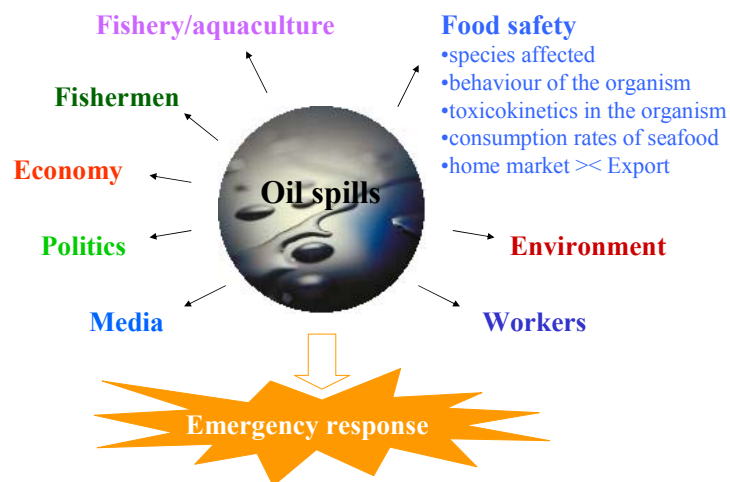


The effect of oil spills on seafood safety

An example of the application of the Nordic risk analysis model



The effect of oil spills on seafood safety

An example of the application of the Nordic risk analysis model

by

Mona-Lise Binderup, Denmark
Lene Duedahl-Olesen, Denmark
Stefán Einarsson, Iceland
Bente Fabech, Denmark
Anne-Katrine Lundebye Haldorsen, Norway
Håkan Johnsson, Sweden
Helle K. Knutsen, Norway
Anne Kirstine Müller, Denmark
Pekka J. Vuorinen, Finland
Marie Louise Wiborg, Norway

TemaNord 2004:553

The effect of oil spills on seafood safety
An example of the application of the Nordic risk analysis model

TemaNord 2004:553

© Nordic Council of Ministers, Copenhagen 2004

ISBN 92-893-1056-1

ISSN 0908-6692

Nordic Council of Ministers

Store Strandstræde 18
DK-1255 Copenhagen K
Phone (+45) 3396 0200
Fax (+45) 3396 0202

Nordic Council

Store Strandstræde 18
DK-1255 Copenhagen K
Phone (+45) 3396 0400
Fax (+45) 3311 1870

www.norden.org

The Nordic Food Policy Co-operation

The Nordic Committee of Senior Officials for Food Issues is concerned with basic Food Policy issues relating to food and nutrition, food toxicology and food microbiology, risk evaluation, food control and food legislation. The co-operation aims at protection of the health of the consumer, common utilisation of professional and administrative resources and at Nordic and international developments in this field.

The Nordic Council of Ministers

was established in 1971. It submits proposals on co-operation between the governments of the five Nordic countries to the Nordic Council, implements the Council's recommendations and reports on results, while directing the work carried out in the targeted areas. The Prime Ministers of the five Nordic countries assume overall responsibility for the co-operation measures, which are co-ordinated by the ministers for co-operation and the Nordic Co-operation committee. The composition of the Council of Ministers varies, depending on the nature of the issue to be treated.

The Nordic Council

was formed in 1952 to promote co-operation between the parliaments and governments of Denmark, Iceland, Norway and Sweden. Finland joined in 1955. At the sessions held by the Council, representatives from the Faroe Islands and Greenland form part of the Danish delegation, while Åland is represented on the Finnish delegation. The Council consists of 87 elected members - all of whom are members of parliament. The Nordic Council takes initiatives, acts in a consultative capacity and monitors co-operation measures. The Council operates via its institutions: the Plenary Assembly, the Presidium and standing committees.

Tabel of content

Preface.....	9
Introduction.....	11
Summary	13
Resume.....	15
Samantekt.....	17
Yhteenveto	19
Risk analysis of food - Codex definitions	21
Risk analysis Terminology used in English and the Nordic languages	25
Abbreviations and explanations	27
1 Risk analysis as a tool for quality assurance in public decision-making processes	29
2 Oil and input of oil into the marine environment.....	35
2.1 Oil and its components.....	36
2.2 Use and transport of oil, offshore production	42
2.3 Input of oil to the sea.....	43
2.4 Offshore oil extraction	44
2.5 Transport	45
2.6 More information about oil spills at sea.....	46
3 Influence on oil spills on seafood.....	47
3.1 PAH metabolism in fish and bivalves molluscs.....	47
3.2 Accumulation, half-life and bioconcentration factors of PAH	48
3.3 Fish behaviour and migrations	49
4 Risk analysis of oil spills and the effect on seafood safety.....	51
4.1 Risk communication - general remarks	52
4.2 Risk management – first step: Risk evaluation of the consequences of oil spill on fish for human consumption	53
4.3 Risk evaluation of oil spills.....	54
4.3.1 The identification of a food safety problem.....	54
4.3.2 Establishment of a risk profile	55
4.3.3 Ranking of the hazard for risk assessment and risk management priority	61

4.3.4	Establishment of a policy for conducting risk assessment.....	61
4.3.5	Commitment of resources	62
4.3.6	Commissioning of a risk assessment	62
5	Risk assessment, including exposure assessment	63
5.1	Introduction to the risk assessment	64
5.2	Hazard identification of PAH	65
5.2.1	Absorption, distribution and excretion.....	65
5.2.2	Metabolism	66
5.2.3	Genotoxicity of PAH	66
5.2.4	Carcinogenicity of PAH.....	69
5.3	Hazard characterization.....	69
5.3.1	Estimation of quantitative risk of B[a]P	69
5.3.2	Hazard assessment approaches	70
5.4	Exposure assessment.....	73
5.4.3	PAH in seafood	77
5.4.4	Exposure estimations	86
5.5	Risk characterization.....	90
5.6	Uncertainties and variabilities in the risk assessment.....	96
5.7	Conclusions and recommendations for the risk assessment	98
6.1	Identification of available management options	101
6.2	Selection of preferred management option.	104
6.3	Final management decision.....	106
6.4	Assessment of the effectiveness of measures taken.....	107
6.5	Monitoring and review.....	107
6.6	Review of the risk management and/or assessment as necessary	107
7	Essential elements in an emergency response system.....	109
8	Proposals and recommendations.....	111
	References.....	113
	Annex I Names of fish and shellfish species, Nordic languages, English and Latin....	119
	Annex II Testing, some general remarks	121
	Annex III Background data for the risk assessment	125
	Annex III.a Using the TEF approach.....	125
	Annex III.b Intake of food related B[a]P for Norwegian and Finnish adults	127
	Annex III.c The intake of seafood in Denmark	129

Annex III.d Sampling details on the ICES data in Table 5.4.....	131
Annex III.e PAH concentrations in seafood items.....	132
Annex III.f Background exposure estimations for adults in Denmark	133
Annex III.g Background exposure estimations for adults in Norway.....	137
Annex III.h Exposure to PAH following oil spill, Denmark	143
Annex III.i Exposure to PAH after oil spill, Norway	148
 Annex IV Background information on oil pollution and seafood	 155
a. Views and wishes from the Danish Fishermens Association <i>by Dorte Grastrup-Hansen, Danish Fishermen's Association (DFA)</i>	155
b. Oil spoilage in the Baltic Sea, Environmental risk from transport of oil in the Baltic Sea <i>by Carsten Jürgensen, COWI AS, Denmark</i>	156
c. Composition of oil, some background information <i>by Asger B. Hansen, Danish Environmental Research Institute</i>	180
d. Experience from the US-Exxon/Valdez oil spill <i>by Parmley Pritchard, Danish Environmental Research Institute</i>	184
e. Survey of the environmental effects after the Oil spil incident from the Baltic Carrier in Grønsund /Denmark in 2001 <i>by Jakob Lysholt Sørensen, Stormstrømsamt, Denmark</i>	187
f. Effects of oil on fish populations <i>by Valery Forbes, Dept of Life Sciences and Chemistry University of Roskilde</i>	189
g. Chemicals in fish for human consumption for oil polluted areas <i>by Lene Duedahl-Olesen, Danish Veterinary and Food Administration</i>	190
h. Safety assessment of contamination of fish with PAH <i>by Mona-Lise Binderup, Danish Veterinary and Food Administration</i>	194
i. Norwegian Petroleum Directorate (NPD), Process and mechanical equipment <i>by Arne Johan Thorsen, Norwegian Petroleum Directorate (NPD)</i>	194
j. Rogaland Research Centre <i>By Endre Aas, RF-Akvamiljø, Norway</i>	196
k. Effects of pollutants on marine animals near harbours in Iceland <i>by Halldór P. Halldórsson, Institute of Biology, University of Iceland</i>	198
 Annex V Authorities involved in oil emergency response and surveillance systems...	 201
a. Denmark Surveillance and emergency response.....	201
b. Finland	202
c. Iceland.....	203
d. Norway	204
e. Sweden	205

Annex VI Nordic authorities and some international contact points involved in pollution prevention at the sea and surveillance	207
Annex VII Some international surveillance systems	211
International Council of Exploring the Sea (ICES)	212
Oslo-Paris Comissionen (OSPAR)	212
Helsinki Commission (HELCOM)	212
AMAP	213
SOCA (Subcommittee on Oceans and Coastal Areas)	214

Preface

The Nordic countries – Denmark, Finland, Iceland, Norway and Sweden – co-operate in many areas and of importance to oil spills, the countries, have coastlines to the same seas. Oil spills in most marine areas around the Nordic countries would affect two or more countries. The risk of oil spills in the marine environment around the Nordic countries is not a new risk, however, the risk is likely to increase in the future as a new Russian harbour in the Baltic Sea is expected to reach a total shipment of 45 million tons crude oil annually when it is completed. This will increase the traffic of oil tankers in the Baltic Sea, the Danish/Swedish sounds and the sea between Northern Denmark and Norway. Furthermore, shipments of oil also occur from the Russian harbour of Murmansk and along the Norwegian coastline and the sea between Norway and Iceland.

When analysing the consequences of contamination in the Nordic countries, the food area is largely subject to the same type of legal requirements in the Food Acts and in the political, democratic decision-making process. Official opinions in one Nordic country will in most cases raise questions in other Nordic countries since awareness of risk is quickly brought to the attention of the public via the media. Frequently, there is a call for uniform interpretations or decisions, hence risk analyses of hazards made in comparable manner are therefore an advantage in the Nordic countries, as well as elsewhere in Europe.

Risk analysis terminology has been developed in Codex Alimentarius and a project group under the Nordic Council of Ministers has developed a practical approach to be used in risk analysis using examples of a chemical and microbiological nature. This practical approach resulted in a checklist, which can be used when analysing risks, like for example oil spills and the consequences for seafood safety.

Decision-making following the Nordic model, “A practical approach to risk analysis”, addresses the modern request for transparency and openness in the public decision making process. Consumers in the Nordic countries are increasingly aware of food safety issues and demand scientifically based management options in public decision-making. Also politicians and food administrations require a scientifically based decision-making process particularly in emergency response situations, which oil spills often are. In such cases, it is advantageous to follow a checklist when conducting the risk analysis.

Quality assurance in public administration has always been demanded. However, as the amount of information and knowledge seems to be growing exponentially and the demands for transparency and participation in the public debate require more and more resources from public administrations, quality assurance becomes increasingly important. In this project, the effect of oil spills at sea on seafood safety are analysed and issues, which should be considered in national and international emergency response systems are addressed.

The following project group has worked out this report:

Denmark	<i>Bente Fabech (project manager)</i> the Danish Veterinary and Food Administration, <i>Mona-Lise Binderup</i> , <i>Lene Duedahl-Olsen</i> and <i>Anne Kirstine Müller</i> , Danish Institute for Food and Veterinary Research
Finland	<i>Pekka J. Vuorinen</i> , Finnish Game and Fisheries Research Institute
Iceland	<i>Stefán Einarsson</i> , Environmental & Food Agency of Iceland
Norway	<i>Ann- Katrine Lundebye Haldorsen</i> , National Institute of Nutrition and Seafood Research, <i>Helle K. Knutsen</i> , Norwegian Institute of Public Health and <i>Marie Louise Wiborg</i> , Norwegian Food Control Authority,
Sweden	<i>Håkan Johnsson</i> , National Food Administration

Text processing was carried out by Karina Knudsen, the Danish Veterinary and Food Administration.

The project group thanks invited speakers, who participated in meetings and shared their knowledge. The project group found it very important to listen to experts and benefit from their knowledge in different fields.

This report has been discussed and approved by the Joint Nordic Working Group on Food Toxicology (NNT) and sponsored by the Nordic Committee of Senior Officials for Food Issues under the Nordic Council of Ministers.

Introduction

Oil spills at sea are a potential consequence of the transportation of oil around the world. Oil may be spilled in smaller quantities in for example harbours or in large volumes if tankers transporting oil run aground. In the Danish marine area approximately 250 oil spills were registered in 2002, the Norwegian Pollution Control reported 478 spills in 2001 (a total of spills of oil and other chemicals) and HELCOM reported 344 oil spills in the Baltic Sea in 2002.

Many such accidents have happened over the years, and international organisations have agreements on surveillance and warning systems and exchange knowledge on the effects on the environment. Even though oil spills will affect seafood, as well as the environment, there do not appear to be emergency response procedures for actions related to fishery in most European countries.

When marine areas are polluted by oil spills, seafood from the area is likely to be contaminated and thereby present a hazard to consumers. Depending on the area affected, seafood may include farmed species hence they are included in the present report. Many of the components in oil are harmful to humans through direct exposure (via inhalation and contact with the skin), but many of these components are also hazardous if they are ingested via foodstuffs. The risk will depend on factors including metabolism of the oil components in exposed organisms etc. Following a major oil spill, authorities will be requested to rapidly conduct a risk analysis. Decisions will normally depend on analytical findings in the food, however such analyses take time and are often expensive. The basis for decisions has to be well-founded and be based on scientific risk assessment, particularly since management options can be very expensive for the fishing industry and society in general.

Since the Nordic countries have coastlines to the same seas, oil spills can potentially affect several countries at the same time. Furthermore, both the public and the media expect similar risk assessments by the Nordic food administrations. As the contact network for emergency responses to oil spills does not include food administrations, the Nordic countries decided to undertake a risk analysis of oil spills at sea and the potential effects on seafood.

The risk analysis process has previously been the topic of another Nordic project and a model for a stepwise procedure as a structured, practical approach has been proposed. The conclusion was that a stepwise process in risk analysis is a useful tool, which can also provide a more transparent analysis and consequently make decisions on food safety more accessible to the public.

During the last decades, international trade has increased and consequently there has been an increased demand for harmonised, transparent global approaches to risk analysis related to food safety. This is covered in the WTO and SPS agreements, for example the SPS Agreement includes risk assessment.

“The concept of risk assessment in the SPS leaves leeway for interpretation of what could be used as a basis for a precautionary approach. The risk assessment on which a measure is based may include non-quantifiable data of a factual or qualitative nature and is not uniquely confined to purely quantitative scientific data. This interpretation has been confirmed by the WTO’s Appellate body in the case of growth hormones, which rejected the panel’s initial interpretation that the risk assessment had to be quantitative and had to establish a minimum degree of risk.”

As none of the Nordic countries have conducted a formal, stepwise risk analysis of oil spills at sea and the potential effects on seafood, this report describes the information and background knowledge required for each step. Seafood¹ covers fish and shellfish (molluscs and crustaceans), echinoderms and tunicates. If literature referred to is more specific, then the specific species will be mentioned in the text. This report includes a risk assessment of some of the PAH present in oil and discusses the management options after an oil spill. In some areas, knowledge on the composition of oil, metabolism in fish etc. may be limited, however one of the goals of the project was to identify gaps in the existing knowledge and provide recommendations for future work. Networks are extremely valuable in many situations, but in emergencies it is of utmost importance to rapidly obtain the information required for risk analysis.

Oil is spilled at sea and on land as a result of many different activities, however the current project has focused on oil spills from major accidents at sea. Furthermore, oil consist of many components of which the three main groups are paraffins, naphthenes and aromatics, but this project has concentrated on PAH, since PAH are always present in oil and are known to be hazardous to humans.

This report includes information on authorities and international organisations involved in emergency responses and surveillance following oil spills, and proposes issues which should be considered in national emergency responses to oil spills and seafood, but since this is not the main objective of the report, this part is not exhaustive.

Even though safety in transportation, the quality of the ships used and qualifications of the staff is of major importance, this is not included as the focus in the report is food safety and the effect of oil spills on seafood safety.

¹ The word *seafood* includes fish, shellfish (molluscs and crustaceans), echinoderms and tunicates.

Molluscs includes bivalve molluscs – *Lamellibranchia/Acephala* - , gastropods - *Gastropoda* - and cephalopods – *Asteroidea* and *Echinoidea*. Crustaceans include *C. Entomostraca* and *C. Malacostraca*, and the sub-species *Natantia* (shrimps) and *Reptantia* (loster and crabs)

Summary

Oil spills at sea are a potential consequence of use and transportation of oil. Oil can be spilled in small quantities for example in harbours or in large volumes if tankers transporting oil run aground. If marine areas are polluted by oil spills, seafood, including farmed seafood in the area is likely to be polluted and may pose a hazard to consumers. Seafood covers fish, shellfish (molluscs and crustaceans), echinoderms and tunicates. Many of the components in oil, e.g. PAH (polycyclic aromatic hydrocarbons) are harmful to humans through direct exposure, but many of these components are also hazardous if they are ingested via foodstuffs.

Oil pollution may give an off-taste and taint seafood, but more importantly the chemicals in the oil may present a risk to the consumer of contaminated seafood. The risk for humans would depend on factors including the metabolism of the oil components in the fish, shellfish etc., which species are affected etc. Also the background level of contaminants in seafood from the area is important knowledge for the risk analysis. The risk is expected to change over time and knowledge on the fate of oil in the marine area in question is also of importance.

The risk analysis process and a Nordic model for a stepwise procedure are used as a structured approach to an imaginary oil spill of 100.000 tons crude oil at a location in the sea between Denmark, Norway and Sweden. The risk analysis focuses on PAH components in the oil and on seafood safety. Other components, which are present in the oil are not covered by this report.

The risk analysis starts with risk evaluation, making a risk profile and a rough estimate of the potential risk to humans. It is followed by the risk assessment, which is conducted using data on the PAH content in seafood and seafood consumption in some of the Nordic countries. The risk assessment includes the use of model calculations and notes the uncertainties in data used. The report concludes, that the oil spill and contamination of seafood constitutes an increased cancer risk, but also that there are uncertainties due to lack of data and the use of modelling. A more correct assessment of the risk would depend on further data including analyses of the PAH content in seafood immediately after an accident. In the next steps of the risk management, the available management options are discussed, including the advantages and disadvantages of the available options.

Risk analysis of the effect of oil spills on seafood would in practice often be conducted under pressure, and therefore the report highlights the need for further data and for networks as part of an emergency response plan. Furthermore, oil spills in the Nordic marine area are likely to affect more than one of the Nordic countries and there is a specific need for cooperation in this area. Cooperation should concentrate both on data compilation and on emergency response plans.

Considerable knowledge is available concerning oil spills and their effects on seafood and an overview of some of the available literature is given in this report. The report includes some of this information relevant for the project and the networks involved, like names of fish species – in the Nordic languages, English and Latin, some general remarks on organoleptic and chemical testing, views and wishes from the Fishermen's Organisation (DK), environmental risk from transport of oil in the Baltic sea, experi-

ence from the US-Exxon-Valdez oil spill, and from research on effects of pollutants on marine animals near harbours in Iceland. National and international authorities and organisations, contact points and organisations involved in emergency response and surveillance are briefly mentioned.

Resume

Oliespild på havet er en mulig konsekvens af brugen og transporten af olien. Olie spildes i små mængder f.eks. i havne eller i større mængder, hvis olietankere går på grund eller kolliderer. Hvis havområder forurenes ved oliespild vil fisk og skaldyr inklusive opdrættet fisk sandsynligvis også blive forurenede og kan udgøre en risiko for forbrugere, der spiser fisken. Fisk og skaldyr omfatter her toskallede skaldyr, muslinger og andre, samt blæksprutter og søpindsvin. Mange af de stoffer, der er i olien f.eks. PAH (polycykliske aromatiske hydrocarboner) er skadelige for mennesker, der udsættes for dem ved direkte kontakt, men mange af disse stoffer er også skadelige, hvis de indtages via fødevaren.

Oliespild kan give en afsmag og misfarvning af fisk og skaldyr, men mere vigtigt er det, at kemiske stoffer i olien kan udgøre en risiko for de forbrugere, der spiser forurenede fisk og skaldyr. Risikoen for mennesker vil afhænge af faktorer, som metabolisme af stofferne i olien i fisk, skaldyr etc, hvilke arter der bliver påvirket mv. Når man skal foretage en risikoanalyse, er det også vigtigt at vide, hvilke baggrundsniveauer af kontaminanter, der kan være i fisk og skaldyr fra det område, der bliver forurenede. Risikoen forventes at ændre sig over tid, og viden om oliens skæbne i havet, og de områder, der er tale om, er således også vigtige.

Risikoanalysen og den nordiske model for en trinvis procedure anvendes i rapporten som et struktureret fremgangsmåde i forbindelse med risikoanalyse af konsekvenserne af et tænkt oliespild på 100.000 tons rå olie, på et sted i havet mellem Danmark, Norge og Sverige. Risikoanalysen fokuserer på PAH i olien og på fødevarsikkerhed. Andre stoffer som findes i olien er ikke omfattet i denne rapport.

Risikoanalysen starter med en risikoevaluering, udarbejdelsen af risikoprofil og et overblik over den potentielle risiko for mennesker. Den følges af risikovurdering, som er gennemført ved anvendelse af data for PAH indhold fisk og skaldyr og indtaget af disse fødevarer i nogle af de nordiske lande. Risikovurderingen omfatter også modelberegninger og en oversigt over de usikkerheder, der er i de data, der anvendes. I rapporten konkluderes, at oliespild og forureningen af fisk og skaldyr udgøre en øget kræftisiko, men også at der er usikkerheder i vurderingen på grund af manglende data og brug af modelleringer. En mere korrekt vurdering af risikoen vil afhænge af fremtidige data, inklusive analyser af indholdet af PAH i fisk og skaldyr umiddelbart efter en ulykke. På det næste skridt i risikohåndteringen diskuteres håndteringsmulighederne inklusive fordele og ulemper ved de muligheder, der foreligger.

Risikoanalyse af effekten af oliespild på fisk og skaldyr ville i praksis ofte skulle gennemføres under pres, og derfor understreger rapporten behovet for at have data og for netværksdannelse, som en del af beredskabsplanen. Det skønnes, at olieulykker i de nordiske havområder sandsynligvis vil få indflydelse på mere end et af de nordiske lande, og der er derfor et særligt behov for samarbejde på området. Samarbejdet skulle koncentreres både om indsamling af data og om udbygning om beredskabsplaner.

Der er betragtelige mængder af viden tilgængelig omkring oliespild og effekt på fisk og skaldyr, og i rapporten gives et overblik over litteratur. Rapporten omfatter nogle informationer, som er relevant for projektet og de netværk, der er involveret f.eks. navne

på fiskearter på de nordiske sprog, engelsk og latin, nogle generelle betragtninger omkring organoleptisk og kemisk testning, ønsker og synspunkter fra Danmarks Fiskeri- og Eksportforening, risiko for miljø i forhold til transport af olie på Østersøen, erfaringer fra US -Exxon -Valdez ulykken og fra forskning vedrørende effekten af forureninger på havdyr nær havne i Island. Nationale og internationale myndigheder og organisationer, kontaktpunkter og organisationer, som er involveret i beredskabsplaner og overvågning, er kort nævnt.

Samantekt

Flutningur og notkun á olíu hefur í för með sér hættu á sjávarmengun. Olíumengun í litlum mæli getur orðið t.d. í höfnum, en ef olíuskip stranda getur mikið af olíu lent í sjónum. Ef hafsvæði mengast af olíu eru líkur á því að sjávarfang, þ.m.t. eldisdýr, mengist, sem getur leitt til hættu fyrir neytendur. Með sjávarfangi er átt við fisk, skelfisk (lindýr og krabbadýr), skrápdýr og möttuldýr. Mörg efna sem finnast í olíu, t.d. PAH-efni (fjölómettaðar hringlaga sameindir gerð úr kolefnis- og vetnisatómum), eru hættuleg mönnum við snertingu, en mörg efnanna eru einnig hættuleg ef þeirra er neytt í menguðum matvælum.

Olíumengun getur leitt til þess að óbragð verður af sjávarfangi, en mikilvægara er að efnasambönd í olíunni geta valdið neytendum mengaðs sjávarfangs hættu. Hættan er háð þáttum eins t.d. því um hvaða sjávarlífverur er um að ræða og niðurbroti efnanna í þeim. Þegar gerð er áhættugreining er auk þess mikilvægt að hafa upplýsingar um magn mengandi efna í sjávarfangi frá öðrum uppsprettum. Þekking á því hvað verður um olíu sem lendir í sjónum er einnig mikilvæg, því áhættan af neyslu sjávarfangsins breytist eftir því sem frá líður.

Áhættugreining og norrænt líkan sem byggir á þrepbundinni aðferð voru notuð sem aðferð til þess að fást kerfisbundið við ímyndað olíuslys þar sem gert var ráð fyrir að 100 000 tonn af hráolíu lentu í sjónum á ákveðnum stað í hafinu milli Noregs, Danmerkur og Svíþjóðar. Áhættugreiningin miðaðist við PAH efni í olíunni og öryggi sjávarafurða. Ekki er fjallað í skýrslunni um aðra efnaflokka sem eru í olíu.

Áhættugreiningin hefst með áhættuskoðun, helstu þættir eru teknir saman og gert gróft mat á hugsanlegri hættu fyrir mannfólk. Síðan er gert áhættumat þar sem notaðar eru upplýsingar um magn PAH efna í sjávarfangi og upplýsingar um neyslu sjávarafurða hjá nokkrum norðurlandabjóðum. Í áhættumatinu felst notkun líkanareikninga og litið er til óvissunnar í þeim upplýsingum sem stuðst er við. Í skýrslunni er ályktað að olíulosun og mengun sjávarfangs auki líkur á krabbameini, en einnig að það er um óvissu að ræða vegna skorts á upplýsingum og vegna notkunar líkana. Nákvæmara áhættumat byggðist á frekari upplýsingum, m.a. mælingum á PAH efnum í sjávarfangi þegar í kjölfar olíuslyss. Í næstu skrefum áhættustjórnunarinnar er rætt um þá stjórnunarkosti sem bjóðast, þ.m.t. kosti og galla þeirra.

Áhættugreining á áhrifum olíulosunar á sjávarfang yrði venjulega gerð undir álagi, og er þess vegna lögð áhersla í skýrslunni á þörfinni á frekari upplýsingum og á tengslanetum sem hluta af viðbragðsáætlunum. Ennfremur eru líkur á að olíuslys á norrænum hafsvæðum snerti fleiri en eitt Norðurlandanna og er því sérstök nauðsyn á samvinnu á þessu sviði. Í slíkri samvinnu ætti að bæði að leggja áherslu á upplýsingasöfnun og viðbragðsáætlanir.

Talsvert er til af aðgengilegum upplýsingum um olíulosun og áhrifum hennar á sjávarfang, og er yfirlit um aðgengilegar heimildir að finna í þessari skýrslu. Hluti þessara upplýsinga, sem skipta máli fyrir efni skýrslunnar og tilheyrandi tengslanet, koma fram í skýrslunni, eins og nöfn á fisktegundum á norðurlandamálunum, ensku og latínu, almenn atriði verðandi skynmat og efnagreiningar, álit og óskir danska fiskimannasambandsins, áhætta sem umhverfinu stafar af flutningi á olíu um Eystrasalt, reynslan af

Exxon-Valdez olíuslysinu, og rannsóknir á áhrifum mengandi efna á sjávarlífverur í nágrenni hafna á Íslandi. Getið er í stuttu máli um yfirvöld í einstökum ríkjum og alþjóðlegar stofnanir, tengiliði og ráð sem koma að viðbrögðum við neyðarástandi og vöktun.

Yhteenveto

Öljykuljetusten ja öljyn käytön vaarana ovat öljypäästöt mereen. Öljyä voi joutua mereen pieninä päästöinä esimerkiksi satamissa tai suurina määrinä kuljetusaluksen joutuessa onnettomuuteen. Jos merialue saastuu öljystä, merenelävät, sekä luonnonvaraiset että kasvatettavat voivat saastua öljyperäisistä aineista ja muodostaa terveysriskin kuluttajille. Mereneläviin luetaan tässä kalat, äyriäiset, simpukat, piikkinahkaiset ja vaippaeläimet. Monet öljyperäisistä aineista, esimerkiksi PAH-yhdisteet (polyaromaattiset hiilivedyt) ovat haitallisia ihmiselle suorassa kosketuksessa, mutta monet niistä ovat vaarallisia joutuessaan ruoka-aineisiin ja sitä kautta ruuansulatuselimistöön.

Öljystä saastuminen voi aiheuttaa haju- ja makuvirheitä mereneläviin, mutta saastuneen ravinnon aiheuttama terveysriski on tärkeämpi. Ihmisille koituvaan riskiin vaikuttaa öljyperäisten yhdisteiden metabolia kaloissa, äyriäisissä ja nilviäisissä, mitkä lajit ovat saastuneet jne. Myös saastuneen alueen taustapitoisuuksien tunteminen on tärkeää tietoa riskinarvioinnissa. Tieto öljyn kulkeutumisesta ja hajoamisesta vaikutusalueella on myös tärkeää, koska öljypäästön aiheuttama riski muuttuu koko ajan.

Riskianalyysiä ja pohjoismaista askeltavaa mallia käytetään lähestymistapana kuvitteelliselle öljyvahingolle, jossa 100 000 tonnia raakaöljyä joutuu mereen Tanskan, Norjan ja Ruotsin aluevesien tuntumassa. Riskianalyysi keskittyy öljyn PAH-yhdisteisiin ja merenelävien turvallisuuteen ihmisravintona. Muita öljyn sisältämiä aineita ja yhdisteitä ei käsitellä tässä raportissa.

Riskianalyysi aloitetaan riskin kokonaisarvioinnilla tekemällä riskiprofiili ja karkea arvio ihmisille koituvasta mahdollisesta riskistä. Sitä seuraa riskinarviointi, joka pohjautuu tietoon PAH-yhdisteiden pitoisuuksista merenelävissä ja tietoon merenelävien kulu- tuksesta ravintona eräissä Pohjoismaissa. Riskinarviointi sisältää myös mallilaskelmia sekä huomioita käytetyn tiedon epävarmuuksista. Raportin johtopäätös on, että öljy- päästöt ja merenelävien saastuminen niistä aiheuttaa kasvaneen syöpäriskin ihmisille, mutta toteaa myös arvioinnin epävarmuudet, jotka aiheutuvat tietojen puutteellisuudesta ja mallinnan käytöstä. Tarkempi riskinarviointi edellyttäisi lisätietoa, esimerkiksi PAH- pitoisuuksista merenelävissä heti öljyonnettomuuden jälkeen. Riskinarvioinnin seuraa- vassa vaiheessa käytettävissä olevia riskinhallinnan vaihtoehtoja puntaroidaan huomioi- den sekä edut että haitat.

Riskinarviointi öljypäästön vaikutuksista mereneläviin joudutaan käytännössä tekemään kiireessä ja paineen alla. Siksi raportissa korostetaan tarvetta taustatietojen hankintaan ja yhteysverkoston luomiseen osana öljypäästöistä aiheutuvan hätätilan suunnittelua. Li- säksi Pohjoismaiden merialueilla tapahtuva öljypäästö todennäköisesti vaikuttaa saman- aikaisesti useampaan Pohjoismaahan ja siksi tämän alan yhteistyötä Pohjoismaiden kes- ken tarvitaan. Yhteistyön pitäisi kohdistua olemassa olevan tiedon kokoamiseen yhtei- seen käyttöön sekä hätäsuunnitelman laatimiseen.

Öljypäästöistä ja niiden vaikutuksista mereneläviin on melko paljon tietoa olemassa ja tässä raportissa annetaan siitä yleiskatsaus kirjallisuuden pohjalta.

Raportti sisältää myös yhteistyöverkostolle oleellista tietoa kuten esimerkiksi kalojen nimet pohjoismaisilla kielillä ja englanniksi sekä tieteelliset nimet, yleistä aistinvarai-

sesta ja kemiallisesta testaamisesta, tanskalaisen Kalastajajärjestön näkemyksiä ja toiveita, tietoa öljykuljetusten ympäristöriskeistä Itämerellä, kokemuksia Exxon-Valdezin öljyonnettomuudesta Alaskan rannikolla ja tutkimustietoa saastumisen vaikutuksista merieläimiin satamien lähivesillä Islannissa. Myös kansalliset ja kansainväliset viranomaiset ja järjestöt sekä muut organisaatiot, jotka osallistuvat hätätoimiin ja suoje-
luvalvontaan kuvataan raportissa lyhyesti.

Risk analysis of food

- Codex definitions

The definitions listed below are definitions adopted by the Codex Alimentarius Commission (when adopted).

Risk analysis	A process consisting of three components: risk assessment, risk management and risk communication.
Risk	A function of the probability of an adverse health effect and the severity of that effect, consequential to a hazard(s) in food.
Hazard	A biological, chemical or physical agent in, or condition of, food with the potential to cause a health effect.
Risk assessment	A scientifically based process consisting of the following steps: (i) hazard identification, (ii) hazard characterization, (iii) exposure assessment, and (iv) risk characterization.
Risk assessment policy	Guidelines for value judgement and policy choices, which may need to be applied at specific decision points in the risk assessment process.
Risk assessment policy setting	Is a risk management responsibility, which should be carried out in full collaboration with risk assessors, and which serves to protect the scientific integrity of the risk assessment. The guidelines should be documented so as to ensure consistency and transparency. Examples of risk assessment policy setting are establishing the population(s) at risk, establishing criteria for ranking of hazards, and guidelines for application of safety factors.
Hazard identification	The identification of biological, chemical, and physical agents capable of causing adverse health effects and which may be present in a particular food or group of food.
Hazard characterization	The qualitative and/or quantitative evaluation of the nature of the adverse health effect associated with biological, chemical and physical agents, which may be present in food. For chemical agents, a dose response assessment should be performed.

For biological or physical agents, a dose response assessment should be performed if data are obtainable.

Exposure assessment	The qualitative and/or quantitative evaluation of the likely intake of biological, chemical, and physical agents via food as well as exposures from other sources if relevant.
Risk characterization	The qualitative and/or quantitative estimation, including attendant uncertainties, of the probability of occurrence and severity of known or potential adverse health effects in a given population based on hazard identification, hazard characterization and exposure assessment.
Risk management	The process, distinct from risk assessment, of weighing, policy alternatives, in consultation with all interested parties, considering risk assessment and other factors relevant for the health protection of consumers and for the promotion of fair trade practices, and, if needed, selecting appropriate prevention and control options.
Risk evaluation	The risk evaluation is the first step of the risk analysis process in the Nordic model. Risk evaluation includes the following questions, which should be considered: Identification of a food safety problem, establishment of a risk profile, ranking of the hazard for risk assessment and risk management priority, establishment of a risk assessment policy for conducting the risk assessment, commitment of resources, commissioning of a risk assessment and consideration of a risk assessment result (The definition has not yet been adopted in Codex)
Management options	The identification of the available management options are based on the results of the risk assessment and identified in communication between risk assessors and risk managers. Other interested parties such as consumers, producers and retailers should have information on the available options and should have the possibility to give comments, especially in this phase. The decision-makers at this step will be risk managers in the relevant administration, in dialogue with the politicians. The responsible politicians would take the final decision based on an evaluation of the available options. (The definition has not yet been adopted in Codex)
Implementation	The implementation is made by issuing laws or orders on the risk or by elaborating the communication strategy on it. (A definition has not yet been adopted in Codex)
Monitoring and Evaluation	The implementation should be followed by surveillance and the in-house control of the producers and at the public food inspection (A definition has not yet been adopted by Codex)

Risk communication

The interactive exchange of information and opinions throughout the risk analysis process concerning hazards and risks, risk related factors and risk perceptions, among risk assessors, risk managers, consumers industry, the academic community and other interested parties, including the explanation of risk assessment findings and the basis of risk management decisions.

Risk analysis Terminology used in English and the Nordic languages

English	Dansk	Suomi	Islandsk	Norsk	Svensk
Hazard	Fare	Vaara	Hætta	Fare	Fara
Risk	Risiko	Riski	Áhætta	Risiko	Risk
Risk analysis	Risikoanalyse	Riski-analyysi	Áhættu-greining	Risikoanalyse	Riskanalys
Risk assessment	Risikovurdering	Riskinarviointi	Áhættumat	Risikovurdering	Riskvärdering
Hazard identification	Identificering af sundhedsfare	Vaaran tunnistaminen	Hættukennsl	Identifisering av helsefare	Faroidentifisering
Hazard characterization	Karakteristik af sundhedsfare	Vaaran kuvaaminen	Hættulýsing	Karakteristikk av helsefare	Farokarakterisering
Risk assessment policy	Risikovurderings-politik	Riskinarvoinnin toimintaperiaatteet	Áhættumatsstefna	Risiko vurderingspolitikk/-retningslinjer	Riskvärderingspolicy
Risk characterization	Risikokarakteristik	Riskin kuvaaminen	Áhættulýsing	Risiko karakterisering	Riskkarakterisering
Risk communication	Risiko- kommunikation	Riskiviestintä	Áhættukynning	Risiko kommunikasjon	Riskkommunikation
Risk evaluation	Risikoevaluering	Riskin kokonaisarviointi	Áhættuskoðun	Risikoevaluering	Risk-evaluering
Risk management	Risikohåndtering	Riskinhallinta	Áhættustjórnun	Risikohåndtering	Riskhantering

Abbreviations and explanations

ADI	Acceptable daily intake; the amount of a certain substance that can be consumed daily during an entire lifetime without risk for negative health effects. ADI is typically expressed in mg/kg body weight.
AMAP	Arctic Monitoring and Assessment Programme
B[a]P	Benzo[a]pyrene
BCF	Bio concentration factor
Benthic	Living on the seabed
BTEX	benzene, toluene, ethylbenzene and the three xylene isomers
Bw	Body weight
EEA	European Economic Agreement.
EPA	Environmental Protection Agency (USA)
EROD	7-ethoxyresorufin- <i>O</i> -deethylation
EU	European Union.
FAO	Food and Agriculture Organization.
Fauna	Animals in a specific area or environment
GC-FID	Gas chromatography with flame ionisation detection
GC-MS	Gas chromatography with mass spectrometry detection
HELCOM	Helsinki Commission.
ICES	International Council for the Exploration of the Sea.
IMO	International Maritime Organisation.
JECFA	Joint Expert Committee on Food Additives and Contaminants.
NNT	Joint Nordic Working Group on Food Toxicology.
LOD	Limit of determination
OPEC	Organisation of Petroleum Exporting Countries.
OSPAR	Oslo-Paris Agreement.
PAH	Polycyclic aromatic hydrocarbons
PCB	polychlorinated biphenyl
POP	Persistent organic pollutants
Pelagic	Living in the sea at middle or surface level
SB-tissue	whole soft-body tissue
SCF	Scientific Committee on Food (no longer existing, the role has been taken over by EFSA scientific panels).

SCOOP	Scientific Cooperation Project (EU)
SOCA	Subcommittee on Oceans and Coastal Areas
SPS	Sanitary and Phytosanitary Measures, as defined by the WTO.
TDI	Tolerable daily intake (expressed in mg/kg body weight).
TEF	Toxic equivalency factors
TM-tissue	tail muscle tissue
VSD	Virtually safe dose
WHO	World Health Organisation.
WTO	World Trade Organisation.

1 Risk analysis as a tool for quality assurance in public decision-making processes

The risk analysis process² is being developed by international co-operation within Codex Alimentarius as a result of various requirements including the need for transparency in the decision-making and the discussion of risks in connection with international trade and disputes thereof. The process of risk analysis includes scientific assessments, and the identification of uncertainties of the assessments and management considerations and final decisions (e.g., management decisions taking political opinions and decisions and other legitimate factors into account).

In public administration and in private enterprises risks are analysed. However, the amount of information available continues to expand as does the public interest in food safety issues and the background documentation for the decisions taken. There is a growing demand from the public to be able to follow the entire decision-making process related to food and therefore there is a need for very systematic decision-making processes which takes into account the increased need for transparency.

To date public administrations in the Nordic countries have a tradition of openness and have followed steps in decisions-making similar to the steps in the current risk analysis process. Nevertheless, a structured approach and a discussion about which type of documentation to use, is beneficial for each type of decision in the risk analysis process. It is also necessary to make a clear distinction between scientifically-based risk assessments and political risk management. Risk analysis should include communication with all of stakeholders involved, ensure independent scientific advice as well as co-ordination and co-operation between authorities. The Nordic model for a practical approach to the risk analysis process takes these factors into account. The steps in this model are illustrated in figure 1.1 and table 1.2 below. The details are found in the report “Risk Analysis, - A Practical Approach to the Risk Analysis Process” (Fabech et al., 2002).

According to this model, risk analysis should start in the risk management section with the risk evaluation as the first step (see figure 1.1). Risk evaluation includes elements such as the establishment of a risk profile and making decisions on prioritisation of a certain hazard for scientific assessment. Furthermore, the risk evaluation step should include the establishment of a risk assessment policy, for example accepted uncertainties in the assessment and the percentage of the population who would be protected by for example, when setting maximum limits for contaminants in food etc. The risk evaluation could conclude that no further action should be taken.

² Definitions are given in the beginning of this report together with the translation into the Nordic languages. The definitions of some of the terms have not yet been adopted in Codex Alimentarius, and in such cases explanations in e.g. WHO Consultation Report are used, see the references to Chapter 5.

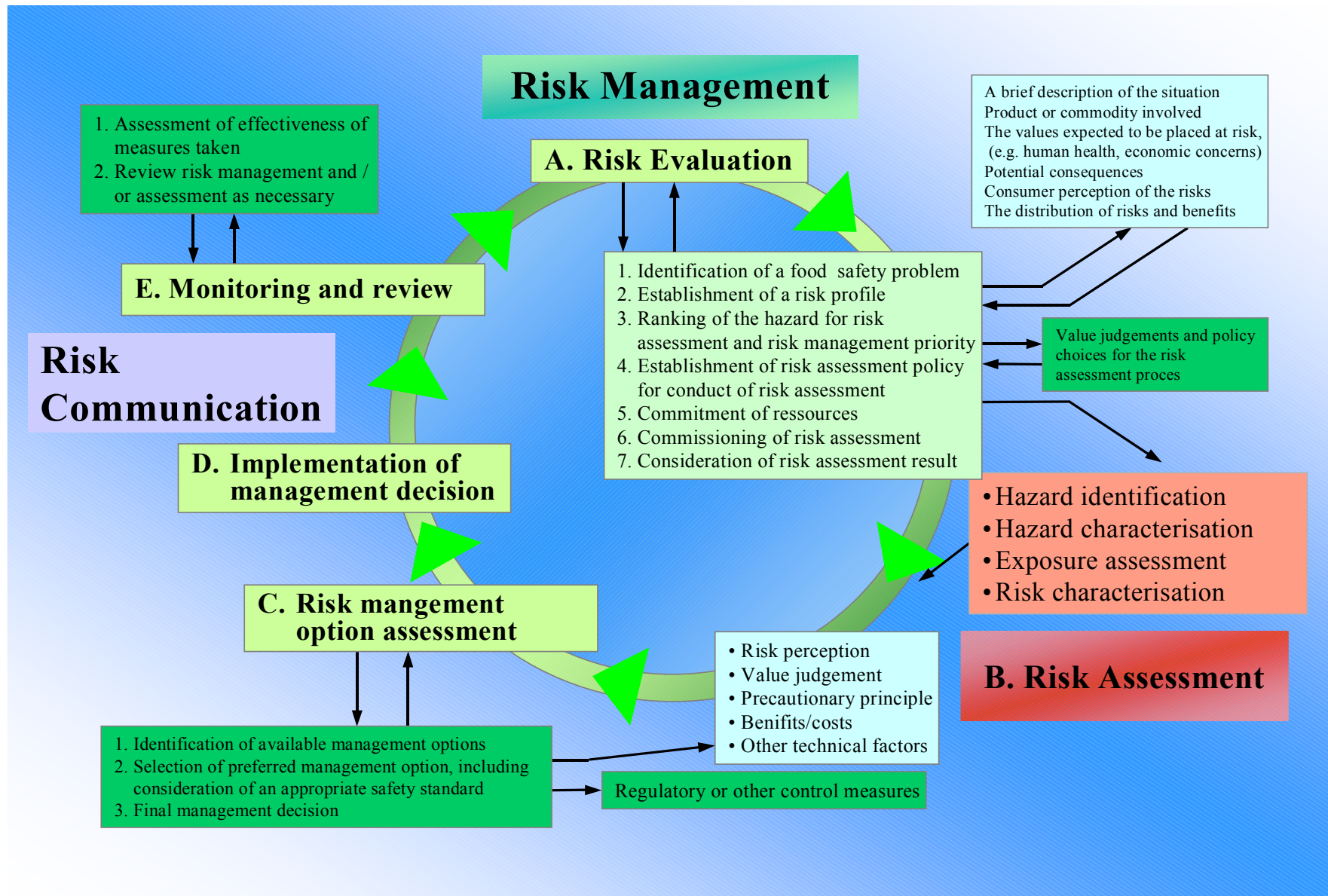
If the decision is taken to conduct a risk assessment, the risk assessment should follow established international guidelines and the results should include information on the uncertainties in the assessment. When the risk assessment is finalised, the next step in the procedure should be risk management and at the following steps management options, cost/benefit considerations etc. should be identified and the final management decision should be taken and implemented. The effects of this decision should subsequently be monitored and controlled in order to validate the measures taken. If the effectiveness of the measures taken is insufficient or if new data becomes available, the risk analysis could be re-started.

The Nordic model for a practical approach to risk analysis identified the following pre-requisites are essential in the procedure:

- **Risk communication:** The process should be based on a dialogue between the stakeholders involved in either the whole process or in individual steps. After each step, the documents describing the risk analysis process should be made available at a dedicated internet site since risk communication is crucial. An evaluation on the further communication of results to stakeholders, the public or government agencies should be made after each step and appropriate actions taken accordingly.
- **Responsibilities:** The government agency responsible for the risk management of food hazards will have the overall responsibility. Responsibility for the initiation, the management and the finalizing of each step of the process, including the risk assessment should be assigned to a designated individual.
- **Teamwork:** The risk analysis should as far as possible be carried out in designated teams.

The process is illustrated in figure 1.1.

Figure 1.1 Risk Analysis – as a Stepwise Process



The steps in the risk analysis are summarised in table 1.1. The table also lists some examples of types of data etc. and gives comments to each step:

Table 1.1 Risk analysis as a stepwise procedure with examples on the content of each step.

Step	Comments
Risk communication	Proper risk communication to all interested stakeholders be ensured during the entire process and when communicating the results/conclusions
A. Risk Management - First step	
Risk evaluation	
Identification of food safety problems	Background data: Surveillance Exposure data Research/Scientific publications Consumer concerns Other relevant information (e.g. production figures for foods)
The establishment of a risk profile	• A brief description of the situation • Product or commodity involved • The values expected to be at risk • Economic concern • Potential consequences • Consumer perception of the risks • The distribution of risks and benefits
Ranking of the hazard for risk assessment and risk management priority	Different hazards are to be ranked in order of priority
Establishment of a risk assessment policy for the conduct of a risk assessment	• Guidelines for the application of safety factors • Establishment of a percentage of the population accepted to be at risk • Criteria for the ranking of hazards • Accepted documentation or models to be used, including accepted uncertainty in the calculation of the result
The commitment of resources	In an acute situation, the responsible person for the risk management of food hazards should assign resources to the work. In other situations, the decision could be taken by the responsible minister. The request will include the identification of hazards, a risk profile, the ranking of priorities and the risk assessment policy.
Commissioning of a risk assessment	In this step, a procedure will be followed where valid criteria pertaining to the selection of assessors and the resources (financial, time, data, ad hoc expertise etc.) will be followed. The assessor(s) selected must be scientifically competent, independent from identified stakeholders, have an established quality control for her/his activities etc.

B. Scientific Risk Assessment	
References to background documentation should be included in a scientific way on all steps	
Hazard identification	• Methods of analysis • Effective agent • Environmental factor • Source of hazard
Hazard characterization	• Chemical substance (specification of identity, physical properties, structure etc. • Toxicity • Health effects, including symptoms. •
Exposure assessment	• Level of food consumed • Consumption pattern • Age and sex
Risk characterization	• Likelihood • Severity effects (adverse effect included) • Uncertainties • Tolerable daily intake • Reported side effects • Reproductive toxicity • Toxicological studies • Epidemiological studies
Consideration of risk assessment result	• Establishment of ADI, TDI, PWTI etc. or accepted risk level • Identification of possible risk management options and calculation of consequences for public health
C. Risk management – further steps	
Risk management option assessment	The options would differ depending on the risk
Identification of available management options	• Legislation (ban, maximum levels etc.) • Guidelines • Information to producers/consumers • Prevention
Selection of the preferred management option, including the consideration of an appropriate safety standard	Regulatory or other control measures
Final management decision	• Risk perception • Value judgement • Precautionary principle • Benefits/costs • Other technical factors
D. Implementation of management decision	• Legislation • Guidelines • Information for producers/consumers
E. Monitoring and review	• Market surveys • Intake studies • Case control studies
Assessment of the effectiveness of measures taken	
Review risk management and/or assessment as necessary	

2 Oil and input of oil into the marine environment

Oil spills in the marine environment occur frequently, most of them are minor spills, but some are of a much greater magnitude. The figure below from the Norwegian Environmental Protection Agency gives an overview of the source of acute oil and chemical spills over the last couple of decades.

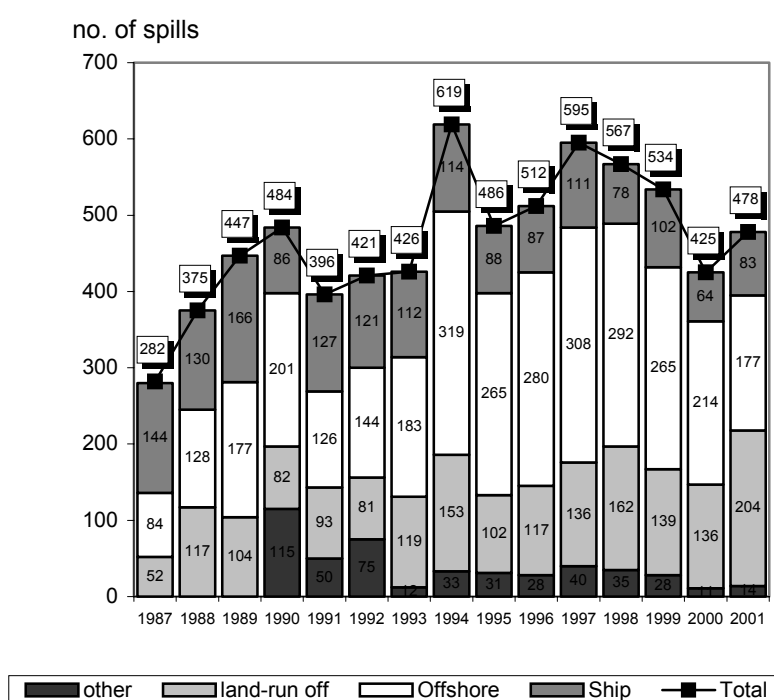


Figure 2.1 Annual numbers of acute spills of oil and chemical substances in Norway, Norwegian Environmental Protection Agency, 2002.

Sources of oil pollution in the sea include land-run off, seepage, offshore oil platforms, and oil spills. The type of pollutants, include oil itself (in its multitude of forms) and extract oil - oil-well produced water (containing metals, radioisotopes, organic acids, phenols and hydrocarbon). The largest input of oil into the marine environment comes from usage of oil, i.e. urban runoff and non-tanker shipping. Oil spills and discharges from transport of oil occur frequently but are judged to have decreased sharply. A little less than sixteen hundred large spills, i.e. involving the release of more than 7 tonnes of oil, are known to have occurred in the period 1970 - 2001. Vast majority of spills result in releases of less than 7 tonnes of oil. The acute and chronic effects on marine organisms of waste associated with offshore oil and gas production have recently been reviewed by Holdway (2002).

The wastes considered in the review include produced formation water, drilling fluid chemicals, oil-based drilling mud's and cuttings, water-based drilling mud's and cuttings

and oils, both crude oil from the extraction process and diesel oil from ships and equipment used in the production of oil and gas.

The effect of contaminants from oil well produced water on marine organisms has recently been the topic of a book by Neff (2002).

Prince et al. (2002) described an experimental oil spill study conducted to assess the natural weathering of oil over time. After 20 years, the majority of the oil had gone, as a result of biodegradation and photooxidation. The most biodegraded sample had 87% reduction in the hydrocarbons present, whereas some samples remained essentially unaltered indicating the complexity of the process. The biodegradation of oils has been studied extensively, and the preferential degradation of linear before branched alkanes, and small before large aromatic compounds is well established (Prince, 2002), whereas photooxidation appears only to be relevant for the breakdown of aromatic compounds in oil (Garrett et al., 1998). Oil and its products contain a wide range of alkylated polycyclic aromatic hydrocarbons (PAH) formed as a result of diagenetic processes. PAH are of concern because they can be directly toxic to marine animals, and because metabolites of some PAH (particularly 4-7 ringed PAH e.g. benzo[*a*]pyrene (B[*a*]P)) are potent animal and human carcinogens.

2.1 Oil and its components

2.1.1. Main components in oil

Oil is a complex mixture of thousands of different organic compounds. The formation of crude oil is a long process starting with the sedimentation and burial of various sources of organic material from once living organisms (marine or terrestrial). During a series of degradation and cracking processes the material first became part of the source rock (kerogen). Then the source rock is successively converted to crude oil, coal or gas. The composition of crude oil is determined by the type of biogenic material and paleo-environment dominating at the time of deposition of the material, the geological conditions during the maturation processes, and the migration route from source rock to reservoir (Storstrøms County, 2002).

Crude oils primarily contain carbon and hydrogen but also smaller amounts of sulphur, oxygen and nitrogen can be found. The overall composition of crude oil can be described by the content of several organic fractions such as asphaltenes, aromatic compounds and saturated hydrocarbons (Storstrøm County, 2002). The aromatic compounds are compounds containing one to seven condensed aromatic rings and their alkylated derivatives. The lower molecular weight mono-aromatics are the most abundant in crude oil, for example the so-called BTEX-fraction, (benzene, toluene, ethylbenzene and xylene fraction). The term polycyclic aromatic hydrocarbons (PAH) are used to describe the compounds consisting of carbon and hydrogen in two to seven condensed aromatic rings. Seen from a long-term toxicological perspective, the PAH are, the most important group of compounds in the crude oil.

PAH are formed either by incomplete combustion of organic material (pyrogenic) or diagenic processes (petrogenic).

In addition to the pyrogenic and petrogenic formations, PAH may also be formed by microorganisms from biogenic precursors (Wang et al., 1999). A summation of the characteristics of oils from the three different origins is found in table 2.1.

The complexity of the mixture of PAH found in the environment is also source dependent. Despite these characteristics, it is often difficult to identify which PAH have been introduced from pyrogenic or petrogenic sources (Wang et al., 1999).

Saturated aliphatic hydrocarbons (*n*-alkanes) from C₄ to C₄₀ are the dominating constituents of most crude oil. The concentration of *n*-alkanes is significantly affected by weathering, for example evaporation and biodegradation in the environment. Iso-alkanes such as isoprenoids are characteristic of oil components originating from the breakdown of chlorophyll-a. The most abundant isoprenoids are pristane (C₁₉) and phytane (C₂₀). The ratio between pristane and phytane can be used together with other alkane ratios to distinguish oil from different areas. *n*-Alkanes such as cyclo-alkanes and naphthenes consist of one- to five-membered cyclic compounds and alkylated derivatives hereof. Several of the cyclo-alkanes like steranes and hopanes are together with the isoprenoids commonly referred to as biomarker compounds. Their structure can be related to naturally occurring precursors and as such provide essential information about the geological history of the oil (Storstrøm County, 2002).

Naturally occurring pigments such as the metallo-porphyrins, also known as petroporphyrins are the product of the metabolism of chlorophyll by microorganisms and are predominately complexed with nickel and vanadium (Storstrøm County, 2002). The chemical identity of petro-porphyrins varies between sources, depending upon the biological conditions inherent to each geographic origin.

Table 2.1. Summation of characteristics of biogenic, pyrogenic and petrogenic sources of oil (Reference: Wang et al., 1999).

Origin	Biogenic	Pyrogenic	Petrogenic
	Generated by biological processes, background in marine areas	Incomplete combustion of organic material	Diagenic processes
Characteristics	High CPI ^{a)} index	Primarily non-alkylated compounds	Mixture of non-alkylated and alkylated PAH
	High Pristane/Phytane ratio	Dominance of high molecular weight 4-6 ringed PAH	Dominance of low molecular PAH. A characteristic bell-shaped alkane distribution profile
	Presence of olefinic hydrocarbons		<i>n</i> -alkanes C15-C40
			Presences of UCMs ^{b)} , hopanes and steranes

^{a)} CPI: The sum of the odd numbered alkanes compared to the sum of the even numbered alkanes.

^{b)} UCM: unresolved complex mixture

2.1.2 Crude oil and refined products

Generally oils are divided into different classes depending on the refining of the final product.

For identification and characterization of the different products chemical-physical analysis including boiling point distribution, density, viscosity and sulphur metal content is used (Hansen, 2002).

