found by Kjøholt et al. (2012, p. 59) cannot be explained. Hufnagl et al. (2005, p.42) measured increased levels of zinc in the Pride of Kent, which they traced back to the facility design. Buhaug et al. (2006, p. 15) also mention the scrubber itself as a possible source of metals in the wastewater. Hansen's test series (2012, p.25) excludes an influence of measurement results by corrosion or abrasion within the facility.

Metals tend to associate with particles (Kjøholt et al., 2012, p. 79, Buhaug et al. 2006, p. 13). Therefore, a high proportion can be filtered from the washwater. In the environment, metals sediment and can be found at higher levels in the soil.

Heavy metals:

- Vanadium and nickel contents in the wastewater are proportional to the fuel sulphur content.
- All other metals appear to associate to a certain extent with particles from the exhaust gas and are therefore relatively easy to filter from the wastewater.
- Wear of the facility may lead to additional metal content in the wastewater.

4.2 Polycyclic aromatic hydrocarbons (PAHs)

All four studies show that long-chain PAHs are almost completely bound to particles. This provides the opportunity to separate them with the particulate load from washwater. Short-chain PAHs with lower molecular weight up to 3 rings, e.g. phenanthrenes, fluoranthenes and pyrenes remain in the wastewater (Table 9).

Significant efficiency differences were found among various washwater filtering methods (Hufnagl et al. 2005, p. 53).

There are seasonal and local differences in background levels of PAHs (Hufnagl et al. 2005, p. 93). In PAHs with higher molecular weight, 4 or more rings, Hufnagl detected no difference between the seawater background contamination and the scrubber effluent (ibid., p. 95).

Hansen (2012, p.23) describes technical difficulties in the continuous measurement of PAHs in low concentrations on board.

PAHs:

- Long-chain PAHs often attach themselves to particles and are easy to filter with these particles from the wastewater. Short-chain PAHs with up to 3 rings are water soluble and remain in the scrubber effluent.
- There are efficiency differences among washwater filter methods. More research is needed.

4.3 Nitrates/sulphates

Nitrogen oxides (NO_x) are generated in combustion processes. NO_x remains essentially unchanged during the scrubber process in the exhaust. In Buhaug (2006) nitrates were not measured but represented in the COD value – chemical oxygen demand, which was slightly elevated.

Hufnagl et al. (2005, p.123) found a doubling of nitrate concentrations in the wastewater, and Hansen (2012, p. 24) detected the same. The measured values of 0.0028 g NO_3/kWh and 0.021 g NO_2/kWh remain well below the limit of 60 mg/l at a flow rate of 45 t/MWh (2700 g NO_2/kWh). The highest concentrations occurred at high engine load (95% MCR).

Sulphates are produced by the scrubbing process from the sulphur oxides of the exhaust gas. Sulphates are to some extent highly soluble in water, for example, Na_2SO_4. Others such as calcium sulphate ($CaSO_4$), also known as gypsum, are very hard to dissolve or insoluble. They can be filtered as a solid component from the washwater.

The measured sulphate content was 0.4 to 4.5% above the inlet values in the Pride of Kent and therefore below the error rate of the measuring method.

Nitrates/sulphates

- Hansen (2012) and Buhaug et al. (2006) detected slightly increased nitrate contents in the wastewater.
- The measured values are well below the limit of 60 mg/l (Guidelines 2009).
- The sulphate values measured by Hufnagl et al. (2005) were below the error rate of the measurement method.

Table 9 The scrubber effluent constituents stem from MS Fjordshell (Buhag et al. 2006) and MS Ficaria Seaways (Kjøholt et al. 2012, Hansen 2012) measurements; the seawater values from the Kjøholt et al. 2012 measurement series and the fuel and scrubber sludge values from the Hansen 2012 measurements series.

		Fjordshell			Ficaria (Kjøholt)			Ficaria (Hansen)				Kjoholt		
		SW *		Sea water	SW (2.2 %)		FW **	SW	FW	Fuel HFO	Sludge	HFO	HFO	MGO
		high load	low load		high load	low load	high load	high load	high load	2.20%		2.2 % S	1.0 %	0.1 %
		90 % MCR	30 % MCR		80-95% MCR	40-45% MCR	T=120 centrif.		85% CR	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
Fuel use	kg/h				3510	1850	3520							
Water use	t/MWh	50	150		50	50		50						
Nitrogen	µg/l			0.12	0.56	0.34	120	31-130						
Sulphur	µg/l			865	900	900	9000							
Vanadium	µg/l	35	23	1.8	180	81	14000	162.9	3	155	6600	150	36	<1
Nickel	µg/l	32.8	10.4	8.9	43	20	3100	41.1	BDL	47	4000	42	22	3
Zinc	µg/l	6	15	< 2.0 - 8.0	450	150	420	200	BDL	BDL	370	<20	<20	<20
Chromium	µg/l	<1	< 1	BDL	BDL	BDL	BDL	4.8	BDL	3	250			
Lead	µg/l	5	0.6	< 0.02	21	3.6	3.8	13.1	BDL	BDL	43	<1	<1	<1
Copper	µg/l	41.6	15.3	5	260	150	860	115.6	BDL	BDL	780	<3	<3	<3
Mercury (Hg)	µg/l	< 0.1	< 0.1	0.12	0.086	0.092	< 0.05	BDL	BDL	BDL	0.03	<0.2	<0.2	<0.2
Arsenic	µg/l	< 0.1	<0.1	1.5	< 1.0	1.8	9.8	0.2	BDL	BDL	6	<0.5	<0.5	<0.5
Cadmium	µg/l	0.05	0.08	< 0.20	< 0.20	< 0.20	0.094	0	BDL	3	< 0.05	<0.1	<0.1	<0.1
Hydrocarbon (THC)	µg/l	50	-8	31 - 53***	110	140								
PAH (USEPA)	µg/l	<0.1	<0.1		0.96	1.1	3.8	5 - 7****	5.2 - 13.1		230			
Naphtalene	µg/l				0.48	0.51	0.32							
Filtered sample	µg/l				0.62	0.65								
PCDD	pg/l	-46.1												
PCDF	pg/l	240.7												
Water throughput	t/MWh	50	150		50	50		50						

* Fjordshell - SW = open loop, measurement directly at scrubber outlet, fuel: HFO, 2.7 % sulphur content

** Investigation in FW mode took place over a period of 2 hours (120 minutes) letting the scrubber water be re-circulated without concurrent removal of particles by centrifugation

*** Background contamination during Fjordshell campaign (Buhaug, 2006)

**** Chiefly naphthalene, fluorene and phenanthrene

DS - dry substance

PCDD - polychlorinated dibenzodioxins

PCDF - polychlorinated dibenzofuranes

BDL - below detection limit

4.4 Wastewater oil content

The study by Hansen (2012, p. 24) takes into account the scrubber effluent oil content using two different fuels (Table 10). For both fuels, oil contents are below the legally permitted bilge water oil content of max. 15 ppm - used here as a comparison.

It should be noted that oil concentrations of 1 ppm can already cause acute lethal toxic effects in marine organisms (Buhaug et al. 2006, p. 28).

Table 10 Effluent oil content, tests using two different fuels (2.2% and 1.0% sulphur content), from Hansen, 2012

Position	mg/l = ppm	mg/kWh
SW influent	1.4	74
SW effluent (sulphur content 1.0%)	1.2	65
SW effluent (sulphur content 2.2%)	1.9	101

4.5 Conclusion: wastewater constituents

The concentrations of pollutants in scrubber effluents differ in part widely in the studies examined. The reasons for these differences have not always been completely clarified. Continuous measurement of low PAH concentrations has been reported to be difficult. In addition, filter technology has a strong influence on PAH concentration and some heavy metal values encourage assumptions about plant-specific influences.

The investigations of Kjøholt and Hansen on the same ship (MS Ficaria Seaways) provided significantly different measurement results. In Hansen, wastewater metal concentrations using the closed mode (FW mode) are below the detection limit. In contrast, metal concentrations in Kjøholt (2012) also in closed mode are largely in the measurable range.

All investigated studies substantiate pollutant concentration in the scrubber washwater well below the IMO Guideline 2009 limits

The pollutant concentration in the wastewater varies with the amount of washwater used. The limits of the Guidelines 2009, therefore, refer to a standardised flow rate of 45 t/MWh.

A dilution in terms of the pH value is permitted before outlet. The influence of acidifying substances here is masked by an increase in the flow rate or subsequent dilution in the wastewater.

There is no clarity on the use of additives in closed scrubbers. Whether and which substances such as flocculants are added in the recycling process of the washwater cannot be fully clarified in this study. To ensure environmental safety, any additives including alkalis used should be subjected to a compulsory ecotoxicological safety investigation in accordance with the G9 Ballast Water Convention of the IMO (Resolution MEPC.12 (53)).

5 Estimation of effluent discharges

Pollutant quantities that may be introduced into the marine environment by the use of scrubbers are estimated here using the example of four different ship types common in German coastal waters.

The model assumptions are intended to better assess future discharges from scrubbers into the waters and discharge quantities of scrubber sludge in harbours.

5.1 Model assumptions

Example ships were selected from among the four different ship types (Table 11). The engine output for the different sailing speed was estimated from the admiralty formula. The auxiliary engine power was assumed to be constant for all speeds.

Table 11 Ship examples: tanker, feeder, cruiser and RoPax

	Tanker Ship 1	Feeder Ship 2	Cruiser Ship 3	RoPax Ship 4
Capacity	15,000 t	950 TEU	2,800 Pax	750 m 600 Pax
Service speed $v_{service}$ [kn]	14.0	18.5	21.5	20.5
Power P_{prop} at $v_{service}$ [kW]	5,000	7,600	35,000	7,500
Power P_{aux} [kW]	750	1,200	8,000	2,000

The engine power required and the energy consumption for each ship on a particular route is calculated according to the scheme in Table 12 below.

Table 12 Calculating engine power and energy consumption per ship and route for the Emden-Cuxhaven route example

Emden - Cuxhaven		Ship 1	Ship 2	Ship 3	Ship 4
Distance d [n.m.]	148	148	148	148	148
Medium speed v_m [kn]		12	16	18	18
Medium power P_m [kW]	$P_m \approx P_{Aux} + P_{prop}*[v_m/v_s]^3$	3,549	6,117	25,539	6,577
Time of journey t [h]	$t = d/v_m$	12.3	9.3	8.2	8.2
Energy E [kWh]	$E \approx t*P_m$	43,767	56,578	209,984	54,079

- Engine power and energy consumption per ship on selected routes

The different service speeds of example ships and in part different engine loads on certain sections were considered in a ship- and route-specific manner for selected routes. Based on the ship- and route-specific energy consumption (in MWh), the washwater amount was calculated for the respective routes as the 50 t/MWh standard quantity for open mode (Hansen 2012) and as 0.1 t/MWh for closed mode (Wärtsilä 2012).

The routes are example routes along the North Sea and Baltic coast, including the Kiel Canal on the Brunsbüttel – Kiel section. The route sections mainly run in coastal areas (e.g. Emden - Cuxhaven) or in rivers and estuaries (e.g. Hamburg - Brunsbüttel).

Table 13 Scrubber effluent volumes per example section and per example vessel (SW: sea water – open system, FW: fresh water – closed system)

Route		Energy in MWh				Scrubber effluent in t							
	n.m.	Ship 1	Ship 2	Ship 3	Ship 4	Ship 1		Ship 2		Ship 3		Ship 4	
						SW	FW	SW	FW	SW	FW	SW	FW
Kiel – Stralsund	104	31	40	126	38	1,538	3	1,988	4	6,313	13	1,900	4
Kiel – Göteborg	230	68	88	279	84	3,401	7	4,396	9	13,962	28	4,202	8
Kiel – Brunsbüttel (NOK)	54	9	12	46	13	450	1	612	1	2296	5	657	1
Hamburg – Cuxhaven	56	12	17	63	17	622	1	826	2	3152	6	828	2
Hamburg – Brunsbüttel	37	8	11	42	11	411	1	548	1	2083	4	547	1
Emden – Cuxhaven	148	44	57	210	54	2,188	4	2,829	6	10,499	21	2,704	5

- Estimation of pollutant and waste quantities

The washwater constituents underlying the estimation of the amount discharges are listed in Table 14. As a model assumption 1 l of seawater is equated to 1 kg. This may vary in reality depending upon the salt content, with a possible deviation of up to 3%.

The calculations used constant pollutant concentration for the calculated energy consumption on each sample route. This pollutant concentration is based on the data in Table 9 for a high engine load and 2.2 % sulphur content fuel.

Table 14 Quantities of washwater constituents on which the assessment of the amount discharges is based (Table 15 – 18). All values used were measured using HFO with 2.2% sulphur content and high engine load (MCR 80-95), Hansen and Kjøholt et al. 2012

		Open mode (SW)	Closed mode (FW)
Nitrate	µg/l	130*	
Total PAH	µg/l	5*	5.2*
Vanadium	µg/l	162.9*	3*
Nickel	µg/l	41.1*	BDL
Mercury	µg/l	0.086**	BDL
Lead	µg/l	13.1*	3.8**
Arsenic	µg/l	0.2*	9.8**
Copper	µg/l	115.6*	
Zinc	µg/l	200*	

* Hansen (2012)

** Kjøholt (2012)

The amounts of potentially introduced washwater constituents in seawater mode (open loop) and fresh water mode (closed loop) are shown for the four example vessels and 6 routes in Tables 15 - 18. The quantities always refer to the entire route section, and the different average engine loads have been considered for the respective route sections.

Table 15 Contaminant amounts for example ship 1 (tanker, Table 11) on selected routes

Values for ship 1		Kiel - Stralsd.	Kiel - Göteborg	Kiel - Brunsbtl.	Hamburg - Cuxhaven	Hamburg - Brunsbtl.	Emden - Cuxhaven
	n.m.	104	230	54	56	37	148
Vanadium in g	SW	251	554	73	101	67	356
	FW	0.01	0.02	0.00	0.00	0.00	0.01
Lead in g	SW	20	45	6	8	5	29
	FW	0.012	0.026	0.003	0.005	0.003	0.017
Arsenic in g	SW	0.3	0.7	0.1	0.1	0.1	0.4
	FW	0.03	0.07	0.01	0.01	0.01	0.04
PAH in g	SW	1.25	2.77	0.37	0.51	0.33	1.78
	FW	0.00	0.00	0.00	0.00	0.00	0.00
Nickel in g	SW	63	140	18	26	17	90
Mercury in g	SW	0.1	0.3	0.0	0.1	0.0	0.2
Copper in g	SW	178	393	52	72	48	253
Zinc in g	SW	307.55	680.17	89.97	124.44	82.22	437.67
Oil in kg	SW	0.62	1.36	0.18	0.25	0.16	0.88
Nitrate in g	SW	200	442	58	81	53	284

Table 16 Contaminant amounts for example ship 2 (feeder, Table 11) on selected routes

Values for ship 2		Kiel - Stralsd.	Kiel - Göteborg	Kiel – Brunsbtl.	Hamburg-Cuxhaven	Hamburg-Brunsbtl.	Emden-Cuxhaven
	n.m.	104	230	54	56	37	148
Vanadium in g	SW	324	716	100	135	89	461
	FW	0.01	0.03	0.00	0.00	0.00	0.02
Lead in g	SW	26.04	57.59	8.02	10.83	7.15	37.06
	FW	0.02	0.03	0.00	0.01	0.00	0.02
Arsenic in g	SW	0.4	0.9	0.1	0.2	0.1	0.6
	FW	0.04	0.09	0.01	0.02	0.01	0.06
PAH in g	SW	1.62	3.58	0.50	0.67	0.44	2.30
	FW	0.00	0.00	0.00	0.00	0.00	0.00
Nickel in g	SW	82	181	25	34	22	116
Mercury in g	SW	0.2	0.4	0.1	0.1	0.0	0.2
Copper in g	SW	230	508	71	96	63	327
Zinc in g	SW	398	879	122	165	109	566
Oil in kg	SW	0.8	1.8	0.2	0.3	0.2	1.1
Nitrate in g	SW	258	572	80	107	71	0

Table 17 Contaminant amounts for example ship 3 (cruiser, Table 11) on selected routes

Values for ship 3		Kiel-Stralsd.	Kiel-Göteborg	Kiel-Brunsbtl.	Hamburg-Cuxhaven	Hamburg-Brunsbtl.	Emden-Cuxhaven
	n.m.	104	230	54	56	37	148
Vanadium in g	SW	1028	2274	374	513	339	1710
	FW	0.04	0.08	0.01	0.02	0.01	0.06
Lead in g	SW	83	183	30	41	27	138
	FW	0.05	0.11	0.02	0.02	0.02	0.08
Arsenic in g	SW	1.3	2.8	0.5	0.6	0.4	2.1
	FW	0.12	0.27	0.05	0.06	0.04	0.21
PAH in g	SW	5.14	11.37	1.87	2.57	1.70	8.55
	FW	0.00	0.00	0.00	0.00	0.00	0.00
Nickel in g	SW	78	574	94	130	86	432
Mercury in g	SW	0.5	1.2	0.2	0.3	0.2	0.9
Copper in g	SW	730	1614	265	364	241	1214
Zinc in g	SW	1263	2792	459	630	417	2100
Oil in kg	SW	2.53	5.58	0.92	1.26	0.83	4.20
Nitrate in g	SW	821	1815	298	410	271	1365

Table 18 Contaminant amounts for example ship 4 (RoPax, Table 11) on selected routes

Values for ship 4		Kiel-Stralsd.	Kiel-Göteborg	Kiel-Brunsbtl.	Hamburg-Cuxhaven	Hamburg-Brunsbtl.	Emden-Cuxhaven
	n.m.	104	230	54	56	37	148
Vanadium in g	SW	310	685	107	135	89	440
	FW	0.01	0.03	0.00	0.00	0.00	0.02
Lead in g	SW	24.89	55.05	8.60	10.85	7.17	35.42
	FW	0.01	0.03	0.00	0.01	0.00	0.02
Arsenic in g	SW	0.4	0.8	0.1	0.2	0.1	0.5
	FW	0.04	0.08	0.01	0.02	0.01	0.05
PAH in g	SW	1.55	3.42	0.53	0.67	0.45	2.20
	FW	0.00	0.00	0.00	0.00	0.00	0.00
Nickel in g	SW	78	173	27	34	22	111
Mercury in g	SW	0.2	0.4	0.1	0.1	0.0	0.2
Copper in g	SW	220	486	76	96	63	313
Zinc in g	SW	380	840	131	166	109	541
Oil in kg	SW	0.76	1.68	0.26	0.33	0.22	1.08
Nitrate in g	SW	247	546	85	108	71	352

5.2 Summary assessment of washwater discharges

From an ecological perspective, the mass flow rate of pollutants in washwater are just as significant as their concentration. Long-term accumulation is particularly relevant from an ecological perspective when it comes to non-degradable components such as metals.

