INSTITUTE FOR SYSTEMS INFORMATICS AND SAFETY

# SUBSTANCES DANGEROUS FOR THE ENVIRONMENT

## IN THE CONTEXT OF COUNCIL DIRECTIVE 96/82/EC

### REPORT BY TECHNICAL WORKING GROUP 7

Edited by

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## Acknowledgements

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**TABLE OF CONTENTS**

## 1. INTRODUCTION

On 9 December 1996 *Directive 96/82/EC on the control of major-accident hazards* (so-called Seveso II Directive) was adopted by the Council of the European Union. Following its publication in the *Official Journal (OJ) of the European Communities (No L 10 of 14 January 1997)* the Directive entered into force on 3 February 1997.

The Seveso II Directive aims at the *prevention* of major-accident hazards involving dangerous substances and the *limitation of the consequences* of such accidents not only for man (*safety and health aspects*) but also for the environment (*environmental aspect*). Both aims should be followed with a view to ensuring high levels of protection throughout the Community in a consistent and effective manner.

Member States had up to two years to bring into force the national laws, regulations and administrative provisions to comply with the Directive (transposition period). From 3 February 1999, the obligations of the Directive have become mandatory for industry as well as the public authorities of the Member States responsible for the implementation and enforcement of the Directive.

The Seveso II Directive has replaced *Directive 82/501/EEC on the major-accident hazards of certain industrial activities (OJ No L 230 of 5 August 1982).* The fact that the original Seveso Directive was not amended but that a completely new Directive has been conceived already indicates that important changes have been made and new concepts have been introduced into the Seveso II Directive.

Although in many cases substances which are dangerous for man are also dangerous for the environment, it can be said that the scope of the Seveso I Directive was more focused on the protection of persons than on the protection of fauna and flora. With the Seveso II Directive, propensity to endanger the environment is an important aspect that has been reinforced by the inclusion, for the first time, of substances classified as *dangerous to the (aquatic) environment* in the scope of the Directive. Such substances were covered by Seveso I only if they were also covered by another classification category.

Annex I, Part 1 of the Seveso II Directive contains a list of *named* substances for which the qualifying quantities for the application of Articles 6 and 7 and Article 9 are set out. Annex I, Part 2 contains 10 defined generic categories of dangerous substances which are not specifically named in Part 1 of Annex I. These refer to classification characteristics such as toxicity, flammability, oxidising or explosive potential.

The category entitled "*dangerous for the environment*" has been included, to regulate dangerous substances which have been viewed as presenting a 'major-accident hazard' to the environment. Substances which are very toxic to aquatic organisms (risk phrase R50) or which are toxic to the aquatic organisms and can cause long term adverse effects on the aquatic environment (risk phrases R51 and R53) are covered.

However, there is some uncertainty about whether the qualifying quantities for the application of Articles 6 and 7 (200 / 500 tonnes) and Article 9 (500 / 2000 tonnes) that have been fixed by Council are appropriate. The need for an immediate review of this area is covered by Statement 6 of the Council minutes related to the Seveso II Directive:

"***The Council and the Commission acknowledge the need to evaluate the qualifying quantities assigned to substances dangerous for the environment in Part 2. To this end, the Council requests the Commission to carry out a detailed examination, in co-operation with the Member States, of the appropriate qualifying quantities for this category of substance, in the context of the objectives pursued by this Directive. The Commission will submit a report on this matter as soon as feasible, accompanied if appropriate by proposals for amending the qualifying quantities assigned to the substances in question.***"

Moreover, the UN/ECE Convention on Transboundary Effects of Industrial Accidents, in its Annex I Part I., sets a different threshold quantity for substances and preparations "dangerous for the environment" for the purposes of defining hazardous activities (200 tonnes). This Convention was signed by the European Community and fourteen of the Member States on 17 March 1992 and approved by the European Community on 24 April 1998.

The Convention lays down a number of provisions aimed at protecting human beings and the environment against industrial accidents capable of causing transboundary effects and at promoting active international co-operation between the Contracting Parties before, during and after such an accident. For EU Member States the Seveso II Directive is considered as the legal and technical instrument to fulfil the obligations arising out of the Convention.