Refining of the oil is done either before shipping the product or after transport of a crude oil. Since, the products are divided into subclasses according to the boiling point, the final product can vary from one distillation to the other. The choice of distillation depends on the use of the final product and four subclasses of oil are listed in Table 2.2 with their main characteristics. Notice that all subclasses have possibilities of formation of intermediary products.

Table 2.2. Main characteristics of crude oil and refined products. Data from Wang *et al.* 1999 is used if no other reference is stated.

Type of oil	Crude oil (not refined)	Light refined products such as diesel and jet fuels	Heavy fuel oil (e.g. Bunker oil)	Lube oil
Boiling point (°C)	?	?	315-425	?
CPI^{a)}	~1.0	~1.0	>1.0	-
Pyrogenic Index^{b)}	<0.010	<0.010	0.014-0.051 Bunker oil (11-12)	no other 3-6 ring PAH
Phen./Ant.^{c)}	13-350	2-50	7-20	-
Main characteristics	Both <i>n</i> -alkanes and UCMs ^{d)} are detected Presence of thiophenes and other heterocyclic aromatics, organic nitrogen (0.1-2%) (Lundanes and Greibrokk, 1994)	Mainly naphthalenes and a large number of <i>n</i> -alkanes are detected Diesel PAH largely 2 and 3 ring PAH and their alkylated homologues (Wang <i>et al.</i> , 2001) >55% are alkylated naphthalenes (Wang <i>et al.</i> , 2001) chrysene < 0.02% (Wang <i>et al.</i> , 2001)	>55% aromatics/TPH ^{e)} UCM > 50% of total hydrocarbons	Mainly hydrocarbons larger C ₂₄ (UCMs) devoid of <i>n</i> -alkanes
<i>n</i>-alkanes	a wide range of <i>n</i> -alkanes are detected	C ₈ -C ₁₂ gasoline or C ₁₂ -C ₂₄ diesel range <i>n</i> -alkanes dominate GC chromatogram	broad resolved <i>n</i> -alkanes (C ₁₂ -C ₃₅)	pristine (C19) phytane (C20)

a) CPI: The sum of the odd numbered alkanes compared to the sum of the even numbered alkanes.

b) Pyrogenic index: $\Sigma \text{other 3-6 ring PAH} / \Sigma 5\text{-alkylated PAH}$

c) Phen./Ant.: Phenanthrene/Anthracene

d) UCM: unresolved complex mixture

e) TPH: Total sum of resolved and unresolved hydrocarbons

Crude oils are non-refined products. Classification of the crude oils depend on the relative content of the three main component groups, paraffins (P), naphthenes (N) and aromatics (A), i.e., according to the PNA group analysis (Hansen, 2002). Crude oil generally has a higher amount of alkylated PAH as compared to the same but unsubstituted PAH, indicated by the low pyrogenic index in table 2.2.

Other heterocyclic aromatics termed polycyclic aromatic compounds, PAC, like sulphur-containing thiophenes are also common constituents in crude oil (Storstrøm County 2002; Lundanes and Greibrokk, 1994).

After refining the lightest product is petrol or gasoline with a large number of *n*-alkanes. The gasoline ranges of *n*-alkanes include toluene (C₇) to dodecane (C₁₂). The diesel products include the diesel range of *n*-alkanes from dodecane (C₁₂) to tetracosane (C₂₄).

The next subclass in table 2.2 is the heavy fuel oils such as Bunker oil. Heavy fuel oils contain a diesel range component of *n*-alkanes as well as a chromatographic envelope of compounds originating at tetracosane (C₂₄) and at higher ranges. This type of oils is mainly used as cracking feed.

Finally, very heavy oil is classified as lube oil. Lube oil is used for motor oils and hydraulic fluids on large ships. This fraction is devoid of *n*-alkanes and only the unresolved complex mixture (UCM) is seen on a GC-chromatogram after analysis. The chromatographic envelope of compounds originating at tetracosane or extending beyond tetracosane. However, little is known about UCMs composition and molecular structures.

2.1.3 Fingerprinting

Refined petroleum products are fractions usually derived by distillation of crude oil. Because of dissimilarities in characteristics of crude oil feed stocks and variations in refinery processes, refined oil products differ in their chemical compositions (Wang et al., 1999). Thus, all crude oils and petroleum products, to some extent, have chemical compositions that differ from each other. This variability results in unique chemical fingerprints of each oil type and provides a basis for identifying, for example the source(s) of spilled oil. Many PAH compounds are more resistant to weathering (degradation by evaporation, dispersion, dissolution, photo-oxidation, and biodegradation) than their saturated hydrocarbon counterparts (*n*-alkanes and isoprenoids) and volatile alkyl-benzene compounds, thus making PAH one of the most valuable fingerprinting classes of hydrocarbons for oil identification. As illustrated in table 2.2 oil products differ significantly in the PAH distribution from the crude oils and from each other. Even differences between the same types of products are discernible through examination of the PAH distribution (Wang et al., 1999).

The oil spill identification system currently used is based on two detailed compositional analytical techniques: gas chromatography with flame ionisation detection (GC-FID) and gas chromatography with mass spectrometry detection (GC-MS). As an example capillary GC-MS, is capable of analysing the oil-specific biomarker compounds and polycyclic aromatic hydrocarbons (PAH). In non-specific methods, such as the GC-FID, only groups or fractions of chemical hydrocarbons like the sum of all resolved and unresolved hydrocarbons (TPH), total saturates, EPA priority PAH, and the content of volatile compounds can be identified.

Compared to the specific methods, such as GC-MS, the non-specific method requires shorter preparation and analytical time and is less expensive to use.

The major shortcoming associated with the non-specific method is that the data generated from this method generally lack detailed individual component and petroleum source specific information.

Therefore the method is of limited value for example for spilled oil characterization and source identification. In addition to measuring TPHs in oil samples, GC-FID chromatograms provide a descriptive fingerprint of the major oil components (e.g. individual resolved *n*-alkanes and major isoprenoids) and the qualitative information can be used to quickly screen the oil and oil product types, which are to be identified by GC profiles, carbon ranges and major component distribution patterns (Wang et al. 1999).

The polycyclic aromatic hydrocarbon compounds in oils are dominated almost exclusively by the C₁-C₄ alkylated homologues of the parent PAH, in particular naphthalene, phenanthrene, dibenzothiophene, fluorene and chrysene, none of which are measured by the standard EPA methods. Other important classes of petroleum hydrocarbons (e.g. aliphatics and biomarkers) are not measured by these methods at all (Wang et al., 1999).

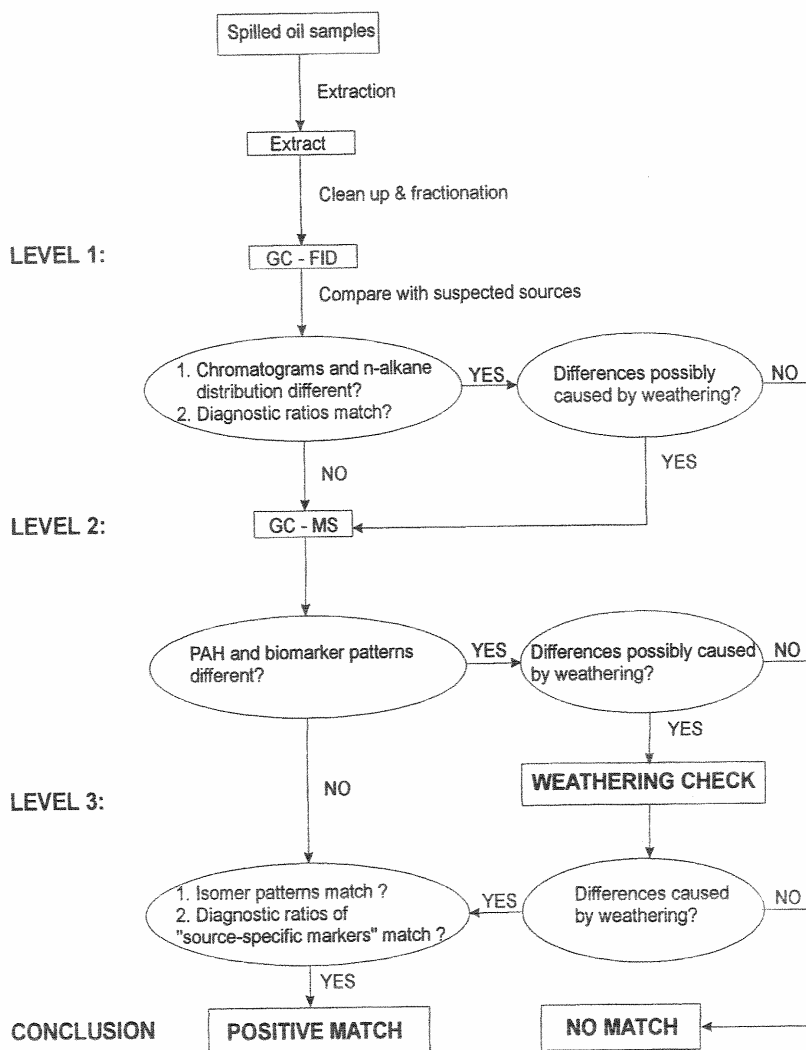


Figure 2.2 Oils spill identification protocol chart (Wang et al., 1999).

A variety of diagnostic ratios, especially ratios of PAH and biomarker compounds, for interpreting chemical data have been proposed for oil source identification and monitoring of degradation processes. These quantitative diagnostic ratios includes phenanthrene/anthracene (Ph/An), phenanthrene/methyl-phenanthrene (Ph/m-Ph), fluoranthene/pyrene (Fl/Py), benz[a]anthracene/chrysene (BaA/Ch), Ph/(Ph+An), benzo[e]pyrene/(B[e]P+B[a]P), and I(1,2,3-cd)P/(I(1,2,3-cd)P+B(ghi)perylene) (Wang et al., 1999).

As an example of the use of ratios values of $\Sigma(\text{other 3-6 ring PAH})/\Sigma(\text{5-alkylated PAH})$ are listed in table 2.2 as the pyrogenic index. Jet fuel, diesel and most crude oils show the ratios of $\Sigma(\text{other 3-6 ring PAH})/\Sigma(\text{5-alkylated PAH})$ to be smaller than 0.01, while heavy oils show significant higher ratios falling in the range of 0.01 to 0.05 (Table 2.2). A ratio of 0.8 to 2.0 for burn soot samples compared to 0.01 for crude oil and petroleum products

illustrates that the values of this ratio will be altered by combustion (Wang et al., 1999). However, long-term degradation only slightly alters the values of this ratio. This quantitative ratio, combined with other qualitative criteria, can be used to differentiate sources of PAH.

Data produced by GC-FID and GC-MS are used to compare spill samples with samples taken from suspected sources. If significant differences in hydrocarbon fingerprints and diagnostic ratios are found at any stage in the identification process, the conclusion will be that the samples are not from the suspected source (Wang et al., 1999). A protocol for oil spill identification includes the use of fingerprinting for oil spill identification as illustrated in figure 2.2.

In general, the major petroleum-specific target analyses that may be needed for chemical oil source identification and *environmental risk assessment* include the following four points, whereof main characteristics are included for some of the oil products in table 2.2.

- Individual saturated hydrocarbons including *n*-alkanes (C₈-C₄₀) and selected isoprenoids such as pristane and phytane, the volatile BTEX (benzene, toluene, ethylbenzene, and the three xylene isomers) and alkylated benzenes (C₃-C₅-benzenes)
- The US Environment Protection Agency (EPA) priority parent PAH and, in particular, the petroleum-specific alkylated (C₁-C₄) homologues of selected PAH (alkylated naphthalene, phenanthrene, dibenzothiophene, fluorene, and chrysene series).
- Biomarkers such as terpanes and steranes are determined to differentiate oils and monitor the degradation process and weathering state of oils.
- For *human risk assessment* it is important to know the fraction of genotoxic and carcinogenic PAH, which is the higher molecular weight PAH.

2.1.4 Weathering and other changes of the chemical composition of the oil in water

Weathering processes will influence various compounds of the oil to different extents and thereby cause considerable changes in the chemical and physical properties of oils for example after spillage.

The extent and rate of weathering depends on the properties of the oil, and is controlled by environmental conditions such as weather, water currents and microbiological activities.

In the first hours or days following an oil spill at sea, evaporation is the dominating process altering the composition of the oil by removing the hydrocarbons with low boiling point from the oil sample. A rapid loss of volatile compounds including the BTEX fraction of the oil is seen, while a pronounced decrease in the alkylated naphthalenes relative to other alkylated PAH series are detected.

A development of a profile in each alkylated PAH-family showing the distribution of C₀ << C₁ < C₂ < C₃ and a significant decrease in the relative ratios of the sum of naphthalenes, phenanthrenes, dibenzothiophenes and fluorenes to chrysenes are found after weathering of the oil (Wang et al, 1999; Wang et al., 2001; Storstrøms County, 2002).

Physical leaching due to waves and currents are, like evaporation, important in the weeks following the spreading of oil from oil spills at sea. Dispersed oil and water-soluble components will associate with particles and spread along the entire area. Photooxidation is dependent on light intensity and temperature. Generally, the PAH are more photosensitive than the saturated hydrocarbons, due to the direct absorption of UV-light by aromatic compounds. Overall, alkylated aromatics are more photosensitive than their unsubstituted parent compounds (Storstrøms county, 2002).

Oil-degrading microorganisms are present in all marine environments, in relatively low numbers in areas not previously affected by oil. The natural microbial degradation of oil can be slow and ineffective, due to lack of especially nitrogen, and the oil pollution can therefore persist for several years. Microorganisms degrade low molecular weight PAH (2-3 rings) more easily than higher molecular weight PAH (more than 4 rings) and alkyl-substituted PAH, respectively (Storstrøm County, 2002).

2.2 Use and transport of oil, offshore production

Oil and petrochemical products play an important role in everyday modern life. Oil accounts for 41% of the world energy fuel and a wide variety of different petrochemical products have been developed ranging from basic chemicals to products such as plastics and detergents (OWEM Scenarios Report, March 2000).

The world oil production in the year 2000, amounted to 76.7 million barrels/day corresponding to 4450 million m³/year. The production has increased since 1985 by 29.4% (IEA Annual Statistical Supplement for 2000). By 2010 the world consumption is expected to rise to 90 million barrels/day. (The Oil and Gas Industry, from Johannesburg and beyond, IPIECA, 2002).

The production volume in the year 2000 was equivalent to the flow of Sweden's largest river, Göta älv, for 13 weeks. Western Europe accounted for little less than a tenth of the total world production of crude oil in 2001. The main fields are located in North Sea and off the coast of Norway. The production is dominated by Norway, 0.5 million m³/day, and the U.K. 0.35 million m³/day (OPEC Annual Statistical Bulletin, 2001).

Import and export of oil and fleet size give an indication of the amount of oil transported by ships. Thirty two million barrels (5 million m³) of crude oil and nine million barrels (1.4 million m³) of oil products are delivered every day worldwide by sea (Peter Swift, INTERTANKO, BIMCO, Beijing 2001). Imports of crude oil and refined products to Western Europe in 2001 amounted to 2.67 million m³/day and exports amounted to 1.49 million m³/day. Figures on the world tanker fleet are given in Table 2.3.

The world tanker fleet counted a total of 3336 ships in 2001 with a total dead weight of 291 million tonnes (OPEC Annual Statistical Bulletin 2001). The average size of tankers was thus 87 thousand tonnes, but tankers vary greatly in size as can be seen in Table 2.3.

Table 2.3 Some figures on the world tanker fleet

Types of ships	Year	Number	Size/dead weight - DWT - Thousand tonnes	Reference
Ultra Large Crude Carriers (ULCCs)	2001	143	> 300	OPEC Annual Statistical Bulletin 2001, World Oil Transit Chokepoints, Energy Information Administration, USA November 2002).
Very Large Crude Carriers (VLCCs)	2001	239	200 – 299,999	
Suezmax tankers	2001	273	120 – 199,999	
Aframax tankers	2001	567	75 – 119,999	
Panamax tankers	2001		50	
Handymax tankers			35	
Handy Size tankers			20 – 30	
World tanker fleet	2001	3336	291 Average 87 with great variation	OPEC Annual Statistical Bulletin 2001
Number of vessels	2001	2039	< 75	

2.3 Input of oil to the sea

The National Academy of Sciences of the United States published estimates in 1975, 1981 and 2002 of the input of oil to the sea, see table 2.4.

The annual release of oil to the marine environment decreased during the last quarter of a century and is currently estimated to be over 1.3 million tonnes (Table 2.4). The input has decreased during the last quarter of a century. In 1975 it was estimated that 6.1 million tonnes entered the sea and in 1985 the estimate was 3.6 million tonnes.

The largest human input comes from usage of oil, 480 thousand tonnes/year, dominated by urban runoff, 140 tonnes, and discharges and losses from non-tanker shipping 277 tonnes.

The input estimate in 2002 is more based on measurements than previous estimates and is considerably lower. The estimate for consumption is associated with the largest margin of error, 130 - 6000 tonnes/year, due to scarcity of data.

Oil spills and discharges from transport of oil are also judged to have decreased sharply since 1985 due to international regulatory standards. The estimated 150 thousand tonnes/year is only 12% of the input in 1985. Natural seepage of oil is now considered the largest single source of oil to the sea.

The input is estimated to be 600 tonnes/year and contributes to 46% of the total. The best-known seeps are located in areas of large-scale oil and gas production such as the Gulf of Mexico.

Table 2.4 Figures on the input of oil into the marine environment

Estimates of inputs of oil to the marine environment per year (thousands of tonnes)			
Source:	Year		
	1975	1985	2002
Natural seeps	600	200 (20 - 2000)	600 (200 - 2000)
Offshore production losses	80	50	38 (20 - 62)
Operational discharges from tankers	1080	700 (400 - 1500)	36 (18 - 72)
Accidents from tankers at sea	300	400 (300 - 400)	100 (93 - 130)
Coastal refineries	200	100 (60 - 600)	17* (2.4/6.1 - 15/37)
Other coastal effluents		50 (50 - 200)	
<i>Transportation (total)</i>	<i>1580</i>	<i>1250</i>	<i>150 (120 - 260)</i>
Urban run-off and discharges	2500	1080 (500 - 2500)	140 (6.8 - 5000)
Atmospheric deposition	600	300 (50 - 500)	52 (23 - 200)
Losses from non-tanker shipping	750	320 (200 - 6000)	277 (90 - 810)
Jettisoned aircraft fuel			7.5 (5 - 22)
<i>Consumption (total)</i>	<i>3850</i>	<i>1700</i>	<i>480 (130 - 6000)</i>
Total discharges	6110	3200	1300 (470 - 8400)
Percentage of totals			
Natural seeps	10	6	46
Offshore production	1	2	3
Transportation of petroleum	26	39	12
Consumption of petroleum	63	54	37

*Includes pipeline spills

2.4 Offshore oil extraction

Oil released to the environment during production of oil and gas derives from produced water, drainage from platforms and rigs and from storage of oil.

Calculations indicate that less than 0.2% of VOC released are deposited to surface waters (Oil in the Sea III, 1999). Produced water accompanies oil and gas from the reservoir to the platform where it is separated from the oil. Produced water is water that is pumped down into the reservoir in order to press the oil and gas out.

The mean concentration of oil in produced water in 1999 from installations on the Norwegian continental shelf was 25 mg/l, below the allowable maximum limit of 40 mg/l.

The total discharge of oil to the Norwegian continental shelf in the area was 2900 tonnes in 1999, 85% from produced water, 10% from drainage and storage and 5% from spills (SFT-rapport 1762/2000).

2.5 Transport

Oil is released from vessels into the sea due to operational discharges and accidental spills. Operational discharges include bilge oil, oil from cargo tank washings and fuel oil sludge. Various sources of ship-generated pollution are regulated through the IMO International Convention for the Prevention of Pollution from Ships as modified by the Protocol of 1978, MARPOL 73/78.

The convention covers commercial vessels 100 gross tons (GT) and over. All vessels between 100 and 400 GT are required to retain all oily wastes on board. Tankers over 150 GT and other vessels above 400 GT are required to have oil/water separators and oil discharge monitoring systems installed. Maximum allowable oil concentration in discharged bilge oil after separation is 15 mg/l. Discharges containing oil less than 15 mg/l do not show visible traces on the sea surface.

Heavy residual fuel oils used for marine applications contain between 1 and 5 percent sludge, which does not burn and must be disposed (oil in the Sea, 2003). Discharge of oil sludge is prohibited according to the provisions of MARPOL 73/78.

Operational discharges from tankers are believed to have decreased from 700 thousand tonnes in 1985 to 36 thousand tonnes in 2002, but releases from other shipping have remained constant, around 300 thousand tonnes (Table 2.4). The North Sea and Baltic Sea are among areas where operational discharges by ships are prohibited in accordance with MARPOL 73/78. Aerial surveillance conducted over these areas show different behaviour. The number of oil slicks in the North Sea has declined steadily in the period 1990 - 2000, while the number of spills in the Baltic has remained constant, showing poor change in shipping habits (EEA Indicator Fact Sheet, Illegal discharges of oil at sea, 2002).

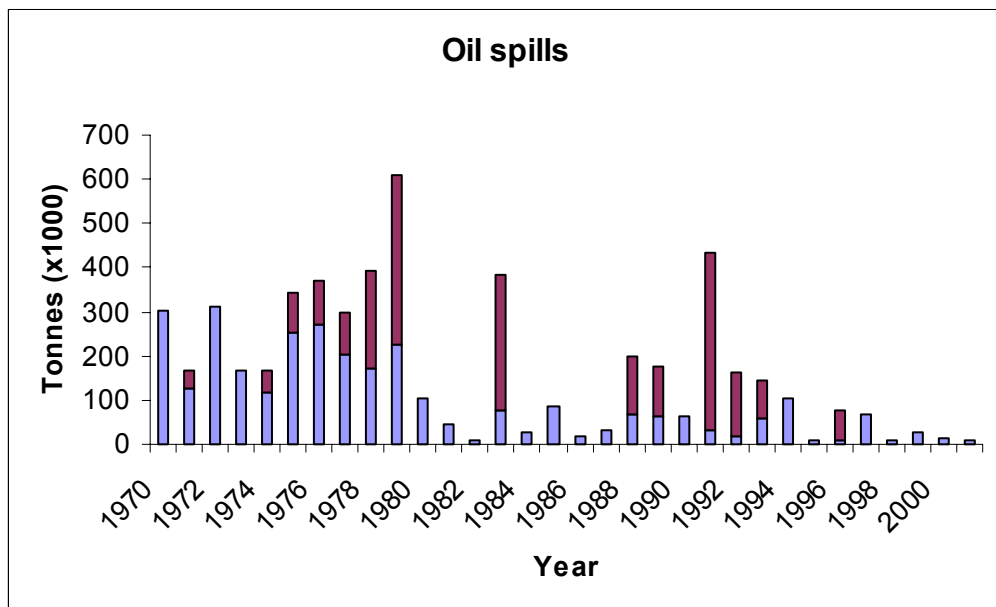


Figure 2.3 Quantity of oil spilled in incidents involving more than 7 tonnes of oil. Darkest columns indicate large spills, 37,000 tonnes or more (ITOPF, 2002).

The International Tanker Owners Pollution Federation has since 1974 maintained a database of oil spills from tankers, combined carriers and barges. The base holds information

on nearly 10,000 incidents categorised by size, < 7 tonnes, 7-700 tonnes and > 700 tonnes.

The vast majority of spills, about 85%, fall in the category of less than 7 tonnes, but data and amount are incomplete. The amount of oil released in 1593 spills greater than 7 tonnes in the period 1970 - 2001 amounted to 5.33 million tonnes of oil, see figure 2.3). Nineteen large spills in that period, all over 37,000 tonnes, accounted for 2.2 million tonnes of oil or 42% of the total

2.6 More information about oil spills at sea

There are many issues of importance for managing accidental oil spills, and an enormous amount of information available. It is important to have knowledge in many different subjects when conducting a risk analysis, and the annexes provide some background information.

Analysis of the seafood would be an important prerequisite for the evaluation of the consequences of an oil spill with regards to seafood safety. Annex I gives a list of fish species caught in seas around the Nordic countries and which are of importance for human consumption, with names in Latin, English and the Nordic languages.

Analytical methods are not described in this report, but Annex II includes some general remarks on testing of the seafood, including organoleptic testing. Finally, the risk assessment, which is found in chapter 5, includes knowledge of seafood consumption and other background information for the risk assessment are found in Annex III.

Speakers at project meetings have provided abstracts of their talks and these are included in Annex IV as background information for the reader. The information includes the composition of oil, environmental surveillance, views of fishermen, experiences from the Exxon Valdez oil spill etc.

It was considered beneficial to include some knowledge on related issues of importance to the risk analysis and in some cases, also of relevance to emergency response in the Nordic countries to oil spills.

The National Oceanic and Atmospheric Administration (NOAA) has published the report "Managing Seafood Safety after an Oil Spill". In the report there are also useful information in relation to the analyse oil spill pose a risk to seafood safety, including information on the factors that influence the likelihood of seafood exposure and contamination and on methods and strategies for monitoring (Yender et al., 2002).

3 Influence on oil spills on seafood

Knowledge about seafood caught in areas polluted after oil spills is of importance for the risk analysis. Furthermore, the effect of oil spills on the different species has to be taken into account in the risk assessment of the seafood. The potential hazard will depend on the metabolism of the components in oil by the species. Furthermore, the behaviour of the different fish species could be of importance, - some species are expected to flee when they detect oil in the water, others stay – pelagic species may be less influenced by oil spills, whereas benthic species may live in polluted sediments for several months or even years after a spill. Farmed fish and sedentary species such as bivalves will be affected since they are confined to the area, and in the case of fish raised in landbased hatcheries, on-growing at sea may be prevented by oil spills and lead to other problems

Knowledge from oil spills has been gained from several accidents for example the oil tanker "Sea Empress" which was grounded in 1996 at the entrance to the port of Milford Haven losing around 72000 tonnes of cargo and 480 tonnes of bunker fuel. To protect consumers from the risk of contaminated seafood the coastal area in the vicinity of the accident (approximately 810 square miles) was closed for fishing. Controls on fisheries for fish and crustaceans were removed relatively quickly (within three to eight months), whereas restrictions covering intertidal mussels and oysters remained in place for about 18 months (Law et al., 1999).

Oil spills have raised concern regarding potential contamination of fish and shellfish, and have led to temporary closure of fisheries while risks are assessed. Due to the lack of standardised protocols these tend to be ad hoc, site-specific assessments with variable risk evaluation criteria. To address this, criteria for reopening of shellfish harvest following oil spills have been devised for the primary contaminants of concern, PAH expressed as total benzo[a]pyrene (B[a]P) equivalents. (Gilroy, 2000). "Safe" ($<10 \mu\text{g kg}^{-1}$) and "unsafe" ($>45 \mu\text{g kg}^{-1}$) B[a]P equivalent levels were derived based on upper end (32.5 g d^{-1}) and average (7.5 g d^{-1}) estimates of shellfish consumption, respectively.

3.1 PAH metabolism in fish and bivalves molluscs

PAH are rapidly accumulated but also fairly readily metabolised in fish. In cod (*Gadus morhua*) exposed to crude oil for 30 days, the concentration of total PAH in liver increased rapidly peaking at day three, after which it gradually decreased with a coincidental increase in EROD-activity³ (Aas et al., 2000). PAH undergo electrophilic substitution, oxidation and reduction reactions (Neff, 1985). The latter two types of reactions destroy the aromatic ring structure of PAH.

Biotransformation reactions are the major determinants for whether a hydrophobic molecule is toxic to fish, how it is distributed in tissues and how it is excreted.

Without these biochemical processes half-lives of PAH would be much longer in fish and other vertebrates. On the other hand, the metabolites of genotoxic and mutagenic PAH are much more toxic than the parent compounds.

³ EROD activity = Ethoxy Resorufin O-Deethylation activity; The activity of CYP 1A1 can be quantified by measuring the metabolism of an isozyme selective substrate, Ethoxy Resorufin, in isolated microsomes.

PAH metabolites are carcinogenic. The occurrence of hepatic tumors in English sole (*Parophrys vetulus*) was statistically associated with exposure to PAH compounds (Malins et al., 1985). PAH metabolites are also genotoxic and can be detected as DNA-adducts (Dunn et al., 1987). In fish the major metabolization pathways are cytochrome P450 monooxygenase, epoxide hydrolase and several conjugating enzymes (Tuvikene, 1995 and figure 5.2). These enzymes, as a first step (Phase I enzymes), add a polar group into a PAH molecule through oxidative, reductive or hydrolytic processes. In the second step (Phase II) the phase I metabolites of the PAH molecule are conjugated with polar endogenous substances such as glucuronide, sulphate, glutathione or an amino acid to produce water-soluble compounds that are excreted via the bile (Tuvikene, 1995 and figure 5.2). This characteristic can be used to detect whether fish have been exposed to PAH compounds as PAH metabolites can easily be measured in bile samples by fluorescent detection (Stagg, 1998).

Some PAH metabolites are excreted through the skin after they are bound to mucus (Varanasi et al., 1978). Cytochrome P450 monooxygenases belonging to CYP1A subfamily of cytochrome enzymes (Stegeman, 1989) are induced by various PAH compounds (Stegeman and Hahn, 1994). Measurement of CYP1A1 as EROD activity is used as another biomarker in fish of exposure to PAH (Collier et al., 1992; Stagg, 1998).

In Atlantic cod (*Gadus morhua*) and dab (*Limanda limanda*) exposed to crude oil, the peak concentration of PAH was detected three days after exposure was initiated, after which there was no further increase and in some cases there was a decrease in concentration (Aas et al., 2000; van Schanke et al., 2001). Apparently, the decrease followed induction of EROD activity and thus increase in PAH metabolism as has been detected with some PAH compounds (Hawkins et al., 2002). Quite large differences exist between fish species both in the basal level of EROD activity and in its induction after chemical exposure. For instance experimental EROD activity was four times higher in flounder (*Platichthys flesus*) and plaice (*Pleuronectes platessa*) and two times higher in cod (*Gadus morhua*) than in herring (*Clupea harengus*) (Whyte et al. 2000). Tissue DNA adduct levels have also been used as biomarkers to assess the exposure of fish to PAH (Tuvikene, 1995).

3.2 Accumulation, half-life and bioconcentration factors of PAH

PAH are absorbed by fish from exposure via food, water and sediments reaching higher levels than in those mediums (Neff, 1985). However, PAH unlike for example organochlorine hydrocarbons are not bioaccumulated through trophic levels but are increasingly metabolised (Porte and Albaiges, 1994). Nevertheless, the retention of PAH and their metabolites is increased in fish tissues at low temperatures (Collier et al., 1978). Within one year from the Exxon Valdez oil accident in 1989 in Prince William Sound, Alaska the concentrations of total aromatic compounds ranged from non-detectable to 34 ng g⁻¹ in muscle of salmonids and bottom-living fish (Hom et al., 1999).

Juvenile turbot *Scophthalmus maximus* exposed to dispersed oil accumulated mainly PAH compounds with two to three aromatic rings, and different bioavailability or increased metabolism of larger PAH was suspected (Baussant et al., 2001).

The 30-day bioconcentration factors (BCF) of individual PAH compounds in fish exposed to North Sea crude oil ranged from 54 to 65733, and BCFs for two- and three-ring PAH were larger than for four- and five-ring ones. After exposure to North Sea crude oil ceased, the concentrations of parent PAH in fish liver were at the background level within a week (Aas et al., 2000). As PAH are hydrophobic, the lipid content of a tissue or an or-

ganism can have an effect on the concentration (Meador et al., 1995). However, due to the rapid biotransformation of PAH in fish even fat fish do not accumulate PAH. In fish, the lowest concentrations of PAH are detected in muscle compared to other tissues (Neff, 1979).

Compared to fish, most shellfish metabolize PAH slowly and inefficiently and therefore they tend to accumulate higher concentrations of a wide range of PAH (Law and Hellou, 1999). Studies have shown that the accumulation of PAH in oysters generally exceeds that of other bivalve molluscs (Gilroy, 2000; Neff, 1982; Meador et al., 1995). In oysters (*Crassostrea virginica*) the BCFs for PAH ranged from 189 to 18000, and in clean water concentrations of some PAH decreased in a week to less than a tenth of the peak concentrations. Nevertheless, three weeks after exposure approximately one third of the concentrations of some PAH remained (Neff, 1979). In estuarine clam (*Rangia cuneata*) the BCFs for PAH compounds were from 6.1 to 32, and after one day in clean water 13–66% of the accumulated PAH were cleared from clams. For most bivalve molluscs (except scallops) the tissue distribution of PAH compounds is not relevant to the consumer since all of the soft parts are eaten. Law et al. (1999) examined the contamination levels in a range of shellfish species, and the temporal changes in contamination resulting from an oil spill. Low concentrations of 2- and 3-ring PAH were generally found in fish and crustaceans, whereas molluscs close to the spill rapidly took up whole oil in their tissues. Concentrations of C₁-, C₂ and C₃- naphthalenes and C₁-phenanthrenes up to 430, 5900, 22800 and 70000 µg kg⁻¹ were recorded in mussels eight days after the grounding. However, sampling over time revealed that not all PAH absorbed were primarily related to the oil spilled, and both spatial and temporal variations were observed indicating other sources in the area. Furthermore, considerable seasonal variations in PAH content were observed which were directly related to the physiology of molluscs. These factors are relevant to monitoring studies of food safety following future oil spills.

3.3 Fish behaviour and migrations

Pelagic fish species, such as herring, sprat (*Sprattus sprattus*), cod, salmon (*Salmo salar*) and mackerel (*Scomber scombrus*), are at risk of being affected by accidental and deliberate oil spills in the open sea. No reports were found for respective effects of oil, but with pulp mill effluents it was found that vendace (*Coregonus albula*), which is a pelagic freshwater species, after being acclimated to low pulp mill effluent concentrations preferred effluent dilutions instead of clean water in experimental arrangements (Myllyvirta and Vuorinen, 1989).

Benthic fish species such as flounder, plaice, and dab (*Limanda limanda*) may be exposed to oil-contaminated sediments.

Fish appear to avoid oil-contaminated waters, for example, after an oil spill on the Lithuanian coast in Palanga in November 2001 it was estimated from the commercial fish catches that approximately 90% of fish disappeared from the area, but the following Spring they returned (Edvardas Bagdonas, personal communication).

4 Risk analysis of oil spills and the effect on seafood safety

The risk analysis in this report of the effects and consequences of oil spills for seafood safety follows the “Nordic model, -a practical approach” described in chapter 1. The checklist for the risk analysis starts in the risk management section with risk evaluation as the first step. It subsequently follows the different steps of the risk assessment and the result of the risk assessment is the basis for the next steps, the risk management decisions. Risk communications will not be dealt with in detail, but in order to have an open and transparent risk analysis, risk communication at all steps of the risk analysis and between all stakeholders is essential.

The structured risk analysis process has been on the agenda for example of the Swedish National Food Administration (NFA) for a long time. However, the use in practice of the risk analysis process, as a stepwise quality assurance process, is not yet included as a routine procedure and is thus unfamiliar to some. A working group at NFA was given the task to examine in detail and also present a proposal for how the risk process should be conducted in practical terms for uniform interpretations and to make the decisions in the area of food safety generally more comprehensible. A stepwise procedure was proposed (Riskanalys GD-beslut VL 1/03) based on the general agreement between the Nordic countries how to deal with the risk analysis process. The proposal was accepted and approved by the Swedish Director General and the formalised procedure should be followed in all types of situations, also in an acute situation.

In this report, the risk analysis will be used as a stepwise risk analysis procedure for an imaginary scenario chosen by the project:

- An accident involving a tanker with 100 000 tons of oil, type Bunker C,
- Position 58°12'52" N and 009°59'33" E,
- The weather at the time of the accident is wind coming from southeast, and changing to southwest.
- The position is in the Danish territory approximately 1.5 nautical miles from the Danish-Norwegian boarder and approx. 3.8 nautical miles from the Danish-Swedish boarder.
- The date is 2nd October.

The area is area III a on the ICES map in figure 4.1

The imaginary accident is chosen in order to describe a situation, which might happen and to have a specific area to use in search for data. In the risk assessment is not used data from this area, as they are not available. Furthermore, the weather conditions are mostly included to illustrate a potential risk for more than one of the countries and hereby the need for networks and cooperation.

As the analysis concerns an imaginary risk, the need for data collection for example via research is identified throughout the different steps of the analysis. The project has also addressed some issues that are relevant for the emergency response plan following acci-

dental oil spills. These issues are critical for conducting a risk analysis of the consequences of an oil spill for seafood safety, and are included in chapter 6.

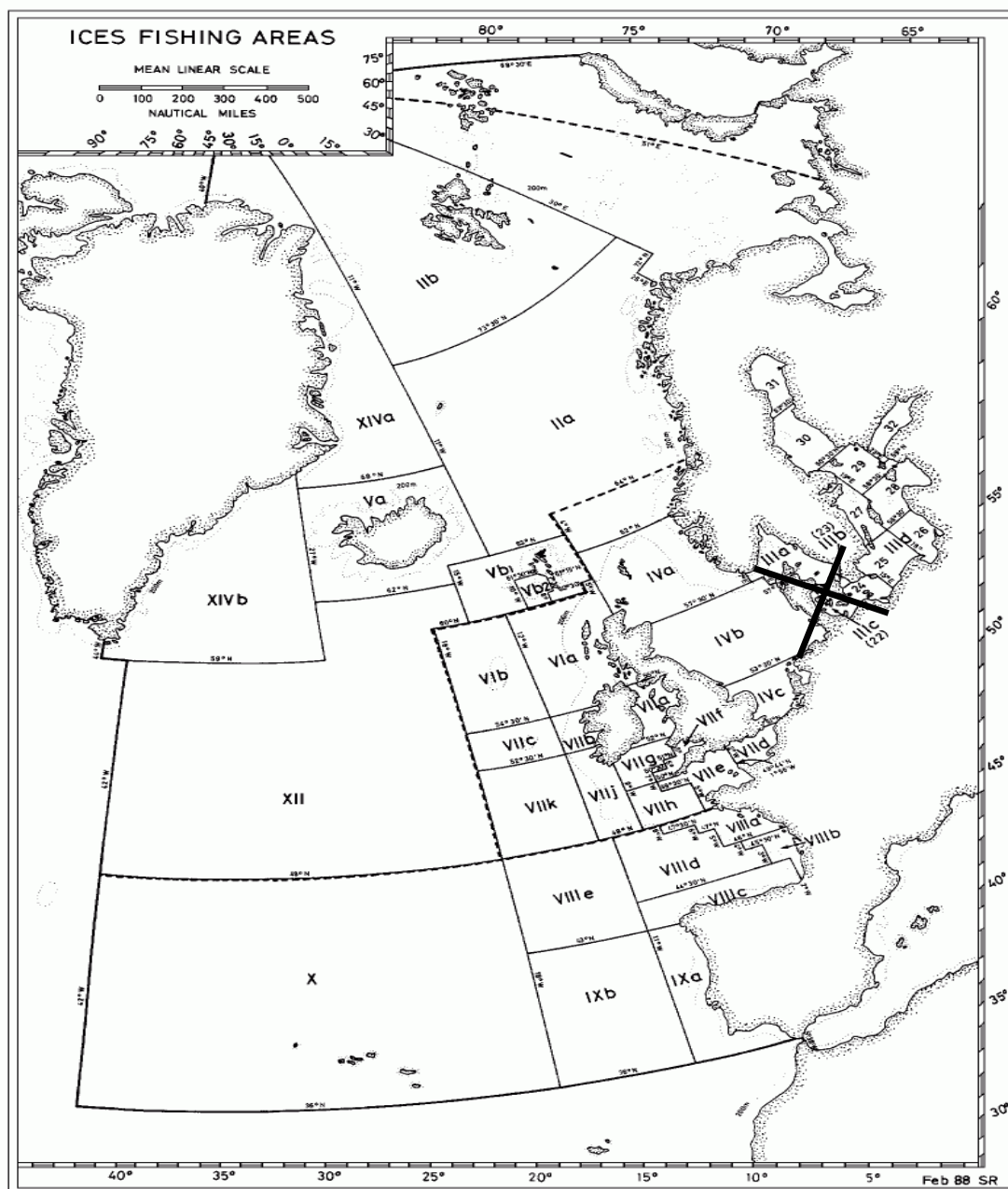


Figure 4.1 ICES map.

4.1 Risk communication - general remarks

Risk communication between interested parties is very important in the risk analysis process, both during the process and afterward when communicating the results of the analysis.

In each step of the risk analysis process, the need for risk communication should be addressed.

The public trust in authorities depends on knowledge and on the transparency of the risk analysis particularly in emergency situations such as oil spills. In the Nordic countries,

there has been a growing interest in food safety issues for several years, and risks related to food are in general of concern to consumers.

Information can be made available on the internet since this is an inexpensive and rapid way to communicate. However, it would not be the best channel for communication to the public in general, and should not be the only tool for communication. Certain groups of consumers with whom the official authorities may wish to communicate may never seek information on the Internet.

Risk assessment and risk management are scientifically-based and are performed by scientists and experts in the fields. In most cases, the competence in the field of risk communication has not been developed within the food authorities in the same manner.

Press releases are generally used by the food authorities in the Nordic countries, but the outcome of such communications is difficult to predict. In some cases, very important messages get limited coverage in the media. Therefore, press releases have to be carefully designed and, if possible, the timing of publication should also be considered. Experts in public relations should be consulted or recruited for this purpose. Distributing brochures, posters and stickers, writing newspaper articles and giving interviews to the media are other means of risk communication commonly used by the public authorities.

When selecting from the various options available to bring messages to the consumers and other interested parties, the authorities should develop a way of measuring the impact of each option. Factors such as identifying target groups, the likelihood of getting the attention of the target group and the likelihood of influencing the behaviour of the target group must be known.

4.2 Risk management – first step: Risk evaluation of the consequences of oil spill on fish for human consumption

According to the general principles of food safety risk management, listed in the WHO Risk Management and Food Safety report, the principles listed below should be addressed:

- a. Risk management should follow a structured approach.
- b. The protection of human health should be the primary consideration in risk management decisions.
- c. Risk management decisions and practices should be transparent.
- d. The determination of risk assessment policy should be included as a specific component of risk management.
- e. Risk management should ensure the scientific integrity of the risk assessment process by maintaining the functional separation of risk management and risk assessment.
- f. Risk management should include clear, interactive communication with consumers and other interested parties in all aspects of the process.
- g. Risk management should be a continuing process that takes into account all newly generated data in the evaluation and review of management decisions.
- h. If, and when other legitimate factors than safety are taken into account in the decisions made, this should be clearly stated in the final management decision. The legitimate factors could be for example, a demand for documented technological need

for the use of food additives, economy etc. Further discussions on the possibility of an international acceptance of this take place in Codex Alimentarius.

The model chosen by the Nordic project group includes these principles.

The risk evaluation is the first step of the risk analysis process in the Nordic model. In theory, risk evaluation is a risk management take, which will often be conducted in a dialog with risk assessors. Risk evaluation includes the following questions, which should be considered:

- Identification of a food safety problem
- Establishment of a risk profile
- Ranking of the hazard for risk assessment and risk management priority
- Establishment of a risk assessment policy for conducting the risk assessment
- Commitment of resources
- Commissioning of a risk assessment
- Consideration of a risk assessment result

Though all the steps in the risk evaluation, decisions should preferably be based on published documentation on the risk and references should be part of the documentation in the risk evaluation.

4.3 Risk evaluation of oil spills

4.3.1 The identification of a food safety problem

Oil spills at sea are generally emergency situations, whether caused by leakage from tankers after collisions, oilrigs or from storage plants on land.

The food safety problem will differ, depending on the type of oil, the time of year and which species of fish and crustaceans etc. are present in the area of importance for human consumption.

Identification of the safety problem should concentrate on:

- In which area is the oil spill
- Type of seafood caught in the area at the time of the year
- Fish and other seafood and their possible behaviour after oil spill
- Chemical composition and amount of oil
- Metabolism/accumulation in the species
- Consumption of seafood from the area
- Markets for the seafood, - local, national and/or international
- Special requirements of national/international markets

This collection of knowledge would a first collection of information and also in some extent science-based data in a dialog with risk assessors.

Some of the international bodies mentioned in Annex VII have information on for example, which fish species are found in an area and the background contamination of the sea and sediments e.g. ICES and HELCOM. The national contact points in different areas are listed in Annex V and VI. In the following sections some information is provided on where to find information and which authorities are involved in some of the Nordic countries.

The food administrations in the Nordic countries are not responsible for the administration of legislation on fisheries, this is the task of separate authority. The registration of seafood caught in the Danish sea, where this imaginary accident takes place, is done by the Danish Directorate of Fisheries. They supply registered data to ICES. In the case of an oil spill, both the Danish authorities and ICES would be able to supply data on fish species in the area, see also chapter 4.3.2 on the establishment of a risk profile. Similar authorities are found in all of the Nordic countries. Furthermore, various research institutes and university departments have knowledge of fish and fish species.

The Danish surveillance authority, Søværnets Operative Kommando (SOK) does not conduct systematic registration of dangerous chemicals transported through Danish seas, but they have knowledge of the transports, and they contact the ships to make them aware of the surveillance taking place. In cases of accidents, the SOK would have the oil analysed, to see whether the composition is in compliance with the datasheets at the ship. The analyses are conducted by the Danish Environmental Research Institute, who can identify the type of oil and e.g. the PAH profile.

An oil spill is a disaster for the environment and for the sea living organisms such as plankton, fishes and birds. Oil is also a food safety problem. Fishermen often become deeply involved because such accidents frequently occur in areas where subsequent fishing is strictly forbidden or restricted for considerable periods of time. The size of the oil spill, fishery and fish farms in the area, the time of year and the type of oil affect the dimension of the problem. For the public such accidents usually only influence tourism because of restricted access to beaches.

Fisheries authorities give permission for commercial fishery. In case of oil spills the Food Control Authority could restrict sales or advise not to eat fish caught in the area immediately by use of the precautionary principle.

Oil spills will affect marine organisms in different ways. Some fish species may disappear from the area but may be contaminated to a greater or lesser degree depending on their prey organisms, which may be plants or animals that have been in contact with the oil spill. Other seafood species as shellfishes, crabs, shrimps and lobsters will also be affected from the oil spill.

It would be useful to estimate the consumption of species which are usually fished in the area surrounding the spill and which are likely to have been affected by the oil. A specific evaluation directed at the substances with identified toxic effects is advisable. This short summary should be based on available knowledge and would not be a complete risk assessment in the first step but should include as much information as possible. This initial background information on the oil spill situation should be considered before any further decision is taken. The follow up would be to establish a risk profile.

4.3.2 Establishment of a risk profile

A risk profiling is the process of describing a food safety problem and its context, in order to identify those elements of hazard or risk relevant to various risk management deci-

sions. The risk profile would be based on available knowledge and would not be a complete risk assessment at the first step.

To follow up or to make a direct action demands more detailed information of the situation:

- Which substances are hazardous and
- What are the concentrations of these substances when seafood has been exposed to oil spills?
- Which species are of interest in the area where the oil has been spilled?
- Are there any fish farms that can be affected and where are they located?

Local fishermen and fish companies may have relevant knowledge and be able to provide this information. The areas which are fished for shellfish and harvesting periods are known and gives the possibility to give the farmers adequate help and advice. It can for example be advisable to postpone the shell harvesting periods until the seawater is free from oil or even later, until the contaminating oil has been removed from both the sea and possibly from the sediment. This can be done either by cleaning up actions or naturally, for example by photodegradation.

A typical risk profile might include the following:

- a. A brief description of the situation
- b. Products or commodities involved
- c. Values expected to be placed at risk
- d. Economic concerns
- e. Potential consequences
- f. Consumer perception of risks, and
- g. Distribution of risks and benefits

The risk profile would describe the extent, including background information for exposure assessment and potential economical consequences of the possible management options.

The risk profile should also inform about specific information, which is lacking. It may be necessary to perform additional investigations before recommendations can be given to consumers. These issues will be on the agenda when the risk profile draft is presented to decision-makers.

A brief description of the situation

The situation chosen in this risk analysis is an imaginary accident with a 100.000 tons oil tanker at position 58°12'52" N and 009°59'33" E. The weather at the time of the accident is wind coming from southeast, and changing to southwest. The position is in Danish territory approximately 1.5 nautical miles from the Danish-Norwegian boarder and approximately 3.8 nautical miles from the Danish-Swedish boarder. The date is 2nd October, and the oil is described as Bunker C oil.

The accident is a potential threat to fish farms in Norway and to the Swedish fishing areas, too. The emergency response in relation to seafood is needed in all three countries.

Products or commodities involved

The national authority registers the seafood species caught in the area. As the area chosen for the risk analysis is in Danish territory, the Danish Directorate of Fisheries can provide information on the species caught there. These are listed in table 4.1 below.

Values expected to be placed at risk

Oil contains PAH some of which are known to be mutagenic and carcinogenic. Oil pollution at sea would give rise to elevated levels of PAH as well as organoleptic changes in seafood. The organoleptic changes themselves are not a risk to humans, but are still regarded as unacceptable, and would be one of the criteria for not accepting the seafood on the market.

More than 200 PAH compounds and isomers have been identified and only a few of them have had their risk assessed by international scientific risk assessing committees. Some of the risk assessed PAH have been characterised as substances with carcinogenic and/or genotoxic effects. One of the most potent PAH is benzo[*a*]pyrene (B[*a*]P) and several nations use this as a reference substance and correlate the toxicity of all other isomers to B[*a*]P.

From investigations of fish and shellfish it is well known that PAH have been found in seafood. Some marine organisms such as shellfish (bivalves and crustaceans) lack effective mechanisms for metabolising these compounds and relatively high concentrations have been found. High consumption of these seafood products from a contaminated area is likely to be a health risk and an immediate action of risk management should be considered.

Tabel 4.1 Fish caught in the ICES- square: "Latitude 45 Lenght :F9", distribution on month and species, 2002

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Unspecified species	285	640	1.709	1.259	965	785	400	1.375	615	1.825	277	40	10.175
Lesser argentine	.	.	.	.	.	.	4.000	.	.	.	.	.	4.000
Blue witing	.	.	.	.	.	10.000	.	260.674	911.000	5.000	.	.	1.186.674
Blue ling	.	200	440	620	.	.	.	.	.	50	.	.	1.310
Lobster	745	55	1.034	4.219	2.815	1.377	535	2.234	2.290	1.805	700	337	18.146
Shrimps	2.680	3.860	1.920	.	2.040	800	6.436	21.000	5.400	15.340	1.060	13.350	73.886
Argentine	.	36.000	34.000	81.000	.	.	.	.	11.000	27.000	.	.	189.000
Anglerfish	495	1.500	3.045	1.413	790	980	550	275	405	345	185	105	10.088
Dab	240	.	.	.	.	880	910	.	560	160	.	.	2.750
Hake	.	.	.	.	320	270	210	.	320	255	70	.	1.445
Lumpsucker	.	480	525	.	.	.	.	.	.	.	.	.	1.005
Haddock	7.310	1.665	2.825	8.397	5.150	8.760	1.790	1.485	1.055	715	145	915	40.212
Ling	85	430	180	525	.	270	.	.	175	.	.	25	1.690
Pollack	165	.	4	.	.	125	.	.	.	.	70	.	364

	January	February	March	April	May	June	July	August	September	October	November	December	Total
Saithe	1.060	1.590	2.680	5.718	2.475	2.895	155	1.735	1.050	1.470	2.490	130	23.448
Dogfish	.	10	1.270	4.300	.	.	.	.	80	.	.	.	5.660
Plaice	2.230	3.390	930	1.412	640	3.730	2.280	.	560	300	130	.	15.602
Goldbud praise	720	165	140	410	160	1.440	255	.	45	45	.	.	3.380
Herring	.	.	.	.	.	4.000	50.000	499.000	412.000	360.000	60.000	.	1.385.000
Gray sole	425	6.905	11.825	4.937	4.740	2.745	430	1.665	870	1.435	640	360	36.977
Grenadiers	.	65.000	45.000	162.500	.	.	.	.	85.000	350.000	220.000	.	927.500
Norway pout	.	.	.	.	.	.	.	8.000	21.000	.	.	.	29.000
Greater sandeel	.	.	.	.	20.000	.	.	.	.	.	.	.	20.000
Common sole	104	103	12	30	380	.	.	.	.	272	80	.	981
Cod	2.260	2.510	2.048	6.598	5.375	5.665	680	1.900	1.790	1.455	615	470	31.366
Total	18.908	124.878	110.418	284.278	45.990	44.977	68.631	799.683	1.455.415	767.472	286.552	15.732	4.022.934

The figures are estimates by the fishermen in kilograms. A derivation of up to 20 % is accepted.

(Fiskeridirektoratets logbogstregister, Fiskeridirektoratet (Statistiksektionen NTH) 12:21 - fredag d. 1. august 2003)

Some fish species are known to flee, when they detect oil in the water. Depending on whether the fish species are migrating or stationary, there will be a variation in the potential content of PAH in fish. However, even fish, which have fled from the area may return and be contaminated by the remaining oil and its components.

Current legislation in the Nordic countries does not include specific limits for PAH in seafood products (May, 2004). PAH in seafood would have to be assessed specifically and decisions would be taken in accordance with the general Food Acts, which states that food should not endanger human health. As that it is well known that some of the PAH components have confirmed carcinogenic effects, they should in principle not be found in foodstuffs. However, they are present in a wide spectrum of foodstuffs and for one food product, olive residue oil, also called “pomace oil” official limits have been established in Sweden, Finland and Norway. Furthermore, the EU legislation has a limit for benz[a]pyrene transferred into foodstuffs by the use of smoke flavours, but has started to draft legislation with limits for PAH in several foodstuffs (2003). In the legislation on drinking water there is a limit for oil components of 0.7 microgram/kg of benz[a]pyrene.

Economic concerns

If a decision were taken to ban fisheries in a contaminated area for a period of time, the fishermen in the area would lose their income. Large fishing boats may be able to fish in other areas, but the smaller ones, may not be able to go very far from their normal fishing grounds. On the other hand, export markets could react negatively if no action is taken. In addition it should be considered that insurance companies might interpret the risk management decisions in a such a way that may be negative for the fishermen and reduce their compensation claims for loss of income.

Potential consequences

Oil pollution in an area can affect the environment for a considerable period of time. This may have consequences for the benthic fauna and flora and may therefore also have an indirect effect on fish etc. by restricting their prey items.

Consumer perception of risks

Consumers in the Nordic countries demand safe food, and they normally react quickly to potential risks. Consumer perception of a risk could ruin the market for seafood, however, during the years, consumers have never raised questions concerning contamination of fish for human consumption in areas polluted by oil spills, with the exception of fish from areas with visible oil spill. Consumers would nevertheless be aware of the risk if they were asked directly.

Distribution of risks and benefits

Fish for human consumption should be safe for consumers and should comply with the general requirements in the Food Acts. Even though there are economical consequences for fishermen if fisheries are banned for long periods of time, it is also beneficial for them in terms of compensation from the insurance of the oil transporting company and for their credibility in export markets.

A number of PAH have been assessed by the EUs Scientific Committee for Food (33 PAH), but several are not yet assessed. Third world countries often rely on risk assessments and guidelines from Codex Alimentarius, but this organisation has not assessed PAH or contamination from oil in general.

4.3.3 Ranking of the hazard for risk assessment and risk management priority

The final risk management conclusion of the risk evaluation should end up with either

- a. Setting the frame for the risk assessment of the safety problem. The frame should specify which toxic components should be assessed, if there are special limits on the task, for example. only some of the components in the oil should be assessed, which degree of uncertainty would be acceptable etc. *or*
- b. A decision not to carry on with the risk analysis, and thereby a decision not to continue with a risk assessment.

For emergency situations, a general, risk management decision could be taken onto whether a detailed risk assessment is required or if decisions in certain situations could be taken without a risk assessment. A decision on not to start could be based on the evaluation of available resources and time, the safety level requested, deadlines etc.

However, oil spills are in many cases a major disaster due to the multitude of effects on the environment, birds and other animals, fishing gear etc. As areas affected by oil spills are often important for commercial fisheries the risk assessment and management should give it high priority.

Ranking the hazards should take into account other food safety risks and prioritise the tasks to be done.

This is an important step particularly since public authorities often have limited resources. In most countries, a major oil spill involves many different authorities; which might not normally co-operate, and may not have joint emergency responses which take food safety into account.

4.3.4 Establishment of a policy for conducting risk assessment

The risk assessment policy should be developed in full collaboration with risk assessors and serves to protect the scientific integrity of the risk assessment. Like the other steps of the risk analysis, the guidelines should be documented so as to ensure consistency and transparency.

Risk assessment policy setting should consider

- Establishment of population(s) at risk
- Criteria for the ranking of hazards,
- Guidelines for the application of safety factors

The risk assessment should include information on which *calculated uncertainties* there would be in the results and highlight which parts of the decision should be discussed with for example risk managers before final conclusions are made. The uncertainties in the risk assessment could be caused by use of data based on average exposure, model calculation, limited data available etc. This would be important information for the risk managers in decision-making.

The risk assessment should include a calculation of the population at risk at different levels of PAH in the seafood. The starting point being that 100% of the population should be at no-risk. However, as PAH are genotoxic, this would require a zero-level, which would not be possible, as PAH are found in the environment due to pollution in general.

Data required would preferably be analyses of background levels in seafood from the area before the accident, levels in the seafood after the accident and during a period of time after, for example three month, depending on the temporal trend in concentration.

Intake data should include data on vulnerable groups, for example children. It is acceptable to use modelling, as long as the uncertainties in the methods used are clearly stated with the results.

4.3.5 Commitment of resources

The commitment of resources is an important part of the risk evaluation. A thorough risk analysis requires resources including scientists, managers, analysts, communicators etc. An estimation of resources needed should form part of the risk evaluation and decision whether a risk analysis should be started or not.

In some cases, a safety problem cannot be solved nationally, so the analysis should be conducted in an international forum.

