DANISH MINISTRY OF THE ENVIRONMENT

Environmental Protection Agency

Possible Control of EU Priority Substances in Danish Waters

Technical and economic consequences examined by three scenarios

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Abbreviations

AA	Annual Average
APEO	Alkylphenol ethoxylates
BaP	Benzo(a)pyrene (a PAH)
BAT	Best Available Techniques
CBA	Cost-benefit analysis
CFC	Chloro-Fluoro-Carbons (ozone depleting substances)
CO_2	Carbon dioxide (greenhouse gas)
DEHP	Di(2-ethylhexyl)phthalate (plasticizer, mainly in PVC)
DEPA	Danish Environmental Protection Agency
DKK	Danish kroner (national currency)
DMU	Danmarks Miljøundersøgelser (in English: NERI; National Environmental Research Institute (of Denmark))
EC	European Community
ELV	End of Life Vehicles (EC Directive)
EoP	End of Production
EQS	Environmental Quality Standard
EU	European Union
FDLF	The Danish Trade Association for the Paint and Lacquer Industry
IMO	International Maritime Organisation
IPPC	Integrated Pollution Prevention and Control
LOD	Limit Of Detection
LRTAP	Long-range Transported Atmospheric Pollutants
MAC	Maximum Acceptable Concentration
µg	micro-gram (0.000001 gram)
mg	milli-gram (0.001 gram)
ng	nano-gram (0.000000001 gram)
NiCd	Nickel-Cadmium (batteries)
NOVANA	The Danish national surveillance programme for the aquatic environment and nature
NP	Nonylphenol
NPE	Nonylphenolethoxylates
NPE1-2EO	Nonylphenolethoxylates with only 1-2 ethoxy groups left (degradation product of more long-chained, commercial NPEs
NPV	Net present value

PAH	Polycyclic aromatic hydrocarbons
ppm	parts per million
PS	Priority Substances
PHS	Priority Hazardous Substances
PSD	Priority Substance Directive, proposal for (WFD Daughter Directive)
PUR	Polyurethane (polymer material)
PVC	Polyvinyl chloride (polymer (plastic) material)
RoHS	Restrictions on the use of certain hazardous substances in electronic and electrical equipment (EC Directive)
SME	Small and medium size enterprises
SPT	The Association of Danish Cosmetics, Toiletries, Soap and Detergent Industries
TBT	Tributyltin (compounds)
WFD	Water Framework Directive (2000/60/EC)
WWTP	Wastewater Treatment Plant

Summary and conclusions

This study comprises a technical and economic assessment of three scenarios for future regulation on priority substances and priority hazardous substances in Denmark. In July 2006 the Commission presented a proposal for a Directive laying down environmental quality standards for 33 priority substances and priority hazardous substances. The proposed Directive is a Daughter Directive to the Water Framework Directive which, among other things, establishes reduction targets for the two substance categories. The three scenarios are without new specific EU legislation, with specific EU legislation according to a draft proposal for a Directive as of May 2005 and with specific EU legislation according to the Commissions proposal presented in July 2006, respectively. In the report it is demonstrated that the environmental quality standards proposed by the Commission are generally met in Danish surface waters with the exception of a few substances in some parts of the country where discharge of stormwater from separate systems has great influence, in particular under summer conditions. The report suggests solutions for potential problems, including EU controls and technical solutions for the cessation of emissions, discharges and losses of priority substances according to the Water Framework Directive, and the economic consequenses are assessed.

Background and objectives

A list of 33 priority substances (PS) and priority hazardous substances (PHS) was established already in 2001 with the adoption of Decision No. 2455/2001/EC of the Council and the Parliament. A screening of these substances was initiated by Danish Environmental Protection Agency (DEPA) in late 2004 with the aim of identifying those substances for which additional national measures might be needed in order to comply with future environmental quality standards. The screening exercise resulted in a reduced list of 10 substances that have been further assessed in the present study. Two of these substances, anthracene and fluoranthene, have been assessed only as members of the group of PAH substances.

The objective of the present study was to review and assess in more detail the consequences to Denmark of implementing EU legislation on priority substances established according to the Water Framework Directive, including the Commission's official proposal for a new Directive, focussing on the following substances (selected on the basis of the results of the screening study):

Priority Substances	***Priority hazardous substances***
DEHP	Anthracene
Fluoranthene	Cadmium
Lead	Mercury
Nickel	Nonylphenol
	PAH
	Tributyltin compounds

About the study

The study has been based on three scenarios as follows:

- Scenario A: No agreement is obtained at EU level on a Daughter Directive, hence Denmark shall establish at the national level environmental quality standards and a strategy for the reduction of pollution with priority substances and priority hazardous substances according to provisions of the Water Framework Directive.

- Scenario B: Agreement is obtained at EU level on a Daughter Directive with content similar to a first draft proposal of early 2005. This draft proposal included common environmental quality standards and provisons on the progressive reduction of emissions, discharges and losses of priority substances and cessation/phase-out of emissions, discharges and losses of priority hazardous substances within 20 years.

- Scenario C: Agreement is obtained at EU level on the Commission's official proposal for a Daughter Directive (Com(2006) 397 final). The proposal includes common environmental quality standards but apart from that no new requirements or controls. Hence, Denmark shall establish at the national level a strategy for the reduction of pollution with priority substances and priority hazardous substances according to provisions of the Water Framework Directive.

In reality, for the environmental quality standards the three scenarios are alike as nationally established environmental quality standards most likely will be (almost) identical to the ones proposed by the Commission. Since in all other respects scenario A and C are the same, no distinction is made between these two scenarios in the report and its conclusions.

By contrast, distinction should be made between scenario A and C on the one hand and scenario B on the other in the binding character of the obligation of achieving the Water Framework Directive reduction target for priority substances and priority hazardous substances. The reason for doing so is that different provisions of the Water Framework Directive apply depending on whether controls are adopted at the EU level (scenario B) or at the national level (scenario A and C).

Main conclusions

From a national perspective the concentrations of priority substances and priority hazardous substances in discharges and emissions into the Danish aquatic environment seem, from a national perspective, to be so low that the ***proposed environmental quality standards*** are already complied with today. However, in the summer season for some substances, in particular nonylphenol, it is likely to be difficult to comply with the environmental quality standards in many streams in some parts of the country in connection with stormwater discharges from separate systems. Community controls appear to be the most appropriate instrument by which pollution with nonylphenol from diffuse sources and from certain products can be sufficiently reduced to complying with the environmental quality standards in surface waters adjacent to stormwater discharges.

The scenarios differ with respect to fulfilling the ***Water Framework Directive reduction target***. As regards discharges from ***point sources*** specific controls might be needed in scenario A and C only for cadmium (substitution of the substance in sacrificial anodes for small ships, no costs), mercury (filters at dental clinics and collection of mercury containing equipment, a total of 16-19 million DKK in financial costs[1]), nonylphenol (substitution of the substance in a number of products, EU control needed) and TBT (ban on use of TBT as a stabiliser in PVC, EU control needed). Additional controls might be needed in scenario B, but the scenario seems no longer topical after the Commission having presented its proposal for a new Directive.

Apparently, in any case additional controls might be needed in order to reduce pollution from ***diffuse sources*** via stormwater discharges in some parts of the country, in particular in scenario B. For all three scenarios measures have been identified that could contribute to the cessation/phasing-out of emissions, discharges and losses of priority hazardous substances. For e.g. nonylphenol, that appears to be the most problematic substance in a Danish context, introduction of Community controls, including product control, is considered being the only practical way of reducing emission of the substance at source.

Results

Considering the reduction targets of the Water Framework Directive for priority substances and priority hazardous substances a technical/economical analysis and assessment is undertaken both for each substance included in the study and for possible common measures addressing diffuse pollution via stormwater discharges from separate systems. The results are summarised in Table 1 below. The costs are indicated in present value, i.e. as a total sum that is supposed to be spread over a number of years.

[1] In present value, i.e. the annual costs will be significantly lower.

Table 1 Summary of proposed measures in Scenarios A/C and Scenario B respectively with indication of welfare-economic costs of the measures (+ financial costs in parenthesis).

Priority substance	*Action category*	*Scenario*	
		A/C *Control of emissions, discharges and losses according to the WFD*	*B* *Control of emissions, discharges and losses according to the 2005 draft proposal for a Daughter Directive*
Cadmium	Progressive reduction	None required	Existing measures sufficient
	Cessation/phase-out	Elimination of cadmium in sacrificial anodes for small ships: *No cost.* (Only "natural" replacement of old down-pipes - no additional cost) Retention arrangements for suspended solids in stormwater[1] (for cost, see stormwater)	Elimination of cadmium in sacrificial anodes or small ships: *No cost.* Replacement of old down-pipes: *1.0-6.6 (0.4-2.9) billion DKK* Retention arrangements for suspended solids in stormwater[2]
DEHP	Progressive reduction	None required	Existing measures sufficient
	Cessation/phase-out	None required	None required
Lead	Progressive reduction	None required	Existing measures sufficient
	Cessation/phase-out	None required	None required
Mercury	Progressive reduction	None required	See cessation/phase-out
	Cessation/phase-out	Mandatory mercury filters at dental clinics: *17(7) million DKK* Collection of mercury containing equipment in use in society: *26-33 (9-12) million DKK*	Mandatory mercury filters at dental clinics: *23 (10) million DKK* Collection of mercury containing equipment in use in society: *35-44 (17-21) million DKK*
Nickel	Progressive reduction	None required	Retention arrangements for suspended solids in stormwater[2]
	Cessation/phase-out	None required	None required
Nonylphenol	Progressive reduction	See cessation/phase-out (stormwater)	See cessation/phase-out
	Cessation/phase-out	Substitution of NPE in paints, cleaning products and use as hardener where possible by best available techniques (*EU action* required) Retention arrangements for suspended solids in stormwater[1] (for cost, see stormwater)	Substitution of NPE in paints, various industrial cleaning products and for the use as hardener in various products(*EU action* required): National action cost estimate *2.5-4.3 (1.0-2.0) million DKK* Retention arrangements for suspended solids in stormwater[2]
PAH	Progressive reduction	None required	See cessation/phase-out
	Cessation/phase-out	Retention arrangements for suspended solids in stormwater[1]	Retention arrangements for suspended solids in stormwater[2]

Priority substance	*Action category*	*Scenario*	
		A/C Control of emissions, discharges and losses according to the WFD	*B Control of emissions, discharges and losses according to the 2005 draft proposal for a Daughter Directive*
TBT	Progressive reduction	None required	See cessation/phase-out
	Cessation/phase-out	Banning of the use of organotin compounds as PVC stabilizers (TBT as impurity) (*EU action* required) Clean-up and safe disposal of contaminated harbour sediments Taking the non-legally binding character of the environmental objectives of the WFD (Article 4) into account, DEPA considers that implementing this measure with the aim to eliminate "losses" of TBT is unrealistic in Scenario A/C as the environmental benefits reaped will be small compared to the disadvantages and the cost.	Banning of the use of organotin compounds as PVC stabilizers (TBT as impurity) (*EU action* required) Clean-up and safe disposal of contaminated harbour sediments (as a national measure): *Between 11-39 and 27-98 (5-16 and 11-40) million DKK*

Stormwater from separate systems	Progressive reduction	See cessation/phase-out - primarily as regards nonylphenol in some parts of the country	See cessation/phase-out
	Cessation/phase-out	Retention arrangements for suspended solids in stormwater in critical areas: 40 % of all runoff with deadline 2035: Investment and O&M costs: *1.6-4.4 (1.0-2.4) billion DKK* Total, with cost of land acquisition *2.0-4.7 (1.2-2.6) billion DKK* DEPA considers that implementing this measure in Scenario A/C solely with the purpose of achieving the reduction target of cessation for priority hazardous substances is unrealistic. This is taking into account that the reduction target is of non-legally binding character, and that the environmental benefits obtained by establishing retention arrangements are small and thus disproportional to the very high cost.	Retention arrangements for suspended solids in stormwater: 85 % of all runoff with deadline 2025: Investment and O&M costs: *4.6-12.7 (3.0-7.1) billion DK* Total, with cost of land acquisition *5.6-13.9 (3.7-7.8) billion DKK*

1 As part of common action against several substances in critical areas (40 % of volume).
2 As part of common action against several substances (85 % of volume).

Sammendrag og konklusioner

Undersøgelsen omfatter en teknisk og økonomisk vurdering af tre scenarier for fremtidig regulering af prioriterede stoffer og prioriterede farlige stoffer i Danmark. Kommissionen fremsatte i juli 2006 et direktivforslag med miljøkvalitetskrav for 33 prioriterede stoffer og prioriterede farlige stoffer. Det foreslåede direktiv er et datterdirektiv til vandrammedirektivet, som bl.a. indeholder reduktionsmål for de to kategorier af stoffer. De tre scenarier er hhv. uden ny EU-lovgivning på området, EU-lovgivning som skitseret i direktivudkast af maj 2005 og EU-lovgivning som officielt foreslået af Kommissionen i juli 2006. Rapporten viser, at de miljøkvalitetskrav, som er indeholdt i Kommissionens forslag, må betegnes som allerede værende opfyldt i det danske vandmiljø med undtagelse af kravene for enkelte stoffer i nogle egne af landet, hvor udledningen af regnvand fra befæstede arealer har stor indflydelse, særligt om sommeren. Rapporten anviser løsninger for de problemer, som kan opstå, herunder både EU-regulering og tekniske muligheder for at stoppe eller udfase udledninger, emissioner og tab til vandmiljøet for prioriterede stoffer, som krævet i vandrammedirektivet, og de økonomiske konsekvenser heraf vurderes.

Baggrund og formål

En liste med 33 prioriterede stoffer (PS) og prioriterede farlige stoffer (PFS) blev vedtaget allerede i 2001 med Rådets og Europa-Parlamentets beslutning nr. 2455/2001/EF. I slutningen af 2004 blev der på Miljøstyrelsens foranledning iværksat en screening af de 33 stoffer med henblik på at identificere dem, der eventuelt kunne være behov for foretage yderligere national regulering af for at kunne overholde de kommende miljøkvalitetskrav. Screeningen resulterede i en reduceret liste på 10 stoffer, som i undersøgelsen, der rapporteres her, er blevet underkastet en nærmere vurdering. To af stofferne, anthracen og fluoranthen, er ikke vurderet særskilt, men kun som del af PAH-gruppen.

Formålet med undersøgelsen har været at foretage en mere detaljeret gennemgang og vurdering af betydningen for Danmark af at implementere EU-lovgivning under vandrammedirektivet til regulering af prioriterede stoffer, herunder Kommissionens officielle forslag til et nyt direktiv, med fokus på følgende stoffer (udvalgt på basis af screeningsundersøgelsen):

Prioriterede stoffer	***Prioriterede farlige stoffer***
Bly	Anthracen
DEHP	Cadmium
Fluoranthen	Kviksølv
Nikkel	Nonylphenol
	PAH
	Tributyltin-forbindelser

Undersøgelsen

Undersøgelsen har taget udgangspunkt i følgende tre scenarier:

- Scenarie A: Der opnås ikke enighed i EU om et datterdirektiv, og Danmark må derfor selv fastsætte miljøkvalitetskrav og fastlægge en national strategi for nedbringelse af forureningen med prioriterede stoffer og prioriterede farlige stoffer i overensstemmelse med vandrammedirektivets bestemmelser.

- Scenarie B: Der opnås enighed i EU om et datterdirektiv med indhold svarende til et første udkast til direktivforslag fra foråret 2005. Udkastet indeholdt både fælles miljøkvalitetskrav og bestemmelser om progressiv reduktion af emissioner, udledninger og tab til vandmiljøet af prioriterede stoffer og om ophør/udfasning af emissioner, udledninger og tab af prioriterede farlige stoffer inden for en tidsramme på 20 år.

- Scenarie C: Der opnås enighed om Kommissionens officielle forslag til datterdirektiv fra juli 2006 (Com(2006) 397 final). Forslaget indeholder fælles miljøkvalitetskrav, men indeholder ikke derudover nye krav eller foranstaltninger til regulering. Danmark må derfor selv fastlægge en national strategi for nedbringelse af forureningen med prioriterede stoffer og prioriterede farlige stoffer i overensstemmelse med vandrammedirektivets bestemmelser.

De tre scenarier er i praksis ens for så vidt angår miljøkvalitetskravene, idet Danmark i scenarie A sandsynligvis ville fastsætte nationale miljøkvalitetskrav svarende til eller næsten svarende til dem, som Kommissionen har foreslået. Da der heller ikke i øvrigt er forskel på scenarie A og C, behandles disse to under et i rapporten og dens konklusioner.

Derimod er der forskel mellem på den ene side scenarie A og C og på den anden side scenarie B med hensyn til den bindende karakter af forpligtelsen til at opfylde vandrammedirektivets reduktionsmål for prioriterede stoffer og prioriterede farlige stoffer. Forskellen skyldes, at forskellige bestemmelser i vandrammedirektivet skal bringes i anvendelse afhængigt af, om der vedtages foranstaltninger på fællesskabsniveau (scenarie B), eller om foranstaltninger fastsættes nationalt (scenarie A og C).

Hovedkonklusioner

Koncentrationerne af prioriterede stoffer og prioriterede farlige stoffer i udledninger og emissioner til vandmiljøet i Danmark synes fra et nationalt synspunkt at være så lave, at ***de foreslåede miljøkvalitetskrav*** kan overholdes allerede i dag. Der er dog områder af landet, hvor der i en del vandløb i sommerperioden sandsynligvis vil være problemer med overholdelse af miljøkvalitetskravene for enkelte stoffer, primært nonylphenol, i forbindelse med regnbetingede udledninger (udledning af regnvand fra veje og andre befæstede arealer). Det vurderes, at foranstaltninger på fællesskabsniveau vil være den mest hensigtsmæssige måde, hvorpå forureningen med nonylphenol fra diffuse kilder og visse produkter kan begrænses tilstrækkeligt til, at miljøkvalitetskravet kan overholdes ved de regnbetingede udledninger.

Der er forskel mellem scenarierne med hensyn til opfyldelse af ***vandrammedirektivets reduktionsmål***. For udledning fra ***punktkilder*** synes der i scenarie A og C kun at kunne blive behov for en specifik regulering i forhold til cadmium (substitution af stoffet i offeranoder til små skibe, ingen omkostninger), kviksølv (filtre på tandlægeklinikker og indsamling af kviksølvholdigt udstyr mv., i alt 16-19 mio. DKK i finansielle omkostninger[2]), nonylphenol (substitution af stoffet i flere produkter, EU-regulering påkrævet) og TBT (forbud mod brug af organotin som stabilisator i PVC, EU-regulering påkrævet). I scenarie B vil der kunne blive behov for yderligere tiltag, men med

[2] Opgjort som nutidsværdier, dvs. at de årlige omkostninger vil være betydeligt lavere.

fremsættelsen af Kommissionens direktivforslag synes dette scenarie ikke længere at være aktuelt.

Der synes i alle tilfælde at kunne blive behov for yderligere regulering i forhold til forurening fra ***diffuse kilder*** via regnbetingede udledninger i en del af landet, navnlig i scenarie B. Der er her for alle tre scenarier identificeret tiltag, der ville kunne bidrage til ophør/udfasning af emissioner, udledninger og tab af prioriterede farlige stoffer. For bl.a. nonylphenol, som synes at være det mest problematiske stof i dansk sammenhæng, peges på regulering på fællesskabsniveau, herunder produktregulering, som den eneste realistiske mulighed for at reducere udledning af stoffet ved kilden.

Projektresultater

Med udgangspunkt i vandrammedirektivets reduktionsmål for prioriterede stoffer og prioriterede farlige stoffer er der i rapporten foretaget en teknisk/økonomisk analyse og vurdering dels af de enkelte undersøgte stoffer og dels af en eventuel generel foranstaltning rettet mod forureningen fra diffuse kilder via regnbetingede udledninger. Resultaterne heraf er opsummeret i omstående tabel 1. Omkostningerne er opgjort som nutidsværdier, dvs. som et engangsbeløb, der forudsættes fordelt over en kortere eller længere årrække.

Tabel 1 Resumé af mulige foranstaltninger til regulering af prioriterede stoffer og prioriterede farlige stoffer i scenarie A/C og B samt tilhørende velfærdsøkonomiske omkostninger (finansielle omkostninger i parentes).

PS/PFS	*Reduktionsmål*	*Scenarie*	
		A/C *Regulering af udledninger, emissioner og tab i henhold til vandrammedirektivet*	*B* *Regulering af udledninger, emissioner og tab i henhold til 2005-udkast til datterdirektiv*
Cadmium	Progressiv reduktion	Intet behov	Nuværende indsats tilstrækkelig
	Ophør/udfasning	Substitution af cadmium i offeranoder til små skibe: *Ingen ekstra omkostning* (Kun "naturlig" udfasning af zinktagrender og nedløbsrør fra før 1980, dvs. ingen ekstra omkostninger). Systemer til tilbageholdelse af suspenderet stof i separate regnudløb[1]	Substitution af cadmium i offeranodertil små skibe: *Ingen ekstra omkostning* Udfasning af zinktagrender/nedløbsrør fra før 1980, der stadig er i brug om 20 år: *1,0-6,6 (0,4-2,9) milliarder DKK* Systemer til tilbageholdelse af suspenderet stof i separate regnudløb[2]
DEHP	Progressiv reduktion	Intet behov	Nuværende indsats tilstrækkelig
	Ophør/udfasning	Intet behov	Intet behov
Bly	Progressiv reduktion	Intet behov	Nuværende indsats tilstrækkelig
	Ophør/udfasning	Intet behov	Intet behov
Kviksølv	Progressiv reduktion	Intet behov	Se ophør/udfasning
	Ophør/udfasning	Tvungen brug af kviksølvfiltre på tandlægeklinikker: *17 (7) millioner DKK* Indsamling af kviksølvholdige udstyr og produkter i samfundet: *26-33 (9-12) millioner DKK*	Tvungen brug af kviksølvfiltre på tandlægeklinikker: *23 (10) millioner DKK* Indsamling af kviksølvholdige udstyr og produkter i samfundet: *35-44 (17-21) millioner DKK*
Nikkel	Progressiv reduktion	Intet behov	Systemer til tilbageholdelse af suspenderet stof i separate regnudløb[2]
	Ophør/udfasning	Intet behov	Intet behov
Nonylphenol	Progressiv reduktion	Se ophør/udfasning (kun regnbetingede udløb) (for omkostninger, se disse)	Se ophør/udfasning
	Ophør/udfasning	Substitution af NPE i malinger, industrielle rengøringsmidler og ved brug som hærder, hvor muligt ved bedste tilgængelige teknik (*EU indsats*) Systemer til tilbageholdelse af suspenderet stof i separate regnudløb[1]	Substitution af NPE i malinger, industrielle rengøringsmidler og hærdere (*EU indsats*). Nationale omkostninger anslås til *2,5-4,3 (1,0-2,0) millioner DKK* Systemer til tilbageholdelse af suspenderet stof i separate regnudløb[2]
PAH	Progressiv reduktion	Intet behov	Se ophør/udfasning
	Ophør/udfasning	Systemer til tilbageholdelse af suspenderet stof i separate regnudløb[1]	Systemer til tilbageholdelse af suspenderet stof i separate regnudløb[2]

PS/PFS	*Reduktionsmål*	*Scenarie*	
		A/C *Regulering af udledninger, emissioner og tab i henhold til vandrammedirektivet*	*B* *Regulering af udledninger, emissioner og tab i henhold til 2005-udkast til datterdirektiv*
TBT	Progressiv reduktion	Intet behov	Se ophør/udfasning
	Ophør/udfasning	Forbud mod brug af organotin som stabilisator i PVC (TBT som urenhed) (*EU indsats*) Oprensning og deponering af TBT-forurenede havnesedimenter Da miljømålet om standsning eller udfasning af emissioner, udledninger og tab af prioriterede farlige stoffer i Scenarie A/C ikke er af juridisk bindende karakter, vurderer MST, at oprensning og deponering af havnesedimenter alene med det formål at standse "tab" af TBT vil være urealistisk i dette scenarie da den opnåelige miljøgevinst er lille i forhold til ulemper og omkostninger.	Forbud mod brug af organotin som stabilisator i PVC (TBT som urenhed) (*EU indsats*) Oprensning og deponering af TBT-forurenede havnesedimenter. Som rent national indsats: *11-39 eller 27-98 (5-16 eller 11-40) mio. DKK*

Regnbetingede udløb fra separat-systemer	Progressiv reduktion	Se ophør/udfasning - primært med hensyn til nonylphenol i nogle egne af landet	Se ophør/udfasning
	Ophør/udfasning	Systemer til tilbageholdelse af suspenderet stof i separate regnudløb[1] 40 % af alle udløb med tidsfrist 2035: Anlægs- og driftsomkostninger: *1,6-4,4 (1,0-2,4) milliarder DKK* Total incl. erhvervelse af arealer: *2,0-4,7 (1,2-2,6) milliarder DKK* Da miljømålet om standsning eller udfasning af emissioner, udledninger og tab af prioriterede farlige stoffer i Scenarie A/C ikke er af juridisk bindende karakter, vurderer MST, at etablering af tilbageholdelsessystemer på regnudløb alene med dette formål vil være urealistisk i dette scenarie da omkostningerne ved implementering er meget store og den opnåelige miljøgevinst begrænset.	Systemer til tilbageholdelse af suspenderet stof i separate regnudløb[2] 85 % af alle udløb med tidsfrist 2025: Anlægs- og driftsomkostninger: *4,6-12,7 (3,0-7,1) milliarder DKK* Total incl. erhvervelse af arealer: *5,6-13,9 (3,7-7,8) milliarder DKK*

[1] Som del af fælles foranstaltning mod adskillige stoffer i kritiske områder (40 % af volumen).
[2] Som del af fælles foranstaltning mod adskillige stoffer (85 % af volumen).

1 Introduction

1.1 Background

The Water Framework Directive (2000/60/EC) was issued to establish a new, comprehensive regime for the protection of inland surface waters, transitional waters, coastal waters and groundwater ***inter alia*** through measures against chemical pollution by priority (hazardous) substances (***Article 1, c***). The WFD ***Article 16*** requires the Commission to bring forward specific proposals for priority substances in surface waters.

The WFD specifies the long-term goals for priority substances which are

- to prevent deterioration for surface and groundwater;
- to achieve good chemical status for surface water and groundwater in 2015 by protection, enhancement and restoration of all surface water and groundwater bodies;
- to progressively reduce pollution from priority substances and ceasing or phasing out emissions, discharges and losses of priority hazardous substances to surface waters.

The list of priority substances (including proposals for priority hazardous substances) was established already in 2001 by Decision no. 2455/2001/EC of the European Parliament and of the Council. Since then work has been ongoing in the Commission to prepare the scientific basis for a Daughter Directive of the WFD intended to establish, among others, environmental quality standards (EQS) for the priority substances (PS), identify the substances to be regarded as priority hazardous substances (PHS), and define the regulatory requirements applying to these substances.

In the autumn of 2004, the Danish Environmental Protection Agency (DEPA) received a draft list of EQSs for the priority substances. As a first step towards assessing the consequences for Denmark of the anticipated Daughter Directive, DEPA decided to undertake a screening exercise to clarify to what extent achieving compliance with the EQSs would require further action by Denmark.

As summarised in Chapter 2 of the report, the screening found that for most of the substances the current levels in discharges and in the aquatic environment in Denmark already comply with the Annual Average (AA) EQS (or, in the case of stormwater, the Maximum Allowed Concentration (MAC) EQS), while 10 substances would potentially require implementation of additional national measures.

In July 2005, an unofficial draft Daughter Directive was made available comprising the mentioned EQSs, a list of PHSs, and requirements to the progressive reduction or phase-out or cessation of emissions, discharges and losses of PSs and PHSs respectively. The main parts of this report were prepared based on this draft version of the Daughter Directive.

However, it was found that the official Daughter Directive proposal (COM(2006) 397 final) released in July 2006had been significantly changed compared with the 2005 draft. It was therefore decided to review the report once more, reconsider the assessments made based on the draft proposal and define an additional impact scenario to accommodate the changes made to the official directive proposal from the Commission.

1.2 Objectives

The objective of this study is to make a technical and economic assessment of the consequences for Denmark of implementing the Priority Substances Daughter Directive. The assessment is intended to serve as part of the basis for national political decision-making on the issue.

1.3 Project implementation

The first phase of the study was initiated in September 2005 and completed in January 2006 while Phase 2, the revision based on the official Daughter Directive proposal, was conducted from July to September 2006.

The work was carried out by a team of COWI A/S consultants consisting of Jesper Kjølholt (project manager), Dorte Vigsø, Peter Engbo Rasmussen, Erik Hansen, Klaus Winther Ringgaard and Karsten Arnbjerg.

A "task force" at DEPA consisting of Lis Morthorst Munk (project responsible), Steen Pedersen, Alf Aagaard, Elisabeth Paludan, Jørgen Schou, Jens Brøgger Jensen, Vibeke Vestergaard Nielsen and Susanne Rasmussen participated actively during the implementation of the project, in particular in the process of clarifying methodological issues.

2 Technical analysis and assessment

2.1 Introduction

Much of the technical description and analysis of the current situation of each of the priority substances presented in this report was made already in the screening project mentioned in Chapter 1, which was conducted in 2004-2005. The results of the screening project are presented in a separate report.

However, some updating and further elaboration of the information and data from the screening report was carried out as part of the current project using publicly available literature although the emphasis was on identifying measures to reduce the current discharges, emissions and losses, where necessary, and to assess the economic consequences to society, private enterprises and consumers.

Whereas the screening project addressed all 33 priority substances established by Decision no. 2455/2001/EC, this project has focused strictly on the substances for which the screening project found that the current concentrations in discharges into or in the aquatic environment itself most likely exceed the environmental quality objectives (EQS) proposed in the draft Daughter Directive.

A brief summary and overview of the main findings and conclusions of the screening project are presented in Section 2.2 below. The subsequent sections of this chapter address the scope and delimitation of the project with respect to the various sub-groups of substances included in the Daughter Directive proposal and present the principles applied to assess the compliance of each of the selected substances with the proposed EQS.

As mentioned in Chapter 1, Introduction, work was carried out in two phases; Phase 1 in the autumn of 2005 based on a draft version of the Daughter Directive proposal and Phase 2 in the summer-early autumn of 2006 based on the official proposal.

The main changes of the official Daughter Directive proposal (COM(2006) 397 final) compared with the 2005 draft are the following:

(1) Contrary to the draft version, the official version does not specify obligations applicable to the Member States regarding progressive reduction or cessation/phase-out of priority (hazardous) substances, and

(2) some of the previously proposed EQS values have been changed, and, further, in the official version some of the previously proposed MAC-EQS values have been omitted (replaced by "not applicable").

2.2 Screening of the 33 priority substances

A national screening level review of consumption, uses, current environmental regulation, pollution sources and occurrence in the aquatic environment was conducted in 2004-2005 for the 33 priority substances established under the Water Framework Directive" (WFD; 2000/60/EC) by the Parliament's and the Council's Decision no. 2455/2001/EC. The aim of the screening was to clarify to what extent further national regulatory measures were likely to be needed in relation to an anticipated WFD Daughter Directive on these substances /1/.

At the time of the screening only the unofficial draft proposals for the annual average (AA) and maximum acceptable concentration (MAC) values of the environmental quality standards (AA-EQS and MAC-EQS, respectively) for the 33 substances were known while other possible requirements to be included in the directive were still under consideration by the Commission.

Table 2-1 provides an overview of the 33 priority substances together with an assessment of their "relevance", i.e. the possible need for further national regulation in Denmark based on the results of the screening level review.

For 10 of the 33 substances it was assessed that it would be relevant for Denmark to evaluate the need for and/or type of further national regulation more thoroughly because there is documentation or strong indications that these substances may occur in the Danish aquatic environment in concentrations above the proposed EQS. A "strong indication" is e.g. if a substance often occurs in wastewater discharges in concentrations significantly higher than the proposed EQS. The substances thus singled out do not necessarily pose a problem in all discharges or in the aquatic environment in general, but on the other hand, they are not limited to just a few special cases. For these substances, it is considered likely that action by Denmark will be required due to the forthcoming Daughter Directive.

As for 20 substances, it was assessed that further national regulatory measures would not be relevant as the substances are not produced or used in Denmark and/or because the concentrations in discharges into the aquatic environment are already now significantly below the proposed EQS values. Another 3 substances probably belong to this category as well, but some reservations about the assessment had to be made due to lack of concrete data. It could not be excluded that for a few of these 23 substances, there are specific cases where a discharge would result in a local violation of the EQS.

For some of the 10 substances singled out as possible items for further national action, it was found that the possible measures required to comply with the EQS would have to address aquatic pollution of a purely historical character as the necessary regulation of uses (including total bans) of the substances in question was already implemented.

Table 2-1
Overview of the 33 priority substances under the Water Framework Directive including an assessment of the needs for further national regulation in Denmark.

Name of substance (No., WFD Annex X)	*Relevant*	*Not relevant*	*Relevance uncertain*	*Comments*
Alachlor (1)		x		No sale since 1986.
Anthracene (2)	(x)			Relevant only in relation to general measures towards PAH.

Name of substance (No., WFD Annex X)	*Relevant*	*Not relevant*	*Relevance uncertain*	*Comments*
Atrazine (3)		x		No sale since 1994. Env. conc. < EQS
Benzene (4)		x		Conc. in discharges < EQS
Brominated diphenylethers (5)		(x)	x	Few environmental data and very low EQS. Concentration trends should be evaluated regularly.
Cadmium + compounds (6)	x			Many sources. Occurs in discharges at levels > EQS
C_{10-13}-chloroalkanes (7)		x	x	Probably not relevant, but very few concrete data available
Chlorfenvinphos (8)		x		No sale since 2000 (small).
Chlorpyrifos (9)		x		Sale small. Marginal releases to aquatic environment.
1,2-Dichloroethane (10)		x		Very marginal use. Very volatile substance.
Dichloromethane (11)		x		Conc. in discharges significantly < EQS, but lack of environmental data. Volatile substance.
Di(2-ethylhexyl)phthalate (12)	x			Widespread use. Conc. in discharges > EQS.
Diuron (13)		x		Still some use as herbicide but resulting environmental conc. hardly > EQS. Use as antifouling agent has practically ceased now.
Endosulfan (14)		x		No sale since 1994.
Fluoranthene (15)	(x)			Relevant only in relation to general measures towards PAH.
Hexachlorobenzene (16)		x		Substance banned. Not is wastewater but possibly in low conc. in rain runoff from separate systems.
Hexachlorobutadiene (17)		x		No production or use in Denmark.
γ-HCH, Lindane(18)		x		No sale since 1994. Not found in discharges-
Isoproturon (19)		x		No sale since 2000. Isoproturon may become relevant again as it has recently been approved by the EU for use as herbicide.
Lead + compounds (20)	x			Still widespread use. Occurs in discharges > EQS.
Mercury + compounds (21)	x			Still some specific uses. Occurs in discharges > EQS. Concentration trends should be evaluated regularly.
Naphthalene (22)		x	x	Widespread occurrence, but conc. in discharges < EQS. Possibly some specific point sources exist.
Nickel + compounds (23)	x			Widespread use. Occurs in discharges > EQS.
Nonylphenol (24)	x			Limited use today, but occurs in discharges > EQS. Trends following regulation of uses should be monitored
Octylphenol (25)		x		Very limited use and conc. in discharges generally well below the EQS. However, only few data available.
Pentachlorobenzene (26)		x		No production or use. No occurrence in discharges.
Pentachlorophenol (27)		x		Occurs in discharges but < EQS.
PAH (28)	x			Conc. in urban rain runoff (separate systems) > EQS.
Simazine (29)		x		Substance recently banned in DK/EU. Conc. < EQS.
Tributyltin compounds (30)	x			Marginal use today, but elevated levels in harbours.
Trichlorobenzene (31)		x		Negligible use and conc. in discharges < EQS.
Trichloromethane (32)		x		Conc. in discharges well below EQS.
Trifluralin (33)		x		No sale since 1998 (except small exemptions granted).

2.3 The selected priority substances

2.3.1 Priority substances

Based on the outcome of the screening project the following 8 (10) priority substances were selected for further analysis and assessment of the economic consequences of implementing the necessary measures to comply with the EQS and other anticipated requirements of the final Daughter Directive:

- Cadmium
- DEHP
- Lead
- Mercury
- Nickel
- Nonylphenol
- PAH (including anthracene and fluoranthene)
- Tributyltin compounds (TBT)

In the screening project 10 substances were pointed out for further analysis and assessment. However, two of the selected substances - anthracene and fluoranthene - were not found to require further action as single substances but only in relation to general actions targeted at the PAH group. Chemically, anthracene and fluoranthene belong to the group of polycyclic aromatic hydrocarbons (PAHs) though not formally included in the list of substances representing this group in the Daughter Directive. Therefore, in reality the current study only comprises 8 substances/groups of substances.

2.3.2 Priority hazardous substances

The final Daughter Directive proposal identifies 13 of the 33 priority substances (PS) as priority hazardous substances (PHS) for which certain, stricter requirements apply, mainly for controls to ensure

> ***"the cessation or phasing out of discharges, emissions and losses of priority hazardous substances",***

irrespective of whether these substances are assessed to comply with the EQS or not (according to the Water Framework Directive).

Among the PS identified for possible further national action in Denmark, the following 6 are also defined as PHS:

- Anthracene
- Cadmium
- Mercury
- Nonylphenol
- PAH
- TBT

Thus, among the PS selected for this study only DEHP, fluoranthene, lead and nickel are not PHS.

2.4 The not-selected priority substances

As mentioned in Section 2.2, the screening project found that 23 out of the 33 priority substances included in the final Daughter Directive proposal would require further national measures/actions in order to comply with the EQS values proposed at that time. A brief, updated assessment of these 23 substances in relation to the Commission's official directive proposal is made in Chapter 12.

2.5 Losses of priority hazardous substances from contaminated sites

According to the Water Framework Directive cessation of "losses" of priority hazardous substances to the aquatic environment should eventually be achieved by means of appropriate control measures, where needed. Such "losses" are considered to occur predominantly as a result of seepage or leaching of the substances from contaminated (historical or present) industrial sites or depots located adjacent or close to surface waters or at locations with very permeable sub-surface layers.

Presently, almost 20,000 contaminated sites have been registered in Denmark /2/ of which, however, the majority are small sites. Further, most sites and depots are thought to be located at some distance from surface water bodies thus rendering the risk of surface contamination insignificant.

A few major sites in the vicinity of streams, lakes or the coast do exist. 11 major sites have been identified at which the cost of remediation is estimated to exceed DKK 30 million. At 7-8 out of the 11 sites, surface water bodies are known to be contaminated already or considered to be at risk. At some of the sites the pollution may comprise one or more of the priority hazardous substances covered by the Daughter Directive e.g. cadmium, mercury and PAH. However, actions to eliminate the pollution from these sites are already planned or even ongoing.

The (by far) most common types of contamination are various types of oil, gasoline and various solvents including those used for dry cleaning. Also, heavy metal contamination of soil is frequently reported but rarely in relation to risk to surface waters. Data on other specific contaminants are difficult to extract from published, aggregated reports on the subject, and it will require a more focused, in-depth analysis to determine to what extent PHSs are part of the problem.

Overall, it is the impression that the major loads of contaminants into surface waters in Denmark originate from emissions or discharges while only a minor part is the result of seepage/leaching from contaminated sites of which the largest are being addressed already. However, it was decided to verify this assessment through a special study on the issue, which will be reported separately.

The study will also include an assessment of extent to which the proposed EQS values for inland or other surface waters are exceeded as a result of impact from contaminated sites. This is not possible to extract from the mentioned report on the state of soil contamination in Denmark /2/.

2.6 Priority hazardous substances in biota

Article 2.3 of the officially proposed Daughter Directive defines maximum allowable concentrations in biota for three PHSs, i.e. concentrations which must not be exceeded in prey tissue (wet weight; ww) of fish, molluscs, crustaceans and other biota:

a. 10 g/kg ww for hexachlorobenzene (HCB),
b. 55 g/kg ww for hexachlorobutadiene (HCBD),
c. 20 g/kg ww for methyl-mercury.