In view of this incoherence, and indications that the number of establishments likely to be covered by the category *substances dangerous for the environment* under the current thresholds of the Seveso II Directive was very limited, and in order to prepare the report that was requested by Council, it was decided in 1996 at the 33rd meeting of the Committee of Competent Authorities (CCA) set up under the original Seveso Directive to establish a Technical Working Group (TWG 7) to carry out the corresponding tasks. The constitution of the group was primarily based on nominations from the Competent Authorities. Furthermore, representatives from the relevant Federations of Industry that could contribute to the work of TWG 7 were invited to the meetings of the group. TWG 7 reported to the CCA.

The principal task for the group was to examine in a detailed manner if the qualifying quantities of substances dangerous for the environment are appropriate for the purposes of applying Articles 6 and 7 and Article 9 of the Directive and, if this turns out not to have been the case, to make proposals for more appropriate qualifying quantities.

Moreover, at the Sixth meeting of the Signatories to the UN/ECE Convention on the Transboundary Effects of Industrial Accidents held in Geneva in March 1997, a decision was taken to extend the work of TWG 7 to the entire ECE region for the purposes of revising the scope of the Convention.

Between November 1996 and December 1999, four meetings of TWG 7 were held in Ispra, Italy at the premises of the Major Accident Hazards Bureau (MAHB) established within the Joint Research Centre (JRC) of the European Commission.

The MAHB was founded in February 1996 with a remit to offer scientific and technical support to other services of the Commission (principally DG Environment) in the successful implementation of European Union policy on the control of major industrial hazards and the prevention and mitigation of major accidents, in particular in connection with the Seveso Directives.

An interim report[1] summarising the opinions of experts issued at the 3rd meeting of TWG 7 (24th-25th March 1999) and containing recommendations from this meeting was presented to the first meeting of the CCA established under the Seveso II Directive that was held on 19-21 May 1999 in Munich, Germany. In the light of the comments made by the CCA and taking into account the results of the fourth and last meeting of TWG 7 (13-14 December 1999), this Final Report was drawn up.

## 2. THE METHODOLOGY

Early on in the work of TWG 7 it became clear that the scientific justification of the appropriate qualifying quantities should be balanced against administrative feasibility in the Member States. For that reason, a threefold approach was followed:

(i) Design and performance of a Study in the Member States and industrial federations in order to estimate the number of establishments likely to be affected by various threshold levels (thus collecting valuable information for taking pragmatic considerations into account);

(ii) Collection and analysis of past accidents involving substances dangerous for the environment (in order to take into consideration "lessons learned" from the past); and

(iii) Other scientific considerations, such as assessment of minimum quantities capable of causing significant effects to the environment.

The analysis of past accidents gave important insights and useful lessons to be learned concerning the routes of contamination, the substances usually involved, the released quantities and the extent of the consequences. It proved that severe consequences can result even from the discharge of small quantities – much smaller that those under discussion in TWG 7. It also gave insights on the type of establishments involved and it showed that severe accidents can also occur in activities not presently covered by the Directive, such as pipelines, transportation and toxic waste from the extractive industries.

Task (iii) also provided insights on the minimum quantities capable of causing significant effects to the aquatic environment. However, none of these two tasks could provide a clear answer to the question of *adequate* qualifying quantities . The answer provided by these two tasks was, from the viewpoint of damage caused to the environment, of the form "qualifying quantities should be as low as possible but definitely higher than xx tonnes – with xx being a very small number".

Therefore, the proposal of TWG 7 presented in this report tries to strike a balance between the risk posed to the environment by substances classified as R50, R51 and R53; the administrative difficulties imposed on the competent authorities and industry by setting very low qualifying quantities, and consideration of the comparative risk posed to mankind and the environment by other generic classifications of substances defined in Annex 1 part 2.

## 3. HAZARDS TO THE AQUATIC ENVIRONMENT FROM THE ACCIDENTAL RELEASES OF DANGEROUS SUBSTANCES

The damage to the aquatic environment following an accidental spill of dangerous substances is determined by a number of parameters. In broad terms, these refer to the intrinsic properties of the substance itself (aquatic toxicity, persistence, bio-accumulation, solubility in water, etc.), the fate of the substance in the aquatic environment (evaporation, sedimentation, dilution, chemical reactions, degradation, etc.), the physical conditions of the aquatic environment (flow rate, dimensions, physicochemical properties of the water, prior pollution, etc.), and the population and sensitivity of the aquatic habitats.

Especially concerning their properties related to environmental effects, the substances are classified according to well-defined criteria as described in the 18th ATP of Directive 67/548/EEC[2].