For the specific scenario in the present project it would be most appropriate to have a three-nation co-operation to evaluate the risk of the oil spill to the consumer. It is also evident that the analytical methods for PAH determination should be strictly validated before any project starts, this should also be a co-operative process.

Since oil spills are often emergency situations, an emergency response should exist, specifying the information required and responsible persons and contact points. Current emergency response for oil spills in many countries do not include the risk analysis of seafood safety hence resources are not allocated for analyses etc. The emergency response plan should include resources for an acute risk assessment and analyses, both organoleptic and chemical. A list of laboratories accredited for the relevant analyses should also be part of the emergency response plan.

Given the importance of the speed of response and decision-making, resources may be available from the Nordic Council of Ministers or from the EU, for developing joint emergency response systems concerning seafood.

4.3.6 Commissioning of a risk assessment

In this step, a procedure will be followed where valid criteria pertaining to the selection of assessors and the resources (financial, time, data, ad hoc expertise etc.) will be established. The assessor(s) selected must be scientifically competent, independent from identified stakeholders, have an established quality control for their activities etc.

Communication should also be addressed, specifying, who would be responsible for communicating specific parts of the risk analysis to the media.

5 Risk assessment, including exposure assessment

Risk assessment consists of 4 steps:

Hazard identification Hazard characterisation Exposure assessment Risk characterization
--

Risk assessment should be scientifically-based, should be transparent and conducted according to a structured approach. Furthermore, risk assessment should comprise a presentation of uncertainties, assumptions and variability of inputs. It should be reassessed and re-evaluated over time, include the presentation of costs, resources and time and finally it should be flexible and related to real life situations.

The hazard identification takes its starting point in the definition of hazard, when considering food safety.

Hazard is defined as: A biological, chemical or physical agent in, or condition of, food with the potential to cause an adverse health effect.

Hazard identification is defined as “The identification of biological, chemical, and physical agents capable of causing adverse health effects and which may be present in a particular food or group of food”. In most cases, scientists like food toxicologists, microbiologists, medical doctors or other professionals will identify a hazard but consumers, politicians and others do also raise questions that start a risk analysis.

The “ideal model” for the decision procedure in the hazard identification step would comprise the initiation of a risk assessment of the problem, once the food safety problem was identified. Then the starting point would be the solid documentation included in the risk profile.

Hazard characterization should be the next step in the risk assessment. In Codex, the definition of hazard characterization is the following: “The qualitative and/or quantitative evaluation of the nature of the adverse health effect associated with biological hazards, chemical and physical agents, which may be present in food. For chemical agents, a dose-response assessment should be performed. For biological or physical agents, a dose-response assessment should be performed if data are obtainable”.

Scientists often make hazard characterization based on animal testing. The result of hazard characterization should include uncertainties like the safety factors used, as safety factors are often used when the data is not necessary solid.

Exposure assessment is defined in Codex as “The qualitative and/or quantitative evaluation of the likely intake of biological, chemical, and physical agents via food as well as exposures from other sources if relevant”.

Exposure assessment is a subject dealt with in many international guidelines on for example food additives, pesticides, flavourings etc. Exposure assessment is based on scientific knowledge on consumption pattern, surveys etc. Since consumption surveys are very expensive and as the consumption pattern changes over time, the assessments are in many cases based on models simulating the real intake of food. These models are often developed through international cooperation and accepted in the guidelines for risk assessment. The exposure assessment should include an evaluation of the problems of cross contamination and possible differences in hygienic behaviour, both in the industrial production and in preparation by the consumer at home. Some of the fundamental assumptions are, however, management decisions and should be incorporated in the risk assessment results as uncertainties. Furthermore, the exposure assessment will often include decisions on how big a percentile of the population should be secured. This is also a risk management decision.

Risk characterization is the last step in the risk assessment process. Risk characterization is defined as “The qualitative and/or quantitative estimation, including attendant uncertainties, of the probability of occurrence and severity of known or potential adverse health effects in a given population based on hazard identification, hazard characterization and exposure assessment”.

The scientists involved in the risk assessment, should point out the uncertainties and assumptions made during the assessment, when reporting the risk assessment results. Uncertainties in risk assessment are discussed in general in the project Food Safety in Europe: Risk Assessment of Chemicals in Food and Diet, 2002 and Risk Characterisation of Chemicals in Food and Diet 2003. The discussion and consideration should involve the risk managers, including politicians.

5.1 Introduction to the risk assessment

Oil is a complex mixture of thousands of chemical compounds formed from a variety of organic materials that have been chemically converted under certain geological conditions and time scales.

The main components of oil are aliphatic and aromatic hydrocarbons including a range of heterocyclic compounds containing nitrogen, sulphur and oxygen. In addition to organic compounds oil also contains a range of metallo-organic complexes (porphyrins) containing especially nickel and vanadium. In figure 5.1, the main fractions of structural related organic components in crude oil are illustrated, see also Chapter 2.

Saturated aliphatic hydrocarbons (the n-alkenes) from C₄-C₄₀ are the dominating constituents in crude oil. Compounds containing one to seven condensed aromatic rings and their alkylated derivatives dominate the aromatic fraction. Among these the low molecular weight monoaromatics are the most abundant in crude oil.

The relative composition of the various substances can be used for the identification of the oil and assessment of the toxicological potential of the oil spill.

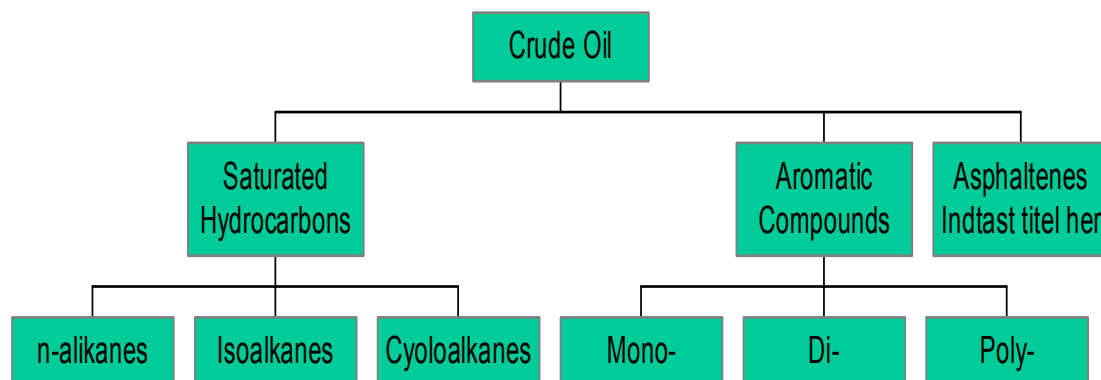


Figure 5.1. Main fractions of structurally related petroleum compounds (from Storstrøms County, 2002)

For human risk assessment the polycyclic aromatic hydrocarbons (PAH) are considered the most important compounds in oil.

PAH constitute a large class of organic compounds containing two or more fused aromatic rings made up of carbon and hydrogen atoms. Although studies in experimental animals on individual PAH, have shown various toxicological effects, such as haematological effects, reproductive and developmental toxicity and immunotoxicity, the critical effects, which can occur at very low doses, are carcinogenicity and genotoxicity. The carcinogenic and genotoxic potentials of PAH are largest among the high molecular weight PAH, i.e. compounds with 4 rings or more.

It is well known that oil spills can have great impacts on the environment (Storstrøms County, 2002). However, the main focus in this project will be on the human risk associated with consumption of seafood after an oil spill. For human risk assessment PAH are considered the most important compounds in oil and only these compounds will be evaluated in the present project.

5.2 Hazard identification of PAH

Thirty-three PAH has recently been evaluated by the SCF (2002). A short review of this opinion will be given here.

5.2.1 Absorption, distribution and excretion

The absorption of PAH from food is in the range of 20-50% and increases with increasing lipophilic components (e.g. fat) in the food. Table 5.0 gives some examples of the lipid content in fish.

Table 5.0 Fish categories and fat content (Balanced view on fish, Andersen et al., 2003)

Catagory	Fat content (gram fat per 100 grams of fish)	Examples
Fat fish	more than 8	Salmon, eel, herring, hali-but, mackerell
Medium fat fish	2-8	Trout, turbot
Lean fish	less than 2	Cod, plaice, tuna, flounder

Shellfish do normally have a relatively low fat content. In Braussant et al. (2001) the average fat content in mussels was 2 g/100 g. The fat content in roe varies, but is also generally low (around 2 g/100 g) (Andersen et al., 2003). PAH are well distributed in almost all organs and crosses the placenta in rodents and have been detected in human breast milk. PAH metabolites are excreted in urine, bile and faeces.

5.2.2 Metabolism

PAH are metabolised by a number of different phase 1 and phase 2 enzymes. Different pathways have been considered. In figure 5.2 the metabolism of benzo[a]pyrene (B[a]P), the most extensive studied PAH, and dibenz[al]pyrene (DBP) is illustrated (for more details se IPCS, 1998). The most prominent pathway of PAH metabolism involves oxidation by different cytochrome-P450 isozymes especially CYP1A1 and CYP1B1 to a range of primary phase 1 metabolites: epoxides, phenols and dihydrodiols (Fig. 5.2). Epoxide hydrolases can convert the reactive epoxides to diols. However, the diol and phenol metabolites of for example benzo[a]pyrene are still able to fit the active sites of the phase 1 enzymes and this results in the introduction of a second epoxide group into the metabolite. These reactive metabolites can react with DNA and form DNA adducts or they can be deactivated by phase 2 enzymes by conjugation with glutathione, glucuronic acid or sulphate (Fig. 5.3). The reactivity of the resulting diol or hydroxy epoxide depends on the relative positions of the substituents since this affects the electrophilicity of the compound. The existence of a bay (B[a]P) - or fjord region (DBP) stabilises the electrophilic intermediates and thereby enhances the tendency to react with macromolecules like DNA, RNA and proteins. The 7,8-diol-9,10-epoxides are considered to be the ultimate genotoxic/carcinogenic metabolite.

5.2.3 Genotoxicity of PAH

As mentioned above, thirty-three PAH were evaluated by the SCF (2002). Among these, 15, namely benz[a]anthracene, benzo[b]-, benzo[j]- and benzo[k]fluoranthene, benzo[ghi]perylene, benzo[a]pyrene, chrysene, cyclopenta[cd]pyrene, dibenz[a,h]anthracene, dibenzo[a,e]-, dibenzo[a,h]-, dibenzo[a,i]-, dibenzo[a,l]pyrene, indeno[1,2,3-cd]pyrene and 5-methylchrysene show clear evidence of mutagenicity/genotoxicity in somatic cells in experimental animals *in vivo*. The most potent PAH appear to be compounds with a bay- or fjord region (Fig. 5.2.).

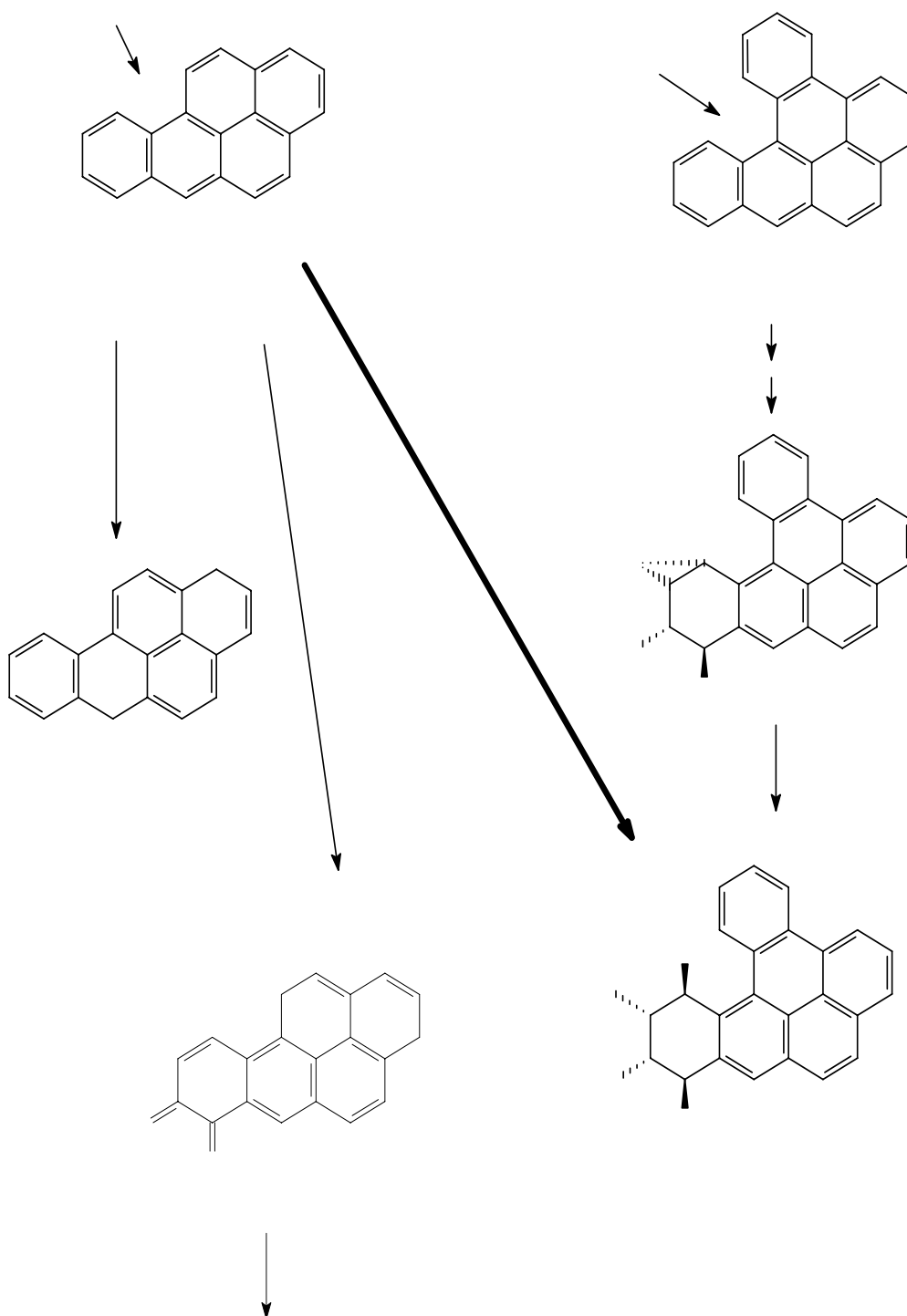


Figure 5.2. Activation of Bay and Fjord region PAH by phase I enzymes (adapted with a few modifications from IPCS, 1998). ROS = Reactive Oxygen Species.

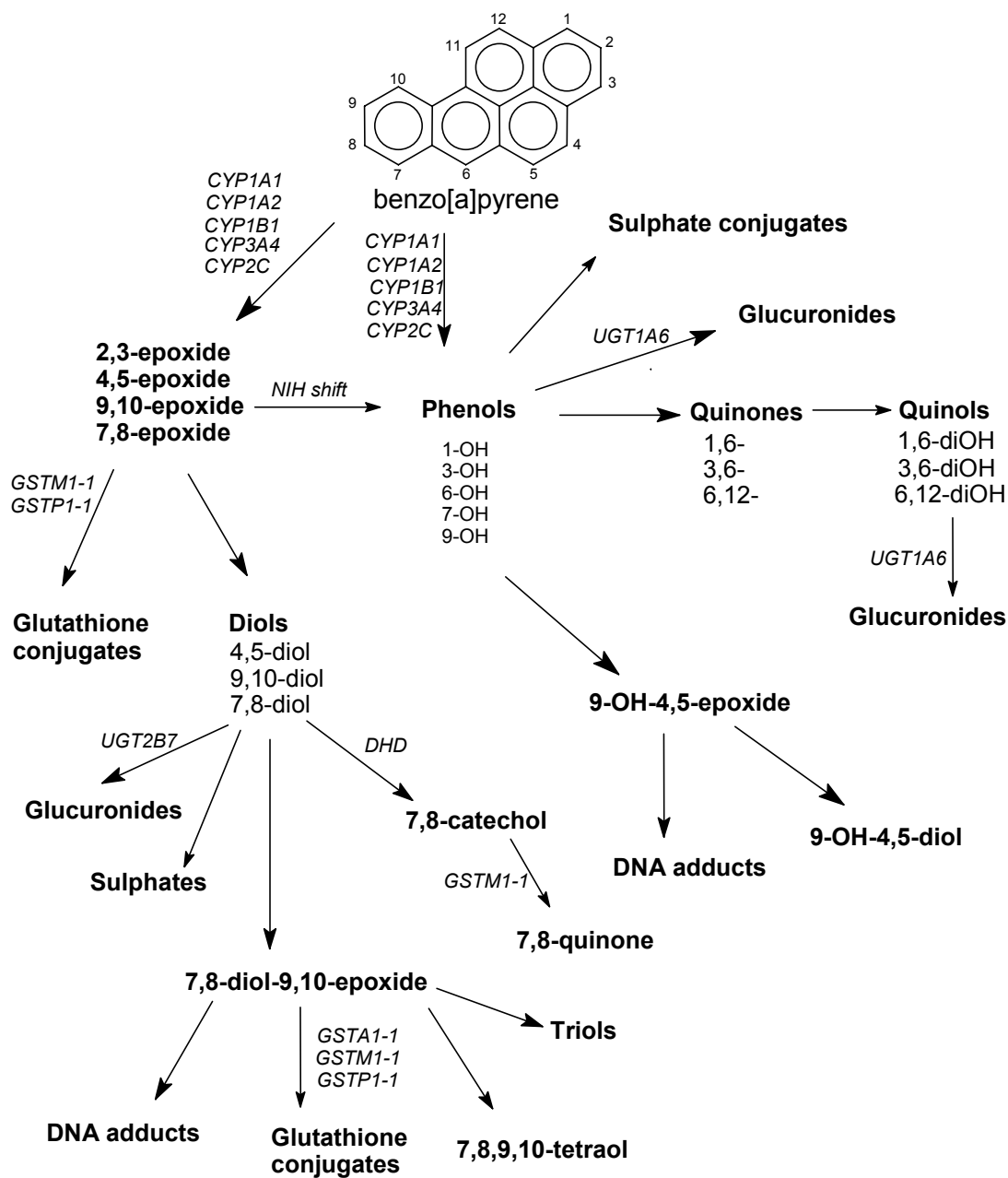


Figure 5.3 Metabolism of benzo[a] pyrene including activation by phase I enzymes (CYP) and deactivation by phase 2 enzymes (GSTA, GSTM, GSTP, UGT) (adapted from Beserati, 2001).

5.2.4 Carcinogenicity of PAH

For most of the PAH, it is the carcinogenic potential that constitutes the critical effect for the hazard and risk characterization. A number of PAH, as well as coal tars and various complex mixtures containing PAH from combustion emissions, have shown carcinogenicity in experimental animals and genotoxicity and mutagenicity *in vitro* and *in vivo*.

In general, the evidence of genotoxicity shows considerable overlapping with carcinogenicity in agreement with the mechanistic link between DNA adduct formation, mutations, and cancer outcome following PAH exposure.

With the exception of benzo[ghi]perylene the 15 genotoxic PAH have also shown clear carcinogenic effects in various types of bioassays in experimental animals. Although only benzo[a]pyrene has been adequately tested using dietary administration, these compounds may be regarded as potentially genotoxic and carcinogenic to humans. They represent a priority group in the assessment of the risk of long-term adverse health effects following dietary intake of PAH.

5.3 Hazard characterization

For hazard characterization of human PAH-exposure from ambient air epidemiological data exist on lung cancer death in relation to workplace exposure (mainly coke-oven emissions). However, there are no human data available that can be used for the assessment of the health effects of PAH exposure from food. Therefore, the assessment must rely on results from studies using experimental animals. Also, most studies assess the carcinogenic potential of single PAH following dermal, subcutaneous, or inhalation exposure and only a limited number of studies following oral administration.

Humans are almost only exposed to mixtures of chemicals, which is also the case if humans eat seafood from oil-polluted areas. A complex PAH mixture like oil can contain many hundred PAH. Only a few of them are identified and toxicological data exist for only a restricted amount of individual PAH. In addition, international bodies have only evaluated a few mixtures of PAH.

5.3.1. Estimation of quantitative risk of B[a]P

As a number of PAH have shown genotoxic and carcinogenic potential, the existence of a threshold cannot be assumed. Instead, quantitative risk estimates in the form of a “slope factor” (human excess cancer risk from oral lifetime exposure to 1 mg B[a]P/kg bw/day) or a “virtually safe dose” (VSD) (a daily dose through the entire lifetime associated with an acceptable lifetime cancer risk of e.g. 1 per 10^5 or 1 per 10^6) can be calculated from dose response-data in long term animal studies. A VSD for a certain risk level can be derived from a cancer “slope factor” by linear extrapolation, but other calculation models have also been used (SCF 2002).

All models imply extrapolation from high doses in animal studies to lower human exposure levels, providing a conservative estimate of the potential cancer risk. The actual risk might be much lower.

Several authors have estimated a VSD from recent studies in rodents. Despite different calculation models, similar results were obtained. The calculated VSDs of benzo[a]pyrene ranged from approximately 0.6 ng/kg bw/day to 5 ng/kg bw/day for a risk level of 1×10^{-6} , when based on all tumours combined.

In some countries, risk managers set the acceptable lifetime cancer risk. Typical risk levels in cancer risk calculations are 10^{-6} or 10^{-5} .

The use of mathematical models has been discussed by the SCF (2002). Traditionally SCF recommend to use the ALARA principle (As Low As Reasonably Achievable) for genotoxic and carcinogenic compounds such as PAH. The Committee has reservations about the use of mathematical modeling to extrapolate from animal tumour data in order to estimate risks to humans at low exposure levels to substances that are both genotoxic and carcinogenic for the following reasons:

- 1) It is rarely known, for a particulate substance, whether a given model actually reflects the underlying biological processes,
- 2) There is no agreement between regulatory bodies as to which model should be used, and
- 3) The numerical estimate of risk obtained is dependent on which model is used.

This can result in estimates of risk for the same substance varying by several orders of magnitude, depending of the model selected.

In spite of the drawbacks of using models, this project group decided to make some calculations in order to illustrate the consequences of PAH pollution in seafood. In the risk calculation examples given in section 5.7.1 the highest VSD with a lifetime cancer risk of 10^{-6} is used as an example.

5.3.2 Hazard assessment approaches

The VSD mentioned in 5.3.1. is the virtually safe dose of one substance, B[a]P. Oil spill exposure as well as many other PAH exposures result in exposure to a mixture of PAH. Different approaches exist for human hazard assessment of mixtures of PAH. The two most common approaches are the TEF approach and the surrogate/indicator approach (mostly B[a]P). They are discussed below.

TEF-approach

Several attempts have been made to derive relative potency factors, expressed as toxic equivalency factors (TEF) for individual PAH (relative to benzo[a]pyrene) with the purpose of summarising the contributions from individual PAH in a mixture into a total benzo[a]pyrene equivalent dose, assuming additivity in their carcinogenic effects.

When using the TEF approach different assumptions are made:

- 1) *It is assumed that all toxicologically relevant PAH are identified.* However, only a few PAH are identified and recent oral studies indicate that other compounds than the normally identified PAH might be responsible for genotoxicity/carcinogenicity in some organs (Koganti et al., 2000).
- 2) *Using the TEF approach, values should be known for each toxicologically relevant PAH.* However adequate animal data exist for only a few compounds, which can be used for calculation of a TEF value, and different values are used in different studies.
- 3) *The TEF approach relies on additive effect of individual PAH.* However, PAH can act in many different ways resulting in synergistic (more than additive) and antagonistic (less than additive) effects. This was shown in studies on mixtures of individual PAH showing that they may interact metabolically in a number of

ways resulting in not only additive but also synergistic and/or antagonistic effects.

- 4) *The use of the TEF approach requires that the compounds in question exert the toxicological effects by the same mechanism of action*, such as is the case for polychlorinated dibenzo-p-dioxins and dibenzofurans, which act through binding to the Ah-receptor. Although a number of PAH bind to the Ah receptor, this effect is not the only effect that determines the carcinogenic potency of PAH. DNA binding and induction of mutations are other significant effects in the carcinogenesis of PAH, and there is no indication that different PAH are activated via the same metabolic route, bind to DNA in the same positions, and induce the same types of mutations in the same organs or tissues.

The TEF values have recently been evaluated on the basis of new long-term oral carcinogenicity studies where coal tar mixtures and B[a]P were tested in the same studies (Culp et al., 1998; SCF 2002; Schneider et al., 2002). These studies show that the TEF approach generally underestimates the potency of the mixture. Figure 5.4 taken from Schneider et al (2002) illustrates this underestimation. The TEF values used in this study were from Brown and Mittelsmann (1993).

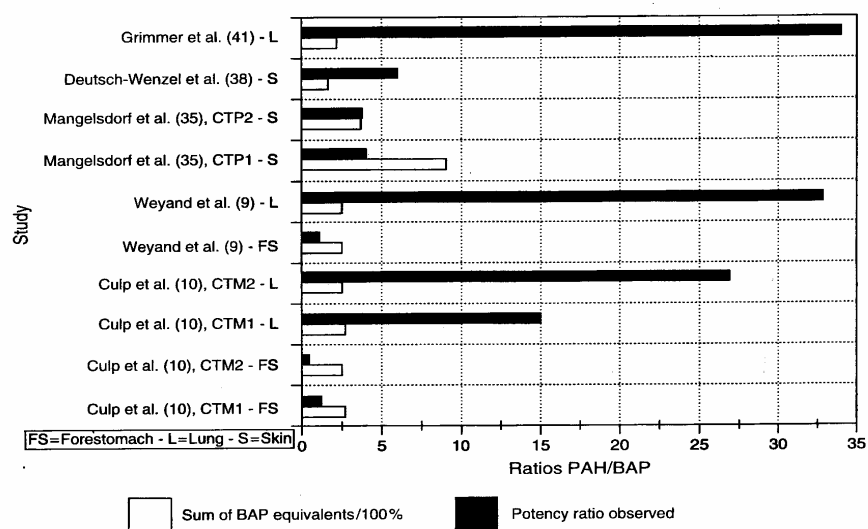


Figure 5.4 Comparison of potency ratios (carcinogenic potency of PAH versus B[a]P in the same bioassay with predictions based on relatively values (B[a]P equivalency values).

When the TEF values derived by Larsen and Larsen (1998) were used, the carcinogenic potency of the two coal tar mixtures, tested by Culp et al., 1998, was predicted to be only approximately 1.5 times that of the benzo[a]pyrene content. However, the observed potencies of the coal tar mixtures were up to 5 times that accounted for by the benzo[a]pyrene content. In this case, the use of the TEF approach would underestimate the PAH carcinogenicity by a factor of 3-4. However, in some cases for example where the PAH profile in food is different from the PAH profile in coal tars the TEF approach might be a better approach. Evaluating the chemical data from fish farms in Grønsund 1½ month after the Baltic carrier accident, B[a]P could not be detected in the trout, however other genotoxic/carcinogenic PAH were measured. In this case the surrogate (B[a]P) approach (described in the next section) could not be used, and therefore the TEF approach was used (se Annex III.a).

5.3.2.2 The surrogate (B[a]P) approach

In the surrogate approach only a single compound is used as an indicator for the whole mixture. This indicator PAH is generally B[a]P because this compound is one of the most potent and intensively studied PAH. Therefore, in the following the surrogate approach is referred to as the B[a]P approach.

The assumptions used in this approach are:

- 1) *The PAH profile in different mixtures are the same or similar.* It was shown (SCF 2002) that the profiles (ratio relative to benzo[a]pyrene) of the measured carcinogenic PAH were surprisingly similar in various foods, irrespective of the supposed origin of the PAH contamination. Overall, these profiles seemed to vary within a factor of less than five. Furthermore, it was shown that the profile of the measured carcinogenic PAH in the coal tars used in the studies of carcinogenicity in mice varied within a factor of less than two from that seen in foods.
- 2) *The potency ratio (potency mixture/potency surrogate compound) of the defined mixture is known for the defined exposure pathway.* The potency ratios for defined tumour locations and exposure pathway have been shown to be the same for a wide range of PAH mixtures.

Recent studies (Culp et al., 1998; Schneider et al., 2002) indicate that the B[a]P approach is the most suitable to express the potency of a PAH mixture following oral exposure to polluted soil. This approach is also recommended by the SCF for the assessment of the risk of PAH in food (2002).

Assuming a less than 2-fold variation between the profiles of carcinogenic PAH in the coal tars and in various foods, and the finding that the carcinogenic potencies of the coal tar mixtures could be up to 5 times that predicted by their benzo[a]pyrene content, a conservative assessment would imply that the carcinogenic potency of total PAH in foods would be 10 times higher than expected on the basis of the benzo[a]pyrene content alone.

According to chapter 5.3.1. a “virtually safe dose” of benzo[a]pyrene alone range from 0.6 to 5 ng B[a]P/kg bw/day with a cancer risk of 10^{-6} .

If B[a]P is used as a marker of the mixture of carcinogenic PAH in food, the VSD for B[a]P in the mixture would range from 0.06 to 0.5 ng B[a]P/kg bw/day with a cancer risk of 10^{-6} .

Accepting a risk of 1×10^{-5} the VSD of B[a]P in mixtures would be in the range of 0.6 to 5 ng B[a]P/kg bw/day for a mixture with the same or close to the same PAH profile as the investigated coal tars. However, further studies on the content and distribution of PAH in food are needed and indeed only a few studies of PAH in polluted seafood exist.

5.4. Exposure assessment

5.4.1 Exposure to PAH – in general

There are several routes of exposure to PAH; the major ones are via food and inhaled air. The exposure via air includes PAH in tobacco smoke, cooking fumes, exhaust from vehicles etc. For non-smoking humans, food is the main source of exposure to PAH. The PAH in food may be formed during processing and food preparation for example smoking and barbecuing. PAH may also be present in food because of environmental contamination for example atmospheric deposition on vegetables and accumulation in marine organisms of PAH present in the water. An estimated mean total daily dietary intake of B[a]P in Finland is 266 ng/day, whereas in Norway it is only 26.3 ng/day for men and 16.5 ng/day for women (SCOOP, unpublished, March 2004). However, it should be noted that the measurements are not directly comparable since the methods of analysis and the management of the data under the limit of detection may be different. Furthermore, only selected food items have been analysed and therefore the data used for the estimations do not cover the whole diet; the total daily intake of B[a]P may be underestimated.

Comparable data on intake of individual PAH have been calculated from five surveys conducted in six EU countries (UK, Italy, The Netherlands, Austria, Germany and Sweden). Mean or nation averaged dietary intake of B[a]P for an adult was between 50-290 ng/day with a worst case scenario estimated for the Netherlands of 420 ng/day (SCF, 2002). The dietary intake of B[a]P in Sweden was estimated to be 80 ng/person/day. In a survey from the UK, the dietary intake by children of B[a]P as well as the sum of PAH on a per kg bodyweight basis was inversely correlated with age. The age group 1.5-2.5 years had an intake 2.4 fold higher than adults (3.8 ng of B[a]P and 166 ng of sum PAH/kg bw/day) (SCF, 2002).

From the SCOOP project (unpublished, March 2004) the contribution from different groups of foodstuff for example seafood, to the total dietary intake of B[a]P can be estimated, but since the SCOOP data do not cover the whole diet the estimations are not very reliable. The figures differ between countries for example the mean intake of B[a]P via seafood was estimated to constitute 0.6% of the total intake of B[a]P in Finland and approximately 30 % in Norway (see also Annex III.b).

As for the total intake of B[a]P (previous section), these differences between countries are not necessarily due to actual differences but may be due to differences in the available data on which the estimates are based.

The Danish Food and Veterinary Administration have published a report on the Balanced View on Seafood Intake (Andersen et al., 2003).

In the report, it was estimated that for an adult in Denmark, the intake of B[a]P via seafood constitute at maximum 4 % of the total intake of B[a]P.

This estimate was based on a worst case total dietary intake of B[a]P estimated for the Netherlands of 420 ng/person/day (SCF, 2002) and the estimated intake of B[a]P via seafood in Denmark (2.4 – 5 ng B[a]P/person/day). This exposure to B[a]P via seafood includes smoked seafood but although smoked seafood has relatively high concentrations of PAH, it is only a minor part of the normal diet.

5.4.2 Seafood consumption

5.4.2.1 Denmark

Information on the Danish consumption of seafood can be obtained from two different sources: purchase registrations from “Dansk Husstandspanel” and a nation-wide survey on dietary habits conducted in 1995 by the Danish Food and Veterinary Administration (LST, 1995).

In the nation wide survey the study population included 1,837 adults between 15-80 and 1,261 children who provided detailed data on their food consumption by the use of a 7-day prospective food record with a pre-coded questionnaire with answering categories for the most commonly eaten foods in the Danish diet. The data were collected in three different periods during a year. The survey was repeated in 2000-2001, but the data processing was not completed at the time of the data collection for the present risk assessment and therefore in the present risk assessment, data from the survey in 1995 will be used. Based on intermediate results there appears to be a slight decrease (3g/day for children and 5 g/day for adults in the total intake of seafood from 1995 to 2001 (Andersen et al., 2003)). The decrease can partly be explained by differences in how the data were collected in the two surveys, but may also reflect a decreasing tendency in seafood consumption. If the latter is the case, the seafood consumption data from 1995 will at least not underestimate the present intake.

The average and 95th percentile intake of seafood in 1995 by children (1-3 years) and adults is presented in Table 5.1. The rate of consumers is the percentage of persons that consumed seafood belonging to the particular seafood category during the one week of dietary registration. The intake of seafood by the age groups 4-6 and 7-14 years old is presented in Annex III.c.

The total intake of seafood for a 72 kg person on average was calculated to 23 g/day with high consumers (95th percentile) eating 66 g/day. On a per kg bodyweight basis the total daily intake of seafood decreases with increasing age (See Annex III.c). This trend also applies to the intake of the different categories of seafood except for the intake of shrimps, salmon and herring where adults eat the same or more (herring) compared to the children (Table 5.1 and Annex III.c).

The intake of mussels was not recorded in the Danish dietary survey, but from “Dansk Husstandspanel” (cited by Andersen et al., 2003) the purchased amount of mussels in cans are 0.03 g/day in average. For fresh mussels no data are available (purchased or consumed).

Table 5.1. The intake of seafood in Denmark by children (1-3 years) and adults (15-80 years)

seafood item	Children, 1-3 years			Adults, 15-80 years		
	g/kg bw/day		rate of consumers (%)	g/kg bw/day		rate of consumers (%)
	average	95 th percentile		average	95 th percentile	
Plaice ⁵	0.14	0.67	42.3	0.07	0.28	42.7
Cod ⁵	0.17	0.69	47.7	0.07	0.28	48.4
Cod roe ⁵	0.11	0.44	53.4	0.02	0.08	36.3
Mackerel ¹	0.12	0.40	67.7	0.05	0.17	74.3
Herring ²	0.05	0.37	14.7	0.07	0.30	45.6
Salmon ⁵	0.01	0.00	4.7	0.01	0.07	14.2
Tuna ³	0.09	0.30	64.5	0.02	0.08	58.6
Shrimp ⁴	0.01	0.02	7.9	0.01	0.09	22.6
Total intake	0.70	1.99	82.1	0.32	0.92	88.7

Data from Fødevaredirektoratet, pers. comm. (2003)

¹Mackerel includes raw, smoked and canned mackerel in tomato sauce.

²Herring includes raw, pickled and smoked herring.

³Tuna include only canned tuna.

⁴Shrimps include both frozen and canned shrimps.

⁵Salmon, cod and plaice include only raw seafood.

⁶ The total number of test persons in each age group: 1-3 years: 279; 4-6 years: 272; 7-14 years: 710; adults: 1837

⁷ The average bodyweight in each age group: 1-3 years: 14.1 kg; 4-6 years: 20.7 kg; 7-14 years: 38.7 kg; adult: 72 kg

5.4.2.2 Norway

In Norway, a national dietary survey was carried out in 1997 (NORKOST 1997) (Johansson et al., 1999). In the survey 2,672 persons between the ages of 16 to 79 years participated.

The participants answered a quantitative food frequency questionnaire, which was distributed and collected in four different periods spread throughout the year and the results from the survey describe the usual diet among the participants.

A more recent dietary survey was carried out to investigate the intake of foods that may have significant effect on the intake of environmental contaminants and the survey therefore contains detailed information on the consumption of seafood (Fish- and Game Survey (Meltzer et al., 2002)). The study included 6,025 persons between 18 and 79 years old. The participants answered questions about frequency of consumption of seafood and game.

The quantitative consumption was estimated in the survey on the basis of the frequency of consumption and standard weights of servings (from NORKOST 1997).

In table 5.2, the estimated intake of different seafood species in Norway is presented both from the detailed "Fish and Game Survey (Meltzer et al., 2002) and from NORKOST 1997 (as cited in Meltzer et al., 2002). The intake was calculated based on average size of servings, and in the present assessment mean bodyweights of men (81 kg) and women (66 kg) from NORKOST 1997 were applied in order to estimate the

consumption on a per kg bodyweight basis. For comparison the intake of seafood by adults in Denmark (Table 5.1) is also included in Table 5.2.

The total consumption of seafood was on average 70 g/day (average size of servings) and high consumers (large size of servings) could eat as much as 140 g/day (Meltzer et al., 2002).

The estimated average intake of seafood in Norway is higher than in Denmark. According to the surveys, the higher intake of fish in Norway covers a higher intake of cod and cod roe, tuna, salmon and prawns, whereas Danes eat more herring and plaice compared with Norwegians.

The comparison between the surveys should be viewed with caution, since the method used in the studies differs, for example with regards to the categories of seafood and the degree of details in the questionnaire.

Table 5.2. The estimated intake of seafood in Norway based on quantitative food frequency questionnaire and standard weights of servings (average)

Seafood item	Norway (Fish and Game Study, 2002) ^{1,2} (g/kg bw/day)		Norway (NORKOST, 1997) ¹ (g/kg bw/day)		Denmark, adults (g/kg bw/day) ³	
	mean, men	mean, women	mean, men	mean, women	mean	95 th per- centile
Cod	0.15	0.15			0.07	0.28
Cod, roe	0.05	0.01			0.02	0.08
Cod, liver	0.01	0.06				
Coalfish	0.11	0.12				
Coalfish, liver	0.01	0.01				
Halibut	0.05	0.06				
Plaice, flounder etc.	0.04	0.05			0.07	0.28
Mackerel	0.05	0.05	0.02	0.02	0.05	0.17
			0.08	0.07		
Herring	0.04	0.03			0.07	0.3
Tuna	0.09	0.09	0.03	0.04	0.02	0.08
Salmon etc	0.16	0.15	0.08	0.07	0.01	0.07
			0.02	0.02		
Eel	0.01	0.03				
Marine fish, other	0.07	0.08				
Prawn	0.10	0.11			0.01	0.09
Crab	0.10	0.12				
Mussels etc.	0.01	0.02				
Shell fish			0.06	0.06	0.0004 ⁵	
Fish cakes, fishspread etc.,	0.05	0.06				
Total	1.1	1.2	0.3 ⁴	0.3 ⁴	0.32	0.92

¹ Fish and Game Survey (2002)

² The average body weight from NORKOST (1997) has been used to estimate the intake per kg body-weight (women=66 kg, men=88 kg)

³ Data from Fødevaredirektoratet, pers. comm.

⁴ Not the whole seafood diet is included in these figures; the total seafood intake in the NORKOST was 65 g/person/day that corresponds to approximately 1 g/kg bw/day.

⁵ Andersen et al. (2003)

5.4.2.4 Iceland

The Icelandic National Nutrition Survey was carried out in 2002. A random sample of 2000 people, 15-80 years of age, was drawn from the national population register. The net participation rate was 70.6%. The dietary assessment method was 24-hour recall and the data was sampled by telephone interviews.

The mean consumption of fish and fish products was 40 g/day, which is in between the mean estimated intake of seafood in Denmark and Norway. Consumption in relation to age and sex is shown in the table 5.3.

Table 5.3 *The estimated average intake (g/day) of seafood in Iceland by both sexes and by different age classes.*

Icelandic National Nutrition Survey 2002. Consumption of fish and fish products			
	Age	g/day	s.d.
Male	15 - 19	20	59
	20 - 39	42	80
	40 - 59	62	101
	60 - 80	65	102
Female	15 - 19	15	39
	20 - 39	23	48
	40 - 59	35	68
	60 - 80	47	63
All		40	76

The Diet of Icelanders. Dietary Survey of
The Icelandic Nutrition Council 2002

5.4.2.5 Sweden

In 1997-98, Statistics Sweden carried out the second nation-wide Swedish dietary survey in co-operation with the National Food Administration (NFA) (Riksmaten, 1997-98). Approximately 1200 persons, 19-74 years old filled in a pre-coded 7-days record book.

For seafood the mean consumption of seafood was approximately 35 gram/day/person for both males and females, which is similar to the mean Icelandic intake and in between the mean estimated intake of seafood in Denmark and Norway.

5.4.3 PAH in seafood

5.4.3.1 Background concentrations

Oil spills do not necessarily impact clean areas unaffected by PAH contamination, since PAH are ubiquitous contaminants. Data from the International Council for the Exploration of the Sea (ICES) has been used as representative of background concentrations of PAH in seafood and other marine organisms. Since data on background concentrations of PAH are scarce it has not been possible to collect data on organisms caught at or close to the position of the imaginary accident assessed in the present report.

Table 5.4 presents the mean concentrations of PAH measured in organisms caught between approximately 53-71° N and 2-67° E. Data for freshwater species have been used in some cases where data for marine species is lacking.

The samples were taken between 1992 and 1996. The concentration of other PAH than those presented in Table 5.4 were also measured. In total the concentration of 19 PAH were analysed, but in the present report only those that show clear evidence of mutagenicity/genotoxicity (SCF, 2002) are specified. For most of the fish species both liver and muscle were investigated, but since it is mainly muscle that is consumed (except in the case of cod liver) only data on the concentration in muscle are given. Both pooled and individual samples are reported, and between 1 and 5 replicate sub-samples were analysed per sample. For many of the investigated species more than one sample has been analysed, hence the mean and range concentrations are given where possible. Further details on sampling (time, position, replicates etc.) are given in Annex III.d.

In Table 5.4, the background concentration of some PAH e.g. B[a]P appears to be similar in many of the species investigated. The reason for the similar concentrations in various species is that the actual measurements were below the limit of determination (LOD). Unfortunately, the LOD for the individual PAH or seafood item were not stated in the ICES data.

In general, the background concentrations of PAH are considerably higher in mussels compared to in the investigated fish species (Table 5.4). Of the investigated fish certain species of whitefish as well as salmon-trout showed relatively high concentrations of especially benzo[b]fluoranthene and benzo[k] fluoranthene compared to the other fish analysed. Also as expected the total concentration of PAH in cod liver was higher than in cod muscles. For the genotoxic PAH, this trend was only seen for benzo[k]fluoranthene. For all the other genotoxic PAH the concentration was below LOD in both muscle and liver tissue.

The fraction of B[a]P to the total amount of genotoxic PAH can give a rough idea of the PAH profile in a sample, which is important for the risk characterization of the PAH. When comparing between investigations, it is necessary to include the same PAH in the calculations.

In the present calculations the ratio of the concentration of B[a]P to the total concentration of 6 genotoxic PAH have been estimated. For the specific list of PAH included in the PAH profile calculations see table text as well as Table 5.11.

For the background measurements of PAH, the fraction of B[a]P to 6 genotoxic PAH ranged from 0.06 to 0.20 (Table 5.4) and they are showing only little variation between samples (species, location etc.).

Table 5.4. The background concentration of PAH in different species. The table present the concentration of each of 8 genotoxic PAH, the sum of these 8 genotoxic PAH, the sum of 19 measured PAH (total PAH) as well as the fraction of B[a]P to 6 of the genotoxic PAH also measured in the coal tar on which the estimation of cancer potency of PAH mixtures is based.

Species ¹	tissue	No. of samples	µg/kg wet weight								Sum of 8 genotox. PAH	Total-PAH (19)	Fraction of B[a]P to 6 genotoxic PAH ²
			benzo[a]-anthracene	benzo[b]-fluoranthene	benzo[k]-fluoranthene	Benzo[g,h,i]perylene	Benzo[a]pyrene	Chrysene	Dibenzo[a,h]-anthracene	indeno-(1,2,3-c,d)-pyrene			
Common whitefish	liver	2	0.16	3.05	1.40	0.10	0.10	0.06	0.10	0.20	5.17	18.2	0.12-0.17
			0.02-0.3	0.2-5.9	0.5-2.3	0.10	0.10	0.06	0.10	0.20	1.28-9.60	11.7-24.7	
Common whitefish	muscle	2	0.14	2.53	1.08	0.10	0.10	0.06	0.10	0.20	4.30	15.1	0.12-0.17
			0.02-0.25	0.2-4.8	0.35-18	0.10	0.10	0.06	0.10	0.20	1.13-7.46	9.7-20.5	
Arctic cisco	muscle	3	0.14	2.15	0.57	0.10	0.10	0.06	0.10	0.20	3.42	16.8	0.14 (0.13-0.15)
			0.1-0.2	0.25-3.8	0.4-0.7	0.10	0.10	0.06	0.10	0.20	1.52-5.20	14.0-22.1	
Muksun	muscle	2	0.02	1.32	0.59	0.10	0.10	0.06	0.10	0.20	2.49	25.1	0.17
			0.02	0.2-2.4	0.4-0.77	0.10	0.10	0.06	0.10	0.20	1.55-3.40	23.9-26.3	
Broad whitefish nasus	muscle	3	0.18	1.34	0.52	0.10	0.10	0.06	0.10	0.20	2.60	19.7	0.15 (0.09-0.17)
			0.02-0.5	0.2-3.0	0.04-1.24	0.10	0.10	0.06	0.10	0.20	0.82-5.30	17.5-21.8	
Cod	liver	1	0.02	0.20	0.50	0.10	0.10	0.06	0.10	0.20	1.28	33.0	0.17
Cod	muscle	1	0.02	0.20	0.28	0.10	0.10	0.06	0.10	0.20	1.06	10.2	0.17
Gobiidae sp.	muscle	2	0.02	0.23	0.17	0.10	0.10	0.06	0.10	0.20	0.98	10.2	0.17
			0.02	0.20-0.25	0.04-0.3	0.10	0.10	0.06	0.10	0.20	0.82-1.13	7.70-12.6	
Blue mussel	SB-tissue	8	1.90	2.72	3.29	1.58	1.21	3.22	1.84	1.11	13.0	60.5	0.14 (0.06-0.20)
			0.5-3.9	0.5-11.2	1.8-4.8	0.5-5.6	0.5-4.7	0.5-6.5	0.8-2.8	0.5-3.1	3.0-43.9	14.8-124	
Deep-water prawn	TM-tissue	1	0.20	0.20		0.20	0.20	0.50		0.20	1.50	12.1	0.15
Plaice	muscle	1	0.20	0.20		0.20	0.20	0.20		0.20	1.20	5.40	0.20
Arctic char	muscle	2	0.14	2.61	1.15	0.10	0.10	0.06	0.10	0.20	4.46	19.8	0.12-0.17
			0.02-0.3	0.4-4.8	0.5-1.8	0.10	0.10	0.06	0.10	0.20	1.48-7.44	19.4-20.2	
Herring	muscle						0.10						

ICES data, RCMA laboratory

¹; See Annex I for names in Latin and Scandinavian languages

²; The fraction of B[a]P to 6 genotoxic PAH is calculated as the ratio of the concentration of B[a]P to the total concentration of 6 genotoxic PAH that was also measured in the coal tar on which the estimation of cancer potency of mixtures is based. The 6 PAH are beside B[a]P also benzo[a]-anthracene, benzo[g,h,i]-perylene, chrysene, dibenzo[a,h]-anthracene and indeno[1,2,3-c,d]-pyrene. See also Table 5.11.

In the Danish Food and Veterinary Administrations report on The Balanced View on Fish Intake (Andersen et al., 2003), measured concentrations of PAH in fish in Denmark were reported as in Table 5.5.

Table 5.5 Data from Denmark on PAH ($\mu\text{g/kg}$) in seafood

Species	Total PAH ($\mu\text{g/kg ww}$) (no. of PAH)	Benzo[a]pyrene ($\mu\text{g/kg ww}$)
Mussels	55-121 (26)	2.1-2.5
Flatfish	29-56 (26)	0.8-1.2
Eel	59-111 (18)	
Trout	94 (18)	
Flounder	40-60 (18)	0.2-0.6 ¹

Cited from Andersen et al. (2003) (data from Pritzl, G. 2001 and Århus County) except

¹; Storstrøms County (2002)

In general, these PAH concentrations measured in seafood from Danish coastal water are slightly higher than the background concentrations collected by ICES (Table 5.4). Other background concentrations of B[a]P in fish were used in SCOOP (unpublished, March 2004; see Annex III.e). They are similar, although the concentration of B[a]P in shellfish is lower than the above concentrations in mussels.

In Finland, PAH concentrations have been measured in various canned seafood products from several different countries (Table 5.6). The concentrations of B[a]P and total PAH are similar to the background levels given in Table 5.4 and 5.5.

Table 5.6. PAH concentrations ($\mu\text{g/kg}$) in canned seafood products imported into Finland in 2003.

Product	Origin	Benzo[a]pyrene	Total PAH
Anchovy	Greece	0.2	11.0
Mackerel, smoked	Greece	0.3	174
Sardine	Portugal	0.3	13.8
Sardine	Portugal	0.6	23.3
Sardine	Spain	0.2	22.5
Sardine	Greece	0.1	10.2
Tuna	Portugal	0.1	8.7
Tuna	Spain	0.2	10.4
Tuna	Greece	0.1	13.2
Tuna	Spain	0.1	18.3
Tuna	Spain	-	6.2
Tuna	Escuris	0.1	10.7
Cuttlefish	Greece	0.4	24.5
Mussels, smoked	Denmark	-	51.3

(Hallikainen and Niemi, 2003)

5.4.3.2 Concentrations following an oil spill

The Baltic Carrier oil spill

In March 2001, in the western Baltic Sea, Denmark, an oil tanker collided with a bulk carrier and 2,700 tons of bunker oil leaked from the tanker into the open sea and the oil drifted towards the Danish shorelines (see also Annex IV). After the accident a monitoring program was initiated where sediment, water and biota were sampled for PAH analysis, the latter were sampled twice, in June and in December 2001, i.e. 2-3 and 9 month after the accident (Storstrøms County, 2002). The concentrations of PAH considered genotoxic (SCF, 2002) in different marine organisms are given in Table 5.7. In total, the concentration of 24 PAH was measured in the tissue and the sum of all PAH is also given in the table. In general, the C₂-phenanthrenes constituted a relatively large part of the total PAH, for example in June C₂-phenanthrenes constituted 50% of the total PAH in mussels.

The more effective metabolism of PAH in fish compared to invertebrates is evident from the higher concentrations of PAH observed in mussels compared to in fish.

The concentration of PAH in liver from eel and flounder were higher than the concentrations in the muscle (Table 5.7). The ratio between the concentrations of total PAH in the liver and the muscle ranged from 4.2 to 6. In the exposure estimations (section 5.4.4), a factor of 5 will be used to extrapolate from concentrations in muscle to concentrations in liver.

In general, the PAH profiles expressed as the ratio of B[a]P to 6 genotoxic PAH were different in the organisms following the Baltic Carrier oil spill (Table 5.7) compared to the background PAH profiles in seafood (Table 5.4); Following the Baltic Carrier oil spill, the concentration of B[a]P in almost all investigated species constituted a relatively larger fraction of the total concentration of 6 genotoxic PAH (0.12-0.48; Table 5.7) compared to in uncontaminated organisms (0.12-0.20; Table 5.4) (see table text as well as table 5.11 for the list of PAH). Whether this was due to the oil spill or other factors (location, other PAH sources, species differences) is unknown. The fraction of B[a]P only decreased from June to December in mussels, whereas in flounder and shrimp the fraction of B[a]P was comparable at the two sampling times indicating that in addition to the oil spill other factors could influence the profile.

As already mentioned in chapter 3, PAH in fish are readily metabolized. Therefore, it is likely that the concentrations of parent PAH in fish measured in June, approximately 2-3 month after the oil spill occurred, was significantly lower than immediately after the oil spill (no measurements). For some PAH in certain species, the concentration measured in December was higher than in June, for example B[a]P in flounders. This indicates that other factors than the oil spill appear to have influenced the PAH profile.

Table 5.7. Concentrations of PAH in marine organisms following the "Baltic Carrier" oil spill in March, 2001 ($\mu\text{g/kg}$ wet weight). The table present the concentration of each of 6 genotoxic PAH, the sum of these 6 genotoxic PAH, the sum of 24 measured PAH as well as the fraction of B[a]P to 6 genotoxic PAH also measured in the coal tar on which the estimation of cancer potency of PAH mixtures is based.

seafood item	Tissue	time, 2001	benzo[a]anthracene	benzo[ghi]perylene	benzo[a]pyrene	dibenzo[a,h]anthracene	Indeno[1,2,3-c,d]pyrene	Chrysene+Triphenylene	Sum of 6 genotox. PAH	Sum of 24 PAH	Fraction of B[a]P to 6 genotoxic PAH ²
Blue mussels(mean, n=11)	SB-tissue	June	1.52 (0.73-3.56)	2.17 (0.91-4.52)	14.58 (3.67-22.5)	1.53 (0.68-2.37)	3.84 (1.58-16.8)	7.56 (2.8-30.5)	31.2	315.2 (113.4-763.0)	0.45 (0.24-0.61)
Blue mussel (mean, n=11)	SB-tissue	Dec.	7.35 (4.03-22.4)	4.46 (1.67-20.4)	4.91 (2.42-18.1)	1.43 (0.05-6.37)	5.01 (2.70-21.3)	17.06 (8.38-57.3)	40.2	215.3 (124.9-586.3)	0.12 (0.07-0.18)
Shrimp		June	0.72	0.26	1.94	0.052	0.18	2.97	6.13	783.0	0.32
Shrimp		Dec.	0.49	0.02	1.49	<0.05 ¹	0.25	0.85	3.10	64.58	0.47
Flounder	Muscle	June	0.39	0.04	1.02	<0.05 ¹	0.07	0.68	2.20	75.98	0.46
Flounder	Liver	June	2.96	0.06	4.53	<0.05 ¹	0.52	4.10	12.7	413.5	0.37
Flounder (mean, n=2)	Muscle	Dec.	0.47 (0.42-0.52)	0.03 (0.006-0.06)	1.52 (1.51-1.52)	<0.05 ¹	0.21 (0.21-0.22)	0.92 (0.90-0.95)	3.15	62.42 (59.66-65.17)	0.48
Flounder (mean, n=2)	Liver	Dec.	3.64 (2.24-5.03)	0.12 (0.10-0.15)	8.11 (7.28-8.94)	<0.05 ¹	1.03 (0.94-1.12)	6.76 (3.72-9.79)	19.7	261.9 (233.4-290.3)	0.31-0.55
Eelpout	Muscle	June	0.82	0.03	1.39	<0.05 ¹	0.12	1.26	3.62	130.6	0.38
Eel	Liver	June	4.05	0.75	7.63	0.17 ¹	1.45	8.64	22.7	751.7	0.33
Eel	Muscle	June	0.15	<0.2 ¹	0.26	<0.05 ¹	0.07	0.93	1.41	149.1	0.15

¹; LOD

²; The fraction of B[a]P to 6 genotoxic PAH is calculated as the ratio of the concentration of B[a]P to the total concentration of 6 genotoxic PAH that was also measured in the coal tar on which the estimation of cancer potency of PAH mixtures is based. The 6 PAH are beside B[a]P also benzo[a]-anthracene, benzo[ghi]-perylene, chrysene, dibenzo[a,h]-anthracene and indeno[1,2,3-c,d]-pyrene. See also Table 5.11 (Storstrøm county, 2002).

Other oil spills

Data on the concentration of total PAH in marine organisms following the Exxon Valdez oil spill in March 1989 and the Braer oil spill in Shetland in 1993 are presented in table 5.8. Unfortunately, these data are only on the sum of PAH and not on individual PAH.

The total concentration of PAH (39 individual PAH) measured in mussels after the Exxon Valdez oil spill was more than one thousand times higher than pre-spill concentrations in mussels from the same area. The concentration was also a lot higher than the sum of PAH (only 24 individual PAH) in mussels sampled following the Baltic Carrier oil spill (315 ng/kg ww). However, the actual difference in concentrations between the oil spills is somewhat smaller as the data from Prince William Sound are expressed in dry weight and not wet weight as for the data from Grønsund.

An almost 500 times increase in the concentration of sum PAH was evident in caged Atlantic salmon (*Salmo salar*) following the Braer spill in Shetland compared to reference samples. In contrast, the concentration of sum PAH in Pink salmon (*Onchorhynchus gorbuscha*) following the Exxon Valdez spill did not increase as dramatically (approximately three-fold) compared to reference concentrations.

Table 5.8. The concentration of total PAH in seafood following oil spill (µg/kg)

Seafood item	location, event mm.	condition, oiltype etc.	tissue	sampling time	ex-pressed as	sum PAH	no. of PAH
Mussels ¹	Prince William sound (n=2)	Non-oiled area	Soft tissue	Pre-spill	Dry weight	343.5 (143-544)	39
Mussels ¹	Prince William sound after Exxon Valdez oil spill (March 1989) (n=5)	Crude oil	Soft tissue	April. 1989	dry weight	77581.7 (1,790-234,001)	39
Mussels ¹	Prince William sound after Exxon Valdez oil spill (March 1989) (n=5)	Crude oil	Soft tissue	1990-1992	dry weight	1738.8 (5.6-4,150)	39
Pink salmon ²	After Exxon Valdez oil spill (March 1989)	Crude oil	Muscle	1989	dry weight	181	
Pink salmon ²	Reference (after Exxon Valdez, March 1989)	Non-oiled area	Muscle	1990	dry weight	54	
Farmed - Atlantic-salmon ²	Braer spill, Shetland (1993)	Gulfaks crude oil	Muscle	1993	wet weight	up to 14,000	
Farmed Atlantic-salmon ²	Reference Shetland	Non-oiled area	Muscle		wet weight	30	
Coho salmon ³	Katalla oilfield	100 m from an active oil seep	Muscle	1997	dry weight	156	

¹; Short and Babcock (1996)

²; Law and Hellou (1999)

³; Short et al. (1999)

Crude oil spills result primarily in contamination by low-weight molecular PAH which are generalconsidered to be only slightly or non-genotoxic. At the first sampling (April, 1989) following the Exxon Valdez oil spill, the phenanthrenes (C₁-C₄) were the most abundant group of PAH in mussels, but also dithiophenes, fluoranthenes and the C₂, C₃ and C₄-naphthalenes contributed significantly to the sum of PAH. Also, a few percent of

the total PAH was chrysenes; the concentration of chrysene increased at later sampling times (Short and Babcock, 1996).