The estimation of the quantities of pollutants in scrubber effluents was carried out using sample vessels on 6 sample routes in the North Sea and Baltic Sea, which are mainly ecologically sensitive areas (see Chapter 6). The pollutant concentrations in scrubber effluents were derived by using heavy oil of a 2.2% sulphur content under high engine load and were based on the data from Hansen (2012) and Kjøholt et al. (2012). Pollutants in the exhaust gas occurring at varying engine loads were not considered.

Despite such model-dependent constraints the assessment confirms a constant discharge of pollutants that accounts for a greater amount in open scrubbers compared to closed scrubbers.

In terms of total amounts of pollutants discharged, it is likely that a significant increase of use of scrubbers in the ecologically sensitive coastal waters of the North Sea and Baltic Sea and the confined waters of harbours will have a substantial environmental impact.

In addition to the total amounts of pollutants, the water flow rate is a further important factor in the assessment of environmental impacts.

This particularly applies to open systems. As such, up to 1,000 t of sea water per hour were pumped through the system of the MS Ficaria Seaways in open mode (FW) (Hansen 2012, p. 27).

The high water flow rate of open systems has not yet been rated in previous studies from an ecological perspective. It must be assumed that the scrubber effluent contains no living organisms. The microalgae and any benthic invertebrates collected with the seawater are thus removed from the food chain. Whether this represents a significant future impairment for the marine ecosystem of the Wadden Sea, the Baltic Sea, the river estuaries and ports cannot be resolved in this study. Further research on this matter is needed.

6 Description of the environmental status according to WFD/MSFD

The North Sea and Baltic Sea as well as the adjacent coastal and transitional waters are extensively studied in their ecological state with the purpose of establishing a baseline review to enable the implementation of the European Water Framework Directive (WFD) and the Marine Strategy Framework Directive (MSFD).

The characterisation of the ecological condition of a natural body of water was created based on a five-point scale: high, good, moderate, poor, bad (WFD 2000). The assessment of the ecological potential of a heavily modified body of water (e.g. estuaries, port areas) was done on a four-point scale: good and above, moderate, poor, bad (Voss et al., 2010). The assessment focuses predominantly on quality components such as phytoplankton, macrophytes/angiosperms, macrozoobenthos and fish. The quality component ranked poorest determines ecological condition and ecological potential. In addition, physical, chemical and hydromorphological quality elements are also consulted.

Measurements and characteristics of the overall water quality are usually indicated by pH value, water temperature, oxygen saturation, O_2 provisions and nutrient concentrations. Biological characteristics are normally determined by samples of chlorophyll, phaeophytin concentration, bacteria, algae and phytoplankton. The qualitative evaluation of the water is based on its content of heavy metals (Cr, Cu, Ni, Zn, Mn, Fe) and arsenic.

This chapter sets out to describe the defining parameters of water more closely, namely pH, temperature, biological components and heavy metals in relation to the scrubber criteria outlined earlier (see Chapter 4)

- pH value

Seawater is extremely well buffered. This means that the pH value changes very little after the introduction of acids or bases. The high buffer capacity of seawater is a result of the high proportion of dissolved carbon dioxide in the water. The CO_2 reacts with the water molecules and acts as bicarbonate, carbonate and hydrogen ions. The latter define the pH. The above components are interdependent:

$$H_2O + CO_2 \rightleftarrows HCO_3^- + H^+ \rightleftarrows CO_3^{2-} + 2H^+$$

The pH of an uninfluenced marine environment ranges between 7.8 and 8.4. These values may vary more in the top 0-25 m layer of the water.

In this buffered environment pH fluctuations are rare. As such, marine organisms do not need to be able to adapt to a changing pH. The pH influences a number of biological processes in marine organisms such as enzymatic activities or the energy required to maintain a physiologically favourable pH; chemical properties may change, e.g. adsorption mechanisms or the degree of toxicity of certain pollutants. Human-induced pH fluctuations are indicated by climate change, for example the phenomenon of "ocean acidification". Such changes are expected and are partly already measurable.

- Pollutants

Heavy metals are a result of human activities and are accumulating in the environment and food chain. Scrubber effluents contain cadmium, lead and mercury.

Other pollutants relevant for this study are PAHs. These result from the combustion of heavy fuel oil and contain, amongst others, polychlorinated biphenyls (PCB) 17 ppm, chlorophenols 40 ppm, chlorobenzene 44 ppm, polychlorinated dibenzodioxins (PCDD) 3.9 ppb, polychlorinated dibenzofuran (PCDF) 2.8 ppb (Buhaug et al. 2006, p. 14). PAHs are ecotoxically mutagenic and carcinogenic. PAHs bind easily to particles and accumulate in the sediment. Fish, for example, suffer long-term liver damage and reduced fertility caused by a PAH concentration of 1 - 2 mg/l in the surrounding water (Hofer & Lackner 1995, p. 138).

- Biological components

The build-up of organic particles ("zooplankton") from dissolved inorganic constituents by photosynthetic active organisms ("phytoplankton") is the starting point and hub of CO_2 buffering of the ocean and the food chain. The amount and number species of silica, green and other phytoplanktonic algae vary in the warmth-, light- and nutrient-rich vegetation period.

The accumulation of nutrients (including nitrates), the discharge of inorganic and organic pollutants, biological disorders and the effects of climate change are the main strains on phytoplankton, which is the first link in the food chain.

- Temperature

Temperature and salinity determine the physical condition of a sea. The immediate effect of a temperature change can be observed from physiological responses of the present organisms. Each type has a specific temperature range which enables the optimal functioning of its physiological processes.

Human-induced changes in the local temperature profile can be caused, for example, by underwater power cables and especially by cooling water discharges from power plants.

6.1 North Sea

The German parts of the North Sea are not in a good environmental condition. According to the initial assessment for the WFD, the ecological condition of the North Sea is predominantly classified as 'moderate' to 'bad' (BLANO 2012).

- pH value

The influence of elevated CO_2 concentrations in the environment is not yet reflected in the pH measurements of the seawater in the German Bight (BLANO 2012).

- Temperature

Rising water temperatures (1 - 2 °C in the last 25 years) as a result of climate change and acidification are phenomena which are already traceable (OSPAR 2010).

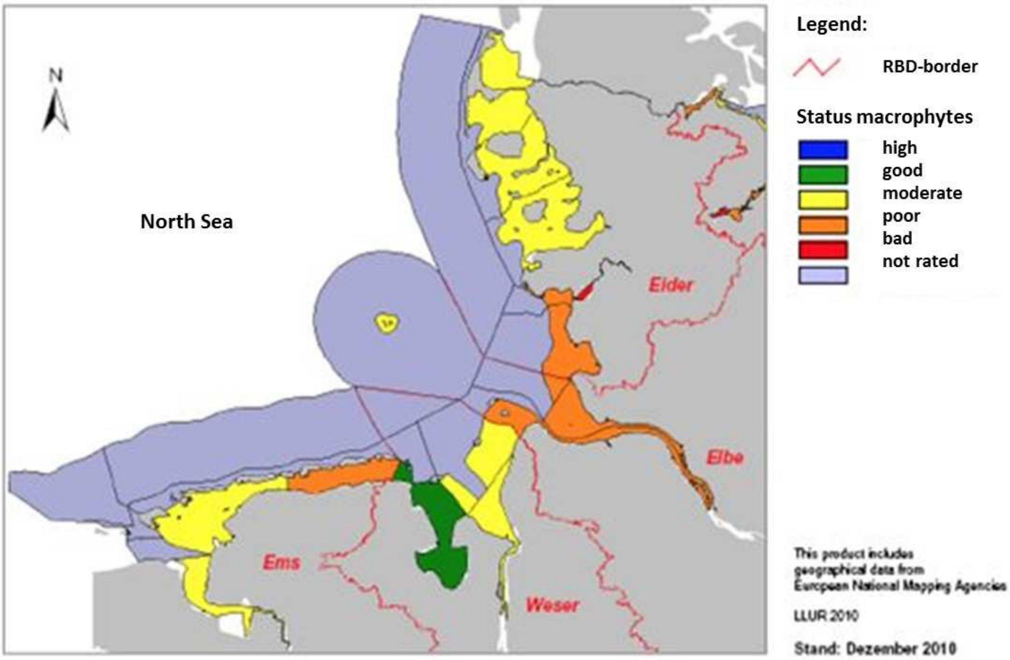
- Biological components

Overall, the phytoplankton in the German North Sea is not in a good environmental condition (BLANO 2012). Within the framework of the investigations, OSPAR and the

Trilateral Wadden Sea Cooperation (TWC) categorised the German North Sea area as a "problem area" or "potential problem area" as concerns eutrophication.

According to the WFD, the ecological state of the macrophytes of coastal waters is classified predominantly as 'moderate' to 'poor' (BLANO 2012). The accumulation of nutrients has the greatest impact on macrophytes. Overall, the macrophytes of the German North Sea are not in a good environmental condition (Figure 1).

Figure 1: Evaluation of the quality component macrophytes according to the WFD from the initial assessment of the German North Sea; from BLANO 2012



Condition of macrophytes on the German North Sea coast according to the WFD inventory (BLANO 2012)

The accumulation of nutrients and bottom fishing has the greatest impact on the macrozoobenthos. Overall, the macrozoobenthos of the German North Sea are not in a good environmental status (BLANO 2012).

Current evaluations of the Habitats Directive, OSPAR and the International Council for the Exploration of the Sea (ICES) found unfavourable to poor conditions for many fish species. Fishing, climate change and eutrophication have the greatest impact on the development of fish stocks and species distribution and composition. Overall, the fish of the German North Sea are not in a good environmental status.

- Pollutants

OSPAR (2010) evaluated the pollution of the North Sea (OSPAR Region II) and concluded that there are "many problems". Its assessment is based on data from 1998 to 2007, and differentiated open sea and coastal waters pollution assessments (Cd, Pb, Hg, PCBs, PAHs) in sediments, in crustaceans and fish (OSPAR 2009). The statistics of the pollutant measurements show that concentrations of the pollutants Cd, Hg, Pb, PAHs and PCBs have reached unacceptable heights at 20%, 37%, 53%, 55% and 71% of all monitoring stations in the North Sea. The German Bight is one of the most highly contaminated areas in the North Sea region (OSPAR, 2009; BLANO 2012).

The Elbe River is the principal input pathway of organic pollutants to the German Bight. Generally, the pollutant levels decrease more or less quickly the further away from the coast and towards the open sea. PAHs and most chlorinated hydrocarbons do not present detectable trends due to high concentration fluctuations in the sea water and a short time series (BLANO 2012).

The contamination of the North Sea by hazardous substances is still too high and has tangible impacts on the ecosystem. Accumulation impacts especially the higher levels of the food chain (BLANO 2012).

6.2 Baltic Sea

The presentation of the analysis of individual components is based on the initial assessment for the MSFD (BLANO 2012) according to which the German areas in the Baltic Sea are not in a good environmental status. Ecological conditions range from 'good' to 'bad', while the majority of the habitats protected by the Habitats Directive were evaluated only as 'unfavourable – inadequate' or 'unfavourable-bad' (BLANO 2012). According to HELCOM, the condition of coastal waters in particular is largely considered 'poor' to 'bad' and, in part, 'moderate' (BLANO 2012).

- pH value

No statements can currently be made about the pH due to lack of data.

- Temperature

Depending on morphological conditions, a partially pronounced vertical salinity and temperature stratification can take form in the entire Baltic. The effects of a significant anthropogenic increase in temperature are locally limited.

- Biological components

Overall, the **phytoplankton** in the German Baltic is not in a good environmental status.

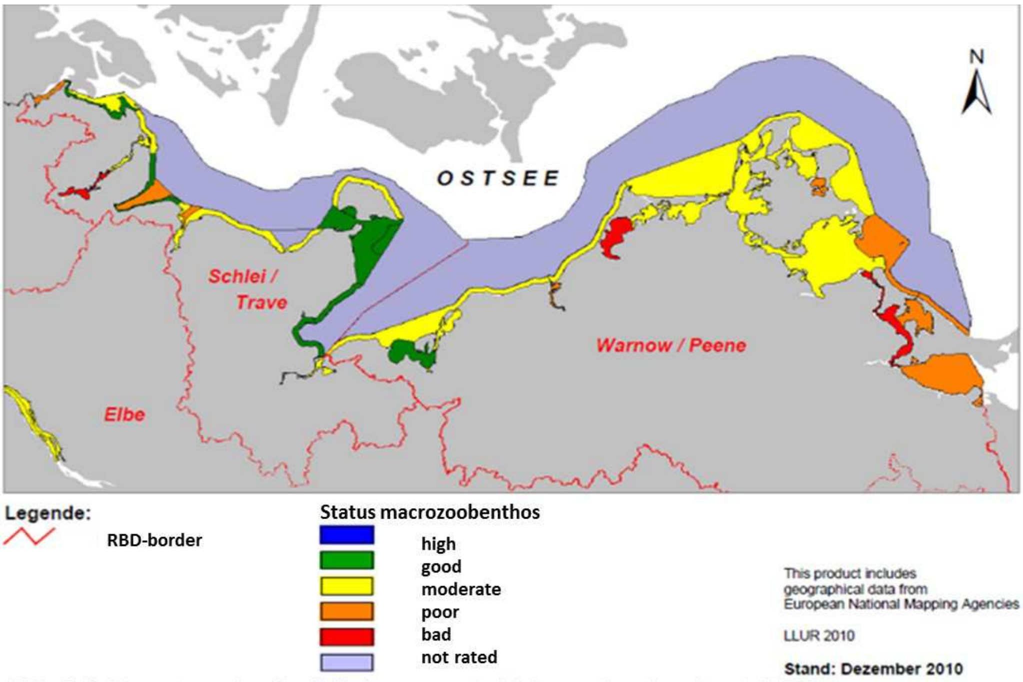
The proportion of calcifying phytoplanktons (coccolithophorids) plays a minor role in the Baltic Sea, which is due to the short time span and sufficient calcium carbonate saturation in the seawater (Tyrell et al. 2008).

According to the WFD, the ecological condition of the **macrophytes** in the coastal waters is classified predominantly as 'moderate' to 'poor'. HELCOM rated the macrophytes off the German Baltic Sea coast as 'moderate' to 'bad' (BLANO 2012, p. 21). The accumulation of nutrients, the large-scale sediment extraction and bottom fishing are the biggest strains on the macrophytes.

Overall, the macrophytes in the German Baltic are not in a good environmental status.

The ecological condition of the **macrozoobenthos** in the coastal waters is primarily classified as 'moderate' or worse (BLANO 2012). HELCOM rated the macrozoobenthos status along the German Baltic coast as 'moderate' to 'high. The accumulation of nutrients, the large-scale sediment extraction and bottom fishing are the biggest strains on the macrozoobenthos. Other impacting factors are changes in sediment composition, being covered with sediment, sealing, lack of light due to turbidity, biological disorders such as non-native species, changes in hydrodynamics and impacts of climate change (BLANO 2012, p. 22). In total, the macrozoobenthos of the German Baltic Sea is not in a good environmental status (Figure 2).

Figure 2: Evaluation of the quality component macrozoobenthos according to the WFD from the initial assessment of the German Baltic Sea; from BLANO 2012



Condition of the macrozoobenthos along the German Baltic coast according to the WFD inventory (BLANO 2012)

The development of fish stocks and species distribution and composition are predominantly impacted by fishing and climate change as well as the accumulation of nutrients. Overall, the fish of the German Baltic Sea are not in a good environmental status.

- Pollutants

Intensive shipping traffic is common in the German part of the Baltic Sea, particularly the Arkona Basin, the Darss Sill, the Belt Sea and the Bay of Mecklenburg. The primary use of heavy oil as a marine fuel on ships leads to air emissions of heavy metals (V, Ni), NO_x, SO_x, CO_2, PAHs and soot particles. The substances have different lifetimes in the atmosphere and are leaked locally or regionally into the open sea.

The use of scrubbers on ships can cause a shift of emissions directly into the sea water.

There is no clear trend for exposure to PAHs in the period between 2001 and 2010 throughout the German EEZ (BLANO 2012). However, the PAHs associated with the combustion of fossil fuels show elevated levels in the winter.