### 3.1. Classification of substances on the basis of environmental effects

In the context of the Directive 67/548/EEC the substances are classified according to their degradability, acute toxicity to the aquatic environment, and bio-accumulation. In particular:

Three risk phrases are applied to characterise the substance's *acute toxicity*:

R50: Very toxic to aquatic organisms

| | | |
|---|---|---|
| Criterion for R50: | 96 hr $LC_{50}$ (for fish) | $\leq$ 1 mg/l |
| or | 48 hr $EC_{50}$ (for *Daphnia*) | $\leq$ 1 mg/l |
| or | 72 hr $IC_{50}$ (for algae) | $\leq$ 1 mg/l |

R51: Toxic to aquatic organisms

| | | |
|---|---|---|
| Criterion for R51: | 96 hr $LC_{50}$ (for fish): | 1 mg/l < $LC_{50}$ $\leq$ 10 mg/l |
| or | 48 hr $EC_{50}$ (for *Daphnia*): | 1 mg/l < $EC_{50}$ $\leq$ 10 mg/l |
| or | 72 hr $IC_{50}$ (for algae): | 1 mg/l < $IC_{50}$ $\leq$ 10 mg/l |

R52: Harmful to aquatic organisms

| | | |
|---|---|---|
| Criterion for R52: | 96 hr $LC_{50}$ (for fish): | 10 mg/l < $LC_{50}$ $\leq$ 100 mg/l |
| or | 48 hr $EC_{50}$ (for *Daphnia*): | 10 mg/l < $EC_{50}$ $\leq$ 100 mg/l |
| or | 72 hr $IC_{50}$ (for algae): | 10 mg/l < $IC_{50}$ $\leq$ 100 mg/l |

Concerning the substance's *persistence*, the following risk phrase is used:

R53: May cause long-term adverse effects in the aquatic environment

Criterion for R53: The substance is not readily degradable
or the log Pow (log octanol/water partition coefficient) $\geq 3.0$
(unless the experimentally determined bio-concentration factor BCF $\leq 100$)

Substances characterised by the following combinations of risk phrases that have been classified as dangerous for the environment by the Directive 67/548/EEC are:

R50, R50/53 and R51/53 which are all classified as "Dangerous to the Environment", labelled with a hazard symbol "N", and given an indication of danger as "Dangerous to the Environment", and

R52/53 which is classified as "Dangerous to the Environment", is not labelled, and is not given an indication of danger.

As a consequence, the substances characterised by risk phrases R50, R50/53 and R51/53 are considered in Annex I, Part 2 of the Seveso II Directive as dangerous for the environment.

It has to be noted and **underlined** that the criteria for evaluation of substances for environmental effects became available only recently (1993) and that this evaluation is a 'dynamic' process. Therefore, not all the substances have been evaluated and as the evaluation progresses, it is likely that more substances be classified as dangerous for the environment.

## 3.2. Critical release quantities for defining severe environmental damage

An interesting question was raised in the group as to whether it is possible to determine the minimum quantity of the dangerous substance which – when released – can cause severe environmental damage. Obviously the question is ill-defined and one needs to make some assumptions in order to address it. Firstly, a "typical" river or lake has to be considered, then comes a comprehensive definition of "severe environmental damage". Analysts addressing this question (see for example [3,4] ) considered a severe accident as a spill in a river which after dilution in the water has still at a distance of 10 km downstream from the source a concentration equal to the $LC_{50}$ value for fish or $EC_{50}$ value for algae. It was assumed that the substance was soluble in water, without evaporation or sedimentation. A simple Gaussian equation was adopted to model the dispersion of the pollutant in the river.

The results presented in that study show for example that 2.4 kg of Phorate released in that "typical" river were enough to pollute it (by the $LC_{50}$ concentration) at a distance of 10 km downstream. The equivalent quantity for Hydrogen Cyanide was 216 kg, whereas it was evident that for most substances *very small quantities released in the aquatic environment can cause severe damage*. Other analysts using more sophisticated models arrived at similar conclusions.

# 4. PAST ACCIDENTS INVOLVING SUBSTANCES DANGEROUS FOR THE ENVIRONMENT

## 4.1. Introduction – Purpose

A number of accidents like the one at the Sandoz warehouse in Basel, Switzerland (1986), (see below), dramatically demonstrated that major accidents in industrial facilities have the potential, not only to cause severe effects to human health and property, but have also significant effects on the environment. These accidents increased the authorities' concern and public awareness on the subject and triggered an amendment to the Seveso Directive (Directive 88/610/EEC of 24 November 1988, amending Directive 82/501/EEC). Moreover, in the Seveso II Directive, protection of the environment became – together with protection of human safety and health – the main aim of the Directive, and substances classified as dangerous to the aquatic environment came under the scope of the Directive.