In 2005, the Danish Veterinary and Food Administration (DVFA) published monitoring data for HCB and mercury (but not methyl-mercury) for a significant number of food items, including some fish species /3/.

For HCB, all data on whole fish (mainly marine species) show compliance at the 90 % percentile level with the proposed maximum concentration of 10 µg HCB/kg ww. Only the content of HCB in cod liver (in which a lipophile substance such as HCB is concentrated) from certain parts of the Danish marine environment (the Baltic Sea, the Sound and the Belts) exceeds the limit value with up to a factor of 2.3 (90 % percentile, Baltic Sea).

The National Environmental Research Institute (NERI) recently presented data on HCB in liver from flatfish caught in different parts of Denmark /4/. The levels range from 0.7 to 1.8 µg HCB/kg ww, i.e. well below the limit value.

Overall, the present HCB levels in biota are considered to comply with the limit value.

No Danish monitoring data on methyl-mercury in aquatic biota have been identified but according to UNEP's "Global Mercury Assessment" (/5/) "The US EPA states in an updated mercury overview paper that in most adult fish, 90 to 100 percent of the mercury content is methyl mercury". Therefore, the total content of mercury in fish as reported in the "Chemical contaminants" report by the DVFA (/3/) is considered to provide a fully satisfactory picture of the situation.

The following concentrations of total mercury (90 % percentile of data) were reported for some of the most common fish species (whole fish):

Cod: 94.7 µg/kg ww (30 samples),
Herring: 64.5 µg/kg ww (18 samples), and
Plaice: 72.4 µg/kg ww (21 samples).

As the proposed limit value for methyl mercury is only 20 µg/kg ww, and as also the median concentrations of mercury in the same three species exceeded this value, it is concluded that presently the (methyl) mercury levels in aquatic biota in Denmark cannot presently be considered as compliant with the requirements in the proposed new Daughter Directive. As the contamination appears to be widespread, on-site clean-up will not be possible, and the only way of actively contributing to a reduction of the current mercury levels in biota is then to further control the existing sources.

Possible actions to reduce the emissions and discharges of mercury in Denmark are described and assessed in Chapter 7.

HCBD has never been monitored in biota in Denmark but the substance has no use in Danish industry, and it was deleted from the national surveillance programme for the aquatic environment and nature (NOVA2003, now NOVANA) because the first rounds of monitoring consistently showed that the concentrations (in water) were below the detection limit. It is therefore considered very unlikely that HCBD should occur in biota at levels equal to or higher than the limit value.

2.7 Other pollutants

The final Daughter Directive also establishes EQSs for a number of "other pollutants" (Annex I, Part B), i.e. some chemicals that are not priority substances but substances which were previously included in a number of directives that will be repealed by 2013 (Directives 82/176/EEC, 83/513/EEC, 84/456/EEC, 84/491/EEC and 86/280/EEC).

The substances included in this group are:

- DDT
- Aldrin
- Dieldrin
- Endrin
- Isodrin
- Carbontetrachloride
- Tetrachloroethylene
- Trichloroethylene

The first five are chlorinated insecticides, which have not been used or permitted for use in Denmark for a considerable number of years, while the three last substances are aliphatic chlorinated solvents of which carbon tetrachloride has only had very restricted use for many years while the two others have been used extensively until rather recently (and are still being used).

Among the chlorinated insecticides, isodrin has never been used in Denmark, while aldrin and endrin have not been on the market since 1963 and heptachlor not since 1972. DDT was banned for agricultural uses in 1970 and other uses were completely banned in 1984. Dieldrin was used in certain wood preservation products until 1988 when it was completely banned for use in Denmark.

For a number of years, chlorinated insecticides were included in the point source part of the national surveillance programme for the aquatic environment, NOVA 2003, but were left out when the programme was revised in 2002-2003 (to become the present NOVANA programme) because the levels had been under the detection limit of 0.01 µg/L in practically all samples during the preceding period.

Trichloroethylene and tetrachloroethylene are both included in the point source part of the NOVA 2003/NOVANA programme while carbon tetrachloride has been omitted due to its insignificant use. The proposed AA_EQS is 10 µg/L for both substances (and 12 for carbon tetrachloride).

In the 2003 survey report of the NOVA 2003 programme the 95 % percentile of effluent measurements at 30 wastewater treatment plants was 0.07 µg/L for trichloroethylene and 0.08 µg/L for tetrachloroethylene while the 95 % percentile of the influent concentrations was 0.7 and 0.5 µg/L respectively/7/.

As WWTP effluents are considered to be the main source of contamination of the aquatic environment with these substances, none of the substances are believed to exceed the proposed EQS values for surface waters.

2.8 Principles for assessment of EQS compliance

The priority substances must, when they occur in inland, transitional or coastal surface waters, at all times comply with the MAC-EQS established and on the average over a period of one year comply with the AA-EQS. However, often data on the occurrence of the PS defined under the Daughter Directive in aquatic environment are very sparse or completely absent while some data on the concentration of the substances in various discharges and emissions, primarily of sewage effluent and stormwater from separate systems, exist. Hence, in many cases the assessment of EQS compliance must rely on an interpretation of such data rather than being based on monitoring data from surface waters.

For this purpose the following principles have been applied:

- For all wastewater and stormwater discharges an initial dilution of sewage effluent or stormwater discharges of up to 10 times is permissible before the EQS must be complied with;

- For discharges directly into the (coastal) marine environment the use of an initial dilution factor of 10-50 has been proposed for regulatory purposes in Denmark (/6/) and the average of 30 will be used here;

- For stormwater the MAC-EQS that must be complied with while for sewage effluents both the MAC- and the AA-EQS requirements must be fulfilled;

- Compliance with the AA-EQS is considered to be reached if the 95% percentile of the averages of the monitoring data from each WWTP included in the NOVA 2003/NOVANA-programme are below the relevant AA-EQS;

- Danish monitoring data for metals are typically based on the total content in a sample, and data have therefore been adjusted (estimated particle bound fraction subtracted) to obtain the "dissolved" concentrations, i.e. the concentrations on which the Daughter Directive's EQS values for metals are based.

2.9 References

/1/ Kjølholt J, Winther Ringgaard K, Skårup S (2006). Kilder og miljøtilstand for prioriterede stoffer under Vandrammedirektivet. Miljøprojekt nr. XXXX (in press). Danish Environmental Protection Agency.

/2/ DEPA: "Redegørelse om jordforurening 2004", Redegørelse Nr. 4 fra Miljøstyrelsen, 2005.

/3/ DVFA (2005). Chemical contaminants. Food monitoring, 1998-2003. Part 1.

/4/ NERI (2006). Hazardous substances and heavy metals in the aquatic environment. State and trends, 1998-2003. The National Environmental Research Institute, Report no. 585, 2006.

/5/ UNEP (2002). Global Mercury Assessment. UNEP Chemicals, Geneva, 2002.

/6/ Miljøstyrelsen (2002). Udledning af miljøfarlige stoffer med spildevand. Miljøprojekt nr. 690, Miljøstyrelsen 2002.

/7/ Miljøstyrelsen (2004). Punktkilder 2003. Orientering nr. 16, 2004 fra Miljøstyrelsen.

3 Economic analysis and assessment

3.1 Approach and methodology

The aim of the economic assessment in this analysis is to give an indicative estimate of the total cost of complying with the proposed WFD Daughter Directive on priority substances. For the purpose of assessing the cost of implementing the Daughter Directive, a number of scenarios have been constructed (see section 3.3 below).

The total cost of compliance must be based on an estimation of the most cost-effective policy strategy or "policy package". Such a strategy is, in turn, based on the findings of the technical assessment of the need for action and relevant/possible measures for the individual substances. Also, the cost of a common measure directed at all substances is estimated by looking at the cost associated with detention of stormwater runoff. Due to the limited scope of this assessment and the gaps in data, the economic assessment is supplemented with some general recommendations based on previous experience with regulation of chemical use (se section 3.2 below).

The methodology used in this assessment is a welfare-economic cost assessment in accordance with the principles laid down by DEPA/the Ministry of the Environment in their guidelines (Møller, Andersen, Grau et al. 2000). Both financial cost to industry and consumers and economic cost to the society as a whole are presented where possible. This is also in accordance with the guidance document from WATECO, which focuses on providing the basis for both welfare economic cost-effectiveness and financing strategies (WATECO/European Communities, (2003).

Economic analyses can be made on different levels depending on the purpose of the analysis and the nature of the initiative to be assessed. Normally, economic analyses are divided into the following groups:

- ***Financial analyses*** assess the purely financial effects (that is, analysis of cash flows) of an initiative for one or more well-defined groups of the economy. It may be for a certain company, for a branch of industry, municipalities, households, the state, or any other group. The financial analysis assesses the cash flow effects from a certain agent or group of agent's point of view. Following this, it is not very often a sufficient tool for economic analysis, since the loss is often fully or partly a gain for another group in society. The financial analysis, however, has its advantages in its ability to assess implicitly income distribution consequences of an initiative at least for the group or groups in focus. Since income distribution is often an aspect of interest in connection with economic assessment, financial analysis is a useful element of the assessment. When assessing financial cost, we look at producers' prices without VAT or other taxes.

- ***Welfare economic analyses*** aim at assessing all the effects - monetary as well as non-monetary - of an initiative on society as a whole. In principle, this includes the sum of financial analyses for various groups of society plus non-monetary effects. This also includes the distortionary effects on the economy of collecting the tax that is necessary to finance the measure. By "society" is normally meant a certain region or country such as EU or Denmark. The aim is to compare all effects by converting the effects into one and same unit, normally monetary terms. In principle, all effects impacting society directly as well as indirectly should be taken into account. Since many of the indirect effects are interlinked and modelling is necessary to explore them fully, a partial approach is commonly applied, which is also the case in this analysis. That means that only the direct effects and the most important indirect effects are taken into account.

The partial welfare economic approach is very suitable to assess a number of political initiatives concerning certain groups in society. Among such initiatives are environmental initiatives such as prohibition against certain chemicals, initiatives to improve water quality etc. More extensive, structural initiatives which affect the whole structure of the economy, such as a substantial change in the tax system, will have many important indirect, interlinked effects through their effects on all sectors of the economy. to analyse such structural changes, general equilibrium analysis must be applied and mathematical models of the relevant economic system must be used. More information about and discussion of the advantages and disadvantages of partial and general equilibrium analyses can be found in Møller (2003).

When estimating the extra cost of a regulation (for instance the substitution of a hazardous substance with a better alternative in industrial production), the starting point is often the difference in price for producers. This is equivalent to the financial cost. In order to estimate the welfare-economic cost on this basis, two standard conversion factors are used: The net tax factor and the marginal cost of public funds[3]. According to the Danish guidelines from DEPA/the Ministry of the Environment (Møller, Andersen, Grau et al. 2000), these increase the cost by 17 %[4] and 20 % respectively.

Other methodological issues of importance for the interpretation of the analysis are discount rate[5], time horizon, geographical delimitation. The discount rate varies depending on whether it is the financial or welfare-economic analysis in accordance with the DEPA guidelines (Møller, Andersen, Grau et al. 2000). For the financial calculation the discount rate used is 6 % per year as a proxy for the alternative return on publicly funded projects. In the welfare economic calculation the discount rate is 3 % per year, which is chosen as a representation of the time preference for the society. According to DEPA guidelines, the welfare economic analysis can take account of the alternative return on investment, by applying a return factor on capital based on the 6 % to the investment share of the cost of the regulation. Due to the uncertainty of the cost estimates at this stage, this principle is, however, not applied here, and 3 % is used for welfare-economic estimates.

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[3] The net tax factor is used to convert factor prices to market prices. The marginal cost of ublic funds is used when the instrument is financed using mandatory taxes, e.g. taxes (and in some cases also user charges).
[4] 25 % for internationally traded goods.
[5] Discount rates are used to estiatme the net present value (NPV) of a project or policy. The NPV can be used to compare projects with different timehorizons. The NPV is found by discounting the flows of cost and benefits over the presumed lifespan of the project.

The analysis has a 30 year time horizon starting from 2005. This approach is chosen in order to fit the scenarios for the situation with and without the directive as is described in chapter 3.3 below.

The geographical delimitation of the analysis is the Danish economy since the aim of the study is to identify the cost to Danish society. It could be argued that a European Community viewpoint should be adopted in the welfare economic analysis since the policy is EU-wide. This is particularly the case if EU-wide implementation is discussed. However, as the cost to the member states is highly relevant to the decision-makers, this national delimitation must be chosen here.

Finally, it should be emphasized that the economic cost estimates in this analysis are only rough estimates and that the results have a high degree of uncertainty stemming from uncertainties in the technical assessment and the limited number of sources for economic data. It is the premise of this study that only existing sources for economic and technical data are used. In some cases this is not sufficient to give an estimate of the cost of the measures needed to comply with the Directives.

A straightforward calculation of the extra cost per kg of an alternative substance or metal based on a price estimate can give an estimate of the total cost. However, there are several problems with this approach. In order to assess this cost, a number of detailed cost-benefit comparisons for specific product types should be made to consider the relative cost of the different substitutions. The comparisons must include the human safety aspects, effectiveness and availability. The cost of alternatives must be assessed to ensure that substitution is a practical option. It is also possible that some substitutions may be more effective than the priority substance in some applications and that they can be used at lower concentrations. Finally, there may well be a need for new investments in production machinery or packaging or there may be other costs related to the transfer from the use of one input substance to another. All in all, a basic cost comparison on an equal weight basis is a very rough estimation method, but for this overview study it is a feasible way of giving an impression of the proportion of the potential cost.

This introductory chapter starts with a review of the main international economic assessments of the Daughter Directive to assess if the results can be transferred to Denmark. As will be seen, this is not the case. Next, the chapter discusses and describes the scenarios needed to evaluate the situation with and without the Daughter Directive. The chapter concludes with a short, general discussion of the relative cost-effectiveness of possible regulatory instruments to implement the directives.

3.2 Lessons from international economic assessments

A possible source of information for cost estimation of the Daughter Directive is to look at international studies already conducted. The cost estimates from these studies could possibly be transferred to the situation in Denmark. This chapter gives an overview of the relevant findings of a number of British studies and the cost-benefit analysis of the Directive made for the Commission. These are considered the most comprehensive analyses of the cost of the proposed Daughter Directive that have been carried out so far.

3.2.1 ECOLAS Study for the Commission

The ECOLAS Study was carried out for the Commission with the objective of evaluating the additional cost of implementing the Daughter Directive in relation to environmental quality standards and pollution control of priority substances in the EU.

The study uses a case study approach to assess the cost to industry of reducing the use of the PS and PHS. The reason for using this approach is that there are limited data and resources available, and a lot more primary data would need to be collected if other approaches were to be applied (see section on quality of data page III in ECOLAS (2005)). The case studies analysed include (pollutant indicated in brackets):

- chlorine production [mercury],
- iron and steel production [polyaromatic hydrocarbons, metals],
- non-ferrous metals production [polyaromatic hydrocarbons, metals],
- PVC conversion [lead, di(2-ethylhexyl)phthalate],
- refineries [benzene],
- short chain chlorinated paraffins [C10-C12-chloroalkanes],
- production and formulation of pesticides [all pesticides], and
- use of plant protection products [all pesticides]

The last two case studies are references to previous studies.

The study establishes a baseline scenario (with no Daughter Directive, i.e. article 16.8 applies) and two additional scenarios with a more or less strict interpretation of the draft proposal for Daughter Directive. The quantitative goals are specified in the Table 3-1 while the findings of the case studies are presented in Table 3-2.

Table 3-1 Overview of quantitative goals in scenarios in ECOLAS study

Category	*Baseline*	*Scenario 1*	*Scenario 2*
	EQS by Member States by 2015	Community wide EQS, which means the adoption of programmes of measures that will lead to:	
PS		- meeting EQS by 2015 - progressive reduction - 50% reduction by 2015 (assumed to be meeting EQS) - 80% reduction by 2021	- meeting EQS by 2015 - reaching Emission Limit Values for point sources by 2015 - progressive reduction by more stringent measures than in scenario 1 by 2015
PHS	- no phase out	- 50% reduction by 2015 - 80% reduction by 2021 - phase out by 2025 (20 years)	- phase out of "known" point sources by 2015 - phase out for diffuse sources and "unknown" point sources over the following 10 years

Table 3-2 Overview of results in scenarios in ECOLAS study

	Scenario 1		*Scenario 2*	
	Annualised cost Millions Euro	Cost per tonnes Euro/tonnes	Annualised cost Millions Euro	Cost per tonnes Euro/tonnes
chlorine production	–	–	-(98)-140	-(20)-28
iron and steel production	59-122	0.32-0.67	824-1423	4.49-7.75
non-ferrous metals production	20-61	–	56-97	–
PVC EoP	7-16	1.2-2.7	12-22	2.0-3.7
PVC subst.	39-88	6.6-15.0	62-122	10.5-20.6
Refineries	138-312	0.19-0.43	502-905	0.70-1.26
short chain chlorinated paraffins	53-131	–	80-157	–

Note: the range is established by using a 12% discount rate for the lower bound and a 4% discount rate for the upper bound.

None of these case studies turned out to be relevant for the assessment of the Danish cost of implementing the proposed Daughter Directive. The measures and substances that are investigated in the Commission's study are not the ones that constitute a problem in the Danish context. The estimated unit cost and the total cost of reducing the emission of the substances can therefore not reasonably be transferred and used for estimating the Danish cost. However, the scenario approach with varied deadlines to illustrate the demands in the Directives is very useful, and we will transfer this practice to our assessment.

3.2.2 British studies

In the UK, two relevant analyses have been published: DEFRA (2002), ***Regulatory Impact Assessment of a Priority List of Substances under Article 16 of the Water Framework Directive***, and RPA (2000), ***Socio-Economic Impacts of the Identification of Priority Hazardous Substances under the Water Framework Directive.*** These studies were conducted before the current proposal for the Daughter Directive was finalised, but they look at the list of priority substances and the hazardous substances under the Water Framework Directive.

Some preliminary cost estimates for achieving the environmental quality standards (EQS) for point sources, pesticides, monitoring and historic pollution are provided. Table 3-3 below summarises the preliminary cost estimates for point sources, pesticides, monitoring and historic information. The costs presented are based on the costs attributable to compliance with EQSs only and do not include specific controls.

Table 3-3 Preliminary cost estimates for point sources, pesticides, monitoring and historic information, DEFRA

Area	*Process*	*Notes*	*Annual cost £ million (equivalent)*
Industry concerning metals	Reduction in metals discharged with secondary treatment		12
Industry concerning metals	Reduction in metals discharged with tertiary treatment		70
Industry (organics)	Reduction in organics discharged with secondary treatment		1
Industry (organics)	Reduction in organics discharged with tertiary treatment		5
Water Companies	Upgrading treatment works		241
Water Companies	Dealing with sludge arising		70
Agricultural sector	Reduction in Priority Substances	Low estimate is £7.8. High estimate is £11.2. Mean figure given	10
Monitoring	Increased analytical costs associated with the need to analyse all 33 PS/PHS substances	Excludes the costs of sample collection and reporting thus costs are likely to be significantly higher. At present, limited cost data are available so estimates of sediment and biota analysis are not given.	6 Water 0.0 Sediment 0.0 Biota
UK	Remediation of historically contaminated sites	Costs attributable to the proposed EQSs and MACs	220
Total			635

Source: Henton, Water Quality Division, DEFRA. *Preliminary Provisional Cost estimates from our consultants.* Summary of DEFRA(2002) and RPA(2000)

The costs provided for point source dischargers only include major industrial sources (IPPC sources). The annual cost from SMEs and diffuse sources, e.g. runoff from roads etc., is not included and, hence, the actual cost is underestimated. Furthermore, the figures do not cover all priority substances, such as e.g. PAHs, anthracene, flouranthene, and pentachlorobenzene.

IPPC sources

The purpose of this section is to describe briefly how the annual costs of the point dischargers presented above were calculated. Based on the current permitted annual loads (kg/year) and the receiving waters an assessment was made of the number of industrial point dischargers that were unlikely to meet the Environmental Quality Standards (EQS).

The estimate of the cost is arrived at in four steps. Firstly, for each site a reduction in discharges is calculated so that the EQS are met. Secondly, the treatment technology required to remove the substances of concern is chosen. Thirdly, the sector-specific unit costs of treatment technology are applied, and finally the annual treatment cost by sector is calculated.

In DEFRA (1999), the sector specific treatment costs are calculated for the following sectors: wastewater treatment plants used in metal finishing, textiles, chemicals and pharmaceuticals, pulp and paper, food and drink, and urban wastewater treatment plants. The costs are grouped in costs for organic substances and metals respectively.

The marginal costs (£/kg of pollutant removed) for the different treatment technologies are arrived at by annualising the capital costs of establishing a treatment facility and calculating the annual treatment costs for the technology being analysed, see calculation example in annex B of DEFRA (1999).

The technology specific marginal costs assume that facilities already have some sort of primary treatment technology in place, such as screening, gravity settling or mechanical filtration. The marginal costs therefore assume a more effective secondary or tertiary abatement technology e.g. aerobic biological filtration, nutrient removal, flocculation and coagulation, dissolved air flotation, membrane technology etc. (see chapter 3 table 3.1 DEFRA (1999).

Applying the marginal costs from the UK study to Denmark will result in an underestimation of the actual marginal costs for Danish facilities. This is because most treatment plants of significance in Denmark have already installed both secondary and tertiary treatment technology. Therefore, the marginal cost of removing an additional kg of substance is much higher as a quaternary level of technology will be required.

It should further be noted that the British study assume that emissions and discharges are spread out evenly throughout a year. This may not be the case as some industries may emit substances in pulses thereby exceeding EQS and/or MAC values, in turn leading to an underestimation of the actual costs.

Wastewater Treatment Plants
The costs of wastewater treatment plants (WWTP) have also been estimated. The number of WWTPs distributed on level of technology and facility size form the basis for the calculation. The cost calculation assumes i) that all facilities with only primary technology installed are upgraded to secondary technology, and ii) 50% of facilities using secondary treatment technology are upgraded to a higher level of treatment technology (higher secondary or tertiary). Also, a number of the treatment options studied in this report relate to standards in other directives such as the Urban Wastewater Treatment Directive, and the estimated costs are therefore higher than those that will accrue due to the Daughter Directive.

Sludge Disposal
With the additional treatment at WWTPs, the loadings (metals and organics) in sludge will increase. This will imply that some of the sludge that was previously applied to agricultural land no longer can be used for this purpose. It will therefore be necessary to dispose of sludge through incineration or landfilling. It is estimated that 300,000 tonnes per year (dry weight) of additional sludge will arise. At a cost of approx. £240 per tonne the total additional cost will be around £70 million.

3.2.3 Assessment

The British studies cannot be directly transferred to a Danish context. This relates primarily to the fact that many WWTPs in the UK operate at a lower level of technology than in Denmark. This implies that the marginal cost of removing an additional amount of a substance in the UK will be lower than the marginal cost in Denmark, since an even higher level of technology would be required.

3.2.4 Benefits

The RPA (2000) report also includes an assessment of expected benefits from introducing the Daughter Directive as implied by article 16 in the WFD. This is interesting from a cost-benefit viewpoint even though such an analysis is not the purpose of this study. The primarily benefits are listed below:

i) Improved water quality;

ii) Protection and enhancement of the quality of aquatic and marine ecosystems, and of wildlife and their predators up the food chain;

iii) Priority substances that are persistent, bioaccumulative and toxic may accumulate in the environment and in biota, leading to future problems. These problems include effects on the reproductive systems in biota. Reducing the amount of these substances in the environment should lead to future benefits as the risk of exceeding the critical levels in biota will then become less likely;

iv) Some substances, such as individual PAHs, generally occur with other substances and may act as an indicator of other non-identified substances. A reduction in or cessation of emissions of such substances will lower the level of potentially harmful unidentified substances in the environment;

v) The development of new safe substitutes for priority substances and priority hazardous substances may potentially create new business opportunities, particularly for the chemical industry.

These benefits cannot directly be transferred to a Danish context as the starting point before the implementation of the proposed Daughter Directive is different from that of the UK as has already been discussed. The chemical industry in Denmark is comparably small, to give one example. That means that the magnitude of the benefits will probably be smaller in Denmark, but the type of benefits will be similar.

3.2.5 Summary of international studies

In conclusion, the studies mentioned in this chapter are all interesting as background information, but the cost-estimates cannot be transferred directly to Denmark, since the need for action is not the same. In Denmark, the number of substances for which action is needed is limited compared to many other countries, and wastewater treatment is more developed and efficient at the onset. To estimate the cost of a Daughter Directive on priority substances in Denmark, it is therefore necessary to look at particular possibilities of substance substitution. We will also consider the combined effect and cost of a general abatement measure for all substances; detention of substances in stormwater runoff.

3.3 Scenarios

The three main scenarios considered relevant for analysis in relation to the regulation of priority substances and priority hazardous substances to surface waters are established and described below:

- Scenario A represents a situation where the EU Member States do not reach an agreement on a Daughter Directive, thus leaving it up to each Member State, in this case Denmark, to establish its own EQS values and adopt a national strategy for the protection of surface waters based on the existing requirements in the Water Framework Directive (i.e. in reality a sort of "zero" scenario).

- Scenario B is the situation where a Daughter Directive is agreed on at EU level establishing not only EQS values but also requirements to community strategies against pollution of surface waters in the EU Member States (this scenario represents the EC Commission's 2005 draft proposal for a Daughter Directive). Scenario B entails binding requirements to meet the environmental quality objectives (represented by Environmental Quality Standards, EQS) for surface waters as well as to ensure progressive reduction of emissions, discharges and losses of priority substances as well as cessation of emissions, discharges or losses of priority hazardous substances within 20 years. This implies that Member States will have to take action on an equal basis, affecting the private and public sectors in similar ways and with the same timeframe.

- Scenario C represents the situation where a Daughter Directive does not imply common control measures, but only the establishment of common EQS values. This scenario represents the final Daughter Directive proposal (Com(2006) 397 final)[6] put forward by the Commission in July 2006. This scenario (Scenario C) will in reality be almost identical with Scenario A as the EQS values to be established nationally in Scenario A would probably not differ significantly from those established at Community level in the Directive proposal. Therefore, the assessments in this report of the implications of the Daughter Directive do not distinguish between A and C in the presentation of the technical and economic issues.

In sum, the relevant scenarios can briefly be described as follows:

- Scenario A: Scenario for the situation without common EQS or common measures (as with Water Framework Directive only);
- Scenario B: Scenario for the situation with common EQS and common measures (as draft proposal for daughter directive);
- Scenario C: Scenario for the situation with common EQS only (as final, proposed daughter directive).

In the following reporting of the findings of the assessment, Scenarios A and C will be presented together (as "Scenario A").

It is common to the three scenarios that Member States must apply the combined approach (WFD ***article 10***) when controlling discharges into surface waters. Following this approach Member States must ensure the establishment of emission controls based on the best available technology (BAT) or community emission limit values (the stricter of the two) for all discharges from point sources (WFD ***article 10.2***). To control and reduce pollution from

[6] Proposal for a Directive of the European Parliament and of the council on environmental quality standards in the field of water policy and amending directive. 2000/60/ec (presented by the commission) {Com(2006) 397 final}

diffuse sources the best environmental practice must be applied. In addition, according to WFD ***article 10.,3*** Member States may be required to apply even stricter controls to meet EQS.

In Denmark, the application of BAT is already required by national legislation and by regulation of discharges into the aquatic environment.

The scenarios will define the overall state as regards environmental objectives that are to be implemented during the coming years as well as briefly discuss the expected impacts on the private sector, consumers and the public authorities. The selected scenarios will be detailed and quantified for each of the selected priority substances with the purpose of carrying out an economic assessment of implementing the respective policies. The overall economic effects that result from the implementation of scenarios are described in Chapter 14.

3.3.1 Current State (Reference State)

The reference state takes into account the current Danish legislation that is in force as of October 1, 2005. This legislation may be fully or only partly implemented today. If the regulation is only partly implemented or have not yet shown its full effect, the reference state will make assessments of the likely effects from the parts that are not yet implemented or that are anticipated to appear, however, with some delay.

In the reference state the existing regulatory measures may for some substances (but not all) lead to reduced concentrations in surface waters over a shorter or longer period of time. However, these possible reductions in concentrations may not be enough to satisfy the EQS established in Scenario A (national) or Scenario B (common EU) below. This would then imply a need for further action by the national authorities for the particular substances not satisfying the EQS.

It should be noted that there may be other external (non-regulatory) factors that influence the use of substances which are not taken into account in the analysis. These factors include among other things new inventions and technology that change the substance amounts consumed, changes in consumer and/or producer behaviour affecting the levels of substances in production as well as socio-economic developments that influence substances consumed. These factors contribute to the possible uncertainty about establishing the "actual" reference state.

The reference state is interpreted as a ***hypothetical state*** that will not be reached in practice as either Scenario B or Scenario A must be implemented to fulfil Danish regulatory obligations to protect the aquatic environment against priority substances and priority hazardous substances.

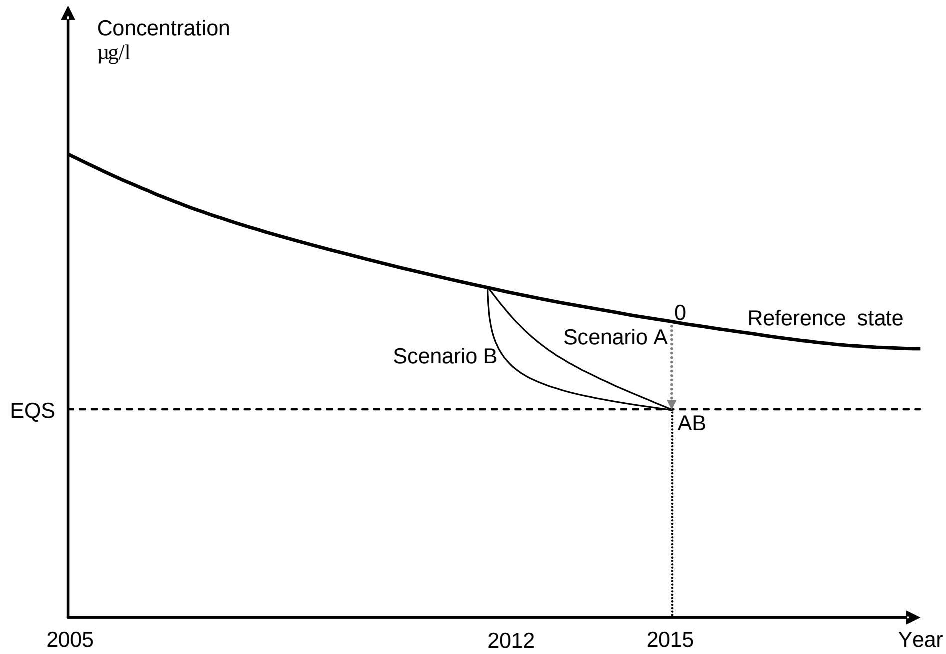

Figure 3-1 Fulfilment of EQS for priority substances. *Source:* COWI.

In Figure 3-1 above, the main dynamic states for priority substances are either scenario A or scenario B. In this analysis, the reference state is only used to measure the additional effects and economic costs that are incurred in order to move from the reference state to Scenario A (0A) and from the reference state to Scenario B (0B) as described below. A main point is the additional costs of moving from A to B.

As can be seen from figure 3-1, there will be no difference between the reference state and scenarios A and B until after 2012. This conclusion is based on DEPA's interpretation of the Water Framework Directive article 4(1)(a)(iv)[7]. The article says that the programmes implementing the directives need not be operationalised until 2012. Further, it should be noted that the two scenarios share the environmental objective of meeting the EQS in 2015 as indicated in the figure above.

Figure 3-2 illustrates the dynamic state for priority hazardous substances. In scenario B, it is required that controls are established for cessation or phasing out of discharges, emissions and losses of priority hazardous substances within a timeframe of 20 years. The aim in scenario A is in principle the same, but this scenario is less rigid with regard to requirements to enforcement and does not include a specific timeframe.[8] As in Figure 3-1, there is no difference between the reference state and scenarios A and B until after 2012, based on the same interpretation of the Water Framework Directive as above, i.e. that the programmes implementing the directives need not be operationalised until 2012.

[7] And the chapeau to this article.

[8] In the economic analysis, it will be assumed that the timeframe is 10 years longer in scenario A. In reality, it could be either longer or shorter and vary between the different substances. 10 years are selected a reasonable representation of the member states' possibility of pushing the deadline in the situation without the Daughter Directive.

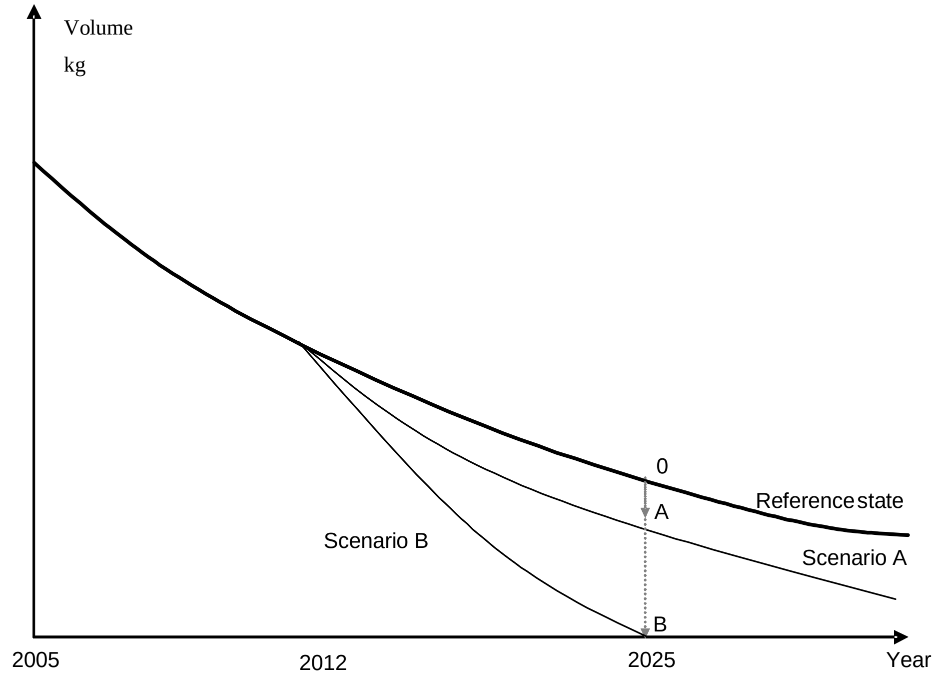

Figure 3-2 Cessation or phasing out of priority hazardous substances. *Source:* COWI.

3.3.2 Scenario A - No common measures and no common EQS (as with Water Framework Directive only)

This scenario assumes that a Daughter Directive on Priority Substances is not agreed on at Community level. In essence, this means that in addition to the regulations governing the reference state this scenario will include actions that must be taken by Member States according to the WFD ***article 16.8*** and ***4.1.a.iv***. These actions essentially require member states to

> article 16.8:… ***establish environmental quality standards for these*** (first list of Priority Substances [Annex X] of WFD) ***substances for all surface waters affected by discharges of those substances, and controls on the principal sources of discharges, based on inter alia, on consideration of all technical reduction options***
>
> article 4.1.a.iv:… ***implement the necessary measures in accordance with article 16.1 and 16.8 with the aim of progressively reducing pollution from priority substances and ceasing or phasing out emissions, discharges and losses of priority hazardous substances.***

In this scenario, Danish authorities are assumed to adopt similar or close to similar environmental quality standards as those that have been proposed for the Daughter Directive. The reason for this is that Danish authorities will establish EQS based on the same detailed technical guidelines as those Commission experts will use, and they have access to the same environmental data as Commission experts. However, in certain cases Danish authorities may attach different weights on the environment data than the Commission experts, thus there may be slight differences in the EQS established by Denmark and the Commission, respectively.

With the aim of progressively reducing aquatic pollution from priority substances and of ceasing or phasing out emissions, discharges and losses of priority hazardous substances Member States must establish controls on the principal sources of discharges based on, ***inter alia***, considerations of all technical reduction options.

Pollution is defined in the WFD (article 2, def. 33) as

> "***the direct or indirect introduction, as a result of human activity, of substances or heat into the air, water or land which may be harmful to human health or the quality of aquatic ecosystems or terrestrial ecosystems directly depending on aquatic ecosystems, which result in damage to material property, or which impair or interfere with amenities and other legitimate uses of the environment***".

In practice, the introduction of a substance into the environment is considered to be harmful only if the resulting concentration level is anticipated to exceed the relevant EQS values.

Therefore, DEPA's interpretation of the obligations pursuant to the WFD in Scenario A, is that progressive reduction of pollution by priority substances only implies ***consideration*** of "all technical reduction options" (WFD article 16.8) and only down to the level where compliance with the EQS is achieved. And, correspondingly, that the aim to eventually cease/phase out emissions, discharges and losses of priority hazardous substances must only be pursued as far as practically possible by ***consideration*** of all technical reduction options.

The WFD (and thus Scenario A) also dictates that the economic analysis should make a decision about the potentially most cost-effective combination of measures (WFD Article 5, Annex II).

3.3.3 Scenario B - Common EQS and common measures (the 2005 draft proposal for Daughter Directive)

Scenario B, on the other hand, assumes that a Daughter Directive establishes the environmental quality standards for priority substances and priority hazardous substances. The environmental quality standards that are to be adhered to are expressed as annual averages and/or maximum allowable concentrations.

This implies that the Commission will establish community environmental quality standards for surface waters for Priority Substances to be met by 2015. Each Member State must identify and subsequently implement controls to meet the community EQS. In addition, Member States must identify and implement controls for the progressive reduction of discharges, emissions and losses of these substances - irrespective of any compliance with EQS. For the Priority Hazardous Substances it is a requirement that the discharges, emissions and losses to surface waters must have ceased or be phased out in the Member States within 20 years after adoption of the Daughter Directive.

Scenarios A and B for priority substances and priority hazardous substances do not differ with regard to the economic guidelines, as the Daughter Directive also stipulates that the combination of measures must be cost-effective.

Thus, the main differences between Scenario B and Scenario A are that:

- with regard to priority substances continued progressive reduction is required in scenario B even after compliance with the EQS has been achieved while in Scenario A the efforts need only to be continued until the EQS is complied with;

- with regard to priority hazardous substances there is a well-defined timeframe (20 years) in Scenario B within which the emissions, discharges and losses must cease/be phased out while in Scenario A no time limit is specified;

- according to DEPA's interpretation scenario B imposes an obligation on Denmark to meet the aim of progressively reducing discharges, emission and losses of priority substances while Scenario A only obliges Denmark to establish controls based on “consideration of all technical reduction options" that target this goal. The two scenarios differ in the same manner with regard to requirements to cessation or phase-out of priority hazardous substances.

3.3.4 Scenario C - Common EQS and no common measures (the official Daughter Directive proposal)

The final proposal for a Daughter Directive (com(2006) 397 final)[9] was put forward by the Commission in July 2006. The assessment presented in this report was started before the final proposal, and therefore Scenarios A and B are based on the unofficial draft proposal from 2005. The final proposal can be interpreted as a "Scenario C" in this assessment. In effect however, this scenario corresponds to Scenario A.

The final Daughter Directive proposal follows the demands in Scenario A with regard to measures, but with a deadline in 2025 when the Commission will evaluate whether the member states, in accordance with the Water Framework Directive, have fulfilled the obligation of initiating the necessary measures with the aim of ensuring progressive reduction of the PS and cessation/phase-out of the PHS. The 2025 deadline is not interpreted by DEPA to have any influence on the timeframe for the implementation of the Directive. There is no specific deadline in Scenario A. In other words, the 2025 deadline is not a deadline for the initiation of the measures or the fulfilment of the environmental quality targets.

It should be noted that in Scenario C the objective of aiming at progressive reduction of priority substances and cessation/phasing out of priority hazardous substances is a requirement according to the existing Water Framework Directive, not explicitly stated in the final Directive proposal.

Regarding the environmental quality targets (The EQS values), the proposed directive is in line with Scenario B, where targets are set at Community level. However, as mentioned above, in practice the difference between national,

[9] Proposal for a Directive of the European Parliament and of the Council on environmental quality standards in the field of water policy and amending directive. 2000/60/ec
(presented by the Commission) {com(2006) 397 final}

Danish target levels and community target levels is anticipated to be insignificant. Scenarios A and B - and "Scenario C" - are therefore considered to be identical with regard to the quality targets.