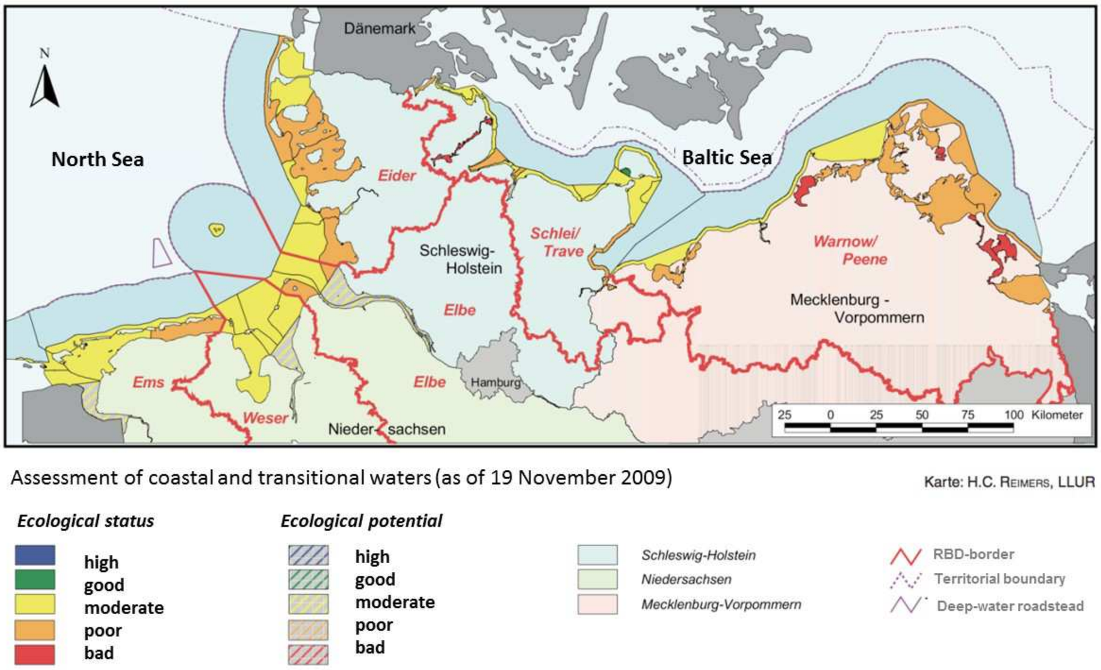
The contamination by hazardous substances in the German Baltic Sea is too high and already has tangible consequences on the ecosystem (BLANO 2012).

6.3 Coastal Waters

German coastal waters lie in the peripheral areas of the North Sea and Baltic Sea. These areas are heavily exploited by shipping, fisheries, offshore activities, wind farms, marine research and tourism. In addition, waste and pollutants are carried by the rivers into the sea and along the same pathways mentioned above. The ecological condition of the coastal waters was rated for the management plans of the WFD in 2009 (Voss et al. 2010). Biological quality components such as phytoplankton, macrophytes and macrozoobenthos as well as fish (in estuaries) were used.

The result is summarised in Figure 3. The ecological condition assessment of the coastal and transitional waters of the North Sea and Baltic Sea exposes a 'moderate' to 'poor' condition in the harbour basins such as Bremen/Bremerhaven and Hamburg and 'poor' on the North side of the Baltic (Voss et al. 2010).

Figure 3: Ecological status assessment of the coastal and transitional waters of the North Sea and Baltic Sea; Voss et al. 2010



The environmental status, including the ecological potential of the German coastal and transitional waters according to the review for the management plans of the WFD (Voss et al. 2010)

- pH value and temperature

In coastal and estuary areas marine organisms must be able to withstand the physiological stress of salinity fluctuations. Comparatively, they are very little adapted to pH and temperature fluctuations.

- Biological components

The ecological condition of phytoplankton in coastal waters is classified mainly as 'moderate' to 'poor' (WFD 2010).

According to HELCOM, the Baltic Sea areas off the German coast are rated from 'high' to 'bad'. The accumulation of nutrients and the effects of climate change are the main strains on the phytoplankton.

The ecological condition of the macrozoobenthos in the coastal waters is classified predominantly as 'moderate' (WFD). The ecological assessment for "fish" in the Eider, Elbe, Weser and Ems exposed a "moderate potential" in 2010 (Voss et al. 2010).

- Pollutants

Pollutants are transported primarily as suspended matter by rivers into the coastal areas and in the adjacent seas. Pollution normally decreases in the open water, away from the coast; pollution in sediments may increase locally. The Hamburg Port Authority had an inventory made of the pollutant situation of sediments and suspended matter in the Elbe and its major tributaries (Heise et al., 2005). The same heavy metals (Hg, Cd, Pb, Cu, Zn, Cr, Ni, As) and organic pollutants (including PAHs, TBT, TeBT, DBT, TPT, HCHs, PCBs) were present in concentrations exceeding the limits of the WFD. Due to high concentration fluctuations in the sea water and short available time series, PAHs and most chlorinated hydrocarbons show no detectable trends (BLANO, 2012).

Heavy metals are generally not biodegradable. Cr, Cu, Ni, Zn are toxic for plants and some marine organisms while As, Be, Cd, Co, Cr, Hg, Pb, Sb, Se and Zn are poisonous for humans and animals.

6.4 Summary of the status assessment

The ecological status of the North Sea and Baltic Sea was described in detail as part of the MSFD (BLANO, 2012): The habitat types, phytoplankton, macrophytes, fish fauna, marine mammals and seabirds are currently not in a good environmental status.

Voss et al. (2010) analysed the condition of the coastal and transitional waters in the context of the implementation of the WFD. Coastal and transitional waters are not in a good ecological status.

The abovementioned studies on the implementation of the WFD and MSFD also confirm that the contamination by hazardous substances, the accumulation of nutrients and organic matter as well as biological disturbances are too high and have a negative impact on the ecosystem.

German waters are already burdened by emissions and human activities which lead to acidification, temperature rise and high levels of pollutants.

7 Environmental Impact Assessment

The expected amounts of washwater from ship operations including waterbodies, tide, season, cumulative effects and other environmental parameters must be modelled for a quantitative environmental impact assessment on the total waters (North Sea, Baltic Sea, coast). This is not within the scope of this study.

In compliance with Resolution 184(59) 2009, at least the following changes can be expected from the use of scrubbers on ships: pH decrease, temperature increase, turbidity, introduction of pollutants from combustion residues and additives.

In this report, an assessment will be given as to whether negative environmental impacts by scrubber effluents can be expected on marine biota when the scrubber technology gains a wider application.

In the environment, many environmental effects are coupled which may enhance the effects themselves. Thus many pollutants temporarily accumulate in the sediments and will be redissolved e.g. at lower pH values or through lack of oxygen and become bioavailable. All factors are very specific to a particular pollutant and local environmental conditions. The effects of pollution often cannot be attributed to any particular pollutant or individual groups of pollutants, and the effects of mixtures and newly developed substances on the marine environment often remain unclear (BLANO 2012).

7.1 Reduction of the pH value

The ability to assemble inorganic to organic matter makes phytoplankton the basic building block of marine food webs. Any changes in the phytoplankton occurrence therefore affect other biological components.

A lowering of the pH in seawater by scrubber effluents occurs rather at a small and mesoscale. An acidification pressure will emerge faster on limited systems than on the open North Sea and Baltic Sea, where acidification is also expected due to climate change over the long term. Nevertheless, it will apply to the phytoplankton affected by scrubber effluents that, above a certain threshold, a decreased pH value

- leads to an increase in energy demand,
- unstable skeletons or floating structures are formed,
- development and propagation are impaired
- and as a result certain calcifiers, e.g. coccolithophorids will disappear.

Overall, it can be assumed that less phytoplankton will be available to consumers in the food web.

A positive effect of decreasing pH is evident in seaweed, which not only tolerates sinking pH values, but even responds to it with growth spurts. The skeletons of cold-water corals in the NE Atlantic produce solid structures and provide a living space and food for many animals (Mayer & Piepenburg 1996). It was expected that these calcifiers would be adversely affected by a low pH; however, they continued to grow in the experimental basin even after a pH reduction.

Echinoderms (Echinodermata), **molluscs** (Mollusca) and **barnacles** (Balanidae) create limestone (calcium carbonate) structures. Lime formation costs organisms a lot of energy and energy demand increases as pH decreases. Free-swimming larvae of sea urchins and other lime-forming soil organisms (e.g. foraminifera) may be impaired in their development.

Since filtering activity is reduced in **mussels** at lower pH, an activity and fitness reduction can be expected in other benthic organisms.

The pH value continues to influence the enzyme activities, e.g. a too low pH inhibits the hatching enzyme chorionase (Hofer & Lackner 1995, p. 141). Acute stress episodes often result in damage to fish gills, while chronic stress affects reproduction, the hatching rate and larvae.

The direct impacts of lowering the pH on **marine mammals and birds** are not serious, but the impact on phytoplankton and thus on the whole food web will also become evident for higher organisms.

All in all, marine organisms are not much adapted to varying pH values, since this was not necessary in terms of evolutionary biology due to the buffering properties of sea water. A decreasing pH will lead to a decrease in species spectrum. pH and temperature fluctuations have combined effects. A pH value reduction will have a greater effect in closed water bodies than on open sea.

7.2 Temporary temperature rise

Temperature and salinity determine the physical conditions of a sea. A warming of water as a result of washwater discharges leads first of all locally to a change in the water body’s natural physical properties, and hence to an influencing of the organisms’ biological metabolic processes. If the amount of the heated water is in an unfavourable ratio to the total size of the water body, or when the dynamics of the water body are so low that heat continues to be maintained, the entire water body’s physical properties may be affected. While direct effects can be measured at high temperatures, long-term slow effects are hard to detect in spatial and temporal contexts.

Anthropogenic warming is already being caused at a large scale by underwater power cables and cooling water discharges from power plants. In open water, permanent temperature increase through climate change superimposes the local influence by temporary temperature increases which include, for example, washwater discharges.

However, it applies to phytoplankton affected by scrubber effluents that even a temporary temperature increase above a certain threshold will lead to

- an earlier onset of flowering,
- a shift in species composition,
- a change in the total mass of phytoplankton
- and possibly the death of individuals.

The natural rhythms of phyto- and zooplankton are decoupled by shifting the onset of flowering and the change in the species spectrum. **Crustacean larvae** (nauplii) hatch in water tank experiments before the spring blossom of phytoplankton and therefore die of starvation (WOR1 2010). If temperature increases, fewer **diatoms** can be found in phytoplankton, replaced instead by more flagellates. The latter feed on copepods (copepoda) more poorly, whereupon they grow more sluggishly, reproduce less and cannot serve as food to more highly developed organisms (fish).

The solubility of oxygen in water is temperature dependent; therefore, an increase in temperature can lead to oxygen deficiency.

These effects are stronger and occur faster in narrow and limited water bodies such as estuaries and harbours than in well-flushed water areas.

The most immediate effect of temperature increase is due to the physiological responses of the organisms present. Each type has a specific temperature range in which their physiological processes can operate optimally. Fish, marine mammals and birds can avoid poor environmental conditions, whereas plankton, macrophytobenthos and benthic animals cannot.

Overall, a relatively limited effect space is assumed for the introduction of warm scrubber effluents. However, interacting multiple stress factors enhance the negative influence of elevated temperature.

7.3 Temporary turbidity

Turbidity causes light deficiency, which negatively influences the photosynthesis of phytoplankton and macrophytes and thus affects the total biomass. Habitat and food source may be impaired or lost entirely. Benthic organisms are limited in their ability to free themselves from physical coverage, and only with increased energy demand. Mussel beds are exposed to risk by recurrent turbidity events.

Strongly increased concentrations of suspended matter in the water column can cause clogging of fish gills, which can result in physiological stress and even mortality of individuals. Suspended solids may be contaminated with pollutants such as heavy metals, which cause additional damage to cells e.g. by blocking enzymatic processes.

Turbidity caused by scrubbers is mainly a concern because of the pollutants in suspended matter which contribute to turbidity.

7.4 Pollutants

Introduction and accumulation of inorganic and organic pollutants generally represent a substantial burden for all biological components of the German North Sea and Baltic Sea (BLANO 2012).

Heavy metals e.g. in mammals lead to acute to chronic toxic symptoms, acting on the central nervous system, lungs, liver, kidneys, skin, bones and thyroid (GDCh 1996).

PAHs – long-chain polycyclic hydrocarbons are poorly soluble in water, they easily bind to particles and thus accumulate in the sediments. Short-chain PAHs are water-soluble and thus bioavailable. They are mutagenic and carcinogenic.

The measurement of PAH metabolites is included in the pollutant-specific biological effect monitoring according to OSPAR CEMP[2] because of their carcinogenic effect. Carcinogenic PAHs cause tumours on the skin and internal organs.

PAHs are ingested by fish and, in the worst case, cause liver tumours. PAH metabolites in fish bile are among the recommended parameters in marine environmental monitoring and are part of the regular monitoring programme performed by the Thünen Institute of Fisheries Ecology in fish from the North and Baltic Seas (Kammann & Haarich 2009a, 2009b).

Fish accumulate fat-soluble pollutants in particular in their organs and muscles. It is assumed that pollutants can directly or indirectly weaken the immune system of fish and thus lead to an increased incidence of disease.

Scrubber effluents also contain nitrates. Nitrate is an important plant nutrient and is to a large extent responsible for nutrient enrichment (eutrophication) of waters in the coastal zone. Eutrophication in the North and Baltic Seas is subject to a pronounced seasonal cycle such that the effect of nitrate inputs varies according to the seasons. Eutrophication ultimately causes oxygen depletion and can lead to the death of populations. Dead organisms contaminated with pollutants sink to the bottom and contribute to the contamination of the sediments.

Summing up, it should be noted that pollutant effects can range from biochemical changes in organisms to changes at the population level.

[2] Coordinated Environmental Monitoring Programme

8 Evaluation of environmental impacts

Environmental quality standards (EQS) are used to estimate environmental impacts. In addition, the precautionary principle can also be applied if adverse effects are highly likely to occur in the future.

8.1 Environmental quality standards (EQS)

Environmental quality standards determine the substance concentrations at which there will be no impact on populations and ecosystems. These standards are referred to as 'No-Effect Concentrations' (NEC) and focus on direct effects of local concentrations of certain substances exerted on organisms.
This means that even if a discharge results in a local concentration which is greater than EQS/NEC for permanent exposure, this introduction is acceptable if the substances to be introduced are sufficiently diluted prior to the introduction or they spread quickly in the environment.

In Europe standards have been introduced for bringing chemicals to the market (REACH), the protection of river and coastal waters (WFD, Directive 2000/60/EC) and the protection of the marine environment (MSFD, Directive 2008/56/EC). The water and marine conservation guidelines are interconnected and the environmental quality standards are based on the essential ecotoxicological statements of REACH[3] with regard to chemical quality criteria.

No risk assessment is undertaken under REACH for substances that are classified as persistent, bioaccumulative and toxic (PBT) due to their environmental effects, as their distribution and effects cannot be predicted for the long term and in combination with other substances. An input of these substances must therefore be completely avoided.

"However, to ensure an adequate level of protection for the environment and human health, the cessation or phasing out of discharges, emissions and losses of priority hazardous substances pursuant to Article 4(1)(a)(iv) of Directive 2000/60/EC should also be aimed at."[4]

HELCOM lists a number of PBTs under "hazardous substances". These are also included in the Baltic Sea Action Plan, which lists a total of 11 PBTs.

OSPAR’s List 1 - Substances for Priority Action - lists substances with PBT properties and List 2 – Substances of Possible Concern - shows suspected PBT substances.

Substances in the OSPAR List 1 and the Baltic Sea Action Plan require the Member States to take measures to reduce concentrations when they are detected above the specified concentrations in the marine environment.

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[3] REACH European Directive concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (Regulation EC No. 1907/2006)

[4] Position of the European Parliament adopted at first reading on 2 July 2013 by the adoption of Directive 2013 /…/ EU of the European Parliament and of the Council amending Directives 2000/60/EC and 2008/105/EC as regards priority substances in the field of water policy

The long-term concentration is of particular ecological importance especially for non-degradable pollutants in a larger sea, coastal, river and estuary area.

The European Water Framework Directive (WFD, 2000/60/EC) Annex X lists particularly hazardous priority substances. Currently, there are 33 priority substances listed in Annex X, including eight polycyclic aromatic hydrocarbons (PAHs), 13 of which are classified as hazardous (e.g. cadmium and mercury).

The following substances from among the priority substances of WFD Annex X have been detected in scrubber effluents: lead, mercury, naphthalene, nickel and PAHs.

Table 19 List of the 33 substances classified as priority substances according to WFD

1	Alachlor	15	Fluoranthene	28	PAH*
2	Anthracene	16	Hexachlorobenzene		Benzo(a)pyrene
3	Atrazine	17	Hexachlorobutadiene		Benzo(b)fluroanthene
4	Benzene	18	Hexachlorocyclohexane (HCH)		Benzo(k)fluoranthene
5	Brominated diphenyl ether	19	Isoproturon		Benzo(ghi)perylene
6	Cadmium	20	Lead*		Ideno(1,2,3-cd)pyrene
7	C10-C13 chloroalkanes	21	Mercury*	29	Simazine
8	Chlorfenvinphos	22	Naphthalene*	30	Tributyltin compounds
9	Chlorpyrifos	23	Nickel*	31	Trichlorobenzene
10	1,2-dichloroethane	24	Nonylphenols		1,2,3-trichlorobenzene
11	Dichloromethane	25	Octylphenols		1,3,5-trichlorobenzene
12	Di-(2-ethylhexyl)phthalate (DEHP)	26	Pentachlorobenzene		1,2,4-trichlorobenzene
13	Diuron	27	Pentachlorophenol	32	Trichloromethane
14	Endosulfan			33	Trifluralin

* Found in scrubber effluents

Priority hazardous substances are no longer to be entered in the Community's aquatic environment at a time yet to be determined (phasing out). Currently, there is a measurement obligation for priority listed substances.