In this context, the selection, study and analysis of past accidents with consequences to the environment is a source of valuable information and can provide us with significant lessons to be learned. For that purpose, a number of accidents with consequences to the (aquatic) environment have been collected from various sources and analysed. The databases consulted include the Major Accident Reporting System (MARS)[5], the International Rhine Committee (IRC)[6], the ENVironmental Incident DAta Service (ENVIDAS)[7], the ARIA-BARPI[8] database, various reports [9,10] and the open literature.

It has to be underlined that the purpose of past accident analysis described herein is only to draw conclusions and learn lessons on the type and quantities of substances involved, the routes of exposure, and the extent of consequences. It is outside the scope of this analysis to provide an exhaustive list of accidents, or to provide long and detailed descriptions; this information can be found in the literature. In this report therefore only a limited number of accidents, considered as 'typical', have been selected and are summarised in Appendix I. In the following section 3.2, a few of them, viewed as "typical example accidents", are described in more detail.

According to the Seveso II Directive, a major accident is defined (Art. 3) as "a major emission, fire, or explosion resulting from uncontrolled developments in the course of the operation of any establishment covered by this Directive, *and leading to serious danger to human health and/or the environment*, immediate or delayed, inside or outside the establishment, and involving one or more dangerous substances". Moreover, Annex VI of the Directive defines in detail the criteria for notifying an accident to the Commission as provided in Art. 15. As far as *damage to the environment* is concerned, the criteria in Annex VI foresee:

**3. Immediate damage to the environment**

— *permanent or long-term damage to terrestrial habitats:*
  — 0,5 ha or more of a habitat of environmental or conservation importance protected by legislation,
  — 10 or more hectares of more widespread habitat, including agricultural land,

— *significant or long-term damage to freshwater and marine habitats(*)*
  — 10 km or more of river or canal,
  — 1 ha or more of a lake or pond,
  — 2 ha or more of delta,
  — 2 ha or more of a coastline or open sea,

— *significant damage to an aquifer or underground water(*)*
— 1 ha or more.

Of course, an accident should be reported if the quantity of the dangerous substance involved is more than 5% of the qualifying quantity for application of Art. 9 (laid down in column 3 of Annex I), or if it results in injury of persons, damage to property, or cross-border damage, in addition to any effects on the environment. For the purposes of the analysis provided herein, the above definition was generally used, with a view however not to exclude accidents from which important conclusions could be drawn.

## 4.2. Examples of past accidents and lessons learned from their analysis

In order to enhance the readability of the report, only a few "typical accidents" are reported in this section, from which significant lessons can be learned and conclusions can be drawn. In general, the conclusions are supported from additional past accident histories, which are described in Appendix I.

***Typical Accident 1: Fire-fighting water contaminated with pesticides – Sandoz***

*Date / Place*: November 1, 1986 – Schweizerhalle (Basel), Switzerland

*Substance(s) involved*: Fire-fighting water contaminated by a variety of pesticides. Mainly organophosphorus insecticides (dichlorvos, disulfoton, parathion, etc.), mercury-based pesticides, zinc-based pesticides, and other pesticides (e.g. endosulfan, DNOC). Most of them are N; R50/53 substances.

*Quantities released / Quantities stored or transported*: The quantities of substances released and stored are given in Table 1. The total amount of pesticides stored was 680 tonnes, out of which about 6-22 tonnes are estimated[11] to have been discharged into the river (about 1-3% of the inventory). Other sources[12] estimate the quantity of pesticides discharged in the Rhine at 5-8 tonnes.

*Description*: Fire-fighting water used to extinguish a fire in an agrochemical warehouse discharged into the Rhine. This caused extensive pollution of the river due to pesticides and insecticides, including mercury-based and zinc-based pesticides. Levels of mercury in the Dutch section of the river were reported to be 3 times the normal limits. 50,000 $m^3$ of soil around the site was contaminated mainly with mercury and needed to be treated. Contamination of shallows prevented cattle from being watered. Waterworks had to close in both Germany and the Netherlands due to pollution and emergency supplies were used. Loss of fishing, tourism and marine industry on the French side. Vacuum pumps were used to remove mercury from the river bed. Site cleanup was completed 3 months later and at a cost of 10 million Swiss francs.