3.3.5 Summary of scenarios

Table 3-4 below provides a summary of the similarities and dissimilarities between the reference state and Scenarios A/C and B.

Table 3-4 Summary of the Reference State and scenarios A /C and B.

	Reference State	Scenario A/C	Scenario B
Priority Substances Regulation	Current regulation and regulation that have not yet taken effect but have been approved by the Danish Parliament or through ministerial powers. Current Directives in force now and after 2013[1]	Current regulation and regulation that have not yet taken effect but have been approved by the Danish Parliament or through ministerial powers. Current Directives in force now and after 2013[1] List of Priority Substances, including Priority Hazardous Substances Additional legislation to be drafted, approved and implemented that will satisfy WFD article 16.8 and 4.1.a.iv: "With the aim of progressively reducing pollution from priority substances and ceasing or phasing out emissions, discharges and losses of priority hazardous substances ".	Current regulation and regulation that have not yet taken effect but have been approved by the Danish Parliament or through ministerial powers. Current Directives in force now and after 2013[1] List of Priority Substances, including Priority Hazardous Substances
Reduction of Priority Substances and cessation of Priority Hazardous Substances	no specific regulation	Progressive reduction of pollution of priority substances until compliance with EQS is achieved Phasing out/Cessation of discharges, emissions and losses of priority hazardous substance without time-frame	Continuous progressive reduction of discharges, emissions and losses of priority substances even after EQS compliance has been achieved Phasing out/Cessation of discharges, emissions and losses of priority hazardous substances within 20 years from entry into force of the Daughter Directive
Environmental Quality Standards (EQS)	Current Standards as stated in the Danish Statutory Order No. 921 of October 8, 1996	National standards, which will be (close to) similar to the proposed EU environmental standards (EQS)	EU environmental quality standards (EQS)
Technology used	Best Available Technology (BAT) Prevention by use of cleaner technology <u>Combined Approach:</u> Point sources: BAT or Emission Limit Values Diffuse sources: as point sources or "best environmental practice"	"Consideration of all technical reduction options". Best Available Technology (BAT). Prevention by use of cleaner technology <u>Combined Approach:</u> Point sources: BAT or Emission Limit Values Diffuse sources: as point sources or "best environmental practice"	Best Available Technology (BAT) Prevention by use of cleaner technology <u>Combined Approach:</u> Point sources: BAT or Emission Limit Values Diffuse sources: as point sources or "best environmental practice"
Timing for fulfilment of EQS	no specific timeframe	2015	2015

Notes: 1) A number of "obsolete" directives will be repealed and replaced by the WFD (Directive 2000/60/EC) and the current Daughter Directive.

Source: Danish Environmental Protection Agency and COWI.

Specifically with regard to possible control measures to be implemented, the differences between Scenario A/C and Scenario B can be summarised as follows (Table 3-5).

Table 3-5 Summary of difference between Scenarios A/C and B with regard to measures required against priority substances and priority hazardous substances, respectively.

Type of control measure (substance category)	Scenario	
	A/C	B
Progressive reduction (PS and PHS)	...with **the aim of** progressively reducing **pollution** ...*	...to **achieve** the progressive reduction of **emissions, discharges and losses**...
Cessation/phase-out (PHS)	...with **the aim of** ceasing or phasing out emissions, discharges and losses...	...to **bring about** a cessation of emissions, discharges and losses **within 20 years**....

* Pollution here defined as environmental concentrations of PS/PHS above the relevant EQS.

3.4 Discussion of possible regulatory instruments

The Water Framework Directive and the proposed Daughter Directive include the demand that the goals are achieved using the most cost-effective combination of measures possible in order to minimise the adverse cost to society. This means that all possible measures should be investigated and ranked according to cost effectiveness.

This section will give a short introduction to the available regulatory instruments that may be considered in the process of selecting the most cost-effective "policy package" that will lead to fulfilment of the requirements of the proposed Daughter Directive with regard to Priority Substances and Priority Hazardous Substances.

The types of instruments most often used in Denmark to protect the environment and human health are:

- Economic instruments
- Administrative measures
- Voluntary Environmental Agreements
- Information (for example the List of unwanted substances)

Examples of Danish experiences with some of these instruments in the regulation of chemicals are briefly discussed below. This section also serves as a short, practical policy-related discussion of regulatory instruments. In the substance-specific analyses, we do not distinguish between specific types of instruments. Instead, the distinction will be made between "abatement measures" and "clean-up measures". Both types of measures can be put into action through all three regulatory instruments described in this chapter.

3.4.1 Economic Instruments

Economic instruments can be subdivided into tariffs and taxes, charges (user fees – e.g. water charges or wastewater treatment charges), subsidies and tradable permits. The experiences with the application of tariffs in Denmark are limited as the time period in which they have been applied is short. However, the initial evaluation of tariffs indicates that they are effective and that they have contributed to the reduction of taxable goods and products having undesirable effects on the environment (DEPA 2003).

An example of a tax is the tariff on NiCd batteries. The assessment is that the tariff seems to have had the desired effect on reducing the use of NiCd batteries and to have entailed substitution of more environmentally friendly batteries for those previously used. Before the tariff was introduced, 30-35 tonnes of NiCd batteries were collected. After implementation of the scheme the amount rose to 95 tonnes (DEPA/COWI 2001). Other experiences with tariffs can be found in Skatteministeriet et.al (2000). These include: tariffs on chlorinated solvents, pesticides, PVC and phthalates.

Wastewater treatment plants (WWTPs) must have a discharge permit that sets the conditions to be met by the plant. This permit also establishes the level of substances that are allowed to be discharged into the water environment. These substance levels are based on the current legislation and the state of the environment in the considered water environment. Excess discharges of certain substances[10] from WWTPs are taxed. The extra expenditures are recovered through user fees, which are collected on a self-sustaining basis (neutrality principle) and will be regulated up or down depending on the profits made by the WWTP (DEPA/COWI 2001).

In general, a tariff imposed on a good (substance) is often a more effective way of reducing environmentally damaging emissions than by implementing standards. This argument relates to there being a risk of over-regulating by standards, which would not be the case for a tax (Hanley, Shogren & White1997).[11]

3.4.2 Administrative Regulation

A number of administrative instruments are available, including complete bans on substances, restrictions on the use of substances, promotion of cleaner technology and environmental responsibility. Complete bans or restrictions on the use of substances have been imposed in Denmark on substances that are considered to be highly hazardous to the environment and human health. An example is the restrictions on mercury which prohibit importing, selling or exporting mercury or products with mercury as defined by Statutory Order no. 627 of 2003[12] (DEPA/COWI 2001).

Environmental responsibility is different from traditional instruments as this is defined as an obligation on companies to restore the environment if environmental damage has been caused and to compensate for the damage if the damage cannot be undone. Environmental responsibility is therefore very

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[10] The sewage tax was introduced in 1994 and was particularly aimed at excess emissions of nitrogen, phosphorous and organic substances (NPO).
[11] Over regulation would also lead to higher environmental benefits. These benefits should be evaluated in relation to the marginal costs that are implied by over regulation.
[12] There are certain uses that are exempt from this regulation, e.g. research, training, special light sources, etc.

close to the polluter-pays principle (for environmental damage). Companies thus have an incentive to prevent environmental damage.

The experiences in Denmark are related to the "Contaminated Soil Act" (Jordforureningsloven) of January 2000 which implies that house owners are liable to pay for damage inflicted by leaking oil tanks used for central heating systems. House owners are covered by a statutory insurance scheme set up by the oil industry together with an insurance company. The experience to date shows that the scheme works as planned and that polluted sites are cleaned without imposing considerable economic burdens on houseowners (DEPA/COWI 2001).

3.4.3 Voluntary Agreements

A voluntary agreement is an agreement between a company (typically an industrial organisation) on the one side and the state on the other side. Companies normally commit themselves to reducing a certain effluent or achieving certain recycling goals during a specified period of time. The advantage of voluntary agreements is that they give companies flexibility to decide how to meet the terms of the agreement in the best and most effective way. One of the drawbacks is that monitoring of the agreement may cause heavy expenses for public authorities.

In Denmark, voluntary agreements have been made for the last 10 to 15 years. Energy intensive companies have for example concluded agreements with public authorities ensuring considerable reductions in costs related to CO_2 tariffs. According to the agreements, companies have to invest in energy-efficient technology with a payback time of maximum four years, and an energy management must be implemented and "special assessments" must be made. There are approx. 100 individual agreements with companies and industry which cover about half of the total energy consumption of the industrial sector (DEPA/COWI 2001).

3.4.4 Summary of Possible Regulatory Instruments

In order to comply with the guidelines of the Water Framework Directive and the proposed Daughter Directive stipulating that goals are to be met in the most cost-effective manner, many possible measures should be considered. In general, the instruments will vary in terms of cost-effectiveness depending on the technology applied and the historic use of the substance. The instruments cannot be ranked in order of priority, but must be evaluated on a case-to-case basis. The short section above, however, made some general recommendations for formulating a cost-effective policy strategy.

Firstly, there are previous, positive Danish experience with both economic instruments, administrative measures and voluntary environmental agreements. If some types of regulation had proven ineffective in the past, it would be an argument for not including them in a future policy. If an instrument is not effective, it is not likely to be cost-effective either. Secondly, economic instrument are generally perceived to be more cost-effective instruments than regulatory instruments such as bans or limit values. This is due to the fact that there is less risk of over-regulation.

In the substance-specific chapters, distinction will only be made between "abatement measures" and "clean-up measures". As mentioned above, both types of measures can be implemented either by economic instruments, administrative measures, or by voluntary environmental agreements.

"Abatement" means to avoid pollution or loss of the substance to the environment in the first place. This means that substitution/phase-out of a substance in its uses or avoiding the loss of the substance from a use is abatement. Clean-up measures concern the cases when the substance has already been lost to the environment and the pollution is being cleaned up. As a rule of thumb in environmental economics, abatement is cheaper than cleaning-up the same substance once it has become an unwanted presence in the environment. This is only a general rule, and it must be subject to evaluation in each particular case. That is the aim of the assessment of the individual substances in the following chapters.

Generally, the regulatory options open to Member States are limited. It is possible to provide incentives for substitution through programmes, information on alternatives and by influencing EU legislation. On the contrary, direct regulation is often not possible due to the rules of the common market. Further, for a number of the priority (hazardous) substances action needs to be taken at transnational level to be effective. This is the case for e.g. regulation of imported products and regulation of ships.

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4 Assessment of cadmium

4.1 Definition of the reference state

4.1.1 Introduction

Cadmium (CAS no. 7440-43-9) is an element, and it is therefore not degradable in nature. Important cadmium compounds include cadmium chloride (CAS no. 10108-64-2), cadmium acetate (CAS no. 543-90-8), cadmium oxide (CAS no. 1306-19-0), cadmium sulphide (CAS no. 1306-23-6) and cadmium sulphate (CAS no. 10124-36-4).

Environmentally, cadmium is a heavy metal with high toxicity. Compared with other heavy metals, cadmium and cadmium compounds are, , relatively water soluble. They are therefore also more mobile in e.g. soil, generally more bioavailable and tend to bioaccumulate. The mobility depends heavily on the pH-level and the sorption capacity of the soil in question /1/.

4.1.2 Main uses and pollution sources

The quantitatively most important use of cadmium is as a component in NiCd-batteries. However, intentionally cadmium is also used as pigments in plastics, ceramics and glasses, as plating on other metals in particular steel, as an element in alloys with zinc, copper, and lead and in low temperature alloys and solders. Unintentionally, cadmium is consumed with fossil fuels, phosphate-based fertilizers, agricultural lime and cement besides being a natural contaminant in zinc.

In 1996, the consumption of cadmium in Denmark was estimated at 43-71 tonnes /2/. Intentional uses were responsible for a consumption of 37-61 tonnes/year, while unintentional uses counted for about 5.4-9.5 tonnes /2/.

The most important pollution sources of cadmium to the environment may briefly be listed as follows:

Air
Air emissions from waste incineration, incineration of oil products, coal power plants, cement manufacturing as well as metal refining and recycling. Total air emissions in 1996 in Denmark were estimated at 0.3-1.6 tonnes yearly /2/.

Water
Sacrificial zinc anodes for corrosion protection together with discharges from sewage treatment plants and stormwater drainage. The total water releases in 1996 in Denmark were estimated at 0.9-2 tonnes yearly /2/.

Soil
Phosphate fertiliser, agricultural lime, sewage sludge and zinc corrosion. Total releases in 1996 in Denmark were estimated at 2.2-3.5 tonnes yearly /2/.

4.1.3 Releases to and state of the aquatic environment

The most important sources of releases of cadmium to the water environment comprise (according to /2/):

- Use of sacrificial anodes made of zinc for protection of steel structures in the water environment;
- Effluents from municipal sewage treatment plants;
- Stormwater discharge;
- Direct atmospheric deposition.

Sacrificial anodes made of zinc are designed to be dissolved thereby protecting steel structures against corrosion. The structures in question includes oil extraction platforms, harbour structures, steel boats etc. The zinc anodes contains about 0.05 % cadmium by weight, which will be dissolved together with the zinc. The amount of cadmium released to the water environment in 1996 was estimated at 0.6 tonnes /2/. Sacrificial anodes are likely to be the most important single source for contamination of the water environment by cadmium in Denmark (mainly coastal/marine environment).

Effluents from sewage treatment plants as well as discharge of stormwater obtain their contents of cadmium from a number of sources. The most important source probably being corrosion of zinc used for corrosion protection of steel in road infrastructure installations such as pylons for lamps and signboards, fences etc. besides galvanized mailboxes, and eaves gutters and downpipes made of zinc. Other sources include releases from galvanization and foundry plants.

Atmospheric deposition from sources within Denmark and abroad adds to the amount of cadmium emitted from sewage treatment plants and by stormwater drainage by being washed off impervious surfaces by rain.

Atmospheric deposition, furthermore, is an important direct source of cadmium to Danish interior waters. The contribution in 1996 was estimated at 2.3 tonnes yearly primarily due to burning of oil for power and heating. The majority of the atmospheric deposition is considered to originate from sources outside Denmark.

Leaching from agricultural soils is believed to be a further source of cadmium releases to many Danish freshwater streams and lakes as these soils contain cadmium from the use of phosphate fertilisers and from atmospheric deposition during many years. There are observations indicating exceedance of the phosphorus-binding capacity of the soils.

Table 4-1
Monitoring data for cadmium (average values). The values in parenthesis are the 95 % percentiles. Sources: /4/ /5/.

Substance	Municipal sewage (µg/l)		Sewage sludge (µg/kg dw)	Stormwater, separate system (µg/l)	Fresh/marine surface water (µg/l)
	Influent	Effluent			
Cadmium	0.5 (1.4)	0.09 (0.5)	1700 (3800)	0.73 0.23*	0.046** 0.002***

* Highways /6/
** Average value of 50% percentile values for five Danish freshwater streams /7/.
*** Average value of 50% percentile values for five Danish lakes /8/.

Studies of ground water have shown 50 % percentile values of cadmium of 0.008 µg/l, while the 90 % percentile value is 0.08 µg/l /3/.

Based on the median values in sewage and in stormwater runoff presented in table 4-1, the total Danish releases of cadmium to the aquatic environment can be estimated at about 55 kg/year and 110 kg/year, respectively.

EQS proposal
The most rigorous of the EQS values for cadmium in the aquatic environment presently proposed for the Daughter Directive on priority substances are AA-EQS = 0.08 µg/l (inland surface waters) and MAC-EQS = 0.45 µg/l (all surface waters).

The background concentration in freshwater used in the elaboration of the EQS proposal for cadmium was 0.003 µg/l ("dissolved"), a value determined for the river Rhine.

4.1.4 Existing legislation/regulation and their impact

Statutory Order no. 1199 of 23 December.1992 from the Ministry of the Environment and Energy on the prohibition of sale, import and manufacture of cadmium-containing products.
This Order prohibits the import, sale and manufacturing of products in which cadmium is present as plating, pigment or stabilizer in plastics in concentrations above 75 ppm in homogeneous materials. A number of exemptions from the ban are established.

Assessment
This Order replaces the original Danish ban on cadmium from 1983 and implements a corresponding EU Directive. The effect of the order is that the amount of cadmium-containing products directed to waste incineration or steel recycling is slowly being reduced thereby also slowly reducing the amount of cadmium which could be emitted to the air or leached from residual products.

However, the dominant source of cadmium to waste incineration is assumed to be NiCd-batteries, which are not covered by the ban.

Statutory Order no. 223 of 5 April.1989 from the Ministry of the Environment on the content of cadmium in phosphorus-containing fertilizers
This Order limits the maximum content of cadmium in phosphate fertilisers to 110 mg Cd/kg phosphorous.

Assessment
Mainly aimed at limiting the content of cadmium in food and feedstuff, this Order also reduces the amount of cadmium added to agricultural soil and thereby eventually also the amount of cadmium leached from soil to fresh water bodies.

Statutory Order no. 998 of 12 October 2004 from the Ministry of Food, Agriculture and Fisheries on feedstuff
This Order limits the maximum content of cadmium in feedstuff to between 0.5 and 10 mg Cd/kg feedstuff depending on the type of animal in question.

Assessment
This Order has the same effect as the order on phosphate fertilisers listed above.

Statutory Order no. 183 of 15 December.1975 from the Ministry of Employment on the prohibition of the use of certain soldering products which contain cadmium.
This Order limits the maximum content of cadmium in solders to 0.1% by weight.

Assessment
By limiting the amount of cadmium used in solders, the amount directed to waste disposal with products is limited. In future, the Order will for most products in reality be replaced by the below-mentioned EU RoHS Directive mentioned.

Act no. 414 of 14 June.1995 on a charge on lead accumulators (closed nickel-cadmium batteries) and Act no. 404 of 14 June.1995 (as amended by Act 1105 of 29 December 1999) on remuneration in connection with collection of hermetically sealed nickel-cadmium accumulators (closed nickel-cadmium batteries).
NiCd-batteries have to be labelled and are subject to a sales tax, which, in turn, is used to finance a payment arrangement for a return system for batteries.

Assessment
The acts render NiCd batteries financially less attractive to the costumer and encourage collection organisations to collect these batteries for recycling purposes. Thereby both acts contribute to the objective of reducing the amount of batteries turning up in waste incineration plants and the emission of cadmium to the air etc. caused by such batteries. It is difficult to assess the collection rate of used NiCd batteries but it is believed to be at least 50%.

Statutory Order no. 298 of 30 April 1997 by the Ministry of the Environment on certain requirements for packaging
The sum of the concentration levels of lead, cadmium, mercury and chromium (VI) present in packaging and packaging components used in Denmark must not exceed 100 ppm by weight.

Assessment
By limiting the amount of cadmium used in packaging and packaging components, the amount directed to waste disposal with products is limited, which, in turn, limit releases from waste incineration etc.

Statutory Order no. 1042 of 17 December 1997 from the Ministry of the Environment on restricting the sale and use of certain dangerous chemical substances and products for specially stated reasons
The Order limits the permissible amount of cadmium to maximum 0.002 % cadmium in colours and glazing for non-commercial manufacturing of ceramics and glass products intended for food purposes. The use of cadmium for colouring paints etc. is prohibited. Cadmium and compounds must not be added to food.

Assessment
In reality, the Order eliminates the use of cadmium in non-commercial manufacturing of ceramics and glass and well as in paint. As a consequence, it reduces the amount of cadmium in solid waste and thereby also the risk of releases associated with the disposal possibilities of various waste types.

Statutory Order no. 1008 of 12 October 2004 from the Ministry of the Environment on import and sale of electric and electronic equipment.
Equipment containing lead, cadmium, mercury, chromium (VI), polybrominated biphenyls (PBB) or polybrominated diphenylethers (PBDE) is prohibited from 1 July 2006.

Assessment
The Order implements the EU RoHS Directive in Denmark. The effect of the order is that the amount of cadmium directed to waste incineration or steel recycling with products containing cadmium is slowly reduced thereby also slowly reducing the amount of cadmium which could be emitted to the air or leached from residual products.

Statutory Order no. 489 of 12 June 2003 from the Ministry of the Environment on cosmetic products.
The order prohibits the use of cadmium and compounds in cosmetics.

Assessment
The order has no significant impact on the water environment as the consumption of cadmium for cosmetics is insignificant.

Other regulations relevant for cadmium include:

- ***Statutory Order no. 655 of 27 June .2000 on recycling of residual products. and soil in building and construction work***
- ***Statutory Order no. 162 of 11 March .2003 on waste incineration plants.***
- ***Statutory Order no. 623 of 30 June2003 on application of waste products for agricultural purposes***

Assessment
The Orders may have a direct impact on the releases to the aquatic environment depending on the rules actually established for reducing the environmental loads of cadmium from various sources.

4.1.5 Conclusion on the need for further regulation

The data presented in table 4-1 show that the proposed AA-EQS and MAC-EQS for cadmium have already been met as only minor dilution of the most important discharge categories is required.

Hence, there is no further need for progressive reduction in Scenario A while in Scenario B the regulatory measures already implemented (the above statutory orders) can be considered to be "progressive reduction" measures as they will undoubtedly contribute to slowly but steadily decreasing concentrations of cadmium in emissions and discharges into the environment.

However, as cadmium is classified as a priority hazardous substance, further regulatory measures need to be considered in order to ensure the cessation or phasing out of emissions, discharges and losses (within a timeframe of 20 years in Scenario B). Possible measures are described in the following. The gradual implementation of the measures could at the same time be regarded as "progressive reduction" measures in Scenario B.

4.2 Possible reduction/elimination measures

4.2.1 Technical measures to reduce/eliminate cadmium

The following options for further reduction of Danish releases of cadmium to the water environment may be considered:

- Elimination of cadmium in sacrificial zinc anodes or substitution of these anodes. It is assessed that at least 50%, and probably more, of the sacrificial zinc anodes are used for protection of ships and boats against corrosion. The content of cadmium in the anodes plays a technical role, which, however, can also be achieved by substituting indium for cadmium (indium will be released in much smaller amounts). In the vast majority, the life-time of sacrificial anodes is, however, in many cases shorter than the 20-year time limit within which releases etc. must cease. Also, many anodes are changed during routine maintenance before their technical lifetime is fully expired. Therefore, it is assessed that there is practically no need to replace existing anodes while would be advisable to ensure that materials for new anodes do not contain cadmium.

- Restrictions on the content of cadmium in zinc used for hot dip galvanizing, gutters, downpipes etc. According to /2/ some of the zinc used contains up to about 200 ppm cadmium while the dominating part of the consumption only contains 2-15 ppm. It should, however, be noted that old zinc gutters and downpipes from before 1980 is still in use. Before cleaning of zinc was initiated in Europe in the late 1970's, zinc for gutters, downpipes and hot dip galvanizing generally contained about 1000 ppm cadmium and more. Such zinc is probably an important source of cadmium in wastewater and stormwater even today. The significance of this source is slowly reduced by replacing the material in question. However, it is assessed that it may take some decades before a complete replacement is in place unless an accelerated phase-out by additional regulatory measures or incentives is introduced. Such measures are only required in Scenario B and only to the extent that downpipes from before 1980 are still in use 20 years from the entry into force of the Daughter Directive. In Scenario A the substitution with cadmium-free alternatives will be part of the "natural" gradual replacement of existing downpipes when they loose their functionality due to weathering.

- Release of cadmium with stormwater, which includes contributions by atmospheric deposition from diffuse sources (also from outside Denmark), may be reduced by precipitation/cleaning arrangements. Such arrangements will actually be effective against cadmium impurities in zinc material as well as cadmium in general atmospheric deposition.

4.2.2 Possible synergies with other (priority) substances

As mentioned in section 4.1.3, the dominant source of release of cadmium to the aquatic environment appears to be stormwater runoff from separate systems. Therefore, an initiative to reduce this input could be considered though it is considered technically as well as economically unrealistic to introduce measures specifically for cadmium in stormwater runoff.

However, the majority of the PS/PHS, including cadmium, are characterised by properties such as lipofilicity and significant sorption onto particulate (organic) matter. Therefore, it is assessed that technological measures that aim to detain suspended particles in surface runoff will significantly reduce the loads of cadmium and many other PS/PHS on the aquatic environment.

Since this type of measure is not substance specific, it is described technically and assessed economically in a separate chapter (Chapter 12).

4.2.3 Summary and assessment of technical possibilities

Cadmium is classified as a priority hazardous substance, PHS, for which the 2005 draft proposal of the Daughter Directive stipulates that the discharges, emissions and losses into the aquatic environment must cease within 20 years after the date when the Daughter Directive enters into force (Scenario B).

The dominant future source of cadmium release to the aquatic environment in Denmark is assessed to be the discharge of stormwater runoff from paved surfaces and roofs.

To meet the requirements for ceasing "discharges, emissions and losses" of cadmium within 20 years (Scenario B), action must be taken against releases caused by stormwater. The most obvious way of doing this is by introducing detention basins and similar technological arrangements by which particulate matter in the effluent is retained prior to the discharge into the aquatic environment (see Chapter 13).

Further, in Scenario B, replacement of old zinc gutters and downpipes should be considered to the extent they are still in use 20 years after the entry into force of the Daughter Directive.

With regard to Scenario A, it is assessed, based on the interpretation of the obligations in the WFD, that mandatory replacement of old zinc gutters and downpipes is not realistic and that the "natural" replacement due to weathering can be considered to be an appropriate measure.

With regard to both scenario A and B elimination of cadmium in sacrificial zinc anodes could be considered.

4.3 Economic Assessment

The technical assessment has identified elimination of the use of zinc for sacrificial anodes as one of the few realistic technical measures specifically targeted at cadmium. This can be achieved by substituting aluminium or magnesium anodes for the zinc anodes. This measure is technically possible and will mean little or no loss of quality or functionality of the anodes. These anodes contain indium instead of cadmium. Table 4-2 below shows the contents - and thereby the potential losses - of cadmium and indium in the two types of anodes.

Table 4-2 Aluminium anodes compared to zinc anodes, same protection of steel surface

Current capacity: Amp./kg	Consumption: Kg/Amp./Year	Efficiency:	Chemical composition:
Zinc 780	11.2	95 %	Cd 0.025-0.07 %
Aluminium 2600	33	90 %	In 0.01-0.03 %

If the average of the chemical composition in Table 4-2 is used, the total content of cadmium and indium in the two types of anodes are:

Zink 95 %: 11.2 kg x 0.05 % Cd = 5.9 g Cadmium /kg anode material

Aluminium 90 %: 3.2 kg x 0.02 % In = 0.7 g Indium /kg anode material

The volume of aluminium anode material will only be about 1/3 compared to zinc anode material because of the much higher capacity of the former. In sum, there will be a much lower release of indium than of cadmium after a total substitution of anodes.

The main use of anodes is on boats. On small boats and yachts the typical amount of anodes is 0.5 to 10 kg per boat. That means an effect of substitution per boat of between 2.8 and 59 g cadmium.

On larger ships and fishing vessels the typical amount is 50 to 2000 kg. For the remaining underwater uses such as floodgates, gutters at seawater intakes and protection of steel constructions in brackish water and pipelines, the amounts used are all quite small and data is limited.

To implement a fully effective substitution scheme to abandon zinc anodes, the scheme would also have to include foreign small ships entering Danish waters.

The market for sacrificial anodes for larger ships and fishing boats is already dominated by aluminium anodes. Almost all large vessels and harbours use aluminium anodes today, since they are slightly cheaper and the change of production technology has already been effected.[13]

There is a short-term, added financial cost of production of aluminium anodes for small ships compared with zinc anodes. This would mean a higher cost for a small production due to the sunk cost of the investment in new production technology. But in the case of a total change-over of production the average cost can be expected to be slightly lower as is the case with anodes for large ships and harbours. In consequence, there must be one or more barriers that prevent the change-over of production even though it appears to be attractive to both producers and consumers. One Danish producer points to consumer conservatism and sluggish demand to explain the situation. In other words, zinc anodes will still be favoured even when a slightly cheaper alternative with identical functional quality and appearance exists. The assessment warrants a further investigation, but this would entail information campaigns targeting consumers. Further, industrial reconversion policies could be helpful in bringing about substitution of the zinc anodes in small ships anodes.

Another possibility in relation to further progressive reduction is to replace old zinc gutters and downpipes. Before further refining of zinc was started in the late 1970's, gutters, downpipes and hot dip galvanizing in zinc generally contained about 1000 ppm cadmium or more as zinc used for these purposes was not refined in order to reduce the content of cadmium. However, concerns related to the impact of cadmium on humans in the late 1970's led to the adoption of a 100 ppm limit on the cadmium content of zinc used for hot dip galvanising of pipes for drinking water. This limit was adopted by zinc manu-

[13] Based on interview with main Danish producer and one mayor shipping company.

facturers all over Europe. During the 1980's the cadmium content of zinc was further reduced by many zinc manufacturers to a level about 10 ppm or even below.

Zinc manufactured and installed before 1978 in use in the Denmark today includes gutters and downpipes in zinc and zinc used for hot dip galvanising in particular for road infrastructure, such as e.g. lamp standards.

The costs and effects for Denmark of replacing gutters and downpipes in zinc installed before 1980 are estimated based on the following assumptions:

- Based on general statistical data /9/, the number of detached houses and similar buildings (dwelling units, institutions, offices and commercial buildings not included) built before 1980 may be estimated to about 1,200,000 units.

- The percentage of houses built before 1980 and equipped with zinc gutters and downpipes from before 1980 may be roughly assumed to be 10-30 % 14.

- A typical detached house requires 30-50 metres of gutters and downpipes. The average price for installing gutters and downpipes will be about DKK 250 per meter not including VAT /10/, replacement of old gutters and downpipes on a detached house will require an investment of DKK 7,500-12,500.

To these figures should be added the cost of replacing gutters and downpipes on dwelling units, institutions, offices and commercial buildings. No detailed investigations have been made of the investments required in this context. However, it seems fair to assume that such investments could well add an extra 10 - 50% to costs considering the fact that the number of buildings in question is probably small compared to detached houses whereas replacement costs in most cases will be significantly higher due to the height of the buildings in question. This investment can be assumed to take place over a five-year period.

The outcome of this investment would be a strong reduction (>90%), estimated to be around 120 - 480 kg/year, of the yearly release of cadmium to wastewater in the years following the investment /2/.

Table 4-3 below presents the result of the estimated cost of a replacement policy meeting the deadline in 2025 (Scenario B). Note that the figures are quoted in billion DKK. In Scenario A/C it is assumed that the ordinary rate of replacement of gutters ("natural replacement") will be sufficient.

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[14] No data available. Tentative assumption based on selected observations and interviews by COWI in 2006.

Table 4-3 Replacement of downpipes in zinc

Financial assessment	NPV in billion DKK
Scenario B - Replacement of downpipes in zinc over a five–year period before the deadline in 2025	0.4- 2.9
Welfare-economic assessment	
Scenario B - Replacement of downpipes in zinc over a five-year period before the deadline in 2025	1.0-6.6

* A discount rate of 3 % is used. If 6 % is used the results for Scenario B will be DKK 0.6-4.0 billion

The financial cost of Scenario B would be between 0.4 and 2.9 billion DKK compared to Scenario A at between 0.2 and 1.4 billion DKK. The corresponding welfare-economic cost is DKK 1.0-6.6 billion in Scenario B and 0.6-4.2 billion DKK in Scenario A. The welfare-economic cost has been calculated on the assumption that the replacement scheme is financed by public funds. If replacement is to be exclusively funded by private house owners, the welfare-economic cost should not include marginal costs of public funds, and roughly estimated the cost would be 20% lower.

The potentially high costs related to replacing old hot dip galvanized items, including road infrastructure (signposts, crash barriers, lamp standards etc.) have not been estimated as a significant fraction of these probably only has a marginal impact on water quality, and the rest is of a diffuse nature that can be addressed through stormwater retention arrangements (Chapter 13).

The cost of general action against suspended matter/pollutants in stormwater runoff is estimated after the substance-specific chapters in this report.

4.4 Conclusion on Cadmium

According to the monitoring data available, the concentrations of cadmium in various discharges as well as in surface waters do not appear to pose a problem in relation to compliance with the proposed EQS values, and therefore there is no need for further progressive reduction measures in Scenario A.

The existing regulatory measures contribute to the decreasing trend of cadmium concentrations in emissions and discharges into the environment and could, thus, possibly fulfil the Scenario B obligation of progressive reduction even after EQS compliance has been achieved.

However, cadmium is categorised as a priority hazardous substance (PHS), and therefore in Scenario B action needs to be taken to ensure cessation of discharges, emissions and losses to the aquatic environment (with a timeframe of 20 years). In Scenario A, additional measures must be taken based on considerations of all technical reduction options with the aim of fulfilling the cessation/phase-out obligations.

The possible means of achieving this include in Scenario A and B substitution of aluminium anodes for sacrificial zinc anodes. Sacrificial zinc anodes for corrosion protection are considered one of the main sources of emissions of cadmium. Three potentially relevant uses of zinc anodes were considered, i.e. on large ships and steel sheet piling and the like in harbours; on smaller ships and yachts; and on metal piping. As it can be seen in Table 4-4 below, only anodes on small ships are relevant for further consideration.

There are good technical and economic possibilities of substituting zinc anodes for aluminium anodes as production costs will not increase even if a total change-over of the production is effected. In fact, the change-over to production of aluminium anodes for large ships have resulted in slightly lower production costs and thus in somewhat lower prices. However, there seems to be barriers preventing the change-over of the production of anodes for small ships in Denmark.

Table 4-4 Overview of potential substitution of zinc anodes

	Yearly consumption in 2012 (estimated)	Possible substitution?	Effect/ kg of anode (reduction in loss to water)	Total effect/ kg of anode (reduction in loss to water)	Financial and welfare economic cost
Zinc anodes on larger ships and in harbours (steel sheet piling etc.)	?	Yes, but aluminium anodes already dominate the market today. In 2012, zinc anodes must be expected to be completely phased out for this use.	n.a.	n.a.	The price today is slightly lower for aluminium anodes than for the corresponding zinc anode. On larger ships and fishing vessels the typical amount was 50 to 2000 kg.
Zinc anodes on smaller ships	?	Yes, with aluminium anodes. No functional difference.	5.9 g Cadmium /kg of anode material	?	Short-term investment cost for producers, and slightly higher cost to consumers. Long-term cost 0 or a slight financial benefit. Potential public costs associated with overcoming barriers preventing the change-over of production.
Zinc anodes on metal piping	?	No, not technically possible	n.a.	n.a.	n.a.

The financial cost of replacing cadmium in sacrificial zinc anodes is estimated to be low or even to give a slight welfare-economic and financial gain in Scenarios A and B. This is a tentative, preliminary estimate. Aluminium anodes for larger ships already dominate the market, and there is no difference in quality or functionality. The price is slightly lower than the price of traditional zinc anodes. In the short-term, substitution of zinc anodes still used for smaller ships would entail investments to be made by producers and slightly higher costs to consumers. However, the long-term cost would probably be 0 or it would lead to a slight financial and welfare-economic benefit. Public expenditure to overcome barriers preventing the change-over of production is foreseen.

The possible replacement of downpipes in zinc manufactured before 1978 and with high cadmium content was also investigated. In scenario A/C it is assumed that the ordinary rate of replacement of the gutters will be appropriate. The potential cost of a substitution scheme was estimated to be quite high as the financial cost of Scenario B would be between DKK 0.4 and 2.9 billion. The corresponding welfare-economic cost is DKK 1.0-6.6 billion. The outcome of this investment would be a strong reduction (>90 %) in the yearly release of cadmium to wastewater (presently 120-480 kg) in the years following the investment /2/. It should be noted that this is the cost of an example of a replacement campaign based on Swedish experiences. A campaign could be conducted on a smaller scale, but the effects would be unknown. A campaign at a scale similar to the Swedish one is assessed to be a cost-effective measure, but this needs further investigation.

A final option is to reduce the level of cadmium in stormwater discharges (common measure affecting a significant number of PS/PHS), which is the largest direct source of releases to surface waters in Denmark. With regard to potential measures targeting stormwater discharges in scenarios A and B, the subject is discussed in technical and economic detail in Chapter 13.

4.5 References

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5 Assessment of DEHP

5.1 Definition of the reference state

5.1.1 Introduction

DEHP (di(2-ethylhexyl)-phthalate; CAS no. 117-81-7)) is a substance belonging to the group of phthalic acid esters whose dominant technical function, as a group, is to act as a plasticizer in a variety of polymer products. DEHP almost exclusively has this technical function and is predominantly used for softening of PVC products.

Environmentally, DEHP is a lipofilic (i.e. fat-soluble) substance with rather low water solubility and affinity to particulate (organic) matter. Also, the volatility of the substance is rather low. It is moderately degradable in the environment (soil and water) under aerobic conditions /1/.

5.1.2 Main uses and pollution sources

By far the largest use of DEHP is as a plasticizer in PVC products. Flexible PVC is used for the production of a wide range of products such as pipes and tubes, flooring and wall lining materials, sealants, various foils, cable and wire sheathing, tarpaulins, rain coats, rubber boots, shoes, toys, office supplies, catheters and other medical utility devices /2/.

The sources of DEHP release to the aquatic environment comprise point sources as well as diffuse sources. The most important point source type is the discharge of effluents from municipal sewage treatment plants. The DEHP in domestic type sewage originates from the release of the substance from the mentioned products and materials by slow diffusion to the surface of the product/material from where it is washed off during cleaning operations or continuously if in direct contact with water (tubes and pipes). Other contributions of DEHP to sewage come from enterprises producing or using products and materials based on flexible PVC.

DEHP also occurs in urban surface runoff, which is discharged either separately or, in the case of combined sewers, mixed with sewage and discharged together with this from the sewage treatment plants. The DEHP in surface runoff originates partly from releases from building materials and vehicles and partly from the diffuse atmospheric deposition of volatilised DEHP from all kinds of PVC products and materials.

The total consumption of phthalates in Denmark was in 2001 approximately 11,000 tonnes of which by far the largest amount was used for producing flexible PVC /2/. There exists no separate figure for the consumption of DEHP but it is considered to be the quantitatively most important of the phthalates and it is the cheapest of the existing plasticizers for PVC /3/. However, recent information from DEPA /4/ indicates that the significance of the substance is decreasing (DEHP slowly being replaced by DINP).

DEPA has assessed that in 2001 the most significant single use of phthalates was for cable and wire sheathing (3,400 tonnes) while the consumption for flexible pipes and tubes was about 1,260 tonnes /4/. About 340 tonnes were used for flooring and wall lining products and 3,450 tonnes for other uses. For two specific outdoor applications, tarpaulins and steel (roof) gutter coatings, the consumption was estimated to 870 tonnes and 1,300 tonnes respectively.

It is assessed that today DEHP still constitutes at least half of the amount of plasticizers used in PVC and, hence, that the present annual consumption in Denmark is at least 5,000 tonnes.

5.1.3 Releases to and state of the aquatic environment

The most important uses of DEHP leading to releases to the aquatic environment are considered to be flexible pipes and tubes, flooring and wall lining products, prints on textiles (plastisols), and, among the outdoor uses, underseal for cars and coating of roof gutters. Further, the combined diffuse contribution from a wide range of product categories to both sewage and urban surface runoff should not be underestimated.

If combining the monitoring results presented in Table 5-1 below with the volumes of sewage effluent and sewage sludge in 2001 (/5/ /6/), the total release of DEHP from municipal sewage treatment plants to the aquatic environment in 2001 can be estimated to about 1.1 tonnes while the effluents from separate rain runoff systems contributed with about 4.8 tonnes. The amount of DEHP ending up in the sewage sludge was about 3.6 tonnes.

The above value for rain runoff may be somewhat overestimated since the concentration in table 5-1 originates from data that are almost 10 years old, and the investigation was carried out in the Copenhagen metropolitan area (a highway and a residential area) where the load is considered to be higher than the average. Recent figures from separate runoff systems in two residential suburban areas in northern Jutland show ranges from 1.8-10 µg/L and 0.5-2.7 µg/L, respectively /10/ /11/. However, in both areas the traffic intensity as well as the contribution from general atmospheric deposition are considered to be rather low.