In salmon caught less than 100 m from an oil seep close to the Katalla oilfield, the phenanthrenes/anthracenes followed by the chrysenes were the most abundant groups of PAH in the fish (Short et al., 1999).

5.4.3.3 Other sources of PAH

Regarding PAH in marine organisms, other sources of contamination especially related to urban areas will also show an impact and the PAH profile can vary depending on the source of contamination. In Table 5.9 the concentration of PAH considered genotoxic (SCF, 2002) in different seafood item are reported and as can be seen in the Table, the concentration of PAH can be relatively high in seafood exposed to PAH via other sources than oil spill.

Table 5.9. The concentrations of genotoxic PAH in fish and mussels in areas with other sources of PAH exposures than oil spill (ng/g)

Seafood item	Area & place of collection	Specific conditions (e.g. oiltype)	Remarks (method, tissue etc.)	benzo[a] anthracene	benzo[a] fluorene	benzo[<i>g,h,i</i>]perylene	benzo[a] pyrene	chrysene	Indeno (1,2,3- <i>c,d</i>) pyrene	Sum of genotoxic PAH	Sum of all PAH	No. of PAH in sum
Blue mussel¹ (mean, n=4)	Larne Lough, Eire	No oil spill	dry weight	11.5	n.m.	14.2	8	12.6	9.5	55.8	147.5	13
Blue mussel¹ (mean, n=4)	Strangford Lough, Eire	No oil spill	dry weight	9.2	n.m.	10.7	5.8	8.4	7.4	41.5	112	13
Dab²	North Sea, UK	Near oil platform	Muscle, wet weight	0.1-88	0.2-0.6	0.1-18	0.1-0.5	n.m.	0.3-3.7			
English sole²	Mukilteo, USA	Near petroleum storage tank	Liver, dry weight	< 21	n.m.	< 25	< 20	< 22	< 25			
Bulhead catfish²	Black River, USA	Near coking plant	whole fish, wet weight	22	n.m.	n.m.	7	61	n.m.	90	6421	10
Bream²	River Elbe, Germany	industrial region of city Hamburg	fillet and liver, wet weight	n.d.-< 0.1	n.m.	n.d.-< 0.1	n.d.-< 0.1	< 0.1-2.1 (incl. triphenylene)	n.d.-< 0.1			

¹; Guinan et al. (2001)

²; IPCS (1998)

n.m. not measured

n.d. not detected

5.4.4 Exposure estimations

In the following section, background PAH exposure as well as the increased exposure to PAH following an oil spill will be estimated.

As only limited data are available on background concentrations of PAH in seafood and levels of PAH found after oil spills the following exposure estimations do not include the frequency and range of occurrence of the PAH. Instead, it is assumed that the measured concentrations are representative for all the individuals of that particular species. Another consequence of the limited data on PAH concentrations in seafood is that extrapolations have been made between species in order to obtain PAH concentrations for all the seafood items where intake data are present. Both consequences of the limited data on PAH introduce uncertainties in the reliability of the exposure estimations. Furthermore, it is assumed that all of the seafood that are consumed by a person are caught in the same area (either background or oil spill area), which is likely only to be true for a very limited part of the population.

The exposure estimations for both background and oil spill exposure can only include the exposure via those seafood items where data on intake are available; that is the most important fish species for consumption as well as mussels and shrimps (see Table 5.1 and 5.2).

5.4.4.1 Background exposure

In the present assessment, the background exposure to PAH will be estimated for Danish children (1-3 years) and adults, as well as for Norwegian men and women based on the background concentrations of potentially genotoxic PAH and total PAH in fish, mussels and prawns caught close to the position of the imaginary accident collected by ICES (Table 5.4). However, it should be noted, that the PAH concentrations reported are upperbound (not detected (nd)=limit of determination (LOD) instead of nd=0), which leads to an overestimation of the actual PAH concentration present. Therefore, the estimated background exposures are worst-case exposures. Unfortunately, it has not been stated in the ICES data when LOD has been given instead of an actual measurement, but it seems particularly to be the case for benzo[*g,h,i*]perylene, benzo[*a*]pyrene, chrysene, dibenzo[*a,h*]anthracene and indeno[1,2,3-*c,d*]pyrene where only the concentration in mussels seems to be higher than the LOD. For benzo[*a*]anthracene, benzo[*b*]fluoranthene and benzo[*k*]fluoranthene, several of the concentrations seems to be higher than LOD.

Since PAH data are not available for all frequently eaten seafood items included in the dietary surveys, it was necessary to assume that the concentration of PAH is similar among different species. However, there are physiological as well as behavioural differences among species, which can affect the internal concentrations of PAH.

The PAH concentration in Arctic char (*Salvelinus alpinus*) was used as representative of the concentration in salmon since data for the latter was lacking. Similarly, due to the lack of data and because even fat fish do not tend to accumulate PAH, the concentration of PAH in herring, mackerel and other pelagic fish species were assumed to be the same as in cod (for benzo[*a*]pyrene, benzo[*ghi*]pyrene, dibenzo[*a,h*]anthracene, indeno[1,2,3-*c,d*]pyrene and chrysene the concentration in cod is similar to the concentration in all the other investigated fish species except plaice (see table 5.4).

One exception of extrapolating from cod to herring, mackerel and other pelagic fish species is made for benzo[*a*]anthracene where the measured concentration in cod is very low compared to the concentration in all of the other investigated fish species (Table 5.4). Instead the concentration of benzo[*a*]anthracene in plaice will be used as the concentration in herring, mackerel and other pelagic fish species. Since data for halibut was also lacking, data on the PAH concentration in plaice was used as representative for halibut (only relevant for the exposure estimations from Norway).

Exposure estimates based on the mean intake of seafood by adults in Denmark gives a background exposure to the 8 genotoxic PAH presented in Table 5.10 ranging from 0.03 ng/kg bw/day (chrysene) to 0.09 ng/kg bw/day (benzo[*b*]fluoranthene) and an estimated intake of B[*a*]P between (0.04 ng/kg bw/ day). The estimated mean total intake of all 8 PAH was 0.4 ng/kg bw/day. For children (1-3 years) the mean background intake of PAH was approximately twice the intake by adults; the mean intake of B[*a*]P was 0.07 ng/kg bw/day (Table 5.10).

Exposure estimates based on the intake of seafood by adults in Norway are higher than for adults in Denmark, due to the higher intake of seafood. The mean background exposure to the 8 genotoxic PAH range from 0.09 ng/kg bw/day (the intake of dibenzo[*a,h*]anthracene by men,) to 0.61 ng/kg bw/day (the intake of benzo[*b*]fluoranthene by women). The estimated intake of B[*a*]P was 0.12 and 0.15 ng/kg bw/day for men and women, respectively and the mean total intake of all 8 PAH was 1.74 and 1.88 ng/kg bw/day for men and women, respectively.

The background exposure estimations for both Denmark and Norway are presented in Table 5.10 and in further details in Annex III.f. and Annex III.g, respectively. In the SCOOP project (unpublished, March 2004) the intake of B[*a*]P via seafood by Norwegian adults was estimated, based on the dietary survey NORKOST 1997, to be only 0.08 ng/kg bw/day. However, in the SCOOP project several fish species were not included and the levels in missing species were not estimated.

5.4.4.2 Exposure following an oil spill

In the present assessment, the exposure to PAH in fish following an oil spill is estimated for Danish children (1-3 years) and adults, as well as for Norwegian men and women. The PAH concentrations measured in marine organisms after the oil spill in Grønsund have been used in the calculations (Table 5.7). However, it should be noted that this potentially leads to an underestimation of the exposure following an oil spill due the time gap between the accident and the sampling time.

Since the only species included in the monitoring program were flounder, eelpout and eel beside mussels and shrimps, concentrations in other frequently eaten species such as cod, herring, mackerel, salmon etc. had to be estimated. Halibut, like plaice and eel, is bottom dwelling, benthic species and therefore, the PAH concentration in halibut used in the Norwegian exposure estimations is the mean concentration measured in plaice. In contrast, herring, cod, mackerel etc. are pelagic species and it is not suitable to use the concentrations in bottom dwelling fish (flounder, eel or eelpout) as the concentration in these species.

Instead, the concentration of PAH in the pelagic fish species is estimated base on the assumption that the ratio between the background concentration of a specific PAH in one specific fish species and the background concentration of that PAH in plaice (Table 5.4) is similar to the ratio between the concentration of the PAH in the same fish species after oil spill and the concentration of that PAH in flounders after oil spill.

e.g.

$$\frac{\text{background } B[a]P \text{ in cod}}{\text{background } B[a]P \text{ in plaice}} = \frac{\text{oil spill } B[a]P \text{ in cod}}{\text{oil spill } B[a]P \text{ in cod: oil spill } B[a]P \text{ in plaice}}$$

The background concentration of dibenzo[*a,h*]anthracene and indeno[1,2,3,*c,d*]pyrene in cod, Arctic char, Arctic cisco and the different species of whitefish is the same as in flounders (Table 5.4). Therefore, in the oil spill exposure scenario, the concentration of dibenzo[*a,h*]anthracene and indeno[1,2,3,*c,d*]pyrene in the pelagic fish included in the exposure estimations (cod, herring, salmon and mackerel) will be similar to the concentration measured in plaice following oil spill (Table 5.7). For benzo[*ghi*]pyrene and benzo[*a*]pyrene, the background concentration in plaice is twice the concentration in the other fish species, and hence, in the oil spill exposure scenario, the concentration of benzo[*ghi*]pyrene and benzo[*a*]pyrene in the pelagic fish included in the exposure estimations will be half the concentration measured in plaice following oil spill (Table 5.7). For chrysene, the background concentration in other fish is 30% of the concentration in plaice (Table 5.4) and hence, in the oil spill exposure scenario, the concentration of chrysene in the pelagic fish included in the exposure estimations will be 30% of the concentration measured in plaice following oil spill (Table 5.7). For benzo[*a*]anthracene, there is a ten fold difference between the highest and lowest background concentration in the various pelagic fish species and therefore also in the estimated ratio. As a worst case situation, the highest estimated ratio (approx. 1) is used and hence, in the oil spill exposure scenario, the concentration of benzo[*a*]anthracene in the pelagic fish included in the exposure estimations will be similar to the concentration measured in plaice following oil spill (Table 5.7).

After the oil spill in Grønsund (March, 2001) samples were taken in June and December. As previously mentioned, it is likely that the concentrations of PAH in the organisms sampled may have decreased in the time between the oil spill occurred and the first sampling time. The concentrations measured in June were not in all cases higher than those measured in December and in the present assessment the maximum concentration of a specific PAH (or the maximum mean concentration, if more than one sample was analysed) was used irrespective of whether the sample was taken in June or December.

In the Norwegian dietary survey (Meltzer et al., 2002) cod and seethe liver were reported separately. Since no data on the concentration of PAH in cod and coalfish liver are available it is assumed that the ratio between the background concentration of total PAH in the liver and the muscle (4.2 to 6, Table 5.4) measured in flounder and eel are representative of the concentration in cod and coalfish liver and muscle after an oil spill. A factor of 5 is used to extrapolate from concentrations in muscle to concentrations in liver.

The oil spill exposure estimates are presented in Table 5.10 and further details are provided in Annex III.h and Annex III.i, for Denmark and Norway, respectively.

When the exposure estimates are based on the mean seafood intake by adults in Denmark, the exposure to the six genotoxic PAH (Table 5.10) following an oil spill range from 0.01 ng/kg bw/day (benzo[*ghi*] perylene) to 0.3 ng/kg bw/day (benzo[*a*]pyrene).

The mean total intake of all six PAH is estimated to 0.7 ng/kg bw/day. When the 95th percentile intake of seafood is used in order to take into account the exposure of high fish-consumers, the exposure ranges from 0.05 ng/kg bw/day (benzo[*ghi*] perylene) to

1.24 ng/kg bw/day (benzo[a]pyrene) and the worst case intake of all six PAH is 2.97 ng/kg bw/day.

Table 5.10 The estimated background B[a]P and sum of genotoxic PAH exposure and exposure following the Baltic Carrier oil spill (two months after the accident).

Country	group	Exposure level	Value	B(a)P (ng/kg bw/day)	range for individual PAH (ng/kg bw/day)	PAH with highest exposure	Total genotox PAH (ng/kg bw/day) (no. of PAH)
Denmark	children (1-3 y)	Background	mean	0.07	0.06-0.14	Benzo(b)flouranth.	0.75 (8)
		Background	95th per	0.32	0.25-0.52	Benzo(b)flouranth.	
		Oil spill	mean	0.57	0.02-0.57	B(a)P	1.32 (6)
		Oil spill	95th per.	2.41	0.70-2.41	B(a)P	
	adults	Background	mean	0.04	0.03-0.09	Benzo(b)flouranth.	0.4 (8)
		Background	95th per	0.16	0.12-0.27	Benzo(b)flouranth.	
		Oil spill	mean	0.3	0.01-0.3	B(a)P	0.7 (6)
		Oil spill	95th per.	1.24	0.05-1.24	B(a)P	
Norway	men	Background	mean	0.11	0.09-0.59	Benzo(b)flouranth.	1.74 (8)
	women	Background	mean	0.14	0.11-0.61	Benzo(b)flouranth.	1.88 (8)
	men	Oil spill	mean	1.03	0.06-1.03	B(a)P	2.73 (6)
	women	Oil spill	mean	1.41	0.09-1.41	B(a)P	3.82 (6)

When the 95th percentile intake of all seafood categories is used to estimate a worst-case exposure, it is important to remember that the total amount of seafood consumed per day is very high; the 95th percentile of the total intake of fish by adults is 0.92 g/kg body weight/day (Table 5.1), but the sum of the 95th percentile intake of all of the different fish categories is approximately 45% higher.

The estimated exposure of children (1-3 years) to the six PAH measured after a theoretical oil spill is twice as high as the exposure of adults. The mean exposure of children ranges from 0.02 ng/kg bw/day (benzo[ghi] perylene) to 0.57 ng/kg bw/day (benzo[a]pyrene), and the worst case exposure based on the 95th percentile seafood intake by children ranges from 0.07 ng/kg bw/day (benzo[ghi] perylene) to 2.41 ng/kg bw/day (benzo[a]pyrene).

When the exposure estimates are based on the seafood intake by adults in Norway, the exposure is higher than for adults in Denmark, due to the higher consumption. The mean exposure to the six genotoxic PAH following an oil spill range from 0.064 ng/kg bw/day (men, dibenzo[a,h]anthracene) to 1.41 ng/kg bw/day (women, benzo[a]pyrene). The estimated mean total intake of all six PAH is 2.73 and 3.82 ng/kg bw/day for men and women, respectively.

The consumption of shellfish (mussels and shrimps) is the dominant seafood-source of PAH in adults in Norway (33-36% of total seafood B[a]P intake). Also, the consumption of cod including liver, and salmon are important sources in Norway.

In Denmark, the consumption of plaice is the most significant contributor to the total intake of PAH (35% of total seafood B[a]P intake), but also cod and herring contribute significantly (17% and 18% of total seafood B[a]P intake, respectively). This is due to a combination of relatively high PAH concentrations in these fish species and a high consumption rate of these species in the respective countries.

Before characterizing the risk in the following section, it is important to consider the main limitations in the exposure estimates:

Due to the limited PAH data available, PAH concentrations have been extrapolated among species. Furthermore, the background exposure is a worst-case scenario, since several of the PAH concentrations used to estimate the exposure are LODs i.e. upper-bound results. Regarding the oil spill exposure, the PAH concentrations were determined in seafood sampled more than two month after the oil spill hence the exposure might be underestimated.

It is however assumed that the few analyses conducted are representative for all the seafood consumed, i.e. that all seafood consumed are caught in the same area (background or area affected by an oil spill) which is only realistic for a very limited part of the population.

Finally, the estimated exposures are prior to processing of the seafood e.g. smoking, which is known to increase the concentration of PAH considerably.

5.5 Risk characterization

As mentioned in the hazard characterization (section 5.3) the B[a]P approach has been shown to be the most suitable to characterize the risk of PAH mixtures compared to the TEF approach (SCF, 2002). Therefore, in the following risk characterization only the B[a]P approach will be used.

As mentioned in section 5.3, virtual safe doses (VSDs), for B[a]P alone, estimated on the basis of recent studies in rodents range from 0.6-5 ng B[a]P/kg bw/day depending on the calculation method, using an acceptable excess cancer risk of 1×10^{-6} . Assuming a ten times higher potency of PAH mixtures compared to B[a]P alone, the VSD of B[a]P in complex PAH mixtures range from 0.06-0.5 ng B[a]P/kg bw/day.

One of the assumptions when using the B[a]P indicator approach is that the PAH profile in the food is similar to the PAH profile in the coal tar on which the estimations of the carcinogenic potency of total PAH in foods has been based. The fraction of B[a]P to the total amount of genotoxic PAH can give a rough idea of the PAH profile in a sample. When comparing between investigations, it is necessary to include the same PAH in the calculations; the PAH profiles in the seafood should be compared with the PAH profile in the coal tar. Therefore, the PAH profile-estimates have been made by including only the PAH that were measured in both fish and coal tar (for the specific list of PAH included in the calculations see table 5.11).

5.5.1 PAH profiles in fish

The PAH measured in both the coal tar studies conducted by Culp et al. (1998) as well as in seafood sampled following the Baltic Carrier oil spill and the background data collected by ICES are listed in Table 5.11. In total, 14 PAH were measured in all of the different samples. Of these 14 PAH, six are considered genotoxic according to SCF (2002) (in bold). The fraction of B[a]P to the six genotoxic PAH in two different coal tar mixtures were 0.19 and 0.20 (5.11).

Table 5.11 A list of 14 PAH that were measured in both the coal tar studies conducted by Culp et al. (1998) as well as in seafood sampled following the Baltic Carrier oil spill and the background data collected by ICES. Those considered genotoxic are in bold. The concentration of the PAH in the coal tar mix are given ($\mu\text{g/kg}$) as well as the fraction of B[a]P to the sum of the six genotoxic PAH.

PAH	Coal tar, mix 1 ($\mu\text{g/kg}$)	Coal tar, mix 2 ($\mu\text{g/kg}$)
acenaphthene	2049	1270
acenaphthylene	3190	5710
anthracene	2524	2900
benzo[a]-anthracene	2374	3340
benzo[g,h,i]-perylene	1493	2290
benzo[a]pyrene	1837	2760
chrysene	2379	2960
dibenzo[a,h]-anthracene	267	370
fluoranthene	4965	6370
fluorene	3692	4770
indeno-[1,2,3-c,d]-pyrene	1353	1990
naphthalene	22203	32300
phenanthrene	7640	10100
pyrene	5092	7220
the fraction of B[a]P to the sum of the 6 genotoxic PAH measured in seafood samples from unpolluted areas (ICES data) and from the oil spill area (Grønsund) as well as in the coal tar mix.	0.19	0.20

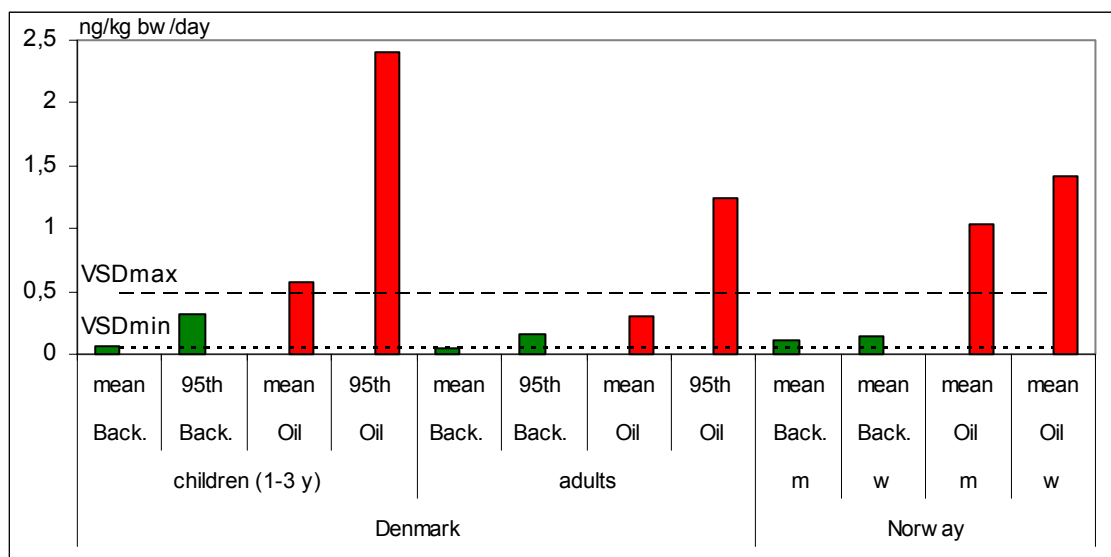
As shown in Table 5.4, the mean fraction of B[a]P in seafood with background contamination varied from 0.14-0.20 with no significant species or location variation. Following the Baltic Carrier oil spill (Table 5.7), the mean fraction of B[a]P varied from 0.12-0.48; the fraction of B[a]P was higher than 0.24 except from in mussels caught in December and in eel (muscle). The increased fraction of B[a]P in these samples compared to in the background samples could potentially be due to the oil spill, but other factors could also be responsible for example other PAH sources.

According to this relatively simple expression of PAH profiles in seafood and coal tar, it can be concluded that the mean fraction of B[a]P to total genotoxic PAH in various seafood is between 0.6 to 2.5 times the fraction of B[a]P to total genotoxic PAH in the coal tar mix.

In the estimate of the potency of total PAH in food (SCF 2002), a factor of 2 has been applied, to cover the differences in PAH profiles between food and coal tar (see section 5.3.2). Therefore, the estimated potency of a PAH mixture based on the coal tar studies appears also to be valid for PAH in seafood, and the B[a]P approach can be used. However, not all genotoxic PAH were measured in the coal tar and seafood samples and therefore not all genotoxic PAH were included in the profiles comparisons.

5.5.2 Comparing exposure estimations with VSD

The intakes of B[a]P via seafood from a “non-polluted” area (background concentrations) by Norwegian adults were estimated to be 0.11 and 0.14 ng/kg bw/day for men and women, respectively. The intakes of B[a]P via seafood from a “non-polluted” area by Danish adults and children were estimated to be 0.04 and 0.07 ng/kg bw/day, respectively. Therefore, the daily intake of B[a]P via the consumption of fish from “non-polluted” areas (background concentrations) in both Denmark and Norway are below the highest VSD (0.5 ng/kg bw/day; 1×10^{-6} excess cancer risk) (see Fig. 5.5), but for Norwegian adults the intake of PAH via seafood is higher than the lowest VSD (0.06 ng/kg bw/day; 1×10^{-6} excess cancer risk).



Figur 5.5 The background exposure (back.) and exposure following an oil spill (oil) to PAH, for Danish adults and children (1-3 years) and Norwegian men (m) and women (w). The low (0.05ng/kg/day) and high (0.5ng/kg/day) VSD of B[a]P in PAH mixtures are also shown.

Following an oil spill the potential exposure to B[a]P via the consumption of fish caught in the area was found to increase almost ten fold. The estimated exposures are, except for the mean exposure to adults in Denmark, above the VSD even before taken into account the intake of B[a]P from other sources.

However, VSD is a virtual safe dose level for lifetime exposure; exposure following an oil spill is not a lifetime exposure since the concentrations in both the environment and seafood species will decrease over time. In the following estimates of the risk after oil spills, shorter exposure duration will be used.

5.5.3 The basis for further risk calculations

For genotoxic carcinogens it is for theoretical reasons not possible to identify a dose under which there is no effect.

Environmental pollutants such as PAH cannot be totally avoided, but human exposure should be kept as low as reasonably achievable (ALARA) (SCF 2002).

Different models have been used in order to estimate an exposure representing a negligible risk or a “virtual safe intake” (amount) and the risk after a certain exposure to PAH polluted food. In these calculations several variables are included, some examples are given below. As mentioned in section 5.3.1, the SCF had reservations about the use of mathematical modelling and risk calculation when evaluating genotoxic and carcino-

genic substances, because there are a number of uncertainties associated with the calculated values. These uncertainties are described below and in the conclusion. In the present estimates a model from Gilroy (2000) with a few modifications has been used:

$$AC = \frac{BW \times VSD}{Seal} \times \frac{LT}{ExpD} \times AF$$

The variables included in the calculations are described below:

- 1) *The acceptable concentration (AC)* of B[a]P in ng/g seafood is the concentration calculated to give a certain risk. e.g. 10^{-5} or 10^{-6} .
- 2) *A calculated VSD* described in section 5.3.1 is used instead of a B[a]P cancer slope factor used by Gilroy (2000). In the VSD, the acceptable risk level e.g. 10^{-5} or 10^{-6} is taken into account.
- 3) *The average lifetime (LT)* used in cancer risk calculations is typically 70 years
- 4) *The body weight (BW)* of the individual consumer. A body weight of 70 kg for an adult has been used in the examples below. However, alternative body-weights may be used e.g. for children, who as mentioned in section 5.4.2 eat more on a per kg bodyweight basis.
- 5) *Exposure duration (ExpD)*. VSD is calculated as a “safe” dose for life-time exposure like exposure to the background PAH level in seafood. After an oil spill the PAH concentration in seafood might increase up to 1000 times above the background level. However, after a certain time the concentration will decrease to background level, due to metabolism and excretion of PAH from the seafood species. Therefore, the exposure duration to PAH following an oil spill will normally be much shorter than a lifetime and this should be included in the risk calculation.
- 6) *Seafood intake (Seal)*. As shown in section 5.4. there are differences in seafood intake among consumers in different countries and between children and adults.
- 7) *The percentage of total intake of PAH from seafood (AF)*. As mentioned previously contaminated seafood is not the only source of B[a]P exposure and the VSD include the intake of B[a]P from all sources.

Therefore, it is necessary to consider how much the intake of B[a]P via seafood contributes to the total daily intake of B[a]P. In example 1 below it is assumed that 30% of the total PAH exposure comes from seafood.

5.5.4 Examples of risk calculations

Example 1: What is the acceptable background concentration if the consumption rate is known?

Assuming a seafood consumption rate of 70 g/day (average consumers in Norway) for a 70 kg person living for 70 years, using a VSD for B[a]P in mixtures of 0.5 ng/kg bw/day (acceptable risk of 10^{-6}) and allocating 30% of total B[a]P intake to seafood intake, the acceptable background concentration in seafood will be:

$$AC = \frac{70\text{kgbw} \times 0.5\text{ng} / \text{kgbw} / \text{day}}{70\text{g} / \text{day}} \times \frac{70\text{years}}{70\text{years}} \times 30\%$$

$$AC = 0.15 \text{ ng B[a]P/g seafood}$$

For comparison, the background concentration of B[a]P in most fish species was below LOD (0.1 µg/kg) (table 5.4). It is very important to note that the calculated acceptable concentration in seafood is highly dependent on the assumptions made for example, the selected VSD and the accepted excess cancer risk. Accepting a risk of 10^{-5} the acceptable concentration in seafood will be 10 times higher (~ 1 µg/kg). Using the lowest VSD of 0.06 ng/ kg bw/day the acceptable concentration will be about ten times lower.

It is not known how much of the total dietary PAH exposure that come from seafood. In England and the Netherlands, cereals, vegetables, oils and fats were the major sources (SCF, 2002). Estimates based on SCOOP data indicated that the daily intake of B[a]P from seafood ranged from 0.6% of the total intake of B[a]P for the Finnish population, 4% for the Danish population and around 30% for the Norwegian population (see section 5.4.1). As already mentioned, the whole diet has not been included in the estimates and the estimates are based on different data sets. Therefore the data should be used with caution and the 30% is only used for exemplification.

Example 2: What is an acceptable consumption of seafood if the PAH (B[a]P) concentration e.g. after an oil spill is known?

Two months after the Baltic Carrier accident, the highest concentration in flounder (muscle) of B[a]P was 1.52 µg/kg. If accepting an additional cancer risk of 10% (0.1×10^{-6}) due to an oil spill (beside the risk of 1×10^{-6} due to background lifetime exposure) and if the exposure time is assumed to be two years, the acceptable intake of flounder (SeaI) from the polluted area would be:

$$SeaI = \frac{70\text{kgbw} \times 0.5\text{ng} / \text{kgbw} / \text{day} \times 10^{-3} \mu\text{g} / \text{ng}}{1.52\mu\text{g} / \text{kg} \times 10^{-3} \text{kg} / \text{g}} \times \frac{70\text{years}}{2\text{years}} \times \frac{0.1 \times 10^{-6}}{10^{-6}}$$

$$SeaI = 81\text{g/person/day}$$

In the above equation no allocation factor (AF) was used. Instead, the acceptable intake of seafood is calculated for a certain increase in cancer risk (0.1×10^{-6}).

With these assumptions the acceptable intake of seafood two months after the Baltic carrier accident is higher than the mean-consumer intake in Norway (70 g/day) but lower than the high consumer intake (140 g/day). However, as mentioned before, the measured concentrations in fish may underestimate the initial concentration in the polluted seafood, because samples were taken 2 months after the oil spill.

Also, this calculation is a quite simple model assuming linearity between exposure duration and cancer risk.

Example 3: What was the increased risk after the Baltic Carrier oil spill?

The increased risk for a Norwegian woman after an accident like the Baltic Carrier oil spill is calculated from exposure data in table 5.10. The increase in exposure ($E_{\text{oilspill}} - E_{\text{background}}$) is 1.27 ng B[a]P/kg bw/day. Using a VSD of PAH mixtures of 0.5 ng/kg bw/day (excess cancer risk of 1×10^{-6}) and an estimated lifetime of 70 years, the increased cancer risk following 2 years increased exposure of 1.27 ng B[a]P/kg bw/day will be:

$$\text{Increase in cancer risk} = \frac{1.27 \text{ ng / kgbw / day}}{0.5 \text{ ng / kgbw / day}} \times 1 \times 10^{-6} \times \frac{2 \text{ years}}{70 \text{ years}} = \underline{\underline{0.7 \times 10^{-7}}}$$

Using the same assumption as above, the average increase in risk after an accident like the Baltic Carrier oil spill estimated from exposure data in Table 5.10 for Danish adults and children will be 0.15 and 0.3×10^{-7} , respectively. For high consumer (95th percentile) adults and children the increased risk will be 0.6 and 1.2×10^{-7} , respectively.

Example 4: What is the acceptable increase in B[a]P concentration in herring in Denmark?

According to Table 4.1 (in section 4.3.2) a large amount (1,385,000 kg/year) of herring is caught close to the position of the imaginary oil spill and herring constitutes a relatively large proportion of the Danish seafood consumption (21 % of the total seafood consumption, see Table 5.1). The 95th percentile intake of herring is 0.3 g/kg bw/d.

There is no data available on B[a]P concentrations in herring following an oil spill, so instead of estimating an increased risk following an oil spill, the maximum concentration of PAH in herring can be estimated if an increased risk of e.g. 1×10^{-7} is accepted following two years increased exposure due to an oil spill. 0.5 ng B[a]P/kg bw/day is used as the VSD for an acceptable excess cancer risk of 1×10^{-6} for lifetime exposure.

The exposure can increase by:

$$\frac{1 \times 10^{-7}}{1 \times 10^{-6}} \times \frac{70 \text{ years}}{2 \text{ years}} \times 0.5 \text{ ng / kgbw / day} = \underline{\underline{1.75 \text{ ng B[a]P / kgbw / day}}}$$

During the two years. If this is a political accepted increase in cancer risk and if the increase in exposure mainly is due to higher B[a]P concentrations in herring, the B[a]P concentration in herring due to the oil spill can increase with 5.8 ng B[a]P/g herring considering the safety of high-consumers (95th percentile).

For comparison, the B[a]P concentration in flounder muscle tissue following the Baltic Carrier oil spill was 1.02-1.52 ng/kg bw/day.

5.5.5 Using the TEF approach

As already mentioned in section 5.3.1, the B[a]P approach is not always appropriate for risk characterization if the PAH profiles differ considerably from the PAH profiles in coal tars on which the estimated potencies are based. The TEF approach was used on data from farmed trout after the Baltic Carrier oil spill because B[a]P was not-detectable

in the fish, but other genotoxic/carcinogenic PAH were measured. The result of this can be seen in annex III.a.

Also in recent investigations following oil spill (e.g. Coos Bay, Oregon, 1999), the TEF approach has been used (Gilroy, 2000) (see section 6.2.1).

5.5.6 Risk characterization of the total dietary intake of B[a]P

In order to put the risk characterization of PAH following an oil spill in perspective, a risk characterization of the total dietary intake of B[a]P can be conducted.

In section 5.4.1 the estimated mean total dietary intakes of B[a]P ranged between nations from 16.5 - 290 ng/day which corresponds to 0.24 – 4 ng B[a]P/kg bw/day assuming a body weight of 70 kg. Since humans are exposed to a mixture of PAH via food the risk characterization of the dietary intake of B[a]P should be as for B[a]P in a mixture. If the VSD for B[a]P in a mixture range from 0.06 – 0.5 ng/kg bw/day for an acceptable excess cancer risk of 1×10^{-6} , the mean dietary intakes exceeds this by 0.5 – 66 times.

5.5.7 Summary of the risk characterization of oil spill

The present risk characterization indicates that oil spills increases the risk of human intake of PAH via seafood.

The risk characterization of an oil spill based on exposure estimations following the Baltic Carrier oil spill indicated that the increase in PAH exposure in Denmark may lead to an increase in the cancer risk between $0.15 - 1.2 \times 10^{-7}$ (adults, mean – children, 95th percentile) in addition to the cancer risk already posed by the general dietary intake of PAH.

Furthermore, if accepting an increase in cancer risk due to increased PAH exposure of 1.0×10^{-7} and assuming an oil spill exposure duration of 2 years, it can also be estimated based on measured concentrations following the Baltic Carrier oil spill that the mean-consumer intake of seafood in Norway is below the acceptable intake of fish whereas the high-consumer intake of seafood in Norway exceeds the acceptable intake of fish.

However, there are important limitations and variabilities in the present risk characterization as described in the next section.

5.6 Uncertainties and variabilities in the risk assessment

Uncertainties and variabilities are present in all the different steps throughout the risk assessment.

a. Hazard identification

In this project only PAH have been addressed. Other components in the oil and the risk of those from seafood intake are not addressed. Furthermore, detailed data on metabolism of PAH in seafood is not available.

b. Hazard characterization:

For hazard characterization only a few PAH (33) and PAH mixtures have been evaluated, recently by the SCF (2002). Also, the combined action and interactions between compounds in the mixtures as well as the health effect of metabolites in seafood are not well investigated.

There is no international agreement on which approach should be used for the estimation of the potency of the PAH mixtures. In EU, SCF (2002) recommended to use the B[a]P approach, which was also done in the present report. However, the TEF approach

has been used in other recent oil spills, e.g. the Exxon Valdez oil spill and the New Carissa oil spill in Oregon.

If using the TEF approach there are uncertainties connected to the choice of TEF values, and if using the B[a]P approach there is no agreement on which PAH that should be measured which is very important when comparing PAH profiles.

There are also uncertainties connected to the models used for estimation of the quantitative risk of B[a]P e.g. which VSD or cancer slope factor should be used. Furthermore, the quite simple model used for the risk calculation assumes linearity between exposure duration and cancer risk. The exposure duration following oil spill was set to 2 years, but there is a need for more data on the PAH elimination rate in seafood species, which influence the exposure duration. In addition, more knowledge on background PAH level in different fish and shellfish species from different locations is needed. Whereas PAH originating from oil spills will dissipate over time, “background” PAH will not and therefore “background” sources may in some instances pose a greater overall health risk, and should be considered in the overall health risk assessment.

There is evidence that organisms after short-term exposure to PAH eliminate almost all the parent compound whereas chronic exposure to PAH more likely result in incorporation of the parent compound in storage tissues and thereby reduces elimination capacity (Meador et al., 1995).

c. Exposure estimations:

Due to the limited data on PAH concentrations in seafood, the figures used in the present assessment are either single measurements or averages of relative few samples and several extrapolations of PAH concentrations among fish species have been made.

The background exposure applied, is likely to be worst-case since several of the PAH concentrations used to estimate the exposure are LODs, i.e. upper bound.

The actual concentration is lower. Regarding the oil spill exposure it may have been underestimated since the PAH concentrations used in the oil spill exposure scenarios was measured in seafood sampled and analysed more than two month after the oil spill.

It is assumed that the few analyses conducted are representative for all the consumed seafood, i.e. that all the seafood consumed are caught in the same area (background or area affected by an oil spill) which is only realistic for a very limited part of the population.

Furthermore, the estimated exposures are prior to processing of the fish e.g. smoking, which is known to increase the concentration of PAH in fish considerably.

d. Risk characterization:

The present risk characterization includes different exposure scenarios. However, the risk characterization is primarily made on the consumption of seafood as a whole and are not very specific as regards seafood items, high exposure groups etc.

In the case of an oil spill more specific exposure scenarios and reliable risk characterization have to be conducted. It is necessary to focus the risk characterization on the actual situation rather than characterizing the general risk based on seafood as a whole.

e. Acceptable risk level

It will be a risk management decision to decide whether a certain estimated increase in cancer risk due to an oil spill is acceptable, and how big an increment would be acceptable.

5.7 Conclusions and recommendations for the risk assessment

The present survey indicates that oil spills increases the risk of human intake of PAH via seafood and therefore, may lead to an increase in the cancer risk already posed by the general dietary intake of PAH.

Aside from the limitations in the present risk characterization, when seen as an isolated part of the total PAH exposure, the increase in exposure following an accident like the Baltic Carrier oil spill does not seem to constitute a severe health problem 2 month after the oil spill especially when taking into account that oil spills do not lead to a chronic but only an occasional and temporary increase in human exposure via contaminated seafood. However, in other oil spills much higher PAH concentrations have been found (see e.g. Table 5.8).

Therefore, the potential increase in human PAH exposure and thereby the increase in cancer risk following an oil spill should always be considered in the case of a specific accident. Many factors have to be taken into account.

The type of oil, the location and the potential distribution of the oil spill will affect the likelihood of an accident to contaminate seafood. The metabolism of PAH in different seafood items differs. Molluscs and in some degree also crustaceans tend to accumulate PAH whereas fish readily metabolise the substances and therefore do not tend to accumulate PAH.

Different species also have different behaviour that can influence the likelihood of contamination e.g. sessile organisms cannot flee the oil and benthic organisms may live in polluted sediments for a relatively long period of time. As a parallel to these behavioural species differences, aquaculture would prevent the farmed fish to flee from the oil. Therefore, if the aquaculture is located in the area of the oil spill, it can increase the risk of PAH exposure via seafood to humans.

The tissue distribution of the PAH is also important since in some cases it is not only the muscles of the fish that is consumed. Also, liver and roe is a part of the seafood diet e.g. in Norway and there seems to be a tendency that higher levels of PAH can be found especially in the liver.

It is important to be aware of groups that are at higher risk compared to the average consumer either because they are more heavily exposed or because their susceptibility to the exposure is higher.

In Denmark the total fish consumption on a per kilo bodyweight basis is higher for children than for adults and the PAH exposure via seafood following oil spill was estimated to be higher for children than for adults. This estimation was based on contamination of the whole seafood diet, but even if only some seafood items were contaminated following an oil spill children could potentially be at higher risk of PAH intake than adults. In addition, cancer is a multi-step-process with a long latency period (up to 20 years), and PAH exposure during childhood/youth may therefore be of greater concern than exposure later in life. Fetuses may be at higher risk, because their metabolic systems are not fully developed, and as mentioned PAH can pass the placental barrier.

Other potentially “higher exposure” groups could be local fishermen and anglers/sport fishers that in general have a higher seafood consumption rate than the average consumer and they may rely more heavily on local seafood.

The present risk characterization following an oil spill was based on a relative general scenario, but in the case of an oil spill more relevant and specific scenario(s) should be put forward. In order to make a qualified seafood safety assessment following an oil spill, a more specific risk characterization is dependent on specific knowledge regarding the actual oil spill and therefore it is important to obtain detailed and valid information regarding:

- which areas are/will be affected by the oil spill
- particular seafood items caught in the areas
- behaviour/metabolism etc. of the particular seafood
- concentration of PAH in the seafood following the oil spill
- how the seafood is distributed on the market – local/regional/export
- high consumer intake of the particular seafood
- potential sensitive groups

When considering the risk of PAH exposure following oil spill it is also important to remember that humans are exposed to PAH from many other sources than seafood e.g. other food items, smoking and occupationally. Therefore, the potential increase in cancer risk due to an oil spill is an addition to the cancer risk already posed by the general lifetime exposure.

Finally, it should be stressed that there is an urgent need for international agreement on standardised protocols based on scientific data, which can facilitate a more rapid and consistent assessment of the potential human health risk from PAH polluted seafood after an oil spill. Especially there is a need for agreement regarding the quantitative risk values (VSD or cancer slope factor) and the assessment of PAH in mixtures (which PAH should be measured and what should be the approach).

6 Risk management, next steps – including management options

When risk evaluation has been fulfilled as the first step of risk management and after the risk assessment, the next steps of the risk management follows. Risk management is defined as “The process, distinct from risk assessment, of weighing policy alternatives in consultation with all interested parties, considering risk assessment and other factors relevant for the health protection of consumers and for the promotion of fair trade practices, and, if needed, selecting appropriate prevention and control options” (WHO/FAO, 1997).

The following steps of risk management, considerations and decision-making are made based on the risk assessment. Risk management should take political decisions and other legitimate factors into account together with the safety aspects. After the preferred management option is chosen, risk managers should monitor the effect of the decisions taken, and if necessary due to unsatisfactory results of the management option chosen, the risk manager should repeat the risk analysis.

The next steps in risk management can be divided as follows:

- a. The identification of available management options.
- b. The selection of preferred management option.
- c. Final management decision.
- d. Implementation of the management decision.
- e. Monitoring and review

6.1 Identification of available management options

The prerequisite for the manager is that the seafood species should not have an off-taste and they should not endanger human health.

Off-taste and/or visible oil taint due to oil contamination is not necessarily a safety problem. Some of the components, which can give an off-taste, are not considered to be a risk. However, off-taste or visible oil taint would not be acceptable in fish sold on the market, and such seafood cannot be sold in accordance with EU legislation on the production and sale of seafood (Council Directive 91/493/EEC).

Even if seafood from an oil polluted area does not have an off-taste or visible oil taint, the uptake of components such as PAH from the oil could represent a safety risk to consumers.

The available management options for a safety risk could be:

- I. Ban of a fishery in a contaminated area
- II. Issue specific legislation, which set maximum levels for the content of oil components in food
- III. Give guidelines and information to producers, consumers etc. on intake.

The identification of the available management options should be based on the results of the risk assessment and identified in communication between risk assessors and risk managers. Other interested parties such as consumers, producers and retailers should have information on the available options found and should have the possibility to give comments, especially in this phase. The decision-makers at this step will be risk managers in the relevant administration, in dialogue with the politicians. The responsible politicians would take the final decision based on an evaluation of the available options.

As an example, the risk due to the Baltic Carrier oil spill can be calculated to give an increased cancer risk of 0.1 cancer cases per 1 million people per year for approximately 2 years. The uncertainties in the risk assessment tend to underestimate the risk, as average exposure figures, biomarkers – B[a]P and mathematical models are used. Furthermore, not all PAH compounds were taken into account, and the concentrations measured 2-3 month after the accident probably underestimate the initial concentrations.

a. Ban on fishery

Major oil spills raise concern regarding the potential contamination of seafood and the temporary closure of fisheries is a justified management option for a limited period of time while the risk is being assessed for the spill in question. The ban could be on the fishery for a specific species, or for all seafood.

A fishing ban would not necessarily be based on chemical analyses of seafood from the affected area since sampling and analysis require some time. Such a ban could be based on the Precautionary Principle and on general knowledge concerning the potential risk. In addition, seafood from oil-polluted areas would be expected to have an off-taste and in many cases also visible taints on the surface.

Risk assessment of the potential chemical contamination would tend to be ad hoc – site-specific assessments with variable risk assessment criteria due to the lack of standardised protocols. If an area is closed for fishing, the closure should be accompanied by a decision on the criteria for re-opening the area. For example criteria for re-opening shellfish harvest following oil spills have been devised for the primary contaminants of concern, PAH, expressed as total benzo[a]pyrene equivalents (Gilroy, 2000) like "Safe" ($<10 \mu\text{g kg}^{-1}$) and "unsafe" ($>45 \mu\text{g kg}^{-1}$) B[a]P equivalent levels were derived based on upper end (32.5 g d^{-1}) and average (7.5 g d^{-1}) estimates of shellfish consumption, respectively for an precise period of time.

The *advantages of banning fishing* include that there would be time for making decisions on the future management of the contamination. The consequences of an oil spill on the contaminant concentrations in seafood could actually be analysed, and data on the relative importance of the fishery in the area could be established.

Furthermore, it would be clearly demonstrated to consumers, importing countries etc., that the risk is managed with the inclusion of the Precautionary Principle. This could be an advantage seen from a consumer point of view, for export and maybe for the possibility to get insurance paid to the fishermen in the area. There could be an economic advantage for exportes due to trust achieved at importing markets.

Disadvantages of a ban include that the degree of contamination may be so limited that it did not pose a significant increase in risk to human health. Fishermen could subsequently claim that there was no scientific basis for the ban, and that the components in the oil are commonly found in food, such as smoked fish. A ban may also in special cases have economic implications for the authorities.

b. Maximum levels

An alternative could be to issue specific legislation with maximum levels for PAH in seafood on the market. This would require:

- knowledge on the background levels in fish and shellfish and levels found associated with contaminated environments
- special action for smoked and dried fish products.

Furthermore, since some PAH are carcinogenic and mutagenic, acceptance of such substances would often be seen as conflicting with the general principles in the Food Acts. However, even if the fishery was closed for a period of time, there would be a need for a decision on a tolerable level, since the ban would subsequently be lifted based on specified criteria.

The *advantages of setting maximum levels* include that it would be easy to decide whether a batch of seafood could be marketed or not.

Disadvantages of setting maximum levels for PAH in seafood include an acceptance of having carcinogenic substances in food, and an acceptance of having a calculated cancer risk due to food intake, furthermore PAH analyses are expensive and the industry would have an extra economical burden. Maximum levels might not be accepted by importing third countries, especially if the limits are not based on an international risk assessment, e.g. from JECFA.

In the legislation, there is also the possibility of defining *action levels*. Action levels would request a specific decision for batches exceeding the limit. This could give a signal to consumers, importers etc., that the contamination is not accepted, and that surveillance and specific decision-making would take place in individual cases.

c. Guidelines and information to producers and consumers

The management option of giving advice to consumers is sometimes used, in relation to contaminants in seafood.

A risk/benefit assessment of seafood consumption would for example in the Nordic countries come to the conclusion that seafood is healthy in a balanced diet and if the intake does not exceed e.g., 2-300 g/60 kg person/day.

Many risks concerning contaminants in seafood are managed by giving advice in the Nordic countries and elsewhere in the EU countries.

To illustrate this, a summary of advice from EU member states to consumers in relation to fish and fish products are listed in the table 6.1 below (unpublished data, July, 2003).

With regards to fish and shellfish species from oil polluted marine areas, this could be managed by advising consumers to reduce the intake or avoid eating seafood from this area or for example advice to avoid seafood from a specific area in conjunction with smoked food for a given period. However, many consumers might consider that if oil pollution gave rise to this kind of advice, then fishing should preferably be banned or managed directly by the authorities.

The *advantages of giving advice to consumers*, e.g. to have a balanced diet and not only eat seafood, would be that minor oil spills would not necessarily lead to a ban or to the establishment of maximum levels of PAH in all types of seafood. If the risk assessment concludes that the specific risk does not increase the total risk from PAH during the period estimated to be relevant for the contamination, then advisory management could be

without economical consequences for the industry and still be without increased risk for the consumers.

Disadvantages of managing the situation after oil spills by giving advice only could cause distrust in consumer groups towards the authorities. This could be a disadvantage even if the risk assessment clearly concludes that there is a minimal increase of the risk.

Table 6.1 Summary of advice given in EU member states on intake of fish, 2003.

Group of foodstuff	Foodstuffs	Contaminant	Advice	Consumer group
Fish and fish-ery products	Fish	Dioxins, PCBs	Balance diet. Nutritional effect contra contaminants. Eat fish 1-2 times a week. Vary between fatty and non-fatty fish.	Adults
	Fish	Mercury	Reduce intake of large predatory fish. 1) Only eat once a month. 2) Do not eat as main meals 3) Avoid eating shark, sword-fish, and marlin. 4) Not eat pike, perch, burbot, eel, halibut and trout larger than 25 cm or 1 kg. 5) Canned tuna is OK.	Pregnant women, young children
	Crustaceans	Dioxins, PCBs, mercury, PAH	Balance diet. Do not eat brown meat from crab	Pregnant women
	Fish liver	POPs, PCBs, dioxins	Reduce intake -> avoid eating	Pregnant women, women in fertile age, children
	Fish from certain geographical areas	POPs	Reduce intake -> avoid eating	All

6.2 Selection of preferred management option.

The selection of preferred management options should be based on the results of the risk assessment and it should be based on consultation of interested parties including consumers, producers and retailers, they should have information and possibilities for commenting in this phase.

Risk managers, mainly politicians, should take the final decision, as this would be a political decision on how to handle the risk.

Selection of a management option might depend on the size of the oil spill, fish species in the area etc., and therefore the hazard from oil spills might not always be managed in the same manner.

The project group is of the opinion that since the oil spills in question would be major spills, affecting the environment and possibly the seafood to such an extent that fast decisions are required. It is of importance to consider the possible scenarios in the emergency response system, and prepare possible proposals for management options in each case. The proposals should preferably be discussed in the Nordic corporation on emergency response plans, since an accident is likely to affect more than one of the Nordic countries. It has to be taken into account that knowledge is lacking on many of the aspects of importance to food safety.

The ideal option no. 1 would be

Issuing of specific legislation which ban fishery in an area for a certain period of time would be the ideal option. The period could be 2-3 months or until visible oil has been removed. This would allow for scientific risk assessment of the specific situation and science-based decision-making. Furthermore, it could be an economical advantage for the fishermen in relation to the possibilities of receiving compensation from the insurance of the ship and in relation to export.

Option no. 2 could be

Issue specific legislation setting maximum levels for the content of oil components (PAH) in food. This could be costly for the industry and might give rise to problems due to the limited shelf-life of seafood.

Option no. 3 could be

Providing guidelines and information to consumers and other interested parties could be an acceptable management option, if there is limited fishing activity in the polluted area. The advice to consumer could be repetition of the general advice to have a balanced diet and to alternate between lean and oily fish.

6.2.1 Examples of risk management following oil spills.

6.2.1.1 Spain and the Prestige accident, 2002

The tanker Prestige were lost in Spain, near the Galician coast 13 November 2002.

The fuel carried by Prestige was fuel type 6 (or bunker oil C) according to the international classification and the spill was around 70.000 tons. The Spanish authorities managed the oil spill in the following way:

- a. Banned fishery
- b. Drawed up sampling plans for fish and shellfish
- c. Defined working criterias for closing and where appropriate, re-opening of the catching and harvesting zones
- d. Defined indicators for the contamination
 - Visual examination of possible traces of fuel in external tissues (skin, carapace, shell, algae) of the fisheries products or on the surface of the water. Any contamination visually detected led to the banning of capture or extraction
 - Organoleptic examination of the fisheries products. Any strange smell or taste was also a criterion for the banning of capture or extraction
 - Analytical inspection of the residue of PAH. When the guide levels mentioned in the following paragraph were exceeded, the affected area was closed until three results was obtained which was below the guide level obtained with an interval of at least one week and corresponding to the same species and point of sampling.

Guide values

A guide value was considered to be an indicative value set in line with the available toxicological knowledge and the consumption data which provides a means of establishing surveillance measures for a specific contaminant. The Spanish authorities selected guide values adopted in various countries in similar circumstances. The values selected was the following:

For molluscs:

- 0.5 mg of PAH per kg of dry weight when the method of determination takes account of the 16 PAH on the list drawn up by the US Environmental Protection Agency (EPA) (see annex II).
- 0.2 mg of PAH per kg of dry weight when the method of determination takes account of the 6 PAH on the list drawn up by the French *Consejo Superior de Higiene Pública de Francia* (CSHPF) on the basis of the recommendations of the WHO and adapted according to the food risk, i.e.: Benzo[a]pyrene, benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[a] anthracene, dibenzo [a,h]anthracene and indeno[1,2,3-c,d]pyrene.

For fish:

The values specified for molluscs divided by 10.

For crustaceans and cephalopods:

The supervisory authorities used a guide value of 0.04 mg of PAH/kg of dry weight when the method of determination takes into account the sum of the 6 PAHs.

6.2.1.2 Cooss Bay, Oregon, 1999

The cargo-ship New Carissa ran aground near Coos Bay, Oregon in February 1999 and 25,000 – 70,000 gallons of oil was released into the sea (Gilroy, 2000). Concern for potential contamination of shellfish made the Oregon Department of Agriculture close shellfish harvesting in areas around the spill. The Oregon Health Division developed re-opening criteria based on the TEF approach (section 5.3.12).

They used the formula (with small modifications) mentioned in section 5.7.1. to derive different action PAH levels for shellfish. They used an acceptable risk level of 10^{-6} , an estimated lifetime of 70 years, an estimated body weight of 70 kg, a cancer slope factor of 7.3 per mg/kg bw/day and an exposure duration of 2 years. The safe and unsafe action levels were derived based on an average (7.5 g/day) and a high (32 g/day) consumption rate of shellfish.

Action levels for shellfish:

- If all the shellfish samples contained $<10 \mu\text{g kg}^{-1}$ B[a]P equivalents the shellfish harvesting can be re-opened.
- If any shellfish sample contained $>45 \mu\text{g kg}^{-1}$ B[a]P equivalents, the shellfish harvesting will be closed until safe action level is achieved.
- If any sample is between the two action levels above (>10 and $<45 \mu\text{g kg}^{-1}$ B[a]P) the need for further monitoring will be assessed case-by-case. (Gilroy, 2000).

6.3 Final management decision

The final management decision should address the safety concern and the result of the risk assessment but should also take consumer concern and the views of the industry on the consequences into account.

6.4 Assessment of the effectiveness of measures taken

The implementation of the selected management option is done by issuing orders on the risk or by elaborating the communication strategy on the measures taken. The implementation would be followed by surveillance and the in-house control of the producers and public food inspection.

6.5 Monitoring and review

The effectiveness of measures taken should be monitored by analyses of PAH in seafood from the area over time. Monitoring should take place for at least 1-2 years, as the effect of oil spills on PAH concentrations in seafood has been shown to last more than 1 year (Storstrøms County, 2002).

Major oil spills could be debated in-depth in the media, and therefore consumers may be very concerned of the consequences of the contamination and intake of seafood. The effect of the management decisions should therefore also be measured by a consumer survey conducted by the authorities. The survey could include interviews of consumers about their consumption of e.g. specific food items or of foodstuffs in general, including the food items of special concern. The responsible politicians would be required to allocate resources for such a survey. Ideally the management decisions should be followed by a measurement of the effect.

6.6 Review of the risk management and/or assessment as necessary

A review of the risk management and/or assessment will in most cases take place, if new knowledge is provided as part of the risk assessment documentation or if human diseases are reported. The public administrations in the Nordic countries have an obligation to follow the scientific literature in general. Furthermore, review could be of importance in relation to oil spills, as there could be a need for another decision on management options in the light of a review of the consequences of the previous decision. Ideally reviews should be conducted on a regular basis like every 5th year and the responsible scientists should concurrently update their literature on the subject.

7 Essential elements in an emergency response system

The goal for an emergency response system is to prevent, limit and repair damage to persons, food safety and the environment when accidents and catastrophes, including war take place or are likely to take place. A major oil spill would normally be the result of an accident, which can influence seafood safety via uptake of oil components by seafood species. The responsibilities of the emergency response system are normally defined by law, and will not be discussed in this report. However, knowledge of existing national and international emergency response systems and organisations involved in surveillance etc. are of importance for risk analysis concerning food safety issues. Annex V, VI and VII provide some general information on the national authorities and national and international contact points. Furthermore, some of the international surveillance systems are briefly described.

The national food administrations have different emergency response plans, but experience of accidental oil spills and the potential effect on seafood is limited and not currently available in an easily operational form.

In the case of a major oil spill the authorities will have to rapidly commence the risk analysis, in order to make risk management decisions in time, and thereby prevent potentially negative impacts on consumers. Major oil spill are usually immediately given publicity in the media, and the public may worry about the consequences for seafood safety.

The public in the Nordic countries would not only request an immediate decision from the responsible authorities, they would expect the authorities in the Nordic countries to take comparable decisions in the same situation. If the authorities were to make conflicting decisions, these should be based on sound scientific assessments, for example on differences in seafood consumption.