*Consequences*: Massive elimination of life in the Rhine. Benthic organisms and eels were completely eradicated 400 km down-stream. The three main fish species affected by the accident were trout, grayling, and eels. Half a million eels (ca. 200 tonnes) were killed, and the eel population was affected for years up to 650 km downstream. All grayling and trout over a 150 km stretch from the spill source died, and these species were affected up to 450 km downstream. Macro-invertebrates were also eradicated near the source and their population was affected for long distances from the source. Large number of birds and insects were also killed by the pollution. The severe impact of the spill may have been due to the synergistic effects of the pesticides, with the additional factor of the existing chronic pollution of the Rhine. After one year, and after extensive cleanup and restocking operations (the river was regularly restocked with eels and other fish species) most of the fish species and benthic organisms had recovered.

Lessons learned: The following conclusions and lessons can be drawn from the accident:

a. *Type of substances*. The substances involved in one of the most widely known environmental disasters were *pesticides* and *insecticides*. The classification of most of them with regard to their environmental effects are R50 and R50/53. Substances from this category were also involved in most of the accidents reported in Table A.1 in Appendix 1).

b. *Synergistic effects*. The fact that many contaminants simultaneously acted on the ecosystem, and the possible synergistic effects in addition to the increased level of chronic pollution of the river, is considered as one of the reasons of the far reaching consequences of the accident.

c. *Type of establishment*. The establishment was an agrochemical warehouse in which only storage of chemicals (pesticides, herbicides, insecticides) took place. Similar establishments (agricultural depots) were involved in accidents 2, 21, 23 (see the relevant Table in Appendix 1).

d. *Route of contamination*. Discharge of fire-fighting water into the river. This seems to be a very common route of contamination of the aquatic environment (see also accidents 10, 22 and 23 in Appendix 1). Usually severe damage to the ecosystem are caused by fires at chemical warehouses. This is due both to the large volumes of fire-fighting water entering the aquatic systems and the complex mixture of fire-fighting foams, pesticides, formulating products, and pyrolysis products that result from a fire. This route of contamination has to be taken into consideration in the design phase of the fire-fighting system and the sewage system of an establishment. It should also be taken into account in emergency planning and response.

e. *Extent of consequences*. The consequences were devastating and extended over the whole aquatic ecosystem: Eradication of life in the first 150 km, extinction of certain species (eels) up to 400 km, damage to their population up to 650 km, large numbers of birds, invertebrates and insects killed were the direct consequences. Other consequences, like interruption of the use of drinking water, waterworks, and fishing and tourism losses, have also to be considered, as well as the cleanup costs.

f. *Ecological consequences in relation to the quantities released*. From an analysis of the accident one can conclude that extremely small quantities – much lower than the quantities under discussion in TWG 7 – can cause severe environmental effects.

g. *Released quantities in relation to the quantities present in the establishment*. The amount released can represent only a small percentage of the inventory (in this case only 1-3%). It is worth noting that in terms of the quantities present in the establishment, the R50/53 substances sum up to 400 tonnes and – according to the existing version of Annex I, Part 2 of the Seveso II Directive for substances dangerous for the environment – this particular establishment would only fall under the requirements of Art.6/7 and not of Art.9. With the proposed thresholds, the establishment would fall under Art.9 on environmental grounds.

**Table 1. Pesticides released into the Rhine following the Sandoz fire**[11]

| *Compound* | *Classification* | *Quantity stored (tonne)* | *Estimated discharge (kg)* |
|---|---|---|---|
| Dichlorvos | T | 0.10 | 1-3 |
| Disulfoton | T+; N;R50/53 | 298.00 | 3000-8900 |
| Etrimfos | $X_n$ | 59.60 | 290-1800 |
| Fenitrothion | N;R50/53 | 9.90 | 2.5-300 |
| Formothion | $X_n$ | 0.30 | 3-6 |
| Parathion | T+; N;R50/53 | 9.70 | 50-290 |
| Propetamphos | T | 63.50 | 160-1900 |
| Quinalphos | T | 0.60 | 6-20 |
| Thiometon | T | 130.00 | 1200-3900 |
| Mercury pesticides | T;C;N;R50/53 | 2.90 | 18-200 |
| Zinc pesticides | $X_i$ | 1.15 | 5-15 |
| Captafol | N;R50/53 | 0.16 | 2-5 |
| DNOC | T+; N;R50/53 | 65.90 | 660-2000 |
| Endosulfan | N;R50/53 | 2.00 | 20-60 |
| Metoxuron | N;R50/53 | 11.50 | 100-350 |
| Oxadixyl | | 25.20 | 250-1900 |
| Scillirosid | T+ | 0.030 | 0.3-0.9 |
| Tetradifon | | 2.30 | 20-70 |

***Typical Accident 2: Discharge of Very Toxic for the environment substance***

*Date / Place*: December 15, 1974 – Hattiesburg, Mississippi, U.S.A.