The above calculation indicates that the largest contribution to the total load of DEHP on the aquatic environment comes from the about 10,000 discharge points from large or small separate surface runoff systems.

Table 5-1
Monitoring data for DEHP (average or 50% percentile values). The values in parenthesis are the 95 % percentiles. References: /5/, /7/, /8/.

Substance	Municipal sewage (µg/l)		Sewage sludge (µg/kg dw)	Stormwater, separate system (µg/l)	Surface water (µg/l)*
	Influent	Effluent			
DEHP	17 (31)	1.8 (6.1)	22,700 (40,600)	32 1.8-10** 0.5-2.7***	0,05 (3.6)

* Average value of 50% percentile values for five Danish lakes; max. value in parenthesis.
** Ref. 10 (range of values)
*** Ref. 11 (range of values)

EQS proposal

The EQS value proposed for DEHP in the aquatic environment is AA-EQS = 1.3 µg/l (surface waters) while no MAC-EQS has been defined in the proposal (stated to be "not applicable").

5.1.4 Existing legislation/regulation and their impact

Act no. 954 of 20/12/1999 from the Ministry of Taxation on taxes on polyvinylchloride and phthalates with subsequent updates

By this Act, which entered into force in 2000, tax was put on phthalates in a significant number of flexible PVC products including pipes and tubes (except for medical uses), electrical cables and wires, flooring and wall lining materials, foils and tarpaulins etc. i.e. most of the significant uses in Denmark.

Assessment: No reporting has been published, which evaluates the effect of the taxation act on the consumption of DEHP or other phthalates for use in flexible PVC. However, five years having elapsed since the entry into force of the act, it is believed that the act cannot exert much more influence on the DEHP consumption. However, many products containing DEHP have a long life and, hence, it may take a considerable number of years before a possible reduced use of PVC plasticizers (or of flexible PVC as such) is reflected in the levels monitored in sewage effluents and other releases to the aquatic environment.

Statutory Order no. 151 of 15/03/1999 from the Ministry of the Environment banning phthalates in toys for children aged 0 – 3 and in certain childcare articles.

Articles aimed for use by children below three years of age must not contain DEHP or other esters of o-phthalic acid in concentrations exceeding 0.05%. This ban also includes inflatable bathing/swimming pools, beach toys and, since January 2004, inflatable safety jackets, bathing rings and bathing wings for children under three years.

Assessment: It is assessed that the full (or close to full) effect of this statutory order has been achieved. Occasionally, however, cases will probably continue to be uncovered where imported products for children turn out to contain DEHP or other phthalates.

Statutory Order no. 786 of 11/07/2006 from the Ministry of the Environment

Toys and childcare articles for use by children below 14 years of age must not contain DEHP, DBP or BBP in concentrations exceeding 0.1%. This ban includes all types of toys and childcare articles which are included in the Toys Directive 88/378/EEC.

Assessment: This Statutory Order, which is by virtue of the 22nd amendment of Council Directive 76/769/EEC, will come into force January 2007. The order is not believed to have any significant influence on the overall level of DEHP in releases and discharges into the aquatic environment.

Statutory Order no. 74 of 14/01/2005 from the Ministry of the Environment on cosmetics

According to this recent statutory order, DEHP and other phthalates are not permitted for use in cosmetic products.

Assessment: This regulation is very new and cannot yet be expected to have been fully enforced, especially because many cosmetic articles are imported.

However, the impact of this ban on the releases of DEHP to the aquatic environment, even when DEHP has become fully phased out of cosmetic products, is believed to be relatively insignificant as DEHP is probably not in general an important constituent of cosmetic products.

Statutory Order no. 439 of 3 June 2002 from the Ministry of the Environment on the list of dangerous substances
Since 1 July 2002 DEHP has been on the so-called "List of dangerous substances" as harmful to reproduction as well as posing a teratogenic risk. The listing implies that products such as paint, glues and cleaning agents etc. must not be sold in retail stores if the content of DEHP in the product exceeds 0.5%.

Assessment: The List of dangerous substances is not believed to have the same judicial power as a specific statutory order and can therefore not in itself be expected to lead to a complete phase-out of such products in retail sale. However, the bad publicity associated with the possible uncovering of violations will probably have a preventive effect.

5.1.5 Conclusion on the need for further regulation

The 50% percentile level of DEHP in sewage treatment plant effluents is presently only approx. 40% higher than the proposed AA-EQS while the 95% percentile level requires an initial dilution of 4.7 times to comply with the AA-EQS. As the decreasing trend in the use of DEHP can be expected to continue and as by far the largest volume of Danish sewage effluents are discharged at locations where the initial dilution is (significantly) more than 5 times, it is assessed that no further national measures are required to achieve AA-EQS compliance for this type of release to the aquatic environment.

To evaluate the possible need for measures in relation to discharges of untreated stormwater from separate systems the concentrations of DEHP observed in this type of discharges (see table 5.1) should be compared to the MAC-EQS. As, however, such a MAC value has not been defined, the evaluation cannot be carried out at present (the AA-EQS is not considered suitable for this purpose).

The monitoring data from Danish lakes indicate that on the average the existing levels easily comply with the AA-EQS while the highest value observed was 2.7 times higher than the AA-EQS.

Thus, there appears to be no need for further measures to be able to comply with the proposed EQS values for DEHP and thereby not either a need for further progressive reduction in Scenario A. Further, it is assessed that the existing Phthalate Action Plan /9/ fulfils the requirement of Scenario B to continue progressive reduction beyond the EQS compliance level.

In conclusion, and as DEHP is not classified as a priority hazardous substance, there appears to be no need for further national regulation, neither in relation to Scenario A nor to Scenario B.

5.2 Possible reduction/elimination measures

5.2.1 Technical measures to reduce/eliminate DEHP

The Phthalate Action Plan comprises proposals for initiatives within practically the whole span of uses of phthalates in flexible plastic products, predominantly PVC. In relation to protection of the aquatic environment, the following are considered to be the most central areas for action:

- flooring and wall lining materials (especially for "wet rooms")
- gutter coating products (roof gutters)
- prints for textiles (plastisols)
- underseal products for cars

Regarding the two former, the Action Plan mentions that alternatives have been identified but that these are more costly to use than DEHP. Therefore, it is suggested in the plan to impose a tax on phthalates for these uses as an incentive to speed up the process of substituting DEHP with alternative substances.

Plastisols for textile prints is recognised as a complex area with many imported products and where common EU action is needed in order for the possible measures to be effective. Danish initiatives in support of this have been announced.

The plan mentions that alternative underseal products for cars without phthalates exist, but that these are not without problems. Also within this area DEPA suggests to work actively for common regulatory measures in the EU. Additionally, since the launching of the Action Plan, fully galvanized car bodies, for which undersealing is unnecessary, have become much more common in the international manufacturing of cars.

As mentioned earlier, the existing Phthalate Action Plan appears to comprise ideas and initiatives within all relevant areas of DEHP/phthalate use and, hence, there seems to be no need for additional initiatives (only common follow-up) in consequence of the requirements in Scenario A/C or B.

Stormwater runoff

As mentioned in section 5.1.3, the dominant source of release to the aquatic environment appears to be stormwater runoff from separate systems affected by diffuse sources of DEHP. Therefore, an initiative to reduce this input could be considered though the need in relation to compliance with a MAC-EQS cannot be evaluated at present and though it is considered technically as well as economically unrealistic to introduce measures specifically aimed at reducing DEHP or phthalates in stormwater runoff.

The majority of the PS/PHS including DEHP are characterised by properties such as lipofilicity and significant sorption onto particulate (organic) matter. Therefore, it is assessed that technological measures that generally aim at retaining suspended particles in surface runoff will significantly reduce the loads of DEHP and many other PS/PHS on the aquatic environment.

Since this type of measure is not substance specific, it is described technically and assessed economically in a separate chapter (Chapter 13).

5.2.2 Possible synergies with other (priority) substances

The specific measures against DEHP/phthalates contained in the Phthalate Action Plan are not assessed to have any significant bearing on the other substances included in the proposed directive's list of PS/PHS.

However, a possible general action against suspended matter/pollutants in stormwater runoff will not only lead to a significant reduction in DEHP inputs to the aquatic environment but also in most of the other PS/PHS.

5.2.3 Summary and assessment of technical possibilities

It is assessed that there is no need for additional initiatives to the Phthalate Action Plan to meet the directive's requirement to progressively reduce the pollution or emissions/discharges/losses of DEHP.

However, a combined, general action against pollutants in stormwater runoff from roads, roofs etc. will have a beneficial impact on the total load of DEHP on the aquatic environment.

5.3 Economic Assessment

Neither the implementation of Scenario A/C nor Scenario B will imply costs additional to the costs resulting from implementing the Phthalate Action Plan (the reference state/Scenario 0). There is therefore no difference in cost between implementing the two scenarios.

The cost of general action against suspended matter/pollutants in stormwater runoff is estimated after the substance-specific chapters in this report.

5.4 Conclusion regarding DEHP

According to the monitoring data available, the concentrations of DEHP in various wastewater discharges as well as in surface waters do not pose a problem in relation to compliance with the proposed AA-EQS. Stormwater discharge is assessed to be the largest direct source of DEHP releases to surface waters in Denmark. However, as no MAC-EQS has been defined for DEHP, the possible need for further measures aimed to reduce the inputs from this type of source to the aquatic environment has not been evaluated.

Because of the initiatives and actions included in the already existing Phthalate Action Plan it is assessed that there no need for additional national initiatives to meet the requirements of Scenario B or Scenario A.

Therefore, it is concluded that implementation of the requirements of Scenario A or Scenario B will not imply additional costs on Denmark with regard to DEHP.

5.5 References

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6 Assessment of lead

6.1 Definition of the reference state

6.1.1 Introduction

Lead (CAS no. 7439-92-1) is an element and is therefore not degradable in nature. Besides metallic lead, there are also a number of lead compounds that must be considered.

Environmentally, lead is a heavy metal with high toxicity. Lead and many lead compounds have very low water solubility. However, the solubility of compounds such as lead chloride and lead nitrate is high. Generally, lead is not considered to be mobile in soil. Lead bioaccumulates in the skeleton and wet tissue in mammals and in aquatic algae and invertebrates /1/.

6.1.2 Main uses and pollution sources

In Denmark, lead is used for many different purposes. It is in reality necessary to distinguish between:

- Intentional uses as lead metal;
- Intentional uses as lead compounds;
- Un-intentional "uses" as contaminant in other materials.

Table 6-1
The most important applications of lead in Denmark and the consumption in year 2000 just before the lead ban (see 6.1.4) entered into force.

Product group	Consumption (tonnes Pb/year)	% of total
Metallic lead		
Lead batteries	8,300-9,300	52
Building materials	3,700-4,100	23
Yacht keels	240-740	2.9
Cable sheets	350-380	2.2
Alloys	360-700	3
Fishing equipment	530-910	4
Other uses*	257-913	3
Chemical compounds		
Glass (incl. cathode ray tubes)	660-980	5
PVC	440-570	3
Pigments i paint and plastics	17-70	0.3
Other uses**	54-230	0.8
As contaminant		
In fuels	43-72	0.3
Other uses	24-67	0.3
Total (rounded)	14,900-19,000	

* Wheel balancing weights (76-160 tons), ammunition (110-200 tonnes), Radiation protection (42-450 tonnes) and miscellaneous other uses.
** Lead oxide paint (0.5-2 tonnes), glazing (40-150 tonnes), fireworks, siccatives and several other uses.

Today the lead ban must be assumed to have resulted in a substantial reduction in the uses of lead in building materials. Apart from this, the use of lead for angling equipment and for most applications of chemical compounds (lead glass for cathode ray tubes is an important exemption) has by and large ceased.

The most important pollution sources of lead releases to the environment may briefly be listed as follows:

Air
Air emissions from fireworks, waste incineration, metal foundry activities, metal refining and recycling as well as incineration of fossil fuels. Total annual air emissions in 2000 in Denmark were estimated at 3-17 tonnes /2/.

Water
Fishing equipment, cable sheets, yacht keels, lead oxide paint together with discharges from sewage treatment plants and stormwater drainage. Total water releases in 2000 in Denmark were estimated at 170-690 tonnes /2/.

Soil
Abandoned cables, ammunition are the main contributors. To this may be added paint residues, phosphate based fertiliser, agricultural chalk, sewage sludge and several other sources. Total annual releases to the soil in 1996 in Denmark were estimated at 470-2200 tonnes /2/.

6.1.3 Releases to and state of the aquatic environment

The most important sources of direct release to the aquatic environment are fishing equipment and cable sheets, lost or abandoned. It is, however, important to note, that these sources contributes only marginally to the amount of lead dissolved in the sea or in freshwater. As a main rule this lead will be buried in sediments. However, there are important exemptions from this rule such as e.g. lead weights on fishing equipment that are dragged along the bottom or sinkers before they end in erosion zones in which wear is possible. So far, it has not been quantified to what extent lead ending in the water environment with fishing equipment and cables dissolve and thereby become biologically available.

The story of yacht keels is very similar to fishing equipment and cable sheets. Occasionally, yachts will sink but to what extent the lead is becoming biologically available has never been quantified.

The consumption of leadoxide paint is small in Denmark today, but losses to the aquatic environment still occur, partly from residues from ships treated with lead-oxide paint some 20 to 40 years ago, and partly from ships treated in other countries where the use of lead-oxide paint is not restricted to the same extent as in Denmark. There are no investigations allowing this source to be quantified.

In 2000, the total release of lead to the aquatic environment from municipal sewage treatment plants and stormwater outlets were estimated to 2.5 - 6.8 tonnes. The lead must be assumed to be biologically available, but will to some extent deposit as sediment close to the outlets. The dominant source is corrosion of lead flashing and lead roofing on buildings. Minor sources to consider include wear of brake linings, pigments and siccatives in paint, corrosion of galvanized surfaces and atmospheric deposition.

Atmospheric deposition also contributes directly to lead in the aquatic environment. The deposition in 2000 for the Danish internal waters was estimated at 26 - 48 tonnes /2/.

Table 6-2
Monitoring data for lead (average values). The values in parenthesis are the 95% percentiles. Sources: /3/,/4/,/5/,/6/.

Substance	Municipal sewage (µg/l)		Sewage sludge (µg/kg dw)	Stormwater, separate system (µg/l)	Fresh/marine surface water (µg/l)
	Influent	Effluent			
Lead	16 (37)	1.9 (5.3)	64,000 (126,000)	17 (<0.4-47) (highways)	1.28* 0.49**

* Average value of 50% percentile values for five Danish freshwater streams.
** Average value of 50% percentile values for five Danish lakes.

Based on the median values in sewage and in stormwater runoff presented in table 6-2, the total Danish release of lead to the aquatic environment can be estimated at about 1200 kg/year and 2600 kg/year respectively.

EQS proposal
The proposed water quality criteria (EQS) for lead is AA-EQS = 7.2 µg/l (all surface waters) while no MAC-EQS has been defined in the proposal (stated to be "not applicable").

The background concentration in freshwater used in the preparation of the EQS proposal for lead was 0.2 µg/l ("dissolved"), a value determined for the river Rhine.

6.1.4 Existing legislation/regulation and their impact

Statutory Order no. 1012 of 13 November 2000 from the Ministry of the Environment on prohibition of import and marketing of products containing lead.
This Order prohibits the import and sale of products, in which lead is present as chemical compound in concentrations above 100 ppm in homogeneous materials. A number of exemptions to the ban have been granted. Also, a number of products made of metallic lead are banned, including roofing and flashing on buildings and fishing equipment.

Assessment
The Order restricts a number of very important sources. It must be emphasised that the Order does not prohibit the use of existing equipment, for which reason existing equipment will continue to cause releases until the equipment for other reasons (wear and tear or technological outdating) is disposed of. The following limitations should be considered important:

- Lead restrictions in fishing equipment should take full effect in 10 to 20 years, assuming that substitutes for all types of commercial fishing equipment are actually developed and marketed. Equipment exposed to significant wear will be replaced relatively quickly while the use of equipment not significantly exposed may continue many years ahead.

Regarding lead for flashing one may note that the use of lead for reconstruction and repair work is still allowed. Furthermore, the effect will only be seen in the long-term perspective as the lifetime of e.g. flashing is in reality determined by the lifetime of the windows or chimneys for which the flashing is used. This means that the full effect will probably not be achieved until 20 to 40 years from now. In the case of lead roofing it must be expected that exemptions from the ban will be granted for historical buildings such as churches, which account for the dominant part of the consumption. A possible effect cannot be expected until in a distant future.

- Lead restrictions on fireworks will produce an immediate and profound effect, only limited by the possible illegal import of fireworks from other countries.

Furthermore, lead restrictions on chemical compounds used in paint (pigments as well as siccatives) can be expected to produce an effect, which will influence release to wastewater and stormwater. Further lead restrictions may also impact the amount of lead released to the air from waste incineration plants and miscellaneous manufacturing activities in Denmark and abroad. However, the effect of restrictions will be limited and only manifests itself slowly in the coming 20 50 years.

The stock of lead in Danish society is huge, and so far it is only Denmark that has placed far-reaching restrictions on the use of lead. Thus, it is not likely that releases of lead with wastewater and stormwater and with atmospheric deposition to the Danish internal waters will be significantly reduced within the next 10 to 20 years. It is noted that DEPA is currently considering whether and in what way it will be necessary to tighten lead restrictions presently established by the Order.

Statutory Order no. 1272 of 17 December1996 on guns and ammunition allowed for hunting etc.
The use of lead shot for hunting and sports shooting has been banned since 1996. However, lead bullets for rifles etc are still allowed.

Assessment
This Order reduces the amount of lead released to agricultural soil and forest soil and thereby eventually also the amount of lead leached from soil to fresh water bodies.

Statuary Order no. 1008 of 12 October 2004 from the Ministry of the Environment on import and sale of electric and electronic equipment.
Equipment containing lead, cadmium, mercury, chromium (VI), polybrominated biphenyls (PBB) or polybrominated diphenylethers (PBDE) is prohibited from 1 June 2006. Some exemptions for lead have been granted.

Assessment
This Order implements the EU RoHS Directive in Denmark. The Order has just entered into force all over Europe, and it will have a significant global impact. The Order will reduce the amount of lead directed to waste incineration plants in Europe with a delay of 5 to 15 years depending on the products in question. While the direct effect of the Order on releases from waste incineration is limited, the Order may have an important set-off effect due to the fact that the knowledge of alternatives is extensive and widespread. Thus, the

RoHS Directive may have a very far-reaching effect on releases from waste incineration although the effect lies 10 years ahead. It is noted that the RoHS Directive supplements the EU ELV-directive, which limits the use of lead in vehicles. Taking into account an anticipated delay of 15 to 20 years, the Directive will reduce releases from scarp-based steel plants and to some extent waste incineration plants all over Europe.

Statutory Order no. 489 of 12 June 2003 from the Ministry of the Environment on cosmetic products.
The order prohibits the use of lead and compounds in cosmetics, apart from lead acetate which is allowed for hair colouring.

Assessment
The order has no significant impact on the aquatic environment since the consumption of lead for cosmetics is insignificant.

Statutory Order no. 298 of 30 April 1997 from the Ministry of the Environment on certain requirements on packaging
This sum of the content of lead, cadmium, mercury and chromium (VI) present in packaging materials to be used in Denmark must not exceed 100 ppm by weight.

Assessment
Limiting the amount of lead used in packaging materials also reduces the amount directed to waste disposal with products, which, in turn, limits releases from waste incineration etc.

Other regulation relevant for lead includes:

- ***Statutory Order no. 655 of 27 June 2000 on recycling of residual products. and soil in building and construction work.***
- ***Statuary Order no. 162 of 11 March 2003 on waste incineration plants.***
- ***Statuary Order no. 623 of 30 June 2003 on application of waste products for agricultural purposes.***

Assessment
The Orders may have a direct impact on the release to the aquatic environment depending on how the rules are actually established.

6.1.5 Conclusion on the need for further regulation

The concentrations of lead in sewage and stormwater discharges presented in table 6-2 show that no initial dilution is required for sewage effluent to comply with the AA-EQS, even for the 95% percentile value of treated sewage effluent. For stormwater a modest dilution of about 2.4 times is required to comply with the AA-EQS (the correct way would be to compare with a MAC-EQS, which, however, has not been defined).

When further considering that the values in table 6-2 represent the total content of lead while the EQS are for the dissolved fraction (which constitutes only a minor part of the total concentration), it is assessed that lead does not pose problems with regard to compliance with the proposed AA-EQSs.

Further, the existing regulation will slowly reduce the releases of lead to the aquatic environment. It is roughly estimated that the current, biologically available contributions to the aquatic environment in Denmark by 2015 might be reduced by 10 to 30 %.

In conclusion, there appears to be no need for further progressive reduction in Scenario A. With regard to Scenario B, the slow but steady reduction of lead in releases and discharges into the (aquatic) environment resulting from the existing regulatory measures can be interpreted as continued "progressive reduction" beyond the EQS compliance level.

Lead is not classified as a priority hazardous substance. Therefore, there is no obligation to completely cease/phase out emissions, discharges and losses.

6.2 Possible reduction/elimination measures

6.2.1 Technical measures to reduce/eliminate lead

Generally, in these years a significant effort is invested in Denmark and via the EU RoHS and ELV Directives to substitute lead for many purposes, and it is not possible to bring forward proposals for substitution of lead that within the short time perspective available would significantly reduce any further the amount of lead directed to the aquatic environment in Denmark. Naturally, it could be proposed that existing lead flashing and lead roofing on buildings in Denmark be replaced with other materials within e.g. five years. While this proposal actually would have a significant impact on the release of lead to the aquatic environment, it is, however, hardly realistic due to the practical and economic consequences.

Therefore, if further measures to reduce releases of lead to the aquatic environment are requested, the primary additional option in the shorter term seems to be:

- The reduction of releases of lead with stormwater by arrangements detaining suspended solids. Such arrangements will actually be effective against lead from corrosion of flashing and roofing as well as atmospheric deposition and other sources.

6.2.2 Possible synergies with other (priority) substances

The dominant source of release of lead into the aquatic environment appears, as mentioned in section 6.1.3, to be stormwater runoff from separate systems. Therefore, an initiative to reduce this input could be considered though it is considered technically as well as economically unrealistic to introduce measures specifically for lead in stormwater runoff.

However, the majority of the PS/PHS including lead are characterised by properties such as lipofilicity and significant sorption onto particulate (organic) matter. Therefore, it is assessed that technological measures that aim to detain suspended particles in surface runoff will significantly reduce the loads of lead and many other PS/PHS on the aquatic environment.

Since this type of measure is not substance specific, it is described technically and assessed economically in a separate chapter (Chapter 13).

6.3 Economic Assessment

No substance-specific economic estimations are relevant since there is no need for action in neither implementing Scenario A nor Scenario B.

The cost of general action against suspended matter/pollutants in stormwater runoff is estimated after the substance-specific chapters in this report.

6.4 Conclusion regarding lead

According to the monitoring data available, the concentrations of lead in various discharges as well as in surface waters do not pose a problem in relation to compliance with the proposed EQS values. Stormwater discharge is the largest direct source of lead emitted to surface waters in Denmark.

It is concluded that there is no need for further national regulatory measures in Scenario A. For Scenario B the ongoing reduction of lead in releases and discharges resulting from the existing regulation can constitute the required progressive reduction beyond the EQS level.

Therefore, it is concluded that implementation of the requirements in Scenario A or Scenario B will not imply additional costs on Denmark with regard to lead.

6.5 References

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7 Assessment of mercury

7.1 Definition of the reference state

7.1.1 Introduction

Mercury (CAS no. 7439-97-6) is an element, and it is therefore not degradable in nature. Besides metallic mercury there are a number of other mercury compounds to consider.

In an environmental context, mercury is a heavy metal with high toxicity. Mercury does not have a high water solubility. In soil mercury forms complexes with organic compounds. This complexing behaviour controls to a large extent the mobility of mercury in soil. Generally, mercury is assumed to have a long retention time in soil. In the environment and in particular in the aquatic environment, mercury is naturally transformed into methyl mercury, which is fat soluble and therefore has the ability of being bio-magnified in the food chain /1/.

7.1.2 Main uses and pollution sources

The dominating use of mercury is as dental amalgams. Intentionally mercury is also used in small quantities in batteries, lamps, thermometers, electrical switches and contacts and miscellaneous monitoring equipment etc. Unintentionally, mercury is consumed with coal, oil products and cement, and as an impurity in most other materials.

In 2001, the consumption of mercury in Denmark was estimated at 2.1-5.0 tonnes /2/. Intentional uses accounted for a consumption of 1.3-1.9 tonnes/year while unintentional uses accounted for about 0.8-3.1 tonnes /2/. The corresponding figures for 1982/83 were 15.1-17 tonnes and 1.1-2.9 tonnes respectively /2/, clearly illustrating that intentional uses have been reduced considerably over the last two decades while unintentional uses remain almost unchanged.

The most important pollution sources of mercury releases to the environment today may briefly be listed as follows:

Air
Air emissions from waste incineration, coal power plants, cement manufacturing, cremation as well as several other sources including scrap handling etc. The total air emissions in 2001 in Denmark were estimated at 0.8-2.0 tonnes yearly of which cremation accounted for 0.17-0.19 tonnes/year /2/.

Water
Discharges from sewage treatment plants and drilling mud (for offshore oil/gas exploration). Total annual water releases in 2001 in Denmark were estimated at 0.05-0.5 tonnes /2/.

Soil
Sewage sludge, and other waste-based residual products used for agricultural purposes and the like, burials and phosphate-based fertilizers etc. Total annual soil releases in 2001 in Denmark were estimated at 0.2-0.3 tonnes /2/.

7.1.3 Releases to and state of the aquatic environment

The most important sources of release of mercury to the aquatic environment comprise:

- Effluents from municipal sewage treatment plants and other discharges of waste and stormwater
- Use of drilling mud
- Atmospheric deposition directly to the aquatic environment.

Effluents from sewage treatment plants as well as discharge of stormwater were estimated to account for 0.03-0.36 tonnes of mercury coming from a number of sources. The most important source is dental clinics as only about 80 % of all clinics are equipped with effective mercury filters. Other significant sources include thermometers and monitoring equipment containing mercury.

As new mercury equipment is banned, the releases in these cases are assumed to originate from old equipment still in use and subject to breakage or other kinds of failure. The amount of actual releases is subject to much uncertainty.

Besides these sources, it must be anticipated that other stocks of mercury may still be present in Denmark, e.g. mercury deposits in siphon traps, and they continue to contribute to the mercury content in wastewater.

Atmospheric deposition from sources within Denmark and abroad adds to the amount of mercury emitted from sewage treatment plants and by stormwater drainage as it is washed away from ground surfaces by rain water.

Drilling liquid and mud are used to undertake and operate drillings for oil and gas in the North Sea. Mercury is a natural contaminant in some of the components (barite, $BaSO_4$) of the drilling liquid and mud.

Atmospheric deposition, furthermore, is an important direct source of mercury to Danish interior waters. The contribution in 2001 was estimated at 0.08 tonnes yearly.

Table 7-1
Monitoring data for mercury (average values). The values in parenthesis are the 95% percentiles. Sources: /4/ /5/ /6/ /7/.

Substance	Municipal sewage (µg/l)		Sewage sludge (µg/kg dw)	Stormwater, separate system (µg/l)	Fresh/marine surface water (µg/l)
	Influent	Effluent			
Mercury	0.4 (1.5)	0.09 (0.3)	1300 (4300)	0.079	0.002* 0.0006**

* Average value of 50% percentile values for five Danish freshwater streams /7/.
** Average value of 50% percentile values for five Danish lakes /8/.

Based on the median values in sewage and in stormwater runoff presented in table 7-1, the total Danish releases of mercury from these sources to the aquatic environment can be estimated at about 55 kg/year and 12 kg/year, respectively.

EQS proposal
The proposed water quality criteria (EQS) for mercury is AA-EQS = 0.05 µg/l (all surface waters) and MAC-EQS = 0.07 µg/l (all surface waters).

7.1.4 Existing legislation/regulation and their impact

Statutory Order no. 627 of 1 July 2003 from the Ministry of the Environment on prohibition of import, sale and export of mercury and mercury-containing products.
The Order prohibits the import, sale and export of products, in which mercury is present in concentrations above 100 ppm in homogeneous materials. A number of exemptions to the ban have been granted, including the use of mercury for certain dental applications, for contacts and switches in certain equipment etc.

Assessment
The Order restricts most intentional uses of mercury, which should eventually result in a strong reduction of emissions to the environment covering air, water as well as soil. However, it must be emphasised, that the Order does not prohibit the use of existing equipment, for which reason existing equipment will continue to cause releases until it is being disposed of for other reasons (wear and tear or outdate technology).

This limitation is important as mercury equipment in thermometers, barometers and other types of monitoring equipment may last for many years if treated carefully, and it will generally first be replaced when it breaks. Mercury equipment in use will thus continue to be a source of release to the aquatic environment for at least the next 20 years.

It may also be noted that mercury amalgam is still allowed for molars where the filling is subject to wear. This limitation means that dental clinics will continue to be a source of release of mercury to wastewater for many years ahead as mercury fillings may well last for about 20 years, and releases come from drilling in and replacing old fillings as well as from putting in new fillings.

Statutory Order no. 1042 of 17 December.1997 from the Ministry of the Environment on restricting the sale and use for specific purposes of certain hazardous chemical substances and products
The Order restricts the use of mercury in paint, varnish, disinfection and conservation of masonry, wood and textiles, for antifouling and similar purposes on ships and equipment used at sea and for water for industrial purposes.

Assessment
Although the use of mercury is not completely banned by the Order, the Order confirms a development towards an almost complete phase-out of mercury used in such products marketed in Denmark (reference is made to /2/). Today, the consumption of mercury for these purposes seems to be almost insignificant /2/.

Statutory Order no. 1044 of 16 December 1999 from the Ministry of the Environment on certain batteries and accumulators containing dangerous substances

The Order restricts the import and sale of batteries and accumulators with more than 0.0005 % mercury by weight. Button cells may, however, contain up to 2 % mercury by weight, but have to be labelled in case the total content exceeds 25 mg mercury.

Assessment
The Order restricts the import and sale of mercury oxide batteries and accumulators, but still allows mercury to be used in other types of button cell batteries such as alkaline, silver oxide and zinc-air batteries. Thus, the Order has reduced the amount of mercury ending up in waste and being emitted to the air etc. by waste incineration.

Statutory Order no. 998 of 12 October 2004 from the Ministry of Food, Agriculture and Fisheries on feedstuff
The Order limits the maximum content of mercury in feedstuff to between 0.1 and 0.5 mg Hg/kg feedstuff depending on the type of animal in question.

Assessment
This Order reduces the amount of mercury added to agricultural soil and thereby by time also the amount of mercury evaporated to air or leached from soil to fresh water.

Statutory Order no. 298 of 30 April 1997 from the Ministry of the Environment on certain requirements on packaging
The sum of the content of lead, cadmium, mercury and chromium (VI) present in packaging materials to be used in Denmark must not exceed 100 ppm by weight.

Assessment
Limiting the amount of mercury used in packaging materials will also limit the amount directed to waste disposal with products, which, in turn, limits the releases from waste incineration etc.

Statutory Order no. 1008 of 12 October 2004 from the Ministry of the Environment on import and sale of electric and electronic equipment.
Equipment containing lead, cadmium, mercury, chromium (VI), polybrominated biphenyls (PBB) or polybrominated diphenylethers (PBDE) is prohibited from 1 July 2006.

Assessment
The Order implements the EU RoHS Directive in Denmark. The effect of the Order is that the amount of mercury directed to waste incineration or steel recycling with products containing mercury is slowly reduced thereby gradually reducing the amount of mercury which could be emitted to the air or leached from residual products.

Statutory Order no. 489 of 12 June 2003 from the Ministry of the Environment on cosmetic products.
This order prohibits the use of mercury and compounds in cosmetics.

Assessment
This order has no significant impact on the aquatic environment since the consumption of mercury for cosmetics is insignificant.

Other regulation relevant for mercury includes:

- ***Statutory Order no. 655 of 27 June 2000 on recycling of residual products. and soil in building and construction work.***
- ***Statutory Order no. 162 of 11 March 2003 on waste incineration plants.***
- ***Statutory Order no. 623 of 30 June 2003 on application of waste products for agricultural purposes.***

Assessment
The Orders may have a direct impact on the release to the aquatic environment depending on how the rules are actually established.

7.1.5 Conclusion on the need for further regulation

The levels of mercury in treated sewage effluents and in stormwater discharges are already today so low that only very limited dilution of these types of discharges is required to comply with the proposed AA-EQS and MAC-EQS values respectively.

Therefore, there is no need for further progressive reduction in Scenario A while additional measures could be considered in Scenario B to further reduce the lifetime of existing mercury-containing equipment in society, which is typically very long (see proposals for technical measures in Section 7.2). However, the existing statutory orders and other regulation contribute significantly to the required continued progressive reduction of mercury and could be considered sufficient in that respect.

Mercury is also classified as a priority hazardous substance for which emissions, discharges and losses must cease/be phased out within 20 years in Scenario B while Scenario A has no timeframe and only implies an obligation to consider "all technical reduction options" targeting the goal.

The regulations adopted regarding mercury in Denmark have focused on restricting the use of mercury in new products. However, the releases of mercury to the aquatic environment in Denmark today must be assumed primarily to be due to existing products already in use in society. In this context the efforts invested by municipalities in assuring that mercury waste is collected and disposed of in an environmentally safe manner is crucial with respect to releases from dental clinics as well as from other sources.

It is noted that no regulation requires dental clinics to install effective mercury filters and that no regulation prohibits the continued use of mercury products until the moment when they break where the content of mercury in many cases at least to some degree will end up with wastewater.

The gradual implementation of the proposed technical measures aimed at ceasing/phasing out mercury releases and discharges will at the same time fulfil the progressive reduction obligations in Scenario B.

In the case of mercury, the proposed options for cessation/phasing out are also relevant for Scenario A, and, apart from the timeframe, the difference between the two scenarios lies mainly in the extent to which collection of mercury-containing equipment in the Danish society is implemented.

7.2 Possible reduction/elimination measures

7.2.1 Technical measures to reduce/eliminate mercury

The following options for further reduction of releases of mercury to the aquatic environment may be considered:

- Use of mercury filters for dental clinics made mandatory.

  Approximately 20 % of the clinics are not equipped with mercury filters. Based on data given in /2/ it can be estimated that the installation of mercury filters at all clinics would eliminate about 80 % of the present releases from dental clinics or ~40-200 kg mercury each year.

- National collection, replacement or labelling of mercury equipment in use and other sources of mercury to wastewater.

  This action deals with a campaign to virtually detoxify Danish society in terms of mercury by identifying mercury equipment still in use in households, institutions, companies etc. and replacing it if feasible and otherwise by labelling it with instructions for environmentally safe disposal.

  Such an exercise was carried out in Sweden in the 1990's. The exercise identified and removed mercury deposits in schools and siphon traps. A rough estimate indicates that the release of 40 to 90 kg mercury annually and perhaps even more could then be avoided.

- Substitution of materials used in drilling liquid and mud that contains mercury. It is likely that other materials than barite can be used.

- Releases of mercury with stormwater may be reduced by op to 10 kg mercury annually by precipitation/cleaning arrangements.

7.2.2 Possible synergies with other (priority) substances

Measures against suspended matter/pollutants in stormwater runoff, as described in Chapter 13, will also result in some (limited) reduction of mercury releases into the aquatic environment but it will mainly reduce the releases of most of the other PS/PHS.

7.3 Economic Assessment

It has been established above that the proposed AA-EQS and MAC-EQS values are already met today. In the technical assessment it is, however, concluded that since mercury is a priority hazardous substance, emissions, discharges and losses to the aquatic environment must cease/be phased out. In the WFD (Scenario A) there is no deadline, but in the proposed Daughter Directive (Scenario B) the deadline is 2025. To calculate the difference in cost, it is assumed that to meet the Scenario A requirement, the national deadline is 2035. The obligation to consider all technical options in Scenario A for the priority substances will be met by either of these deadlines.

The economic assessment looks at the two most realistic technical measures, i.e.

- mandatory use of mercury filters in dental clinics;
- national collection/replacement or labelling of mercury equipment in use.

With regard to filters in dental clinics, it was assessed in 2003 that approximately 20 % of the clinics did not have such mercury filters /2/. There is no data available to support this assumption, which is based on the number of municipalities in which installation of filters is not mandatory. The number may already have decreased since then, and the 20 % estimate is therefore probably a high-end estimate. The Danish Dental Association (Dansk Tandlægeforening) estimates that out of the approx. 5,000 dentists in the work force, 4,700 practice dentistry and are potential users of mercury filters /8/. If it is assumed that 20 % of these do not have a filter today, there could be 940 filters more in Denmark.

The price of the filters depends on the specific technological solution chosen, but since 80 % or more of the dentists already have filters, the market is well established. The most common types of filters are mechanical installations that do not require any electricity or incur any other running costs. These types of filters are produced by two manufacturers, one in Denmark and one in Sweden. Together they cover about 80 % of the Danish market. The cost is just under DKK 1,800 per filter, which needs to be changed one to four times a year /9/. This is equivalent to the financial cost per filter since it is the price without VAT. The welfare-economic cost per filter is just under DKK 2,400 when tax distortion and net tax factor[15] are taken into account. As such there is no investment cost since the lifetime is less than a year. For the purpose of this economic estimation, the average lifetime of filters is assumed to be 10 months,

To calculate the difference in cost between Scenarios A and B, it is assumed that the use of filters is gradually increased until all dentists have filters. For scenario B, the deadline is 2025, while for scenario A the deadline is set to 2035 to illustrate the possibility of adopting a more lenient strategy that still complies with the WFD. The compulsory use of filters is not assumed to take effect before 2012 according to the definition of the scenarios in Chapter 3.3. The two different time horizons are shown in the figure below, by the resulting number of new filters per year. It should be noted that the lifetime of a filter is assumed to be less than one year and that the 940 dentists without filters today will need a total of 1,128 filters per year.

[15] See the methodology chapter 3.1.

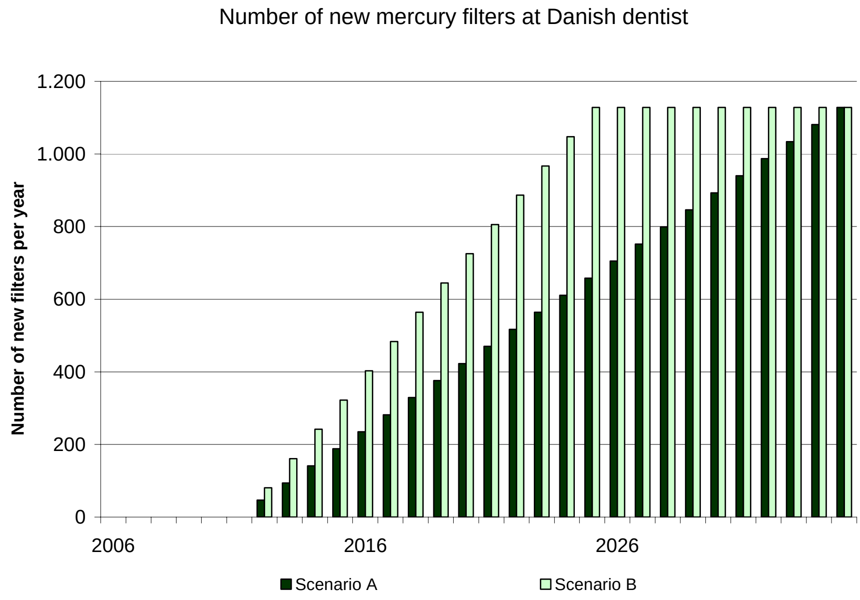

Figure 7-1 Scenarios A/C and B for instalment rate of mercury filters

The two scenarios imply a gradual build-up to a yearly financial cost for the dentists of almost DKK 2 million DKK when fully implemented. The welfare-economic cost representing the cost to society would be about 2.7 million DKK/year when fully implemented.