The prerequisite for taking decision would be specific knowledge about the situation. This knowledge should include the following:

- a. Estimate of the legal consequences of the available management options, for example what would be the consequences of a ban on fisheries for 3 month
- b. Information on the composition of different types of oil
- c. Information on the amount of oil spilled
- d. Risk assessment of all relevant components in oil and the risk for consumers
- e. Information on background contamination in the marine area
- f. Information on seafood species fished and used commercially in the area, both as feed and food
- g. Information on the importance of export of the types of seafood
- h. Economical resources for risk assessment and analysis, both organoleptic and chemical.
- i. Decision on analyses required following an oil spill

- j. List of laboratories accredited for the relevant analyses (including prices)
- k. Sampling plans, both for seafood and sediments, including consideration of the most sensitive species, relevant edible parts of the seafood species (e.g. fish muscle versus liver) and sampling time
- l. Criteria for re-opening of a fishing area after a ban.

Some of this information may be collected as part of the emergency response by using the ICES grid and information collected by ICES on contaminants and seafood caught in each grid. In addition, national data on seafood from a specific area could be made available in an easily accessible form, for example via an emergency contact-network. Model oil spill scenarios could be assessed, for example oil spills of < 1000 tons, size 10^3 - 10^4 etc. up to 300.000 tons, the latter being the approximate size of super tankers from Russian oil harbours.

Co-operation with food authorities in neighbouring countries could also be relevant for comparable decision-making. Since oil spills are usually emergencies, networks should be already established and be readily activated if the situation arose. Food networks could be linked to existing national and international surveillance/environmental emergency response systems.

8 Proposals and recommendations

Major oil spills could potentially occur in marine areas around all of the Nordic countries. They could happen as a result of tankers colliding or running aground, by damage to pipelines, from industrial oil platforms or from other activities. The spill could be enormous if, for example a 100.000 tons or even larger tanker was damaged. Considering the potential impact, it is advisable to include the question of food safety in the emergency response.

The Nordic project group recommends that initiatives be taken in several different areas.

Emergency response management

- a. Establish Nordic cooperation between the authorities involved in such situations
- b. Collect information on oil composition
- c. Map background contamination and fisheries
- d. Improved cooperation between authorities in clean-up actions after accidents

Food safety assessment

- a. Establish a Nordic and/or EU network concerning food safety assessment and oil spills
- b. Collect data on oil composition
- c. Uptake and metabolism of relevant polyaromatic hydrocarbons (PAH) in seafood species should be assessed in more detail
- d. Risk assessment of other oil components than PAH in seafood species should be conducted
- e. Development of reliable methods of analysis and sampling plans for all PAH and other components in oil, which are considered to be a potential risk to consumers
- f. Decision on which risk assessment model (for example which virtually safe dose (VSD)) is most appropriate
- g. Risk assessment of PAH-metabolites in seafood and their effects on humans
- h. Collect data on PAH and PAH-metabolites, including data from environmental surveillance
- i. Make data collected available e.g. via the ICES databank

Food safety management

- a. Map background levels of PAH in the marine environment including levels in water, sediment and seafood species
- b. Improve cooperation between authorities involved in the following sectors: food, environment and fishery
- c. Decision on tolerable levels of PAH in seafood in the Nordic countries

- d. Collection of data on PAH profiles in different foodstuffs, including various species of fish and other types of seafood
- e. Decision of which level of risk is considered acceptable

Other research areas

- a. Knowledge on fish behaviour in relation to oil spills

Given the importance of the ability to make decisions and react rapidly in emergency situations such as accidental oils spills, specific resources from The Nordic Council of Ministers or from the EU should be available for joint emergency response systems concerning seafood.

References

Chapter 1

Fabech, B, Bryhni, K., Plym Forshell, Lars, Georgsson, F., Gry, J., Thiim Hansen, B., Hallström, H., Hatakka, M., Holene, E., Kapperud, G., Kristinsson, J., Majjala, R., Nielsen, N.L., Nordström, U., Schulz, A. C., Solheim, C. and Thorkelsson, A.E. (2002). A Practical Approach to the Application of the Risk Analysis Process, TemaNord 2002:510

Chapter 2

EEA Indicator Fact Sheet (2002). Illegal discharges of oil at sea.

Hansen, A.B. (2002). The effect of oil spill on seafood safety. Annex III, C: Composition of oil, some background information.

International Convention for the Prevention of Pollution from ships (1973) changed by Protocol – Marpol 73/78

International Tanker Owners Pollution Federation Limited (ITOPF). Oil Tanker Spill Statistics (www.itopf.org)

Lundanes, E. and Greibrokk, T. (1994). Separation of fuels, heavy fractions, and crude oils into compound classes. A review. *Journal of High Resolution Chromatography* Vol. 17: 197-202.

Norwegian Environmental Protection Agency (2002)

Neff, J.M. (2002). Bioaccumulation in marine organisms: Effect of contaminants from oil well produced water. Elsevier, 452 pp.

Oil in the Sea III Inputs, Fates and Effects (2003). The National Academies Press, Washington, D.C.

The oil and gas industry from Rio to Johannesburg and beyond. Contributing to sustainable development (2002). IPIECA/OGP

OPEC Annual Statistical Bulletin (2001) (www.opec.org)

OWEM (OPEC's World Energy Model) (2000). Scenarios Report, March

Storstrøms county (2002). The "Baltic Carrier" oil spill. Monitoring an assessment of environmental effects in Grønsund (DK). pp.9-13

Utslipp på norsk kontinentalsokkel (1999). Olje, kjemikalier og utslipp til luft. SFT-rapport 1762/2000.

Wang, Z., Fingas, M., and Page, D.S. (1999). Oil spill Identification, *Journal of Chromatography A* Vol. 843: 369-411.

Wang, Z., Fingas, M., and Sigonin, L. (2001). Characterisation and identification of a "mystery" oil spill from Quebec (1999), *Journal of Chromatography A* Vol. 909: 155-169.

World Oil Transit Chokepoints (November 2002). EIA Country analysis Briefs (eia.doc.gov)

Yender, R., Michel, J. and Lord, C. (2002). Managing seafood safety after an oil spill. Seattle: Hazardous Materials Response Division, Office of Response and Restoration, National Oceanic and Atmospheric Administration, 72 pp.

Chapter 3

Aas, E., Baussant, T., Balk, L., Liewenborg, B. and Andersen, O. K. (2000). PAH metabolites in bile, cytochrome P4501A and DNA adducts as environmental risk parameters for chronic oil exposure: a laboratory experiment with Atlantic cod. *Aquat. Toxicol.* 51, 241-258.

Baussant, T., Sanni, S., Jonsson, G., Skadsheim, A. and Borseth, J. F. (2001). Bioaccumulation of polycyclic aromatic compounds: 1. Bioconcentration in two marine species and in semipermeable membrane devices during chronic exposure to dispersed crude oil. *Environ. Toxicol. Chem.* 20, 1175-1184.

- Collier, T. C., Thomas, L. C. and Malins, D. C. (1978). Influence of environmental temperature on disposition of dietary naphthalene in coho salmon (*Oncorhynchus kisutch*): isolation and identification of individual metabolites. *Comp. Biochem. Physiol. C*. 61C, 23-28.
- Collier, T. K., Connor, S. D., Eberhart, B. T. L., Anulacion, B. F., Goksøyr, A. and Varanasi, U. (1992). Using cytochrome-p450 to monitor the aquatic environment - initial results from regional and national surveys. *Mar. Environ. Res.* 34, 195-199.
- Dunn, B. P., Black, J. J. and Maccubbin, A. (1987). ³²P-postlabelling analysis of aromatic DNA adducts in fish from polluted areas. *Cancer Research* 47, 6543-6548.
- Gilroy, D.J. (2000). Derivation of shellfish harvest reopening criteria following the Hew Carissa oil spill in Cos Bay, Oregon. *Journal of Toxicology and Environmental Health*, 60A: 317-329.
- Hawkins, S. A., Billiard, S. M., Tabash, S. P., Brown, R. S. and Hodson, P. V. (2002). Altering cytochrome P4501A activity affects polyaromatic hydrocarbon metabolism and toxicity in rainbow trout (*Oncorhynchus mykiss*). *Environ. Toxicol. Chem.* 21, 1845-1853.
- Hom, T., Brown, D. W., Stein, J. E. and Varanasi, U. (1999). Measuring the exposure of subsistence fish and marine mammal species to aromatic compounds following the Exxon Valdez oil spill. In: Field, L.J., Fall, J.A., Nighswander, T.S., Peacock, N., Varanasi, U. (Eds.), *Evaluating and communicating subsistence seafood safety in a cross-cultural context: lessons learned from the Exxon Valdez oil spill*. Society of Environmental Toxicology and Chemistry (SETAC), Pensacola, pp. 169-194.
- Law, R. and Hellou, J. (1999). Contamination of fish and shellfish following oil spill incidents, *Environmental Geoscience*, 6: 90-98.
- Law, R.J., Kelly, C.A. and Nicholson, M.D. (1999). Polycyclic aromatic hydrocarbons (PAH) in shellfish affected by the Sea Empress oil spill in Wales in 1996. *Polycyclic Aromatic Hydrocarbons*, 17: 229-239.
- Malins, D. C., Krahn, M. M., Myers, M. S., Rhodes, L. D., Brown, D. W., Krone, C. A., McCain, B. B. and Chan, S.-L., (1985). Toxic chemicals in sediments and biota from creosote-polluted harbor: relationships with hepatic neoplasms and other hepatic lesions in English sole (*Parophrys vetulus*). *Carcinogenesis* 6, 1464-1469.
- Meador, J.P., Stein, J.E., Reichert, W.L. and Varanasi, U. (1995). Bioaccumulation of Polycyclic aromatic hydrocarbons by marine organisms. *Reviews of Environmental Contamination and Toxicology*, 143: 79-165.
- Myllyvirta, T. P. and Vuorinen, P. J. (1989). Avoidance of bleached kraft mill effluent by pre-exposed *Coregonus albula* L. *Water Res.* 23, 1219-1227.
- Neff, J. M. (1979). Polycyclic aromatic hydrocarbons in the aquatic environment, sources, fates and biological effects. Applied Science Publishers Ltd, London. 262 p.
- Neff, J. M. (1985). Polycyclic aromatic hydrocarbons. In: Rand, G.M., Petrocelli, S.R. (Eds.), *Fundamentals of aquatic toxicology, methods and applications*. Hemisphere Publishing Corporation (McGraw-Hill International Book Company), Washington, New York, London, pp. 416-454.
- Porte, C. and Albaiges, J. (1994). Bioaccumulation patterns of hydrocarbons and polychlorinated biphenyls in bivalves, crustaceans, and fishes. *Arch. Environ. Contam. Toxicol.* 26, 273-281.
- Stagg, R. M. (1998). The Development of an International Programme for Monitoring the Biological Effects of Contaminants in the OSPAR Convention Area. *Mar. Environ. Res.* 46, 307-313.
- Stegeman, J. J. (1989). Cytochrome P450 forms in fish: catalytic, immunological and sequence similarities. *Xenobiotica* 19, 1093-1110.
- Stegeman, J. J. and Hahn, M. E. (1994). Biochemistry and molecular biology of monooxygenases: current perspectives on forms, functions and regulation of cytochrome P450 in aquatic species. In: Malins, D.C., Ostrander, G.K. (Eds.), *Aquatic toxicology: molecular, biochemical, and cellular perspectives*. CRC Press, pp. 87-206.
- Tuvikene, A. (1995). Responses of fish to polycyclic aromatic hydrocarbons (PAH). *Ann. Zool. Fennici* 32, 295-309.
- van Schanke, A., Holtz, F., van der Meer, J., Boon, J. P., Ariese, F., Stroomberg, G., Van den Berg, M. and Everaarts, J. M. (2001). Dose- and time-dependent formation of biliary benzo[a]pyrene metabolites in the marine flatfish dab (*Limanda limanda*). *Environ. Toxicol. Chem.* 20, 1641-1647.

- Varanasi, U., Uhler, M. and Stranahan, S. U. (1978). Uptake and release of naphthalene and its metabolites in skin and epidermal mucus of salmonids. *Toxicol. Appl. Pharmacol.* 44, 277-289.
- Whittle, K.J., Anderson, D.A., Mackie, P.R., Moffat, C.F., Sheperd, N.J. and McVicar, A.H. (1997). The impact of the Braer oil on caged salmon. In *The Impact of an oil spill in Turbulent waters, The Braer. Proc. Of a Symp. Held at the Royal Soc. of Edinburgh.* Eds. J.M. Davies, G. Topping, The Stationary Office, Edinburgh, pp. 144-160.

Chapter 4

- Codex Alimentarius Commission, CL 1996/21-GEN, June (1996).
- Codex Alimentarius Commission: Procedural Manual, 10th ed., page 147, Rome (1997).
- Communication from the Commission on the Precautionary Principle, COM (2000) 1 Final, Brussels, 2.2.2000.
- EU Council Directive 91/493/EEC on safety conditions for the production and sale of fishery products
- FAO/WHO (1995). Application of Risk Analysis to Food Standard Issues. Report of the Joint FAO/WHO Expert Consultation. Geneva, Switzerland, 13-17 March 1995. WHO: Geneva.
- FAO/WHO (1997). Risk Management and Food Safety. Report of a Joint FAO/WHO Consultation. Rome, Italy, 27-31 January 1997. Rome: FAO
- FAO/WHO (1998). Application of Risk Communication to Food Standards and Safety Matters. Report of the Joint FAO/WHO Expert Consultation. Rome, Italy, 2-6 February 1998.
- ICES. International Council for the Exploration of the Sea.
- Klinke, A. and Renn, O. (1999): Prometheus Unbound. Challenges of Risk Evaluation, Risk Classification, and Risk Management. Working Paper No. 153 of the Center of Technology Assessment. Stuttgart: Center of Technology Assessment
- Sovarnets Operative Kommando (2003). personal communication
- WHO (1997). Risk management and food safety. FAO Food and nutrition paper no 65.

Chapter 5

- Andersen, J.K., Büchert, A., Koch, B., Ladefoged, O., Leth, T., Licht, D. and Ovesen, L (2003) Balanced view on fish., National Veterinary and Food Administration, Denmark
- Barlow, S, Dybing, E, Edler, L (editors), *Food Chemical Toxicology*, vol. 40 (2/3), 2002, p. 237-427
- Baussant, T., Sanni, S., Jonsson, G., Skadsheim, A. and Borseth, J. F. (2001). Bioaccumulation of polycyclic aromatic compounds: 1. Bioconcentration in two marine species and in semipermeable membrane devices during chronic exposure to dispersed crude oil. *Environ. Toxicol. Chem.* 20, 1175-1184.
- Beserati, N. (2001) Molecular dosimetry studies of smoking – induced carcinogenesis in target and surrogate tissues of humans. PhD Dissertation, University of Maastricht, pp. 160.
- Borzelleca, J.F. and Verhagen, H., *Food and Chemical Toxicology*, vol. 41 (9), 2003, p.1211-1271.
- Brown, R. and Mittelman, A. (1993). Evaluation of Existing Methods to Rank the Relative Carcinogenicity of Polycyclic Aromatic Compounds(PAH), Draft. US Environmental Protection Agency.
- Culp, S.J., Gaylor, D.W., Sheldon, W.G., Goldstein, L.S., and Beland, F.A. (1998). A comparison of the tumors induced by coal tar and benzo[a]pyrene in a 2-year bioassay. *Carcinogenesis* 19, 117-124.
- Fødevaredirektoratet, pers. comm.
- Gilroy, D.J. (2000). Derivation of shellfish harvest reopening criteria following the Hew Carissa oil spill in Coos Bay, Oregon. *Journal of Toxicology and Environmental Health*, 60A: 317-329.
- Guinan, J., Charlesworth, M., Service, M. and Oliver, T. (2001). Sources and geochemical constraints of polycyclic aromatic hydrocarbons (PAH) in sediments and mussels of two Northern Irish Sea-loughs. *Marine Pollution Bulletin* 42 (11), 1073-1081..
- Hallikainen, A. and Niemi, E. 2003. Maahantuotujen kalasäilykkeiden vierasaineita valvotaan. *Kaari* 3/2003, p. 14-15.

- IARC (1983). Polynuclear Aromatic Compounds. IARC Monographs on the evaluation of the Carcinogenic Risk of Chemicals to Humans, vol. 32. IARC, France.
- IPCS (1998). Environmental Health Criteria 202, Selected non-heterocyclic Polycyclic Aromatic Hydrocarbons. World Health Organization, Geneva.
- Johansson, L. and Solvoll, K. (1999). NORKOST 1997. Landsomfattende kostholdsundersøkelse blant menn og kvinner I alderen 16-79 år. Rapport nr. 2/1999. Statens råd for ernæring og fysisk aktivitet.
- Koganti, A., Singh, R., Rozett, K., Modi, N., Goldstein, L.S., Roy, T.A., Zhang, F.J., Harvey, R.G., and Weyand, E.H. (2000). 7H-benzo[c]fluorene: a major DNA adduct-forming component of coal tæger. *Carcinogenesis* 21, 1601-1609.
- Larsen, J.C. and Larsen, P.B. (1998). Chemical Carcinogens. In "Air Pollution and Health", Environmental Science and Technology. Hester, R.E., Harrison, R.M. (eds). Cambridge, UK: The Royal Society of Chemistry, pp. 33-56.
- Law, R. J. and Hellou, J. (1999) Contamination of fish and shellfish following oil spill incidents. *Environmental Geoscience* 6 (2), 90-98.
- LST (1995) Danskernes kostvaner 1995 Hovedresultater. Levnedsmiddelstyrelsen.
- Meltzer, H. M., Bergsten, C. and Stigum, H. (2002). Fisk- og Vildtundersøkelsen. Konsum af matvarer som kan ha betydning for inntaket av kviksløv, kadmium og PCB/dioksin I norsk kosthold. SNT rapport 6. Statens Næringsmiddeltilsyn, Norge.
- Precautionary Principle and Discursive Strategies, to be published as a special issue of the Journal of Risk Research at the end of this year or at the beginning of next year.
- Riksmaten (1997-98), Kostvaner och näringsintag i Sverige, Livsmedelsverket 2002, Box 622, S-751 26 Uppsala, Sweden
- Schneider, K., Roller, M., Kalberlah, F., and Schumacher-Wolz, U. (2002). Cancer Risk Assessment for Oral Exposure to PAH mixtures. *Journal of Applied Toxicology*, 22, 73-83
- SCF (2002) Opinion of the Scientific Committee on Food on the risks to human health of polycyclic aromatic hydrocarbons in food. Scientific Committee on Food, European Commission.
- Short, J. W. and Babcock, M. M. (1996) Prespill and postspill concentrations of hydrocarbons in mussels and sediments in Prince William sound. *American Fisheries Society Symposium* 18, 149-166
- Short, J. W., Kvenvoldsen, K. A., Carlson, P. R., Hostettler, F. D., Rosenbauer, R. J. and Wright, B. A. (1999) Natural Hydrocarbon Background in Benthic Sediments of Prince William Sound, Alaska: oil vs coal. *Environ. Sci. Technol.* 33, 34-42
- SCOOP, unpublished, March 2004
- Storstrøms County (2002). The Baltic Carrier oil spill. Monitoring and assessment of Environmental effects in Grønsund (DK). Teknik og Miljøforvaltningen, Storstrøms Amt

Chapter 6

Repercussions of the Prestige oil spill on food safety, 1 April 2003, SANCO-93-2003-4a, <http://www.msc.es/aesa/documentosWeb/Informe%20t%E9cnico%20Prestige/prestige.pdf>

Annex I

<http://www.norden.org/faktaof/Tabel-med-latin.htm>

Annex II

GESAMP (1982). The evaluation of the hazards of harmful substances carried by ships. GESAMP Reports and Studies 17.

Höfer, T. (1998). Tainting of seafood and marine pollution. Wat. Res. 32, 3505-3512.

Annex V-VII

Decision No. 2850/2000/EC of the European Parliament and the Council of 20 December 2000 setting up a Community Framework for Cooperation in the Field of Accidental or Deliberate Marine Pollution

Københavnsaftalen: Aftale mellem Danmark, Finland, Island; Norge og Sverige om samarbejde vedrørende bekæmpelse af forurening af havet med olie eller andre skadelige stoffer, 1993.

Annex I

Names of fish⁴ and shellfish species, Nordic languages, English and Latin

This annex includes a list of fish and shellfish species mentioned in the report.

English	Latin	Danish	Finish	Icelandic	Norwegian	Swedish
Fish						
Anchovy	<i>Engraulis encrasicolus</i>	Ansjoser	Anjovis	ansjósa	Ansjos	
Arctic char	<i>Salvelinus alpinus</i>	Fjældørred	Nieriä	Bleikja	Arktisk røye	Fjällröding
Argentine	<i>Argentina silus</i>	Guldlaks	Kultakuore	Gulllax	Vassild	Guldlax
Blue ling	<i>Molva dypterygia</i>	Byrkelange	Tylppäpyrstömlöva	Blálanga	Blålange	Blålånga
Broad whitefish	<i>Coregonus nasus</i>	Stor bundhelt				Krumnos-sik
Cod	<i>Gadus morhua</i>	Torsk	Turska	Þorskur	Torsk	Torsk
Common Whitefish	<i>Coregonus lavaretus</i>	Helt	Vaellussii-ka		Sik	Lavaretsik
Dab	<i>Limanda limanda</i>	Ising	Hietakamela	Sandkoli	sandflyndre	SAndskäde
Eel, European	<i>Anguilla anguilla</i>	Ål	Ankerias	Áll	Ål	Ål
Flounder	<i>Platichthys flesus</i>	Skrubbe	Kampela	Flundra	Flyndre	Skrubba, skrubbfundra
Garfish, hornfish	<i>Belone belone</i>	Hornfisk	Nokkakala	Hornfiskur	Horngjel	Näbgädde hornskädda
Goby	<i>Gobiidae</i>	Kutling	Tokko	Kytlingur	Kutlinger	Smörbult
Haddock	<i>Melanogrammus aeglefinus</i>	Kuller	Kolja	Ýsa	Hyse	Kolja

⁴ In the text, the word *seafood* is used covering fish, shellfish (molluscs and crustaceans), echinoderms and tunicates. Molluscs includes bivalve molluscs – *Lamellibranchia/Acephala* -, gastropods - *Gastropoda* - and cephalopods – *Asteroidea* and *Echinoidea*. Crustaceans include *C. Entomostraca* and *C. Malacostraca*, and the sub-species *Natantia* (shrimps) and *Reptantia* (loster and crabs)

Hake	<i>Merluccius merluccius</i>	Kulmule	Kummeli-turska	Lýsingur	Lysing	Kummel
Halibut , Atlantic	<i>Hippoglossus hippoglossus</i>	Helleflynder	Pallas, Ruijan-pallas	Flyðra, heilagfiski	Kveite	Häl-laflundra
Halibut Greenland	<i>Cyclopterus ruptus</i>	Kulso stenbider	Rasvakala	Hrognkelsi	Rognkjeks	Sjurygg
Herring	<i>Clupea harengus</i>	Sild	Silli	Síld	Sild	Sill
Mackerel	<i>Scomber scombrus</i>	Makrel	Makrelli	Makríll	Makrell	Makrill
Pilchard, sardine	<i>Sardina pilchardus</i>	Sardine	Sardiini	Sardina	Sardiner	
Plaice	<i>Pleuronectes platessa</i>	Rødspætte	Punakampela	Rauðspretta	Rødspætte	Rödspätta, rödspåtta
Pollock, saithe, coal-fish	<i>Pollachius virens</i>	Mørksej	Seiti	Ufsi	Sei	Sej, gråsej
Salmon , atlantic	<i>Salmo salar</i>	Laks	Lohi	Lax	Laks	Lax
Salmon, coho	<i>Oncorhynchus kisutch</i>				Stillehavslaks	
Salmon, pink	<i>Oncorhynchus gorbuscha</i>				Stillehavslaks	
Trout, brown	<i>Salmo trutta</i>	Ørred	Purotaimen, Tammukka	Urriði	Innlandsørret	Bäcköring
Trout, sea	<i>Salmo trutta</i>	Havørred	Taimen, meritaimen	Sjóbirtingur	Sjørret	Öring
Tuna	<i>Thunnidae</i>	Tun	Tonnikala	Tonno	Størje/tunfisk	Tonfisk
Turbot	<i>Scophthalmus maximus</i>	Pighvar	Piikkikampela	Sandhverfa	Piggvar	Piggvar
Shellfish						
Bivalves	<i>Bivalvia, Lamellibranchia</i>	Muslinger		Samlokur	Skjell	
Blue mussel	<i>Mytilus edulis</i>	Blåmusling	Sinisimpukka	kræklingur	Blåskjell	Blåmussla
Crustaceans		Skaldyr			Krepsdyr	
Deep-water prawn	<i>Pandalus borealis</i>	Dybhavstreje	Pohjankatkarapu	Kampalampi	Dypvannsreke	Nordhavsräka
Edible crab	<i>Cancer pagurus</i>	Krabbe	Taskurapu	Krabbi	Krabbe	Krabba

Annex II

Testing, some general remarks

Methods for testing and evaluation of these methods are not included in the terms of reference of this project. However, some general remarks are listed in this Annex in order to provide information on the types of testing, which is discussed in relation to oil spills.

I Visual

Seafood from areas with oil spills can have oil on the surface. Visual inspection could be chosen as a first step in the evaluation on whether specific seafood could be used for human consumption. If there is visible oil taints on the seafood, this would be sufficient basis for discarding the products.

II Organoleptic testing

Organoleptic testing would be a useful tool in the examination of seafood from areas with oil spills. Tainting was introduced as a technical term to describe gustatory and/or olfactory impairment of foods. The Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP, 1982) defined tainting as: "a foreign flavour or odour in the organism induced by conditions on the water to which they are exposed".

Off-taste is considered a warning sign, indicating an onset of enzymatic degradation and bacteria-associated spoilage. This is particularly the case for seafood. The cause may be natural, for example fish from stagnant waters can have an unpleasant taste, alternatively the cause for off-taste may be a result of pollution. There have been reports of tainting after tanker accidents, however quantitative determinations of levels of contaminants in fish flesh are scarce (GESAMP, 1993). Höfer (1998) reviewed the topic of tainting of seafood and marine pollution. Studies of the aromatic hydrocarbon levels in caged fish following the Braer oil spill, revealed a rapid increase in the levels in edible tissues from 0.03 to 14 mg l⁻¹ followed by a rapid decrease to 1 mg l⁻¹ and a much slower decrease to background concentrations over a period of 12 months. Wild fish ceased to have an oily taste a few weeks after the Braer accident, whereas tainting was still obvious in farmed fish after 50 days accident (Whittle et al., 1997). As a consequence of research following the Braer accident, tainting in addition to high levels of aromatic hydrocarbons have been considered to be good indicators of fish contamination (Höfer, 1998). However, with knowledge of the constituents of oil, chemical analyses that provide quantitative data may be preferable to the use of sensory panels.

III Chemical analysis

Chemical analysis could be both analyses of the oil spilled, and of the contaminants in seafood from the contaminated area.

Furthermore, the analysis could be e.g. "fingerprint" of the oil either as an identification of the type of oil spilled, or as a first step in the quantitative analysis of the individual components in the oil, especially the component that could endanger human health. See also Chapter 2.

Some of the specific components in the oil, e.g. the PAH can be analysed, or PAH as well as other hazardous components in the oil can be analysed either qualitatively

and/or quantitatively. As this project is concentrating on PAH this Annex include more details on analysis of these components.

Determination of polycyclic aromatic hydrocarbons (PAH).

For the general population, the major routes of exposure to PAH are from food and inhaled air. PAH enter the environment via the atmosphere from a variety of combustion processes and pyrolysis sources. PAH have been detected in a variety of foods, notably vegetables, as a result of airborne PAH, and in fish and mussels from contaminated waters. They have also been found in vegetable oils and margarine. PAH are also formed as a result of certain preparation methods, such as barbecuing roasting and smoking.

Because of the numerous sources of PAH there are also numerous analytical methods using different techniques prior to clean up and purification. PAH are most often identified and quantified using either gas chromatography (GC) with flame ionisation detection (FID) or coupled to mass spectrometry (MS) or high performance liquid chromatography (HPLC) with ultraviolet or fluorescence detection or coupled MS.

The EPA (US Environmental Protection Agency) has listed sixteen PAH in order to have a standard for which component should be analysed, when relevant, comparable PAH-profiles are requested. The list of EPA-priority PAH is as follows (listed after molecular weight):

Naphthalene
Acenaphthylene
Acenaphthalene
Fluorene
Phenanthrene
Anthracene
Fluoranthene
Pyrene
Benz[*a*]anthracene
Chrysene
Benzo[*b*]fluoranthene
Benzo[*k*]fluoranthene
Benzo[*a*]pyrene
Dibenzo[*ah*]anthracene
Benzo[*ghi*]perylene
Indeno[1,2,3-*cd*]pyrene

There are a number of factors that may lead to erroneous analytical results. The working up procedures as homogenisation, extraction and different clean up techniques are critical steps in the analytical performance that may cause losses of PAH. During sample collection and storage it is important that the sample not be exposed to light and high temperature. Also storage for a prolonged time before analysis may result in a breaking down process of PAH or a reaction of some PAH with components of the food matrix.

In the PAH quantitation process attention should also be paid to possible co-elution of some PAH components.

In the following part an analytical procedure will be described in some details. Determination of PAH in vegetable fats and oil can act as an analytical model for analysis of PAH.

Principle

Extraction of PAH with an acetonitrile/acetone mixture followed by purification on C₁₈ then Florisil bond end-phase cartridges. Determination of the content of the individual PAH substances after separation by means of HPLC using fluorescence detection at various excitation and emission wavelengths.

Procedure – general method

To obtain repeatable results it is important that temperature in the laboratory is constant ($\geq 20^{\circ}\text{C}$).

Each sequence of samples must include a blank and a standard solution extracted in the same conditions as the samples in order to calculate the recoveries of the extractions

The samples is extracted with the solvent mixture and then centrifuged. The solvent is evaporated and the residue is purified first on a C₁₈ column (size-exclusion) and than on a Florisil (size) bonded-phase cartridge.

The eluent solvent is removed under a flow of nitrogen and the residue is taken up in a small amount of tetrahydrofuran/methanol. Then the solution will be injected in GC and quantified by means of fluorescence or MS. The chromatogram has to be carefully analysed to investigate possible co-eluted peaks.

According to the EU legislation analytical methods have to be carefully validated before the methods routinely can be used in monitoring and/or official control purposes.

Annex III

Background data for the risk assessment⁵

Annex III.a Using the TEF approach

The TEF approach (using TEF values from Larsen & Larsen, 1998) and the surrogate (B[a]P) approach were used on chemical data from trout from aquacultures in Grønsund 1½ month after the “Baltic Carrier” accident and on bottom dwelling fish from comparable areas not affected by oil. The results are shown in the table below.

B[a]P and B[a]P toxic equivalences (µg/kg wet weight) calculated for trout from fish farms in the Grønsund area 1½ month after oil-spill and flounder (Platichthys flesus) representing background levels in Danish waters. Numbers in brackets are maximum levels for eelpout (Zoarces viviparous)

µg/kg ww	Trout, Grønsund	Bottom dwelling fish, background levels DK
B[a]P TEQ (liver)	0.13 - 2.3	1.25 – 3.0 (14)
B[a]P TEQ (muscle)	0.14 - 0.2 *	0.35 – 1.03
B[a]P (liver)	n.d.	0.52 – 1.79 (8.55)
B[a]P (muscle)	n.d.	0.17 – 0.57

n.d.: not detectable

*: Muscle and skin

The B[a]P –TEQ values calculated for the contaminated fish 1½ month after the oil spill were of the same order of magnitude as calculated B[a]P-TEQ values from comparable areas not affected by oil. Furthermore, B[a]P itself was not found in the trout from aquacultures from the polluted area.

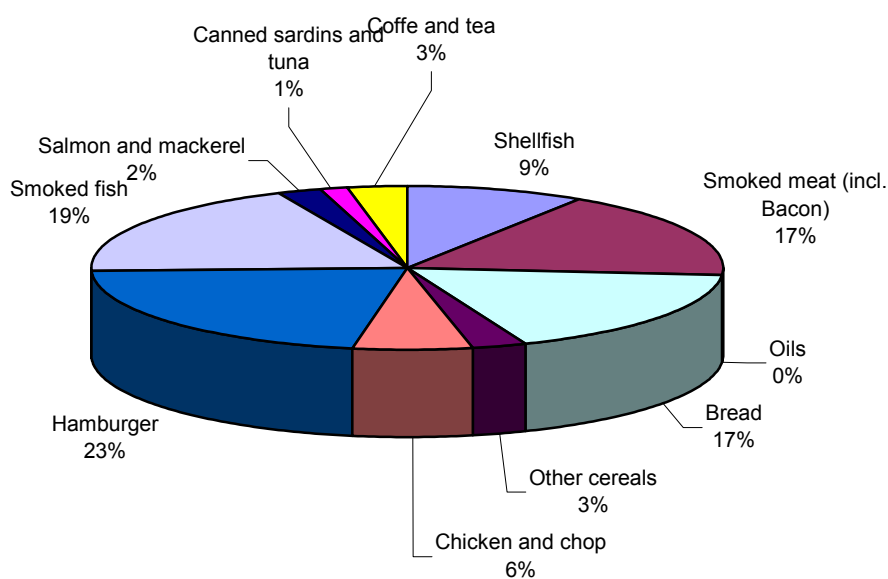
However, the following reservations has to be taken: there was only a limited amount of chemical data available, fish from fish farms were compared with fish living at the bottom of the sea, and the fish were collected 1½ month after the accident. At this time a pronounced metabolism/excretion of PAH in the fish must be expected.

⁵ Annex III includes data used in the risk assessment in Chapter 5 in the report.

In addition, in this example there might be some uncertainties related to the B[a]P approach; no B[a]P were detected in the trout following oil spill. While the PAH profiles seem to be different in the compared fish, the B[a]P-TEQ values were quite similar.

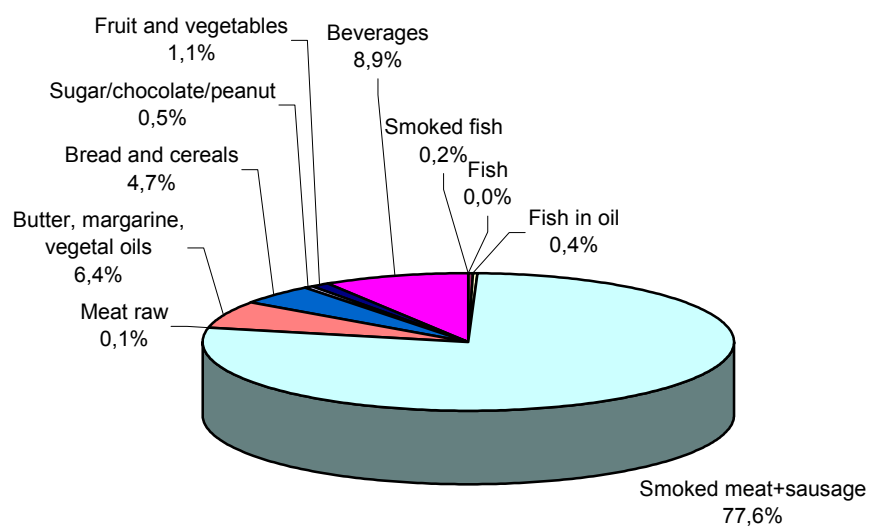
Annex III.b Intake of food related B[a]P for Norwegian and Finnish adults⁶

It should be noticed that only selected food items have been analysed and therefore the data used for the estimations do not cover the whole diet; the contribution from different groups of foodstuff e.g. seafood to the total dietary intake of B[a]P depends on which food groups are included and therefore, the figures are not comparable between countries.



Intake of food related B[a]P (% of total) for Norwegian women

⁶ (estimated on the basis of data from SCOOP, unpublished, March 2004).



Intake of food related B[a]P (% of total) for Finnish adults

Annex III.c The intake of seafood in Denmark

Species	1-3 years old			4-6 years old			7-14 years old			Adults		
	g/kg bw/day		Rate of consumers	g/kg bw/day		Rate of consumers	g/kg bw/day		Rate of consumers	g/kg bw/day		Rate of consumers
	Average	95 th percentile		Average	95 th percentile		Average	95 th percentile		Average	95 th percentile	
Plaice ⁵	0.14	0.67	42.3	0.12	0.47	41.2	0.08	0.40	27.2	0.07	0.28	42.7
Cod ⁵	0.17	0.69	47.7	0.14	0.51	50.4	0.08	0.40	33.4	0.07	0.28	48.4
Cod, roe ⁵	0.11	0.44	53.4	0.10	0.36	45.2	0.05	0.19	39.6	0.02	0.08	36.3
Mackerel ¹	0.12	0.40	67.7	0.09	0.36	65.8	0.06	0.22	58.6	0.05	0.17	74.3
Herring ²	0.05	0.37	14.7	0.04	0.28	15.8	0.03	0.24	17.9	0.07	0.30	45.6
Salmon ⁵	0.01	0.00	4.7	0.01	0.10	7.0	0.01	0.09	6.6	0.01	0.07	14.2
Tuna ³	0.09	0.30	64.5	0.07	0.28	64.3	0.05	0.18	57.3	0.02	0.08	58.6
Shrimp ⁴	0.01	0.02	7.9	0.01	0.14	12.5	0.01	0.02	12.1	0.01	0.09	22.6
Total intake	0.70	1.99	82.1	0.59	1.64	82.4	0.36	1.19	77.5	0.32	0.92	88.7

¹Mackerel include raw, smoked and canned mackerel in tomato sauce.

²Herring include raw, pickled and smoked herring.

³Tuna include only canned tuna.

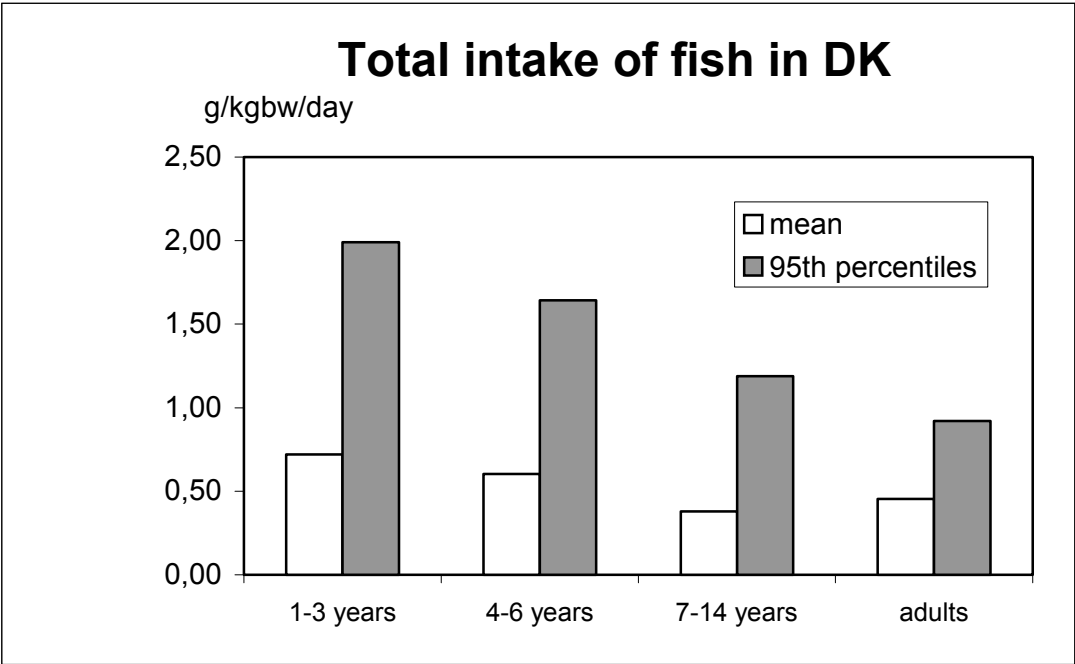
⁴Shrimps include both frozen and canned shrimps.

⁵Salmon, cod and plaice include only raw fish.

⁶The total number of test persons in each age group: 1-3 years: 279; 4-6 years: 272; 7-14 years: 710; adults: 1837

⁷The average bodyweight in each age group: 1-3 years: 14.1 kg; 4-6 years: 20.7 kg; 7-14 years: 38.7 kg; adult: 72 kg

The total intake of seafood in Denmark



Annex III.d Sampling details on the ICES data in Table 5.4.

Fish species	Date	Place of collection	Tissue	Samples	No. of replicates
<i>Coregonus lavaretus pidschian</i>	950702	lat.70,45,80/lon.48,0,0	Liver	Individual	1
<i>Coregonus lavaretus pidschian</i>	950715	lat.66,36,30/lon.66,21,60	Liver	Individual	1
<i>Coregonus lavaretus pidschian</i>	950702	lat.70,45,80/lon.48,0,0	Muscle	Individual	1
<i>Coregonus lavaretus pidschian</i>	950715	lat.66,36,30/lon.66,21,60	Muscle	Individual	1
<i>Coregonus autumnalis</i>	950715	lat.66,36,30/lon.66,21,60	Muscle	Individual	2
<i>Coregonus autumnalis</i>	950907	lat.68,58,83/lon.54,48,8	Muscle	Individual	1
<i>Coregonus autumnalis</i>	951130	lat.71,57,0/lon.2,10,0	Muscle	Individual	1
<i>Coregonus muksun</i>	950702	lat.70,45,80/lon.48,0,0	Muscle	Individual	2
<i>Coregonus muksun</i>	951130	lat.71,57,0/lon.2,10,0	Muscle	Individual	1
<i>Coregonus nasus</i>	950702	lat.70,45,80/lon.48,0,0	Muscle	Individual	1
<i>Coregonus nasus</i>	951111	lat.70,5,50/lon.83,6,0	Muscle	Individual	2
<i>Coregonus nasus</i>	951130	lat.71,57,0/lon.2,10,0	Muscle	Individual	1
<i>Gadus morhua</i>	950907	lat.69,9,0/lon.67,40,10	Liver	Individual	1
<i>Gadus morhua</i>	950907	lat.69,9,0/lon.67,40,10	Muscle	Individual	1
<i>Gobiidae sp.</i>	950907	lat.68,58,83/lon.54,48,8	Muscle	Individual	1
<i>Gobiidae sp.</i>	950907	lat.68,51,70/lon.67,1,80	Muscle	Individual	1
<i>Mytilus edulis</i>	960900	lat.51,21,0/lon.2,50,0	SB-tissue	Pooled	5
<i>Mytilus edulis</i>	960900	lat.53,22,0/lon.6,54,0	SB-tissue	Pooled	5
<i>Mytilus edulis</i>	960905	lat.70,4,19/lon.30,9,83	SB-tissue	Pooled	3
<i>Mytilus edulis</i>	960906	lat.70,41,61/lon.28,33,28	SB-tissue	Pooled	3
<i>Mytilus edulis</i>	960907	lat.70,58,38/lon.25,48,14	SB-tissue	Pooled	3
<i>Mytilus edulis</i>	960908	lat.70,30,97/lon.22,14,80	SB-tissue	Pooled	3
<i>Mytilus edulis</i>	960910	lat.68,56,9/lon.16,38,47	SB-tissue	Pooled	2
<i>Mytilus edulis</i>	961003	lat.59,52,50/lon.10,43,0	SB-tissue	Pooled	3
<i>Pandalus borealis</i>	921220	lat.59,49,0/lon.10,33,0	TM-tissue	Pooled	2
<i>Pleuronectes platessa</i>	921215	lat.59,44,0/lon.10,32,0	Muscle	Pooled	2
<i>Salvelinus alpinus</i>	950715	lat.66,36,30/lon.66,21,60	Muscle	Individual	1
<i>Salvelinus alpinus</i>	951130	lat.71,57,0/lon.2,10,0	Muscle	Individual	1
<i>Stenodus levachtus nelma</i>	951111	lat.70,5,50/lon.83,6,0	Muscle	Individual	1

Annex III.e PAH concentrations in seafood items

Figures from the EU SCOOP project on B[a]P in some marine organisms

In a SCOOP project the following concentrations of B[a]P in some marine organisms were used to estimate the total daily intake of B[a]P.

Seafood item	B[a]P, mean concentration (nanogram/g)
Shellfish	0.38
Salmon, fresh	0.04
Salmon, smoked	0.31
Mackerel, fresh	0.17
Mackerel, smoked for sandwich	0.56
Canned sardines/tuna	0.1

Figures of sum PAH and estimated B[a]P equivalents for different samples e.g. in monitoring programs, following crude oil and gas oil spills and following processing (smoking).

Area & place of collection	Specific conditions (e.g. oil type)	n (year)	No. of PAH in sum	Sum PAH (µg/kg)		Benz[a]pyrene Equivalents ¹	
				Min.	Max.	Min.	Max.
Alaska, USA	Crude oil spill (Exxon Valdez)	42 (1989)	35	n.d.	18,460	n.d.	53
England	Crude oil spill (Tetney monobuoy)	4 (2000)	23	214	322	14	17
England	Gasoil spill (Erimo)	4 (2000)	23	235	631	12	15
England	Gasoil spill (Lagik)	6 (2000)	23	143	355	5.3	18
Wales	Crude oil spill (Sea Empress)	30 (1996)	18	34	103,000	n.d.	326
USA	National status and trends programme	1,689 (1986-1996)	43	1	3,760	n.d.	222
England and Wales	Spatial survey of commercial shellfish	85 (1997)	18	36	8,930	1.1	141
Alaska, USA	Monitoring study	2,297 (1993-1997)	39	4.5	1,370	0.1	9.3
England	Comparative data for 8 hot-smoked fish	8 (2000)	18	97	2,990	0.1	4.4

¹; estimated on the basis of USFDA equivalency factors for 10 PAH (Bolger, M., Henry, S.H. and Carington, C.D. (1996). Am. Fish. Soc. Symp. Vol. 18: 837)

Annex III.f Background exposure estimations for adults in Denmark

The background exposure to PAH via seafood has been estimated based on seafood intake data and PAH measurements in seafood.

The exposure estimations for adults in Denmark are based on the seafood intake data from the nation-wide survey on dietary habits made in 1995 by the Danish Food and Veterinary Administration (Table 5.1).

The background concentrations of PAH in seafood are from ICES (Table 5.4). However, since background concentrations of PAH are not available for all fish species included in the dietary surveys it has been assumed, that the concentration of PAH is similar among different fish species:

- The concentration used to estimate the intake via plaice is the concentration measured in plaice
- The concentration used to estimate the intake via cod is the concentration measured in cod
- The concentration used to estimate the intake via mackerel, herring and tuna is the concentration measured in cod (one exception is made for benzo[a]anthracene where the concentration in cod is very low compared to all the other fish species and therefore the concentration in plaice will be used).
- The concentration used to estimate the intake via salmon is the average concentration measured in salmon trout
- The concentration used to estimate the intake via shrimps is the concentration measured in prawn
- The concentration used to estimate the intake via mussels is the average concentration measured in mussels

The intake of PAH by adults in Denmark, background exposure
Benzo[a]pyrene - Adult

Food item	Mean intake (g/kg bw/day)	95 % percentile intake (g/kg bw/day)	rate of consumers (%)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	95 % percentile intake (ng/kg bw/day)
Plaice	0,07	0,28	42,7	0,2	0,014	0,056
Cod	0,07	0,28	48,4	0,1	0,007	0,028
Cod, roe	0,02	0,08	36,3			0
Mackerel	0,05	0,17	74,30	0,1	0,005	0,017
Herring	0,07	0,30	45,60	0,1	0,007	0,03
Salmon	0,01	0,07	14,2	0,1	0,001	0,001
Tuna	0,02	0,08	58,6	0,1	0,002	0,008
Shrimp	0,01	0,09	22,6	0,2	0,002	0,018
Mussel	0,0004			1,21	0,000484	0,000484
Total	0,45	0,92	88,7			
				Sum	0,04	

Benzo[ghi]perylene - Adult

Food item	Mean intake (g/kg bw/day)	95 % percentile intake (g/kg bw/day)	rate of consumers (%)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	95 % percentile intake (ng/kg bw/day)
Plaice	0,07	0,28	42,7	0,2	0,014	0,056
Cod	0,07	0,28	48,4	0,1	0,007	0,028
Cod, roe	0,02	0,08	36,3			0
Mackerel	0,05	0,17	74,30	0,1	0,005	0,017
Herring	0,07	0,30	45,60	0,1	0,007	0,03
Salmon	0,01	0,07	14,2	0,1	0,001	0,001
Tuna	0,02	0,08	58,6	0,1	0,002	0,008
Shrimp	0,01	0,09	22,6	0,2	0,002	0,018
Mussel	0,0004			1,58	0,000632	0,000632
Total	0,45	0,92	88,7			
				Sum	0,04	

Chrysene - Adult

Food item	Mean intake (g/kg bw/day)	95 % percentile intake (g/kg bw/day)	rate of consumers (%)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	95 % percentile intake (ng/kg bw/day)
Plaice	0,07	0,28	42,7	0,2	0,014	0,056
Cod	0,07	0,28	48,4	0,06	0,0042	0,0168
Cod, roe	0,02	0,08	36,3			
Mackerel	0,05	0,17	74,30	0,06	0,003	0,0102
Herring	0,07	0,30	45,60	0,06	0,0042	0,018
Salmon	0,01	0,07	14,2	0,06	0,0006	0,0006
Tuna	0,02	0,08	58,6	0,06	0,0012	0,0048
Shrimp	0,01	0,09	22,6	0,5	0,005	0,045
Mussel	0,0004			3,22	0,001288	0,001288
Total	0,45	0,92	88,7			
				Sum	0,03	

**Dibenzo
[a,h]anthracene - Adult**

Food item	Mean intake (g/kg bw/day)	95 % percentile intake (g/kg bw/day)	rate of consumers (%)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	95 % percentile intake (ng/kg bw/day)
Plaice	0,07	0,28	42,7	0,1	0,007	0,028
Cod	0,07	0,28	48,4	0,1	0,007	0,028
Cod, roe	0,02	0,08	36,3			
Mackerel	0,05	0,17	74,30	0,1	0,005	0,017
Herring	0,07	0,30	45,60	0,1	0,007	0,03
Salmon	0,01	0,07	14,2	0,1	0,001	0,001
Tuna	0,02	0,08	58,6	0,1	0,002	0,008
Shrimp	0,01	0,09	22,6	0,1	0,001	0,009
Mussel	0,0004			0,46	0,000184	0,000184
Total	0,45	0,92	88,7			
Sum					0,03	

**Indeno[1,2,3
c,d]pyrene - Adult**

Food item	Mean intake (g/kg bw/day)	95 % percentile intake (g/kg bw/day)	rate of consumers (%)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	95 % percentile intake (ng/kg bw/day)
Plaice	0,07	0,28	42,7	0,2	0,014	0,056
Cod	0,07	0,28	48,4	0,2	0,014	0,056
Cod, roe	0,02	0,08	36,3			
Mackerel	0,05	0,17	74,30	0,2	0,01	0,034
Herring	0,07	0,30	45,60	0,2	0,014	0,06
Salmon	0,01	0,07	14,2	0,2	0,002	0,002
Tuna	0,02	0,08	58,6	0,2	0,004	0,016
Shrimp	0,01	0,09	22,6	0,2	0,002	0,018
Mussel	0,0004			1,11	0,000444	0,000444
Total	0,45	0,92	88,7			
Sum					0,06	

Benzo[a]anthracene - Adult

Food item	Mean intake (g/kg bw/day)	95 % percentile intake (g/kg bw/day)	rate of consumers (%)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	95 % percentile intake (ng/kg bw/day)
Plaice	0,07	0,28	42,7	0,2	0,014	0,056
Cod	0,07	0,28	48,4	0,02	0,0014	0,0056
Cod, roe	0,02	0,08	36,3			
Mackerel	0,05	0,17	74,30	0,2	0,01	0,034
Herring	0,07	0,30	45,60	0,2	0,014	0,06
Salmon	0,01	0,07	14,2	0,14	0,0014	0,0014
Tuna	0,02	0,08	58,6	0,2	0,004	0,016
Shrimp	0,01	0,09	22,6	0,2	0,002	0,018
Mussel	0,0004			1,9	0,00076	0,00076
Total	0,45	0,92	88,7			
Sum					0,05	

Benzo[k]flouranthene - Adult

Food item	Mean intake (g/kg bw/day)	95 % percentile intake (g/kg bw/day)	rate of consumers (%)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	95 % percentile intake (ng/kg bw/day)
Plaice	0,07	0,28	42,7	0	0	0
Cod	0,07	0,28	48,4	0,28	0,0196	0,0784
Cod, roe	0,02	0,08	36,3			
Mackerel	0,05	0,17	74,30	0,28	0,014	0,0476
Herring	0,07	0,30	45,60	0,28	0,0196	0,084
Salmon	0,01	0,07	14,2	1,15	0,0115	0,0115
Tuna	0,02	0,08	58,6	0,28	0,0056	0,0224
Shrimp	0,01	0,09	22,6	0	0	0
Mussel	0,0004			0,82	0,000328	0,000328
Total	0,45	0,92	88,7			
				Sum	0,07	

Benzo[b]flouranthene - Adult

Food item	Mean intake (g/kg bw/day)	95 % percentile intake (g/kg bw/day)	rate of consumers (%)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	95 % percentile intake (ng/kg bw/day)
Plaice	0,07	0,28	42,7	0,2	0,014	0,056
Cod	0,07	0,28	48,4	0,2	0,014	0,056
Cod, roe	0,02	0,08	36,3			
Mackerel	0,05	0,17	74,30	0,2	0,01	0,034
Herring	0,07	0,30	45,60	0,2	0,014	0,06
Salmon	0,01	0,07	14,2	2,61	0,0261	0,0261
Tuna	0,02	0,08	58,6	0,2	0,004	0,016
Shrimp	0,01	0,09	22,6	0,2	0,002	0,018
Mussel	0,0004			2,72	0,001088	0,001088
Total	0,45	0,92	88,7			
				Sum	0,09	

Annex III.g Background exposure estimations for adults in Norway

The background exposure to PAH via seafood has been estimated based on seafood intake data and PAH measurements in seafood.

The exposure estimations for adults in Norway are based on the seafood intake data from the “Fish and Game survey” (Table 5.2).