The WFD assessment of water bodies classifies pollutants as *significant* if they considerably contribute to falling short of 'good status' in the water body and this results in a requirement for specific measures to be implemented (Janson 2011, p. 3).

The "Notes to the Schleswig-Holstein part of the Elbe Management Plan" (2009) consider those material stresses substantial that have a greater than 20% share in the total load of surface waters within a planning unit[5].

[5] From the "Notes to the Schleswig-Holstein part of the Elbe Management Plan" (2009)

Table 20 EQS for priority substances contained in scrubber effluents. Excerpt from Part A of Directive 2013/39/EU of priority substances in the field of water policy.

No.	Name of substance	CAS number	AA-EQS	MAC-EQS	Biota EQS
			Other surface waters	Other surface waters	
			µg/l	µg/l	µg/kg wet weight
2	Anthracene	120-12-7	0.1	0.1	
6	Cadmium and its compounds (depending on water hardness classes)*	7440-43-9	0.2	≤ 0.45 (Class 1) 0.45 (Class 2) 0.6 (Class 3) 0.9 (Class 4) 1.5 (Class 5)	
20	Lead and its compounds	7439-92-1	1.3	14	
21	Mercury and its compounds	7439-97-6		0.07	20
22	Naphthalene	91-20-3	2	130	
23	Nickel and its compounds	7440-02-0	8.6	34	
28	Polycyclic aromatic hydrocarbons (PAH)**				
	Benzo(a)pyrene	50-32-8	1.7×10^{-4}	0.027	5
	Benzo(b)fluoranthene	205-99-2	**	0.017	**
	Benzo(k)fluoranthene	207-08-9	**	0.017	**
37	Dioxins and dioxin-like compounds		n/a	n/a	Sum of PCDD + PCDF + PCB-DL 0.0065 $\mu g.kg^{-1}$ TEQ***

* For cadmium and its compounds (No. 6) EQS depends on water hardness, as specified in the five class categories (Class 1: <40 mg $CaCO_3$/l, Class 2: 40 to <50 mg $CaCO_3$/l, Class 3: 50 to <100 mg $CaCO_3$/l, Class 4: 100 to <200 mg $CaCO_3$/l and Class 5: ≥ 200 mg $CaCO_3$/l).

** For the group of polycyclic aromatic hydrocarbons (PAH) (No. 28) the biota EQS and corresponding AA-EQS in water refer to the benzo(a)pyrene concentration, on whose toxicity they are based. Benzo(a)pyrene can be considered as a marker for the other PAHs; hence only benzo(a)pyrene needs to be monitored for comparison with the biota EQS and corresponding AA-EQS in water.

*** PCDD: polychlorinated dibenzo-p-dioxins; PCDF: polychlorinated dibenzofurans; PCB-DL: dioxin-like polychlorinated biphenyls; TEQ: toxic equivalents according to the World Health Organisation 2005 Toxic Equivalency Factors

Measurement results on heavy metals in the scrubber effluents (Table 9) exhibit high values for nickel, mercury, lead and vanadium. However, they fail to exceed any of the EQS for the maximum allowable concentration per year.

Both the aforementioned heavy metals (with the exception of vanadium) and PAHs are on the list of priority hazardous substances according to WFD (DIRECTIVE 2013/39/EU).

8.2 Precautionary principle/improvement requirement

The precautionary principle is enshrined in the Water Framework Directive and, for the marine environment, in the Marine Strategy Framework Directive (MSFD).

The WFD introduces the objective of avoiding the origin of environmental degradation and consistently implementing the 'polluter pays' principle according to Recital 11 of WFD.

The MSFD's aim is to achieve good ecological status in the European marine areas by 2020. The most important elements of MSFD are the improvement requirements and the explicit demand for a precautionary approach (Recitals 27 and 44 of MSFD).

The use of scrubber technology and open systems in particular can, under certain circumstances, prevent achieving the aim of "no deterioration" and the improvement requirement.

8.3 Summary assessment of environmental impacts

The European directives contain both the precautionary principle, as in the WFD and MSFD, and environmental quality standards for certain substances.

The WFD and its equivalent for the marine environment, the MSFD, are both committed to the precautionary principle.

The priority substance EQS pursuant to WFD (Table 20) contain allowable annual average concentrations and maximum concentrations, and in some cases maximum concentrations in organisms (biota). Once this limit is exceeded in the environment, the direct consequence is that appropriate measures must be implemented to stop or reduce the discharges.

The substances anthracene, lead, mercury, naphthalene, nickel and PAHs are included in scrubber effluents and are identified by WFD as priority substances to be monitored by the monitoring programmes. Current EQS are not violated by the pollutant contents in scrubber effluents according to the current state of knowledge. Since they are in part non-biodegradable substances, it must be assumed that they are accumulating in the environment.

Assessment of environmental impacts

Scrubber effluents contain priority listed substances pursuant to WFD Annex X and are therefore within the scope of the mandatory environmental monitoring of these substances.

- Contaminant concentrations in the scrubber effluents are below the allowable EQS according to current knowledge.
- Some substances are persistent, hence EQS may be exceeded in the future due to accumulation or high shipping volume in certain areas.

The discharge of persistent pollutants is not consistent with the precautionary principle / improvement requirements of WFD/MSFD.

9 Proposed measures

The knowledge about the environmental impact of scrubbers and scrubber effluents is still insufficient. The reviewed assessments found no consistent account of the composition of washwater constituents. There are questions which remain unanswered.

In principle, the use of clean liquid (diesel) and gas (LNG) fuels is preferable to aftertreatment for sulphur reduction.

If scrubbers are used, systems without or with minimal emissions to the water only are preferable (dry scrubbers, closed wet scrubbers).

Taking into account the international character of shipping and in order to avoid the creation of economic disadvantages on the global market for national port locations, international regulations are always preferable to those at European, national and local levels. To avoid competitive disadvantages a large-scale adoption of the same rules is the most desirable. To achieve this, ports should seek economic interaction at the international level and look to strengthen cooperation within the marine conventions OSPAR, HELCOM and Trilateral Wadden Sea Cooperation (TWC).

9.1 Targeted monitoring of potential environmental consequences as a scientific foundation for further protective measures

Programmes for environmental monitoring were introduced in order to examine the policy implementation and the achievement of WFD and MSFD objectives (see Chapter 6).

In order to better assess the cumulative impacts of scrubber emissions on the marine environment, the existing environmental monitoring should be adapted to this additional source of discharge. The most critical components of the scrubber effluents should be recorded in potential cumulative areas - for example, near main shipping routes and estuaries – and should be included in the regular monitoring programme of the North Sea and Baltic Sea.

Due to the current low number of emission control systems this is only a precautionary measure which can create the basis for handling stress scenarios. Their results can then be incorporated into the risk assessment of the cumulative effects.

If, in the coming years the measurement programmes detect a pollutant accumulation resulted from the increased use of scrubbers beyond the EQS list of priority substances, a new basis for further regulation of scrubber discharges might be established.

9.2 Restrictions on the use of scrubbers/restricting the discharge of scrubber effluents

The use of scrubbers causes an environmental impact through short-term and spatially limited pH decrease, temperature and turbidity increase and pollutant discharges of partially persistent substances.

The shipping routes of the North Sea and Baltic Sea traverse ecologically valuable and sensitive areas. These areas are already burdened by heavy traffic. The use of scrubbers constitutes an additional strain.

According to current available knowledge, open scrubbers are particularly impairing because they require a very large amount of water. Thus, the ecological effects of temporary pH decrease, temperature and turbidity increase, and the mass flow of pollutants in the washwater are much higher than in closed systems.

It is necessary to examine whether the use of such systems - including the ecologically precarious open scrubbers, as these cause higher pollutant loads and larger flow rates of washwater – in areas with high protection requirements can be prohibited and the deterioration of the ecological condition may be prevented (Part B).

9.3 Approval of scrubbers with active substances only in accordance with G9

According to the Guidelines 2009 (MEPC Resolution 184 (59)), the regulation of scrubber effluents was carried out based on the available knowledge at the time of adoption. The amount and type of washwater constituents are insufficiently examined, in particular in relation to the most environmentally critical heavy metals, PAHs and washwater temperature (see Chapters 4.5).

The IMO seeks to close this gap by addressing a possible revision of the discharge requirements (Guidelines 2009) once more adequate data is available. For this purpose, it has issued a request to record a series of previously omitted substances in the data collection (Annex III of MEPC Res. 184 (59)).

Potentially used active substances are not included in the list of observed pollutants.

The use of active substances in closed scrubbers is so far only mentioned under 10.1.6.1 of the Guidelines 2009. Thus, the Guidelines 2009 fall short of the scope of control of the Ballast Water Convention. The Ballast Water Convention can be considered as the IMO equivalent regulation for shipping for water protection. It requires an ecotoxicological investigation of active substances is compulsory.

The approval of scrubbers that use active substances is related to an environmental study on the qualification standard of Resolution 126 (53) of the MEPC to establish "requirements for the approval of ballast water systems which use active substances (G9)".

The differences in regulating depth between the Ballast Water Convention and the Guidelines 2009 should be equalised.

9.4 Adjustment of the pH criterion in the Guidelines 2009

Discharges with a low pH have a negative impact on ecosystems. Depending on the season, extreme pH fluctuations already occur locally in estuaries, rivers and ports. These would be further exacerbated by the introduction of scrubber discharges.

On a global scale, climate change has already caused a pH decrease of 0.1 compared to the pre-industrial era. Scrubber effluents contribute to an acceleration of the expected consequences of climate change.

To reduce the effects in sensitive and already damaged areas, the pH of the outlet should be no more than 0.5 units below the value of the surrounding water.

10 Further need for action and research

There is a great need for further research due to the small number of previously conducted tests regarding scrubber effluent effects and the difficult comparability of the measurement results from these studies.

- Improvement of the database regarding washwater constituents and discharge quantities generated by scrubbers

There should be an investigation into the causes of deviations in the measurement results of present studies (see Chapter 4) and the gaps in knowledge should be closed by additional tests of washwater constituents. Furthermore, after estimating the frequency of scrubber uses in the targeted waters, a conclusion should be drawn from the quantities of generated washwater.

- Modelling of environmental factors in the German coastal waters

With improved data on washwater constituents and waste quantities, the expected environmental impacts on the German coastal waters should be modelled with regard to regional and seasonal environmental strains.

- Standardisation of phenanthrene and benzo(a)pyrene equivalents

According to the Guidelines 2009, PAHs are currently indicated in phenanthrene equivalents. In the environment and according to the WFD, PAHs are indicated in benzo(a)pyrene equivalents. In order to assess scrubber effluent discharges within the context of the WFD, it requires either an approximation of the measured parameters and standardisation of the measurement methods or a general conversion factor of the measured values.

11 Overall conclusion

The present study has demonstrated that wet scrubbers influence the marine environment through pH decrease, temperature increase, pollutant discharges and possibly through the use of active substances. Open scrubbers in particular have a greater environmental impact than closed or dry scrubbers due to their high water consumption and significantly larger amounts of generated washwater. The environmental impact of active substances which are sometimes used in closed systems is completely unresolved.

German coastal waters are already suffering under great pressure from shipping, resource extraction, energy production, tourism and discharges from industry and agriculture. The existing pressures are substantial in some sections of the German coast. The current environmental condition of German coastal waters is moderate to bad. The contaminated washwater poses an additional strain on marine organisms in the North Sea and Baltic Sea and the adjacent river basins affected by shipping.

It seems that the WFD/MSFD environmental quality standards are not likely to be breached at the present time. The discharges of large amounts of washwater with partially persistent substances, lower pH and elevated temperature, however, are not compatible with the precautionary principles of the WFD/MSFD.

In principle, the use of clean liquid (diesel) and gas (LNG) fuels is preferable to the aftertreatment of exhaust gases to reduce sulphur dioxide emissions.

There still is great need for research and measurements and, where possible, the development of international activities to prevent environmental degradation by future increase of scrubber discharges.

Part B: Legal instruments for the regulation of and requirements for the use of scrubbers

Authors: Dr. Till Markus, Lutz Philipp Helfst

1 Introduction

In light of the potential environmental hazards and damage of the marine environment that may result from the discharge of washwater from scrubbers, the legal precepts and options should be verified for regulating the use of scrubbers.

Due to their functional and geographic scope and in light of the competitive situation of port states, international regulations are generally preferable to national ones. It is important to ensure that any regional or national regulation complies with international marine law. Against the background of long-ranging international decision-making processes it is also important to examine the possibilities of unilateral regulations by the Federal Republic of Germany or the European Union.

As a first step towards establishing a regulatory requirement with regard to the discharge of scrubber effluents, current protection requirements of the international and European maritime environmental law will be presented. In a second step, control opportunities will be established which would assign the applicable marine law to the coastal states to regulate shipping discharges into the marine environment. In a third step, two marine law compatible regulatory action strategies will be presented.

2 International and EU legal obligations to protect the marine environment

2.1 Environmental protection requirements under UNCLOS

The starting point of the discourse regarding maritime and marine environment legal issues is the United Nations Convention on the Law of the Sea (UNCLOS). As the framework agreement of international maritime law it states in its preamble that the Parties are prompted by the desire to "settle, in a spirit of mutual understanding and cooperation, all issues relating to the law of the sea [...]".

General requirements for the protection of the marine environment

UNCLOS establishes obligations for the protection of the marine environment. Part XII (Articles 192-237) of UNCLOS contains the central rules of international law on marine environment and nature conservation (Czybulka 2011, p. 823). Articles 192-196 UNCLOS define a set of general obligations as concerns marine conservation. The following section of this paper highlights the obligations under Articles 192-195 UNCLOS. According to Article 192 UNCLOS, states are obliged to protect and maintain the marine environment. Due to its not purely political and programmatic design, Article 192 UNCLOS has been rightly described as the general legal principle of marine conservation (Proelß 2004, p.

77). Particularly with regard to the regulation regarding types of pollution outlined in Part XII of UNCLOS it is assumed that the obligation in Article 192 UNCLOS refers to the entire marine environment, i.e. is indefinite in territorial scope of application. Article 192 UNCLOS is supplemented by other provisions contained in Part XII and is especially substantiated in terms of individual types of pollution. This is evident in particular in Article 194, Para 1: "States shall take, individually or jointly as appropriate, all measures consistent with this Convention that are necessary to prevent, reduce and control pollution of the marine environment from any source [...]".The duty to take the necessary measures is discussed in further detail in Article 194 Para 2-5, Article 195, and particularly in Articles 207-212 UNCLOS.

2.1.1 Requirements for the protection of the marine environment from pollution by ships

With regard to the obligation to take measures to prevent, reduce and control the pollution of the marine environment, Article 194 Para 3 No. 1 UNCLOS establishes that all sources of pollution of the marine environment must be covered. In terms of pollution of the marine environment by ships, Article 194 Para 3 No. 2(b) UNCLOS further establishes that relevant actions include those which are aimed at limiting pollution by ships to a minimum. This will include "in particular measures for preventing accidents and dealing with emergencies, ensuring the safety of operations at sea, preventing intentional and unintentional discharges, and regulating the design, construction, equipment, operation and manning of vessels".

Article 211 UNCLOS substantiates Article 194 Para 3 No. 2(b) UNCLOS. It especially details pollution caused by discharges from the operation of ships, but not the atmospheric pollution of the marine environment caused by ships (the latter is covered by Article 212 UNCLOS). Article 211 UNCLOS itself contains no direct restrictions on shipping to protect the marine environment, but requires that the parties outside of the UNCLOS framework regulate shipping for the protection of the marine environment. In this respect, Article 211 Para 1 UNCLOS refers to the International Maritime Organization (IMO) as "competent international organization" and alternatively, a "general diplomatic conference". Within this framework States "shall establish international rules and standards to prevent, reduce and control pollution of the marine environment from vessels [...]". Otherwise, the arrangement of the responsibility to protect is conducted pursuant to Article 211 Para 2 UNCLOS through the national laws of the parties. "Such laws and regulations shall at least have the same effect as that of generally accepted international rules and standards established through the competent international organization [...]". In this respect, UNCLOS once again refers to measures taken by IMO.

2.1.2 Duty not to transfer damage or hazards or transform one type of pollution into another

Part of the legal framework for the marine environment of the UNCLOS are also the obligations contained in Article 195 UNCLOS. According to Article 195 UNCLOS states are required to take “measures to prevent, reduce and control pollution of the marine environment. States shall act so as not to transfer, directly or indirectly, hazards from one area to another or transform one type of pollution into another”. The regulatory content of this provision is not fully explained. Its wording, however, suggests that its objective is to be interpreted as meaning to guide States to prevent environmental damage at its origin and to refrain from shifting actions to avoid any responsibilities to cover the costs of environmental damage. To that extent Article 195 UNCLOS was rightly understood as the formulation of the origin and polluter pays principle (Proelß 2004, p. 84; otherwise Wolfrum 2000, p. 72 who considers Article 195 UNCLOS as a refinement of the precautionary principle). The result is an environmentally appropriate legal protection derived from Article 195 UNCLOS. Firstly, states are compelled by environmental protection measures not to transfer pollution from one place or medium to another by any means. Secondly, possible transformations of pollution would not lead to new environmental damage or risks (Sands/Peel 2013, p. 131; Doelle 2006, p. 323; Charney 1995, p. 732 and 1994, p 887; Teclaff/Teclaff 1991, p. 188). Article 195 UNCLOS thus pursues an integrative approach that aims to protect the environment as a whole, while drawing the attention to various exposure pathways and different environmental media that require protection (Sands/Peel 2013, p. 131; for background information on the integration approach see Kloepfer 2004, p. 205).