The total financial and welfare-economic costs can also be calculated as the discounted net present value (NPV), which is the expression of the cost today of expenses over a period of time. This is done in order to be able to compare the difference in time horizon for the two scenarios. The discount rate used is 3% for the welfare-economic cost and 6 % for the financial cost. The results of the estimation can be seen in the tables below. The total extra cost of Scenario B over Scenario A is estimated to be approximately DKK 3 million in terms of financial cost and DKK 8 million in terms of welfare-economic cost. It should be emphasized that the figures are tentative given the gaps in data on the number of filters needed. The financial unit cost of the filters is, however, well known since the filters are already on the market being manufactured by several producers.

Table 7-2 Financial and welfare-economic cost, Mercury filters at dental clinics

Financial	NPV in million DKK
Scenario A: Mercury filters for all dental clinics by 2035	7
Scenario B: Mercury filters for all dental clinics by 2025	10
*Welfare- economic **	
Scenario A: Mercury filters for all dental clinics by 2035	17
Scenario B: Mercury filters for all dental clinics by 2025	25

*	A discount rate of 3 % is used. If 6 % is used. The results for Scenarios A and B are DKK 10 and 14 million respectively.

It is also attempted to estimate the cost of a national collection/replacement or labelling of mercury equipment in use. This will be a very rough estimate based on Swedish experiences.

There is no doubt that a significant quantity of mercury is present in Denmark. The stocks include mercury in electrical and technical equipment and instruments in use in society (e.g. in thermometers, thermostats, blood pressure gauges, level switches). To this may be added intentional stocks in educational institutions and private companies.

The stock of mercury will slowly be disposed as mercury-containing instruments or equipment are outdated or broken. The actual lifetime is difficult to predict as the mercury-containing instruments are simple in construction (e.g. mercury contained in a closed glass tube) and in principle may last for decades. To the extent that mercury-containing instruments are not collected and disposed of in a controlled manner, there is a risk that the mercury will eventually be released into wastewater, the air etc. when the instruments are broken.

While no significant organised effort has been made in Denmark to collect waste mercury in instruments, huge efforts were made in Sweden in the years from 1994 to 1999. The effort was directed towards:

- Intentional stocks of mercury in educational and training institutions and private companies;
- Mercury contained in electrical/technical equipment and instruments in use in Sweden;
- Residues of mercury in e.g. siphon traps in schools and training institutions where mercury was used for educational or scientific purposes.

In the years from 1995 to 1998, the Swedish EPA used approximately SEK 15 million partly as contributions (SEK 10 million) to local authorities (counties and municipalities) undertaking collection and labelling efforts, and partly to finance projects directly carried out by the Swedish EPA (collection in schools inclusive of siphon traps - collection directly from major industries) /10/. By this effort about 9-11 tonnes of mercury was identified while about 6-7 tonnes were collected /10/.

It was roughly estimated that the collection/labelling effort undertaken by the local authorities reached approximately 1/3 of the Swedish population /12/, while the coverage rate regarding other projects was assumed to be higher.

Apart from the direct contribution from the Swedish EPA, local authorities made an effort to carry out the projects. In the case of the project collecting mercury from schools and training institutions, the institutions financed at least 1/4 of the total project costs /11/.

The project activities carried out generally had the following elements:

- Training of personnel to identify and handle mercury instruments;
- Preparation and publishing of information material, labels etc.;

- Visits to private companies, institutions and households and collection, labelling, and disposal of equipment and instruments;
- Administration.

Based on the Swedish experience presented above it is estimated that the total costs of an almost complete collection of mercury equipment and instruments in Denmark are likely to be in the range of DKK 40-50 million. This investment would be a one-time investment with no additional administrative costs or running costs in the years following the campaign. The outcome of the investment would eliminate the annual release of mercury into wastewater (estimated to be 40-90 kg /3/) in the years following the investment.

For the purpose of assigning the cost in the scenarios to the Daughter Directive implementation in Denmark, it is assumed that a national campaign similar to the Swedish one is conducted in Denmark. This would entail national collection, replacement or labelling of mercury equipment in use and similar initiatives. The campaign in Sweden did produce quite rapid results and the campaign could therefore be postponed to for instance five years prior to the deadlines in the two scenarios. It is therefore assumed that the campaign is initiated in either 2020 (Scenario B) or 2030 (Scenario A). The financial cost of such a campaign is set to DKK 40-50 million as a one-time investment and to DKK 100,000 annually in running costs, mainly being administration.[16] This corresponds to a welfare-economic cost to society of DKK 55-68.5 million in investment and DKK 137,000 DKK/year in running costs.

As above, the total financial and welfare-economic cost can be calculated as the discounted net present value (NPV). The results of the estimation can be seen in the table below.

Table 7-3 Financial and welfare economic cost, National collection

Financial	NPV in million DKK
Scenario A: National collection, replacement or labelling of mercury equipment in use from 2030	9-12
Scenario B: National collection, replacement or labelling of mercury equipment in use from 2020	17-21
*Welfare-economic **	
Scenario A: National collection, replacement or labelling of mercury equipment in use from 2030	26-33
Scenario B: National collection, replacement or labelling of mercury equipment in use from 2020	35-44

* A discount rate of 3 % is used. If 6 % is used the results for Scenarios A and B are DKK 13-16 million and DKK 23-29 million respectively.

The financial cost of Scenario B would be DKK 17-21 million compared to Scenario A estimated at DKK 9-12 million. The corresponding welfare-economic cost is DKK 26-33 million in Scenario A and DKK 35-44 million in Scenario B. Again, it must be emphasized that these are only very rough estimates.

[16] COWI expert assessment based on proposal for a similar, small-scale municipal campaign in 2005.

7.4 Conclusion on mercury

According to the monitoring data available, the concentrations of mercury in various discharges as well as in surface waters do not pose a problem in relation to compliance with the proposed EQS values. There is no need for further progressive reduction in Scenario A. For the progressive reduction of discharges, emission and losses in Scenario B, additional measures are needed to shorten the present very long lifetime of existing mercury-containing equipment in society. However, the existing regulation already contributes to some extent to the progressive reduction beyond the EQS.

Mercury is classified as a priority hazardous substance for which emissions, discharges and losses eventually (Scenario A) or within 20 years (Scenario B) must cease/be phased out. The gradual implementation of the proposed technical measures aimed at ceasing emissions and discharges will also cover the progressive reduction obligation in Scenario B.

Mercury is one of the few substances included in this study for which the total load on surface waters from sewage effluent is larger than that from discharge of stormwater. The two main sources affecting the mercury level in urban sewage are dental clinics and the variety of mercury-containing equipment (e.g. thermometers), currently in use in Denmark.

The most realistic technical measures reducing the level of mercury in sewage target the mentioned two sources. Mandatory use of mercury filters at dental clinics and national collection/replacement or labelling of mercury equipment in use. A cost assessment was made for these two measures for Scenarios A and B.

Today, around 80 % of all dentists in Denmark use mercury filters though the data supporting the figure are uncertain. If the remaining 20 % also used filters, it is assessed that around 40-200 kg of mercury could be collected each year.

The result of the cost estimation of such a policy, adopted in 2025 (Scenario B) instead of 2035 (Scenario A), is a net present value of approximately DKK 3 million in financial costs (for the dentists). The cost of Scenario A is DKK 7 million and the cost of Scenario B is DKK 10 million. In welfare-economic terms, the difference is DKK 8 million as the costs related to Scenarios A and B are DKK 17 and DKK 25 million respectively..

A rough estimate of the cost of a campaign to enhance national collection of mercury equipment in use is also given. Based on Swedish experiences, the extra economic cost of such a campaign initiated in 2020 (Scenario B) instead of 2030 (Scenario A) is estimated to approximately DKK 8-9 million in financial cost as the cost of the two Scenarios are 9-12 and 17-21 million DKK, respectively. The welfare-economic estimates are DKK 26-33 and DKK 35-44 million for Scenarios B and A respectively, and the difference is thus DKK 7-9 million. For this amount, an estimated annual release of 40-90 kg mercury (and perhaps more) could be eliminated.

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8 Assessment of nickel

8.1 Definition of the reference state

8.1.1 Introduction

Nickel (CAS no. 7440-02-0) is an element, and it is therefore not degradable in nature. Besides metallic nickel there are also a number of nickel compounds to consider.

Nickel is essential to animals and plants. Generally, the main impact of nickel on humans is considered to be allergic reactions (contact allergy). Nickel compounds are regarded as having a relatively high water solubility and mobility in soil. The mobility depends, however, strongly on the pH and the sorption capacity of the soil in question /1/.

8.1.2 Main uses and pollution sources

Nickel is primarily used in stainless steel, but will also be present as an alloy component in other steels as well as in cupper alloys. Nickel is furthermore widely used for plating, catalysts, NiCd batteries and pigments. Unintentionally, nickel is consumed with fossil fuels, phosphate-based fertilizers, agricultural chalk, and cement etc.

The consumption of nickel in Denmark in 1992/93 was estimated at 5400-7800 tonnes/year /2/. Intentional uses were responsible for a consumption of 5200-7300 tonnes/year while unintentional uses accounted for about 240-480 tonnes /2/.

The most important pollution sources of nickel to the environment may briefly be listed as follows:

Air
Emissions to the air from combustion of oil products, in particular heavy oil products, waste incineration, coal power plants and steel recycling. Total air emissions in 1992/93 in Denmark were estimated at 23-54 tonnes yearly /2/.

Water
Direct industrial discharges together with discharges from sewage treatment plants and stormwater drainage. Total water releases in 1992/93 in Denmark were estimated at 14-15 tonnes yearly /2/.

Soil
Use of feeding stuff, phosphate-based fertilizers, agricultural chalk, sewage sludge and loss of coins. Total soil releases in 1996 in Denmark were estimated at 46-140 tonnes yearly /2/.

8.1.3 Releases to and state of the aquatic environment

The most important sources of nickel released to the water environment comprise:

- Direct industrial releases
- Effluents from municipal sewage treatment plants.
- Discharge of stormwater
- Direct atmospheric deposition

Direct industrial releases may come from industries using nickel as a catalyst, undertaking nickel plating, or processing stainless steel or copper alloys. Precise knowledge of the importance of the different industrial sources is not available. The total amount of nickel released into the aquatic environment in 1992/93 by such activities was estimated at 0.5-1.0 tonnes/year /2/.

Effluents from sewage treatment plants as well as discharge into stormwater result from a number of sources. The most important source is probably the presence of nickel in bitumen used in tarmac on roads. This nickel is released as dust and collected and discharged with stormwater both directly from stormwater outlets and indirectly via sewage treatment plants. Another important source is wear of plated surfaces resulting in nickel metal and nickel ions being lost to soil and street surfaces and from there washed off by rain. The total amount of nickel released to the aquatic environment in 1992/93 by wastewater and stormwater was estimated at 13-14 tonnes/year /2/. This figure also includes a small contribution from atmospheric deposition.

Furthermore, atmospheric deposition is an important direct source of nickel to Danish interior waters. The contribution in 1992/93 was estimated at 15 tonnes yearly.

It should be noted that an important source of nickel in Danish freshwater streams and lakes in many places may be due to the natural content in groundwater as well as leaching of nickel from agricultural soils as agricultural soils contain nickel originating from feedstuff as well as from the use of phosphate fertilizers and atmospheric deposition having taken place for many years.

Table 8-1
Monitoring data for nickel (average values). The values in parenthesis are the 95 % percentiles.
Sources: /4/ /5/ /6/ /7/.

Substance	Municipal sewage (µg/l)		Sewage sludge (µg/kg dw)	Stormwater, separate system (µg/l)	Fresh/marine surface water (µg/l)
	Influent	Effluent			
Nickel	11 (26)	6.4 (16)	26,000 (50,000)	19	4.05* 0.88**

* Average value of 50 % percentile values for five Danish freshwater streams.
** Average value of 50 % percentile values for five Danish lakes.

Based on the median values in sewage and in stormwater runoff presented in table 8-1, the total Danish releases of nickel to the aquatic environment can be estimated at about 3900 kg/year and 2900 kg/year respectively.

EQS proposal
The proposed water quality criteria (EQS) for nickel is AA-EQS = 20 µg/l (all surface waters) while no MAC-EQS has been defined in the proposal (stated to be "not applicable").

The background concentration in freshwater used in the elaboration of the EQS proposal for nickel was 2.1 µg/l ("dissolved"), a value determined for the river Rhine.

8.1.4 Existing legislation/regulation and their impact

Statutory Order no. 24 of 14 January 2000 from the Ministry of the Environment on prohibition of the import and sale of certain products containing nickel (as amended by EU directive 2004/96/EEC of 27 September 2004 by Statutory Order no. 789 of 12 August 2005 from the Ministry of the Environment).
The Order restricts the use of nickel from products intended to be in long-term direct contact with the skin .

Assessment
The Order has no significant impact on releases of nickel to the aquatic environment.

Statutory Order no. 998 of 12 October 2004 from the Ministry of Food, Agriculture and Fisheries on nickel in feedstuff
Fat containing 10 mg Ni/kg or more must not be used for manufacturing of feedstuff or sold and used for feeding of animals.

Assessment
The Order reduces the amount of nickel released to agricultural soil and thereby eventually also the amount of nickel leached from soil to fresh water bodies.

Act no. 414 of 14 June 1995 from the Ministry of the Environment on a charge on lead accumulators (closed nickel-cadmium batteries) and Act no. 404 of 14 June 1995 (as amended by Act 1105 of 29 December 1999) on remuneration in connection with collection of hermetically sealed nickel-cadmium accumulators (closed nickel-cadmium batteries).
NiCd-batteries have to be labelled and are subject to a sales tax, which, in turn, is used to finance a payment scheme for batteries collected for recycling.

Assessment
The Acts make NiCd batteries financially less attractive to the consumer and encourage collection organisations to collect the batteries for recycling purposes. Thereby both Acts contribute to the objective of reducing the amount of batteries ending up in waste incineration plants and the emission of nickel to the air etc. caused by such batteries. The Acts have been passed to control cadmium, but they will have an effect on nickel as well.

Other regulation relevant for cadmium includes:

- ***Statutory Order no. 655 of 27 June 2000 on recycling of residual products. and soil in building and construction work.***
- ***Statutory Order no. 162 of 11. March 2003 on waste incineration plants.***

- ***Statutory Order no. 623 of 30 June 2003 on application of waste products for agricultural purposes..***

Assessment
The Orders may have a direct impact on the emission to the air and the aquatic environment, depending on how the rules are actually established.

8.1.5 Conclusion on the need for further regulation

The data presented in table 8-1 show that the present concentrations in sewage effluent already comply with the proposed AA-EQS even at the 95% percentile level. Also, the levels observed in stormwater are slightly lower than the AA-EQS (no MAC-EQS has presently been defined for nickel).

Furthermore, the values in table 8-1 are for the total content of nickel while the EQS values are for dissolved nickel. It is assessed that at least 75% of the total nickel content (probably more) is particle bound and, hence, the concentrations to be compared to the EQS will in reality be significantly lower than those stated in table 8.1.

Apart from regulations on waste incineration plants and discharge permits issued to specific industrial companies, the existing regulatory instruments do not seriously restrict releases, nor will they further reduce releases of nickel to the aquatic environment.

In conclusion, there is no need for further progressive reduction in Scenario A while in Scenario B there is an obligation to progressively reduce emissions, discharges and losses also after the EQS has been achieved. Possible technical measures are described in the following.

Nickel is not a priority hazardous substance. Hence, there is no obligation to cease/phase out emissions, discharges and losses completely.

8.2 Possible reduction/elimination measures

8.2.1 Technical measures to reduce/eliminate nickel

The following options for further reduction of releases of nickel to the aquatic environment may be considered:

- Restriction on the nickel content in bitumen used in tarmac.

  The nickel content will depend on the origin of the bitumen. In Denmark, bitumen originating from the North Sea oil reservoirs is typically used, and it is assumed to be relatively rich in nickel. It is assessed that it would be possible to identify oil reservoirs with lower levels of nickel causing lower releases when bitumen is used in tarmac. The possible additional cost associated with this measure is not known.

- Substitution of nickel used for plating.

  Nickel is used for plating either as the top layer or as a sub-layer. Traditionally, nickel is applied on top of a layer of copper, while the layer of nickel may be covered by a layer of chromium.

It is known that other plating materials and technologies are available on the market (e.g. electro and hot dip galvanisation, plating with aluminium etc.) but no investigations have been made of the possible substitution of these materials or technologies for nickel.

- Releases of nickel with stormwater can be reduced by precipitation/cleaning arrangements. Such arrangements will actually be effective against nickel from plating as well as from atmospheric deposition etc.

8.2.2 Possible synergies with other (priority) substances

A significant fraction (more than 40 %) of the nickel released into the aquatic environment appears, as mentioned in section 8.1.3, to be stormwater runoff from separate systems. Therefore, an initiative to reduce this input could be considered though it is considered technically as well as economically unrealistic to introduce measures specifically for nickel.

It is assessed that technological measures that aim to detain suspended particles in surface runoff will significantly reduce the loads of nickel and many other PS/PHS on the aquatic environment.

Since this type of measure is not substance specific, it is described technically and assessed economically in a separate chapter (Chapter 13).

8.3 Economic Assessment

In the technical assessment it was concluded that there is no need for further national reduction measures in Scenario A, while in Scenario B there is an obligation to continue the progressive reduction. However, no sources of economic data on the technical measures for substitution could be identified. For instance, the possible additional costs associated with replacing nickel in bitumen used for tarmac are not known.

Since the technologies and measures available for substitution are relatively complex or only possible using technology and/or substitutes that are not yet commercially available on the market, it must be assessed that the cost of substituting nickel in the remaining uses would be relatively high. Attention therefore turns from abatement to clean-up measures.

More than 40 % of the nickel released into the aquatic environment is estimated to stem from stormwater runoff from separate systems. Therefore, an initiative to reduce this input should be considered for Scenario B, which implies an obligation to progressively reduce the emissions and discharges even after compliance with the EQS has been achieved. The cost-effectiveness of such a measure should, however, be evaluated not only with regard to nickel, but as a common measure. This is done in Chapter 13.

8.4 Conclusion on nickel

According to the monitoring data available, the concentrations of nickel in various discharges and in surface waters do not pose a problem in relation to compliance with the proposed EQS value. Nickel is one of the two substances (mercury is the other) included in this study for which the total load on surface waters from sewage effluent is larger than that from discharge of stormwater (approx. 60 % in sewage).

It is concluded that there is no need for further national reduction measures in Scenario A while in Scenario B there is a need for further national reduction measures to fulfil the obligation to progressively reduce emissions, discharges and losses also after the EQS has been achieved.

The possible further reducing measures (Scenario B) include implementing general measures to reduce the content of suspended matter in stormwater prior to discharge, as described in Chapter 13.

8.5 References

/1/ Kjeldsen, P. ; Christensen, T.H. 1996. Kemiske stoffers opførsel i jord og grundvand: Bind 2. Projekt om jord og grundvand fra Miljøstyrelsen nr. 20. Miljøstyrelsen.

/2/ Massestrømsanalyse for nikkel. Miljøprojekt nr. 318, 1996. Udført af C. Lassen, T. Drivsholm og E. Hansen, COWI A/S og B. Rasmussen, K. Christiansen, I. Krüger A/S.

/3/ GEUS (2004). Grundvandsovervågningen 2003.

/4/ Miljøstyrelsen (2004). Punktkilder 2003.

/5/ Miljøstyrelsen (1997). Miljøfremmede stoffer i overfladeafstrømning fra befæstede arealer. Miljøprojekt nr. 355.

/6/ Bøgestrand, J. (red.) (2002): Vandløb 2001. NOVA 2003. Danmarks Miljøundersøgelser. - Faglig rapport fra DMU 422: 39 s. (elektronisk).

/7/ DMU (2004). Søer 2003. Faglig rapport fra DMU nr. 516 (elektronisk).

9 Assessment of nonylphenol

9.1 Definition of the reference state

9.1.1 Introduction

The name "nonylphenol" is used for a number of isomer substances having a phenol ring structure and alkyl chain of C_9H_{19}. The variations include the location of the nonyl group (C_9H_{19}) on the phenyl molecule, the number and the location of branching of the alkyl chain. The CAS no. 25154-52-3 originally covered all nonylphenols but later only the linear molecule while the branched ones have received a CAS no. of their own (90481-04-2: nonylphenol, branched).

Nonylphenol is a starting material for the production of a number of surfactants (cleaning agents) used in household and commercial products. It is also used directly to assist in keeping other slightly soluble or insoluble materials in solution. The surfactant products produced from nonylphenol are called "nonylphenol ethoxylates" (also NPE). They are produced by adding one or more ethoxy groups to the parent nonylphenol. NPE have been used for decades in a wide variety of consumer products (e.g., personal care, laundry products and cleaners), commercial products (e.g., floor and surface cleaners), and in many industrial cleaning processes (e.g., textile scouring). NPE are very relevant when discussing nonylphenol in the environment, as the NPE relatively quickly breaks down to nonylphenol when released to the environment.

Environmentally, nonylphenol is lipophilic (i.e. fat-soluble), has low water solubility (around 10 mg/l) and sorbs to particulate (organic) matter. The volatility of the substance is low. Nonylphenol is very low degradable in the environment, with the highest degradation seen under aerobic conditions /12/. NP has been reported to cause a number of estrogenic responses in a variety of aquatic organisms.

9.1.2 Main uses and pollution sources

Based on registrations in the Danish Product Registry (autumn 2004), the primary use of nonylphenol in Denmark is as hardeners in for instance concrete, epoxy and PUR products. An example of the use of nonylphenol as hardener is when laying out an epoxy floor where nonylphenol is used for accelerating the epoxy hardening process. The registered total consumption of nonylphenol for use in hardeners was around 70 tonnes when the data run was performed in the autumn of 2004 /3/.

Other main uses of nonylphenol are in paints and lacquers (11 tonnes) and in filling products (9 tonnes) /3/. Nonylphenol and nonylphenol ethoxylates are not used as additives for the production of paints and lacquers in Denmark /4/ but is present in imported products or semi-manufactured articles. Nonylphenol is further used in binders, construction materials, floorings etc.

Nonylphenol is used for the production of nonylphenol ethoxylates, which belong to the group of non-ionic tensides, used in cleaning materials and detergents for cleaning, as vehicle cleaners, anti-static cleaners and metal cleaning. This application has historically been the most dominant use of nonylphenol ethoxylates in Denmark, but since January 2005 it has been prohibited except for some specific industrial applications where the cleaning material is recovered or burned under controlled conditions /1/.

Nonylphenol ethoxylates and other alkylphenol ethoxylates accounted for around 20 % of the tensides used for cleaning materials in 1998, but this percentage is probably lower today due to regulatory actions including legislation and a voluntary agreement with industry /2/.

Nonylphenol and its ethoxylates have been used in cosmetics, cooling/lubricating oils and stain removers, but has been prohibited since January 2005 /9/.

A very rough estimate of the use of the total consumption of alkylphenol and alkylphenol ethoxylates in Denmark is 300-800 tonnes/year /3/.

9.1.3 Releases to and state of the aquatic environment

Monitoring data for nonylphenol in the environment are shown in table 9-1. The monitoring data show the concentrations of nonylphenols without its ethoxylates. The two small ethoxylates, nonylphenol ethoxylate (NP1EO) and nonylphenol diethoxylate (NP2EO), are often included to express the nonylphenol potential as these two ethoxylates are easily degraded into nonylphenol.

The monitoring data are all from before the new legislation on the use of nonylphenolethoxylates and related substances (see section 9.1.4) entered into force (in January 2005).

Table 9-1 Monitoring data for nonylphenol (mean values). Numbers in brackets are 95 % percentiles. Numbers in italic exceed the proposed EQS. Refs. /3/ /7/ /8/

Nonylphenols	Wastewater (µg/l)		Sludge (µg/kg dm)	Separate rain runoff (µg/l)	Fresh/marine surface water (µg/l)**
	Inlet	Outlet			
From screening project /3/	*3.2 (8.4)*	*0.3 (0.6)*	17255 (46200)	*5.7**	0.064 (0.13)
Additional data /7/ /8/ /13/ /14/	*1.74 (3.7)*	0.13 (0.3)		0.5 (0.9)*** 0.2 (0.4) 3.4*	0.18 (0.52)

* Combined concentration of NP + NP1EO and NP2EO

** Ref. /3/: Median of 7 measurements in Damhusåen (Hvidovre), max value in brackets
Ref. /13/: Median of 7 measurements in selected water courses (LOOP catchments). A total of 43 samples were analysed but only 7 were >LOD and the median value is only for these 7.

*** Combined system

Based on the median values from the screening project in sewage and in stormwater runoff presented in table 9-1, the total Danish releases of nonylphenol to the aquatic environment can be estimated as having been at about 180 kg/year and 860 kg/year respectively at the time when the present legislation entered into force.

Table 9-2 Monitoring data (mean values) for nonylphenol potential (sum of NP, NP1E and NP2E). Numbers in brackets are 95 %-percentiles. Numbers in italic exceed the proposed EQS. Refs. /3/ /7/ /8/

Nonylphenol potential	Wastewater (g/l)	
	Inlet	Outlet
From screening project /3/	*7.2 (21.8)*	*0.42 (0.9)*
New data /7/ /8/	*4.3 (10.6)*	0.27 *(0.60)*

EQS proposal

The proposed EQS for nonylphenol are AA-EQS = 0.3 µg/l and MAC-EQS = 2.0 µg/l respectively. Monitoring data, which exceed the proposed EQS, are marked in bold in the table above.

9.1.3.1 Point sources

Important point sources are discharge of nonylphenol-containing wastewater as this go directly to the surface water environment (following passage of a WWTP) and sewage overflow in case of heavy rain events.

Relevant wastewater discharges are from production facilities for nonylphenol (ethoxylates) containing products, e.g. paints, lacquers, PUR products and filling materials. The use of nonylphenol (ethoxylate)-containing products can further lead to release of nonylphenol (ethoxylate)-containing wastewater. Especially cleaning of nonylphenol-containing materials can produce nonylphenol wastewater, e.g. wet cleaning (washing) of epoxy floors, washing of paint brushes etc.

Discharge of cleaning products containing other alkylphenol ethoxylates could further constitute a source of pollution of the aquatic environment following partial degradation of the alkylphenol ethoxylates. According to information from SPT (the Association of Danish Cosmetics, Toiletries, Soap and Detergent Industries), the use of other alkylphenol ethoxylates in cleaning products in Denmark is probably limited /5/ as only concentrations below 0.1% ww are allowed.

9.1.3.2 Diffuse sources

Due to the use of nonylphenol (ethoxylates) in construction materials as concrete and filling products runoffs from buildings etc. are believed to constitute an important diffuse source for release of nonylphenol to the water environment.

Another diffuse source for release of nonylphenol to the water environment is leaching from soil where sludge from wastewater treatment plants (WWTP) has been spread out. This source is, however, found to be of minor importance due to the relatively small part of the farm land receiving sludge and the strong binding properties of nonylphenol to organic matter in the soil.

Around 85,000 tonnes/year of WWTP sludge are applied to agricultural soils or in forests /6/). The maximum permitted load of WWTP sludge to farm land is 7 tonnes dw/ha as an average over 10 years /7/, and the total area receiving sludge can thus be estimated to 0.5-1 % of the total farm land in Denmark annually. The maximum allowable concentration of NPE in the sludge is 10 mg/kg sludge (dry weight basis).

9.1.4 Existing legislation/regulation and their impact

Statutory Order no 1006 of 12 October 2004 from the Ministry of the Environment

The order came into force in January 2005 and includes a ban on the use of nonylphenol and nonylphenol ethoxylates for/in:

- industrial cleaning with few exceptions
- cleaning in private homes
- manufacture of textiles and leather with few exceptions
- emulsifier in agricultural teat dips
- metal manufacturing with few exceptions
- production of paper and paper pulp
- cosmetic products and other personal care products except in spermicides
- pesticides

The three main uses of nonylphenol in Denmark according to the Product Registry (hardener, in paints and lacquers and in filling products) are not covered by the new regulation. However, since the mid 1990's there has been a voluntary agreement among the Danish paint and lacquer producers and importers not to use nonylphenol as an additive. As a rule of thumb, raw materials and semi-manufactured products with nonylpehol are not used either. Further, the regulation does not include alkylphenol ethoxylates other than nonylphenol ethoxylates, which can degrade into nonylphenol, and thus are relevant in this context.

Assessment:

It is assessed that the full effect of the Order has not been seen yet. The environmental monitoring data included above are further dates back to before the Order went into force.

The regulation prohibits some of the problematic uses of nonylphenol and its ethoxylates in relation to direct release to the aquatic environment. Especially the ban of nonylphenol (ethoxylates) in cleaning materials will result in a drop in the concentration of nonylphenol in wastewater.

The magnitude of the drop in concentrations is difficult to estimate as the use of nonylphenol and its ethoxylates in cleaning materials has been on the decline for a number of years as a result of a voluntary agreement from 1987 between the Association of Danish Cosmetics, Toiletries, Soap and Detergent Industries (SPT) and the Danish Environmental Protection Agency. This agreement included elimination of nonylphenol (ethoxylates) in the products of the companies organised in SPT (around 60-80 % of companies supplying household cleaning materials, but much less for industrial cleaning materials as for instance car shampoos /5/).

Separate wastewater discharges from industries producing or using nonylphenol-containing products can possibly include higher concentrations of nonylphenol and possibly exceed the AA-EQS. The number of such discharges is, however, believed to be relatively low.

It is expected that the reduction in the level of nonylphenol in surface runoff as a result of the Order will only be limited as the quality of runoff with regard to the chemical in question is probably mainly affected by general atmospheric deposition and by impacts of the use of car-care and maintenance products of which many are imported/marketed by companies not being members of SPT.

9.1.5 Conclusion on the need for further regulation

The concentration of nonylphenol in wastewater, both inlet and outlet, have dropped by around a factor 2 from 2003 to 2004. The decline in the wastewater concentrations of nonylphenol is a result of the voluntary agreement between SPT and DEPA from 1987 and the Executive Order No. 1006 of 12 October 2004. The full effect of this Order is not reflected in the environmental data above. Further reductions in the concentrations of nonylphenol in wastewater discharges can thus be expected in the coming two to three years (but hardly much longer).

The mean concentration of nonylphenol (NP) in sewage effluents is at the same level as the AA-EQS while the 95 % percentile concentration is about a factor 2 above this value. Hence, only a modest, normally obtainable initial dilution of sewage discharges is required to comply with the AA-EQS.

If instead the nonylphenol potential (NP + NP1EO + NP2EO) is being considered as the relevant parameter for evaluating discharges, emissions and losses of NP to the aquatic environment, then the required reduction of the concentration in the wastewater discharges will be moderately higher. A 1.4 times reduction of the average "nonylphenol potential" concentration is required to comply with the AA-EQS while a reduction factor of 3 is required for the 95 % percentile concentrations.

In stormwater from separate systems an initial dilution factor of about 3 is required for nonylphenol to comply with the MAC-EQS (based on the average concentration of 5.7 µg/L from the screening project, Table 9-1), which mainly in the eastern parts of Denmark is difficult to achieve in the streams in the summer season (at median minimum flow conditions).

The study from which this figure originates covers samples representing a wide range of situations including runoff after long periods of dry weather prior to the rain event sampled. Such conditions are known to result in elevated concentrations of pollutants. The samples were taken during the first 5 mm of rain in each event, which represent about 80-85 % of the rain events in Denmark. In the following, the 5.7 µg/L value will be used in this study as a conservative, but realistic value for nonylphenol in stormwater from separate systems.

Thus, there appears to be some need for further national measures in order to comply with the MAC-EQS value for nonylphenol at summer minimum flow conditions, primarily in the eastern part of Denmark. A proposal for common measures to reduce PS in separate stormwater is presented in Chapter 13.

However, other studies indicate that the average concentrations of nonylphenol in separate stormwater could be lower than the values used in the assessment. As the latter data are from the mid 1990's, after which new regulation of NPE has been implemented, a more in-depth analysis of the issue is recommended before deciding finally on implementation of the measures described in Chapter 13.

Nonylphenol is classified as a priority hazardous substance, which implies that despite the compliance with the EQS the "discharges, emissions and losses" to the aquatic environment in Scenario B must cease/be phased out within 20 years from the date of entry into force of the Directive. In Scenario A/C there is an obligation to consider all technical reduction measures that can lead to this goal, but no timeframe is specified.

9.2 Possible reduction/elimination measures

9.2.1 Technical measures to reduce/eliminate nonylphenol

To eliminate discharges, emissions and losses of nonylphenol to the aquatic environment, nonylphenol for all of the uses discussed above should be investigated to look for further possibilities of substitution.

A Canadian study (based on available foreign data[17]) indicates that the substitution of NP/NPE is feasible from a technical point of view in most products for consumer, institutional and industrial use /11/. A Danish study has explored the possibilities of substituting nonylphenol ethoxylates in paints, which is still permitted and constitutes one of the largest sources for use of nonylphenol ethoxylates in Denmark /10/. The study identified a number of possible substitutes for nonylphenol in paints such as styrene/maleic anhydride polymer, secondary ethoxylated alcohol (C_{12}-C_{14}) and ethoxylated acetylenic alcohol. All of the alkylphenol ethoxylates (APEOs) investigated could in principle be substituted by alternative substances, but in some cases it would be a time-consuming process /10/.

Thus, it is technically possible to replace nonylphenol ethoxylates in paints etc. It is, however, not clear whether these possibilities are presently so well developed for all uses that they can be termed "best available techniques" and thereby should be included among "all technical reduction measures" that need to be considered in Scenario A. It is assessed that the overall regulation of the use nonylphenol ethoxylates in paints and other products must take place at EU level to become effective.

The primary use of nonylphenol ethoxylates in Denmark is as hardeners in for instance concrete, epoxy and PUR products, which constituted 70 tonnes/year in 2004, according to the Danish Product Registry. No regulation or voluntary agreements are targeted at this use of the substance, and an option could therefore be to consider measures in this respect to reduce emissions/discharges of nonylphenol.

The use of NPE is almost completely phased out in Denmark. The Danish market for paints and lacquers is almost exclusively served by Danish producers and importers that according to voluntary agreements have refrained from using NPE as an additive since the mid 1990's /4/. Imported raw material used in the production is checked for the presence of NPE using the CAS Registry System. If an exporter circumvents the system or incomplete information is available to the importer, NPE may end up in Danish paints and lacquers.[18] In

[17] Based on the examples of phase-out from household and I&I cleaning products in the European Union (EU), and other substitution initiatives.

[18] Cas no.: 25154-52-3 is on the list of hazardous substances but cas. no. 90481-04-2 is not.

some cases, economic considerations may also account for less stringent adherence to the voluntary agreement. Together, these two factors probably account for the use of 11 tonnes registered by the Danish Product Register. As REACH will become effective within the next 11 years, importers will get more information about the substances contained in the raw materials they use in their production. This should help eliminate any remaining unintended uses caused by the gaps due to the CAS Registry System, which is complicated regarding NPE.

With regard to cleaning products, uses are also limited due to Statutory Order No. 1006 and a voluntary agreement among Danish producers not to use the substances as an additive. A small number of products are exempted from the statutory order, and not all producers and importers adhere to the voluntary agreement. However, there is not sufficient knowledge available to suggest technical or policy options that may address this aspect.

Stormwater runoff

The estimate made in section 9.1.3 shows stormwater runoff from roads, other paved surfaces and roofs can be considered the presently main source of release of nonylphenol into the aquatic environment. Therefore, technological measures that can reduce this input should be considered though it appears unrealistic to introduce measures specifically aimed at eliminating nonylphenol.

The majority of the PS/PHS including nonylphenol are characterised by properties such as lipophilicity and significant sorption onto particulate (organic) matter. Therefore, it is assessed that technological measures that generally aim at retaining suspended particles in surface runoff will substantially reduce the loads of nonylphenol and many other PS/PHS on the aquatic environment. This option is described and assessed in more detail in Chapter 13.

9.2.2 Possible synergies with other (priority) substances

A possible overall action against suspended matter/pollutants in stormwater runoff will not only lead to a significant reduction in NP/NPE inputs to the aquatic environment but also in most of the other PS/PHS.

9.2.3 Summary and assessment of technical possibilities

Nonylphenol is classified as a priority hazardous substance, PHS, for which Scenario B requires that the discharges, emissions and losses into the aquatic environment must cease within 20 years after the date when the Daughter Directive enters into force.

Considering the already implemented regulations on the use of nonylphenol containing products, the future dominant source type of nonylphenol release into the aquatic environment in Denmark is assessed to be the discharge of stormwater runoff from paved surfaces and roofs.

To meet the requirements to cessation of "discharges, emissions and losses" of nonylphenols within 20 years in Scenario B, action must be taken against the stormwater-mediated releases. The most obvious way of doing this is by introducing detention basins and similar technological arrangements by which particulate matter in the effluent is retained prior to the discharge into fresh or coastal surface waters (see Chapter 13).

With regard to Scenario A, it is assessed, based on the interpretation of the obligations in the WFD, that such measures, due to very high costs, are probably not realistic if aimed exclusively at eliminating nonylphenol.

9.3 Economic Assessment

It was concluded in the technical assessment of available options that there are technical possibilities of replacing nonylphenolethoxylates used as hardeners in for instance concrete, epoxy and PUR products, and in paints and fillers. Voluntary agreements are already in place with regard to paints, but the Product Register still shows a use of 11 tonnes, so there appears to be scope for further substitution. It should be noted that REACH would improve the product data information for Danish producers so that NPE used as an additive in imported raw materials can increasingly be avoided rendering voluntary agreements even more effective.

The overall regulation of the use of nonylphenol ethoxylates in products must take place at EU level to be effective. No national programmes should be implemented unless community action is taken to substitute the remaining uses of nonylphenol ethoxylates.

The technical assessment concluded that the "discharges, emissions and losses" to the aquatic environment must cease/be phased out in Scenario A, but only to the extent that it can be reached by considering all technical options. Further, nationally enforced substitution is therefore not likely in Scenario A as this is not a domestic, technical problem, but rather lends itself to Community-level action. For the purpose of an economic estimation, in Scenario B it is assumed that substitution is enforced in Denmark in order to meet the 2025 deadline of the Daughter Directive.

What would be the cost if all remaining uses of nonylphenol, which are not already banned in Denmark, must be substituted? The alternatives to nonylphenol are more expensive to use, but the above-mentioned studies indicate that the substitution of NP/NPE is feasible from a technical point of view in most products. The current use of NP/NPE in hardeners, paints, lacquers, and filling products was estimated to be 90 tonnes a year.[19]

If we assume that the use is constant over the next 30 years, this is considered the status quo assumption. In Scenario A, no Danish programme of substitution will be initiated because such a measure will only be effective if implemented by common action at Community level. Therefore, there is no cost associated with this scenario. In Scenario B it could be deemed necessary to initiate and finance a national programme of phasing-out NP/NPE as a hazardous substance in accordance with the 20-year deadline.

The two scenarios' deadlines are illustrated in the figure below.

[19] 70 tonnes plus 11 tonnes plus 9 tonnes.

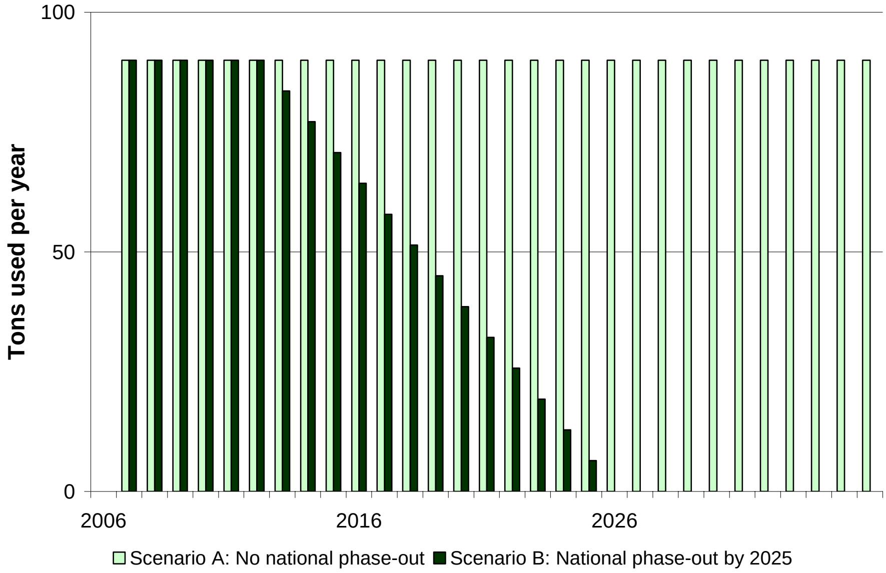

Figure 9-1 National Phase-out of total use of NP/NPE in products

By far the most common replacements for NPE are alcohol ethoxylates. The cost of the alternatives fluctuates with the price of raw materials e.g. the cost of ethoxylates fluctuates with the price of ethylene. In the Canadian report it is stated that in recent years, the prices of alternatives to NPE have been, on average, around 20-40 % higher than NPE /11/. This is the main conclusion of the report, and the fact that no actual total cost has been calculated is a clear indication of the uncertainty regarding the prices. However, if the prices from the study on NP/NPE and the alternative substances are used, the extra financial cost per tonne of the latter is roughly 2-4 DKK/kg. The lower and higher values are both used in the following estimation.