The background concentrations of PAH in seafood are from ICES (Table 5.4). However, since background concentrations of PAH are not available for all fish species included in the dietary surveys it has been assumed, that the concentration of PAH is similar among different fish species:

- The concentration used to estimate the PAH intake via cod is the concentration measured in cod
- The concentration used to estimate the PAH intake via cod liver is the concentration measured in cod liver
- The concentration used to estimate the PAH intake via coalfish, mackerel, herring, tuna and eel is the concentration measured in cod (one exception is made for benzo[a]anthracene where the concentration in cod is very low compared to all the other fish species and therefore the concentration in plaice will be used).
- The concentration used to estimate the PAH intake via coal fish liver is the concentration measured in cod liver
- The concentration used to estimate the PAH intake via plaice is the concentration measured in plaice
- The concentration used to estimate the PAH intake via halibut is the concentration measured in plaice
- The concentration used to estimate the PAH intake via salmon is the average concentration measured in salmon trout
- The concentration used to estimate the PAH intake via shrimps is the concentration measured in prawn
- The concentration used to estimate the PAH intake via mussels is the average concentration measured in mussels

The intake of PAH by adults in Norway, background exposure

Benzo[a]pyrene - Adult

Food item	Mean intake, men (g/kg bw/day)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	Mean intake, women (g/kg bw/day)	Mean intake (ng/kg bw/day)
cod	0,15	0,1	0,015	0,15	0,015
cod, roe	0,05			0,01	
cod, liver	0,01	0,1	0,001	0,06	0,006
coalfish	0,11	0,1	0,011	0,12	0,012
coalfish, liver	0,01	0,1	0,001	0,01	0,001
halibut	0,05	0,2	0,01	0,06	0,012
plaice, flounder etc.	0,04	0,2	0,008	0,05	0,01
mackerel	0,05	0,1	0,005	0,05	0,005
heering	0,04	0,1	0,004	0,03	0,003
tuna	0,09	0,1	0,009	0,09	0,009
salmon etc	0,16	0,1	0,016	0,15	0,015
eel	0,01	0,1	0,001	0,03	0,003
marine fish, other	0,07	0,1	0,007	0,08	0,008
shrimp	0,1	0,2	0,02	0,11	0,022
Crab	0,1			0,12	
Mussels etc.	0,01	1,21	0,0121	0,02	0,0242
			0,1201		0,1452

Benzo[ghi]perylene - Adult

Food item	Mean intake, men (g/kg bw/day)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	Mean intake, women (g/kg bw/day)	Mean intake (ng/kg bw/day)
cod	0,15	0,1	0,015	0,15	0,015
cod, roe	0,05			0,01	
cod, liver	0,01	0,1	0,001	0,06	0,006
coalfish	0,11	0,1	0,011	0,12	0,012
coalfish, liver	0,01	0,1	0,001	0,01	0,001
halibut	0,05	0,2	0,01	0,06	0,012
plaice, flounder etc.	0,04	0,2	0,008	0,05	0,01
mackerel	0,05	0,1	0,005	0,05	0,005
heering	0,04	0,1	0,004	0,03	0,003
tuna	0,09	0,1	0,009	0,09	0,009
salmon etc	0,16	0,1	0,016	0,15	0,015
eel	0,01	0,1	0,001	0,03	0,003
marine fish, other	0,07	0,1	0,007	0,08	0,008
shrimp	0,1	0,2	0,02	0,11	0,022
Crab	0,1			0,12	
Mussels etc.	0,01	1,58	0,0158	0,02	0,0316
			0,1238		0,1526

Chrysene - Adult

Food item	Mean intake, men (g/kg bw/day)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	Mean intake, women (g/kg bw/day)	Mean intake (ng/kg bw/day)
cod	0,15	0,06	0,009	0,15	0,009
cod, roe	0,05			0,01	
cod, liver	0,01	0,06	0,0006	0,06	0,0036
coalfish	0,11	0,06	0,0066	0,12	0,0072
coalfish, liver	0,01	0,06	0,0006	0,01	0,0006
halibut	0,05	0,2	0,01	0,06	0,012
plaice, flounder etc.	0,04	0,2	0,008	0,05	0,01
mackerel	0,05	0,06	0,003	0,05	0,003
heering	0,04	0,06	0,0024	0,03	0,0018
tuna	0,09	0,06	0,0054	0,09	0,0054
salmon etc	0,16	0,06	0,0096	0,15	0,009
eel	0,01	0,06	0,0006	0,03	0,0018
marine fish, other	0,07	0,06	0,0042	0,08	0,0048
shrimp	0,1	0,5	0,06	0,11	0,055
Crab	0,1			0,12	
Mussels etc.	0,01	3,22	0,06	0,02	0,0644
			0,24		0,1874

Dibenzo [a,h]anthracene - Adult

Food item	Mean intake, men (g/kg bw/day)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	Mean intake, women (g/kg bw/day)	Mean intake (ng/kg bw/day)
cod	0,15	0,1	0,015	0,15	0,015
cod, roe	0,05			0,01	
cod, liver	0,01	0,1	0,001	0,06	0,006
coalfish	0,11	0,1	0,011	0,12	0,012
coalfish, liver	0,01	0,1	0,001	0,01	0,001
halibut	0,05	0,1	0,005	0,06	0,006
plaice, flounder etc.	0,04	0,1	0,004	0,05	0,005
mackerel	0,05	0,1	0,005	0,05	0,005
heering	0,04	0,1	0,004	0,03	0,003
tuna	0,09	0,1	0,009	0,09	0,009
salmon etc	0,16	0,1	0,016	0,15	0,015
eel	0,01	0,1	0,001	0,03	0,003
marine fish, other	0,07	0,1	0,007	0,08	0,008
shrimp	0,1	0,1	0,01	0,11	0,011
Crab	0,1			0,12	
Mussels etc.	0,01	0,46	0,0046	0,02	0,0092
			0,0936		0,1082

Indeno[1,2,3 c,d]pyrene - Adult

Food item	Mean intake, men (g/kg bw/day)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	Mean intake, women (g/kg bw/day)	Mean intake (ng/kg bw/day)
cod	0,15	0,2	0,03	0,15	0,03
cod, roe	0,05			0,01	
cod, liver	0,01	0,2	0,002	0,06	0,012
coalfish	0,11	0,2	0,022	0,12	0,024
coalfish, liver	0,01	0,2	0,002	0,01	0,002
halibut	0,05	0,2	0,01	0,06	0,012
plaice, flounder etc.	0,04	0,2	0,008	0,05	0,01
mackerel	0,05	0,2	0,01	0,05	0,01
heering	0,04	0,2	0,008	0,03	0,006
tuna	0,09	0,2	0,018	0,09	0,018
salmon etc	0,16	0,2	0,032	0,15	0,03
eel	0,01	0,2	0,002	0,03	0,006
marine fish, other	0,07	0,2	0,014	0,08	0,016
shrimp	0,1	0,2	0,02	0,11	0,022
Crab	0,1			0,12	
Mussels etc.	0,01	1,11	0,0111	0,02	0,0222
			0,1891		0,2202

Benzo[a]anthracene - Adult

Food item	Mean intake, men (g/kg bw/day)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	Mean intake, women (g/kg bw/day)	Mean intake (ng/kg bw/day)
cod	0,15	0,02	0,003	0,15	0,003
cod, roe	0,05			0,01	
cod, liver	0,01	0,02	0,0002	0,06	0,0012
coalfish	0,11	0,2	0,022	0,12	0,024
coalfish, liver	0,01	0,2	0,002	0,01	0,002
halibut	0,05	0,2	0,01	0,06	0,012
plaice, flounder etc.	0,04	0,2	0,008	0,05	0,01
mackerel	0,05	0,2	0,01	0,05	0,01
heering	0,04	0,2	0,008	0,03	0,006
tuna	0,09	0,2	0,018	0,09	0,018
salmon etc	0,16	0,14	0,0224	0,15	0,021
eel	0,01	0,2	0,002	0,03	0,006
marine fish, other	0,07	0,2	0,014	0,08	0,016
shrimp	0,1	0,2	0,02	0,11	0,022
Crab	0,1			0,12	
Mussels etc.	0,01	1,9	0,019	0,02	0,038
			0,1586		0,1892

Benzo[k]flouranthene - Adult

Food item	Mean intake, men (g/kg bw/day)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	Mean intake, women (g/kg bw/day)	Mean intake (ng/kg bw/day)
cod	0,15	0,28	0,042	0,15	0,042
cod, roe	0,05			0,01	
cod, liver	0,01	0,5	0,005	0,06	0,03
coalfish	0,11	0,28	0,0308	0,12	0,0336
coalfish, liver	0,01	0,5	0,005	0,01	0,005
halibut	0,05	0,28	0,014	0,06	0,0168
plaice, flounder etc.	0,04	0	0	0,05	0
mackerel	0,05	0,28	0,014	0,05	0,014
heering	0,04	0,28	0,0112	0,03	0,0084
tuna	0,09	0,28	0,0252	0,09	0,0252
salmon etc	0,16	0,28	0,0448	0,15	0,042
eel	0,01	0,28	0,0028	0,03	0,0084
marine fish, other	0,07	0,28	0,0196	0,08	0,0224
shrimp	0,1	0	0	0,11	0
Crab	0,1			0,12	
Mussels etc.	0,01	0,82	0,0082	0,02	0,0164
			0,2226		0,2642

Benzo[b]flouranthene - Adult

Food item	Mean intake, men (g/kg bw/day)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	Mean intake, women (g/kg bw/day)	Mean intake (ng/kg bw/day)
cod	0,15	0,2	0,03	0,15	0,03
cod, roe	0,05			0,01	
cod, liver	0,01	0,2	0,002	0,06	0,012
coalfish	0,11	0,2	0,022	0,12	0,024
coalfish, liver	0,01	0,2	0,002	0,01	0,002
halibut	0,05	0,2	0,01	0,06	0,012
plaice, flounder etc.	0,04	0,2	0,008	0,05	0,01
mackerel	0,05	0,2	0,01	0,05	0,01
heering	0,04	0,2	0,008	0,03	0,006
tuna	0,09	0,2	0,018	0,09	0,018
salmon etc	0,16	2,61	0,4176	0,15	0,3915
eel	0,01	0,2	0,002	0,03	0,006
marine fish, other	0,07	0,2	0,014	0,08	0,016
shrimp	0,1	0,2	0,02	0,11	0,022
Crab	0,1			0,12	
Mussels etc.	0,01	2,72	0,0272	0,02	0,0544
			0,5908		0,6139

Summary tables of the background exposure to PAH via seafood

Background intake of PAH (ng/kg bw/day), adults, Denmark

Food item	Benzo[a]pyrene		Benzo[ghi]perylene		Chrysene		dibenzo[a,h]anthracene		ideno[1,2,3c,d]pyrene		benzo[a]anthracene		benzo[k]flouranthene		benzo[b]flouranthene	
	mean	95th percentile	mean	95th percentile	mean	95th percentile	mean	95th percentile	mean	95th percentile	mean	95th percentile	mean	95th percentile	mean	95th percentile
Plaice	0,014	0,056	0,014	0,056	0,014	0,056	0,007	0,028	0,014	0,056	0,014	0,056	0,000	0,000	0,014	0,056
Cod	0,007	0,028	0,007	0,028	0,004	0,017	0,007	0,028	0,014	0,056	0,001	0,006	0,020	0,078	0,014	0,056
Mackerel	0,005	0,017	0,005	0,017	0,003	0,010	0,005	0,017	0,010	0,034	0,010	0,034	0,014	0,048	0,010	0,034
Herring	0,007	0,030	0,007	0,030	0,004	0,018	0,007	0,030	0,014	0,060	0,014	0,060	0,020	0,084	0,014	0,060
Salmon	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,001	0,002	0,002	0,001	0,001	0,012	0,012	0,026	0,026
Tuna	0,002	0,008	0,002	0,008	0,001	0,005	0,002	0,008	0,004	0,016	0,004	0,016	0,006	0,022	0,004	0,016
Shrimp	0,002	0,018	0,002	0,018	0,005	0,045	0,001	0,009	0,002	0,018	0,002	0,018	0,000	0,000	0,002	0,018
Mussel	0,0005	0,0005	0,0006	0,0006	0,0013	0,0013	0,0002	0,0002	0,0004	0,0004	0,0008	0,0008	0,0003	0,0003	0,0011	0,0011
Total	0,04		0,04		0,03		0,03		0,06		0,05		0,07		0,09	

Background mean intake of PAH (ng/kg bw/day), adults, Norway

1.1.2.1.1 Food item	Benzo(a) Pyrene		Benzo[ghi]perylene		Chrysene		dibenzo[a,h]anthracene		ideno[1,2,3c,d]pyrene		benzo[a]anthracene		benzo[k]flouranthene		benzo[b]flouranthene	
	men	women	men	women	men	women	men	women	men	women	men	women	men	women	men	women
cod	0,015	0,015	0,015	0,015	0,009	0,009	0,015	0,015	0,03	0,03	0,003	0,003	0,042	0,042	0,03	0,03
cod, liver	0,001	0,006	0,001	0,006	0,0006	0,0036	0,001	0,006	0,002	0,012	0,0002	0,0012	0,005	0,03	0,002	0,012
coalfish	0,011	0,012	0,011	0,012	0,0066	0,0072	0,011	0,012	0,022	0,024	0,022	0,024	0,0308	0,0336	0,022	0,024
coalfish, liver	0,001	0,001	0,001	0,001	0,0006	0,0006	0,001	0,001	0,002	0,002	0,002	0,002	0,005	0,005	0,002	0,002
halibut	0,01	0,012	0,01	0,012	0,01	0,012	0,005	0,006	0,01	0,012	0,01	0,012	0,014	0,0168	0,01	0,012
plaice, flounder etc.	0,008	0,01	0,008	0,01	0,008	0,01	0,004	0,005	0,008	0,01	0,008	0,01	0	0	0,008	0,01
mackerel	0,005	0,005	0,005	0,005	0,003	0,003	0,005	0,005	0,01	0,01	0,01	0,01	0,014	0,014	0,01	0,01
heering	0,004	0,003	0,004	0,003	0,0024	0,0018	0,004	0,003	0,008	0,006	0,008	0,006	0,0112	0,0084	0,008	0,006
tuna	0,009	0,009	0,009	0,009	0,0054	0,0054	0,009	0,009	0,018	0,018	0,018	0,018	0,0252	0,0252	0,018	0,018
salmon etc	0,016	0,015	0,016	0,015	0,0096	0,009	0,016	0,015	0,032	0,03	0,0224	0,021	0,0448	0,042	0,4176	0,3915
eel	0,001	0,003	0,001	0,003	0,0006	0,0018	0,001	0,003	0,002	0,006	0,002	0,006	0,0028	0,0084	0,002	0,006
marine fish, other	0,007	0,008	0,007	0,008	0,0042	0,0048	0,007	0,008	0,014	0,016	0,014	0,016	0,0196	0,0224	0,014	0,016
shrimp	0,02	0,022	0,02	0,022	0,06	0,055	0,01	0,011	0,02	0,022	0,02	0,022	0	0	0,02	0,022
Mussels etc.	0,0121	0,0242	0,0158	0,0316	0,06	0,0644	0,0046	0,0092	0,0111	0,0222	0,019	0,038	0,0082	0,0164	0,0272	0,0544
Total	0,1201	0,1452	0,1238	0,1526	0,240	0,1874	0,0936	0,1082	0,1891	0,2202	0,1586	0,1892	0,2226	0,2642	0,5908	0,6139

Annex III.h Exposure to PAH following oil spill, Denmark

The exposure to PAH via seafood following oil spill has been estimated based on seafood intake data and PAH measurements in seafood.

The exposure estimations for children and adults in Denmark are based on the seafood intake data from the nation-wide survey on dietary habits made in 1995 by the Danish Food and Veterinary Administration (Table 5.1).

The concentrations of PAH in seafood are from the Baltic Carrier oil spill in Denmark (Table 5.7). However, since measurements of PAH concentrations are not available for all the fish species that are included in the dietary surveys it has been assumed, that the concentration of PAH is similar among different fish species:

- The concentration used to estimate the intake via plaice is the maximum mean concentration measured in plaice in either June or December.
- The concentration used to estimate the intake via coal fish, cod, mackerel, herring, salmon and tuna is the maximum mean concentration measured in plaice in either June or December divided by 1 (dibenzo[*a,h*]anthracene, indeno[1,2,3-*c,d*]pyrene) and benzo[*a*]anthracene), 2 (benzo[*ghi*]pyrene and benzo[*a*]pyrene) and 3 (chrysene) (based on the assumption that the ratio between the background concentration (Table 5.4.3) of a specific PAH in pelagic fish species and the background concentration of that PAH in plaice is similar to the ratio between the concentration of the PAH in pelagic fish species after oil spill and the concentration of that PAH in flounders after oil spill).
- The concentration used to estimate the intake via shrimps is the maximum concentration measured in shrimps in either June or December
- The concentration used to estimate the intake via mussels is the maximum average concentration measured in mussels in either June or December

See also section 5.4.4.2.Exposure to PAH after oil spill, Children (1-3 years), Denmark

Benzo[a]pyrene - Children, 1-3 years

Food item	Mean intake (g/kg bw/day)	95 % percentile intake (g/kg bw/day)	rate of consumers (%)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	95 % percentile intake (ng/kg bw/day)
Plaice	0,14	0,67	42,3	1,52	0,213	1,018
Cod	0,17	0,69	47,7	0,76	0,129	0,524
Cod, roe	0,11	0,44	53,4			0,000
Mackerel	0,12	0,40	67,70	0,76	0,091	0,304
Herring, total	0,05	0,37	14,70	0,76	0,038	0,281
Salmon	0,01		4,7	0,76	0,008	0,008
Tuna	0,09	0,3	64,5	0,76	0,068	0,228
Shrimp	0,01	0,02	7,9	1,94	0,019	0,039
Mussel	0,0004			14,58	0,006	0,006
Total	0,7	1,99	82,1			
				Sum	0,57	

Benzo[ghi]perylene - Children, 1-3 years

Food item	Mean intake (g/kg bw/day)	95 % percentile intake (g/kg bw/day)	rate of consumers (%)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	95 % percentile intake (ng/kg bw/day)
Plaice	0,14	0,67	42,3	0,04	0,006	0,027
Cod	0,17	0,69	47,7	0,02	0,003	0,014
Cod, roe	0,11	0,44	53,4			
Mackerel	0,12	0,40	67,70	0,02	0,002	0,008
Herring, total	0,05	0,37	14,70	0,02	0,001	0,007
Salmon	0,01		4,7	0,02	0,000	0,000
Tuna	0,09	0,3	64,5	0,02	0,002	0,006
Shrimp	0,01	0,02	7,9	0,26	0,003	0,005
Mussel	0,0004			4,46	0,002	0,002
Total	0,7	1,99	82,1			
				Sum	0,02	

Chrysene - Children, 1-3 years

Food item	Mean intake (g/kg bw/day)	95 % percentile intake (g/kg bw/day)	rate of consumers (%)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	95 % percentile intake (ng/kg bw/day)
Plaice	0,14	0,67	42,3	0,92	0,129	0,616
Cod	0,17	0,69	47,7	0,276	0,047	0,190
Cod, roe	0,11	0,44	53,4			
Mackerel	0,12	0,40	67,70	0,276	0,033	0,110
Herring, total	0,05	0,37	14,70	0,276	0,014	0,102
Salmon	0,01		4,7	0,276	0,003	0,003
Tuna	0,09	0,3	64,5	0,276	0,025	0,083
Shrimp	0,01	0,02	7,9	2,97	0,030	0,059
Mussel	0,0004			17,06	0,007	0,007
Total	0,7	1,99	82,1			
				Sum	0,29	

Dibenzo [a,h]anthracene - Children, 1-3 years

Food item	Mean intake (g/kg bw/day)	95 % percentile intake (g/kg bw/day)	rate of consumers (%)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	95 % percentile intake (ng/kg bw/day)
Plaice	0,14	0,67	42,3	0,05	0,007	0,034
Cod	0,17	0,69	47,7	0,05	0,009	0,035
Cod, roe	0,11	0,44	53,4			
Mackerel	0,12	0,40	67,70	0,05	0,006	0,020
Herring, total	0,05	0,37	14,70	0,05	0,003	0,019
Salmon	0,01		4,7	0,05	0,001	0,001
Tuna	0,09	0,3	64,5	0,05	0,005	0,015
Shrimp	0,01	0,02	7,9	0,052	0,001	0,001
Mussel	0,0004			1,53	0,001	0,001
Total	0,7	1,99	82,1			
				Sum	0,03	

Indeno[1,2,3 c,d]pyrene - Children, 1-3 years

Food item	Mean intake (g/kg bw/day)	95 % percentile intake (g/kg bw/day)	rate of consumers (%)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	95 % percentile intake (ng/kg bw/day)
Plaice	0,14	0,67	42,3	0,21	0,029	0,141
Cod	0,17	0,69	47,7	0,21	0,036	0,145
Cod, roe	0,11	0,44	53,4			
Mackerel	0,12	0,40	67,70	0,21	0,025	0,084
Herring, total	0,05	0,37	14,70	0,21	0,011	0,078
Salmon	0,01		4,7	0,21	0,002	0,002
Tuna	0,09	0,3	64,5	0,21	0,019	0,063
Shrimp	0,01	0,02	7,9	0,25	0,003	0,005
Mussel	0,0004			5,01	0,002	0,002
Total	0,7	1,99	82,1			
				Sum	0,13	

Benzo[a]anthracene - Children, 1-3 years

Food item	Mean intake (g/kg bw/day)	95 % percentile intake (g/kg bw/day)	rate of consumers (%)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	95 % percentile intake (ng/kg bw/day)
Plaice	0,14	0,67	42,3	0,47	0,066	0,315
Cod	0,17	0,69	47,7	0,47	0,080	0,324
Cod, roe	0,11	0,44	53,4			
Mackerel	0,12	0,40	67,70	0,47	0,056	0,188
Herring, total	0,05	0,37	14,70	0,47	0,024	0,174
Salmon	0,01		4,7	0,47	0,005	0,005
Tuna	0,09	0,3	64,5	0,47	0,042	0,141
Shrimp	0,01	0,02	7,9	0,72	0,007	0,014
Mussel	0,0004			7,35	0,003	0,003
Total	0,7	1,99	82,1			
				Sum	0,28	

Exposure to PAH after oil spill, Adults, Denmark

Benzo[a]pyrene - Adult

Food item	Mean intake (g/kg bw/day)	95 % percentile intake (g/kg bw/day)	rate of consumers (%)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	95 % percentile intake (ng/kg bw/day)
Plaice	0,07	0,28	42,7	1,52	0,1064	0,4256
Cod	0,07	0,28	48,4	0,76	0,0532	0,2128
Cod, roe	0,02	0,08	36,3			0
Mackerel	0,05	0,17	74,30	0,76	0,038	0,1292
Herring, total	0,07	0,30	45,60	0,76	0,0532	0,228
Salmon	0,01	0,07	14,2	0,76	0,0076	0,0076
Tuna	0,02	0,08	58,6	0,76	0,0152	0,0608
Shrimp	0,01	0,09	22,6	1,94	0,0194	0,1746
Mussel	0,0004			14,58	0,005832	0,005832
Total	0,45	0,92	88,7			
				Sum	0,30	

Benzo[ghi]perylene - Adult

Food item	Mean intake (g/kg bw/day)	95 % percentile intake (g/kg bw/day)	rate of consumers (%)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	95 % percentile intake (ng/kg bw/day)
Plaice	0,07	0,28	42,7	0,04	0,0028	0,0112
Cod	0,07	0,28	48,4	0,02	0,0014	0,0056
Cod, roe	0,02	0,08	36,3			0
Mackerel	0,05	0,17	74,30	0,02	0,001	0,0034
Herring, total	0,07	0,30	45,60	0,02	0,0014	0,006
Salmon	0,01	0,07	14,2	0,02	0,0002	0,0002
Tuna	0,02	0,08	58,6	0,02	0,0004	0,0016
Shrimp	0,01	0,09	22,6	0,26	0,0026	0,0234
Mussel	0,0004			4,46	0,001784	0,001784
Total	0,45	0,92	88,7			
				Sum	0,01	

Chrysene - Adult

Food item	Mean intake (g/kg bw/day)	95 % percentile intake (g/kg bw/day)	rate of consumers (%)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	95 % percentile intake (ng/kg bw/day)
Plaice	0,07	0,28	42,7	0,92	0,0644	0,2576
Cod	0,07	0,28	48,4	0,276	0,01932	0,07728
Cod, roe	0,02	0,08	36,3			
Mackerel	0,05	0,17	74,30	0,276	0,0138	0,04692
Herring, total	0,07	0,30	45,60	0,276	0,01932	0,0828
Salmon	0,01	0,07	14,2	0,276	0,00276	0,00276
Tuna	0,02	0,08	58,6	0,276	0,00552	0,02208
Shrimp	0,01	0,09	22,6	2,97	0,0297	0,2673
Mussel	0,0004			17,06	0,006824	0,006824
Total	0,45	0,92	88,7			
				Sum	0,16	

Dibenzo [a,h]anthracene - Adult

Food item	Mean intake (g/kg bw/day)	95 % percentile intake (g/kg bw/day)	rate of consumers (%)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	95 % percentile intake (ng/kg bw/day)
Plaice	0,07	0,28	42,7	0,05	0,0035	0,014
Cod	0,07	0,28	48,4	0,05	0,0035	0,014
Cod, roe	0,02	0,08	36,3			
Mackerel	0,05	0,17	74,30	0,05	0,0025	0,0085
Herring, total	0,07	0,30	45,60	0,05	0,0035	0,015
Salmon	0,01	0,07	14,2	0,05	0,0005	0,0005
Tuna	0,02	0,08	58,6	0,05	0,001	0,004
Shrimp	0,01	0,09	22,6	0,052	0,00052	0,00468
Mussel	0,0004			1,53	0,000612	0,000612
Total	0,45	0,92	88,7			
Sum					0,02	

Indeno[1,2,3 c,d]pyrene - Adult

Food item	Mean intake (g/kg bw/day)	95 % percentile intake (g/kg bw/day)	rate of consumers (%)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	95 % percentile intake (ng/kg bw/day)
Plaice	0,07	0,28	42,7	0,21	0,0147	0,0588
Cod	0,07	0,28	48,4	0,21	0,0147	0,0588
Cod, roe	0,02	0,08	36,3			
Mackerel	0,05	0,17	74,30	0,21	0,0105	0,0357
Herring, total	0,07	0,30	45,60	0,21	0,0147	0,063
Salmon	0,01	0,07	14,2	0,21	0,0021	0,0021
Tuna	0,02	0,08	58,6	0,21	0,0042	0,0168
Shrimp	0,01	0,09	22,6	0,25	0,0025	0,0225
Mussel	0,0004			5,01	0,002004	0,002004
Total	0,45	0,92	88,7			
Sum					0,07	

Benzo[a]anthracene - Adult

Food item	Mean intake (g/kg bw/day)	95 % percentile intake (g/kg bw/day)	rate of consumers (%)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	95 % percentile intake (ng/kg bw/day)
Plaice	0,07	0,28	42,7	0,47	0,0329	0,1316
Cod	0,07	0,28	48,4	0,47	0,0329	0,1316
Cod, roe	0,02	0,08	36,3			
Mackerel	0,05	0,17	74,30	0,47	0,0235	0,0799
Herring, total	0,07	0,30	45,60	0,47	0,0329	0,141
Salmon	0,01	0,07	14,2	0,47	0,0047	0,0047
Tuna	0,02	0,08	58,6	0,47	0,0094	0,0376
Shrimp	0,01	0,09	22,6	0,72	0,0072	0,0648
Mussel	0,0004			7,35	0,00294	0,00294
Total	0,45	0,92	88,7			
Sum					0,15	

Annex III.i Exposure to PAH after oil spill, Norway

The exposure to PAH via seafood following oil spill has been estimated based on seafood intake data and PAH measurements in seafood.

The exposure estimations for adults from Norway are based on the seafood intake data from the “Fish and Game survey” (Table 5.2).

The concentrations of PAH in seafood are from the Baltic Carrier oil spill in Denmark. (Table 5.7). However, since measurements of PAH concentrations are not available for all the fish species that are included in the dietary surveys it has been assumed, that the concentration of PAH is similar among different fish species:

- The concentration used to estimate the intake via plaice is the maximum mean concentration measured in plaice in either June or December.
- The concentration used to estimate the PAH intake via halibut is the maximum mean concentration measured in plaice in either June or December
- The concentration used to estimate the PAH intake via eel is the maximum concentration measured in eel in either June or December
- The concentration used to estimate the intake via cod, mackerel, herring, salmon and tuna is the maximum mean concentration measured in plaice in either June or December divided by 1 (dibenzo[*a,h*]anthracene, indeno[1,2,3,*c,d*]pyrene) and benzo[*a*]anthracene), 2 (benzo[*ghi*]pyrene and benzo[*a*]pyrene) and 3 (chrysene) (based on the assumption that the ratio between the background concentration (Table 5.4) of a specific PAH in pelagic fish species and the background concentration of that PAH in plaice is similar to the ratio between the concentration of the PAH in pelagic fish species after oil spill and the concentration of that PAH in flounders after oil spill).
- The concentration used to estimate the PAH intake via cod liver is the concentration estimated for cod multiplied with 5 (based on the difference between the concentration in liver and the concentration in muscles of flounder and eel following the Baltic Carrier oil spill)
- The concentration used to estimate the PAH intake via coal fish liver is the concentration estimate for cod multiplied with 5 (based on the difference between the concentration in liver and the concentration in muscles of flounder and eel following the Baltic Carrier oil spill)
- The concentration used to estimate the intake via shrimps is the maximum concentration measured in shrimps in either June or December
- The concentration used to estimate the intake via mussels is the maximum average concentration measured in mussels in either June or December

See also section 5.4.4.2.

Exposure to PAH after oil spill, Adults, Norway

Benzo[a]pyrene - Adults

Food item	Mean intake, men (g/kg bw/day)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	Mean intake, women (g/kg bw/day)	Mean intake (ng/kg bw/day)
cod	0,150	0,760	0,114	0,150	0,114
cod, roe	0,050			0,010	
cod, liver	0,010	3,800	0,038	0,060	0,228
coalfish	0,110	0,760	0,084	0,120	0,091
coalfish, liver	0,010	3,800	0,038	0,010	0,038
halibut	0,050	1,520	0,076	0,060	0,091
plaice, flounder etc.	0,040	1,520	0,061	0,050	0,076
mackerel	0,050	0,760	0,038	0,050	0,038
heering	0,040	0,760	0,030	0,030	0,023
tuna	0,090	0,760	0,068	0,090	0,068
salmon etc	0,160	0,760	0,122	0,150	0,114
eel	0,010	0,260	0,003	0,030	0,008
marine fish, other	0,070	0,760	0,053	0,080	0,061
shrimp	0,100	1,940	0,194	0,110	0,213
Crab	0,100			0,120	
Mussels etc.	0,010	14,580	0,146	0,020	0,292
			1,064		1,455

Benzo[ghi]perylene

Adults

Food item	Mean intake, men (g/kg bw/day)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	Mean intake, women (g/kg bw/day)	Mean intake (ng/kg bw/day)
cod	0,150	0,020	0,003	0,150	0,003
cod, roe	0,050			0,010	
cod, liver	0,010	0,100	0,001	0,060	0,006
coalfish	0,110	0,020	0,002	0,120	0,002
coalfish, liver	0,010	0,100	0,001	0,010	0,001
halibut	0,050	0,040	0,002	0,060	0,002
plaice, flounder etc.	0,040	0,040	0,002	0,050	0,002
mackerel	0,050	0,020	0,001	0,050	0,001
heering	0,040	0,020	0,001	0,030	0,001
tuna	0,090	0,020	0,002	0,090	0,002
salmon etc	0,160	0,020	0,003	0,150	0,003
eel	0,010	0,200	0,002	0,030	0,006
marine fish, other	0,070	0,020	0,001	0,080	0,002
shrimp	0,100	0,260	0,026	0,110	0,029
Crab	0,100			0,120	
Mussels etc.	0,010	4,460	0,045	0,020	0,089
			0,092		0,149

Chrysene**Adults**

Food item	Mean intake, men (g/kg bw/day)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	Mean intake, women (g/kg bw/day)	Mean intake (ng/kg bw/day)
cod	0,150	0,276	0,041	0,150	0,041
cod, roe	0,050			0,010	
cod, liver	0,010	1,380	0,014	0,060	0,083
coalfish	0,110	0,276	0,030	0,120	0,033
coalfish, liver	0,010	1,380	0,014	0,010	0,014
halibut	0,050	0,920	0,046	0,060	0,055
plaice, flounder etc.	0,040	0,920	0,037	0,050	0,046
mackerel	0,050	0,276	0,014	0,050	0,014
heering	0,040	0,276	0,011	0,030	0,008
tuna	0,090	0,276	0,025	0,090	0,025
salmon etc	0,160	0,276	0,044	0,150	0,041
eel	0,010	0,930	0,009	0,030	0,028
marine fish, other	0,070	0,276	0,019	0,080	0,022
shrimp	0,100	2,970	0,297	0,110	0,327
Crab	0,100			0,120	
Mussels etc.	0,010	17,060	0,171	0,020	0,341
			0,772		1,079

Dibenzo [a,h]anthracene**Adults**

Food item	Mean intake, men (g/kg bw/day)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	Mean intake, women (g/kg bw/day)	Mean intake (ng/kg bw/day)
cod	0,150	0,050	0,008	0,150	0,008
cod, roe	0,050			0,010	
cod, liver	0,010	0,250	0,003	0,060	0,015
coalfish	0,110	0,050	0,006	0,120	0,006
coalfish, liver	0,010	0,250	0,003	0,010	0,003
halibut	0,050	0,050	0,003	0,060	0,003
plaice, flounder etc.	0,040	0,050	0,002	0,050	0,003
mackerel	0,050	0,050	0,003	0,050	0,003
heering	0,040	0,050	0,002	0,030	0,002
tuna	0,090	0,050	0,005	0,090	0,005
salmon etc	0,160	0,050	0,008	0,150	0,008
eel	0,010	0,050	0,001	0,030	0,002
marine fish, other	0,070	0,050	0,004	0,080	0,004
shrimp	0,100	0,052	0,005	0,110	0,006
Crab	0,100			0,120	
Mussels etc.	0,010	1,530	0,015	0,020	0,031
			0,064		0,094

Indeno[1,2,3 c,d]pyrene**Adults**

Food item	Mean intake, men (g/kg bw/day)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	Mean intake, women (g/kg bw/day)	Mean intake (ng/kg bw/day)
cod	0,150	0,210	0,032	0,150	0,032
cod, roe	0,050			0,010	
cod, liver	0,010	1,050	0,011	0,060	0,063
coalfish	0,110	0,210	0,023	0,120	0,025
coalfish, liver	0,010	1,050	0,011	0,010	0,011
halibut	0,050	0,210	0,011	0,060	0,013
plaice, flounder etc.	0,040	0,210	0,008	0,050	0,011
mackerel	0,050	0,210	0,011	0,050	0,011
heering	0,040	0,210	0,008	0,030	0,006
tuna	0,090	0,210	0,019	0,090	0,019
salmon etc	0,160	0,210	0,034	0,150	0,032
eel	0,010	0,070	0,001	0,030	0,002
marine fish, other	0,070	0,210	0,015	0,080	0,017
shrimp	0,100	0,250	0,025	0,110	0,028
Crab	0,100			0,120	
Mussels etc.	0,010	5,010	0,050	0,020	0,100
			0,256		0,367

benzo[a]anthracene**Adults**

Food item	Mean intake, men (g/kg bw/day)	Mean concentration (ng/g)	Mean intake (ng/kg bw/day)	Mean intake, women (g/kg bw/day)	Mean intake (ng/kg bw/day)
cod	0,150	0,470	0,071	0,150	0,071
cod, roe	0,050			0,010	
cod, liver	0,010	2,350	0,024	0,060	0,141
coalfish	0,110	0,470	0,052	0,120	0,056
coalfish, liver	0,010	2,350	0,024	0,010	0,024
halibut	0,050	0,470	0,024	0,060	0,028
plaice, flounder etc.	0,040	0,470	0,019	0,050	0,024
mackerel	0,050	0,470	0,024	0,050	0,024
heering	0,040	0,470	0,019	0,030	0,014
tuna	0,090	0,470	0,042	0,090	0,042
salmon etc	0,160	0,470	0,075	0,150	0,071
eel	0,010	0,150	0,002	0,030	0,005
marine fish, other	0,070	0,470	0,033	0,080	0,038
shrimp	0,100	0,720	0,072	0,110	0,079
Crab	0,100			0,120	
Mussels etc.	0,010	7,350	0,074	0,020	0,147
			0,551		0,762

Summary Tables of the PAH exposure via seafood after an oil spill

Mean intake of PAH (ng/kg bw/day), Denmark

Food item	Benzo[a]Pyrene		Benzo[ghi]perylene		Chrysene		dibenzo[a,h]anthracene		ideno[1,2,3 c,d]pyrene		benzo[a]anthracene	
	Child (1-3 y)	Adult	Child (1-3 y)	Adult	Child (1-3 y)	Adult	Child (1-3 y)	Adult	Child (1-3 y)	Adult	Child (1-3 y)	Adult
Plaice	0,2128	0,1064	0,0056	0,0028	0,1288	0,0644	0,0070	0,0035	0,0294	0,0147	0,0658	0,0329
Cod	0,1292	0,0532	0,0034	0,0014	0,0469	0,0193	0,0085	0,0035	0,0357	0,0147	0,0799	0,0329
Mackerel	0,0912	0,0380	0,0024	0,0010	0,0331	0,0138	0,0060	0,0025	0,0252	0,0105	0,0564	0,0235
Herring	0,0380	0,0532	0,0010	0,0014	0,0138	0,0193	0,0025	0,0035	0,0105	0,0147	0,0235	0,0329
Salmon	0,0076	0,0076	0,0002	0,0002	0,0028	0,0028	0,0005	0,0005	0,0021	0,0021	0,0047	0,0047
Tuna	0,0684	0,0152	0,0018	0,0004	0,0248	0,0055	0,0045	0,0010	0,0189	0,0042	0,0423	0,0094
Shrimp	0,0194	0,0194	0,0026	0,0026	0,0297	0,0297	0,0005	0,0005	0,0025	0,0025	0,0072	0,0072
Mussel	0,0058	0,0058	0,0018	0,0018	0,0068	0,0068	0,0006	0,0006	0,0020	0,0020	0,0029	0,0029
Total	0,57	0,30	0,02	0,01	0,29	0,16	0,03	0,02	0,13	0,07	0,28	0,15

95th percentile intake of PAH (ng/kg bw/day), Denmark

Food item	Benzo[a]Pyrene		Benzo[ghi]perylene		Chrysene		dibenzo[a,h]anthracene		ideno[1,2,3 c,d]pyrene		benzo[a]anthracene	
	Child (1-3 y)	Adult	Child (1-3 y)	Adult	Child (1-3 y)	Adult	Child (1-3 y)	Adult	Child (1-3 y)	Adult	Child (1-3 y)	Adult
Plaice	1,0184	0,4256	0,0268	0,0112	0,6164	0,2576	0,0335	0,0140	0,1407	0,0588	0,3149	0,1316
Cod	0,5244	0,2128	0,0138	0,0056	0,1904	0,0773	0,0345	0,0140	0,1449	0,0588	0,3243	0,1316
Mackerel	0,3040	0,1292	0,0080	0,0034	0,1104	0,0469	0,0200	0,0085	0,0840	0,0357	0,1880	0,0799
Herring	0,2812	0,2280	0,0074	0,0060	0,1021	0,0828	0,0185	0,0150	0,0777	0,0630	0,1739	0,1410
Salmon	0,0076	0,0076	0,0002	0,0002	0,0028	0,0028	0,0005	0,0005	0,0021	0,0021	0,0047	0,0047
Tuna	0,2280	0,0608	0,0060	0,0016	0,0828	0,0221	0,0150	0,0040	0,0630	0,0168	0,1410	0,0376
Shrimp	0,0388	0,1746	0,0052	0,0234	0,0594	0,2673	0,0010	0,0047	0,0050	0,0225	0,0144	0,0648
Mussel	0,0058	0,0058	0,0018	0,0018	0,0068	0,0068	0,0006	0,0006	0,0020	0,0020	0,0029	0,0029
Total	2,41	1,24	0,07	0,05	1,17	0,76	0,12	0,06	0,52	0,26	1,16	0,59

Mean intake of PAH (ng/kg bw/day), Norway

Species	Benzo[a]Pyrene		Benzo[ghi]perylene		Chrysene		dibenzo [a,h]anthracene		ideno[1,2,3 c,d]pyrene		benzo[a]anthracene	
	men	women	men	women	men	women	men	women	men	women	men	women
cod	0,114	0,114	0,003	0,003	0,0414	0,0414	0,0075	0,0075	0,0315	0,0315	0,0705	0,0705
cod, liver	0,038	0,228	0,001	0,006	0,0138	0,0828	0,0025	0,015	0,0105	0,063	0,0235	0,141
coalfish	0,0836	0,0912	0,0022	0,0024	0,03036	0,03312	0,0055	0,006	0,0231	0,0252	0,0517	0,0564
coalfish, liver	0,038	0,038	0,001	0,001	0,0138	0,0138	0,0025	0,0025	0,0105	0,0105	0,0235	0,0235
halibut	0,076	0,0912	0,002	0,002	0,046	0,0552	0,0025	0,003	0,0105	0,0126	0,0235	0,0282
plaice, flounder etc.	0,0608	0,076	0,0016	0,002	0,0368	0,046	0,002	0,0025	0,0084	0,0105	0,0188	0,0235
mackerel	0,038	0,038	0,001	0,001	0,0138	0,0138	0,0025	0,0025	0,0105	0,0105	0,0235	0,0235
heering	0,0304	0,0228	0,0008	0,0006	0,01104	0,00828	0,002	0,0015	0,0084	0,0063	0,0188	0,0141
tuna	0,0684	0,0684	0,0018	0,0018	0,02484	0,02484	0,0045	0,0045	0,0189	0,0189	0,0423	0,0423
salmon etc	0,1216	0,114	0,0032	0,003	0,04416	0,0414	0,008	0,0075	0,0336	0,0315	0,0752	0,0705
eel	0,0026	0,0078	0,002	0,006	0,0093	0,0279	0,0005	0,0015	0,0007	0,0021	0,0015	0,0045
marine fish, other	0,0532	0,0608	0,0014	0,0016	0,01932	0,02208	0,0035	0,004	0,0147	0,0168	0,0329	0,0376
shrimp	0,194	0,2134	0,026	0,0286	0,297	0,3267	0,0052	0,00572	0,025	0,0275	0,072	0,0792
Mussels etc.	0,1458	0,2916	0,0446	0,0892	0,1706	0,3412	0,0153	0,0306	0,0501	0,1002	0,0735	0,147
Total	1,064	1,455	0,092	0,149	0,772	1,079	0,064	0,094	0,256	0,367	0,551	0,762

Annex IV

Background information on oil pollution and seafood

Experts in different fields participated during meetings in the project group and shared their knowledge on the complex area with the group. Abstracts of the speeches are included in this annex.

a. Views and wishes from the Danish Fishermens Association by Dorte Grastrup-Hansen, Danish Fishermen's Association (DFA)

Abstract

Fortunately we do not have so much experience with large oil spill in Denmark. So this presentation will be based on the experiences from the "Baltic Carrier" oil spill incident in March 2001 in Grønsund.

The apparent consequences of an oil spill are destroyed fishing gear and catches, and disappearance of the fish. The less apparent effects may be destroyed feeding and nursery grounds for the fish as well as the destruction of eggs and fish larvae that cannot swim away. The degree of damage of an oil spill will depend on the locality and time of the year. The long term effects are difficult to estimate because the toxic effects after the oil spill may first be apparent some time after the spill, e.g., fail in recruitment in the next generations of fish.

Pound net characterizes the fishing industry in the area of Grønsund, which is a passive fishing gear. The pound nets are placed along the coast and are vulnerable in case of an oil spill, as it cannot be removed quickly. The destruction of fishing gear and catches has seriously economical complications for the fishermen.

After the incident in Grønsund the fishermen kept fishing, but the fish had disappeared. The first 5-6 months after the incident there were no catches, but after approximately 8 months the fish came back to the area. It is still too early to forecast any long term effects. In general the visible indications of an oil spill, e.g. oil spots are gone much quicker than the toxic components, which accumulate in the environment e.g. in organisms and sediment. From the fishermen's point of view the situation has normalized when it comes to catches.

The fishermen were compensated for the loss of gear and catches, and are quite content about the way the situation has been handled. The fishermen would have liked a faster and more effective readiness though, and points out the importance of having a fast and effective readiness so that the problems afterwards can be minimized.

The fishermen do not want prohibition zones unless there are substantiate reasons for it. However the fishermen and Danish Fishermen's Association (DFA) cannot bear any uncertainty about the product. The fish must be safe to eat.

Monitoring is important and this demands the coordination between different authorities. DFA has received a report after the “Baltic Carrier” oil spill, which has been made in cooperation between Storstrøm County, the National Environmental Research Institute and Roskilde University. Those kinds of reports are important tools for gathering information and knowledge. But DFA still finds that data on the effects on fishes after an oil spill is lacking.

In relation to the incident the fishermen experienced, that clear statements from the authorities are very important. Furthermore it is important that the Environmental and Food Authorities work together, and gives the same information to the fishermen regarding handling the gear and catches, fx. if the pound net should be removed or destroyed, is the fish uneatable/poisonous.

Unfortunately in the “Baltic Carrier”-case one year after the accident, we could read in the press that the different authorities disagreed about whether there still was a problem or not in Grønsund. This situation is very unfortunate both for the fishermen and for the consumer conception of the food safety.

DFA finds that compulsory pilotage, double-hull ships, certain routes for oil traffic, more education to the ship masters with oil cargo, could minimize the risk for future oil spills. DFA has also participated in the working group appointing area or ports of refuge. DFA finds it very important to prevent and avoid oil spills, but if the accident has happened, the following is required:

- sufficient readiness to recover the oil fast
- effective command
- monitoring in relation to the food safety, but also to refute accusations about the fish is poisonous
- compensation the fishermen for lost fishery and gears

In concluding remarks DFA is also concerned about the continuous exposure of PAH's and other substances that may take place in relation to the off-shore oil and gas industry. It is chronic oil pollution without much focus, and the long term effect of this industry is not investigated.

b. Oil spoilage in the Baltic Sea, Environmental risk from transport of oil in the Baltic Sea

by Carsten Jürgensen, COWI AS, Denmark

Abstract

The purpose of the article is to present scope, methods and results of the Baltic Sea Environmental Study, an EC-funded environmental risk analysis regarding oil shipping in the Baltic Sea.

Following the future development of the north western Russian oil fields, export of crude oil by tanker from Primorsk through the Baltic Sea is planned to reach about 30-40 million tons/year (starting with 12 million tons/year). During the years 1997-2000 COWI AS performed an environmental impact study as a sub-consultant to Pipeline Engineering, GmbH (Germany) for the present and the future oil transport in the Baltic

Sea. The study is financially supported by the TACIS-programme of the European Commission (Baltic Pipeline System, ERUS 9511), and the Russian beneficial is Transneft.

The multidisciplinary study comprises analysis of accidents, risk of oil spills, an environmental impact study, and a review of regulations and emergency response equipment present in the Baltic Sea area. Finally, comparative studies for alternative routes through the Barents Sea and the Black Sea have been prepared. The environmental sensitivity of the sea and the coastlines of the Baltic Sea have been described in terms of maps, using a ranking system. By use of an in-house computer programme COWI AS has estimated the geographical distribution of the risk of oil spills due to tanker transport, including the risk contributions from the entire ship traffic. Based on such oil spill risk maps and taking the drift and weathering of the oil into account, areas with high risk for oil impact were found. They were compared to the maps of environmental sensitivity. Furthermore, a comprehensive study of the implications of the project for Russia's international commitments and a set of oil drift simulations were added to the main study.

The main conclusions are that the total amount of spilled oil in the Baltic Sea will increase considerably, especially the risk for large spills will increase. As the risk for oil impact will increase in general on the course between Primorsk and the North Sea, the increase will be most pronounced in the Danish Waters. This is due to the combination of both, the relatively high environmental sensitivity and the high risk for spills due to complicated navigational conditions.

The full content of selected reports are available on CD-ROM can be required from crj@cowi.dk.

Brief summary

The objective of the present non-technical summary is to summarise and present the key results of the Baltic Sea Environmental Study.

A few general findings are extracted because they appear to be of special consequence for the feasibility of the Baltic Pipeline System

- Areas with seabirds (especially in winter seasons), marsh areas and protected areas are found to represent the environmentally most sensitive areas.
- The probability of a sensitive area being affected by oil due to BPS is highest in Danish waters, the Western Baltic south of Sweden and the Gulf of Finland west of Porvoo.
- The long time average amount of oil spilled into the Baltic will increase by approximately 10% (~170 t/year) compared to the expected "background" spill in the year 2017. In the Gulf of Finland this increase will be approximately 20% (~24 t/year).
- The risk for spills smaller than 10,000 tons in the Baltic Sea is not changed significantly.
- The risk for spills between 10,000 and 100,000 tons is increased from 1/75 years to 1/50 years for the Baltic region in the year 2017 due to the BPS project.
- The risk for a spill of this large size increases by 35% for the entire Baltic Sea and by 100% for the Gulf of Finland.

- Compared to alternatives the Baltic Sea route is the best prepared for coping with an increase in tanker traffic regarding background environmental organisations, legal framework and oil spill response capabilities, nationally and in the region.
- The Baltic Sea and the Barents Sea appear to be equally sensitive and more sensitive than the Black Sea.
- For the Black Sea route the Bosphorus and the Strait at Canakkale (Dardanelles) represent a severe navigational risk.
- The Black Sea region is badly equipped to cope with environmental problems due to the lack of a strong institutional framework and inadequate oil response capabilities.

Framework of the Baltic Sea Environmental Study

The Timan-Pechora basin is one of the major areas of recent development where Russian and joint venture companies have been active. Producers have been facing difficulties in transporting their products out of the region. In order to solve this problem, the Russian Government, by Decree no 728 of March 1993, has ordered the Ministry of Fuel and Energy and Transneft, the Russian oil transportation company, to construct or upgrade the Baltic Pipeline System (BPS).

The final phase of the programme will bring the capacity to 32-42 million tonnes/year. The proposed new pipeline will:

- upgrade the existing network from Kharyaga to Kirishi
- link Kirishi to a planned new oil export terminal at Primorsk
- continue to the Finnish oil terminal and refinery at Porvoo.

The overall investment feasibility study can be broken into several components for which different contractors are being appointed:

- engineering component to secure Russian approval
- environmental component to secure Russian approval
- engineering component to international standards
- environmental component to international standard
- Finnish component from Russian-Finnish border to Porvoo
- comparative terminal study between Primorsk and Porvoo

Additionally, financial and legal advisors are appointed who will provide additional relevant input and information required for the successful completion of this investment feasibility study.

Funds for the financing of these studies are being provided from pooled resources from the western companies that have entered into preliminary agreements with Russian oil producers and Transneft, from a World Bank loan to the Russian government and from the TACIS programme of the European Commission. The TACIS funds providing assistance to Transneft are being used to finance the environmental component to be prepared to international standard, taking Russian norms into account.

The Baltic Sea Environmental Study is a component of the Baltic Pipeline System and contains a detailed environmental study of the Baltic Sea. The study includes the following issues:

- Current status of the environment in the main export routes for Russian oil
- Present status of the Baltic Sea
- Regulatory review of the Baltic Sea
- Existing shipping through the Baltic Sea
- Accidents at sea
- Accidents in harbours and terminals
- Risk assessment
- Accident prevention and remediation in the Baltic sea
- Comparative risk assessment.

Environmental impact on the Baltic Sea

The assessment of environmental impacts on the Baltic Sea from increased tanker traffic due to the BPS project is described in Volume 2. The report contains:

- A description of the existing environmental conditions in the Baltic Sea
- Oil spill sensitivity ranking and mapping of the Baltic Sea with a view to identifying areas which are particularly sensitive to oil spills
- Assessment of areas potentially influenced by oil spills
- Overall risk assessment of increased tanker traffic due to the BPS project.

Existing environmental conditions in the Baltic Sea

The marine environment in the Baltic Sea is described. Emphasis is put on topics especially relevant for oil spills. The description includes: Hydrography, sediments, coast types, plankton, benthic vegetation, benthic fauna, fish, birds, mammals, protected areas, eutrophication and pollution and human exploitation of the Baltic Sea. Maps of the extent of relevant environmental parameters are presented.

Oil spill sensitivity ranking and mapping of the Baltic Sea

Oil spills can cause serious deleterious impacts on certain marine species and habitats and they can have severe economic impacts on coastal areas. Marine organisms may be affected by oil in several ways:

- as a result of physical contamination (smothering)
- by toxic effects of chemical components and
- by accumulation of substances leading to tainting.

Table b.1 Ranking of environmental parameters according to their sensitivity to oil spill. A short description of the justification of the ranking is given for each parameter

Sensitivity	Parameter	Justification for ranking
Very high	Wintering area for seabirds (10 most important areas of international importance)	Seabirds are the most vulnerable species to oil pollution. A substantial amount of the north-west European populations of a number of very sensitive seabirds are found in these areas during the winter
	Marsh areas	Oil may persist for a long time and there is a high risk of clean-up damage. Marshes are extremely productive and valuable habitats. Essential habitats for roosting and breeding birds
	Protected areas	Areas protected by national or international laws and conventions to prevent human impacts
High	Wintering area for birds (areas of international importance exclusive of the ten most important)	Populations of international importance of a number of very sensitive seabirds are found in these areas during the winter
	Sheltered rocky shores, indented low coast, Archipelagos	High biological productivity. Important breeding areas for sea and shore birds during the summer. Spawning and nursery areas for fish. Important habitat for seals. The low energy nature of sheltered shores result in high persistence of oil at the shoreline and sediments
	Waters covered with ice each year	Natural weathering processes seriously hampered in ice and it is very difficult to collect oil in the ice. Oil may be encapsulated in ice and when the ice is melting, the oil is released into the water as if it was a fresh oil spill. Some seals breed on the ice
Medium	Waters frequently covered with ice but not each year (Approx. 70% of the time)	As above
	Shallow water (<10m)	Productive zone. Herring spawning grounds, benthic fauna, benthic vegetation (algae, eelgrass) nursery areas for fish fry. Fishing grounds. May be effected by oil spill, but the recovery of impacted areas is usually fast
	Towns/harbours	An oil spill represents a nuisance. However, clean up operations are relatively easy
	Exposed rocky shores	Wave reflection generally prevents oil deposition, but sticky oil may remain as a band at the high tide line. Algae and invertebrates on the rocks may be temporarily affected
	Sandy and gravel beaches	Sandy beaches are often important as tourist areas, but sand beaches are relatively easy to clean up. Gravel beaches are not important for the tourist industry, but they are more difficult to clean
Low	Offshore fish spawning areas and fish populations	Mainly cod and sprat spawning on deep water. Oil slicks and toxic concentrations often float above the eggs, larvae and adult fish. Adult fish can avoid oil

	Plankton	Plankton not seriously affected by oil spill, due to dilution of oil and due to the fact that plankton has high reproductive rates.
	Benthic fauna on deeper waters (>10m)	Oil slicks and toxic concentrations float above the fauna
	Offshore fishing grounds	Fishing only hampered when oil slicks pass the fishing grounds. Stock size not affected by oil spill.

Physical smothering by oil components is the main threat to marine organisms and habitats after an oil spill. The organisms most at risk are those that could come into contact with oil slicks on the sea surface or on the beach such as seabirds, marine mammals and organisms on shorelines.

The volatile components of oil which are rapidly lost through evaporation when oil is spilled are the most toxic components. Therefore, large scale mortalities of marine organisms, due to toxic effects, are relatively rare, localised and short-lived.

The sensitivity to oil of different environmental parameters are described and assessed based on a literature survey of observed impacts of oil spills in the marine environment. Based on this assessment a ranking system has been established and maps indicating the sensitivity of different areas in the Baltic Sea towards oil spills prepared. The relevant environmental parameters in the Baltic Sea are ranked in four categories according to their sensitivity to oil as indicated in table 01.

There are areas with more than one very highly or highly sensitive parameter. Therefore, it was necessary to rank according to numbers of very highly and highly sensitive parameters as indicated in table b.2.

Table b.2 Ranking of biological sensitive areas

Ranking	
1	Areas with more than one very highly sensitive parameter
2	Areas with one very highly sensitive parameter
3	Areas with more than one highly sensitive parameter
4	Areas with one highly sensitive parameter in the same area
5	Areas with medium sensitive features
6	Areas with low sensitive features

Maps indicating the sensitivity of different areas in the Baltic Sea towards oils spills during summer and winter have been prepared based on the ranking and the maps of the extent of various parameters in the Baltic Sea. Generally, the environment is most vulnerable to an oil spill during winter. The most sensitive areas with the largest risks of severe environmental impacts are:

- The Danish waters
- The waters and shorelines at Szczecin, Vorpommern and Pomearnian Bay
- The waters immediately east of Gotland

- Gulf of Riga and the waters and shorelines around Saaremaa and Hiiumaa
- The Finnish Archipelago Sea and certain areas in the Gulf of Finland, including the areas around Porvoo and Primorsk.

Assessment of areas potentially influenced by oil spills

An assessment of areas potentially influenced by oil spills has been carried out, based on the assessments of accident and release frequencies (prepared in Volume 5) and assessments of the transformation and dispersion of oil from the sites of potential oil spills (Volume 2).

The physical processes of e.g. drift, evaporation, entrainment of spilled oil are described based on the meteorological and oceanographic statistics and a description of selected properties of the Komi type crude oil.

The calculations of the oil transforming processes indicate a distance from the route of high impact (50% oil remaining on the surface) of approximately 70 km in the Danish waters and approximately 25 km in the Gulf of Finland. The corresponding impact distance, in the case of low impact (10% oil remaining on the surface), varies between 180 km in the Danish waters and 60 km in the Gulf of Finland.

For the Danish waters the magnitude of the calculated impact distances is of the same order or larger than the width of the Kattegat and the Belt Sea. In these areas any oil spill of the magnitude of 30,000 tons can quickly affect any of the sensitive sites.

The conditions, with respect to the consequences of the BPS, in the Gulf of Finland are also found to be severe.

The cross sectional dimension of the Gulf is larger than that of the Belts, and the orientation of the Gulf is parallel with the prevailing wind, which, on average, will allow for a longer time for evaporation and dispersion before reaching a coastline. The conditions are, however, assessed as critical also for the Gulf of Finland.

The results from the risk analysis show that the long time average amount of oil spilled in the Baltic will increase by approximately 10% (~170 t/year) compared to the expected background spill in the year 2017. In the Gulf of Finland this increase will be approximately 20% (~24 t/year). By looking at the spill size with the most pronounced risk increase compared with the general ship traffic in the year 2017, the spill size of 30,000 t was chosen as design spill. The probability for this design spill will increase by approximately 35% for the entire Baltic Sea and by approximately 100% for the Gulf of Finland.

The probability distribution for different spill sizes is combined with the above oil drift and fate calculations in order to provide a map that indicates a ranking of areas potentially affected by oil spills.

The results indicate that the Danish waters are more exposed to increased oil spills than other parts of the Baltic Sea. The Gulf of Finland shows the second highest ranking whereas the Baltic Proper shows the lowest ranking.

Due to the relatively large volume of the design spill the entire Baltic Sea including south east parts of the Baltic Proper and the entire Bothnian Bay can be affected.

Although less than 10% of the spilled oil may remain in these regions, 3,000 t of weathered oil may still represent a severe impact.

Overall assessment

The risk analysis showed that the BPS project will result in an increased risk of larger oil spills of more than 10,000 tonnes and that the risk of spills below 10,000 tonnes is unchanged by the project.

It has been estimated that spills of more than 10,000 tonnes is expected to happen once in 50 years in the future (2017 scenario), if the BPS is implemented, compared to once in 75 years if BPS is not implemented.