It is crucial, therefore, that a) atmospheric emissions of SO_x and other exhaust components caused by vessels represent pollution of the marine environment within the meaning of the UNCLOS, b) the obligation to reduce atmospheric emissions outlined in the framework of MARPOL as well as the permission to reach appropriate limits through the use of scrubbers must be regarded as state measures to prevent, reduce and control the pollution of the marine environment, c) which finally results or may result in both a shift of damage and risks as well as a transformation of one type of pollution into another. According to Article 1 Para 1 No. 4 UNCLOS:

Pollution of the marine environment means the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, which results or is likely to result in such deleterious effects as harm to living resources and marine life, hazards to human health, hindrance to marine activities, including fishing and other legitimate uses of the sea, impairment of quality for use of sea water and reduction of amenities.

The definition contained in Article 1 Para 1 No. 4 UNCLOS refers to "direct or indirect introduction of substances". The pollution of the marine environment includes the pollution of the atmosphere as well, which presents itself as an indirect supply of substances into the actual body of sea. This broad understanding of the concept of marine environment is also based on the fact that Article 212 UNCLOS essentially covers pollution of the marine environment from or by pollution in the atmosphere (Hafner 2006, p. 361). It is crucial, therefore, that the UNCLOS, especially with regard to the protection of sea water, recognises that its pollution occurs indirectly through contamination of areas beyond the body of water, such as "from activities in the area", "on the seabed", "from land-based sources", “through the atmosphere” (see Article 207, Article 208, Article 209, Article 212 UNCLOS). In this respect, the concept of pollution of the marine environment also includes atmospheric emissions from ships, provided that they induce the adverse effect "which results or is likely to result" mentioned in Article 1 Para 1 No. 4 UNCLOS.

With regard to adverse effects it should be noted that a substantial amount of atmospheric emissions caused by shipping reaches the marine environment through atmospheric deposition (OSPAR 2007). Besides sulphur oxides, atmospheric emissions contain various heavy metals (such as vanadium, nickel, zinc, lead, copper, arsenic and cadmium) as well as polycyclic aromatic hydrocarbons. While sulphur oxides contribute particularly to the lowering of the pH in the upper layers of the water (Hassellöv et al. 2013), heavy metals and polycyclic aromatic hydrocarbons have a poisonous or mutagenic and carcinogenic effect on aquatic fauna (GdCH 1996). The lowering of the pH can in turn have adverse effects on the marine environment, e.g. on the development of calcifying organisms. The wording hints that the definition of the pollution of the marine environment includes such discharges as well, from which deleterious effects are "likely to result". In this respect, the above mentioned emissions clearly point to pollution of the marine environment, because it exposes anthropogenic introduction of substances into the sea which can provoke deleterious effects on aquatic flora and fauna.

As a result, the legal requirements for the reduction of atmospheric SO_x emissions constitute the possibility to accomplish this through the use of scrubber systems, a measure to "prevent, reduce [...] the pollution of the marine environment" within the meaning of Article 195 UNCLOS.

According to Article 195 UNCLOS appropriate measures should not lead to a spatial and medial displacement of damage and hazards or to the conversion of one type of pollution into another. In the case of discharge of scrubber effluents into the marine environment Article 195 UNCLOS provides two applicable alternatives. Firstly, regarding the marine environment there is an indirect risk of transfer from one marine area to another. The atmospheric emissions that would be spread over wide areas of the marine environment by means of atmospheric deposition as a result of lacking aftertreatment are, in the follow-up of exhaust aftertreatments, distributed in marine areas with comparatively low geographical expansion (partly in chemically converted form) by way of washwater discharge. The threats to the marine environment, which would have resulted from the wide-scale atmospheric deposition (acidification and poisoning effects as well as mutagenic and carcinogenic effects), are now generated by the discharge of scrubber effluents. The discharge of scrubber effluents that have a low pH and contain heavy metals and polycyclic hydrocarbons may be detrimental particularly in comparison with the corresponding areas sensitive to discharges. Sensitive areas are so far particularly those which neutralise poorly due to their low water exchange and low pH (e.g. lagoons, inland seas, or shore-located port areas) or those which show little resilience due to their ecological characteristics and high anthropogenic bias against corresponding discharges.

The discharge of scrubber effluents also leads to a shift of pollution from one medium to another. This applies to the part of atmospheric emissions that would have remained without the use of exhaust aftertreatment in the atmosphere or would have been distributed over land areas. In this respect, atmospheric and terrestrial contamination through the discharge of scrubber effluents transforms into pollution of the marine environment.

Furthermore, it should be noted that in certain cases the use of aftertreatment systems involves the use of chemically-biologically active substances which under certain circumstances are introduced into the marine environment together with the washwater. Such cases create new threats and potential harm to the marine environment which would insofar contradict the objective of Article 195 UNCLOS.

Interim conclusion: As a Contracting State of the UNCLOS, the Federal Republic of Germany is bestowed with the general obligation to protect the marine environment and to take measures necessary to prevent, reduce and control the pollution of the marine environment. These measures include those which deal with the pollution of the marine environment through ships, namely ship routeing in particular, discharge regulations as well as those that regulate the "design, construction, equipment, operation and manning" (CDEMS). When taking appropriate measures the Parties shall ensure that neither geographical or medial displacement occurs nor a transformation of pollution. According to the notion presented here, the discharge of scrubber effluents with a low pH containing heavy metals and polycyclic hydrocarbons represents both a spatial and medial displacement as well as a potential transformation of the type of pollution of the marine environment. If existing international or national regulations of the Contracting States to UNCLOS enable this shift or transformation, they contradict the normative requirements of Article 195 UNCLOS.

2.2 Protection requirements of IMO regulations

In the context of the IMO, various marine environmental protection regulations were established. These include measures for ship routeing and the designation of protected areas. They are devised by considering marine environmental protection interests and the interests of free and unhindered navigation within the meaning of Article 58 Para 1 UNCLOS (Lagoni, 2002, p. 125).

2.2.1 Environmental protection mechanisms under the MARPOL Convention

The MARPOL Convention amended in 1978 (1973 International Convention for the Prevention of Pollution from Ships, MARPOL 73/78) provides the option of establishing special areas. Their geographical scope may extend to the area of the territorial sea, the EEZ and the high seas within the meaning of UNCLOS. Special areas are legally defined as certain marine areas in which "for recognised technical reasons with regard to its oceanographical and ecological condition and to the particular character of its traffic, the adoption of special mandatory methods for the prevention of sea pollution (...)" is necessary, Annex I Regulation 1 No. 11 MARPOL 73/78. Specific shipping-related activities may be limited within the special areas. Special areas are established based on the relevant annexes to the MARPOL Convention, which differ in protective purpose. Geographical restrictions of shipping are possible under all MARPOL annexes (except Annex III) (see Annex I Regulation 1 Para 11, Regulation 15; Annex II Regulation 13; Annex IV Regulation 11 Para 1; Annex V Regulation 5; Annex VI Regulations 13, 14 MARPOL 73/78).

2.2.1.1 Annex I (Regulations for the Prevention of Pollution by Oil)

Special areas as per Annex I have been set up for the North Sea and Baltic Sea. The entire North Sea (including its approaches) is part of the "North West European Waters" Special Area in the meaning of Annex I (see Annex I Regulation 1 Para 11 No. 8). In the Baltic Sea, the special area comprises the "Baltic Sea proper with the Gulf of Bothnia, the Gulf of

Finland and the entrance to the Baltic Sea bounded by the parallel of Skagen in the Skagerrak at 57°44'.8 N".

The scope of application of Annex I basically covers "all ships" and is aimed at preventing pollution of the sea by oil (Annex I Regulation 2 Para 1) by harmonising construction standards (Annex I Regulation 12 et seqq.) as well as introducing a prohibition of discharge of oil and oily mixtures into the sea (Annex I Regulation 15 Para 1). The prohibition of discharge is only all-encompassing in the Antarctic region; otherwise, there are numerous exceptions that allow a partial discharge of oil or oily mixtures (see Annex I Regulations 4, 15 Paras 2, 3, 6).

Annex I is only relevant for scrubber effluents in so far as they contain oil or constitute oily mixtures themselves. Scrubber effluents may contain oil components. According to Regulation 1 Para 3, however, the issue whether it is an oily mixture or not does not depend on the concentration limits; thus scrubber effluents in principle must be considered oily mixtures within the meaning of Annex I. The general prohibition of discharge as per Regulation 15 Para 1 shall only apply according to Regulation 15 Para 2 No. 3 and Para 3 No. 3 if the oil content of the effluent "without dilution" is higher than 15 ppm. It must therefore be ensured that scrubber effluents discharged into the marine environment do not exceed this limit. However, there is no reliable evidence up to now as to the quality and quantity of oil content in scrubber effluents. Therefore, action must be undertaken to generate relevant information for various scrubber types.

2.2.1.2 Other annexes to MARPOL

The other MARPOL Annexes pursue the control of pollution by noxious liquid substances in bulk (Annex II), by ship sewage (Annex IV), by garbage from ships (Annex V) and of air pollution from ships (Annex VI). Scrubber effluents, however constitute neither a bulk substance within the meaning of Appendix II nor garbage in the sense of Regulation 3. Scrubber effluents are not covered by the term wastewater as per Annex IV - Regulation 3, Para 1 either.

Annex VI contains regulations for protection of the marine environment from air pollution by ships. Regulation 14 of the Annex includes the option to set up Sulphur Emission Control Areas (SECAs). SECAs were established throughout both the North Sea and the Baltic Sea. However, the emission limits set out in Annex VI only refer to atmospheric emissions from ships and do not cover the discharge of scrubber effluents. Thus Annex II to VI are not relevant for scrubber effluents.

2.2.2 Environmental protection mechanisms under the SOLAS Convention

SOLAS (International Convention for the Safety of Life at Sea) allows in connection with the IMO Resolution A. 572 (14) to establish Areas To Be Avoided where, accordingly, ships are not allowed to sail or only those of certain classes (Chapter V, Regulation 8 Annex SOLAS 74, in conjunction with Resolution A. 572(14)). While SOLAS earlier chiefly contained regulations for ship safety, since its amendment ship routeing can also be determined to serve marine environmental protection purposes (see Article 1.1 Resolution A. 572(14); Chapter V, Regulation 8 of the Annex to SOLAS; see also Gellerman/Stoll/Czybulka, 2012, p. 268; Czybulka 2011, p. 870). Naturally, the absence of vessel traffic within a certain region prevents a local threat to the marine environment by shipping. To develop general applicability, Areas To Be Avoided must be developed and explained in accordance with the criteria and guidelines of IMO (Gellermann/Stoll/Czybulka 2012, p. 269). Accordingly, a ship routeing system must be devised in line with the recommendations of IMO Resolution A. 572(14) and international law (Gellermann/Stoll/Czybulka 2012, p. 269). Corresponding areas have only been set up in the marine areas of the Member States off the Shetland Islands.

2.2.3 Particularly Sensitive Sea Areas (PSSAs)

IMO Resolution A. 982(24) of 01.12.2005 on the "Revised Guidelines for the Identification and Designation of Particularly Sensitive Sea Areas" (PSSAs) promotes the protection of particularly sensitive sea areas. A PSSA is defined as an area that needs special protection through action by IMO because of its significance for recognized ecological, socio-economic, or scientific attributes where such attributes may be vulnerable to damage by international shipping activities (Section 1.2 of the Amended Guidelines). Similar to a MARPOL Special Area, a PSSA can also lie within territorial seas, EEZs or the high seas. It may well also be installed within an existing special area (Lagoni, 2002, p. 125). Certain parts of the North Sea (Wadden Sea) and of the Baltic Sea are PSSAs. The establishment of a PSSA is based on an application by at least one IMO Member State, by a decision of the MEPC (Van Dyke/Broder 2012 p. 476 et seqq.; IMO Resolutions A. 927(22), A. 982 (24)). The establishment of PSSAs does not provide the coastal state with additional powers to unilaterally interfere with the freedom of maritime navigation for the sake of the marine environment. So the protective measures within a proposed PSSA cannot be more stringent than those allowed under existing international treaty or customary law (Lagoni, 2002, p. 126). Protection requirements therefore result from PSSAs only indirectly: as an instrument for determining the need of protection for a marine area, the establishment of a PSSA facilitates the establishment of specific marine environmental protection measures (APMs; associated protective measures), such as ship routeing systems ("areas to be avoided") or binding or recommended actions under other marine legal treaties (Lagoni, 2002, p. 126).

Interim conclusion: Marine environmental legal requirements regarding the discharge of scrubber effluents result from various IMO conventions as well as from IMO Resolutions. MARPOL Annex I in particular specifies limits for the discharge of oil, which in principle also applies to scrubber effluents, insofar as they contain oil. Currently, however, it is not sufficiently clear whether oil contained in scrubber effluents exceeds the limits specified in individual cases. Accordingly, MARPOL Annex I provisions currently probably do not apply to scrubber effluents. An effect of other MARPOL annexes on scrubber effluents can likely be ruled out.

As part of the SOLAS Convention, it is possible to set up ships' routeing. The establishment of these "Areas To Be Avoided" is limited by the regulations of international law.

There is also the option of designating PSSAs. They themselves represent no specific protective measures (i.e. they do not provide new marine legal powers to the coastal state), but serve the coordination and application of known and new marine environmental protection measures under the authority of IMO (APMs).

2.3 EU's marine environmental law requirements

The Union's marine environmental and nature protection laws are increasingly raising the obligations of EU Member States to establish legal guidelines for the protection of the marine environment. These regulations include in particular the Marine Strategy Framework Directive, the Water Framework Directive, the Habitats Directive and the Birds Directive. The aims of the regulations are to achieve good status of the marine environment, good chemical and ecological status of some marine surface waters, and the protection of special marine species and habitats. Although these rules do not contain direct legal requirements for marine shipping, they do provide the EU Member States with significant obligations to protect the marine environment and objectives in terms of the compatibility of marine shipping with the interests of marine protection.

2.3.1 Marine Strategy Framework Directive (MSFD)

The MSFD aims at ensuring that the Member States shall take the necessary measures "to achieve or maintain good environmental status in the marine environment by the year 2020 at the latest" (Article 1 MSFD). The Member States are required to develop marine strategies for their own marine areas with the purpose of protecting and preserving the marine environment and preventing the deterioration or, where practicable, eliminating damage to marine ecosystems and preventing or reducing discharges into the marine environment and phasing out pollution and avoiding impacts on e.g. biodiversity (Article 1 Para 2 a) and b) MSFD). Member States' strategies shall apply an ecosystem-based approach to the management of human activities and should coordinate with states sharing a marine region or subregion (Article 1 Para 3 and Article 5 Para 2 MSFD). The process of marine strategies development can be divided into six steps: 1) initial assessment (Article 8); 2) determination of good environmental status (Article 9 Para 1 MSFD); 3) establishment of environmental targets (Article 10 Para 1 MSFD); 4) developing and implementing monitoring programmes (Article 11 Para 1 MSFD) and 5) developing programmes of measures designed to achieve or maintain good environmental status (Article 13 Paras 1, 2 and 3 MSFD) and 6) practical implementation of the programme of measures (Article 13 Para 10 MSFD).

The MSFD in principle neither stipulates concrete protection measures at Community level nor does it compel the Member States directly and bindingly to take such actions (see Article 13 MSFD and Article 14 Para 1 - 4). Setting of objectives and selection of instruments should be made at the national level (see Markus/Schlacke 2010, p. 464-472, Markus/Schlacke/Maier 2011, p. 1-32; see also Salomon/Krohn 2006, p. 371-378 at an early stage of development of MSFD). The MSFD contains a "no deterioration“ concept with regard to the level of protection under environmental law (as noticed by the German federal legislature, see BT-Drs. 17/6055, p. 18). In addition, where they describe good environmental status, the Member States commit themselves to specifying environmental objectives and to creating action programmes to achieve good environmental status by 2020 which they specify in detail themselves. The Member States " shall, [...] determine, for the marine waters, a set of characteristics for good environmental status, on the basis of the qualitative descriptors listed in Annex I." and take into account the indicative lists in Annex III, Table 1 and the pressures and impacts caused by human actions in Annex III, Table 2 (Article 9 MSFD) when they define the essence of good environmental status.

Currently, most Member States have made their initial assessments, described good status of the marine environment for their marine waters and established environmental targets (see for Germany: http://www.meeresschutz.info/).