Financial cost	NPV in million DKK (Min - Max)
Scenario A: Phase-out of NP/NPE	0 (Community action needed)
Scenario B: Phase-out of NP/NPE by 2025	1.0-2.0
*Welfare-economic cost **	
Scenario A: Phase-out of NP/NPE	0 (Community action needed)
Scenario B: Phase-out of NP/NPE by 2025	2.5-4.3

* If a discount rate of 6% is used the result are: Scenario B = 1.4 to 2.5

The table illustrates the very uncertain estimate of the cost of gradually substituting the 90 tonnes of NP/NPE a year. Both a minimum and a maximum value are shown. The values are given in net present value (NPV) which is an expression of the discounted value today of future investments. The discount rate used is 3 % in the welfare economic calculation and 6 % in the financial cost estimation. There is no cost associated with Scenario A as there will be no national programme and no phase-out measures aimed exclusively at NP (stormwater in general, see Chapter 13). Scenario B is estimated to cost industry and consumers between DKK 1 and 2 million in total financial cost. This represents the extra cost of implementing the Daughter Directive. In welfare-economic terms, the cost is estimated to between DKK 2.5 and 4.3 million.

It should also be noted that total substitution might imply that some uses of the substance in question will probably have a unit cost considerable higher than the average viewpoint of this kind of calculation. As a rule of thumb, the marginal cost of substance substitution in many uses gets higher and higher the closer to 100 % substitution we wish to go. However, for NP/NPE there, seem to be alternatives readily available for all or most uses, which will tend to keep the cost of substitution down.

The policy instruments available to implement substance substitution are discussed in the general concluding economic chapter of the report.

In this case there are no data available that document the proportion of the substance used in products produced for the home market and in imported goods respectively. The cost of the substitution will be borne by the manufacturing sector, but given the data available it is impossible to assess the share of costs to be borne specifically by the Danish manufacturing industry. Finally, the proportion of the cost that will be passed on to consumers or to downstream manufactures using the products as input factors is not known. Since the 90 tonnes a year cover the total Danish consumption of NP/NPE in various products, it can, however, be assumed that the majority of the cost will accrue nationally.

On a final note, it should be repeated that in order to assess this cost in more detail, a more thorough analysis and data gathering for specific product types should be made.

9.4 Conclusion on Nonylphenol

The concentrations of nonylphenol in treated sewage effluent are so low (95% percentile level) that they need to be reduced by only a factor 2 to comply with the AA-EQS. This will be possible in almost all cases under normal circumstances. However, in stormwater from separate systems an initial dilution factor of almost 3 is required to comply with the MAC-EQS (based on the data from the screening project presented in Table 9-1), which mainly in the eastern part of Denmark is difficult to achieve in the streams in the summer season (at median minimum flow conditions).

Thus, there appears to be some need for further national measures in order to comply with the MAC-EQS value for nonylphenol at summer minimum flow conditions, primarily in the eastern part of Denmark, see proposal for a common measure to reduce PS in separate stormwater in Chapter 13.

However, other studies indicate that the average concentrations of nonylphenol in separate stormwater could be lower than the values used in the assessment. As the latter are from the mid 1990's, after which new regulation of NPE has been implemented, a more in-depth analysis of the issue is recommended before deciding finally on implementation of the measures described in Chapter 13.

Further, in Scenario B it is an obligation to continue the progressive reduction beyond the EQS compliance level. To fulfil this requirement it will probably be necessary to introduce additional measures such as substitution for some of the uses that are not banned already.

Nonylphenol ethoxylates are still being used in a number of products in Denmark, mainly for industrial/professional uses, but it appears that there are alternatives to all applications. If the total consumption of NP/NPE in various products of 90 tonnes per year is to be substituted, it will impose a cost on the Danish manufacturing sector and consumers. In order to assess this cost in detail, a number of detailed cost-benefit comparisons for specific product types should be made in order to consider the relative cost of relevant substitutions.

A Canadian study have estimated the price of the alternative substances are 20-40 % higher than NP/NPE, but with some variation. Using these figures as a basis, it can be calculated that the financial cost of implementing the proposed Daughter Directive in Scenario B could be approximately 1 to 2 million DKK in financial terms higher than implementing the WFD without an agreement on a Daughter Directive in Scenario A. The extra cost associated with Scenario B in welfare-economic terms is 2.3 to 1.4 million DKK. It is assessed that there will be no additional cost associated with Scenario A in this calculation as a national programme of substitution is not considered a "technical option", but rather a matter of community regulation. The costs estimated here are those associated with Scenario B, where it is assumed that national action towards substitution must be taken and phase-out achieved by 2025, though community regulation is recommended.

Nonylphenol is classified as a priority hazardous substance, which implies that despite compliance with the EQS "discharges, emissions and losses" to the aquatic environment must eventually cease/be phased out. In Scenario A, Denmark is only obliged to pursue the aim to the extent it can be achieved by considering "all technical options" and without a fixed time frame. In Scenario B the cessation/phase-out must be achieved within 20 years from the date of entry into force of the Directive. The gradual implementation of the proposed technical measures aimed at ceasing/phasing out nonylphenol emissions and discharges is considered also to cover the progressive reduction obligation in Scenario B.

To meet the requirements to cease nonylphenol releases in Scenario B, action must, however, be taken against the stormwater-mediated releases. The most obvious way of doing this is by introducing detention basins and similar technological arrangements by which particulate matter in the effluent is retained prior to the discharge into fresh or coastal surface waters (see Chapter 13).

9.5 References

/1/ Bekendtgørelse nr. 1006 af 12/10/2004: Import, salg og anvendelse samt mærkning af nonylphenol, nonylphenolethoxylat eller cement.

/2/ Anvendelse og udbredelse af østrogenlignende stoffer. Virkning på mennesker og miljø. Bodil M. Jacobsen, Dansk Toksikologi Center og Torben Madsen, VKI. Økonomisk støttet af Dansk Planteværn. Februar 1998.

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/4/ Personal communication with the Danish "Brancheforening for Farve- og Lakindustrien". October 2005

/5/ Personal communication with the Association of Danish Cosmetics, Toiletries, Soap and Detergent Industries, SPT. October 2005

/6/ Spildevandsslam fra kommunale og private renseanlæg i 2000 og 2001. Orientering fra Miljøstyrelsen nr. 9 2003.

/7/ Miljøstyrelsen (2005). Punktkilder 2004. Orientering nr. 9 fra MST.

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/9/ Mapping of chemicals in dry-cleaned textiles from Rynex and hydrocarbon dry-cleaning shops. Survey of chemicals in consumer products. Survey no. 21, 2003. Dorte Glensvig, COWI A/S and Peter Mortensen, Eurofins Danmark A/S for DEPA

/10/ Substitution af alkylphenolethoxylater (APEO). Arbejdsrapport fra Miljøstyrelsen nr. 45 2003

/11/ Report on Alternatives to Nonylphenol Ethoxylates Review of Toxicity, Biodegradation, & Technical-Economic Aspects. Final Report - March 2002. Environment Canada.

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10 Assessment of PAH

10.1 Definition of the reference state

10.1.1 Introduction

Polycyclic Aromatic Hydrocarbons (PAH) constitute a group of chemicals comprising several individual substances, which are all characterized by being composed of at least three aromatic (i.e. benzene) rings. They occur as a constituent of oil from fossil sources and as a by-product of incomplete combustion of organic materials. Their intended use in certain products (creosote and other tar products) is mainly due to their impregnating properties.

The following five PAHs represent the PAH group in the context of the proposed Directive on priority substances:

CAS no:	50-32-8	(benzo(a)pyrene)
	205-99-2	(benzo(b)fluoranthene)
	191-24-2	(benzo(g,h,i)perylene)
	207-08-9	(benzo(k)fluoranthene)
	193-39-5	(indeno(1,2,3-cd)pyrene)

The list of priority substances also mention separately two other PAHs, namely anthracene (CAS no. 120-12-7) and fluoranthene (CAS no. 206-44-0), the latter exclusively as an indicator of PAH. As these two substances will never occur in isolation from other PAHs, and as they are assessed not to pose separate problems in relation to compliance with the proposed EQS values, they are in this report included in the description and assessment of the PAH group.

Environmentally, the PAHs are characterised by low water solubility, low volatility and high affinity to particulate matter, especially organic matter. Anthracene and fluoranthene, which are among the small PAHs (few rings), have a somewhat higher, although still low, water solubility and volatility than the five others. The PAHs are moderately to slowly degradable in the environment depending on the specific substance and the environmental circumstances /1/.

10.1.2 Main uses and pollution sources

PAHs occur mainly in tar products, e.g. creosote, but also in much lower concentrations in mineral oil e.g. fuel oil. However, today the largest amounts of PAHs are generated as by-products of incomplete combustion of organic materials.

Earlier, creosote was used in significant amounts to impregnate wooden materials with critical long-term outdoor uses such as railway sleepers, pylons/masts, wharves and fishing stakes. Creosote contains significant amounts of PAHs. According to information from DEPA creosote was permitted as an industrial wood preservative until 1991, but it has not been sold since 1989. However, some of the creosote-treated wood is still in use for the above-mentioned purposes.

Coal tar, which also has a high content of PAH, was earlier distilled and used for a range of products e.g. as a binding material for asphalt, tarring of fishing nets and in roofing felt (tar paper). Later, bitumen was substituted for coal tar for these purposes as the content of PAH in bitumen is somewhat lower.

Due to these uses, former locations for tarring of fishing nets, production and storage of roofing felt, and roads and other asphalted surfaces are possible point sources of surface and groundwater contaminated with PAH /2/. PAHs are also found in car tyres and, hence, tyre wear will contribute to the contamination of roads, parking lots etc. with PAH.

The Danish Product Register has registered a number of commodities that contain the five priority hazardous substance PAHs. As the total amount is considerable, more than 17,500 tonnes /1/, it is assumed that these commodities include various types of mineral oil (including fuel oil), which, of course, are consumed in huge amounts.

10.1.3 Releases to and state of the aquatic environment

Locations of previous production and use of creosote and other tar products are possible point sources of aquatic contamination, not least the uses where the products were placed directly in the aquatic environment such as wharves and fishing stakes.

Further, facilities such as garages, bus terminals, service stations etc. release PAHs and are typically connected to municipal sewage systems. In addition, wastewater effluents from petrochemical industries including refineries are to be considered potential point sources of PAH contamination.

However, the most significant releases to the aquatic environment are due to the incomplete combustion of organic materials, including fossil fuels and wood. The PAHs thus generated are emitted to the atmospheric environment from which they will deposited again (by dry or wet deposition) as diffuse contamination onto surfaces including roads, parking lots and roofs etc. from where they can run off into drainage systems during rain events.

Urban or road rain runoff discharges are known to contain PAHs in concentrations that often exceed the current Danish water quality criteria for PAH. The PAH content in road runoff is typically related to traffic intensity and includes, in addition to the combustion by-products (main contribution), also a (smaller) contribution from the tear and wear of tyres produced using PAH-containing extender oils.

PAHs are included in the point source programme under the National Monitoring and Assessment Programme for the Aquatic and Terrestrial Environment, NOVANA, and therefore a considerable amount of data document the occurrence in municipal sewage effluents and sewage sludge. There are also a number of monitoring data regarding rain runoff discharges and water courses. As to the latter, it should be mentioned that only in one out of 23 samples did the concentration of the four measured priority PAHs exceed the limit of detection. The monitoring data are summarised in Table 10-1.

Table 10-1
Monitoring data for PAH substances (average or median values). The values in parenthesis are the 95% percentiles.
References: /3/ /4/ /5/ /6/.

Substance	Municipal sewage (µg/l)		Sewage sludge (µg/kg dw)	Stormwater, separate system (µg/l)	Surface water (µg/l)*
	Influent	Effluent			
Anthracene	0.04 (0.1)	<0.01	101 (320)	0.088	<0.01 (0.03)
Fluoranthene	0.1(0.2)	0.002 (0.01)	805 (1380)	0.66	<0.01 - 0.011
B(a)pyrene	0.05 (0.1)	<0.01	289 (480)	0.14	<0.01 - 0.013
B(bjk)fluoranthene	0.1 (0.2)	<0.01	546 (910)	0.39	<0.01 - 0.029
B(ghi)perylene	0.04 (0.1)	<0.01	213 (432)	0.25	<0.01 - 0.012
I(1,2,3-cd)pyrene	0.08 (0.3)	<0.01	241 (712)	0.11	<0.01 - 0.014

* n.d.: no data.
*: Only in one out of 23 analyses of each PAH did the content exceed the detection limit of 0.01 µg/l. The max. values found were: Benzo(a)pyrene: 0.013 µg/l, Benzo(bjk)fluoranthene: 0.029 µg/l, Benzo(ghi)perylene: 0.012 µg/l and Indeno(1,2,3-cd)pyrene: 0.014 µg/l.

Based on the median values in sewage and in stormwater runoff presented in table 10-1, the total Danish releases of PAH to the aquatic environment by sewage effluent and stormwater are estimated to less than 6 kg/year and 21 kg/year respectively.

EQS proposal
The EQS values proposed for PAH substances are presented in Table 10-2.

Table 10-2
Proposed environmental quality standards (EQS) for priority PAH substances.

Substance	AA-EQS (µg/l)	MAC-EQS (µg/l)
Anthracene	0.1	0.4
Fluoranthene	0.1	1.0
∑PAH	none	none
Benzo(a)pyrene	0.05	0.1
∑Benzo(b and k)fluoranthene	0.03	N.A.
∑Benzo(ghi)perylene and Indeno(1,2,4-cd)pyrene	0.002	N.A.

N.A. = Not applicable.

There has not yet been proposed any value for the background concentration of PAH in the aquatic environment.

10.1.4 Existing legislation/regulation and their impact

Statutory Order no. 665 of 4 July 1996 from the Ministry of the Environment on restricting the sale. and use of creosote as amended by Statutory Order no. 535 of 18 June 2003 from the Ministry of the Environment, and Statutory Order no. 534 of 16 June 2003 from the Ministry of the Environment on restricting the sale and use of creosote for wood preservation and creosote-treated wood .
The Statutory Orders ban the import, sale and use of products containing creosote. However, under specific preconditions such products can be "imported, sold and used as an industrial wood preservative or for professional re-preservation of wood".

Similarly, the import, sale and use of creosote-treated wood is generally banned, however, with the exemption of professional and industrial uses such as for railways, electrical power and teletransmission, fencing, and in ports and waterways. Re-use of wood that was treated before 30 June 2003 is also permitted on condition that the wood is marketed as second-hand wood.

The five specific priority PAHs are not mentioned in the definition of creosote (while anthracene is) in the above-mentioned Orders, but their use will be regulated indirectly by the Order.

Assessment
According to information from DEPA creosote has not been sold in Denmark for industrial preservation of wood since 1989. It is therefore assessed that the two above-mentioned Orders will not have any additional impact on reducing PAH releases into the environment.

Statutory Order no. 74 of 14 January 2005 from the Ministry of the Environment on cosmetics
According to this recent statutory order, benzo(a)pyrene, benzo(k)fluoranthene and benzo(b)fluoranthene are not permitted for use in cosmetic products.

Assessment
The use of PAH in cosmetics is marginal compared to the other known sources of PAH contamination and the Order will as such not have any measurable impact on the level of releases into the environment.

Statutory Order no. 439 of 3 June 2002 from the Ministry of the Environment on the list of dangerous substances
The three priority PAH substances benzo(a)pyrene, benzo(k)fluoranthene and benzo(b)fluoranthene are included in the list of dangerous substances. None of the three substances must be used in aerosol spray cans.

Assessment
The use of PAH in spray cans is assessed to be marginal compared to the other known sources of PAH contamination and the Orderwill, as such, have no measurable impact on the level of releases into the environment.

International regulations etc.

Directive 2005/69/EC of 16 November 2005 relating to restrictions on the marketing and use of certain dangerous substances and preparations (polycyclic aromatic bydrocarbons on extender oils and tyres).
This new EC directive limits the content of benzo(a)pyrene and other PAHs in extender oils for production of tyres and will thereby, in principle, reduce the release to road surfaces and, consequently, also to rain runoff from these surfaces. However, it is not known to what extent these oils already comply with the new requirements.

PAHs are included in ***EC Regulation no. 850 on Persistent Organic Pollutants*** (POPs) with an obligation to eliminate the substances, and they are among the substances included in the ***LRTAP Protocol (Long Range Transported Atmospheric Pollutants).***

10.1.5 Conclusion on the need for further regulation

In treated sewage effluent, the 95% percentile levels of anthracene, fluoranthene, benzo(a)pyrene and the sum of benzofluoranthenes are all lower than the AA-EQS values. The AA-EQS for the sum of benzo(ghi)perylene and indeno(1,2,3-cd) pyrene is 5 times lower than the LOD in the performed monitoring programme. Hence, it cannot be evaluated whether these substances comply with the EQS value or not.

To evaluate the possible need for measures in relation to discharges of stormwater from separate systems the concentrations of the selected PAHs observed in this type of discharges (see table 10.1) should be compared to the MAC-EQS. However, MAC-EQSs have presently only been defined for anthracene, fluoranthene and benzo(a)pyrene. The levels of the two former substances are below the MAC values in effluents from separate stormwater runoff systems while benzo(a)pyrene requires a reduction of 1.4 times to obtain compliance. MAC values for the sum of benzo(ghi)perylene and indeno(1,2,3-cd) pyrene have not been defined, and therefore the evaluation of these two specific PAH-substances cannot be made at present (the AA-EQS is not considered suitable for this purpose).

The levels found in surface water are, with the possible exception of the sum of benzo(ghi)perylene and indeno(1,2,3-cd)pyrene, all below the AA-EQS.

In summary, there appears to be no need for further national measures to be able to comply with the proposed EQS values for PAH (with a reservation for the sum of benzo(ghi)perylene and indeno(1,2,3-cd) pyrene in stormwater) and, consequently, there is no need for further progressive reduction in Scenario A. In Scenario B, however, there is an obligation to continue the progressive reduction of emissions, discharges and losses beyond the EQS compliance level. As the existing legislation is assessed not to provide any further significant reduction, some possible additional measures are described in Section 10.2.

The five substances in the PAH group and anthracene are all classified as priority hazardous substances while fluoranthene is just a priority substance. This implies that the "discharges, emissions and losses" to the aquatic environment must eventually cease. In Scenario A, which only implies an obligation to consider all technical reduction options, there is no time frame for this to be achieved while in Scenario B the time -frame is 20 years from the date of entry into force of the directive.

The gradual implementation of technical measures aimed at ceasing/phasing out PAH emissions, discharges and losses is considered also to cover the progressive reduction obligation in Scenario B.

Finally, it should be mentioned that as the PAHs are naturally occurring substances there is a need for a background level to be defined because an absolute "zero" will not be possible to obtain. Such a level remains yet to be proposed.

10.2 Possible reduction/elimination measures

10.2.1 Technical measures to reduce/eliminate PAH

The use of creosote in Denmark for preservation of wood for particularly demanding purposes is believed to have ceased already about 15 years ago, and much of the remaining creosote-treated wood has probably been replaced within the last few years. Some of it is, however, still in use, but the release of PAH from such, aged materials is assessed to be small and probably not relevant as a target for an action to eliminate the discharges, emissions and losses of PAH into the aquatic environment.

PAHs are natural constituents of fossil fuel products and do as such occur in asphalt and bitumen used for road surfaces. Earlier, coal tar was used for this purpose but was already in the mid 1970's replaced by bitumen, which has a lower content of PAH. It is, however, considered outside the scope of the study to suggest a society based on another primary energy source than fossil fuels The use of another material than asphalt for the general paving of roads etc. appears unrealistic in this context and will not be dealt with further in this report.

Stormwater runoff
Stormwater runoff from roads, other paved surfaces and roofs are today considered the dominant source of release of PAH into the aquatic environment. Therefore, technological measures that can reduce this input should be considered though it appears unrealistic to introduce measures specifically aimed at eliminating PAHs.

The majority of the PS/PHS including PAHs are characterised by properties such as lipofilicity and significant sorption onto particulate (organic) matter. Therefore, it is assessed that technological measures that generally aim at retaining suspended particles in surface runoff will substantially reduce the loads of PAH and other PS/PHS on the aquatic environment.

10.2.2 Possible synergies with other (priority) substances

A general action against suspended matter/pollutants in stormwater runoff will not only lead to a significant reduction in PAH inputs to the aquatic environment but also bring down the inputs of most of the other PS/PHS.

10.2.3 Summary and assessment of technical possibilities

As the PAHs are classified as priority hazardous substances, PHS, Scenario B requires that the anthropogenic discharges, emissions and losses into the aquatic environment must cease within 20 years after the date when the Daughter Directive enters into force.

Considering the already implemented regulations on the use of PAH-containing products other than fossil fuels for power and heating purposes, the present and future dominant source type of PAH release into the aquatic environment is the discharge of stormwater runoff from paved surfaces and roofs.

To meet the requirements of ceasing "discharges, emissions and losses" of PAHs within 20 years in Scenario B, action must be taken against the storm-water mediated releases. It is assessed that the only realistic way of doing this is by introducing detention basins and similar technological arrangements by which particulate matter in the effluent is retained prior to the discharge into fresh or coastal surface waters (see Chapter 13).

With regard to Scenario A, it is assessed, based on the interpretation of the obligations in the WFD (article 16.8), that such measures are probably not realistic if aimed exclusively at eliminating PAHs (but possibly as a common measure, see Chapter 13).

10.3 Economic Assessment

The technical assessment concluded that the only realistic measures are general technological measures aimed at retaining suspended particles in surface runoff. Since this type of measure is not substance specific, it is described technically and assessed economically in a separate chapter (Chapter 13).

10.4 Conclusion on PAH

According to the monitoring data available, the concentrations of PAH in various discharges as well as in surface waters do not pose a problem in relation to compliance with the proposed EQS values. However, reservation is made regarding the sum of benzo(ghi)perylene and indeno(1,2,3-cd) pyrene, for which the EQS is lower than the detection limit in the monitoring programmes and for which a MAC-EQS has not been established (relevant for evaluation of stormwater discharges). With this reservation, there appears to be no need for further national progressive reduction measures in Scenario A while Scenario B implies an obligation to continue the reduction of emissions, discharges and losses of PAH.

The PAH group is defined as a priority hazardous substance for which cessation of discharges, emissions and losses to the aquatic environment must be achieved. In Scenario A the time -frame of this is undefined (and there is only an obligation to consider all technical reduction options), while in Scenario B it is 20 years from the date of entry into force of the Daughter Directive.

There are no longer any intended uses in Denmark of products with high contents of PAH as the use of creosote ceased already 15 years ago. It is assessed that practically all remaining creosote-treated wood will be replaced within 20 years from now. Today, stormwater discharge, in which the PAH content mainly originates from combustion by-products, is by far the largest direct source of PAH emitted to surface waters in Denmark.

Therefore, the most relevant measure to be taken to eliminate PAH discharge, i.e. fulfilling the cessation/phase-out obligation in Scenario B, is the general action against suspended matter/pollutants in stormwater runoff, which is described in Chapter 13. As mentioned before, Scenario B requires cessation measures to be fully implemented within 20 years after entry into force of the Daughter Directive.

The stormwater runoff initiative can also be regarded as the main progressive reduction measure in Scenario B. An accelerated replacement of the remaining creosote-treated wood is not considered to give environmental benefits that can justify the costs.

With regard to Scenario A, it is assessed, based on the interpretation of the obligations in the WFD (article 16.8), that such measures are probably not realistic if aimed exclusively at eliminating PAHs (but possibly as a common measure, see Chapter 13).

10.5 References

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11 Assessment of tributyltin

11.1 Definition of the reference state

11.1.1 Introduction

Tributyltin compounds (TBT; CAS no. 56573-85-4) belong to the group of organotin compounds whose dominant technical function, as a group, is to act as stabilizer in PVC and as a biocide. However, the primary use of TBT is as antifouling compound.

Environmentally, TBT is moderately lipofilic, has a moderately high octanol-water partition coefficient and low water solubility. Bioconcentration factors up to above 100,000 have been reported for mussels and from 210 - 7,000 for fish and molluscs /13/. TBT will be degraded in the environment by dealkylation to di- and monobutyltin and then mineralised to inorganic tin. Abiotic degradation is very slow, and biodegradation is the most important route of degradation. In anaerobic environments degradation is slow. TBT half-life in water varies from few days to months and in sediments up to 1-5 years and even more in undisturbed anaerobic mud /13/.

11.1.2 Main uses and pollution sources

Historically, TBT has been widely used in Denmark as a biocide in wood preservatives, in antifouling paints and as a pesticide /1/. This use has, however, been regulated for a number of years, and today it is prohibited to apply new TBT-containing antifouling paint on ships in Denmark.

According to the national statistics on the sale and use of pesticides in Denmark, which is published yearly, use of TBT has not been registered in the statistics since 1999 /2/. These statistics further include paint primers for the impregnation of wood and products used for vacuum impregnation of wood. TBT has thus not been used for these applications: pesticide, paint primers for impregnation of wood and vacuum impregnation of wood since 1999.

TBT has also been used in coatings. According to information from the Trade Association for the Paints and Lacquer Industry (FDLF) a newly performed survey at their members showed that TBT is not used anymore in Denmark for this application /6/. FDLF organises around 90-95 % of the relevant Danish companies. Naturally, there is always the risk that TBT is used in coatings by companies not organised under FDLF, but this is not believed to be the case. Even if it were the case, uses of TBT in this respect would be insignificant.

Organic tin compounds are used for stabilisation of PVC. Normally dioctyl- and dibutyltin compounds are used for this application, but other compounds such as TBT are often seen as impurities. TBT are for instance found in shower curtains, vinyl wallpaper, vinyl flooring, vinyl gloves etc. /7/

According to information from The Danish Plastics Federation organotin compounds are not used in Denmark /8/.

11.1.3 Releases to and state of the aquatic environment

Monitoring data for TBT in the environment can be seen in the table below.

Table 11-1 Monitoring data for TBT (mean values).
Sources: /1/ /3/ /4/ /5/

TBT	Wastewater (µg Sn/l)*		Sludge (µg Sn/kg dm)	Separate rain runoff (µg Sn/l)	Fresh/marine surface water (µg Sn/l)
	Inlet (median)	Outlet (median)			
From screening project /12/	*<0.0005-0.006 (0.002)*	*<0.0005-0.002 (<0.0005)*	40 - 200	No data	*0.042-8.7***

*: In total six wastewater treatment plants with two measuring rounds on three plants
**: Marine water (inside harbour area)

Mathematical model calculations of water concentrations of TBT in harbours in 2000 showed concentrations of around 0.15-0.2 µg/l in a traffic harbour and around 4 times higher concentrations in a marina /9/.

Based on the median values in sewage and in stormwater runoff presented in table 11-1, the total Danish releases of TBT to the aquatic environment with sewage effluent can be estimated at less than 0.3 kg/year while no data are available to make a similar estimate for stormwater.

EQS proposal
The proposed EQS for TBT are AA-EQS = 0.0002 µg/l and MAC-EQS = 0.0015 µg/l. Monitoring data, which exceed the proposed EQS, are marked with bold in the table above.

11.1.3.1 Point sources
Vacuum impregnated wood has a lifetime of more than 30 years. In 1994, there was still a consumption of around 5-8 tonnes of TBT for this use in Denmark. TBT will thus be found in impregnated wood in Denmark many years from now, and TBT-impregnated wood thus constitutes a point source for introducing TBT to the aquatic environment. However, over time TBT will degrade to dibutyl and monobutyl compounds, which have less fungicidal toxic effects than TBT /1/. On the wood surface TBT are further expected to degrade, due to exposure to sunlight /1/.

Since July 2003, it has been prohibited to use TBT-containing antifouling paints in Denmark and the EU. The ban came into force in 1991 for boats below 25 metres and for boats used predominantly in inland waters. Ships painted before 2003 may, however, still release TBT to the aquatic environment as antifouling paints on ships are believed to last for 3-5 years /1/. Around 2/3 of the TBT is believed to be washed out/leach from the paint during navigation /1/.

In consequence, , larger Danish ships thus constitute a point source for introducing TBT to the marine environment for some years ahead. Further, foreign and Danish ships painted with TBT-containing antifouling paint can still pass through Danish waters until 2008. The highest TBT concentrations are found close to harbours and shipping routes.

The remainder of TBT in antifouling paints on ships will either be covered by a new paint surface or eventually be removed (scraped or flushed off) before re-painting. Therefore, repair yards might be point sources of TBT emissions to the environment still a few years ahead.

Due to the previous, very extensive use of TBT in antifouling paints for ships, the sediments in many harbours are today highly contaminated with TBT. TBT has a long lifetime in sediments and can thus be a source for release of TBT to the water phase in the harbours for a number of years.

11.1.3.2 Diffuse sources
Runoff from buildings and constructions may release TBT into the aquatic environment directly through separate rainwater outlets and via wastewater discharges and overflows.

11.1.4 Existing legislation/regulation and their impact

Statutory Order No. 926 of 18 November 2002 on limiting the sale and use of certain dangerous chemical substances and products for special purposes.
The Order bans the sale and use of organic tin compounds for paints where the tin compounds function as biocides, unless the compounds are chemically bound or polymerised with the other compounds in the paint. The order further bans the sale and use of organic tin compounds as a biocide for anti-fouling on all vessels, equipment and apparatus used in marine fish and shellfish farming, and other equipment and apparatus to be fully or partly immersed in water. Finally, the order bans the sale and use of organic tin compounds for industrial treatment of water.

Assessment
The Order banned the sale and use of organic tin compounds, including TBT, for the above-mentioned applications from January 2003. In relation to vessels, the order had most impact on larger ships as the use of TBT-containing anti-fouling paints on smaller boats at that time had been prohibited for a number of years already (e.g. the use of TBT on ships smaller than 25 metres used predominantly in inland waters has been banned since 1991). The vessels, equipment and apparatus that had been painted with TBT-containing paint before 2003 could, however, still be used after that date implying that TBT could still be released to the aquatic environment for some years after 2003. These releases are believed to be low today and will be close to zero within a few years.

IMO International Convention on the Control of Harmful Anti-fouling Systems on Ships adopted 5 October 2001 and Regulation (EC) No 782/2003 of the European Parliament and of the Council of 14 April 2003. on the prohibition of organotin compounds on ships ...
In 2001 the International Maritime Organisation (IMO) adopted the International Convention on the Control of Harmful Anti-fouling Systems on Ships. This convention prohibited application of TBT-containing antifouling paints on all boats from 2003 and prohibits navigation of ships with active TBT-containing paint from 2008. The Convention was ratified by Denmark in 2002, but the Convention is not in force yet. The EC implemented the con-

vention through EC regulation 782/03 of 14 April 2003 and Directive 2002/62/EC of 9 July 2002..

Assessment:
The IMO Convention and the related EC Regulation prohibit the application of new TBT-containing antifouling paints on all EC ships and ships from other countries, which have ratified the IMO Convention. These regulatory steps have significantly reduced the release of TBT to the marine environment in Denmark. TBT from antifouling paints on ships is, however, still emitted to the marine environment from ships painted before 2003 and from foreign ships entering Danish waters.

From 2008, release to the marine environment in Danish and EU waters of TBT from antifouling paints should completely cease because of the regulation. The status regarding TBT for non-EU-ships entering EU waters will be decided upon around January 1, 2007 depending on the status of the IMO Convention. It is assessed that some foreign ship owners could possibly try to avoid the prohibition and still apply TBT-containing antifouling paint for a few years as the known alternatives are not as effective as the traditional TBT-containing products. The release of TBT from ships will, however, be reduced after 2008.

Due to the extensive TBT-pollution of marine sediments in Denmark, TBT will be released from sediments to the water phase for a number of years from now.

The prohibition list on Consolidated Act No 21 of 16 January 1996 from the Ministry of the Environment on chemical substances and products
Bis-tributyltin oxide is included in the prohibition list of active substance which may not be used in pesticides in Denmark.

Assessment:
Inclusion in the prohibition list has implied that bis-tributyltin oxide has not been used in pesticides in Denmark since 1999 /2/.

11.1.5 Conclusion on the need for further regulation

Assessment of the environmental concentration of TBT in relation to the proposed EQS is complicated by the fact that the analytical detection limit for the TBT-analyses is higher than the proposed AA-EQS. However, even a level corresponding to the detection limit will be acceptable for discharges of sewage effluent and stormwater from separate systems (no data exist for the latter).

TBT is classified as a priority hazardous substance, which implies that in Scenario B "discharges, emissions and losses" of TBT to the aquatic environment must cease/be phased out within 20 years from the date of entry into force of the directive. Scenario A implies only an obligation to consider the technical reduction measures that can be applied in order to achieve the goal, and there is no specified time frame.

11.1.5.1 Wastewater
The highest concentration measured in a sewage effluent is 10 times the AA-EQS while the average value is significantly lower. Thus, compliance of such discharges with the EQS requirement is regarded as having been achieved

already. However, generation of more data to support this conclusion is recommended. If possible, an analytical analysis method with a detection limit below the AA-EQS should be used for this.

Thus, there is no need for further national progressive reduction measures in Scenario A while Scenario B implies an obligation to continue the progressive reduction of emissions, discharges and losses of TBT. It is, however, the interpretation that the existing regulation will fulfil this obligation.

As TBT is a prioritised hazardous substance, Scenario B implies an obligation to eliminate TBT in emissions and discharges including wastewater outlets while in scenario A the obligation only goes as far as to consider all technical reduction measures that can contribute to achieve this goal. A main source for TBT in wastewater could be the tear and wear of PVC-products stabilised with organotin compounds.

To cease/phase out TBT emissions/discharges in Scenario B it seems necessary to regulate (prohibit) the import and use of organotin-stabilised PVC-products to Denmark (according to information /8/ organotin-stabilised PVC is only seen in imported products). Such regulation, which can also be regarded as a progressive reduction measure in Scenario B, can, however, not only be adopted at the national level but requires action at EU level.

11.1.5.2 Marine waters

Most of the very limited data on TBT-concentration in marine waters (harbours) exceed the proposed AA-EQS significantly (by a factor 200-44,000). However, it is believed that less stringent environmental quality objectives will be defined for the waters inside the harbour boundaries (WFD article 4.5), i.e. the AA-EQS does not apply until outside the breakwaters.

The concentration of TBT in marine waters has been and will be further reduced over the coming years because of the prohibition of the use of TBT-containing antifouling paints. TBT will, however, continue to be lost to the marine water phase from the pool of TBT in the marine sediments. This process will go on for a number of years due to the long lifetime of TBT in sediments.

If such release of TBT from sediments to the water phase is covered by the Directive's requirement in scenario B for ceasing "discharges, emissions and losses" within 20 years, the most heavily TBT-contaminated marine sediments could be demanded removed and deposited on land.

Such contaminated sediments will be found in harbours or marinas with limited natural sediment exchange. Within the next 20 years, dredging and subsequent disposal of harbour sediments at sea ("klapning") or on land will, however, significantly reduce the volume of remaining contaminated sediments and lower TBT concentrations in the harbours in general. It is not believed that the Daughter Directive will prevent future marine disposal of dredged sediments that today are allowed for disposal at sea according to the existing guideline for marine disposal /16/.

Marine disposal of sediment containing up to 200 µg TBT/kg (dry weight) (under normal conditions the maximum TBT-concentration in sediments for marine disposal according to the guideline) is thus not estimated to result in

TBT concentrations higher than the AA-EQS in the water outside the disposal site. This estimation is based on a calculation of the corresponding TBT-concentrations in the water phase and sediment phase (0.5 µg/l and 2,000 µg/kg dw respectively) for a marina /17/, combined with the much larger water exchange at most marine disposal sites /15/.

In Scenario A, all technical reduction options to achieve the goal of ceasing/phasing out of emissions, discharges and losses must be considered, however, without a fixed time frame. It is considered unlikely that this obligation should include disposal on land of the most contaminated fractions as a purely national measure, but only if this is introduced as a common measure in the EU.

11.2 Possible reduction/elimination measures

11.2.1 Technical measures to reduce/eliminate TBT

There are a number of substitutes for stabilisation of PVC, including calcium/zinc, lead (not a recommendable substitute from an environmental point of view), antimony etc.

The fact that TBT is a prioritised hazardous substance in scenario B will possibly in 20 years demand dredging and disposal on land of sediments from some harbours to fulfil the obligation to eliminate “discharges, emissions and losses" of such substances to the marine aquatic environment.

The present mean dredging volume of sediments from Danish harbours is around 3-4 million m^3/year of which potentially up to 675,000 m^3/year is so contaminated with TBT that it could be required to dispose of it on land /10/. In 20 years this volume will, however, be reduced compared to now due to the significant reduction in future TBT-releases to Danish harbours, the environmental degradation of TBT etc.

11.2.2 Possible synergies with other (priority) substances

A general action against suspended matter/pollutants in stormwater runoff will not only lead to a significant reduction in TBT releases to the aquatic environment but also bring down releases of most of the other PS/PHS.

11.3 Economic Assessment

There are a number of replacements for stabilisation of PVC, but since the relevant products are not produced in Denmark, it is not assessed as a viable Danish policy option to enforce substitution. Since TBT is a prioritised hazardous substance, there is, however, a need for further action and the cost of dredging TBT-contaminated sediments and disposing of the sediments on land is estimated here.

The price of dredging harbour sediments and disposing of it on land is around 145-515 DKK/m^3 sediment /10/ depending on the kind of disposal facility on land (disposal area ("spulefelt"), landfill etc.). This is an estimate of the financial cost, and the corresponding welfare-economic cost to society is thus around 200-700 DKK/m^3 sediment.

The cost estimates are unit costs that include both marginal investment cost and operating and maintenance costs.[20]

The total number of harbours in Denmark is around 400 of which around 60 are industrial harbours /14/. The number of harbours that in 20 years will contain sediments being so contaminated with TBT that removal and safe disposal will be required will be considerably lower. This is a result of the stop for introduction of new TBT to the harbour sediments after 2008, degradation of existing TBT in the sediments, and of dredging carried out between today and 2025.

Especially the dredging anticipated to be carried out between today and 2025 will considerably reduce the number of harbours from which the sediments must be dredged away in 20 years. In most harbours dredging will have taken place several times within that period /14/ /18/. The number of harbours, which have not been cleaned during the 20 year period, will most likely be delimited to few marinas on Funen, Zealand (except harbours at the Sound) and the southern part of the east coast of Jutland. Sediments from harbours on the west coast and northern part of Jutland are removed very frequently (every year or every second year), the same goes for industrial harbours in general /14/ /18/.

In 2001, a survey was conducted to examine the present and future need for marine disposal of harbour sediments in the period 1998 to 2003 /15/. The survey found that 110 out of 121 harbours were in need of removal and marine disposal of (some of their) harbour sediments /15/. In other words, 90-95 % of the harbours needed dredging and disposing of sediments within the six-year period. However, only around 30 % of the Danish harbours were included in the survey.

Based on the 2001 survey and discussions with relevant actors (/14/ /18/ /19/), it is conservatively estimated that the number of places with “untouched” sediment in 20 years will correspond to 10-25 % of the Danish marinas. A “high mean value” per dredging in marinas in 2001 is estimated to be around 3,000 m^3 /15/. Based on these numbers, the volume of TBT-contaminated sediments to be dredged from harbours in 20 years and disposed of on land (as a means of eliminating unacceptable “losses" to the marine aquatic environment) can be roughly calculated to about 100,000-250,000 m^3.