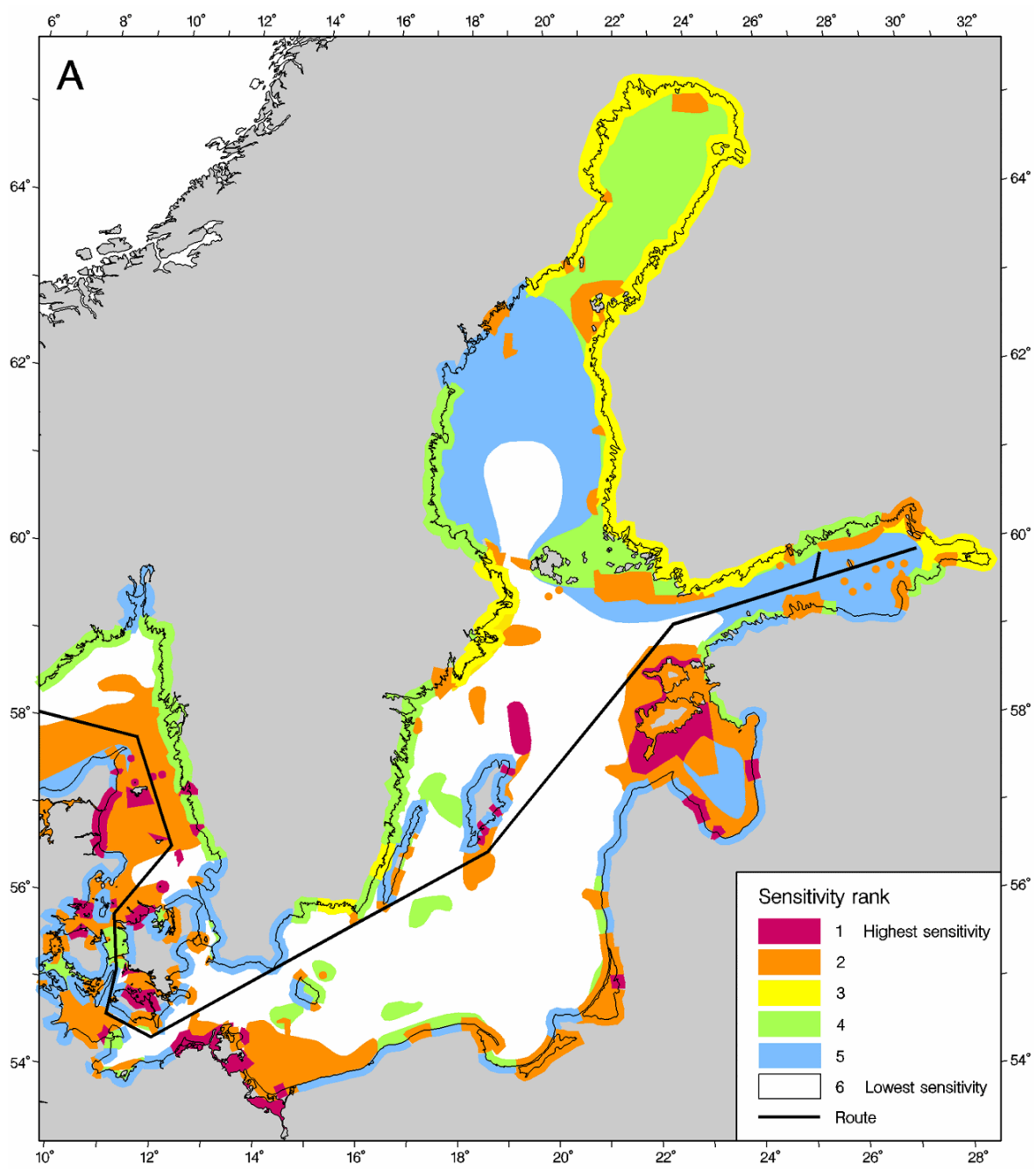
Areas sensitive to oil spills are compared to areas which may potentially be influenced by oil spills, in winter situation and summer situation.

The probability of an area being affected by oil due to the BPS project is highest in the Danish waters and the Western Baltic south of Sweden, followed by the Gulf of Finland west of Porvoo to an area west of Hiiuma.

The Danish waters are among the most sensitive areas with the largest risk of severe environmental impacts in case of an oil spill. The sensitivity is largest during the winter, due to the massive concentrations of seabirds during wintering and migration. A substantial part of the entire north-west European populations of a number of very sensitive seabirds are found in Danish waters during the winter. Seabirds are the group of species that are most at risk to be harmed by an oil spill. For one or few species a spill might eliminate significant proportions of the entire north-west European population. In addition, there are many protected areas in the Danish waters and the risk of oil stranding on large stretches of the beaches is high in case of an oil spill.

The area from west of Porvoo to the east of Hiiuma also holds some very sensitive areas especially around Hiiuma.

There are sensitive sheltered rocky shores, indented low coasts and archipelagos in the area. These coast types are characterised by a high biological productivity. They are important breeding areas for sea and shore birds during the summer. They are also spawning and nursery areas for fish and important habitats for seals. The low energy nature of sheltered shores results in high persistence of oil at the shoreline and sediments. The areas around Hiiuma and Saaremaa and the north east coast of Estonia are also wintering areas for seabirds of international importance. The areas are also very frequently covered by ice during winter. Oil spill in ice is very undesirable as the natural weathering processes are seriously hampered and because it is very difficult to collect the oil in the ice. If the oil is frozen into the ice, evaporation stops completely. Ice encapsulated oil may be transported over wide areas with the drifting ice and when the ice melts, the oil is released into the water as if it was a fresh oil spill.



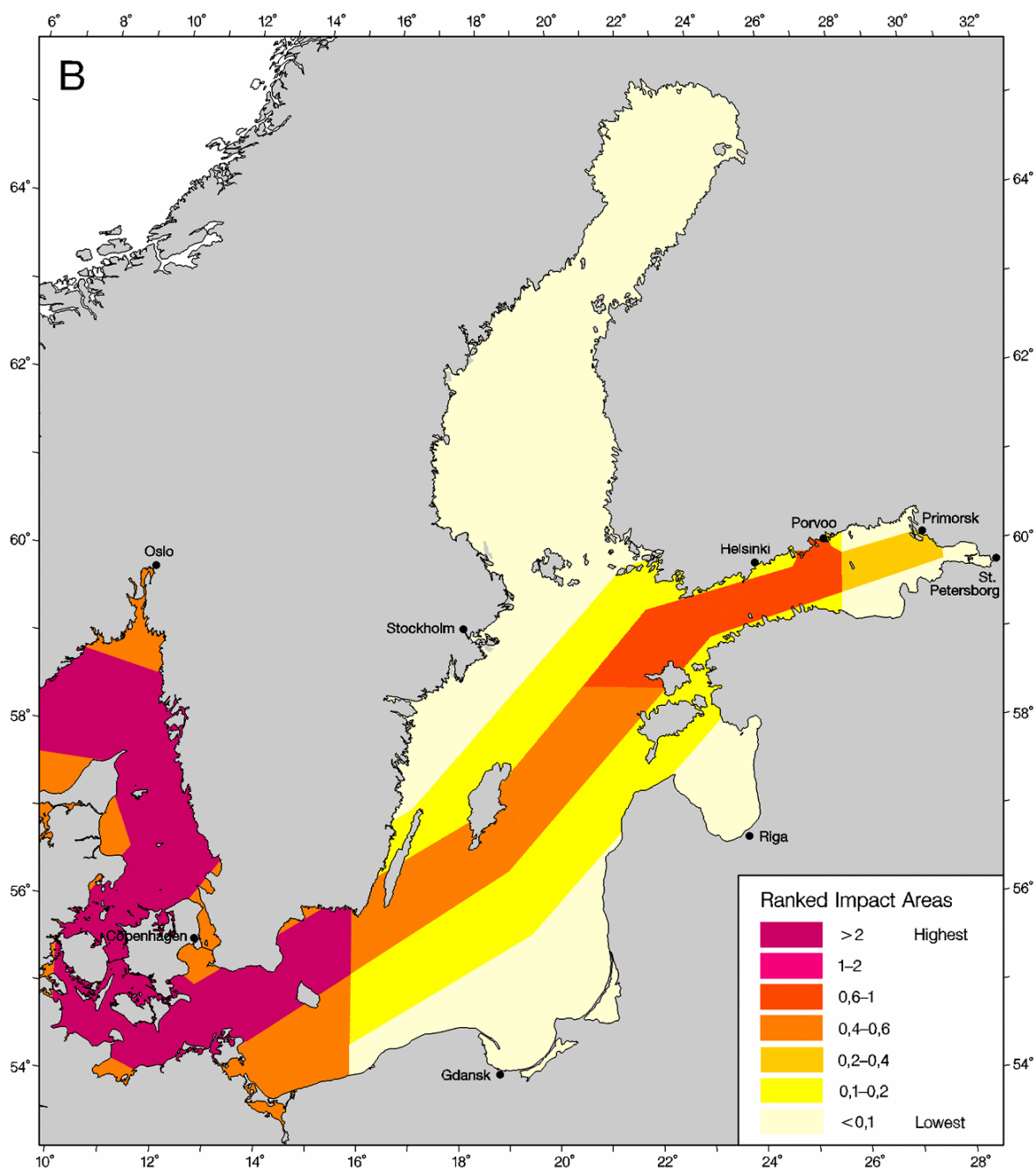
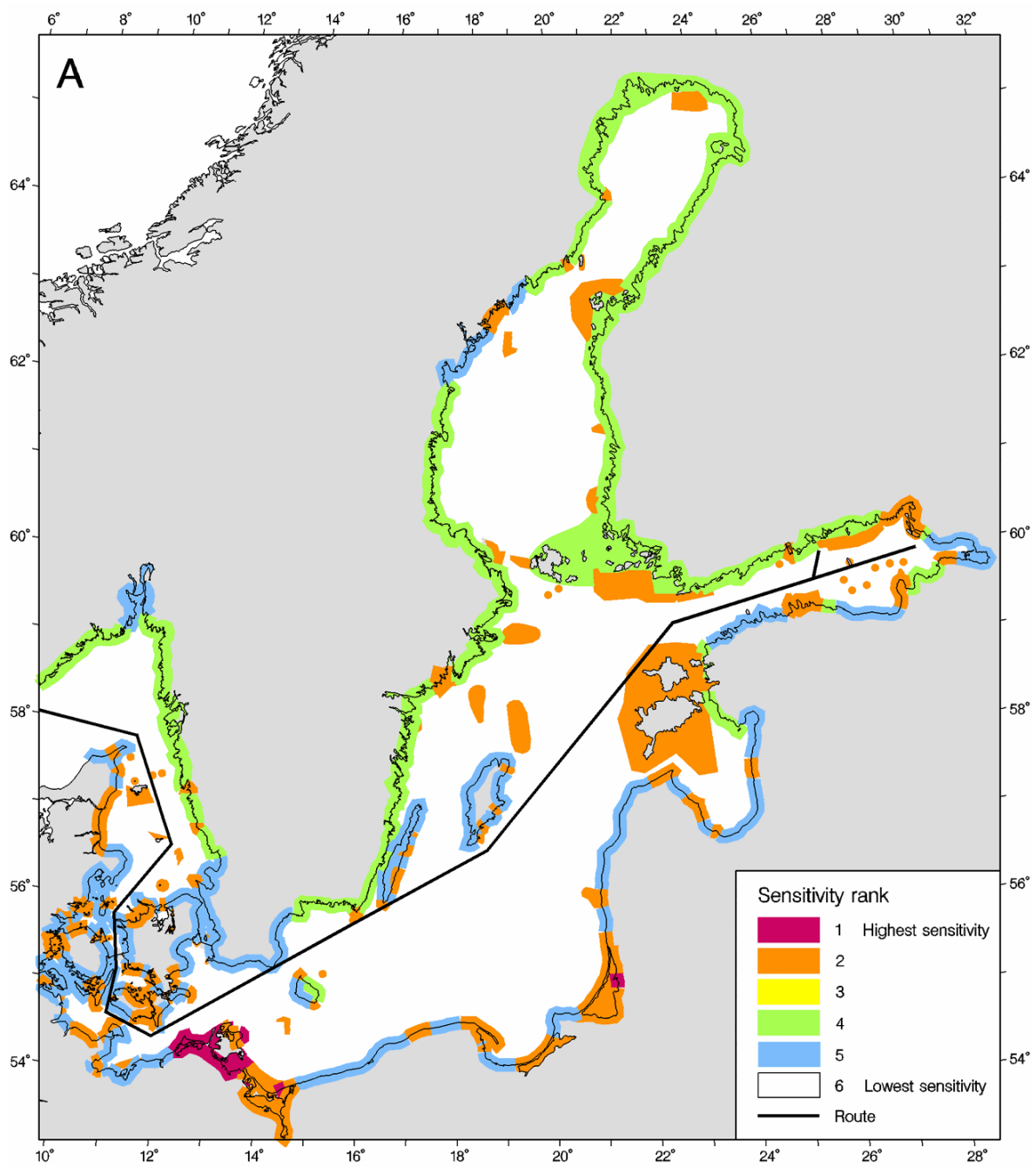


Figure b.1 Comparison of areas sensitive to oils spills during the winter ("A" on previous page) and areas potentially influenced by oil spills ("B"). The areas are ranked according to sensitivity to oil spills and probability of oil entering an area after a spill of 30,000 t respectively



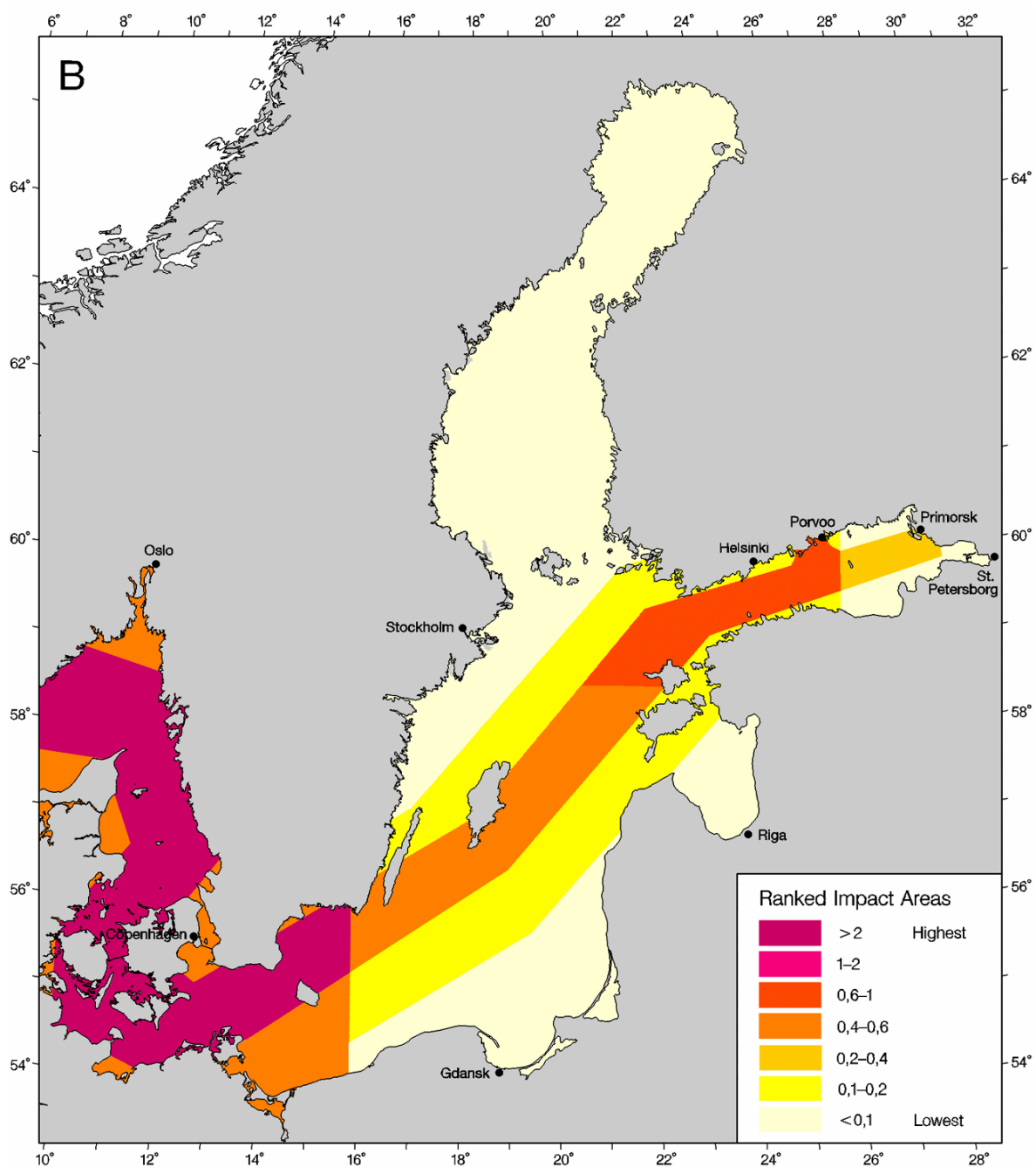


Figure b.2 Comparison of areas sensitive to oils spills during the summer ("A" on previous page)) and areas potentially influenced by oil spills ("B"). The areas are ranked according to sensitivity to oil spills and probability of oil entering an area after a spill of 30,000 t respectively

Environmental impact on alternative routes. Comparative assessment

Volume 3 of the Baltic Sea Environmental study outlines a brief description of the current environmental status in three potential export routes for Russian oil, see Figure b.3

- the Arctic route from the south-eastern Barents Sea and westwards, north of Norway and into the Norwegian Sea
- the Baltic Sea route from the inner part of the Gulf of Finland, through the Baltic Proper, the Danish Straits, Skagerrak and into the North Sea
- the Black Sea route from Novorossisk, across the Black Sea and through the Bosphorous Strait, the Marmara Sea and the Dardanelles into the Aegean Sea.

Major environmental risks and problems regarding oil transport along these routes are assessed and compared.

Present environment

The marine environment in the Barents Sea, the Baltic Sea and the Black Sea is described. Emphasis is put on topics especially relevant for oil spills. The description includes: Hydrography, sediments, coast types, plankton, benthic vegetation, benthic fauna, fish, birds, mammals, protected areas, eutrophication and pollution and human exploitation.

Comparison

The risks of deleterious impacts on key environmental parameters following a larger oil spill in the Barents Sea, the Baltic Sea and the Black Sea have been compared based on the assessments of the sensitivity to oil of different species and habitats and on the occurrence and locations of species and habitats in relation to the transport route. The risks of impact have been grouped as follows:

- Very high risk of deleterious impacts
- High risk of deleterious impacts
- Medium risk of deleterious impacts
- Low risk of deleterious impacts
- No risk of deleterious impacts.

The degrees of risks are compared in Table b.1.

It would appear that the Barents Sea and the Baltic Sea routes are environmentally more sensitive to oil spills than the Black Sea route and that the routes in the Barents Sea and in the Baltic Sea are equally sensitive.

The risk that an oil spill will actually arise is not included in the comparison. In addition it should be stressed that there are extreme navigational constraints for the Black Sea route at the very narrow Bosphorus strait will give rise to a relatively high risk for spills and hence a higher risk for the environment in the Bosphorus and Dardanelle region.

Table b.1

Comparison of risks of deleterious impacts on various environmental parameters following a larger oil spill. The risk that an oil spill will actually arise is not included in the comparison. The risks of impacts have been ranked as: ++++ = Very high, +++= High, ++ = Medium, + = Low, 0 = no risk of impact

Parameter	Barents Sea	Baltic Sea	Black Sea
Ice	++++	+++	0
Coast/shoreline	+++	+++	+
Plankton	+	+	+
Benthic vegetation	++	++	+
Benthic Invertebrates	++	++	+
Fish	+	+	+
Seabirds	++++	++++	++
Mammals	+++	+	+
Protected areas	+++	+++	++
Human use	++	+++	+

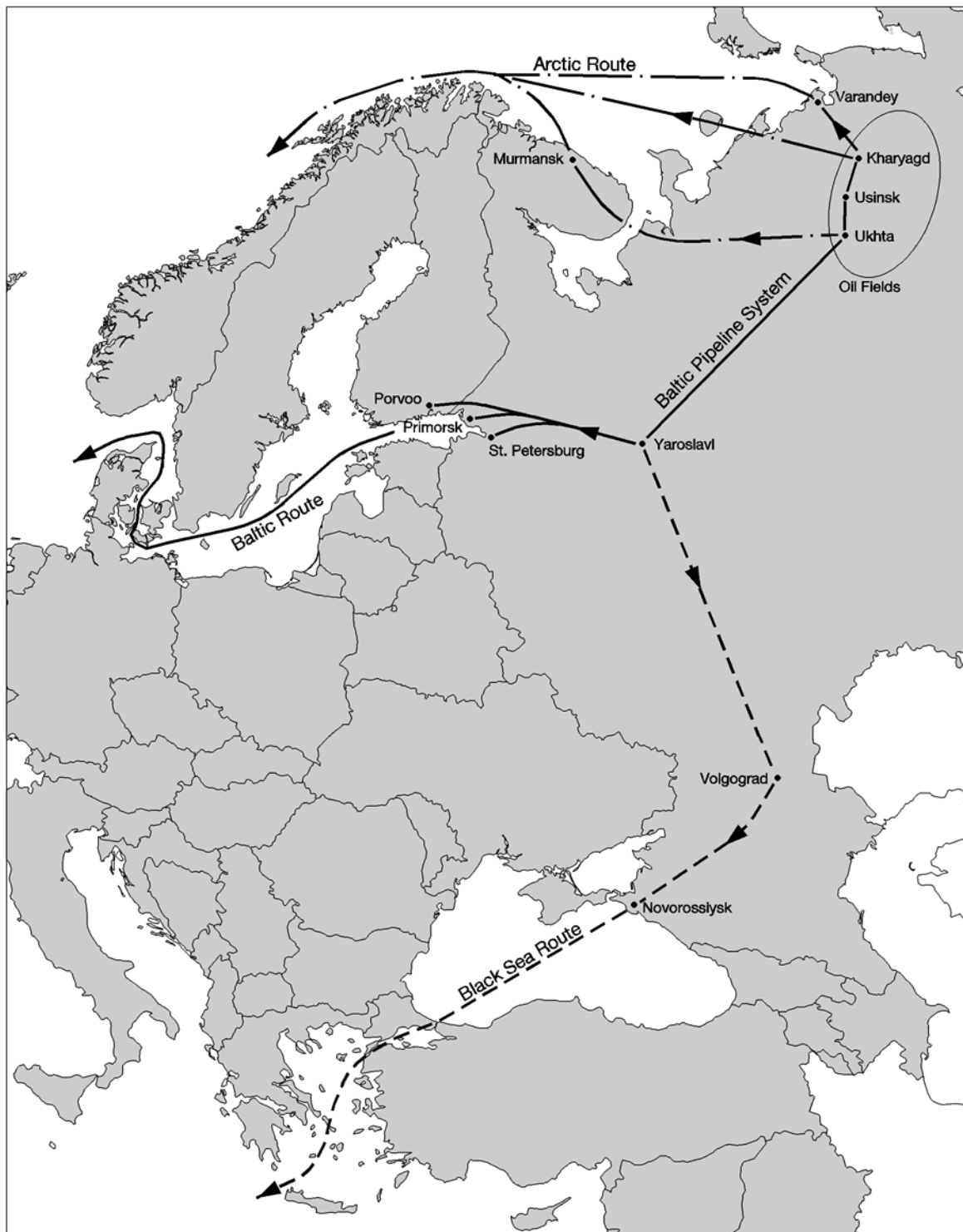


Figure b.3 Map showing the three main options. The arctic route through the Barents Sea, the Baltic Sea route, and the route through the Black Sea (Petroleum Economist 1998)

Regulatory review and accident prevention in the Baltic Sea

The present chapter summarises the contents of Volume 4. Since this volume to a large extent consists of lists of authorities, laws, facilities, etc. remarks of concluding character are only applied where appropriate.

Regulatory review

This review of the regulatory framework of the Baltic Sea and brief surveys of the legal regimes which impose environmental limitations on the alternative Black Sea/Mediterranean Sea and Arctic Ocean routes shows that the level of protection provided by well established organisations and reinforced by legal constraints is not at the same level in each of the regions.

It is clear that from the regulatory viewpoint, the Baltic Sea is best protected both at the regional and national levels. The Helsinki Convention has provided the regional framework for co-operation in the Baltic for the last 25 years. It is evident (see the analysis in the report: Accidents, Prevention and Remediation in the Baltic Sea) that during this time, and particularly in the last 10 years of dramatic political and economic change, co-operation has developed and a regional legal framework has been agreed among the States concerned.

This regional co-operation has developed on a two-fold basis as regards the BPS project. First, through the HELCOM Maritime Committee, a number of HELCOM Recommendations have been elaborated and agreed with the objective of improving the quality of shipping visiting Baltic ports and also by seeking co-operation for better enforcement and control. Second, through the HELCOM Combatting Committee, the response capabilities of Baltic States have been improved through the means of guidance and procedures laid down in the HELCOM Combatting Manual, joint exercises, exchanges of information, etc.

At the national level, the Baltic Sea is well served by having half its riparian States at an advanced level of environmental management and supporting legislation. Denmark, Finland, Germany and Sweden have always been in the vanguard of environmental protection policies and their membership of the EU has contributed to the advancement of environmental protection and improved quality of shipping within the Community. The HELCOM countries in transition (Estonia, Latvia, Lithuania, Poland and the Russian Federation) have all made progress in the last decade. In particular, the 4 Baltic States which are trying to accede to the EU have made significant progress in updating their legislation and administrations in order to be able to comply with EU laws and considerable progress has been made in recent years to improve oil spill response capability, with the help of external donor support.

By contrast, the regulatory regime in the Black Sea is less well developed. Although political progress has been made during the 1990s, it is evident that at regional level the institutions which have been established (notably the Bucharest Convention and the Istanbul Commission) are not yet functioning effectively. This is partly due to lack of adequate economic resources, but also due to a failure to turn political rhetoric into concrete action. Taken together, this would seem to indicate that, despite the chronic environmental problems of the Black Sea, there is a failure to give high priority to environmental protection in the region.

Although it has not been possible to carry out in the context of this BPS study an in-depth evaluation of the institutional and legal framework in the Black Sea countries at the national level, it is evident from the available literature that these structures are not as far as advanced as in the Baltic. Although the legal and institutional framework in the Mediterranean is well established through the Barcelona Convention, taken as a whole the Black Sea/Mediterranean Sea route is not well protected by the current institutional and legal regimes.

The Arctic Ocean alternative route is similarly not well served by any regional framework with legal "teeth". Nevertheless, it is clear that progress is being made, especially through the recently established Arctic Council and, in particular, through bilateral agreements between Norway and the Russian Federation concerning both the oil spill combat and environmental protection. The Arctic route, however, is particularly adversely affected by its climatic conditions: long ice-bound winters and long periods of darkness. These factors significantly increase the risk of accidents occurring and the conditions will also prevent - or at the least - severely hamper any clean-up and oil spill response actions.

In conclusion, if considerations of environmental sensitivity are excluded, it would seem that the Baltic Sea route is the best prepared for coping with an increase in tanker traffic from the point of view of the background environmental organisational and legal framework and from the oil spill response capabilities nationally and in the region. The Arctic route would be the second option, but the adverse climatic conditions would pose serious problems which would have to be overcome by high technology vessels. The Black Sea region is badly equipped to cope with environmental problems due to the lack of a strong institutional framework and inadequate oil response capabilities.

A list of the relevant national and international authorities with the names of responsible officials, addresses, telephone and fax numbers has been prepared (see Volume 4). Accidents, prevention and remediation in the Baltic Sea

Technical measures

Technical measures for prevention and remediation of accidents and subsequent oil spill are described concerning the design and the construction of oil tankers and concerning navigational and operational aspects. The study describes the existing and possible requirements and restrictions to tanker traffic as well as improved navigational arrangements (straightening of routes, marking, icebreaker assistance) and improved information (VTS, electronic communication). Arrangements that increase safety during cargo transfer procedures are recommended.

Legal measures and multinational co-operation for accident prevention: International organisations and bodies are listed and described in terms of their respective responsibilities and measures (laws):

- International Maritime Organization (IMO),
- European Union (EU),
- Helsinki Commission (HELCOM)
- Ministerial Conferences

Emergency oil spill response measures:

The national emergency response capabilities are described for each country in terms of:

- legal basis,
- competent authorities,
- national point for receipt of oil spill notifications
- contingency plans
- response strategy and resources

A database of national equipment is prepared in terms of booms, skimmers, pumps, vessels and resources. An analysis of oil spill response capability is performed for the different sub-regions in the Baltic Sea and proposals for improvement are given for the Primorsk area, the Gulf of Finland, Baltic Proper, the Danish Straits and the Kattegat. Although the risk for oil spill will increase in general, the BPS will give rise to significantly higher demands to the preparedness.

Establishment of overall environmental body for the Baltic Sea area: A thorough description of HELCOM is given along with relations with other bodies (IMO, EU). Also the views of the Baltic Sea states on the effectiveness of HELCOM are given. The chapter concludes that there is no need to create a new environmental body to cover the Baltic Sea. The very real needs are already met - to the general satisfaction of the Baltic States - by the Helsinki Commission. The present tri-lateral framework - HELCOM, IMO and the EU - each body with its individual strengths, seems to be an adequate mechanism to achieve the goal of preventing accidents in the Baltic Sea area and reducing the environmental impacts when they do occur.

Ship traffic, accidents and oil spills

Volume 5 of the Baltic Sea Environmental study outlines a brief description of the shipping and accidents aspects of the Baltic Pipeline System. The following is included:

- Existing and future shipping through the Baltic Sea
- Accidents at sea
- Accidents in harbours
- Accident and release frequencies
- Comparative risk analysis. Accidents and spills on alternative routes.

Existing and future shipping through the Baltic Sea

This study reviews and analyses tanker and other ship traffic over the past 20 years (1978-1997) in the Baltic Sea, and forecasts future shipping, especially tanker traffic, covering a period of 20 years (projection to year 2017).

Two projection scenarios are described:

- 1) Projection to year 2017 based on trade trends in the region
- 2) Projection to year 2017 based on trade trends in the region and addition of increased oil transport due to the Baltic Pipeline System.

The results are presented as maps showing the traffic distribution for year 1997 and the two traffic projection scenarios on a route net. The report describes general traffic patterns, however, oil tanker traffic is described in more details.

The most noticeable effect of BPS is an increase of more than a factor of 7 in oil tanker traffic larger than 100,000 DWT in the Gulf of Finland. The effect is down to a factor of 1.6 in the Great Belt.

The total volume passing through the Gulf of Finland will increase markedly. The effects of BPS are smaller when the increased traffic is related to the total traffic increase in the Baltic Sea.

Accidents at sea

A database of 294 tanker accidents in the Baltic Sea during the period 1978-1997 has been established through contact to relevant authorities in all the states bordering the Baltic Sea. Furthermore, 14 severe accidents were recorded for the Black Sea, see Figure b.4.

The analysis of accidents resulted in the following major observations:

Most accidents happen close to the coasts and groundings seem to occur approximately twice as frequently as collisions. There seems to be a decrease in accidents, especially groundings, over the 20 year period covered.

Frequently crossing ferry traffic seems to introduce high collision risk areas. This was shown near the ferries in the Sound and the Great Belt. The reason for this might be that 3-vessel situations are considerably more difficult to handle than 2-vessel situations.

Small tankers seem to have the same grounding frequency as large tankers when travelling through the same straits. This is shown for the Danish Straits.

Structural damage accidents have most often happened at the latitude of Gotland in the Baltic Proper. A large part of these accidents were caused by ice conditions. That these accidents happen especially at this latitude and not farther north might be due to the fact that vessels travelling here do not necessarily expect ice, whereas those going further north have a structural strength that can handle the pressure from the ice.

Comparisons between the Baltic Sea and the Black Sea indicated that cargo fire/explosions seem to be less frequent in the Baltic Sea than in the Black Sea and the whole world as an average. This might be explained by the generally lower air and water temperatures in the Baltic Sea reducing the probability of ignition of oils.

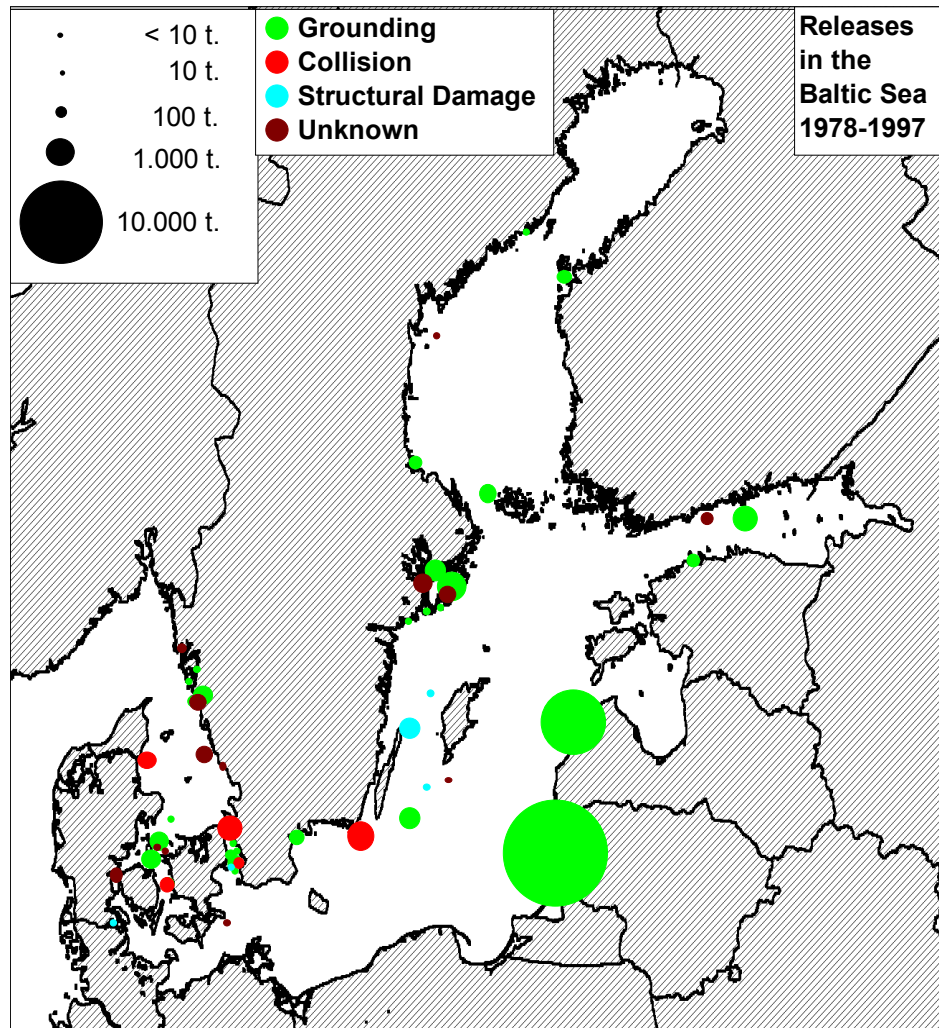


Figure b.4 Releases in the Baltic Sea from 1978 to 1997 (Volume 5-2, fig.4.8). Spills of unknown size are shown as spills < 10 t. The area of the circles is proportional to the release size,

The analysis of accidental releases shows that the number of releases and the quantity released over the years have decreased, especially due to reduction in releases from groundings. Approximately 20% of the registered groundings and 10% of the collisions resulted in a release of oil and approximately half of the releases were larger than 100 t. The maximum spill amounts registered are 200 t for bunker spills and 17000 t for cargo spills. Most of the registered spills have occurred in Danish waters.

Air surveillance (1990-1996) of oil spills, regardless of origination, surprisingly indicates that only a small fraction of the oil spills of 10 - 100 t and even of spills larger than 100 t originates from tanker accidents.

The most extreme drift of oil registered was from an accident at Ventspils. The oil drifted all the way to Stockholm archipelago and Åland (approximately 300 km). Spills drifting in multiple directions have also been registered.

Concerning environmental consequences it is found that in 4 out of 294 accidents there is a description of fatality to birds.

Consequences to other types of living organisms have not been described in any of the accident reports. The accident registered resulting in the highest number of dead birds happened in 1979 in Kattegat, Denmark. 30,000 birds were killed following release of 400 t fuel oil. Comparison with accidents world wide indicates that it is important to consider not only the quantity spilled, but also the type of oil and sensitivity of the environment.

The conclusion from the study of financial losses from spills world wide is that the cleanup costs were in the range of 0-300 USD per gallon or 0-75,000 USD per ton (1997 prices). It was shown that the cleanup costs vary with the specific gravity of the oil and the location of the accident. The higher the gravity, the more expensive the cleanup. Releases at rocky shores are more expensive to clean up than releases at non-rocky shores. Releases at non-rocky shores are more expensive to clean up than releases at sea. The average loss of ship was approximately 20 mill. USD.

Accidents in harbours

The study considers spills and releases of crude oil and oil products in connection with transportation and loading/discharging of oil by oil tankers in harbours and at oil terminals within the Baltic Sea. During the study the following was produced:

- A general identification of hazards in connection with oil tanker activities in harbours including a review of required and desirable safety measures
- A review of relevant previous studies of accidents in harbours
- A list of harbours around the Baltic Sea having a considerable import/export of oil
- A list of accidents recorded in these harbours related to oil transportation by ship
- Estimates of oil spill frequencies and size
- Lessons learned and future trends in accident types.

Information about accidents occurred in the harbours was obtained through communication with harbour authorities and terminals in terms of questionnaires. Based on the filled in questionnaires and information received during the visits a database was set up.

In total 637 oil spill accidents were reported. The amount of oil spilled was indicated or deductible for 604 of these accidents.

The accident description was sufficient to indicate the type of circumstances (marine event, transfer, terminal) in 134 cases. In 81 cases the accident description was detailed enough to identify the type of event initiating the release.

The results on the overall importance of oil spill accidents indicate that the marine events (collision and grounding) in the harbours of the Baltic Sea constitutes 4% of the accidents but account for 76% of the oil spilled.

The results on oil spill frequency and amount indicate that the average amount of oil spilled per 100 million tons oil handled is in the order of 400 l for oil terminals.

However, the calculated average amount spilled is very sensitive to large spills. For oil terminals the number of oil spills above 1 m³ is in the order of 0.05 per 100 million tons oil handled.

The number of spill accidents with spills above 1 m³ is in the order of 10 per 10,000 harbour calls. The number of minor spills, i.e. spills below 1 m³, is within the interval 0.5 - 5 spills per 100 million tons oil handled.

Estimates from a HELCOM-study and the averages derived in the present study for oil spills in harbours are compared and it is found that estimates above 1 m³ compare well.

The analysis of accident cause indicates that:

- Leaks in pipes, leaking valves, and defective gaskets or seals account for 30% of the releases
- In total 28% of the reported oil spills are due to malfunction of hoses
- Overfilling of one of the cargo tanks of the ship accounts for 15% of the releases
- Wrong position of valves including reverse flow from the terminal accounts for 14% of the incidents
- Releases due to transfer of waste products account for 9% of the events.

Many failures leading to frequent oil releases in the past have been eliminated or the amount of oil spilled have been reduced. At present, problems like the following are causing new types of accidents and improved measures to prevent them or reduce their consequences are under development:

- Leaks between oil tanks and ballast water tanks may result in oil contaminated ballast water and possibly in a flammable atmosphere in the space above. Double hull constructions are now experiencing pitting (corrosion) problems leading to an increased frequency of small leaks between oil and ballast tanks. Thus the frequency of such incidents may be expected to increase during the next years.
- Overfilling of cargo tanks resulting in oil release through high-jet valve. The oil is released as a flammable mist of oil droplets.
- Release of organisms toxic or harmful to the environment. This may occur if contaminated ballast water or the like, loaded in other parts of the world, are dumped in the Baltic.

It is planned to introduce new systems for recovering vapours from the displaced gases of the oil tanks. Such systems are as yet untested and they may introduce a potential source for fire/explosion.

Accident and release frequencies

In the present study models for accidents and releases of oil at sea and in harbours have been implemented in a PC based computer program. The models for accidents at sea were based on models available in literature modified with the conclusions of the study of accidents in the Baltic Sea. The models for accidental releases in harbours were based directly on the study of accidental releases in harbours bordering the Baltic Sea.

Accidental spills at sea

The analysis of accidents at sea shows that the expected number of releases is 10 and 14 for the years 1997 and 2017 respectively. The introduction of the traffic from the BPS project does not change the estimate for 2017.

Releases of more than 1,000 tonnes are expected to happen approximately once every 10 years.

Releases of more than 10,000 tonnes are expected to happen with a return period of 100 years for 1997, increasing to 75 years for 2017. Including the BPS traffic in the traffic estimate for 2017 changes the return period for spills of more than 10,000 tonnes from 75 to 50 years.

Concerning spills of 100-1,000 tonnes bunker spills from merchant vessels other than tankers dominate. Spills of less than 100 tonnes are evenly distributed between tankers and other merchant vessels, whereas spills of more than 1,000 tonnes involve only tanker spills.

The estimated average amount spilled per year for the entire Baltic Sea is expected to increase from approximately 1,200 tonnes to 1,700 tonnes during the period from 1997 to 2017. The extra traffic due to the BPS project is expected to give rise to an additional 200 tonnes released per year, averaged over a long period of years.

The most exposed region is by far the Danish waters accounting for approximately 90% of the total spill risk.

The region with the largest relative increase in risk due to the traffic from the BPS project is the Gulf of Finland. The risk of releases of more than 10,000 tonnes is expected to be doubled compared to the risk from the traffic in the year 2017. An increase of approximately 25% is expected in the long term average spill amount in the Gulf of Finland.

Accidental spills in harbours

The results of the analysis of release frequencies in harbours suggest that the most exposed harbours are Gothenburg, Brofjorden and Ventspils, regardless of traffic scenario. The expected long term average release per year is up to 30 tonnes for Gothenburg. Seven harbours are expected to spill of more than 10 tonnes per year on average due to accidents, four of these harbours being localised in Kattegat/Great Belt.

The total number of harbour spills of more than 1 ton due to accidents is expected to rise from 15 to 20 during the period of 1997 to 2017. Releases of more than 1000 tonnes are expected to happen with a 20 year return period.

Inclusion of the traffic due to the BPS project does not change the total harbour risk estimates significantly, and will only have influence on the spill risk in Porvoo and Primorsk.

The results of the risk calculations have been verified by comparing the results and models with actual observations and models in other studies. Good agreement was shown.

Comparative risk analysis. Accidents and spills on alternative routes

On the basis of in-house knowledge, the study of 'Accidents at Sea', information available in the literature and on the internet the expected accident frequencies for the Black Sea route and the Arctic Sea route have been compared to the expected frequencies for the Baltic Sea route.

The main features in relation to oil tanker accident frequencies for the Black Sea route are:

- The narrow Turkish Straits, of which the Bosphorus Strait is very heavily trafficked and very difficult to navigate.
- The Black Sea generally has higher temperatures than the Baltic Sea.

The main features in relation to tanker accident frequencies for the Arctic Sea route are:

- Severe ice conditions
- Low temperatures
- Low traffic intensity.

Navigational accidents (collision and grounding) are expected to be more frequent per vessel mile using the Black Sea route. This is due to an expected higher frequency in the Bosphorus Strait. The frequency of navigational accidents, especially groundings, may be somewhat lower in the Arctic than in the Baltic due to the lower traffic density and more simple routes.

Fire/explosion accidents are expected to be more frequent on the Black Sea route than the Baltic Sea route. This is based on observation of accidents, and the fact that oil is more readily ignited at higher surrounding temperatures. The frequency on the Arctic Sea route may be lower than in the Baltic Sea.

Structural damage accidents are expected to be more frequent for the Arctic Sea route than for the Baltic Sea route and the Black Sea route due to impact from ice. However, it is only expected to be slightly higher.

The release size, given an accidental release, is expected to be higher on average at the Black Sea route.

This is mainly due to expected higher probability of fire/explosion both as initial event and as secondary event to a release from a navigational or structural damage accident.

The overall evaluation is that using the Black Sea route will give the highest number of releases, and probably also larger releases. The frequency of releases may be lower using the Arctic Sea route than if using the Baltic Sea route.

c. **Composition of oil, some background information**
by Asger B. Hansen, Danish Environmental Research Institute

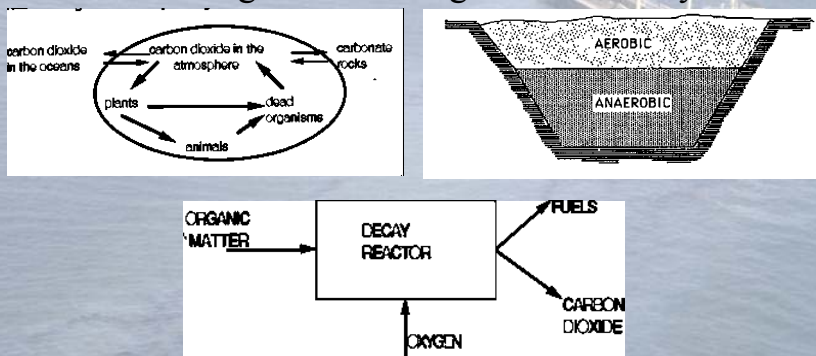
This presentation gives a brief overview on petroleum, from the generation crude oil over the processing and refining of petroleum products to the fate of crude oil and petroleum products spilled in the environment.

The generation of petroleum is discussed in relation to the sedimentation and burial of various sources of organic material from once-living organisms, part of the global carbon cycle. Through a series of degradative and cracking processes (diagenesis - catagenesis - methagenesis) that depend on burial depth and temperature, the dead organic matter first becomes part of kerogen ("source rock") that successively is converted to crude oil, coal or gas.

Petroleum generation

● The global carbon cycle

✿ Natural gas, petroleum and coal derived from once-living matter through the carbon cycle



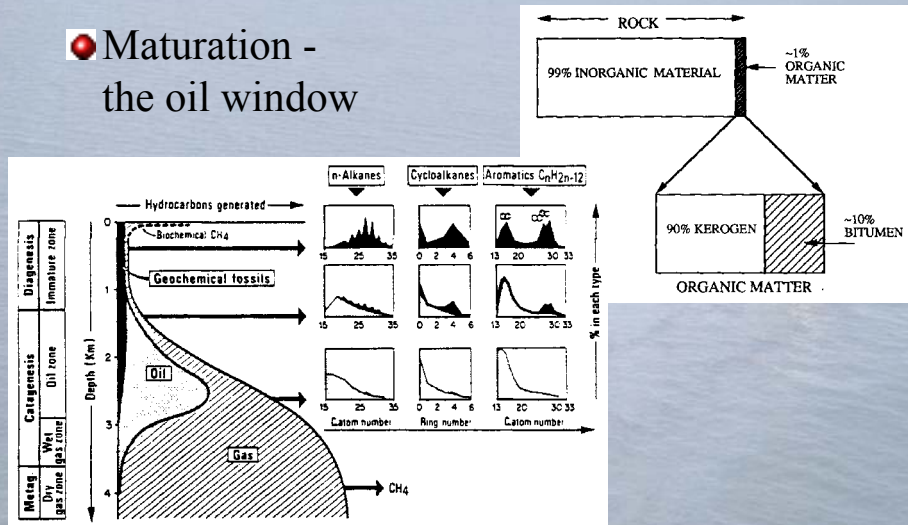
Dan. Vet. & Food Adm., 01-10-02

Petroleum composition - A.B. Hansen, NERI

3

Petroleum generation - 4

Maturation - the oil window



Dan. Vet. & Food Adm., 01-10-02

Petroleum composition - A.B. Hansen, NERI

6

Petroleum characterization

Chemical-physical

- ✱ Boiling point distribution (distillation – SIMDIS)
- ✱ Density (gravity)
- ✱ Viscosity
- ✱ Sulphur/metal content

Chemical

- ✱ PNA group analysis
- ✱ GC-FID analysis (n-alkane distribution)
- ✱ GC-MS fingerprinting (biomarkers, PAHs etc.)

Dan. Vet. & Food Adm., 01-10-02

Petroleum composition - A.B. Hansen, NERI

9

The “oil window” is introduced, and it is discussed how the type and composition of the generated petroleum (crude oil) depends on the source organic material. Examples illustrate how crude oils can be characterised by physical-chemical analysis and how most crude oils are classified depending on the relative content of the three main component groups, paraffins (P), naphthenes (N) and aromatics [a]. Examples are also presented that show how crude oils can be characterised by gas chromatographic (GC-FID) analysis of the alkane distribution.

The processing of crude oil and refining of petroleum products are discussed followed by a brief description of the main product types like petrol, diesel/gas oil, fuel oil and lubricating oil. Examples are shown on how these product types can be characterised and distinguished by GC-FID analysis delineating the n-alkane boiling range (distillation cuts).

Crude oil classification

Paraffinic (1)

$P > 40\% > N$, $P+N > 50\%$

Naphthenic (3)

$N > 40\% > P$, $P+N > 50\%$

Aromatic-intermed. (4)

$A > 50\%$, $P > 10\%$

Paraffinic-naphthenic (2)

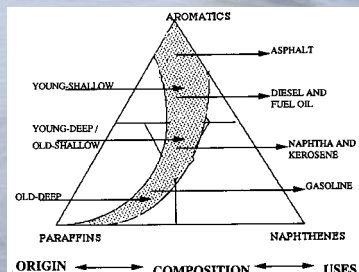
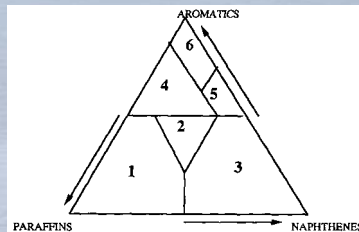
$P+N > 50\%$, $P-N < 40\%$

Aromatic-naphthenic (5)

$A > 50\%$, $N > 25\%$, $P > 10\%$

Aromatic-asphaltic (6)

$A > 50\%$, $P < 10\%$, $N < 25\%$



Dan. Vet. & Food Adm., 01-10-02

Petroleum composition - A.B. Hansen, NERI

10

Petroleum refined products - 2

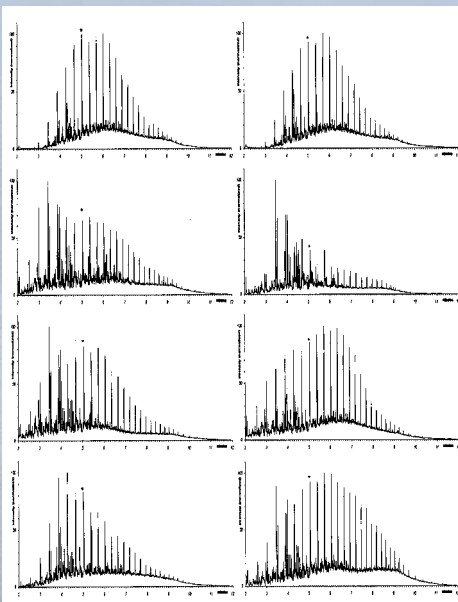
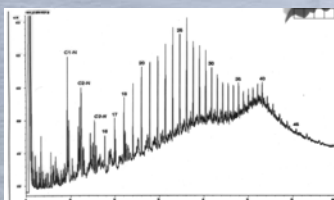
Heavy fuel oils

$\sim C_{12} - C_{35}$

BP $\sim 315 - 425^\circ\text{C}$

Fuel/bunker oil

Cracking feed

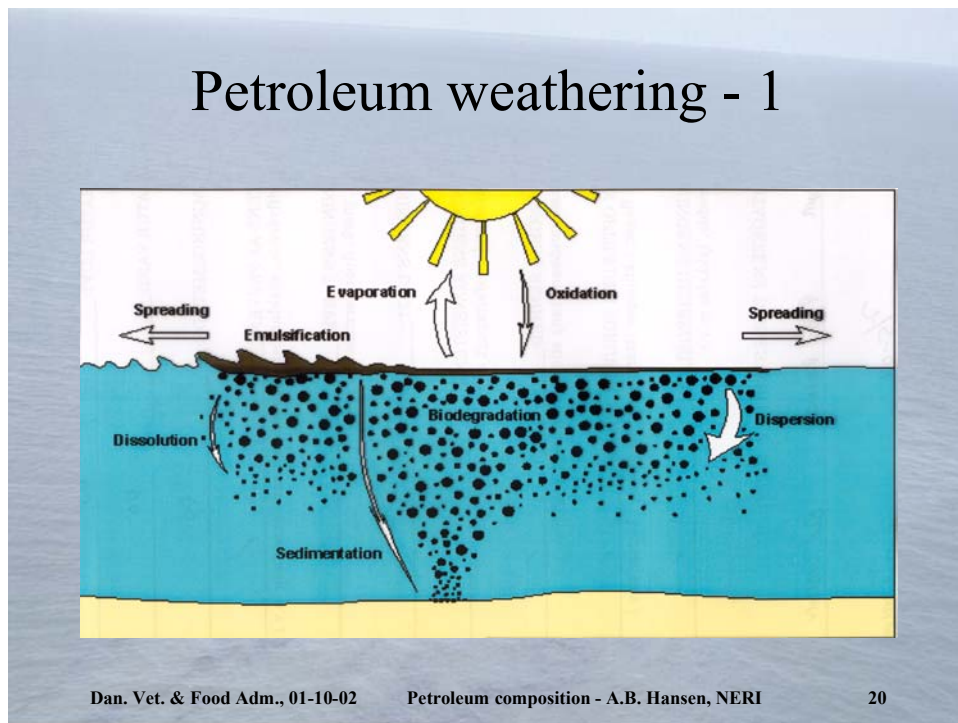


Dan. Vet. & Food Adm., 01-10-02

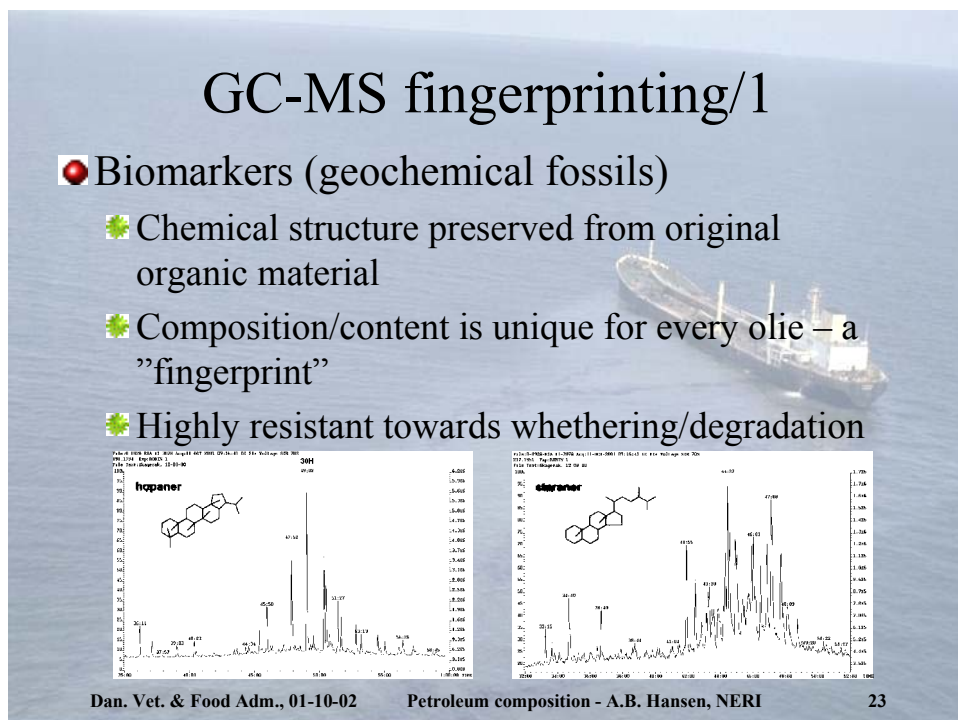
Petroleum composition - A.B. Hansen, NERI

16

Finally, a short introduction is presented on the fate of oil spilled in the environment. The weathering processes are discussed and illustrated by examples on how the different petroleum products react towards weathering and degradation.



The concept of GC-MS fingerprinting is also introduced, and it is discussed how this analytical technique can be used to retrieve highly selective and diagnostic data on petroleum composition, like PAH and biomarker profiles, and how these are affected by weathering.



- d. Experience from the US-Exxon/Valdez oil spill
by Parmley Pritchard, Danish Environmental Research Institute

The Exxon Valdez oil spill was unique in many ways. The majority of the oil that went ashore in Prince William sound was not substantially emulsified with water and thus crude oil was, in essence, “painted” on the shoreline, but of course in excessive amounts.

Public Aspects of the *Exxon Valdez* Oil Spill Clean Up

- **Alaska Department of Environmental Conservation**
- tremendous scientific, public, and political pressure
- **Spend before you have the money - wealth of the polluter**
- **Economic contrasts - hire fisherman away from the industry you polluted**
- **Concern for sunken oil**
- **Paranoia about “do nothing”, dispersants, burning, oil sheens**
- **Clean up criteria - no visible oil**
- **Disposal of oily wastes**

The amount of money spent in the clean up effort was unparalleled and the amount of research information generated during and after the clean up was significantly greater than any oil spill previously. The presence of high tidal ranges (up to 3 meters) and glacial till in the waters, were also unique features of Alaska that were important in the eventual natural clean up of the Prince William Sound area. In addition, the clean up efforts included the use of bioremediation, a relative untested technology at the time, particularly at the scale in which it was used.

However, despite these unique features, clean up of the Exxon Valdez spill occurred under conditions that are similar to those found in the Baltic, including areas around Denmark. That is, shoreline geomorphology (sandy to very rocky terrain), weather conditions (water temperatures, winter storms, etc.), potentially impacted habitat (birds, mammals, fisheries, wetlands, etc.), and multiple ownership of affected resources (assuming a spill might affected the shorelines of several countries) are all generally similar, and thus there are lessons from Alaska that are very relevant to the Baltic region. With any spill, the initial clean up of shoreline areas will involve mechanical methods, primarily direct removal of contaminated beach material and some type of washing procedure (high pressure hot water spaying was used in Alaska). Disposal of the excavated materials becomes substantial burden and the physical damage to the shoreline can be as damaging as the oil. In Alaska, no chemical dispersants or detergents were ever used because of fears of secondary effects (sinking of the oil, toxicity, etc.).

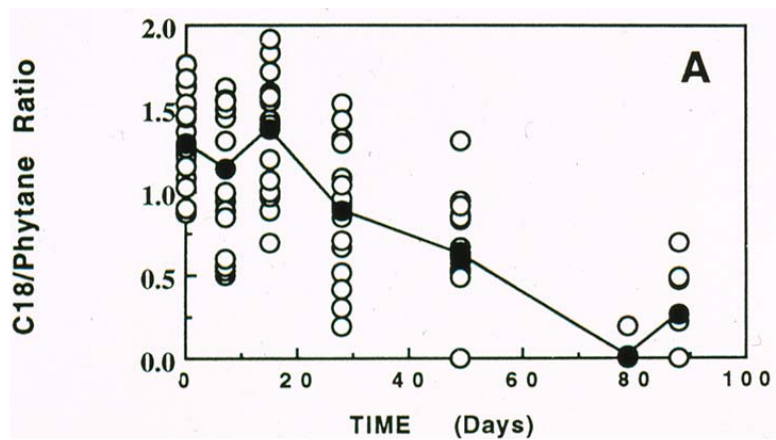
However, the existence of more environmentally friendly and effective dispersants now makes their use a possibility in certain situations.