Descriptors 8 and 9 are particularly relevant within the current context. The requirements of environmental protection stemming from the specifications made by Germany with regard to Descriptor 8 or Descriptor 9 cannot be fully described here because of the extent of a relevant investigation. Instead, this report lists only the standards and quality specifications that should be achieved or complied with according to the definition of good environmental status. Descriptor 8 defines good environmental status in terms of contaminants as follows: "Concentrations of contaminants are at levels not giving rise to pollution effects". The description of good environmental status of the North Sea - Baltic Sea Federal-State Committee (BLANO) has established the following definition of good marine environmental status (GES) for the area of the North Sea:

The good environmental status in terms of the Descriptor "Contaminants" has been achieved when the concentrations of contaminants in biota, sediments and water comply with the environmental quality standards set out in the WFD, the EQS Daughter Directive 2008/105/EC and the Surface Water Ordinance (SWO), and the Ecological Quality Objectives and environmental quality objectives of OSPAR [Joint Monitoring and Assessment Programme] (JAMP) and [Co-ordinated Environmental Monitoring Programme] (CEMP). Due to major uncertainties and knowledge gaps that still exist in current EQS and EACs (Environmental Assessment Criteria), the precautionary principle should be used as an additional assessment criterion. In addition, specific requirements resulting from the MSFD must be met for the GES: in particular compliance with other environmental quality standards/environmental quality objectives to be established for sediments and biota and the consideration of biological effects of contaminants.

As mentioned above, the Member States commit themselves to achieving good environmental status by 2020 as they have defined it. In principle, it follows that there would be a conflict with the environmental provisions of MSFD where the discharge of scrubber effluents into waters covered by MSFD’s scope contradicts these objectives. This would result in an obligation for Germany and the EU to take actions in order to bring the discharge of scrubber effluents into line with MSFD’s legal requirements. However, it cannot be fully assessed within this legal opinion whether the above protection requirements specified by the Member States in detail (for their respective waters) would actually be violated by the discharge of scrubber effluents or whether the applicable international discharge standards contradict these requirements. In this respect, there is a need for further clarification.

2.3.2 Water Framework Directive (WFD)

In addition to the MSFD, protection requirements also arise from the WFD for the discharge of scrubber effluents into the marine environment. The WFD aims to achieve good chemical and ecological status of those surface waters within its scope. This also includes the water column of coastal waters within the meaning of WFD, which extends one nautical mile seaward from the baseline, and the chemical status of the entire territorial sea (12 nautical miles). WFD’s rules override those of the MSFD in these geographical areas (see Article 2 Para 1 MSFD and Article 1 and Article 2 No. 1, No. 7

WFD). Therefore WFD's provisions are applicable in internal waters, including the Federal German ports as well as the territorial sea in UNCLOS's sense.

One of WFD's central requirements for protection is the "no deterioration" concept (Article 4 Para 1(a) and (b) WFD). Despite prevailing uncertainties regarding the regulatory content of this requirement, prohibited deterioration can be assumed when the state of a water body has considerably deteriorated in comparison to the status quo it had when the WFD entered into force (Epiney 2012, p. 400). In addition, the level of protection of existing EU legislation must be ensured (Article 4 Para 9 WFD). Less stringent standards apply to artificial and strongly modified water bodies (e.g. federal waterways, Article 4 Para 3 WFD).

In addition to the minimum standard of the "no deterioration" concept, Article 4, Para 1(a)(ii) also demands Member States to protect, enhance and restore all bodies of surface water (including coastal waters). The aim should be pursued to achieve good status of surface waters according to the provisions of Annex V no later than 15 years after the Directive's entry into force. The parameters that classify water quality as "good" are specified in Annex V. No. 1.2 of the Directive. Although the scientific concepts have achieved a degree of precision, no exact limits have been established, thus the assessment of the discharge of scrubber effluents in terms of achieving good status remains uncertain to some degree.

Also, the WFD itself basically contains no clear emission or exposure limits for the discharge of substances. However, certain standards of the WFD refer to adhering to the emission limits. Thus, in particular Article 4 Para 1(a)(iv) WFD states that, in accordance with Article 16 Para 1 WFD, Member States shall implement the necessary measures with the aim of progressively reducing pollution from priority substances and ceasing or phasing out emissions, discharges and losses of priority hazardous substances. Priority substances are listed in Annex X WFD. Furthermore, WFD refers to various directives (see Article 16 WFD in particular). In this respect, especially "Directive 2008/105 on environmental quality standards in the field of water policy" should be emphasised. It defines environmental quality standards for priority and other pollutants with the aim to achieve good chemical status of surface waters. Member States must ensure that the concentration of substances monitored in sediments and/or biota does not increase significantly according to Article 3 Para 3 p. 2 of Directive 2008/105. With regard to the discharge of scrubber effluents into surface waters (including coastal waters) it is therefore important that discharge must be stopped and terminated where effluents contain priority substances. The Member States must prohibit the discharge of scrubber effluents where this would increase the concentration in sediments and biota of substances specified in Directive 2008/105.

2.3.3 Habitats Directive and Birds Directive (HD, BD)

The Habitats Directive and the Birds Directive specify certain legal requirements for marine conservation. The applicability of both Directives to the EEZ and the continental shelf of the Member States was confirmed by the European Court of Justice (ECJ) some time ago (see ECJ Case C-6/04, Commission/United Kingdom, Coll. 2005 I-9017, No. 115 et seqq. in particular; also Ell/Heugel 2007, p. 315 et seqq.). Both directives refer explicitly to marine components of nature. Article 4 Para 1 Sent 3 of the Habitats Directive sets guidelines for the selection of protected areas for "aquatic species". In addition, Annex I of the Habitats Directive also specifies sandbanks (NHT 1110), reefs (NHT 1170), posidonia meadows (NHT 1120) and estuaries (NHT 1130). The most suitable areas must be specified as protected areas in terms of numbers and sizes for these species and habitat types according to Article 4 Para 1 of the Habitats Directive and Article 2 of the Birds Directive. The areas should help build a European ecological network, "Natura 2000", according to Article 3 Para 1 of the Habitats Directive. The designation of protected areas is accompanied not least with the obligation of taking conservation measures for their protection. Article 6 Para 1 Habitats Directive requires that the Member States shall take appropriate statutory, administrative or contractual character which correspond to the ecological requirements of Annex I Habitat types and Annex II Species. Article 6 Para 2 of the Habitats Directive also contains a general ”no deterioration“ concept for protected areas. The obligation to take conservation measures for bird sanctuaries in principle follows from Article 4 in connection with Annex I of the Birds Directive and Article 3 of the Birds Directive for species that are not listed in Annex I (for details see: Gellerman/Stoll/Czybulka 2012, p. 42-93).

Currently, Germany has identified ten marine protected areas (Natura 2000 sites) in the EEZ, which cover about 31.5% of Germany’s EEZ area (see in detail Nordheim/Boedeker/Krause 2012). Four of the areas are in the North Sea and six in the Baltic Sea. Two of these ten Natura 2000 sites are the "Eastern German Bight" and "Pomeranian Bay" bird sanctuaries (located in the North Sea and Baltic Sea). These were placed under protection by law. The Habitats sites have not yet been declared marine protected areas under German federal law (as of March 2014, see www.bfn.de/0314_meeres-kuesten_naturschutz.html), but have been listed as sites of community importance since 2007.

2.3.4 EU Sulphur Directive (Directive 1999/32/EC as amended by Directive 2012/33/EU of 21 November 2012 amending Directive 1999/32/EC as regards the sulphur content of marine fuels)

Directive 1999/32/EC last amended by Directive 2012/33/EU, is the central instrument of European Union legislation to reduce sulphur emissions from marine fuels. In accordance with MARPOL Annex VI, the Directive regulates the maximum limits of sulphur content in marine fuels to protect the environment and human health, in part with regard to the emission source (Articles 3a, 4a, 4b). The aim is to promote the use of low-pollutant fuels. Alternatively Article 4c of the Directive allows the continued use of moderately low-emission fuels when emission mitigation methods are implemented. According to Article 4c in connection with Annex II of the Directive, this also implies the use of emission control systems, which include scrubbers. According to Article 3a, fuels with a sulphur content exceeding 3.5% by mass, which are generally prohibited by the Directive, can still be used as long as closed-system emission mitigation methods are used. The Directive thus provides the impetus to use closed scrubbers. Open systems are allowed for fuels with a sulphur content of less than 3.5% by mass.

According to Annex II of the Directive, the provisions of MEPC Resolution 184 (59) apply to the use of exhaust gas cleaning systems: accordingly, effluents can only be discharged if the operator demonstrates that the effluents do not cause significant negative impacts on the environment and human health and their discharge does not pose any such risks. As long as the chemicals discharged by the effluent only consist of caustic soda, according to the resolution or Annex II it suffices if the effluent meets the criteria of Resolution 184 (59) and the effluent pH does not exceed 8.0. Thus Directive 1999/32/EC specifies the qualitative limits of scrubber effluent discharges.

2.4 National marine environmental law requirements

The national law of the Federal Republic of Germany falls into line with the system of inter- and supranational marine conservation law illustrated here. Two federal laws appear relevant to date with regard to the discharge of scrubber effluents, namely the Federal Nature Conservation Act (see Articles 56-58 Federal Nature Conservation Act, BNatSchG) and the Federal Water Act (WHG).

The Federal Nature Conservation Act also applies to a large extent to the areas of the territorial sea and EEZ (Article 56 BNatSchG). The discharge of scrubber effluents could be problematic in ports, internal waters and the maritime areas mentioned in terms of marine nature conservation, particularly the nature protection legal obligations for habitat protection. Article 30 Para 2 Sent 1 No. 6 BNatSchG, in particular, basically prohibits all actions that "could lead to the destruction or other significant adverse effects on the following biotopes" and specifically lists "posidonia meadows and other marine macrophyte populations, reefs, sublittoral sandbanks and silty bottoms with boring bottom megafauna and species-rich gravel, coarse sand and shell layers in marine and coastal regions".

Furthermore, the discharge of scrubber effluents from the perspective of WHG could be problematic. WHG applies in principle to coastal waters and, to a limited extent (i.e. in accordance with the MSFD), to the areas of EEZ and the continental shelf (Article 2 Para 1 and Article 3 Para 2 WHG). Insofar, the discharge of scrubber effluents into inner and coastal waters basically constitutes the use of waters in the meaning of Article 9 Para 1 No. 4 WHG. Consequently, similar discharges currently require a permission under Article 8 WHG in these areas. A water permit may only be granted under the conditions specified in Article 57 WHG, which in turn refer to "other legal requirements" and the "best available technology".

Interim conclusion: In addition to international legal requirements for protection, further protection obligations arise for the Federal Republic of Germany from current EU legislation. The MSFD in principle requires a "no deterioration" concept for Member State territorial waters and their EEZs and also the achievement of good environmental status as determined by the Member States in detail. Insofar the Federal Republic has committed itself to complying with environmental quality standards within existing EU law as well as various Ecological Quality Objectives and environmental objectives of OSPAR JAMP/CEMP. In addition, a "no deterioration" concept results from the WFD for a narrow marine coastal area on the one hand, and a requirement for improvement on the other. In particular, the Member States are required by WFD to end and terminate discharges of priority substances listed in Annex X WFD. Where scrubber effluents contain such substances, the requirement to end and terminate applies. In addition, WFD refers to the environmental quality standards of Directive 2008/105 with regard to the restriction of pollutants. The concentration of the substances referred to therein may not significantly increase in the sediments and biota covered by the Directive. A "no deterioration" concept results in particular from the provisions of the Habitats Directive and the Bird Directive with regard to existing and emerging marine Natura 2000 protected areas in the North Sea and Baltic Sea. In addition, Directive 1999/32/EC contains the EU statutory implementation of parts of the MEPC Resolution 184(59), which sets certain limits for the discharge of scrubber effluents.

Furthermore, federal German nature conservation law prohibits the deterioration or other major impairment of marine habitats in coastal waters and the EEZ. WHG already sets certain requirements for the discharge of scrubber effluents in the area of coastal waters and for internal waters as defined by UNCLOS.

3 Options for restricting the use of scrubbers under international maritime law

The implementation of the obligations mentioned for the protection of the marine environment by the Federal Republic as a coastal state must respect the freedom of navigation granted by UNCLOS. When drafting these rights by UNCLOS it was important to attempt to reconcile the flag states' interests in freedom of navigation with the interests of coastal states in protecting their territories against any environmental damage arising from shipping. From the perspective of the flag states, it was in particular necessary to limit the possibilities of coastal states to unilaterally restrict the freedom of navigation. A "legal patchwork" that would restrict free shipping and thus global trade beyond measure should be avoided. The UNCLOS approach is to balance the respective interests of coastal and flag states for the different zones specified in detail. The farther a maritime zone is from the territory of the coastal state, the lower its ability to unilaterally restrict the freedom of navigation.

3.1 Regulation options under UNCLOS

3.1.1 Regulations for vessels flying the flag of coastal states

The flag state principle is recognised by international customary law. There are different dogmatic views from which this principle stems, but there is wide consensus with regard to its regulatory content. In principle, a country like Germany can regulate all activities at sea and thus in all maritime zones applicable to vessels flying its flag. Therefore this also includes the right to restrict the discharge of effluents from the operation of scrubbers into the marine environment. The rights established by international law of third countries have to be considered (especially the right of territorial sovereignty, see König, 2010; Wolfrum 2006, p. 300). With regard to the protection of the marine environment from pollution by ships, Article 211 Para 2 UNCLOS requires that flag states ensure a minimum level of protection when enacting laws on prevention, reduction and control of pollution of the marine environment. It requires that these laws "shall at least have the same effect as that of generally accepted rules and standards established through the competent international organisation [...]", i.e. IMO.

3.1.2 Regulations for vessels from third countries

The various regulation options of coastal states such as Germany to regulate the use of scrubbers by vessels from third countries for environmental protection purposes shall be presented below against the background of the maritime zones as defined by UNCLOS. To understand the regulatory options available, we should distinguish among three types of regulation of maritime transport (see Article 194 Para 3 Sent. 2(b) UNCLOS): a) regulations of “construction, design, equipment, and manning standards [CDEMs]” (for this, see the wording of Article 21 Para 2 UNCLOS), b) discharge standards and c) navigation standards. CDEMs refer to the properties of the ship itself, the equipment and the crew qualification and constitute a far-reaching interference with the freedom of navigation. Discharge standards primarily cover the operational discharges of certain substances. Navigation standards primarily refer to the ship's routeing.

3.1.2.1 Regulation possibilities in internal waters and ports

The principle of territorial sovereignty gives coastal States the right to deny access to foreign vessels in their internal waters. As a port state, a coastal State - with few exceptions – can deny port access to foreign vessels or subject it to certain conditions (Graf Vitzthum, 2006, p. 88-91; Johnson 2004, p. 36 et seqq.). Article 25 Para 2 UNCLOS states that "in the case of ships proceeding to internal waters or a call at a port facility outside internal waters, the coastal State also has the right to take the necessary steps to prevent any breach of the conditions to which admission of those ships to internal waters or such a call is subject“. Such conditions include the terms exposed in Article 211 Para 3 UNCLOS called "particular requirements to prevent, reduce and control the pollution of the marine environment". It is crucial that these conditions also include national laws concerning the design, construction, manning or equipment of foreign ships (CDEMs) (see Bodansky, 1991, 747; Molenaar 1998, p. 103; Johnson 2004, p. 40). Discharge prohibitions of scrubber effluents have a significantly lower interference with the freedom of navigation of third countries than the CDEMs allowed under such provisions, which is why its unilateral enactment causes little concern in terms of marine international law. In cases where third-country ships are subjected to certain provisions, coastal States shall give due publicity to such requirements and shall communicate them to the competent international organisation (Article 211 Para 3 UNCLOS).

3.1.2.2 Regulation possibilities in coastal waters

According to Article 211 Para 4 UNCLOS and Article 21 Para 1(f) UNCLOS coastal States may, within their coastal waters, issue regulations for the prevention, reduction and control of marine pollution from foreign vessels, including vessels exercising the right of innocent passage. At the same time Article 21, Para 2 UNCLOS implies that these rules shall not apply to the design, construction, manning or equipment of foreign ships "unless they are giving effect to generally accepted international rules or standards". It is crucial therefore that coastal States be empowered to establish national standards for the discharge of effluents on the one hand, but must adhere to generally accepted international rules with regard to the CDEMs on the other (Bodansky, 1991, p. 750). The scheme represents a compromise. A slight interference with the freedom of shipping is possible, but a far-reaching type is not. In addition, coastal States can also unilaterally define ships' routeing and traffic separation schemes within their coastal waters (Article 22 Para 1 UNCLOS).

According to Article 211 Para 4 Sent 2 UNCLOS (and Article 24 Para 1 UNCLOS), the rules adopted by coastal States do not have the right to impede an innocent passage. In so far, the coastal State is therefore limited in its legislative and executive power. While the term "passage" is examined and defined in more detail in Article 18 UNCLOS (e.g. "without entering internal waters", "continuous and expeditiously"), Article 19 Para 1 UNCLOS states that a passage is innocent as long as it is not prejudicial to the peace, good order or security of the coastal State. Regarding pollution, Article 19 Para 2(h) UNCLOS points out that impairment of the peace, good order or security of the coastal State occurs when a foreign ship within the territorial sea commits "any act of wilful and serious pollution contrary to this Convention". Pollution must be particularly "wilful and serious" in order to qualify as a malevolent passage, thus permitting the coastal State to exercise its right to prevent this passage in accordance with Article 25 UNCLOS. The problem so far is that the UNCLOS does not exactly define what is to be understood by "wilful and serious". The degree of intent therefore remains unclear (Johnson 2004, p. 65-66; Jensen 2006, p. 21). On the other hand, it is difficult to universally assess the quantity or quality of the discharge as serious pollution (Molenaar, p. 197). As a result, it is probably reasonable and necessary to take the environmental condition of the coastal waters of the coastal State into account. As such, in an already highly polluted area a small discharge of a particular substance can mean serious environmental pollution. In this respect, coastal States are given a certain room for judgment by UNCLOS regulations (Johnson, p. 66, in its conclusion also Graf Vitzthum, p. 124)

3.1.2.3 Regulation possibilities for the area of the EEZ

The jurisdiction of coastal States in their EEZ regarding the protection and preservation of the marine environment in the context of shipping is outlined in Article 211 Para 5 and Para 6 UNCLOS. Article 211 Para 5 UNCLOS states: "Coastal States may [...] adopt laws and regulations for the prevention, reduction and control of pollution from vessels conforming to and giving effect to generally accepted international rules and standards established through the competent international organization [...]". In this respect, it is essentially possible to adopt area-based regulations for the purposes of marine conservation. This is outlined in Article 211 Para 5 UNCLOS (slightly abbreviated) which requires that the restrictions are a) established within the framework of the IMO and b) "generally accepted". According to Article 211 Para 5 UNCLOS coastal States are therefore bound by the set of IMO laws which acts as a "guardian of the freedom of free navigation" (Proelß 2010, p. 363).