In Scenario A/C, considering the non-legally binding character of the reduction/cessation targets of the WFD (Article 4), any future clean-up and land disposal of the low-contaminated sediments at the marine disposal sites with the aim to eliminate "losses" of TBT is assessed by the DEPA to be out of the question as the environmental benefits reaped will be insignificant compared to the disadvantages, and the costs of such action will thus become disproportionally high. Therefore, in this assessment of TBT no cost is associated with scenario A/C.

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[20] This means that the scrap values are not included in the estimation.

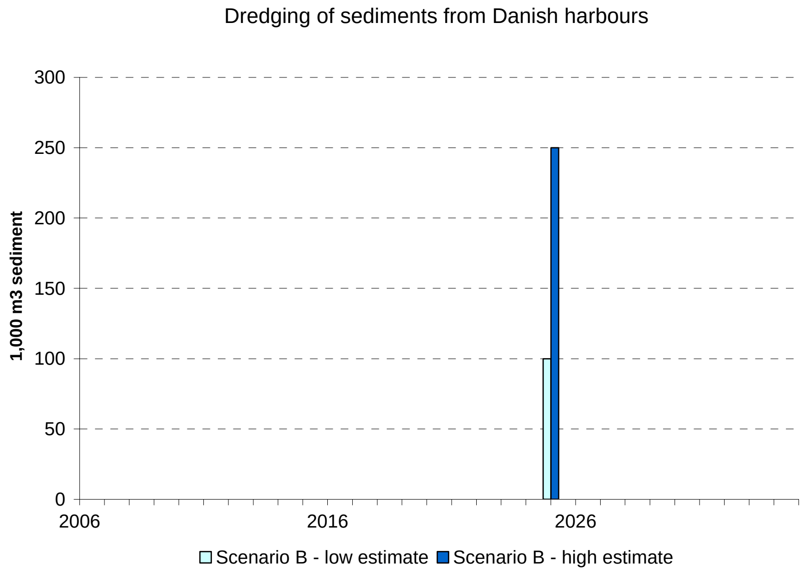

Figure 11-1
Amount of TBT-contaminated sediment for dredging and disposal on land in 20 years - High and low estimate for Scenario B
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The financial and welfare-economic costs can be calculated as the discounted net present value (NPV), which is the expression of the cost today of expenses over a period of time. The discount rate used by the Ministry of the Environment is 6 % and for the financial analysis and 3 % for the welfare-economic calculation. The results of the estimation are presented in the tables below. The welfare-economic cost is the cost which is relevant to this study as it expresses the total cost to society.

Table 11-2 Financial and welfare economic cost, dredging and disposal of TBT-contaminated sediment on land in 20 years - High and low estimates

Financial cost	*NPV in million DKK (Min - Max cost)**
Dredging and disposal of TBT-contaminated sediments from harbours	
Scenario B - low estimate	5-16
Scenario B - high estimate	11-40
Welfare-economic cost	
Scenario B - low estimate	11-39
Scenario B - high estimate	27-98

*) The minimum cost is 145 DKK/m^3 and the maximum cost is 515 DKK/m^3
Note: With 6 % discount rate, the welfare-economic estimates are DKK 6-22 million for the low estimate of sediment disposal and DKK 15-55 million for the high estimate.

The extra financial cost of Scenario B is estimated to be between DKK 5-16 and DKK 11-40 million in net present value depending on whether the low estimate of 100,000 m^3 or the high estimate of 250,000 m^3 is used. The welfare-economic cost is estimated to be between DKK 11-39 million and DKK 27-98 million in net present value. It should be emphasized that this is a very tentative estimate.

Another possible technical measure for the purpose of ceasing/phasing out TBT emissions/discharges is regulation (prohibition) of the sale and use of organotin-stabilised PVC-products in Denmark. Organotin- stabilised PVC is only seen in imported products. If substitute additives or products were to be used instead, the functionality, environmental effects and price would have to be mapped to in order to assess the economic consequences of such a policy. Finally, a ban on imports of certain products due to environmental concerns would conflict with international trade agreements and the EU common market. However, as mentioned above, an EU-wide measure would probably be more cost-effective than a purely Danish measure.

11.4 Conclusion on TBT

Compliance with the EQS is not a problem with respect to the present discharges into surface waters. However, the concentrations in harbours, especially marinas, may reach levels way above the AA-EQS for coastal waters, and consequently concentrations in discharge of surplus water from land based disposal of dredged material could also exceed the EQS.

As TBT is classified as a priority hazardous substance, also losses originating from the historical use of TBT containing ship paints must cease within 20 years in Scenario B. In Scenario A, Denmark is only obliged to pursue the aim to the extent it can be achieved by considering technical reduction options.

Some imported products still appear to contain organotin compounds to stabilize certain PVC products. For these products it is assessed that action (in relation to the progressive reduction required in Scenario B) needs to be taken at EU level to be effective. The most important release of TBT to the aquatic environment appears, however, to be the release from contaminated harbour sediments.

The cost in Scenario B of dredging remaining, TBT-contaminated sediments and disposing of them on land in 2025 (as a means of eliminating unacceptable “losses" to the marine aquatic environment) was calculated. This results in a total extra welfare-economic cost of between DKK 11-39 and SKK 27-98 million in net present value depending on whether the low estimate of 100,000 m^3 or the high estimate of 250,000 m^3 is used. The corresponding financial cost is estimated to be between DKK 5-16 and DKK 11-40 million in net present value.

It is considered unlikely that the obligation in Scenario A/C should include disposal on land of the most contaminated fractions as a purely national measure, but only if this is introduced as a common measure in the EU. Hence, there is no cost associated with Scenario A/C.

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/10/ Klapning - konsekvenser af ændring af klapningsstrategi med indførelse af koncentrationsgrænse og øvre mængdegrænse. Note prepared by COWI for DEPA, November 2004. Document no.: 59129-A-1 rev. 01.

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/15/ Jensen A og Gustavson K (2001). Havnesedimenters indhold af miljøfremmede organiske stoffer. Kortlægning af nuværende og fremtidige behov for klapning og deponering. Miljøprojekt Nr. 627, 2001. Danish Environmental Protection Agency

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12 Assessment of the other 23 priority pollutants

12.1 Priority substances

As mentioned in Section 2.2, 23 out of the 33 priority substances included in the Daughter Directive proposal were in the screening project found not to require further national measures/actions in order to comply with the EQS values proposed at that time.

Some of the proposed EQS values have been changed since the draft version of the directive proposal on which the screening assessment was based. As, further, the screening was conducted more than 1½ years before the current study, it was decided to briefly review the assessments of these substances again and adjust them, if necessary.

From this review it is concluded that the vast majority of the AA- and MAC-EQS are either unchanged or less strict than in the draft proposal, and in these cases the assessment in relation to EQS compliance remains the same, i.e. the environmental levels of the substances already comply with the requirements.

For atrazine, hexachlorocyclohexane (HCH) and isoproturon (some of) the MAC values have been lowered by up to a factor 2. This does not either lead to any changes in the original conclusions (i.e. compliance).

For octylphenol, the AA-EQS for "other surface waters", i.e. transitional and coastal waters, has been lowered from 0.06 µg/L to 0.01 µg/L. However, as the required reduction in sewage effluent concentrations to comply with this value is less than 10 times and the obtainable initial dilution in transitional and coastal waters is normally more than 10 times, it is assessed that the tightened EQS does not lead to a different conclusion than previously (i.e. compliance).

The AA-EQS for trichloromethane was lowered from 12 µg/L to 2.5 µg/L in the final directive proposal. Also, with this more strict value the concentrations of the substance in sewage effluent etc. are compliant with the requirements.

In conclusion, it is assessed that at the national level there is no need for further measures against any of the 23 not-selected PS to comply with the EQS requirements stated in the final proposal for the Daughter Directive (Scenario C)..

12.2 Priority hazardous substances

A few of the substances that originally were proposed for inclusion in the group of Priority Hazardous Substances, PHS, have been omitted from this category in the final version of the directive proposal (Scenario C).

The PHS among the 23 priority substances that were not selected for this study are now the following:

- Pentabromodiphenylether
- Chloroalkanes, C10-C13
- Endosulfan
- Hexachlorobenzene
- Hexachlorobutadiene
- Hexachlorocyclohexane
- Pentachlorobenzene

Regarding the five latter PHS, the conclusion from the screening assessment remains unchanged, i.e. the substances were either not used in Denmark at all or theywere phased out years ago, i.e. it is not relevant to initiate further regulatory measures aiming at ceasing or phasing out discharges or emissions of these substances.

The import, sale and use of pentachlorodiphenylether (PeBDE) (as a substance or in products containing more than 0.1 % of the substance) were banned in 2004 (Statutory Order No. 76 of 9 February 2004). A general ban on import and sale of electrical and electronic equipment containing brominated diphenylethers entered into force on 1 July 2006 (Statutory Order No. 1008 of 12 October 2004). Therefore, it is concluded that relevant national regulatory measures to phase out PeBDE have already been implemented though the beneficial environmental effect of these will not fully materialise before some years.

It is uncertain whether C_{10}-C_{13} chloroalkanes are still used in Denmark, but if so, the amount is very limited (< 1 ton/year). Previously, chloroalkanes were used as additives to certain lubricants, but this use was banned a few years ago by Statutory Order No. 461 of 26 May 2003. It cannot be completely excluded that other uses of chloroalkanes still exist, e.g. as an additive in certain hardeners and sealants, but it has not been possible to obtain any exact information on the issue.

The issue has not been pursued further in this study, as additional measures against chloroalkanes in any case will have to be implemented at EU-level to have the desired effect and as the impact of the present use, if any, on the aquatic environment is believed to be very small.

13 Assessment of measures against stormwater discharges

13.1 Introduction

For six out of the eight priority substances described and assessed in the preceding chapters it was found that the dominant input to surface waters in Denmark comes from the discharge of stormwater from separate systems. In some parts of Denmark the reduction factor required to comply with the EQS may for a few of the substances (nonylphenol and maybe PAH) be higher than the diluting capacity of the receiving streams at median minimum flow (summer conditions).

Further, a number of the substances are priority hazardous substances (cadmium, mercury, nonylphenol, PAH (including anthracene) and TBT) for which measures aiming to cease/phase-out pollution in accordance with the WFD must be introduced in Scenario A/C while progressive reduction and complete cessation/phase-out of discharges, emissions and losses must be achieved within 20 years in Scenario B in accordance with the draft proposal of the Daughter Directive.

Also among the other 23 priority substances not included in this study there are a number (7) of priority hazardous substances. In was concluded in the preceding chapter (Section 12.2) that five of the substances were not relevant to consider further in a Danish context while the remaining two, PeBDE and chloroalkanes, were presumably of little significance in relation to EQS compliance or being addressed already. However, all seven substances would, to the extent they occur in Danish stormwater, also be positively affected by the measures described in this chapter.

This chapter addresses the technical and economic aspects of minimizing the discharge into the aquatic environment of these and many other priority pollutants appearing in stormwater from separate systems.

Sewage can be divided into two main components: dry weather flow and wet weather flow. Dry weather flow consists mainly of domestic sewage, industrial sewage, and drains. Wet weather flow consists mainly of stormwater from paved areas in cities. Both dry weather and wet weather flows contain heavy metals as well as a large number of organic micropollutants. Figure 13-1 below indicates the main sources and processes in the "production" of wet weather flow pollution.

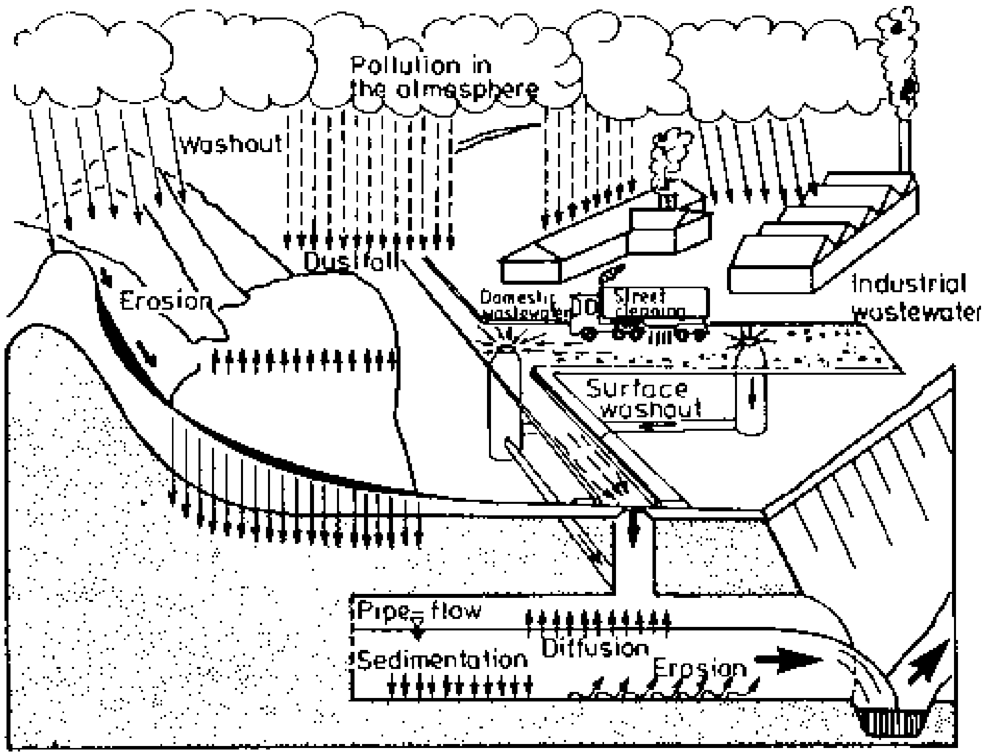

Figure 13-1.
Sources and processes affecting pollutants in stormwater (Göettle (1978): Ursachen und mechanismen der regenwasserverschmutzung. Ein beitrag zur modellierung der abflussbeschaffenheit in städtischen gebieten. Institut für Bauingenieurwesen V, TU Munchen. Berichte aus wassergütewirtschaft und gesundheitswesen, nr 23.).

Old sewer systems convey both sanitary sewage and wet weather runoff. In order to prevent surcharge of this unhealthy mixture a number of spills were designed that discharged into nearby surface waters, creating environmental as well as aesthetic problems. During the 1950's it became standard practice to design sewer systems as a two-stringed system; one system conveying sanitary sewage and the other system conveying wet weather runoff. Discharges from sewer systems can therefore be divided into three components:

- Dry weather discharges from wastewater treatment plants
- Wet weather discharges from combined sewer systems
- Wet weather discharges from stormwater systems

The wet weather runoff is discharged into nearby surface waters, usually without treatment. If treatment is implemented, it has in general been designed to reduce the hydraulic overloading of small rivers. In fact, with few exceptions storage facilities in relation to stormwater discharges are optimized to reduce retention of matter as much as possible thus reducing the operating and maintenance costs of the treatment facility.

During the last 10 to 20 years there has been a growing understanding that discharging wet weather runoff through separate sewer outfalls also creates environmental problems. The contents of heavy metals, PAH and a number of other substances are quite high, and studies have also shown that discharges from separate sewers are more toxic than discharges from combined sewers. Table 13-1 gives an overall indication of the importance of each of the three types of discharges into surface waters in Denmark.

Table 13-1
Comparison of discharges from separate sewers to other main types of point discharges. The assessment of the amount of discharged pollutants is quite uncertain.

	Volume (10^6 m3)	*Number of discharge points*	*Amount of SS*	*Amount, sum of PAHs*
Wastewater Treatment Plants	712[1)]	1,193[1)]	7,100 t/yr[2)]	50 kg/yr[1)]
Combined sewer overflows	31.8[1)]	5,044[1)]	5,100 t/yr[3)]	10 kg/yr[3)]
Separate sewer outfalls	155.6[1)]	10,474[1)]	12,000 t/yr[4)]	110 kg/yr[4)]

1) Punktkilder 2004. Orientering fra Miljøstyrelsen nr. 9, 2005.
2) Assessment made by COWI
3) Assessment based on Arnbjerg-Nielsen et al (2002): Regnbetingede udledninger fra fællessytemer af NPO-stoffer, tungmetaller og miljøfremmede organiske stoffer. Miljøprojekt 701. Miljøstyrelsen, København.
4) Assessment based on Miljøstyrelsen (2006): Målinger af forureningsindhold i regnudledninger. Arbejdsrapport nr. 10, 2006 fra Miljøstyrelsen.

Table 13-2
Separate sewer systems, basic statistics

	National statistics on separate sewers, based on 1)
Number of outfalls with detention	2,004
Number of outfalls without detention	8,112
Connected paved area with detention	14,153 ha
Connected paved area without detention	24,226 ha

1) Punktkilder 2003 (revideret). Orientering fra Miljøstyrelsen nr. 1, 2005.

Table 13-2 shows the basic relation between the number of outfalls and area of paved surface connected (in hectares, ha).

Based on the data provided in the "Punktkilder 2003" ("Point Sources 2003") report (Miljøstyrelsen 2005), it is assessed that approximately 85 % of the volumetric amount of discharges from separate sewer outfalls in Denmark occurs into fresh water.

13.2 Technical measures for retention of suspended particles in stormwater discharges

So far, technical measures at separate sewer outlets have been directed towards securing an acceptable hydraulic peak loading of the surface water, implying that the treatment should be simple storage. Since the water was considered to have a low content of pollutants, the detention ponds were often designed to minimize treatment in order to minimize operation and maintenance costs. In the following various methods for retention of suspended solids are discussed. The methods have been applied in Denmark or are based on technologies that are well known from treatment of combined sewage.[21]

Danish and international experiences are very limited with respect to measurements on treatment efficiencies of organic micro-pollutants. However, it is well known that none of the technical measures that are mentioned in the following section are able to treat the organic micro-pollutants in the sense that

[21] With the exception of technology No. 4. This is elaborated below in connection with each technology.

they are transformed into other (hopefully) harmless substances. Rather, the technical measures are based on some sort of physical removal of suspended solids. Removal of the organic micro-pollutants therefore depends on the sorptivity of the compounds. Alternatively, both water and solids can be discharged into another water body.

The treatment efficiencies with respect to the priority substances are assessed in two steps. First the removal of suspended solids is assessed for each of the relevant technical measures. Secondly, the proportion of the priority substance that will follow the suspended solids is assessed.

The technical measures can be divided into the following types of treatment:

1. Storage and routing to wastewater treatment plant in dry weather periods;
2. Storage in combination with treatment;
3. Infiltration (discharging into groundwater);
4. Filtration at point of discharge or distributed throughout the collection system.

The different types are discussed briefly below.

1. Storage and routing to wastewater treatment plant

One of the solutions to minimize the release of suspended particles from stormwater discharges is to reconnect the separate system to the treatment plant after proper storage. The technology is fully developed, but the solution has not been implemented anywhere, primarily because it implies less efficient treatment of nutrients and organic matter at the wastewater treatment plant.

The main drawbacks of this type of solution are:

- May cause more pollution at the overall scale;
- May jeopardize current treatment technology at wastewater treatment plants.

2. Storage in combination with treatment

The most well-known treatment options in relation to storage are the following:

a. Treatment by means of optimizing sedimentation in the storage chamber;
b. Treatment by means of filtration of the outlet of the storage chamber into the surface water.

Internationally, guidelines exist for optimized sedimentation in the storage chamber. Typically the sedimentation is enhanced by dividing the chamber into several subsections. By design, each of these subsections has a permanent water body also during dry weather flow, and each subsection also contains plants. Such storage chambers have been designed for several years by the Danish Road Directorate for treatment of road runoff at the national highways, and several municipalities have experiences with this type of treatment as well. Treatment efficiencies of suspended solids can be quite high if designed properly.

Removal of micro-pollutants will happen primarily through sorption to suspended solids, but some of the micro-pollutants will also be retained through sorption to other surfaces in the biological detention basin and uptake in the biomass. There are only few experiences with treatment by means of filtration of the outlet of the storage chamber into the surface water. The method is expected to lead to increased operating and maintenance costs, and therefore it is assumed that it will primarily be used as a second treatment step after sedimentation in the storage chamber has been obtained. Treatment efficiencies are high, up to 90 % for water receiving full treatment.

The main drawbacks of this type of solution (both options a and b) are:

- It requires extra operation and maintenance;
- Space requirements are estimated to be 2% of the connected paved area.

3. Infiltration
Infiltration of stormwater can take place at three levels

a. Local infiltration of roof water
b. Local infiltration of road water
c. Infiltration trenches at collection points

Infiltration will have a removal of sorbed micro-pollutants of close to 100% with respect to surface water. However, there is a risk that groundwater may be contaminated by substances with poor sorption characteristics.

The main drawbacks of this type of solution (all three options) are:

- The system is distributed and requires regular visits;
- Local landowners must build and operate the systems (roof water).

4. Filtration
Filtration systems are currently being developed that focus on sorption of micro-pollutants through different media. The systems can either be distributed throughout the separate sewer network or in a centralized treatment facility. The technology is not yet ready for large-scale implementation, and it is therefore not feasible to attempt to assess the economic aspects of implementation. The main drawback of this type of solution is:

- The technology is not ready for implementation yet

Common to all of the above solutions is the fact that they are quite expensive and require space. At many locations in city centres, it will be very difficult to acquire the physical space needed for the optimal solutions. This is the most important uncertainty factor in relation to implementing the above-mentioned measures.

13.3 Assessment of treatment efficiencies for selected options

In this study the focus will be on the two types of treatment that seems to be most suitable, i.e. option 2: Storage in combination with treatment, and option 3: Infiltration. The first of these methods aims at treating the stormwater and then discharge it into the same surface water as previously while the second of these methods aim at redirecting the water from the surface water and discharging it into the groundwater instead. As will be shown in the next section, storage in combination with treatment is relatively cost-effective when considering suspended solids. However, one of the priority (hazardous) pollutants in question - mercury - has rather poor sorption characteristics, i.e. a large proportion of the pollutant follows the water rather than the suspended solids. For mercury infiltration is a theoretically possible alternative although this technology is more expensive and also implies a risk of groundwater contamination. Other types of reducing measures are suggested for mercury (se Chapter 7).

The assessment of removal of suspended solids and the corresponding removal of micro-pollutants are described in Tables 13-3 and 13-4. For PAHs a removal of up to 80 % can be expected if applying technology type 2, Storage with treatment. For a substance like mercury the removal using this technology will in general be less than 30 % (but no need for removal from stormwater was identified for mercury).

When choosing technology type 3, Infiltration, all substances will have a removal of more than 95 % with respect to surface water. The relative cost-efficiency of the different types of technologies therefore depends significantly on the substance in question. In the specific context, technology type 2 will be the most relevant to consider for all the priority substances with the exception of mercury.

The above-mentioned two main types of solutions are considered to be the best treatment options available for full-scale implementation today. Both of these options require physical space between the connected paved area and the point of discharge. The space requirements typically correspond to 1-2 % of the paved areas connected to the treatment system. Further, land use is restricted near the location of the facilities.

If treatment at the location of the existing outlet is not feasible, other solutions must be studied, e.g. leading the surface water to another location, expropriating private property in order to recover the needed physical space, implementing novel/untested technologies etc. If the physical space is not available on site, the typical cost of moving the facility will be DKK 2,000-7,000 for every metre the facility is to be moved. The costs associated with these types of actions may, however, vary greatly. An upper limit of the costs is recovery of land by means of expropriation, which in city centres may be more expensive than the installation of the actual treatment facility, if at all politically and legally feasible.

Table 13-3.
Rough assessment of treatment efficiencies associated with implementation the most feasible technical measures. The reported treatment efficiencies are based on data from facilities that are well designed and operated. The assessment is based on treatment of approximately 95 % of the stormwater.

Technology	*Removal, % SS*	*Removal, % water*
2a. Storage with sedimentation	60-75	0-3
2b. Storage with sedimentation and treatment of outlet	70-90	0-3
3a. Local infiltration of roof water	95-100	95-100
3b. Local infiltration of road water	95-100	95-100
3c. Infiltration in trenches	95-100	95-100

Table 13-4
Rough assessments of the potential reduction of substance concentration in stormwater discharge through removal of suspended solids (SS)

Substance	*Reduction in substance concentration*
Lead	Up to 90 %
Cadmium	60-80 %
Mercury	25-35 %
Nickel	70-80 %
DEHP	70-80 %
Nonylphenol	60-70 %
PAHs	About 90 %
TBT	Lack of data - but at least 50 % is expected

Source: Based on COWI expert assessment from a previous project for DEPA regarding filtered and un-filtered runoffs from roads (Miljøprojekt 355, 1997)

Among the 23 priority substances not included in this study, the majority is also believed to be reduced by more than 50 % in stormwater by the mentioned detention systems. At least the following should benefit from these systems to this extent (assessed on basis of the $LogK_{ow}$/$Log\ K_{oc}$, i.e. if higher than 3):

Brominated diphenylethers (PeBDE), chloroalkanes, chlorpyrifos, endosulfan, hexachlorobenzene (HCB), hexachlorobutadiene (HCBD), hexachlorocyclohexane (HCH including lindane), octylphenol, pentachlorobenzene, trichlorobenzenes and trifluralin.

13.4 Economic Assessment

Based on various previous studies and literature sources, the overall costs and treatment efficiencies are assessed to be as presented in Table 13-5 under the assumption that physical space is available at the location without costs.

Table 13-5
Rough assessment of the costs associated with implementing the technical measures suggested in the previous section. The costs are unit costs per hectare (ha) of connected paved area. They are based on median values, and prices may vary significantly due to local conditions. Costs of land recovery are not included.

Type of treatment	*Financial cost*			*Welfare-economic cost **	
	Investment cost DKK/ha	*Annual operating and maintenance cost DKK/ha*	*Technical lifetime Years*	*Investment cost DKK/ha*	*Annual operating and maintenance cost DKK/ha*
2a. Storage with sedimentation	165,000	1,700	50	225,000	2,300
2b. Storage with sedimentation and treatment of outlet**	190,000 - 350,000	7,800 - 9,400	30	260,000 - 480,000	11,000 - 13,000
3a. Local infiltration of roof water	2,000,000	0	30	2,700,000	0
3b. Local infiltration of road water	1,100,000	5,400	30	1,500,000	7,400
3c. Infiltration in trenches	1,500,000	7,500	50	2,100,000	10,000

Note: *) If the cost will be financed directly by the customers, the tax distortion factor of 20 % used to calculate the welfare-economic cost may be too high.
**) At outlets without existing storage facilities, new storage facilities are necessary. In this case the high-end cost is relevant.

13.4.1 General assumptions on the potential extent of the measure

The concentration in the surface water after initial dilution is mainly dominated by two factors: (1) the concentration of the pollutants in the stormwater runoff and (2) the magnitude of (usually less polluted) dry weather water flow in the receiving water. The two factors are discussed below.

The concentration levels in the stormwater can to some extent be predicted based on a description of the catchment. High traffic intensity usually implies higher concentrations of pollutants, and runoff from newly paved areas has a higher content of pollutants than the average. The change in the use of polluting substances is also reflected in the concentration levels, most notably in the concentrations of lead and copper.

However, there is also a significant variation in the concentration levels between wet weather events. This variation is random and in general supersedes the variation that can be described by catchment properties. Therefore, when considering possible measures, the variation of concentration levels in the stormwater runoff has relatively minor importance and can mainly be used as a guideline for deciding on which types of catchments should be treated first.

The initial dilution is large during small storms. The heavy storms nearly all occur during summer where the Danish streams and rivers have a relatively small dry weather flow (median minimum flow). The dry weather flow varies greatly throughout Denmark. Most streams in Zealand and other places in the eastern part of Denmark are characterized by low dry weather flows, and often they have a high number of discharges into the streams. In the summer, the wet weather flows in surface waters are typically about 10 times higher than the dry weather flows, i.e. in many places, it is only possible to obtain a dilution factor of about 1.1 at this time of year. In certain areas, therefore, the (summer) maximum concentration levels in the surface water are almost the same as in stormwater. In other parts of the country the ratio is substantially higher, because the level of urbanization is lower and because the dry weather flow is higher.

About 37 % of the stormwater discharges undergo some type of treatment prior to the discharge. The treatment is most often installed due to hydraulic overloading of the surface waters. Due to optimization of the operation including minimization of maintenance there is little or no retention of pollutants. Storage facilities designed near the Danish highways within the last 20-30 years are important exceptions. Facilities designed according to the guidelines provided by the Danish Road Directorate will, if properly operated, retain a significant part of the priority pollutants.

An increasing area is being paved and connected to separate stormwater runoff drainage. The development since 2001 has been used to forecast the area in 2025, and the result is presented in Figure 13-2 below.

Further, the number of separate stormwater runoffs that are connected to storage basins before discharge increases. The development in the percentage of separate stormwater runoff connected to some form of storage is shown in Figure 13-3. The rise in the percentage indicates that in general new separate stormwater discharges are constructed with retention basins and that detention basins are installed at some of the old systems as well.

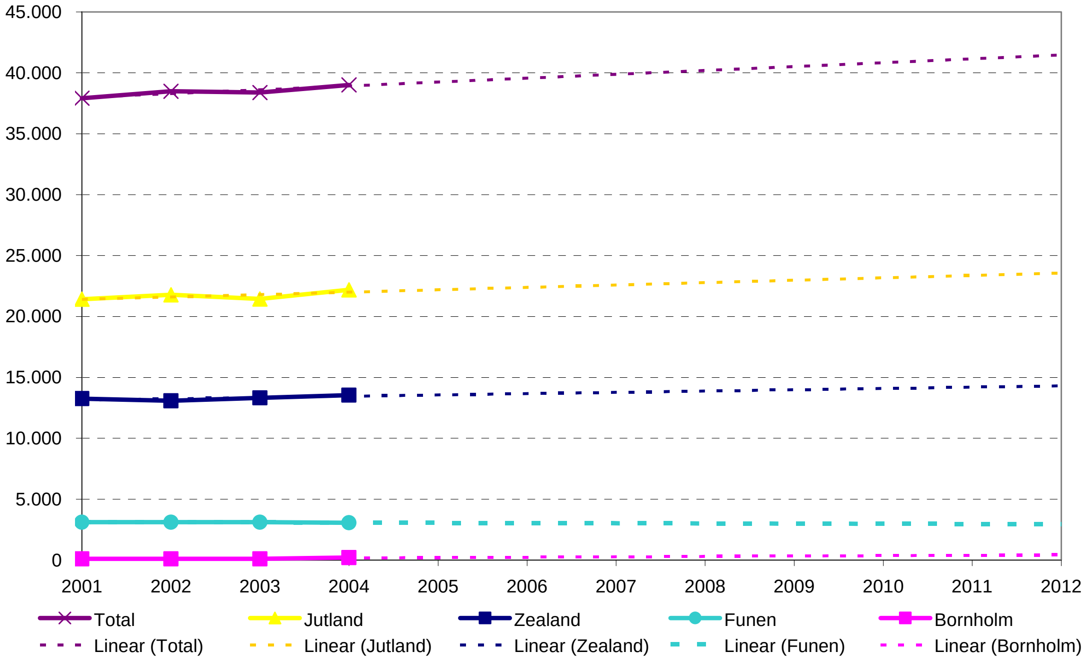

Figure 13-2
Overview of the development and forecasted paved area connected to separate storm-water drainage

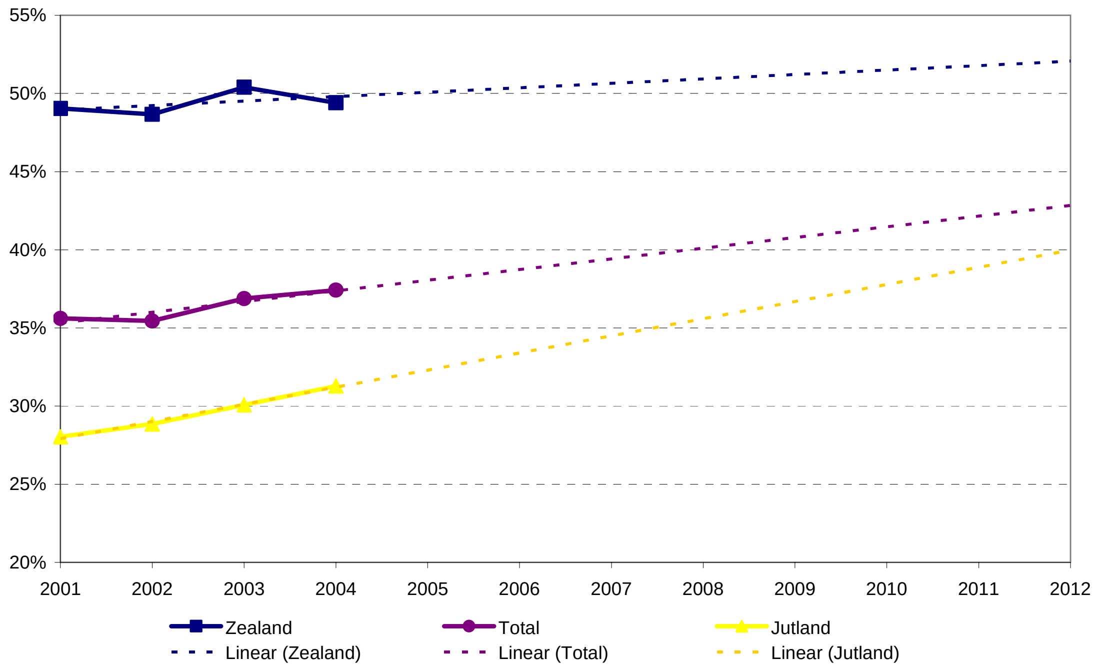

Figure 13-3
Proportion of areas connected to storage prior to discharge.
Note: *) Break in data series means that trends cannot be calculated for Funen and Bornholm. Instead, a discrete forecast is made.

13.4.2 "Worst case" - Scenario B

In the following, a calculation is made of the financial and welfare-economic cost of reducing the discharge of the PHSs through treatment of stormwater. Since about 85 % of the total volumetric amount of discharges from separate sewer outfalls occur to freshwater and since the water quality criteria are set as concentrations, it is assumed as a "worst case" scenario that eventually practically all separate outfalls that discharge into the freshwater environment will have to be fitted with storage facilities. This corresponds to Scenario B where ceasing/phasing out discharges, emissions and losses of priority hazardous substances to the aquatic environment must be achieved within a time frame of 20 years in accordance with the draft proposal of the Daughter Directive.

Some stormwater detention structures are already equipped with storage facilities (approx. 37%). However, the majority of these structures must be redesigned extensively in order to obtain the required functionality. Therefore, as a rough assessment, it is assumed that no existing treatment exists. Thus, treatment must be installed at discharges representing runoff from 33,000 ha impervious surface area. This is a conservative assessment.

With regard to assessing the cost of acquiring the necessary plots of land, space requirements are 2 % of the connected paved area. Further, we know that 37 % of the stormwater discharges presently undergo some type of treatment prior to the discharge. Though these treatment faciltities will have to be rebuilt, as they provide little or no retention of pollutants, the new treatment can be placed on the same area. The resulting need for additional land is around 415 ha. Of this, it is assumed that one third of the land will not have alternative use of any value and already be in the ownership of the municipality or the water company. Another third is assumed to be placed on agricultural land with an average purchasing price of DKK 150,000 per hectare. This corresponds to a welfare economic cost of just over 200,000 DKK per hectare. The last third of the land required is assumed to be located in urban areas and city centres and must be purchased and/or be acquired by expropriation. It is difficult to set an average price for such land as it will be highly dependent on local conditions. If the price is very high for land in the relevant area, moving the water to another location can be a more cost-effective solution while less space-requiring technical treatment technologies can be the most cost-effective solution at some locations. In the following estimation, an average price per hectare of land in urban areas is set to DKK 10 million. This gives a welfare-economic cost of 13.7 million DKK per hectare. In sum, the average cost of land for the basins is set to just over DKK 3.4 million per hectare in financial cost and DKK 4.6 million in welfare economic cost, which makes it the most important factor in the cost estimation.

Table 13-6 shows the financial and welfare-economic results for the situation where measures have to be implemented for 85 % of all runoffs in Denmark (Scenario B). As mentioned, the focus is on the two types of treatment that seem to be most suitable, i.e. options 2a and 2b: Storage in combination with treatment by sedimentation and by filtration respectively. The welfare-economic results are shown with both a 3 % and 6 % discount rate.

It must be noted that the estimations are made on the basis of unit costs based on the assumptions mentioned earlier in this chapter. Handling all runoff stormwater currently running to separate sewer systems would in reality imply a number of special measures that could both increase or decrease the cost significantly compared to the results below.

Table 13-6
Financial and welfare-economic costs in worst case (Scenario B) of retention of sediments in stormwater runoff.

	Financial NPV in mio. DKK	*Welfare-economic* NPV in mio. DKK (3 %)	*Welfare-economic* NPV in mio. DKK (6 %)
Scenario B:"Deadline 2025"			
2a. Storage with sedimentation total	3,700	5,600	5,000
Investment cost	2,600	3,700	3,500
O&M cost	400	900	600
Cost of land acquisition	700	1,000	900
2b. Storage with sedimentation + treatment of outlet total	7,800	13,700	10,600
Investment cost	5,000	8,000	6,800
O&M cost	2,100	4,700	2,900
Cost of land acquisition	700	1,000	900

Note: Results have been rounded up or down.

The results in Table 13-6 show that in the worst case the welfare-economic cost with a deadline 2025 (Scenario B) is DKK 5.6 billion for storage chambers with sedimentation and DKK 13.9 billion if treatment of outlet is added (discount rate of 3 % is used). The cost of land acquisitions less than 1 billion in both cases whereas the cost of investment and the operating and maintenance cost of the technology is DKK 4.6 and 12.7 billion respectively.

The total financial cost is DKK 3.7 billion for storage chambers with sedimentation and DKK 7.8 billion if treatment of outlet is added (discount rate of 6 % is used). The cost of investment and operating and maintenance cost of the technology alone is DKK 3 and 7.1 billion respectively.

13.4.3 "Critical areas" - Scenario A/C

The "critical areas" scenario addresses the situations where compliance with the MAC-EQS appears not to be possible to achieve at present and, thus, in this respect it is relevant not only to Scenario A/C but also to Scenario B. The scenario only considers modification of outlets in the critical parts of the country where the MAC-EQS compliance problem exists. In this report these parts are identified as those where typically only a dilution factor of less than 3 can be achieved in the summer season - the approximate reduction factor that is needed for the most critical substance, nonylphenol, in stormwater to comply with the MAC-EQS value (see section 9.1.5).

This scenario is considered also to represent Scenario A/C (but not B) with regard to the objective of the WFD of aiming at ceasing or phasing out priority hazardous substances

A forecast of the geographical distribution of the areas connected to some type of storage in 2025 is given in Table 13-7 below as well as a very crude assessment of where treatment might be necessary and where installation of treatment facilities is technically feasible. Some of the existing treatment facilities can be renovated to meet demands of higher treatment efficiency. However, it must be expected that a substantial part of the existing detention ponds can only be used with large modifications. Therefore, the economic benefit of reusing the existing ponds is limited, and it will not affect the overall assessment of costs.

Table 13-7
Forecasted assessment of connected areas in 2025

	Connected paved area (ha) 2025	*Proportion of areas in 20025 connected to storage prior to discharges*	*Assessment of possible reuse of existing technology**	*Assessment of areas that may be connected to treatment options***	*Areas where new measures may be necessary ****
Zealand	15,700	56 %	10 - 20 %	70 - 90 %	65 - 80 %
Funen	3,000	100 %	10 - 20 %	30 - 85 %	20 - 70%
Jutland	26,100	54 %	10 - 20 %	30 - 70 %	25 - 60 %
Bornholm	900	50 %	10 - 20 %	30 - 70 %	25 - 60 %
Total	45,600	52 %			40 - 70 %

* Existing storage is sufficient because treatment measures are already implemented.
** Assessment of the percentage of areas that may require treatment measures in Scenario A/C
*** Percentage of areas where new measures may be necessary in Scenario A/C.