But following the initial cleanup, there will invariably be considerable oil remaining in certain areas and in addition to the potential long term environmental effects, these areas will still “look” badly polluted and thus in need of some further clean up.

Clean Up Technologies Used and Considered

- **Sorbent Booms - oil sheen control, oil herding, oil collection**
- **Manuel pick up - collection and disposal of oil beach material**
- **Excavation - removal by mechanical means; “rock washers” (with chemicals)**
- **Washing/flushing - warm water, high pressure spray, flushing, booms, skimmers.**
- **Chemical dispersants - oil slick control, beach material washing**
- **Bioremediation - enhancement of natural oil degradation by overcoming limitations**

There are few options in this so called “phase II” part of the clean up but two prominent possibilities are “do nothing” (in other words, allow nature to take it’s course, which can often be quite effective), and bioremediation. In the Exxon Valdez oil spill, bioremediation was the option of choice, based on successful field demonstrations conducted in a joint effort by EPA and Exxon. Since natural oil biodegradation, which will occur in any aquatic environment, often becomes quickly limited by the availability of nitrogen (oil is largely carbon and for bacteria to grow on the oil, they will require a source of nitrogen), the application of nitrogen-containing fertilizers becomes an obvious choice. Experiences in Alaska, and in many other studies since, have shown that different “slow release” fertilizer formulations can be added to the contaminated beaches and significant additional clean up of the oil obtained. Examples will be given of formulations used in Alaska. Most important to remember, however, is that “phase II” clean up will undoubtedly bring attention to the use of bioremediation and one should be prepared for the considerations and consequences. In the latter case, those include the possibilities of ecosystems that very sensitive to the addition of nitrogen and the possibilities of secondary toxic effects to resident biota. Overall, however, bioremediation is an accepted and effective technology that can be quite helpful in oil spill clean up.



Conclusions

- Evaluate cleanup options and criteria before the spill
- Determine your most sensitive coastal habitats and develop ecological baseline studies.
- Reserve money for extensive post-spill monitoring of oil concentrations and oil chemistry.
- Ecosystems in general, recover remarkably from oil spills - for example, improving on natural oil degradation in Prince William Sound was a challenge
- Consider “phase II” options - bioremediation produced a 2-4 enhancement of oil degradation - approximately a summer’s worth of clean up saved.
- Pre-spill public education

- e. Survey of the environmental effects after the Oil spil incident from the Baltic Carrier in Grønsund /Denmark in 2001
by Jakob Lysholt Sørensen, Stormstrømsamt, Denmark

On March 29th 2001, the oil tanker “Baltic Carrier” collided with the bulk carrier “Tern” at the western Baltic Sea, near the naval border between Germany and Denmark. The collision between the two vessels was caused by a mechanical defect in the steering mechanism of the “Baltic Carrier”.

Because of the collision 2400 tons of heavy fuel oil leaked from the cargo tanks into the open sea. The spilled oil stranded along the shorelines of the sound Grønsund, on the islands of Farø, Bogø, Møn and the North-eastern Falster. So far, this oil pollution is the worst one in Danish coastal waters.

The action

Storstrøm County planned and carried out the environmental survey and monitoring programme in co-operation with the National Environmental Research Institute (NERI), Denmark, and Roskilde University (RUC) under the Grant Agreement SUB 01/323479.

Samples for chemical analysis were collected three times in the first year following the oil spill. In April 2001, shortly after the accident, the first sampling programme was initiated. In mid-June 2001 the second part of the sampling took place, and in December 2001 a third round of samples were collected. Biota samples, flounder and shrimps, were additionally sampled and analysed in May 2002.

Immediately after the oil spill, oil from the ship was analysed. Later, seawater, sediment and biota have been analysed for 86 different polycyclic aromatic hydrocarbons (PAH), which are considered to constitute the most toxic fraction of the oil. The PAH levels measured in invertebrates and fish were used to evaluate potentially toxic effects to wildlife in the area. Furthermore the obtained data formed the basis of a human toxicology assessment used by the human health authorities in deciding on regulations on fishery and aquaculture in especially the Grønsund area.

In the survey the effects of the oil spill were investigated for the following topics: The acute toxicity of the oil to marine invertebrates was estimated on the basis of laboratory acute toxicity tests. The long-term effects on the macrofauna was assessed on the basis of benthic macrofauna analyses in the field and by comparison to international guidelines on levels of especially polycyclic aromatic hydrocarbons in the environment. Furthermore the effects on birds in the area and the impact of the cleaning operations on the flora were investigated. Finally the issue of human toxicology was assessed.

The aims

The aim of this monitoring programme has been to investigate and assess the environmental consequences of the oil spill after the “Baltic Carrier” in the western Baltic Sea.

In the project the extension and magnitude of the oil pollution after the “Baltic Carrier” incident, were investigated in order to successively provide the basis for information and recommendations to local municipal administrations, citizens, tourists, NGOs as well as relevant industries on the current pollution situation in affected areas.

Based on the results of the project, decisions will be taken regarding further clean-up measures and development of long-term monitoring programmes in the area.

The results/impact for the future

Acute toxicity tests demonstrated that both the oil from the "Baltic Carrier" and its water-soluble components were highly toxic to pelagic organisms in concentrations realistic with respect to the situation in the Grønsund.

The toxicity towards benthic fauna of sediments contaminated with oil from the "Baltic Carrier" was much lower. However, exposure of a selection of benthic species to oil-contaminated sediment for longer periods of time lead to increased mortality and sub-lethal effects, showing that realistic concentrations of the "Baltic Carrier" oil could have adverse effects to pelagic invertebrates representative of shallow subtidal habitats of the Grønsund.

Spilled oil may disappear and/or change in toxicological potency as a result of various processes. Analysis of the composition of the oil at a test locality show disappearance of the oil as a result of physical and chemical processes as well as biodegradation. In April 2001, PAH levels in seawater from the Grønsund were of the range 641 to 12 833 ng/L with a median value of 1 115 ng/L. Even after 2½ months, PAH concentrations in seawater had decreased to between 29 and 124 ng/L, close to baseline levels. In general the sediments were very heterogenous in PAH content. The largest petrogenic input was found at the southern coast of Møn, Bogø and Farø. PAH levels measured in sediments from April, 11 days after the oil spill, were in the range 90-4,119 µg/kg DW. In June the overall level was 46-1304 µg/kg DW, and in December total concentrations of 81-1018 µg/kg DW were measured in sediments from the area.

The PAH level in blue mussels only decreased slowly. In June concentrations of 132-1031 µg/kg ww were measured, while levels in December were 185-894 µg/kg ww. These later values are up to 5 times above levels measured elsewhere in Danish waters. PAH levels in shrimps from Grønsund decreased from 770 µg/kg ww by a factor of 10 during the first year after the "Baltic Carrier" incident.

The levels of PAH in trout from aquacultures in the area created the basis for the recommendations by the National Veterinary and Food Administration. Both the sum of PAH and the calculated benzo(a)pyren (B[a]P) TEQ values in contaminated fish 1½ months after the accident were of the same order of magnitude as calculated B[a]P-TEQ values from comparable Danish areas unaffected by the oil. Therefore it was considered safe to eat fish from the Grønsund area.

Levels of PAH in seawater, sediments and biota were compared to the Ecotoxicological assesment criteria (EAC) defined by OSPAR. In April, immediately after the oil spill, concentrations of anthracene in water samples from the entire Grønsund region were at a level likely to cause detrimental long-term biological effects. In sediment samples from the same period especially pyrene exceeded international guidelines at several stations, thus indicating the risk of harmful effects to organisms in the area. Based on international guidelines the toxicological potential of both water and sediment has decreased during the three sampling periods described in this survey. In December, levels of all studied PAH compounds were stillexceeding the EAC values in the Brede-made Hage –Fanefjord area, while the rest of the area revealed concentrations below these valuesThe risk of long-term adverse biological effects in the Grønsund area as

such, caused by PAH from the oil spill, therefore seems limited outside the mentioned locations.

The oil accident had an immediate and lethal effect on all birds caught by the oil. The number of collected dead birds was relatively small (1750 birds), whereas the estimated number is much higher – maybe tenfold. One year after the oil accident, local breeding birds show fast recovery, except for breeding waders.

Apparently, the impact of the oil and the cleaning up has caused no irreversible damage to the flora in the affected areas. There is a notable difference in the degree of coverage between the affected and the unaffected test sections at the salt meadow and in the reed layer. The laying open of the sediment by the cleaning up gave way for several new species like marsh samphire and reflexed sea meadow grass, whereas perennial species are of more frequent occurrence in the unaffected test sections. The more rare perennial species like the sea rush and the hard rush are not found in the affected test sections.

Impact on tourism in year 2001 could not be recognized. The impact on fishery and private property resulted in compensation of in all 3,5 million Euro.

The following future actions were recommended:

- Further monitoring of the levels of oil compounds in both abiotic and biotic samples from the area until levels are normalized.
- Implement county wise survey on the coastline to map valuable habitats and human installations especially sensitive to oil contamination, and develop plans for protective measures for these areas in connection with oil spill situations.
- Establish basic contingency plans for environmental survey in connection with oil spill situations, and establish a standing advisory body with experts in modelling of oil drift and monitoring of especially oil and PAH the environment.
- Develop more case specific guidelines for clean up methods, covering a broader range of different oil types and different impacted area types.
- Develop more robust and flexible contingency plans for disposal of oil waste.
- Establish a regulatory body to implement bans on fishing following major oil spills until surveillance shows acceptable concentrations of oil and oil components in affected seafood.
- Establish a national fund body providing funding of the initial monitoring phase in connection with oil spill situations.

f. **Effects of oil on fish populations**

by Valery Forbes, Dept of Life Sciences and Chemistry University of Roskilde

Oil enters the aquatic environment from both land-based and sea-based sources, and inputs may occur continuously (e.g., from atmospheric inputs of partially combusted fossil fuels) or episodically (e.g., accidental spills of crude oil). Spatial and temporal variability in the chemical composition of ‘oil’ complicates assessments of the effects of oil pollution on natural populations of fish and other aquatic species.

Exposure of fish to oil may occur through contact with contaminated water, sediment, and or food, and toxicity of at least some oil components may be strongly influenced by environmental factors (e.g., light). Variability in sensitivity among fish species as well as among different life stages of the same species can be substantial. There is a relatively large body of evidence indicating that exposure to particular fractions of oil or specific oil components (e.g., individual PAH) results in biochemical changes in fish cells or tissues.

Likewise, controlled laboratory experiments have indicated effects of oil or oil components on fish behaviour, survival, growth and reproduction. There is less evidence for effects of oil pollution on the dynamics of fish populations in the field, though some oil spill case studies indicate that impacts can be potentially serious.

g. Chemicals in fish for human consumption for oil polluted areas

by Lene Duedahl-Olesen, Danish Veterinary and Food Administration

Crude oil is mainly composed of saturated hydrocarbons and aromatic compounds. The distribution of the individual components is characteristic for the type of the oil. The aromatic compounds include mono-, di- and poly-cyclic aromatic compounds. The Polycyclic Aromatic Hydrocarbons (PAH) are mainly responsible for the carcinogenic potentials of the oils. A contamination of fish for human consumption by these chemicals is therefore of great concern.

Polycyclic aromatic hydrocarbons (PAH) are compounds consisting of carbon and hydrogen arranged in two (e.g. naphthalene) or more aromatic rings. PAH include in total around 100 different chemical compounds. Examples of these compounds include flourene and phenanthrene with three aromatic rings, fluoranthene and pyrene with four aromatic rings, benzo[a]pyrene with five aromatic rings and anthanthrene with six aromatic rings. The Polycyclic Aromatic Compounds (PAC) includes the PAH and similar cyclic aromatic compounds with sulfur (e.g. dibenzothiophene), nitrogen (e.g. phenanthridine, carbazole) and/or oxygen (e.g. anthraquinone) in the ring system.

Crude oils are not the only source to PAH-contamination of the aquatic environment. Deposition of PAH formed during incomplete combustion or pyrolysis of organic matter is also an important source contributing to the general background level. Aquatic organisms may accumulate PAH from the environment, including water, sediments and their food. To be able to estimate the level of contamination in fish for human consumption it is important to obtain knowledge on the background levels of PAH in fish from waters believed to be free of contamination.

The concentration of different PAH in fish from such waters varied from 1 to 215 µg/kg wet weight depending on the type of fish and type of PAH analysed. The highest concentration was found to be naphthalene in seafish from Finland (IPCS, 1998), however differences in the choice of individual PAH-compounds to be analysed are making the evaluation and comparison of data difficult.

As well as the PAH profile depends on the type of the oil, the type of a point source for a PAH-contamination is also giving raise to a specific and characteristic PAH profile. This is illustrated by the findings that fluoranthene was the dominating PAH-contamination in fish collected close to a petroleum pilot plant in USA, while benz[a]anthracene was found to be dominating in fish collected close to an oil platform

in UK. Fish collected at places with industrial effluents were found to contain PAH compounds such as benzo[b]fluoranthene, benz[a]anthracene, benzo[a]pyrene, benzo[e]pyrene, fluoranthene, pyrene and phenanthrene in major concentrations. The average levels of individual PAH in aquatic organisms from these sites ranged from 1 to 4000 µg/kg wet weight, the differences in levels generally corresponded to the degree of industrial and urban development and shipping movements (IPCS, 1998).

In Denmark, only few analyses have been made of PAH in fish from waters being free of any oil contamination. The National Environmental Research Institute, Department of Environmental Chemistry, Roskilde, DK, has analysed flounder from three different Danish coastal waters and the results for a selection of nine individual PAH are found in Table 1 (Pritzl, 1999). The concentration of these PAH is generally below 1 µg/kg wet weight, only fluoranthene (1.1 to 9.5 µg/kg wet weight) and phenanthrene (4.2 to 6.6 µg/kg wet weight) are found in higher concentrations. A total of 26 different PAH were analysed and the sum of these is listed in the lower row.

Table g.1. Concentration (µg/kg wet weight) of selected PAH in flounder from Danish non-polluted coastal waters collected in 1998-1999 (Pritzl, 1999).

PAH\Geografic location	South Jutland, Fanø	Århus, Århus Bay	Copenhagen, Øresund
Acenaphthene	0.2	0.2	0.2
Acenaphthylene	0.3	0.1	0.3
Anthracene	0.3	0.1	0.2
Benz[a]Anthracene	0.3	0.2	0.1
Benzo[a]Pyrene	1.1	1.2	0.8
Fluoranthene	1.1	4.6	9.5
Fluorene	1.0	0.7	1.8
Naphthalene	0.4	1.5	1.2
Phenanthrene	4.2	5.2	6.6
Sum PAH (26)	29	36	56

Mussels are known to be a good indicator organism for the levels of contaminations in the aquatic environment. Data on selected PAH for blue mussels (*Mytilus edulis*) collected at different coastal waters in Denmark are found in Table 2 (Pritzl, 1999).

Compared to the concentration of PAH in flounder, the concentration of the selected PAH are slightly higher in blue mussels. This includes the concentration of fluoranthene (5.6 to 14.6 µg/kg wet weight), phenanthrene (5.6 to 17.1 µg/kg wet weight) and an over-all increase in the sum of PAH for blue mussels.

The slightly higher concentration of PAH in blue mussels is probably due to the difference between fish species in the speed of uptake, metabolism and excretion of the contaminants. In general, mussels are found to have a slower metabolism of the PAH.

As part of the same study blue mussels were collected from Danish coastal waters acting as reservoirs for industrial effluents.

The PAH-levels found in these mussels are given in Table 3. The results indicates, that the total concentration of PAH (sum PAH) in mussels from such areas is increased by 2 - 5 times compared to mussels collected from waters believed to be unaffected by any point source contamination.

In table g.3, the concentration of the different PAH varies due to different sources of contamination at the three locations. A spill of refined oil was found in Jutland, Horsens, giving raise to a level of naphthalene in the mussels at 61.8 µg/kg wet weight, while at West Zealand, Agersø the contamination from crude oil resulted in increased levels of dibenzothiophene (7.9 µg/kg compared to <1 µg/kg for mussels from other locations, data not shown). The contamination at the harbour in Copenhagen, resulting in higher concentrations of fluoranthene (58.4 µg/kg) was found to be due to combustion processes.

Table g.2. Concentration (µg/kg wet weight) of selected PAH in blue mussels (*mytilus edulis*) from Danish non-polluted coastal waters collected in 1998-1999 (Pritzl, 1999).

PAH\Geografic location	South Jutland, Manø	North Jutland, Hirtshals	Århus, Århus Bay	Copenhagen, Øresund
Acenaphthene	0.1	0.3	0.6	0.3
Acenaphthylene	0.1	0.5	0.5	0.2
Anthracene	0.8	0.3	0.4	0.2
Benz[a]Anthracene	1.4	0.4	1.3	1.0
Benzo[a]Pyrene	2.1	2.2	2.2	2.5
Fluoranthene	11.5	5.6	14.6	8.4
Fluorene	1.7	0.3	1.7	1.9
Naphthalene	1.1	2.6	3.9	1.6
Phenanthrene	5.6	10.7	13.6	17.1
Sum PAH (26)	55	70	108	121

The concentration of Benzo[a]pyren of 1.3 to 5.1 µg/kg wet weight for blue mussels collected from waters affected by industrial effluents (Table 3) are lower than the concentration of Benzo[a]pyren up to 18 µg/kg detected in smoked fish (IPCS, 1998). However, the concentration in smoked fish varies considerably due to factors such as the type of smoke generator, the temperature of combustion, and the degree of smoking. As an example concentrations of Benzo[a]pyren of 60 µg/kg wet weight has been detected for smoked eel skin (IPCS, 1998).

The impact of an oil spill accident on the aquatic environment was clearly demonstrated by the Exxon Valdez accident in Canada in 1989. Studies of especially waters, sediments and biota after the accident showed that the distribution of PAH in biota corresponded well to the PAH profile of the oil. A total number of 45 individual PAH were detected. Shortly after the oil spill, the content of all the PAH (sum) in the mussels was found to be 18,000 to 234,000 µg/kg wet weight depending on the geographical location. A year after the oil spill, the content of the sum of the same 45 PAH in mussels was found to be approximately 100 times lower.

Table g.3. Concentration ($\mu\text{g/kg}$ wet weight) of selected PAH in blue mussels (*mytilus edulis*) from Danish coastal waters with industrial emission collected in 1998-1999 (Pritzl, 1999).

PAH\Geografic location	Jutland, Horsens	West Zealand, Agersø	Copenhagen, Harbour
Acenaphthene	3.0	3.7	0.3
Acenaphthylene	2.4	3.6	0.3
Anthracene	3.7	1.2	6.7
Benz[a]Anthracene	0.9	2.1	5.4
Benzo[a]Pyrene	1.3	4.6	5.1
Fluoranthene	16.6	17.8	58.4
Fluorene	7.4	3.0	1.5
Naphthalene	61.8	31.3	5.1
Phenanthrene	24.4	38.1	46.4
Sum PAH (26)	325	350	249

Due to the increased PAH-contamination of fish and mussels after an oil spill, it is important to assess the health risk for consumers by eating such fish from the contaminated areas. Such an assessment should be based on an estimation of the contamination of aquatic biota sampled from the area close to the oil spill. The assessment should as far as possible be made just after the oil spill. Furthermore, the restoration of the contaminated area should be followed by an appropriate monitoring programme to give the necessary data to update the risk-assessment.

The first step in the assessment of the contamination of fish for human consumption is an evaluation of the extent of contamination. This step includes the first estimation of the amount of dead fishes and birds in the surface of the waters. Then collection of fish material good enough to evaluate the contamination level should be made. Sampling of fish should take into account the usual species variability in the water before the contamination. It should also be considered that some species do not metabolise PAH to any great extent (like algae and molluscs) and therefore accumulate high concentrations of PAH, whereas organisms that do metabolise PAH, like fish and higher invertebrates, only accumulate the contaminants to a lesser degree. As resources for sampling might be limited, considerations of whether some fish species can be used as models for others should be considered. The time of the year for collecting the samples are important for the expected PAH concentration. The PAH concentration in biota has been found generally to be higher during the winter period and lower in summer due to the variation in metabolic activity and seasonal breeding. The choice of locations for sampling should take into account the stream, weather and geographical variations within the contaminated area.

The second step in the assessment includes a follow up on the levels of contamination found in fish and if possible the restoration of the aquatic environment. This step obviously includes a monitoring programme based on an appropriate continuous sampling and analysis of the contaminants. As data on the background level of PAH for different fish species at various locations is normally lacking, it can be difficult to follow the restoration process. With the aim of collecting data on PAH in various foods the EU Commission has initiated a so-called SCOOP-project, that might result in a better illustration of the background PAH-levels in fish.

References

Pritzl, G. (1999). Personal communication by E-mail: PAH in marine biota.

IPCS (1998). Environmental Health Criteria 202. Selected Non-heterocyclic Polycyclic Aromatic Hydrocarbons. Pp.235-237+250-263

- h. **Safety assessment of contamination of fish with PAH**
 by Mona-Lise Binderup, Danish Veterinary and Food Administration

Speech incorporated in the main report as part of the risk assessment in chapter 6.

- i. **Norwegian Petroleum Directorate (NPD), Process and mechanical equipment**
 by Arne Johan Thorsen, Norwegian Petroleum Directorate (NPD)

Norwegian Petroleum Directorate (NPD) was established in 1973 and has its main office in Stavanger. There is a small office in Harstad with 7-8 people. Totally there are 350 employees. The main goal for NPD is to contribute to create highest possible values for society from oil and gas activities founded on a sound management of resources, safety and the environment.

In its work NPD reports to two ministries. Regarding resource management we report to the Ministry of oil and energy and regarding safety and working environment management we report to the Ministry of labour and government administration. Environmental matters are partly HSE issues and partly resource management issues and are reported to both ministries.

NPD is organised in three product areas:

- Framework and advice
- Supervision of activities
- Data, information and knowledge management

and are a team based organisation. One person can be member of several teams.

- Data on background levels
- Sampling
- Geography and Seasonal changes
- Evaluate level and type of PAH (EVO-levels)

Rules and regulations

The Petroleum Act is the base for the legislation. On this basis has the regulations been developed. On top we have the regulations relating to health, environment and safety in the petroleum activities (*the framework regulations*). This is a royal decree.



Under the framework regulation we have four more detailed regulations

- Regulations relating to management in the petroleum activities (*the management regulations*)
- Regulations relating to design and outfitting of facilities etc. in the petroleum activities (*the facilities regulations*)
- Regulations relating to conduct of activities in the petroleum activities (*the activities regulations*)
- Regulations relating to material and information in the petroleum activities (*the information duty regulations*)

These regulations give functional requirements of how to build, run, maintain and in the end, remove installations. The regulations can be found on NPD's web page www.npd.no.

The regulations are joint regulations for the three bodies supervising the activities on the Norwegian continental shelf:

- Norwegian Petroleum Directorate (NPD)
- Norwegian Pollution Control Authority (SFT)
- Norwegian Social and Health Directorate (NSHD)

Authorities

In the drilling and production phases NPD is "responsible" for seeing to that the facilities are designed and run in such a way that discharges are prevented. SFT will give permits for operational discharges, and Kystverket (KYV) will be responsible for cleaning up if there has been an accidental discharge.

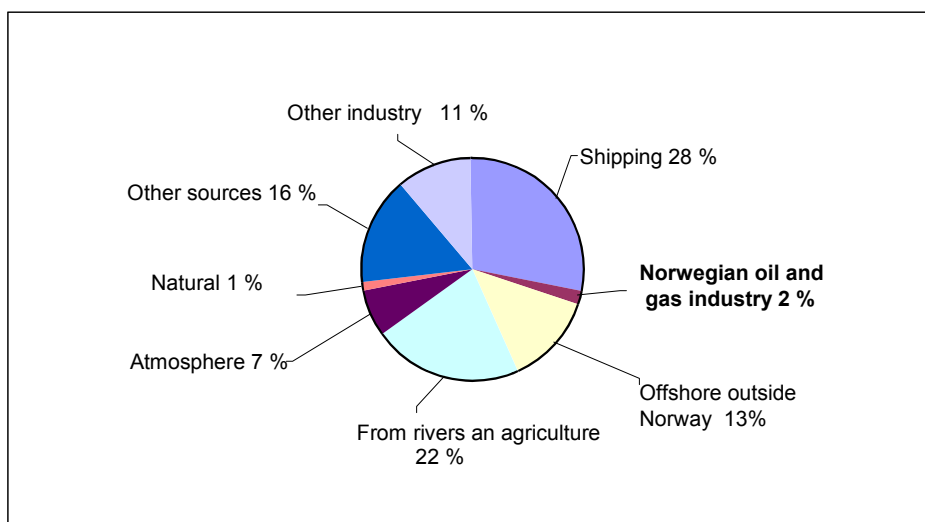
Environmental work

NPD is involved in environmental work on several areas. Some of the important arenas are:

- Oslo – Paris convention (OSPAR)
 - Protection of NE Atlantic Ocean against all kind of pollution
- Zero discharge philosophy
 - Cooperation between authorities and oil companies to reduce environmental harmful discharges as close to zero as possible

In the work of supervision of the industry, NPD collects and ask for a lot of data. These data are used to get an overview of the past and to look into the future to see where the challenges will be.

Oil spill to sea



Nordic project on consequences of oil spill on fish for human consumption, Stavanger
7.4.2003

20

Abstract

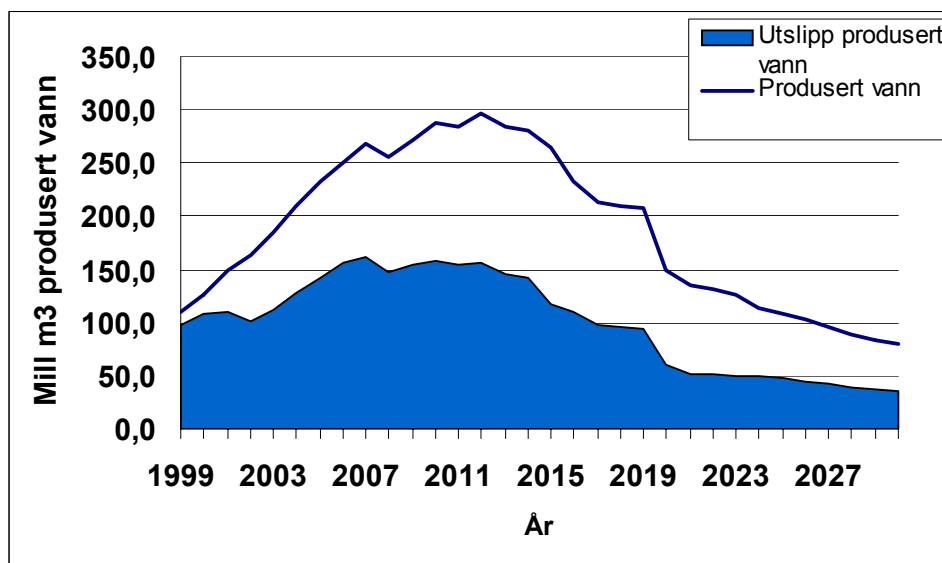
Monitoring oil pollution in marine organisms

The core activity of RF-Akvamiljø is research and monitoring of marine pollution with special emphasis; impact on marine organisms. The main clients are the industry, particularly the oil and gas industry, and national and international research financing bodies, e.g. the Norwegian Research Council and EU. As the industry now is obliged to account for the environmental impact of their activities, RF-Akvamiljø is engaged by industry to develop tools for environmental impact assessments.

This includes assessing levels of contaminants and monitor and evaluating biological effects of contaminants. The work consists of laboratory experiments, field experiments

and desk-top evaluations, which include the use of computer modeling, or combinations of these. A special focus has been set on the so-called biomarkers. These are various readily measurable responses of contaminants at the molecular, cellular or physiological level in organisms. The potential link to adverse effects for the organism makes these methods indicators of environmental risk.

Produced water



Nordic project on consequences of oil spill on fish for human consumption, Stavanger
7.4.2003

23

Examples of biomarkers applied by RF-Akvamiljø are:

- Metabolites of Polycyclic Aromatic Hydrocarbons (PAH) and alkyl phenols in bile
- Metals in bile
- Biotransformation enzyme level (induction by certain contaminants)
- DNA damage (adducts, strand breaks, chromosome damage)
- Reproduction parameters (level of egg proteins, imposex/ intersex)
- Oxyradical defense system parameters
- Histopathology (morphological changes)
- General stress parameters (immune defense parameters, growth inhibition)
- Continuous development on-going

The most appropriate way of monitoring potential impact of pollutants in a marine environment is often to apply a suite of various biomarkers together, preferably on several species, in addition to chemical measurements for exposure characterization. The selection of methods is naturally dependent upon the actual situation to be investigated, the

type of contamination suspected, the marine organisms present at the location and how thorough monitoring is required.

One biomarker that has been applied to assess impact of oil on marine organisms is the detection of PAH metabolites in fish bile (and crab urine). PAH is a compound group present in oil which is regarded a health risk particularly due to the carcinogenic properties of some PAH structures.

Fish metabolise PAH rather rapidly and PAH is therefore normally detected in low concentrations in e.g. fish flesh. However, PAH metabolites accumulates and concentrates in the gallbladder bile, and the bile is for this reason a suited sample for sensitive analyses of PAH in fish. Analyses can be performed either by direct fluorescence detection based on the inherent fluorescence properties of PAH, or by Gas Chromatography - Mass Spectrometry in Single Ion Mode detection (GC-MS-SIM), eventually High Performance Liquid Chromatography with Fluorescence detection (HPLC-F). Specificity and quantifiability vary according to the method.

The detection of PAH metabolites in bile provides evidence of presence, uptake and metabolism/ biotransformation of PAH compounds. It is regarded a risk factor for further adverse effects. For instance are several studies demonstrating correlations between increased PAH metabolite levels and increased occurrence of DNA damage in liver of fish. PAH metabolites in bile has been applied in monitoring programs in the wake of several smaller and larger oil spill episodes since the Exxon Valdez accident in 1989.

k. **Effects of pollutants on marine animals near harbours in Iceland**
by Halldór P. Halldórsson, *Institute of Biology, University of Iceland.*

Harbours and shipping routes are well known sources of various pollutants, such as oil compounds (PAH and other hydrocarbons) and tributyltin (TBT; antifouling substance) that may exert toxic effects in marine organisms. To evaluate effects of pollution on marine animals near harbours in Iceland, different species of animals have been studied. The two most studied species are the blue mussel (*Mytilus edulis*) and lumpfish (*Cyclopterus lumpus*) but several biomarkers in these animals have been used to detect possible alterations. Biomarkers can give a useful indication of whether organisms are affected by pollutants or not and they can show if pollutants are present at a level high enough to cause a detectable effect.

Blue mussel (Mytilus edulis)

The blue mussel has many advantages as a test animal. It is widely distributed in the northern hemisphere and related species can be found all around the world. They are effective filter feeders, sessile, tolerant and easily collected on the shores.

They can accumulate large amounts of contaminants, both from sediment particles and straight from the water column, due to ineffective enzyme system to metabolize pollutants.

Scope for Growth

Scope for Growth (SFG) is a method used to estimate the energy budget of individual mussels. By measuring physiological parameters like food consumption, respiration

rate, food efficiency and excretion, it is possible to see if the mussels are physiologically stressed. When everything has been standardised and measured, the SFG value is calculated in joules per hour per gram dry weight of the mussel. Low SFG value indicates that the mussels are stressed, reflecting polluted environment, hence decreased food consumption and increased respiration rate. SFG is a general biomarker (where wide range of chemicals can have effects) but hydrocarbons and PAH have been shown to affect SFG of mussels in relatively low concentrations.

Comet assay

Comet assay (single cell gel electrophoresis) is a method to detect DNA single strand breaks. It allows the quantification of DNA strand breaks at the single cell level and virtually any eukaryotic cell can be analysed by that method. It is designed to detect the most frequent type of DNA damage and has been demonstrated previously to be a reliable genotoxicity biomarker for both field and laboratory studies. DNA strand breaks may be caused directly by genotoxic compounds, through the induction of apoptosis or necrosis, secondarily through the interaction with oxygen radicals or other reactive intermediates, or as a consequence of excision repair enzymes. It is a general biomarker since many reactive chemicals can cause strand breaks.

DNA adducts

DNA adducts are structural alterations of the genetic material, formed when reactive electrophilic metabolites of chemicals bind covalently to the DNA. DNA adducts are a clear demonstration of exposure to environmental pollutants, mainly PAH.

They are an early warning of genotoxic exposure and an indication of possible adverse effects, for example tumors. DNA adducts are considered to be a sensitive biomarker of exposure of animals to genotoxic contaminants.

The aforementioned biomarkers have shown that both resident and transplanted mussels are affected by pollution near harbours in Iceland. Mussels from Reykjavík harbour, which had the highest PAH and TBT concentrations of all sites studied, showed the most physiological- and genotoxic stress response. Elevated PAH levels were presumably the main cause of these effects, that is lowered SFG values and increased DNA strand breaks and DNA adducts.

*Lumpfish (*Cyclopterus lumpus*)*

Like mussels, the lumpfish has many advantages in environmental studies. It is for example a very tolerant species, it lays big masses of big eggs and newly hatched larvae have well developed sucktion on their ventral side which they use to attach themselves to a substrate.

The aim of the studies with the lumpfish is to develop a method to investigate the effects of pollutants on early life stages of fish, both in situ and under laboratory conditions.

The egg-masses of the lumpfish, laid and fertilised in the laboratory under flow-through conditions, are divided into small lumps and put into net bags. These are then transferred to different sites in the field. After exposure for up to 50 days in the field, the

mortality and development of the eggs and the larvae is determined and different biomarkers are used in order to detect sub-lethal effects of contaminants. The development of the larvae is then followed up to and after yolk sac absorption, a period of about 10 to 50 days, and samples for different biomarkers are taken. At present, biological effects of antifouling agents are being studied, as well as effects of harbour pollutants at different sites in Iceland. That involves studies on several biomarkers in the lumpfish, like morphology, physiology and enzymatic activity.

This new approach makes exposure of lumpfish larvae and embryos at clean and polluted field sites possible. It has showed to work efficiently and will now give new possibilities to study the early development of fish, a period of up to 50 days, which covers the most sensitive stages of the life cycle.

Annex V

Authorities involved in oil emergency response and surveillance systems

Oil spills or contamination with other chemicals in the environment are accidents, which do happen in modern societies. Contamination can have effects on both the environment, on drinking water and in animals like fish, corps etc.. The effects could both be on conditions of life and survival of flora and fauna and on the suitability of corps, fish etc. for human consumption. When major oil spills occur, the first visible effect will often be suffering or dead birds and fish, oily water and or beaches. Furthermore fishing gear etc. can be contaminated and the first action to be taken will often be actions towards protection of the environment.

In many cases, the aspects of food safety do not get very much attention in the first place after an accident. Therefore the normal used emergency response does often involve the national Environment Protection Agencies, but maybe not the food authorities at all. As knowledge of contact persons etc. could be adventurous for the food safety assessment and managing this chapter has a brief description of the existing emergency response in the various Nordic countries. The description of the national surveillance system will include information on both the environment and foodstuffs. Some national contact points are mentioned in Annex I.

In the Baltic region, there are co-operation within the HELCOM agreement also including co-operation in emergency situations like major oil spills in the area. In the Atlantic there is corporation within OSPAR. Furthermore, the Nordic countries has an agreement on surveillance and reporting in the Copenhagen agreement, 1993. This agreement does especially address pollution with oil. Internationally, corporation takes place in EU and in the International Marine Organisation.

National and international surveillance systems do also exist both on the environmental situation and on food safety issues. The surveillance of the marine environment is briefly described here, as data from this work could be used as information on the background levels of contaminants in an area, if data on the content of chemicals in foods are not available for the risk assessors. The organisation ICES (International Council for Exploration of the Sea) collect data from several international surveillance organisations. In Annex II is given a short description of some international surveillance organisations.

a. Denmark

Surveillance and emergency response

In Denmark, the Ministry of Defence, Søværnets Operative Kommando (SOK), is responsible for the surveillance of the sea and would be the first authority to take action. One of their responsibilities is protection of the environmental and the marine area.

This includes the EU emergency response concerning ships transporting dangerous cargo. In cases of oil spills, their first priority would be to isolate the oil by e.g. by physical means and to remove it from the sea. In order to protect workers involved, the composition of the oil would be analysed. The analysis would include data from the owner of the cargo and chemical analysis by the Danish Environmental Research Institute, DMU.

Involvement of other authorities will depend on where the accident takes place and could involve the Ministry of Environment, the EPA, the regions and the municipalities. The emergency response is concentrated on the environmental damages and workers protection and they do not include actions concerning fish for human consumption.

Surveillance of environment

In Denmark, the surveillance program NOVA has existed since 1987. The program started in 1988 and includes surveillance of the contaminants transferred into the water environment, including surveillance of groundwater, streams, lakes and the sea. The surveillance should also function in relation to measurements of the effects of initiatives for improvement of the quality of the water. The results should be used in decision making in relation to further initiatives.

NOVA-2003 consists of a surveillance program and an organisation. The NOVA 2002 is a corporation between the regions and the Ministry of Environment.

In the program, e.g. PAH's and heavy metals in fish and common mussels are measured. The organisms analysed are not necessarily caught in areas with commercial fishery.

Surveillance of foodstuffs

Denmark has had a surveillance program for several types of foodstuffs during many years. This surveillance does not include analysis of PAH's in food, including fish species, but certain fish species are subject to a special surveillance program on dioxins.

b. Finland

The Finnish Environment Institute (SYKE) is in charge against all kinds of chemical pollution incidents, and that is why it is also the competent governmental authority against oil spills. SYKE has a 24-hour duty for environmental incidences. As well, in case of oil accidents, SYKE is empowered to give and request for international assistance in operating against marine pollution caused by oil.

If a vessel is in a situation of pollution risk, SYKE may give an order to undertake salvation measures that are directed to avoid and limit the risks of pollution.

That happens within the Finnish territorial waters and even outside them. Arrangement of resources, information services and investigations of incidents are assisted by SYKE.

If an oil accident happens, SYKE gives orders to oil prevention vessels, commands the prevention actions to proceed, nominates the leadership for the prevention measures, gets materials and personnel needed, takes care of information according to the international treaties and communications in general and sets up investigations needed. An-

nouncement of an oil spill to SYKE is usually done by Local Alarm Control Centres or Maritime Rescue Coordination Centres.

For the costs of combating oil spills a special financial arrangement has been implemented. The acquisition and maintenance of oil spill combating materials and equipment is subsidized through a special oil pollution fund, in which the Government is also entitled. The fund is based on tonnes of oil imported to or transported through Finland. The charge is doubled if oil is transported in a single-hull tanker.

Because of the sensitivity of the Baltic Sea ecology it has been agreed internationally (within HELCOM) that in the Baltic countries oil combating is based on mechanical means. However, the agreement allows also the use of chemicals, i.e. dispersants, in oil combating, but such chemicals are not used in Finland. Every oil recovery vessel in Finland, which is owned by government, is capable of working independently. In Finland there are 11 ship-sized vessels and 12 boats of 10–18 meters long with oil recovery brush systems permanently installed.

Finnish national oil combating is connected to international treaties that have been made in order for cooperation necessary in combating marine environmental incidents. Finnish monitoring aeroplanes and vessels take yearly part in national and international exercises.

Finland is especially devoted to develop efforts for combating against oil in low temperatures and in icy conditions due to its geographical location. As well SYKE is constantly involved in developing methods to recover oil from shipwrecks.

Surveillance

In addition to oil accidents, illegal oil discharges are also under surveillance. Finnish Frontier Guard in cooperation with SYKE performs these actions. Finnish Frontier Guard has two Dornier 228 aeroplanes, which are used in monitoring. As well, Navy, Frontier Guard vessels and merchant vessels inform about their observations. The crew of aeroplanes is capable to make real-time observations of substances floating on the surface even in darkness or bad visibility with the equipments installed. These include, in addition to ordinary video and photographic cameras, a side-looking airborne radar, a IR/UV/VIS scanner and a forward-looking infrared radar that can be locked on target to enable following it. All observations during the flight can be saved on computer, on videotape or printed as hard copy. When the aeroplane detects oil at sea, the pilot contacts the nearest Marine Rescue Centre, which further contacts the SYKE duty officer. If necessary he or she will send a Navy or a Frontier Guard vessel to verify the observation and to take samples of oil.

c. Iceland

The Icelandic Coast Guard is responsible for the aerial surveillance of the coastal area around Iceland.

The surveyed area is limited to the exclusive economic zone, e.g., up to 200 nautical miles from the shore. Statistical information regarding the surveillance is submitted to the secretariat of the Copenhagen agreement.

Information about pollution incidents should be reported to the Icelandic Coast Guard Command Centre, which forwards the report to the Environment and Food Agency. The Environment and Food Agency is responsible for responses to pollution incidents and making action plans for managing pollution incidents outside harbour areas. The Agency is also responsible for coordinating responses to such incidents.

Harbours in Iceland are divided into five groups depending on location. Committees in each of the areas are responsible for drawing up response plans and the management of booms and other equipment for pollution prevention. Port authorities are responsible for responses to pollution incidents within harbour areas.

d. Norway

Several national authorities are involved in oil surveillance in Norway. Generally, the Norwegian Petroleum Directorate is involved in preventing discharges from facilities, the Norwegian Pollution Control Authorities gives outlet permissions, whereas Kystverkets beredskapsavdeling (must find English name) is responsible for cleanup and follow-up studies after acute oil pollution into the sea.

Kystverkets beredskapsavdeling is organised under the Department of Fisheries and is the governmental authority against oil spills. It is in charge for the Norwegian preparedness against acute oil pollution. The purpose of the preparedness is to protect life, health, environment and production interests. Kystverkets beredskapsavdeling ensure that polluter or municipal takes action after acute outlet of oil to the sea. In case of larger oil spill national resources are mobilised and kystverkets beredskapsavdeling commands the action to proceed.

In case of oil spills the first priority would be to isolate the oil as close to the outlet as possible or to isolate it at the coastline already polluted in order to prevent further spreading. The use of oil dispersants is evaluated in each case and will be used if it benefits the environment.

Kystverket are also in charge for organising follow-up studies after oil spills. A guideline that forms an outline of relevant chemical and monitoring methods for implementation on course of (or after) acute oil pollution in the marine environment has been made⁷. However, seafood for human consumption is not taken into consideration.

The Directorate of Fisheries with regional offices has preparedness plans in case of oil spill that affects fishery resources.

An advisory group has been created that will meet in case of accidental oil spill.

It has representatives from the Directorate for Nature Management, Kystverket, the Directorate of Fisheries, Institute of Marine Research, and Norwegian Polar institute. So far, the Norwegian Food Control Authority is not a part of this group.

⁷ SFT Veiledning 99:05. Etterkantundersøkelser etter akutt oljeforurensning i marint miljø

Surveillance

Illegal oil discharges are under surveillance. The Norwegian coastline is surveyed for oil spills by plane 600-800 hours/year in co-operation with the Norwegian Navy. Radar and distance survey equipment makes it possible to find and calculate oil amounts. Furthermore, surveillance by satellite is available through Kongsberg satellite Services in Tromsø. Eventual satellite observations will be verified by inspection by ship or plane.

The Norwegian Pollution Control Authority has a program that survey level of environmental chemicals in sediments, fish and shellfish in selected fjords and harbours. PAH level in mussels has been measured in several places.

e. Sweden

The Swedish Coast Guard is the appointed competent authority for oil spill responsible in Swedish waters, including the three large lakes. The Coast Guard (CG) is an independent non-military authority, supervised by the Ministry of Defence. CG has the overall responsibility for contingency planning regarding environmental response to spills of oil and other harmful substances. There are four CG districts: Northern, Southern, Eastern and Western. The local organisation consists of 26 stations along the Swedish coastline as well as one air station. There are six stores of environmental response equipment divided into six groups, booms, skimmers, pumps, vessels and temporary storage of recovered oil, dispersants and finally miscellaneous. Where relevant and possible, the equipment is listed according to the place where it is stored, but sometimes it is listed in country regions or even for the whole country.

The duty for environmental response activities on the shoreline, in municipal harbours and in some private harbours is primarily undertaken by local authorities. The fire service carries out actions toward off and reduce damage, while beach cleaning operations are performed by or under supervision by other municipal agencies. The National Rescue Services Board, (Statens Räddningsverk, SRV), has the overall administrative responsibility. Co-ordination of land and sea activities is achieved through close contact between the relevant commanders

The level of preparedness is based on risk analysis and assessment of possible environmental damage. The objective is to be able with a spill up to 5000 tonnes by means of national resources.

The aim of the Coast Guard oil spill response activities at sea is to limit the damage of momentary outflow within 4 hours and also start oil spill recovery actions by mechanical response methods within 8 hours, before the oil reaches the shoreline.

Sweden has made considerable efforts as regards oil spill detection by means of aerial surveillance. The CG has three reconnaissance aircraft, which are fitted with sophisticated remote sensing equipment.

Priority is given to mechanical recovery of oil spill. In the case of minor pollution incidents, mechanical agitation may be sufficient.

If the oil threatens the coast, it could preferably be diverted from the vulnerable zone, and if possible, be contained by booms for recovery. Sinking agents are prohibited and dispersants are not used.

Annex VI

Nordic authorities and some international contact points involved in pollution prevention at the sea and surveillance

International

EU has an organisation concerning oil spills. Information on contactpoint etc. can be found on the webpage adress: <http://europa.eu.int/comm/environment/civil/marpol-cis/index.htm>

Denmark

The Danish Environmental Protection Agency, Danish EPA under the Ministry of the Environment and Energy is the administration of legislation concerning environmental protection (the Danish Act for the Protection of the Marine Environment) and environmental regulation of offshore activities.

The Danish Ministry of Defence has delegated the contingency functions to Defence Command Denmark, which for its part has delegated the contingency functions to Admiral Danish Fleet (Royal Danish Navy).

Regarding illegal discharges into the sea from ships, Defence Command Denmark has taken over the enforcement of the Danish Act for the Protection of the Marine Environment from the Danish EPA. The enforcement jurisdiction for violations of this Act are the Danish territorial waters and the Exclusive Economic Zone and beyond this area where it is consistent with international law (UNCLOS 1982). The Act is based on MARPOL 73/78 and incorporates the regulations concerning discharges into the sea.

ORGANISATION

- (i) Admiral Danish Fleet is responsible for combating pollution caused by oil or other harmful substances on the high seas and in coastal waters.
- (ii) The regional councils or the local councils are responsible for combating pollution caused by oil or other harmful substances on the shoreline.
- (iii) The local authorities are responsible for combating pollution in ports and harbours.
- (iv) The Danish EPA, the regional councils or the local councils are responsible for restoration of beaches, according to the extent and nature of the pollution

The responsibility mentioned under point 1.1 (i) implies that:

- Admiral Danish Fleet establishes and maintains the necessary contingency organisation at government level for combating marine pollution

- Admiral Danish Fleet, when receiving information concerning marine pollution or risk of pollution decides whether a combating operation shall be launched and, if so, which combating methods are to be used, or decides upon countermeasures to prevent pollution from taking place.
- Planning of the aerial surveillance is in direct co-ordination between the Royal Danish Air Force and Admiral Danish Fleet. Aircraft from the Royal Danish Air Force are carrying out the aerial surveillance.

To support Admiral Danish Fleet an abatement staff including members from relevant authorities, etc may be established.

Administrative contact point

Admiral Danish Fleet
Maritime Environment Section
PO Box 483 DK-8100 Aarhus C
Tel: +45 89 43 33 81
Fax: +45 89 43 33 88
E-mail: pol.con.den@sok.dk

Finland

Finnish Environment Institute (SYKE) is the competent government oil pollution combatting authority. It is in charge of measures against pollution incidents at open waters and whenever severity of an incident so necessitates. SYKE is also the nationally appointed competent authority, that is empowered to request and give international assistance in combatting marine pollution caused by oil or other harmful substances. Finnish Environment Institute is a governmental body under the Finnish Ministry of the Environment

The oil combatting vessels are manned and owned by the Navy, Frontier Guard and Maritime Administration. The local municipalities have small boats.

Administrative contact point

Finnish Environment Institute
Head of unit Mr Kalervo JOLMA
P.O. Box 140
FIN-00251 Helsinki
FINLAND
Phone: +358 9 4030 0468
Telefax: +358 9 4030 0478

Norwegian Pollution Control Authority
Statens forurensningstilsyn (SFT)
POB 8100 Dep,
N-0032 Oslo
Tlf: 47 22 57 34 00
Internet: www.sft.no

The food emergency response authorities
The Directorate of Fisheries
Fiskeridirektoratet
POB 185 Sentrum
N-5804 Bergen
Phone: 47 55 23 80 00
Internet: www.fiskeridir.no

Norwegian Food Control Authorities
Statens næringsmiddeltilsyn,
POB 8187 Dep,
N-0034 Oslo
Phone: 23 21 70 00
Internet: www.snt.no

Sweden

Overall National Swedish Organization

Delimitation of responsibilities regarding oil and chemical spill abatement

	AT SEA		ON LAND	
	General preparedness	Field operations	General preparedness	Field operations
Government Level	Ministry of Defence		Ministry of Defence	
Central Authority	Coast Guard Headquarters	Officer on Duty Coast Guard Headquarters	Rescue Services Agency	Officer on Duty
Regional Level	Regional Coast Guard Office	Response Commander Regional Coast Guard Office	County Administration	Command Staff
Local Level		Coast Guard On-Scene Commander	Local Government	Municipal Rescue Commander

Swedish Administrative contact point

Swedish Coast Guard HQ

Box 536

SE-371 23 KARLSKRONA

Sweden

Phone +46 455 35 34 00

Fax +46 455 105 21

Email kcl@coastguard.se

Annex VII

Some international surveillance systems

There are several international organisations involved in activities which has a one goal to protect the environment and who has surveillance systems among there activities. As some of the data from these organisations might be useful in the risk analysis of oil spills and the contamination of fish for human consumption, some of these organisations are described in brief here.

International Maritime Organization (IMO)

The purposes of the Organization are "to provide machinery for cooperation among Governments in the field of governmental regulation and practices relating to technical matters of all kinds affecting shipping engaged in international trade; to encourage and facilitate the general adoption of the highest practicable standards in matters concerning maritime safety, efficiency of navigation and prevention and control of marine pollution from ships". The Organization is also empowered to deal with administrative and legal matters related to these purposes.

The IMO Convention entered into force in 1958 and the new Organization met for the first time the following year.

Shipping is perhaps the most international of all the world's great industries and one of the most dangerous. It has always been recognized that the best way of improving safety at sea is by developing international regulations that are followed by all shipping nations and from the mid-19th century onwards a number of such treaties were adopted. Several countries proposed that a permanent international body should be established to promote maritime safety more effectively, but it was not until the establishment of the United Nations itself that these hopes were realized. In 1948 an international conference in Geneva adopted a convention formally establishing IMO (the original name was the Inter-Governmental Maritime Consultative Organization, or IMCO, but the name was changed in 1982 to IMO).

IMO's first task was to adopt a new version of the International Convention for the Safety of Life at Sea (SOLAS), the most important of all treaties dealing with maritime safety. This was achieved in 1960 and IMO then turned its attention to such matters as the facilitation of international maritime traffic, load lines and the carriage of dangerous goods, while the system of measuring the tonnage of ships was revised.

European Union (EU)

The European Union has regulation concerning the shipping and pollution prevention. This regulation should ensure the exchange of information between actors in the marine community, improve surveillance of navigation, develop the liability of various players in the seaborne oil trade etc.. This regulation will not be described in further details. The Nordic authorities involved in this area are listed in this Annex.

International Council of Exploring the Sea (ICES)

ICES is the organisation that coordinates and promotes marine research in the North Atlantic. This includes adjacent seas such as the Baltic Sea and North Sea. ICES act as a meeting point for a community of more than 1600 marine scientists from 19 countries around the North Atlantic. ICES is the prime source of advice on the marine ecosystem to governments and international regulatory bodies that manage the North Atlantic Ocean and adjacent seas.

ICES has among its data Catch Statistics - STATLANT Database Queries to be addressed to ICES Data Centre (mailto: info.ices@ices.dk) Yearly nominal catches of fish and shellfish officially submitted by 19 ICES member countries in the Northeast Atlantic including over 200 species.

Oslo-Paris Comissionen (OSPAR)

The Oslo and Paris Commission, formerly known as PARCOM. The commission is a group of experts who advise North Sea countries on environmental policy and legislation. OSPAR has been influential in establishing North Sea legislation on drilling fluids that has served as the model for other operating areas. OSPAR has published lists of environmentally acceptable and unacceptable products, referred to as the "green," "grey" and "black" lists. The Green or A list consists of products posing relatively little harm to the environment (specifically the marine environment). The Grey List consists of products 'requiring strong regulatory control' and includes heavy metals such as zinc, lead and chromium. The Black list covers products considered unsuitable for discharge and includes mercury, cadmium and 'persistent oils and hydrocarbons of a petroleum origin.

Helsinki Commission (HELCOM)

The Helsinki Commission, or HELCOM, works to protect the marine environment of the Baltic Sea from all sources of pollution through intergovernmental co-operation between Denmark, Estonia, the European Community, Finland, Germany, Latvia, Lithuania, Poland, Russia and Sweden.

HELCOM is the governing body of the "Convention on the Protection of the Marine Environment of the Baltic Sea Area" - more usually known as the Helsinki Convention

HELCOM's main goal is to protect the marine environment of the Baltic Sea from all sources of pollution, and to restore and safeguard its ecological balance.

HELCOM's objective with regard to hazardous substances is to prevent pollution of the convention area by continuously reducing discharges, emissions and losses of hazardous substances towards the target of their cessation by the year 2020, with the ultimate aim of achieving concentrations in the environment near background values for naturally occurring substances and close to zero for man-made synthetic substances. This objective was adopted within HELCOM Recommendation 19/5 in March 1998.

Co-operation in combatting marine pollution

In the Helcom Agreement, the co-operation in combating marine pollution is described. The Contracting Parties shall individually and jointly take, all appropriate measures to maintain adequate ability and to respond to pollution incidents in order to eliminate or minimize the consequences of these incidents to the marine environment of the Baltic Sea Area.

1. Each Contracting Party shall provide information to the other Contracting Parties and the Commission about:
 - a) organization for dealing with spillages at sea of oil and other harmful substances;
 - b) its regulations and other matters which have a direct bearing on preparedness and response to pollution at sea by oil and other harmful substances;
 - c) the competent authority responsible for receiving and dispatching reports of pollution at sea by oil and other harmful substances;
 - d) the competent authorities for dealing with questions concerning measures for mutual assistance, information and co-operation between the Contracting Parties according to agreement
 - e) actions taken in accordance with Regulations.
2. The Contracting Parties shall exchange information on research and development programs, results concerning ways in which pollution by oil and other harmful substances at sea may be dealt with and experiences in surveillance activities and in responding to such pollution.
3. The Contracting Parties shall on a regular basis arrange joint operational combatting exercises as well as alarm exercises.
4. The Contracting Parties shall co-operate within the International Maritime Organization in matters concerning the implementation and further development of the International Convention on Oil Pollution Preparedness, Response and Co-operation.

AMAP

Arctic Monitoring and Assessment Programme (AMAP) was started after a Finnish proposal to convene a conference on the protection of the Arctic environment led to preparatory meetings in September 1989 where the 'Rovaniemi process' was initiated.

In June 1991 Environment Ministers from the Eight Arctic rim countries (Canada, Denmark/Greenland, Iceland, Norway, Sweden, Soviet Union, and United States) met in Rovaniemi, Finland, for the First Arctic Ministerial Conference.

Important outcomes of this conference were the Rovaniemi Declaration and the adoption of the *Arctic Environmental Protection Strategy* (AEPS), the objectives of which are:

- to protect the Arctic ecosystems, including humans;
- to provide for the protection, enhancement and restoration of environmental quality and sustainable utilization of natural resources, including their use by local populations and indigenous peoples in the Arctic;
- to recognize and, to the extent possible, seek to accommodate the traditional and cultural needs, values and practises of indigenous peoples as determined by themselves, related to the protection of the Arctic environment;
- to review regularly the state of the Arctic environment;
- to identify, reduce and, as a final goal, eliminate pollution.

The AEPS also formally recognized the importance of the active participation in the process of groups representing the indigenous peoples of the North.

The Arctic Monitoring and Assessment Programme (AMAP) was established in 1991 to implement certain components of the AEPS.

SOCA (Subcommittee on Oceans and Coastal Areas)

SOCA was established with in FN in 1993, for the purpose of meeting the coordination needs defined in Chapter 17 of Agenda 21.

Terms of Reference are that the Subcommittee shall:

1. monitor and review progress in the implementation of chapter 17, programme areas A to F and relevant parts of programme area G of Agenda 21 and report thereon to IACSD;
2. prepare proposals for IACSD and other relevant bodies to enhance the effectiveness of cooperation and coordination, and facilitate such cooperation and coordination in the implementation of chapter 17 of Agenda 21, including financial means of implementation;
3. consider and give effect to the possibilities and means with respect to joint activities and programming for the implementation of chapter 17 of Agenda 21;
4. identify the needs for and facilitate the coordination of activities of the United Nations system relating to chapter 17 of Agenda 21;
5. interact with joint scientific advisory bodies such as the Joint Group of Experts on the Scientific Aspects of Marine Environmental Protection (GESAMP), which may provide the scientific basis for policy recommendations;
6. Enhance exchange of information, including information on relevant intergovernmental agreements and decisions, existing and proposed programmes, operational activities and cooperative and coordinating arrangements, and promote, where appropriate, harmonized and shared information systems;

Assist in the preparation of system-wide reports, as required, on developments with respect to oceans and costal area issues and the implementation of Agenda 21 as regards the protection of the oceans, all kinds of seas, including enclosed and semi-enclosed seas, and coastal areas and the protection, rational use and development of their living resources, and related capacity-building.