In addition, Article 211 Para 6(a) UNCLOS 6 allows coastal States to adopt further shipping-related restrictions. According to Article 211 Para 6(a) UNCLOS a coastal State may take special mandatory measures within "specific and clearly defined areas of its [EEZ]" for the prevention of pollution from vessels. As concerns the coastal States such measures may be necessary for "recognized technical reasons in relation to its oceanographical and ecological conditions, as well as its utilization or the protection of its resources and the particular character of its traffic". A further prerequisite for coastal State measures is consultation with other affected States, the notification about the area to IMO and a positive decision regarding the latter with respect to the question of "whether the conditions in that area correspond to the [agreed on] requirements". Should the organisation decide in this sense, the coastal State may adopt "laws and regulations" for the selected area for the prevention, reduction and control of pollution from ships, which give effect to international rules and standards established by the organisation for the specific area. Therefore, the coastal State is in turn bound by the requirements of IMO. It is argued that the reference to "international rules and standards or shipping practices" is in fact a reference to the rules for special areas within the framework of MARPOL 73/78 (Gellerman/Stoll/Czybulka 2012, p. 281). This assumption is problematic because IMO has not adopted any clear criteria with regard to the procedure outlined in Article 211 Para 6(a) UNCLOS (Kieß 2012 § 57, Para 21). Existing shipping regulations governing IMO protected areas such as special areas, areas to be avoided or PSSAs depend, however, on the specified conditions established in the MARPOL and SOLAS Convention as well as Resolution A.982(24) IMO from 01.12.2005 on the "Revised Guidelines for the Identification and Designation of [PSSAs]", which differ from those in Article 211 Para 6(a) UNCLOS (Proelß 2006, p. 256; Proelß 2013, p. 428; Kachel 2008, p. 250 et seqq.). The question of how far-reaching coastal State measures are according to Article 211 Para 6(a) UNCLOS has not been fully answered.

The fact that there are no clear IMO guidelines for the designation process of areas in the EEZ under Article 211 Para 6 UNCLOS to date suggests that the process has no current practical importance next to the existing procedures of MARPOL and SOLAS.

In addition to the possibilities outlined in Article 211 Para 6(a) UNCLOS, coastal States can adopt "additional laws and regulations for the prevention, reduction and control of pollution from vessels" under Article 211 Para 6(c) UNCLOS. Corresponding schemes can refer only to discharges or shipping customs and expressly do not include any CDEMs.

A typical regulatory instrument in this context might include a discharge limitation, which is not listed in MARPOL annexes (Gellerman/Stoll/Czybulka 2012, p. 283) which at the time also includes discharge restrictions of scrubber effluents. In procedural terms the decree of "additional" laws and regulations requires the consent of IMO. Only when the procedure outlined in Article 211 Para 6(c) UNCLOS is completed can the corresponding laws and regulations be applied to foreign vessels from third countries. However, they are only valid in the EEZ.

3.1.2.4 International Waters

Freedom of navigation is a generally accepted norm in international waters in conjunction with the flag state principle, according to which ships in international waters are subject exclusively to the jurisdiction of their flag state (Articles 87-92 UNCLOS). Limitations are only possible under international treaties or as provided by UNCLOS. In this respect, a coastal State like the Federal Republic of Germany may determine CDEMS or restrictions in international waters only for vessels flying its flag.

Interim Conclusion: The international maritime law determines and limits the possibilities of the coastal State to regulate the discharge of scrubber effluents. In principle, Germany may adopt comprehensive arrangements regarding vessels flying its own flag. This includes initiating prohibitions, navigation requirements and CDEMs. In this respect, the general prohibition of the use of scrubbers would be just as feasible as issuing discharge regulations. Concerning third-country vessels, however, German regulatory sovereignty is limited by the freedom of navigation granted by international law. Nevertheless, Germany as a coastal State has full regulatory powers in its internal waters and ports. In principle, it can therefore deny access to ships with scrubbers on board. The same applies to smaller interventions such as the provision of discharge restrictions or to a specific routeing.

In coastal waters, the Federal Republic has the right to establish discharge restrictions and to regulate the use of scrubbers, provided that the arrangements in the latter case comply with internationally recognised guidelines. However, its executive right is partially limited by the right to innocent passage. Restrictions may be imposed only in case of a "wilful and serious pollution“ contrary to UNCLOS. The legal situation has not been clarified.

In EEZs, the Federal Republic can essentially only adopt rules regarding the use of scrubbers or the discharge of scrubber effluents that meet the regulations and standards established by IMO. There is, however, the possibility to adopt territorial restrictions. For example, Article 211 Para 6(a) UNCLOS gives the opportunity upon following the appropriate procedure to take measures for the prevention of pollution from vessels, which give effect to the rules set out by IMO for special areas. Theoretically the use of scrubbers, whose use would be regulated for special areas, would also fall under these regulations. On the other hand Article 211 Para 6(c) UNCLOS enables, after approval by the IMO, the adoption of discharge regulations for certain territories in the EEZ that would be effective against vessels flying the flag of third countries.

3.1.3 Regulation possibilities within the framework of IMO

3.1.3.1 MARPOL

Under present law, in the context of MARPOL, Annex I only is relevant to the discharge of scrubber effluents. The possibility of setting up a special area in accordance with the Annex was already implemented in North Sea and Baltic Sea. There are therefore protected areas where the discharge of oil or oily mixtures is essentially limited. Due to the existing limit (15 ppm) the existing discharge decree from Annex I has very weak to no limiting effect for the discharge of scrubber effluents. A further restriction could only occur through an amendment of Annex I.

3.1.3.2 SOLAS

The SOLAS Convention provides the option to establish areas to be avoided or ships’ routeing systems to protect the marine environment from the discharge of scrubber effluents. Since such measures have not been taken in the North Sea and Baltic Sea, this policy option is still available.

The selection and development of ships’ routeing systems is the responsibility of each government of the SOLAS Contracting Party, while IMO and its MEPC is responsible for their assignment. According to Resolution A. 575(14) the government has to consider numerous planning factors (own rights and practices with regard to resource-oriented activities, existing ships’ routeing and traffic conditions; foreseeable changes due to the development of ports or offshore activities and total existing and foreseeable offshore explorations and exploitations of the seabed; existing fishing grounds; the adequacy of existing navigational aids, charts, hydrographic conditions, environmental factors, including weather, tidal and current conditions; existing environmental protection areas and environmental protection areas to be expected; technical and natural conditions; the lack of navigability of certain areas). Routeing may also depend on the consent of all affected coastal states (Gellerman/Stoll/Czybulka 2012, p. 274). Ships' routeing systems are generally binding, as long as they comply with IMO Guidelines for ships' routeing systems of Resolution A. 572(14) and other international laws (Gellerman/Stoll/Czybulka 2012, p. 269). Hereafter, both absolute bans and restrictions depending on the class of the ship are only permissible in case of stranding risk, the need for local knowledge for safe passage and in case of concern regarding unacceptable environmental damage. The establishment of "areas to be avoided" is not restricted spatially to regions; in practice, however, it is made easier by the existence of a PSSA (Gellerman/Stoll/Czybulka 2012, p. 2).

3.1.3.3 Particularly Sensitive Sea Areas (PSSAs)

The establishment of PSSAs does not give the respective coastal state additional powers to unilaterally intervene for environmental purposes in international shipping. When establishing a PSSA a state is bound to existing international treaties and customary law (see also A. II. c. of this report). The establishment of a PSSA is initiated by one or more coastal States and shall be executed according to the IMO Resolution A.927(22) and A. 982(24). IMO decides to establish a PSSA in special environmental conditions and with regard to the vulnerability of the area in light of international shipping activities as well as availability of specific protection measures within IMO competencies, Section 1.5 Resolution A. 982(24). These safeguards include the measures outlined in Article 211 Para 6 UNCLOS. The adequate conditions for the establishment of a PSSA must be proven by the requesting coastal State.

According to Section 7.5.2. of the Annex to Resolution A. 927(22), IMO disposes over a certain regulatory flexibility in establishing PSSAs. It cannot only grant protection measures that are already part of the IMO regime but can also introduce additional new instruments (7.5.2 Part II No. 3. ii): This can be done by amending the existing IMO regulations or by adopting new rules. In case of the establishment of a new instrument, a State party may only legally appeal to it if IMO has acknowledged it in an appropriate act as a lawful and future legal basis. IMO also has the freedom to propose any permissible instrument within coastal waters and to bring forward measures in accordance with Article 211 Para 6 UNCLOS. According to Section 7.5.2. Part II No. 4 measures can include ships’ routeing, reporting requirements, unloading restrictions, operating criteria, as well as prohibitions of certain activities.

The Baltic Sea was declared a PSSA in 2005, which was preceded by the identification of the Wadden Sea in the North Sea as a Particularly Sensitive Sea Area. The parts of the North Sea outside of the Wadden Sea are thus still open to classification as a PSSA. Within the PSSA all existing protective instruments can be used and new ones can be established under the authority of IMO.

Interim conclusion: An amendment to Annex I would in principle be possible within the framework of the IMO Agreement. This would give effect to its prescribed discharge bans on oil and oily mixtures into the North Sea and Baltic Sea by means of reducing the limit values for the discharge of scrubber effluents. Determining new shipping routes in the context of SOLAS is also theoretically possible, within which particularly sensitive areas would be protected from the discharge of scrubber effluents by implementing transit restrictions. Lastly, the fact that parts of the North Sea and the Baltic Sea were qualified as PSSAs offers the Federal Republic the possibility to propose already established or new protections under a special procedure in the IMO Convention. In this respect, the selection and description of areas should be considered where scrubber effluents can only be introduced under certain conditions into the marine environment, or be eliminated completely.

4 Proposed regulations

Against the background of the performed description and analysis of the regulation requirements and regulatory options regarding the use of scrubbers and the discharge of scrubber effluents, the following will consider various regulatory options, with particular focus on two regulatory options, and will provide further recommendations.

4.1 Summary of regulatory requirements and possibilities

As a Contracting State to UNCLOS, the Federal Republic of Germany has the general obligation to protect the marine environment and to take necessary measures to prevent, reduce and control the pollution of the marine environment. These measures include those which deal with the pollution of the marine environment from ships, namely particularly ships' routeing systems, discharge regulations as well as those that regulate the "design, construction, equipment, operation and manning of vessels" (CDEMS). When taking appropriate measures Parties shall ensure that neither geographical nor medial displacement occurs nor a transformation of the targeted pollution. According to the view represented in this paper, the discharge of scrubber effluents with low pH and containing heavy metals and polycyclic hydrocarbons represents both a spatial and medial displacement and potentially a transformation of pollution from one marine environment to another. If existing international or national regulations of the Parties to UNCLOS enable this shift or transformation, they do so by contradicting the normative requirements of Article 195 UNCLOS.

In addition to the obligations set out by UNCLOS, marine environmental law requirements relating to the discharge of scrubber effluents also arise from various IMO agreements. In this respect, Annex I of MARPOL sets limits for the discharge of oil, which apply in principle also to scrubber effluents in so far as they contain oil. Currently, however, it is not sufficiently clear whether the oil components contained in scrubber effluents exceed the specified limits in individual cases, which is why the provisions of Annex I of MARPOL are most likely not applicable to scrubber effluents. There is a need for revision of the effluent guidelines, and the oil content of scrubber effluents must be determined. If these tests show that the oil content in scrubber effluents can cause damage to the marine environment, the limits outlined in Annex I of MARPOL should be verified.

In addition to the international protection requirements, the Federal Republic (and other EU Member States) is subject to further protective decrees from Union legislation. The MSFD essentially demands a ban on deterioration of the coastal waters of Member States and their EEZ. Additionally, it requires the achievement of good environmental conditions determined in detail by the Member States. Insofar the Federal Republic has agreed to comply with existing EU environmental quality standards as well as various Ecological Quality Objectives and environmental objectives of the OSPAR JAMP/CEMP.

In addition, the WFD establishes a “no deterioration” concept for narrow coastal areas on the one hand, and a requirement for improvement on the other. The WFD contains a requirement which compels Member States to end and suspend discharges of priority substances listed in Annex X WFD. Where scrubber effluents contain such substances, the requirement calls for ending and suspension. In terms of restriction of pollutants, the WFD refers to the environmental quality standards of Directive 2008/105. The concentration of the substances referred to therein may not significantly increase in sediment and biota covered by the Directive. A "no deterioration" concept is established particularly by the provisions of the Habitats Directive and the Bird Directive in terms of existing and emerging marine Natura 2000 protection areas in the North Sea and Baltic Sea.

In addition, Directive 1999/32/EC contains a Union legal implementation of the MEPC Resolution 184 (59), which sets certain limits for discharge of scrubber effluents.

The German Federal Nature Conservation Act prohibits the destruction of or other significant adverse effects on marine habitats in coastal waters and the EEZ. The WHG has already outlined certain requirements for the discharge of scrubber effluents into coastal waters within the meaning of the WHG and internal waters within the meaning of UNCLOS. On one hand, discharges are subject to authorisation, while on the other they may be granted only under the conditions specified in Article 57 WHG.

These requirements meet with the possibilities of the Federal Republic as a coastal State to regulate the discharge of scrubber effluents, specified or limited by international maritime law. The Federal Republic may essentially adopt comprehensive arrangements affecting vessels flying its own flag. This includes discharge restrictions, navigation requirements and CDEMs. In this respect, both the general prohibition of the use of scrubbers as well as the adoption of discharge requirements would be possible. Compared to third-country vessels, German regulatory sovereignty is limited by the freedom of maritime navigation granted by international law. Nevertheless, as a coastal State, Germany in principle has full regulatory powers in its internal waters and ports. As a result, it can essentially deny access to ships with scrubbers on board. The same applies to smaller operations, such as the determination of discharge limitations or a specific routeing.

In coastal waters, the Federal Republic has the right to establish discharge restrictions and to regulate the use of scrubbers provided that the arrangements in the latter case correspond with the internationally recognised guidelines. However, its executive right is partially limited by the right to innocent passage. Restrictions may be imposed only in case of a “wilful and serious pollution“ contrary to UNCLOS. The legal situation has not been fully explained to date.

In EEZs, the Federal Republic of Germany can essentially only adopt rules regarding the use of scrubbers or the discharge of scrubber effluents that meet the established rules and standards within IMO. There is, however, the possibility to adopt territorial restrictions. For example, Article 211 Para 6(a) UNCLOS grants the opportunity upon adherence to the appropriate procedure to take measures for the prevention of pollution from ships, which give effect to the rules set out by IMO for special areas. Theoretically the use of scrubbers, whose use would be regulated for special areas, would also be covered by these regulations. On the other hand Article 211 Para 6(c) UNCLOS enables – after the approval of IMO – the adoption of discharge regulations for certain territories in the EEZ that would be effective against vessels flying the flag of third countries.

An amendment to Annex I would in principle be possible within the framework of the IMO Convention. This would give effect to its prescribed discharge bans on oil and oily mixtures into the North Sea and Baltic Sea by means of reducing the limit values for the discharge of scrubber effluents. Determining new shipping routes in the context of SOLAS is also theoretically possible, within which particularly sensitive areas would be protected from the discharge of scrubber effluents by setting transit restrictions. Lastly, the fact that parts of the North Sea and the Baltic Sea were qualified as PSSAs offers the Federal Republic the possibility to propose already established or new protection measures (APMs) under a special procedure in the IMO Convention. In this respect, the selection and explanation of areas should be considered where scrubber effluents can only be introduced into the marine environment under certain conditions, or be eliminated completely.

4.2 Regulation possibilities

4.2.1 Scrubber restrictions or design requirements

From a legal perspective, regulations concerning the requirements for the entrainment and equipment of vessels with scrubbers establish so-called CDEMs. Appropriate guidelines and restrictions in this area are primarily the result of international regulations. Unilateral measures are consistent with the applicable maritime law, especially concerning own vessels and vessels flying the flag of third countries in internal waters or ports. Accordingly, particularly long-term prohibitions or regulations for the construction of scrubbers would be achievable within IMO.

From a pragmatic perspective, this approach only seems sensible as part of a long-term strategy. The scrubber technology basically enables a flexible approach to the reduction of international guidelines regarding marine-related atmospheric SO_x emissions and appears to provide an internationally desired bridging technology. A unilateral regulation by the coastal State Germany for ships under its flag or in internal waters would in any case result in a competitive disadvantage in international maritime navigation.

4.2.2 Discharge restrictions

From the point of view of international maritime law, the introduction of regulations for scrubber effluents represents a less restrictive means for regulating shipping for environmental purposes than CDEMs. Corresponding discharge provisions could be limited to certain sensitive areas or be determined in spatial terms.