Based on the general assumptions in Section 13.4.1 above and the values in Table 13-7, it is roughly assessed that the "critical areas" scenario (Scenario A/C) should include detention/treatment of about 40 % of the volume of stormwater from separate systems (including the vast majority with existing detention systems as these generally need to be strongly modified to fulfil the objective (retention of suspended solids). The same assumptions on the need for additional land are used in this scenario as in Scenario B. The size of this land is around 195 ha in Scenario A/C. For at better estimate of the volume of stormwater from separate systems representing “most critical areas” a more in-depth analysis of the issue is recommened.

The "critical areas" scenario includes only the outlets for which the initial dilution that can be obtained under summer dry weather flow (median minimum flow) in the streams/rivers is less than a factor of 3. Only nonylphenol (NP) requires such a high reduction factor to comply with the EQS while cadmium requires a reduction factor of 1.6. Presumably, also the PAH levels require reduction prior to discharge, but it is not possible to state an exact reduction factor as currently no MAC-EQS has been established for PAH.

The year 2035 is set as the deadline for implementation of the necessary measures in Scenario A/C. This deadline has been selected arbitrarily, but can illustrate the difference in cost of delaying the actions against these substances compared to Scenario B having a mandatory deadline in 2025. In the discussion of the economic results, the interpretation of the deadlines is further discussed. The starting point of the implementation is set to 2006, even though programmes to implement the WFD do not have to be made operational until 2012. This means that the cost may be slightly overestimated as delaying the investments will reduce the cost in net present value. The results are the net present value of the cost of land acquisition (based on the same cost model as described for Scenario B in Section 13.4.2), the investment cost plus the operation and maintenance costs over the time period[22]. The net present value

[22] The following assumptions and arithmetic assumptions are made: The time horizon for the calculation is 30 years, the price level is 2005 prices, linear depreciation of the assets is assumed to calculate scrap values, the discount rate used is 3 % according to the guidelines for economic project evaluation by the Danish Ministry of the Environment, investments are assumed to be

discounts expenses made in the future back to the value of that expense today in order to be able to compare different investment packages.

As mentioned, the focus is on the two types of treatment that seem to be most suitable, i.e. options 2a and 2b: Storage in combination with treatment by sedimentation and by filtration respectively. The results are calculated both as a financial cost, which illustrate the cost of the project to the contractors. Another relevant result is the welfare-economic cost, which includes the cost of publicly financing of the investment package - that is a policy action to implement the directives.

Table 13-8 shows the same results for the "critical areas" scenario comprising 40 % of the volume of separate stormwater discharges in Denmark. The welfare-economic cost is DKK 2.0 billion for storage chambers with sedimentation and DKK 4.7 billion if treatment of outlet is added (discount rate of 3 % is used). Some of the cost is due to land acquisitions whereas the cost of investment and operating and maintenance costs of the technology is DKK 1.6 and 4.4 billion respectively.

The total financial cost is DKK 1.2 billion for storage chambers with sedimentation and DKK 2.6 billion if treatment of outlet is added (discount rate of 6 % is used). The cost of investment and operating and maintenance cost of the technology alone (with no cost of land) is 1.0 and 2.4 billion DKK, respectively.

Table 13-8 Financial and welfare-economic costs in a scenario of implementation of retention of sediments in 40 % of all stormwater runoff

	Financial NPV in mio. DKK	*Welfare-economic* NPV in mio. DKK (3 %)	*Welfare-economic* NPV in mio. DKK (6 %)
Scenario A/C: "Deadline 2035"			
2a. Storage with sedimentation total	1,200	2,000	1,700
Investment cost	900	1,300	1,200
O&M cost	100	300	200
Cost of land acquisition	200	300	300
2b. Storage with sedimentation + treatment of outlet total	2,600	4,700	3,600
Investment cost	1,700	2,800	2,300
O&M cost	700	1,600	1,000
Cost of land acquisition	200	300	300

Note: Results have been rounded up or down.

In both cases - the "critical areas" scenario (A/C) and the "worst-case" scenario (B) - the costs (reported in Table 13-8 and 13-6 respectively) are considered to be high compared to the typical level of public spending on environmental policy in Denmark for purposes having the degree of specificity as these.

made at the end of the year for the purpose of the net present value calculation, the 2005 net present value is calculated.

13.5 Concluding remarks on removal of priority substances from stormwater discharges

It is possible to significantly reduce or, in some situations, even practically remove the pollution with priority substances from stormwater, but at a high cost compared to the general level of public spending on the environment. The technology proposed is a well-known (though not currently not often applied in Denmark) general technology which reduces or removes suspended solids to which priority (hazardous) pollutants (and many other harmful chemical substances) tend to be bound and therefore will be retained to a significant degree along with the suspended particles.

It is assessed that in general the concentrations of priority substances in discharges of stormwater from separate systems are so low that to comply with the MAC-EQS values only a very modest, if any, reduction by initial dilution in the receiving stream is necessary. However, in some parts of Denmark (corresponding to about 40 % of the volume of the stormwater discharges) the natural flow in the streams is so low under realistic worst-case conditions (summer median minimum flow) that for a few substances (in particular nonylphenol and maybe PAH) the required reduction in concentration appears not to be achievable in this situation.

With focus on environmental protection the mentioned 40 % scenario is at the same time considered to represent the reasonable requirements for ceasing/phasing out the priority hazardous substances in Scenario A/C while the establishment of detention systems at all stormwater outlets to fresh water systems, i.e. 85 % of the volume of all separate stormwater outlets, represents the "worst-case" scenario, Scenario B, for these substances.

Implementing stormwater retention arrangements in Scenario A/C solely with the purpose of achieving the reduction target of cessation for priority hazardous substances is, however, assessed by the DEPA to be unrealistic. This is taking into account that the reduction target is of non-legally binding character, and that the environmental benefits obtained by establishing retention arrangements are small and thus disproportional to the very high costs.

14 Conclusion

14.1 The need for further national regulation

Firstly, the need for further national regulation of a priority substance depends on whether the concentration of the substance in discharges into surface waters and into the aquatic environment itself exceeds the EQS or not. Secondly, there may a need for further national regulation aiming at cessationg/phase out of priority hazardous substances. The extent of necessary measures depends on the scenario considered (briefly summarised, for a full description see Section 3.3):

(1) Scenario A/C representing the situation with the current, official proposal for the Daughter Directive, which only esta blishes specific requirements to compliance with the proposed EQS values while possible measures aimed at progressive reduction and cessation/phase-out must be based on WFD requirements. In the assessment this scenario is considered almost identical to not having a Daughter Directive but only the requirements of the existing WFD (Scenario A), or

(2) Scenario B representing the 2005 draft proposal for the Daughter Directive in which, additionally to the A/C scenario, binding requirements to measures to achieve progressive reduction or cessation/phas out were included with a 20-year time limit for implementation.

It should be noted that the reduction target of aiming at cessation/phase-out and progressive reduction in Scenario A/C is an obligation according to the existing WFD. Hence, estimated costs related to this reduction target are not a consequence of the final Daugher Directive proposal.

Therefore, in the following, the EQS issue and the effort to ceasing/phasing out PHS are described separately.

Further, a number of other, minor issues are dealt with in separate subsections.

14.1.1 EQS compliance

In Table 14-1 the AA-EQS and MAC-EQS (where applicable) values of the eight selected PS are compared to data from monitoring of the levels of the substances in sewage effluent and in stormwater from separate systems respectively, in order to calculate the initial reduction necessary to lower the effluent concentrations to the EQS value. With regard to the 23 priority substances that were not selected for this study it is the assessment that they, at the national level, already comply with the proposed EQS values.

For sewage effluent two sets of data are available, the average concentration in the effluent and the 95 % percentile concentration. Compliance with the AA-

EQS is assumed when less than 10 times initial dilution of the 95 % percentile data is required to reach the AA-EQS value.

For stormwater, Table 14-1 is based on average data from measurements of concentrations in the first 5 mm of six rain events at each of two locations in suburban Copenhagen. These are compared with the MAC-EQS. The initial dilution, after which compliance with the MAC-EQS must be obtained, may in some parts of eastern Denmark be considerably lower than the factor 10 applied to sewage effluent, especially during the summer period.

Table 14-1
Required initial dilution of priority substances in sewage effluent and stormwater (separate system) to comply with the most rigorous AA-EQS and MAC-EQS value, respectively (in the cases where the values differ). All EQS values and concentrations are in µg/l.

Substance	*EQS*		*Sewage, average*		*Sewage, 95 %*		*Stormwater, average*	
	AA	*MAC*	*Conc.*	*Dilution*	*Conc.*	*Dilution*	*Conc.*	*Dilution*
Cadmium	0.08-0.2[1]	0.45	0.09	1.1-none	0.5	6.3-2.5	0.73	1.6
DEHP	1.3	N.A.	1.8	1.4	6.1	4.7	32	N.A.
Lead	7.2	N.A.	1.9	none	5.3	none	17	N.A.
Mercury	0.05	0.07	0.09	1.8	0.3	6.0	0.079	1.1
Nickel	20	N.A.	6.4	none	16	none	19	none
Nonylphenol*	0.3	2.0	0.3	none	0.6	2.0	5.7	2.9
PAH :								
B(a)pyrene	0.05	0.1	<0.01	none	<0.01	none	0.14	1.4
B(b+k)fluoranthene	0.03	N.A.	<0.01	none	<0.01	none	0.39	N.A.
B(ghi)perylene + Indeno(123-cd)yrene	0.002	N.A.	<0.01	<5	<0.01	<5	0.36	N.A.
TBT	0.0002	0.0015	<0.0005	<2.5	0.002	10	No data	-

N.A. = "not applicable" (as stated in the directive proposal).
* Nonylphenol "potential" i.e. NP + NPE1-2EO

As can be seen from the table, with regard to sewage effluent none of the priority substances require an initial dilution of more than 10 times (standard initial dilution factor applied in the environmental regulation of wastewater discharges in Denmark), even for the 95 % percentile of the discharges, in order to comply with the AA-EQS.

The stormwater effluents generally require very little initial dilution to comply with the MAC-EQS. The maximum reduction required is a factor 2.9 for nonylphenol while cadmium only requires a factor 1.6. Further, it is believed that PAH will also require reduction in stormwater prior to discharge but an exact reduction factor cannot be defined at present.

In a national perspective the majority of stormwater discharges are considered to comply with the MAC-EQS. However, in some parts, mainly the eastern, of the country there may problems in the summer season (at median minimum of dry weather flow) in obtaining even a dilution factor of about 3 as required for nonylphenol. As this situation may represent as much as 40 % of the volume of separate stormwater discharges, the likely non-compliance with the MAC-EQS should not be overlooked and has therefore been assessed economically under measures for stormwater (relevant for all three scenarios).

For nonylphenol, the 5.7 µg/L value in stormwater (constituting the basis of the above reduction factor 3) can be regarded a conservative, but not unrealistic value representing the average of a wide range of situations including long periods of dry weather prior to the rain event sampled (i.e. with significant build-up of pollutant levels). Other, later data indicate that the average concentration in stormwater may now be somewhat lower. An in-depth analysis of the issue is therefore recommended prior to initiating implementation of the proposed technical measures for stormwater.

Finally, it should be noted that for a number of the priority substances the official Daughter Directive proposal has not defined any MAC-EQS value but only stated such a value to be "not applicable". This prevents an evaluation of these substances with regard to stormwater as the MAC value would be the relevant evaluation basis. Presumably, the PAH levels require reduction prior to discharge but it is not possible to state a exact reduction factor as currently no MAC-EQS has been established for PAH.

14.1.2 Cessation/phase-out of discharges, emissions and losses

Priority hazardous substances (PHS) require regulation to ensure cessation or phasing out of discharges, emissions and losses irrespective of whether the substances comply with the EQS or not. Therefore, the PHSs among the PSs included in this study will require further national action as discharges, emissions and losses of these substances still occur. Scenario B implies an obligation to reach the target within a time frame of 20 years while in Scenario A a time frame is not specified, and the obligation is limited to considering all technical reduction options (though this will not necessarily result in reaching the target).

The PHSs among the PSs in this study are:

- Cadmium
- Mercury
- Nonylphenol
- PAH (including anthracene)
- TBT

With the exception of nonylphenol (and maybe PAH) in stormwater there generally already appears to be compliance with the proposed AA- and MAC-EQS and the need for national measures to ensure progressive reduction of pollution in Scenario A/C is therefore confined to the stormwater issue. Please note that the objective of aiming at progressive reduction of priority substances in Scenario A/C is a requirement according to the existing WFD, not the final Daughter Directive proposal. In Scenario B (referring to the 2005 draft Daughter Directive), however, there is an obligation to continue progressive reduction in a cost-effective manner of emissions, discharges and losses even beyond the EQS compliance level. Proposed measures are briefly summarised in Section 14.2.

It should also be noted that the objective of aiming at cessation/phasing-out of priority hazardous substances in Scenario A/C is a requirement according to the existing WFD, not the final Daughter Directive proposal.

With regard to the 23 priority pollutants not selected for this study, the following are classified as PHS:

- Pentabromodiphenylether (PeBDE)
- Chloroalkanes, C10-C13
- Endosulfan
- Hexachlorobenzene
- Hexachlorobutadiene
- Hexachlorocyclohexane
- Pentachlorobenzene

As far as the five latter PHS are concerned, the conclusion from the screening assessment remains unchanged, i.e. the substances were either not used in Denmark at all or they were phased out years ago, i.e. it is not relevant to initiate further regulatory measures aiming at ceasing or phasing out discharges or emissions of these substances.

For PeBDE it is concluded that the necessary national phase-out measures have been taken already (recently) while for chloroalkanes common action at EU-level is needed for a measure to become effective. The current use of chloroalkanes in Denmark is, however, believed to be very limited and with only little impact on the quality of surface waters.

14.1.3 Losses of priority substances from contaminated sites

This report mainly deals with the discharges and emissions of priority substances from society today. However, losses of certain substances from contaminated sites to the aquatic environment may occur though the extent of such a potential problem is believed to be quite limited from a national perspective It has not been possible to gather specific information about this issue within the framework of this study and, therefore, a specific study on losses from contaminated sites has been initiated and will be reported separately.

14.1.4 Certain priority hazardous substances in biota

The maximum allowable concentrations in edible biota(fish, shellfish etc.) are set in the final proposal for Daughter Directive (Scenario C) for the substances hexachlorobenzene (HCB), hexachlorobutadiene (HCBD) and methyl-mercury.

While it is assessed that the concentrations of HCB and HCBD in biota comply with the limit value, the concentrations of mercury in fish (of which 90 % is assessed to be due to methyl-mercury) in many places exceed the acceptable level. Hence, action is required but as the contamination leading to the too high levels is widespread and diffuse such action must be aimed at the sources of contamination. A number of such actions are proposed for mercury in relation to the general cessation/phase-out requirement for this metal.

14.1.5 Other pollutants

The final proposal for the Daughter Directive (Scenario C) also establishes EQS values for a number of other, non-priority pollutants: DDT, aldrin, dieldrin, endrin, isodrin, carbon tetrachloride, tetrachloroethylene and trichloroethylene.

DDT and the "drins" have all been phased out in Denmark many years ago while the use of carbon tetrachloride is insignificant. There is still some use of tetrachloroethylene and trichloroethylene but monitoring data show that the concentrations in wastewater effluents are below the EQS.

14.2 Progressive reduction and cessation/phase-out measures

Table 14-2 gives an overview of the specific measures proposed for inclusion in a possible future national programme for progressive reduction and/or cessation of the discharges, emissions and losses of priority substances and priority hazardous substances into the aquatic environment.

Different sets of measures are proposed for Scenarios A/C and Scenario B respectively as "progressive reduction" in Scenario A/C only entails measures if the EQSs are not complied with while in Scenario B the progressive reduction must continue independent of EQS compliance. Further, the requirements to cessation/phase-out measures are stricter in Scenario B than in Scenario A/C.

Please note that in Scenario A/C the objective of aiming at progressive reduction of priority substances and cessation/phasing out of priority hazardous substances is a requirement according to the existing WFD, not the final Daughter Directive proposal.

In addition to the substance-specific measures it has been demonstrated for the majority of the eight selected priority substances that the main release into surface waters in Denmark (i.e. as total amounts) originates from the content of the substances in stormwater discharges. Only mercury and nickel are predominantly discharged with sewage effluent.

Table 14-2

Overview of national measures proposed for progressive reduction of priority substances and/or cessation/phasing out of priority hazardous substances.

Priority substance	*Reduction target*	*Scenario*	
		A/C *Measures aimed to fulfil WFD objectives*	*B* *Measures aimed to fulfil objectives of 2005 Daughter Directive proposal*
Cadmium	Progressive reduction	None required	Existing measures sufficient
	Cessation/phase-out	Elimination of cadmium in sacrificial anodes¨ (only "natural" replacement of old down-pipes - no additional cost) Retention arrangements for suspended solids in stormwater[1]	Elimination of cadmium in sacrificial anodes Phase-out of existing zinc gutters and downpipes in zinc from before 1980 and still in use after 20 years Retention arrangements for suspended solids in stormwater[2]
DEHP	Progressive reduction	None required	Existing measures sufficient
	Cessation/phase-out	None required	None required
Lead	Progressive reduction	None required	Existing measures sufficient
	Cessation/phase-out	None required	None required
Mercury	Progressive reduction	None required	See cessation/phase-out
	Cessation/phase-out	Mandatory mercury filters for dental clinics Collection of mercury containing equipment in use in the society	Mandatory mercury filters for dental clinics Collection of mercury containing equipment in use in the society
Nickel	Progressive reduction	None required	Retention arrangements for suspended solids in stormwater[2]
	Cessation/phase-out	None required	None required
Nonylphenol	Progressive reduction	See cessation/phase-out (stormwater)	See cessation/phase-out
	Cessation/phase-out	Substitution of NPE in paints, cleaning products and use as hardener where possible by best available techniques (*EU action* required) Retention arrangements for suspended solids in stormwater[1]	Substitution of NPE in paints, cleaning products and use as hardener (*EU action* required) Retention arrangements for suspended solids in stormwater[2]
PAH	Progressive reduction	None required	See cessation/phase-out
	Cessation/phase-out	Retention arrangements for suspended solids in stormwater[1]	Retention arrangements for suspended solids in stormwater[2]
TBT	Progressive reduction	None required	See cessation/phase-out
	Cessation/phase-out	Banning of the use of organotin compounds as PVC stabilizers (TBT as impurity) (*EU action* required) Clean-up and safe disposal of contaminated harbour sediments	Banning of the use of organotin compounds as PVC stabilizers (TBT as impurity) (*EU action* required) Clean-up and safe disposal of contaminated harbour sediments
Stormwater	Progressive reduction	None required	See cessation/phase-out
	Cessation/phase-out	Retention arrangements for suspended solids in stormwater in critical areas	Retention arrangements for suspended solids in stormwater

1 As part of common action against several substances in critical areas (40 % of volume).
2 As part of common action against several substances (85 % of volume).

With a few exceptions, the biggest fraction of the most critical environmental pollutants in stormwater is associated with the suspended solids. Hence, a common technological measure such as storage with sedimentation and treatment of outlet that would reduce the concentration in the discharge of all substances with this feature could be implemented at least on the outfalls from separate stormwater systems in areas with little dilution potential, and high population density and contamination levels.

The results for Scenarios A and C are presented together above. Scenario C represents the final proposal for the Directive put forward in July 2006. In effect, this scenario corresponds to Scenario A, i.e. the situation without an agreement on a Daughter Directive (i.e. only the WFD).

The final proposal (Scenario C) does have a deadline in 2025 with regard to the Commission's evaluation of the Member States' fulfilment of the obligation to initiate the necessary measures with the aim of ensuring progressive reduction of the PS and cessation/phase-out of the PHS. This deadline is, however, not interpreted by DEPA to have any influence on the timeframe for the implementation of the Directive compared to the described Scenario A.

Regarding the environmental quality targets (the EQS), the proposed Daughter Directive, Scenario C, is in line with Scenario B where targets are set at Community level. DEPA assumes that in practice the difference between national Danish target levels (Scenario A) and Community target levels will be insignificant. All three scenarios are therefore the same with regard to the quality targets.

Table 14-3 below presents the main types of measures that can be used to initiate the actions required to meet the Directive requirements to priority substances and the priority hazardous substances. Distinction is made between national and Community level type of measures. Basically, bans and use restriction types of measures (including substitution) can only be implemented nationally if Community level action has been agreed on in EU.

Table 14-3 National or community level implementation of proposed technical measures

<table>
<tr><th>Types of measures that can be implemented individually in the member states</th><th>Types of measures that should be implemented at community level to be effective</th></tr>
<tr><td>Examples of implementation:
A. Campaigns to collect used equipment containing substances
B. Campaigns to induce change in consumer demand for products without a substance
C. Point source abatement/clean-up measures
D. Voluntary agreements for industrial reconversion</td><td>Examples of implementation:
E. Ban/tax on substance use in production
F. Ban/tax on use/sale of products containing substances
G. Subsidies to investment for change in production technology
H. Other industrial reconversion policies</td></tr>
<tr><td colspan="2">Technical reduction measures proposed for Denmark(possible national implementation in italic):
▪ Substitution of cadmium in anodes - could be implemented through B, D, E , F, G or H
▪ Replacement of cadmium in downpipes - A
▪ Mercury filters in remaining dental clinics - could be implemented through C
▪ Collection of mercury-containing equipment - could be implemented through A
▪ Substitution of nonyphenolethoxylates (NPE) in paint and epoxy - could be implemented through E, F, G or H
▪ Banning of the use of organotin compounds as PVC stabilizers (TBT as impurity) - E, or F
▪ Deposition on land of marine sediments containing tributyltin (TBT) - could be implemented through C
▪ Substitution of organotin in PVC products - could be implemented through E, F, G or H
▪ Detention of stormwater runoff - could be implemented through C</td></tr>
</table>

14.3 Overall economic assessment

14.3.1 Substance-specific assessments

Substance-specific economic assessments have been made of four of the substances: cadmium, mercury, nonylphenol, and TBT. The need for action and technical possibilities of substitution of the use of nickel were identified (progressive reduction in Scenario B), but the economic data was insufficient to make a substance- specific economic assessment of nickel within the scope of this study. For the remaining three substances - DEHP, lead and PAH - the technical assessment did not identify a clear need for action neither in Scenario A/C nor in Scenario B.

Several relevant technical possibilities for substitution of ***cadmium*** in products were identified. Elimination of zinc-based sacrificial anodes was identified as a realistic technical measure. This can be achieved by substituting zinc anodes with anodes made of aluminium or indium. This is technically possible, and it will imply little or no loss of quality or functionality of the anodes. Further, in the large ship market aluminium anodes dominate. The possibility of substituting anodes on smaller ships was therefore investigated.

The financial cost of substituting cadmium in sacrificial zinc anodes is estimated to be low or even result in a slight welfare-economic and financial gain in both Scenario A and B. This is a tentative, preliminary estimate. Alternative anodes with aluminium for larger ships already dominate the market, and there is no difference in quality or functionality. The price is slightly lower than that of traditional zinc anodes. In the short term, substitution of zinc anodes still used on smaller ships would impose an investment cost on producersand lead to a slightly higher cost to consumers. However, the long-term cost would probably be 0 or even a slight financial and welfare-economic benefit. Public expenditure is probably needed to overcome barriers preventing the change-over of production

An alternative measure would be to replace old gutters and downpipes in zinc with high content of cadmium (i.e. from before approx. 1980). This is a possible phase-out measure in Scenario B. The potential cost was estimated to be quite high as the financial cost of Scenario B would be between DKK 0.4 and 2.9 billion compared to Scenario A standing at between DKK 0.2 and 1.4 billion. The corresponding welfare-economic costs are DKK 1.0-6.6 billion in Scenario B and DKK 0.6-4.2 billion in Scenario A. The outcome of this investment would be a strong reduction (> 90 %) of the yearly release of cadmium to wastewater (estimated to be 120-480 kg/year) in the years following the investment /2/.

For ***mercury***, an economic assessment was made of the two most realistic technical possibilities, which are mandatory use of mercury filters at dental clinics and national collection/ replacement or labelling of mercury equipment in use. Today, it is estimated that around 80 % of all dentists in Denmark use mercury filters though data are uncertain. If the last 20 % were forced to use filters, it is assessed that around 40-200 kg of mercury could be collected each year. The cost of such a measure, gradually executed with a deadline in 2035 (Scenario A) is estimated to be approx. DKK 7 million in terms of financial costs (to the dentists) or DKK 17 million in terms of welfare-economic costs to society. Shortening the deadline to 2025, as proposed in Scenario B, implies higher costs as the financial cost would stand at DKK 10 million DKK and the welfare-economic cost would stand at DKK 23 million. A gradual implementation of the proposed technical measures aimed at ceasing/phasing out mercury emissions and discharges will (irrespective of the deadline) at the same time fulfil the progressive reduction obligations in Scenario B.

A rough estimation of the cost of a campaign to improve national collection of ***mercury*** equipment in use is also given. Based on Swedish experiences the extra economic cost of such a campaign initiated in 2020 (Scenario B) instead of 2030 (Scenario A) is estimated to be approximately DKK 9-10 million in terms of financial costs as the cost of the two scenarios are DKK 9-12 and DK 17-21 million respectively. The welfare-economic estimates stand at DKK 35-44 and DKK 26-33 million for Scenario B and A, and the difference is thus DKK 7-9 million. For that sum of money, an estimated emission of 40-90 kg mercury per year (and perhaps more) could be eliminated.

If the total Danish consumption of ***NP/NPE*** in various products of 90 tonnes a year is to be substituted, it would imply a cost to Danish industry and consumers. In order to assess this cost properly, a number of detailed cost-benefit comparisons for specific product types should be made in order to consider the relative cost of relevant substitutions. As an indication of the proportion of the possible cost, a Canadian study estimated that the price of the alternative substances are 20-40 % higher than NP/NPE, but with some variations. The price estimates illustrate the magnitude of the direct financial cost, but not the welfare-economic cost to society. In this case, we do not have current data on the proportion of the substance found in products produced in Denmark and in imported goods. The cost of replacement with alternative substances will be borne by the manufacturing industry, but given the available data, it is not possible to estimate the proportion of costs to be borne specifically by the Danish manufacturing sector. Finally, it remains to be seen how much of the cost that will be passed on to the consumers or to downstream manufactures using the products as input factors. Since the annual 90 tonnes illustrate the total Danish consumption of NP/NPE in various products, it can be assumed that most of the cost will accrue nationally. An illustrative calculation in this report shows that the earlier the deadline is for total substitution, the higher will the cost be: There is not assessed to be any cost associated with Scenario A. In Scenario B, the cost would be DKK 2.5 to 4.3 million, also in welfare-economic terms.

The cost in Scenario B of dredging remaining ***TBT*** contaminated sediments and dispose of the sediments on land in 2025 (as a means of eliminating unacceptable “losses" to the marine aquatic environment) was calculated. This results in a total welfare-economic cost of between DKK 11-39 and DKK 27-98 million DKK in net present value depending on whether the low estimate of 100,000 m^3 or the high estimate of 250,000 m^3 is used. The corresponding financial cost is estimated to be between DKK 5-16 and DKK 11-40 million in net present value. There is no cost associated with Scenario A/C.

14.3.2 Assessment of common measures for all substances

In a national perspective the majority of stormwater discharges are considered to comply with the MAC-EQS values. However, in some parts of the country, mainly the eastern, there may problems in the summer season (at median minimum of dry weather flow) in obtaining even a dilution factor of about 3 as required for nonylphenol. As this situation may represent as much as 40 % of the of the volume of separate stormwater discharges, the likely non-compliance with the MAC-EQS should not be overlooked and has therefore been assessed economically under common measures for stormwater.

A common measure was proposed to fulfil the obligations of progressive reduction of priority substances and cessation/phasing-out of priority hazardous substances. It should be noted that in Scenario A/C the objective of aiming at progressive reduction of priority substances and cessation/phasing out of priority hazardous substances is a requirement according to the existing WFD, not the final Daughter Directive proposal.

An economic assessment was made of the common measure for all substances. Detention of suspended solids in stormwater runoff was investigated in Chapter 13. A cost assessment was made of the gradual implementation of two types of technology to an end result of 40 % (critical areas where the MAC-EQS requirement cannot be met for an extended period, Scenario A/C) and in the worst-case 85 % (Scenario B) of the volume of all stormwater runoff discharges being treated.

The 85 % scenario corresponds to the total volume of stormwater discharges into freshwater bodies, all of which, when interpreting the obligations in Scenario B in a strict way, must be equipped with detention arrangements before 2025 to ensure cessation/phase-out of the discharges of priority hazardous substances.

The 40 % scenario in Scenario C reflects the fraction of the stormwater volume being discharged into streams where less than 3 times initial dilution (needed for MAC-EQS compliance for the most critical substance, nonylphenol) can be obtained in the summer at median minimum flow. Therefore, the same percentage has been used for illustrating the costs of cessation/phase-out of priority hazardous substances in Scenario A/C. If an in-depth analysis shows that a lower initial dilution requirement can be justified for the most critical substance (currently nonylphenol) with regard to EQS, Scenario A/C should be based on a lower percentage than 40 % of the volume also for cessation/phase-out.

The total welfare-economic cost in the two scenarios is estimated. In the case of retention of sediment in 40 % (Scenario A/C) of all stormwater runoff, the cost of the technology "storage with sedimentation alone" is DKK 2.0 billion for storage chambers with sedimentation and DKK 4.7 billion if treatment of outlet is added (discount rate of 3 % is used). The majority of the cost can be attributed the cost of investment and the operating and maintenance costs of the technology, which are DKK 1.6 and DKK 4.4 billion respectively.

The total financial cost is DKK 1.2 billion for storage chambers with sedimentation and DKK 2.6 billion if treatment of outlet is added (discount rate of 6 % is used). The cost of investment and the operating and maintenance costs of the technology alone are DKK 1.0 and DKK 2.4 billion respectively.

In the worst case where 85 % of the stormwater runoff must be treated, the cost of the technology "storage with sedimentation alone" with a deadline in 2025 (Scenario B) is DKK 5.6 billion for storage chambers with sedimentation and DKK 13.9 billion if treatment of outlet is added (discount rate of 3 % is used). The bulk of this cost can be attributed to the cost of investment and the operating and maintenance costs of the technology are DKK 4.6 and DKK 12.7 billion respectively.

The total financial cost is DKK 3.7 billion for storage chambers with sedimentation and DKK 7.8 billion if treatment of outlet is added (discount rate of 6 % is used). The cost of investment and the operating and maintenance costs of the technology alone are DKK 3.0 and DKK 7.1 billion respectively.

14.3.3 Conclusion on economic consequences

Recommendations for the most useful measures in regulating PS and PHS should be based on both technical effectiveness and the financial cost to industry and consumers, and the welfare-economic cost to society as a whole. A thorough economic analysis of the various measures would be required to make such a decision. A detailed analysis is beyond the scope of this study but some general conclusions can be drawn.

For the purpose of estimating the total cost of the most cost-effective package of policies to comply with the objectives of Scenario A/C and Scenario B, we first looked at possible substitution of the substances. This option is generally assumed to be the most cost-effective measure (since it is abatement), but this can vary greatly depending on whether there are any known substitutes and on other factors. Also, the degree of substitution needed will have a significant effect on the cost since total substitution as mentioned often will be very expensive due to high costs of replacing the last few percent of the use of a substance. Again, this may vary between substances and their uses. We have attempted to give a rough assessment of the cost of substitution where it was technically assessed to be relevant the prerequisite beingavailability of data on the cost.

We also looked at common substance reduction measures. This may be the only option for some substances for which the main contribution to the aquatic environment comes from diffuse sources to stormwater including atmospheric deposition. From an economic point of view, it may also be the overall most cost-effective measure because of the synergy effect. General reduction measures such as detention of suspended solids in wastewater or stormwater runoff have an effect on all the priority substances at the same time. The effect will vary from substance to substance depending on the inherent properties of the substances, in particular their inclination to sorb to suspended solids. The cost of this sort of measures can therefore not be attributed to one particular substance, but instead gives an idea of the total cost of measures and an estimate of the effect on the individual priority substances.

Abatement measures such as phasing-out the use of a substance or limiting the emissions to the environment are generally recommended as being less costly than clean-up measures. In the case of significant synergies in cleaning up this may, however, not be the case. The cost of substance-specific measures must therefore be considered against the common measures that target all substances. The economic estimates in this analysis are not sufficient to give a clear recommendation on whether abatement or clean-up measures are the most cost-effective. It would, however, appear to be the case given that alternatives appear to be available for most of the substances in question. However, for some substances the only technical option that remains to meet the quality criteria are clean-up measures as the sources losses to the environment originate from uses that are now historical.

It is obvious that the longer the time period that is allowed for a substance to be phased out or cleaned up, the easier and less costly it will be for companies to adapt to consumers and society. This assumes a positive discount rate. Hence, there will be an extra cost of complying with the Daughter Directive in the cases where faster phasing-out of hazardous substances is required than otherwise intended in Danish environmental policy based on the WFD.

A final relevant conclusion regarding the potential economic cost of Scenario A/C and Scenario B is that many of the relevant measures will only be possible and effective if implemented Community-wide. There are two reasons for this; firstly, there are regulatory constraints on bans, environmental taxes, and other measures that counteracting the Common Market. And secondly, the global market for goods means that national agreements may only have limited effects.

In conclusion, from Table 14-3, no purely national options are available with regard to nonylphenol(ethoxylates). For cadmium, both national and Community-wide implementation of measures will be possible. As discussed in Chapter 3.4, initiation of measures at the national level will probably have a lower cost-efficiency than Community-wide initiatives. For mercury, TBT in harbour sediments and general regulation of priority substances in stormwater runoff only national measures are relevant.

Since the analysis does not involve a regulatory impact assessment of the proposed Directive, it is difficult to draw conclusions on the financial costs to the state, industry and consumers. The issue is further complicated by the fact that regulatory impact assessments have yet to be made for the Water Frame Directive in Denmark. The welfare-economic cost to society as a whole has thus been the main focus of this report. However, based on current practices in the Danish environmental policy, the financial cost can be expected to accrue to the different groups as shown in Table 14-4 below.

Table 14-4 Potential distribution of financial cost of proposed measures

Technical option	*Cost to State*	*Cost to Municipalities*	*Cost to Industry*	*Cost to Consumers*
Substitution of cadmium in anodes			No cost	
Replacement of cadmium in down pipes	Considerable cost if subsidies are given			Moderate cost if financed by house owners *
Mercury filters in remaining dental clinics	Moderate cost if subsidies are given		Moderate cost*	
Collection of mercury	Moderate cost			
Substitution of nonyphenol (NP) in paint and epoxy			Low cost*	
Substitution of organotin as PVC stabilizer			Unknown cost	Unknown cost
Deposition on land of marine sediments containing TBT	None to moderate cost			
Detention of stormwater runoff		High cost		High cost if user financed *

*) Note that consumer financing is not assumed in the calculation of the welfare-economic cost.

For PS/PHS in sewage/wastewater it is assessed that the requirement to comply with the proposed EQS values will not imply additional costs to Denmark as the current levels in the aquatic environment and in wastewater discharges are so low that the EQS values are generally not at risk to be exceeded.

In a national perspective the majority of stormwater discharges are also considered to comply with the MAC-EQS values. However, in some parts of the country, mainly the eastern, there may problems in the summer season (at median minimum of dry weather flow) in obtaining even a dilution factor of about 3 as required for nonylphenol. As this situation may represent as much as 40 % of the volume of separate stormwater discharges, the likely non-compliance with the MAC-EQS should not be overlooked.

The welfare and financial cost of proposed measures to fulfil the obligations of progressive reduction of priority substances and cessation/phasing-out of priority substances is shown in table 14-5. The table corresponds to table 14.2 which summed up the technical assessment. The estimated cost for each potential measure is given in welfare economic terms. It should be noted that in Sceanario A/C the objective of aiming at progressive reduction of priority substances and cessation/phasing out of priority hazardous substances is a requirement according to the existing WFD, not the final Daughter Directive proposal.

Table 14-5 Welfare-economic cost of proposed measures (as in Table 14-2). Financial costs are shown in parenthesis. Net Present Value with a 30-year horizon.

Priority substance	*Reduction target*	*Scenario*	
		A/C *Measures aimed to fulfil WFD objectives*	*B* *Measures aimed to fulfil objectives of 2005 Daughter Directive proposal*
Cadmium	Progressive reduction	None required	Existing measures sufficient
	Cessation/phase-out	Elimination of cadmium in sacrificial anodes for small ships: No cost. (Only "natural" replacement of old down-pipes - no additional cost) Retention arrangements for suspended solids in stormwater1 (for cost, see stormwater)	Elimination of cadmium in sacrificial anodes or small ships: No cost. Replacement of old down-pipes: *1.0-6.6 (0.4-2.9) billion DKK* Retention arrangements for suspended solids in stormwater2
DEHP	Progressive reduction	None required	Existing measures sufficient
	Cessation/phase-out	None required	None required
Lead	Progressive reduction	None required	Existing measures sufficient
	Cessation/phase-out	None required	None required
Mercury	Progressive reduction	None required	See cessation/phase-out
	Cessation/phase-out	Mandatory mercury filters at dental clinics: *17(7) million DKK* Collection of mercury containing equipment in use in society: *26-33 (9-12) million DKK*	Mandatory mercury filters at dental clinics: *23 (10) million DKK* Collection of mercury containing equipment in use in society: *35-44 (17-21) million DKK*
Nickel	Progressive reduction	None required	Retention arrangements for suspended solids in stormwater[2]
	Cessation/phase-out	None required	None required
Nonylphenol	Progressive reduction	See cessation/phase-out (stormwater)	See cessation/phase-out
	Cessation/phase-out	Substitution of NPE in paints, cleaning products and use as hardener where possible by best available techniques (*EU action* required) Retention arrangements for suspended solids in stormwater[1] (for cost, see stormwater)	Substitution of NPE in paints, various industrial cleaning products and for the use as hardener in various products(EU action required): National action cost estimate *2.5-4.3 (1.0-2.0) million DKK* Retention arrangements for suspended solids in stormwater[2]
PAH	Progressive reduction	None required	See cessation/phase-out
	Cessation/phase-out	Retention arrangements for suspended solids in stormwater[1]	Retention arrangements for suspended solids in stormwater[2]
TBT	Progressive reduction	None required	See cessation/phase-out
	Cessation/phase-out	Banning of the use of organotin compounds as PVC stabilizers (TBT as impurity) (*EU action* required) Clean-up and safe disposal of contaminated harbour sediments: Taking the non-legally binding character of the environmental objectives of the WFD (Article 4) into account, DEPA considers that implementing this measure with the aim to eliminate "losses" of TBT is unrealistic in Scenario A/C as the environmental benefits reaped will be small compared to the disadvantages and the cost.	Banning of the use of organotin compounds as PVC stabilizers (TBT as impurity) (*EU action* required) Clean-up and safe disposal of contaminated harbour sediments (as a national measure): *Between 11-39 and 27-98 (5-16 and 11-40) million DKK*

Priority substance	*Reduction target*	*Scenario*	
		A/C *Measures aimed to fulfil WFD objectives*	*B* *Measures aimed to fulfil objectives of 2005 Daughter Directive proposal*
Stormwater	Progressive reduction	See cessation/phase-out - primarily as regards nonylphenol in some parts of the country	See cessation/phase-out
	Cessation/phase-out	Retention arrangements for suspended solids in stormwater in critical areas: 40 % of all runoff with deadline 2035: Investment and O&M costs: *1.6-4.4 (1.0-2.4) billion DKK* Total, with cost of land acquisition *2.0-4.7 (1.2-2.6) billion DKK* DEPA considers that implementing this measure in Scenario A/C solely with the purpose of achieving the reduction target of cessation for priority hazardous substances is unrealistic. This is taking into account that the reduction target is of non-legally binding character, and that the environmental benefits obtained by establishing retention arrangements are small and thus disproportional to the very high cost.	Retention arrangements for suspended solids in stormwater: 85 % of all runoff with deadline 2025: Investment and O&M costs: *4.6-12.7 (3-7.1) billion DK* Total, with cost of land acquisition *5.6-13.9 (3.7-7.8) billion DKK*

1 As part of common action against several substances in critical areas (40 % of volume).
2 As part of common action against several substances (85 % of volume).