4.2.2.1 Unilateral discharge restrictions

Discharge restrictions can be adopted comprehensively by a coastal State such as the Federal Republic for vessels flying its own flag. Compared to scrubber prohibitions or design requirements for scrubber systems, bans are much easier to adopt from an international maritime law perspective but also as concerns vessels flying the flag of third country. Generally binding rules on discharge can be established in internal waters and ports as well as coastal seas. In coastal seas legislative and executive powers (e.g. powers of control) are partially limited by the right to innocent passage. In the zones of the EEZ, however, the coastal State cannot establish unilateral generally binding regulations, but is insofar dependent of the approval of the IMO.

4.2.2.2 Discharge restrictions within the framework of IMO

On one hand, coastal States, in compliance with the requirements of Article 211 Para 6(c) UNCLOS and with the consent of IMO, have the possibility of initiating restrictions for areas of the EEZ. In light of the existing PSSAs in the North Sea and Baltic Sea, there is the additional possibility to propose the application of existing and creation of new legal instruments to IMO, in order to prevent marine pollution by the introduction of scrubber effluents. In this respect, territorial discharge provisions which target the potential damage from the discharge of scrubber effluents would be taken into account. These territorial restrictions could include both qualitative dilution requirements and quantitative, even complete, prohibition.

There is the option to create new protective instruments under the authority of the IMO for existing and future PSSAs (including so-called APMS). Such protection instruments can also be related to scrubbers. The establishment of a new protective instrument is preconditioned by the recognition of the instrument as legitimate by IMO; only thereafter can an appeal for the new instrument be made. The instrument may only be set up within a PSSA. Thus, in the context of the number of existing PSSAs, this option is spatially more limited, but more suitable especially in the North Sea and Baltic Sea due to existing PSSAs. Since no new instruments have been created so far for this purpose, the time required for creating a scrubber related instrument is not foreseeable. However, the option should not be considered fundamentally unsuitable.

4.2.2.3 Assessment of the alternatives

The regulation of the discharge of washwater would be a relatively flexible instrument for preventing or reducing the possibility of marine pollution. Firstly, it essentially allows the use of alternative technology of scrubbers to reduce atmospheric sulphur emissions, granting the maritime industry a degree of flexibility to adjust to the reduced sulphur emission limits. At the same time it promotes the use of more environmentally friendly scrubber types, i.e. closed wet scrubbers, hybrid systems, or possibly dry scrubbers which at least partially enable the interruption of the discharge of washwater into the marine environment during operation.

An approach which territorially limits the discharge is appropriate in light of the current state of knowledge about the potential adverse effects of the discharge of scrubber effluents into the marine environment. Potential effects have a negative impact particularly on relatively closed water areas with low water flow and low pH. In such cases, inner coastal waters and coastal seas tend to be affected. International maritime law grants extensive regulatory and executive powers to coastal States for these areas in particular. In this respect regulatory competence and environmental risks run parallel to each other.

There are two reasons for a multilateral approach: firstly, there is the interaction of EU Member States, and secondly, within the framework of IMO. A common approach adopted by EU Member States is desirable because many of the safety requirements set out are Union laws. The requirements of the WFD, the Habitats Directive and Birds Directive and the MSFD in particular favour a uniform regulatory approach. There must be demand from all sides of the EU to ensure that the rules resulting from their requirements are effective and uniformly implemented across the EU (where applicable). In addition to European Union legal considerations, the competition of ports in international navigation presents a strong case for a multilateral approach within the framework of IMO. Unilateral discharge restrictions may practically act as "competitive disadvantage" and lead to shifts of traffic flows to other ports. From an economic perspective, uniform rules can, in principle, also provide an advantage as uniformity increases the transparency of provisions and reduces transaction costs by minimising complexity.

4.2.3 Amendment of MARPOL Annex I, ship routeing systems according to SOLAS

In principle, the issue of prohibiting the discharge of scrubber effluents can only occur through an amendment of MARPOL Annex I. This course of action seems problematic for several reasons: currently, there is no reliable information about the oil content of scrubber effluents, and the extent to which the Annex should be amended is not clear. An amendment should ensure in future that scrubber manufacturers do not only merely reduce their effluent’s oil content but continue to be allowed to freely discharge other environmentally relevant substances of the effluents into the marine environment. These environmentally relevant substances are currently not covered by the Annex and would require a corresponding amendment. An amendment of the MARPOL Convention can be performed according to the procedures specified in Article 16 MARPOL 73/78. In this case, the consent of a two-thirds majority of the Parties to the Convention is required. In practical terms the process appears fairly lengthy and extensive and seems feasible rather as part of a long-term strategy.

There is also the option of setting up ship routeing systems under the SOLAS Convention. This option can also be selected within a PSSA; a ship routeing system here is then an APM, but it would still be based on SOLAS. The procedure of establishing areas to be avoided or new routes includes continuous trade-offs between economic, transportation and environmental needs. In particular, ships' routeing systems are regularly only allowed if each coastal state affected has given its consent. Thus the procedure as a whole is very extensive and time-consuming. In addition, the practical benefit of ship routeing systems in the North Sea and Baltic Sea is questionable because of the sea routes’ connections, logistics and supply function for the surrounding regions. Thus ship routeing systems should generally be regarded as a less suitable course of action.

4.2.4 Overall conclusions regarding regulatory options

Based on the legal and regulatory policy considerations discussed and current knowledge on the effect of scrubber effluents in the marine environment, limiting the discharge of scrubber effluents generally appears the most suitable tool to prevent potential damage caused by the use of scrubbers. It only constitutes a minor interference with the freedom of navigation in relation to construction requirements. At the same time, it enables a basic use of scrubber technology while taking into account the needs of marine environmental protection. An amendment to MARPOL Annex I does not appear a very promising option. The same applies to establishing ship routeing systems.

Primarily, a multilateral approach within IMO can be recommended. Territorial control of discharging scrubber effluents seems a feasible objective. The application of protection methods (APMs) within PSSAs should be taken into account in particular. Secondly, as a short-term strategy, the concentrated prohibition of discharges in the areas of internal waters and coastal waters could be regulated either in a unilateral way or together with other EU Member States. The regulatory content of this latter option, however, would remain subordinate to a multilateral regulation within IMO.

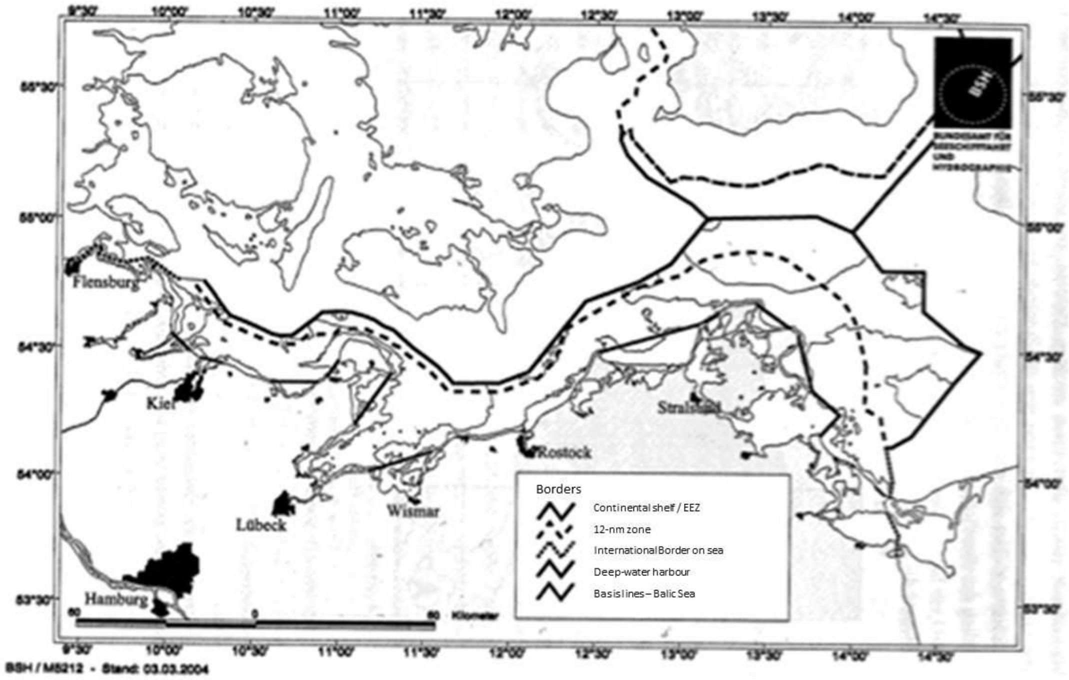

Figure 4: Maritime map according to UNCLOS (example Baltic Sea)

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6 Annex 1 Selection of current/planned ECGS

Table 21 Selection of ships with scrubbers and planned expansions

IMO No.	Name of vessel	Type	Flag	Operator		Year of scrubber install.	Area	Name of device/ manufacturer	Source
8506311	Kronprins Harald	RoPax	Bahamas	Irish Ferries	R	1991	Ireland-France	-	Kjøholt et al.
	Fjordshell	Tanker	-	-	R	1993		Kvaerner/Norske Shell	Kjøholt et al.
6705937	Louis S. St. Laurent	Ice breaker	Canada	Canadian Coastguard	R	1998	Canada	MEL/ MES	Kjøholt et al.
8917388	Leif Ericson	RoPax	Canada		R	2001	Canada	MES EcoSilencer®	Kjøholt et al.
9250098	Containerships VII	Container	Finland	Reederei Containerships Oy	R	2001	North Sea - Baltic Sea	Wärtsilä (closed loop)	wärtsilä.com
9015266	Pride of Kent	Ferry	UK	P&O Ferries	R	2005	English Channel	MES EcoSilencer®	
9156527	Zaandam	Cruiser	NL	Holland America Line	R	2007	Alaska, Antarctica, Hawaii, America	Hamworthy Krystallon	hollandamerica.com
9267560	Suula	Chem. tanker	Finland	Neste Shipping	R	2008	Baltic Sea	Wärtsilä	wärtsilä.com
9198680	Timbus	Multipurpose	Germany	Rörd Braren GmbH	R	2009	Baltic Sea	DryECGS	Couple-systems.de
9320568	Ficaria Seaways	Ferry	DK	DFDS Line	R	2009	Baltic Sea	PureSOx Alpha Laval	alfalaval.com
9164237	Alexander Maersk	Container	DK	Maersk	R	2010	Mediterranean, wordwide	MAN EGR	marinelink.com[4]
9218650	APL England	Container	Singapore	APL	R	2011	America ECA	Wärtsilä (open loop)	Wärtsilä 2013
9578957	Jolly Diamante	RoRo	Italy	Ignazio Messina	N	2011	Indian Ocean	Wärtsilä (open loop)	wärtsilä.com [1]
9330032	Liberty of The Seas	Cruiser	Bahamas	Royal Caribbean International	R	2011	Mediterranean, Caribbean, Transatlantic	GTM-R	royalcaribbean.de
9334674	Maersk Taurus	Container	Singapore	Maersk	R	2011	worldwide	Belco	Dupont.com
9233416	Balder	Handymax Bulk	Marshall Is	Klaveness Shipmanagement	R	2012	America ECA	Clean Marine (hybrid)	cleanmarine.no

9578969	Jolly Perla	RoRo	Italy	Ignazio Messina	N	2012	Indian Ocean	Wärtsilä (open loop)	Wärtsilä 2013
9345398	MV Plyca		NL	Spliethoff	R	2012	North Europe ECA	PureSOx Alpha Laval	alfalaval.com
9191321	MV Tarago	Car carrier	Norway	Wilh. Wilhelmsen ASA	R	2012	worldwide	Hamworthy Hybrid EGCS	hamworthy.com
9424053	Levana	Tanker	Gibraltar	Reederei Carl Büttner	R	2013	worldwide	SAAKE LMC-EGS	saake.com[3]
9630755	Clipper Quito	VLGC	Norway	Solvang	N	2013	America ECA	Wärtsilä (open loop)	wärtsilä.com
9613927	Equinox	Bulk carrier	Canada	Algoma Central Corp.	N	2013	Great Lakes	Wärtsila (closed loop)	wärtsilä.com
9578971	Jolly Cristallo	RoRo container	Italy	Ignazio Messina	N	2013	Indian Ocean	Wärtsilä (open loop)	Wärtsilä 2013, messinaline.it
9578983	Jolly Quarzo	RoRo container	Italy	Ignazio Messina	N	2013	Indian Ocean	Wärtsilä (open loop)	Wärtsilä 2013, messinaline.it
9649718	Oceanex Connaigra	ConRo	Canada	Oceanex Inc.	N	2013	Newfoundland + Labrador	DryECGS	Couple-systems.de
9191307	Tamesis	Auto carrier	Norway	Wilh. Wilhelmsen ASA	R	2013	worldwide	Hamworthy Krystallon	hamworthy.com
9209221	Pride of America	Cruiser	USA	NCL	R	2014		GTM-R	greentechmarine.com
	NN, NN	Chem. tanker		NYK Stolt Tankers	N	2014		Clean Marine	cleanmarine.no
9606912	Norwegian Breakaway	Cruiser	Bahamas	NCL	R	2014		GTM-R	greentechmarine.com
9195169	Norwegian Dawn	Cruiser	Bahamas	NCL	R	2014		GTM-R	greentechmarine.com
9355733	Norwegian Gem	Cruiser	Bahamas	NCL	R	2014		GTM-R	greentechmarine.com
9304045	Norwegian Jewel	Cruiser	Bahamas	NCL	R	2014		GTM-R	greentechmarine.com
9342281	Norwegian Pearl	Cruiser	Bahamas	NCL	R	2014		GTM-R	greentechmarine.com
	TBN	5 Con Ro		Spliethoff	R	2014		PureSOx	alfalaval.com
	Norwegian Escape			NCL	N	2015		GTM-R	greentechmarine.com
	Norwegian Bliss	Cruiser		NCL	N	2016		GTM-R	greentechmarine.com
9173068	Clipper Harald	LPG-Tanker	Norway	Solvang	R	04 2014	America ECA	Wärtsilä (open loop)	wärtsilä.com
9191321	Tarago	Car carrier	Norway	Wilhelmsen	R	04 2014	worldwide	Hamwothy hybrid	wartsila.com[5]

	Carnival NN	70 Cruiser		Carnival	R	2014 - 2016	US ECAs		environmentalleader.com[6]
9218131	Norwegian Sun	Cruiser	Bahamas	NCL	n/a	n/a	n/a	n/a	n/a
	TBN	VLGC		Reederei Dorian LPG Ltd	N	Q2 2014		Clean Marine	cleanmarine.no [2]
9378682	SuperSpeed 2	Ferry	Norway	ColorLine		Q4 2014		Wärtsila (4 separate open loop)	wartsila.com [7]
	TBN	VLGC		Solvang	N			Wärtsilä (hybrid)	Wärtsilä 2013
9087465	MS Robin Hood	RoPax	Germany	TT-Line	R	Q 2014	Baltic	Wärtsilä (hybrid)	ttline.com

[1] Wärtsila, http://www.wartsila.com/en/references/jolly-diamante

[2] Clean Marine, PM 13.10.2013, http://cleanmarine.no/press_room/ (combined for 1 main engine, 3 auxiliary diesels and 1 boiler)

[3] SAAKE, PM 24.10.2013 http://www.saacke.com/de/presse/carl-buettner-reederei-setzt-auf-neuartige-abgasreinigung-aus-dem-hause-saacke/

[4] http://www.marinelink.com/news/tieriii-diesel-turbo359279.aspx

[5] http://www.wartsila.com/sv/references/Tarago

[6] environmentalleader.com/2013/09/06/carnival-to-install-scrubber-technology-on-32-cruise-ships/

[7] Wärtsilä, http://www.wartsila.com/en/references/superspeed2

7 Annex 2 Statement of Endorsement - Liberty of the Seas

Statement no.: SOE 2013-0380

DNV

DET NORSKE VERITAS

STATEMENT OF ENDORSEMENT

This is to state that qualification of the

Green Tech Marine SOx scrubber for the RCCL Liberty of the Seas project

has been conducted in accordance with DNV RP-A203 Qualification of New Technology /1/ Sections 5 through 9 as reported in DNV Technical Report 2013-0380 /3/. Det Norske Veritas AS (DNV) has found that the technology can be proven Fit for Service, as defined in /2/, through the remaining planned qualification activities.

Technology owner:	Green Tech Marine AS
Name of technology:	Green Tech Marine Exhaust Gas Cleaning System
Description:	A wet scrubber type, exhaust gas cleaning system with an open loop using seawater and closed loop using seawater water and magnesium oxide for SOx emission control to meet the requirements in Marpol Annex VI.
Application:	For use on the RCCL Liberty of the Seas cruise ship.
Involvement:	DNV has taken part in and verified the Qualification Basis formulation and the Technology Assessment and evaluated the main challenges of the technology as reported in /3/.
Limitations:	The Statement of Endorsement is subject to any limitations reported in /3/.
Reference documents:	/1/ DNV-RP-A203, Qualification of New Technology, July 2011. /2/ DNV-OSS-401, Technology Qualification Management, October 2010. /3/ DNV Technical Report No. 2013-0380 Rev.0 "Technology Qualification Plan for the GTM SO_x scrubber for the RCCL Liberty of the Seas project", 2013-03-22.

DNV shall not be responsible for not having identified failure modes or causes that has resulted in loss or damage or for not having prescribed the qualification activities necessary to avoid the loss or damage.

Høvik, 2013-03-22
for Det Norske Veritas AS

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