*Substance(s) involved*: Pentachlorophenol (PCP). This substance is classified as very toxic for the aquatic environment and persistent, i.e. N; R50/53.

*Quantities released / Quantities stored or transported*: Not specified.

*Description*: Discharge of pentachlorophenol into a lake and a river, due to the unexpected overflow of a wastewater pond[13].

*Consequences*: Large numbers of fish killed and many fish species were affected. It was noted that fish remained contaminated for at least 6 months. PCP was found in the sediment and leaf litter 18 months after the incident.

*Lessons learned*: The following lessons can be learned from the accident:

a. *Type of substance*. The substance involved in the accident was *pentachlorophenol*, an R50/53 substance. PCP has been involved in some accidents with very severe consequences for the aquatic environment. The lethal concentration of PCP for various species is very low (e.g. $LC_{50}$ for rainbow trout is 0.093 mg/l for 48 hr), which means that even small quantities discharged in the aquatic environment can have significant effects on the aquatic habitats. Substances from the same category have been involved in many environmental accidents.

b. *Route of contamination*. Discharge from a wastewater pond or system is another important route of contamination (see also accidents 1, 4, 5 and 26 in Appendix 1). This has to be taken into consideration in the design of the sewage and wastewater system of the establishment.

c. *Extent of consequences*. Not only the consequences of the accident were devastating, but the recovery period was rather long (due to the persistence of the toxicity of the substance).

***Typical Accident 3: Discharge of Very Toxic for the environment substance***

*Date / Place*: October 10, 1988 – Dampniat, France.

*Substance(s) involved*: Lindane and sodium pentachlorophenate. Lindane is classified as very toxic for the aquatic environment and persistent, i.e. N; R50/53.

*Quantities released / Quantities stored or transported*: The quantity released was 40 kg.

*Description*: Due to a human or technical failure, 40 kg of Lindane and sodium pentachlorophenate solution were released into La Correze river[14].

*Consequences*: The ecosystem up to 14 km from the point of discharge to La Correze river was affected. 15 tonnes of fish died.

*Lessons learned*: The following lessons can be learned from the accident:

a. *Type of substance*. The main ecotoxic substance involved in the accident was *Lindane*, an R50/53 substance.

b. *Ecological consequences in relation to the quantities released*. It is worth noting that only 40 kg of the substance caused the death of 15 tonnes of fish. Once again it appears that extremely small quantities – much lower than the quantities under discussion in TWG 7 – can cause severe environmental effects.

***Typical Accident 4: Discharge of Very Toxic for the environment substance***

*Date / Place*: September 15, 1983 – Drogobych, Ukraine.

*Substance(s) involved*: Potassium salts, mainly sulphates and sulphides. Potassium sulphides are classified as very toxic for the aquatic environment, i.e. N; R50, while other salts are also persistent, i.e. N; R50/53.

*Quantities released / Quantities stored or transported*: Vast amounts of potasssium salts solution were released (according to some sources[7] approximately 4.5 million cubic meters).

*Description*: Ukraine suffered severe environmental damage when the waste retaining wall at a fertiliser plant collapsed, releasing vast amounts of concentrated potassium salts (mainly sulphates) into the Dniester river. The salt solution sank to the bottom of the river and then moved slowly down the river accumulating at the base of a dam. This dam, where the salt had collected, prevented the pollution from reaching other towns downstream. Brine was pumped from the bottom of the dam and diluted in upper layers of water and then was pumped to the Black Sea.

*Consequences*: Wildlife and cattle that drank water from the river died. Over 2000 tonnes of fish were killed and 360 miles of the river Dniester were polluted. All water plants, algae and most of the biological systems in the river were destroyed. 500 acres of farmland were flooded and contaminated by the waste salt solution. Due to the severe damage to the ecology of the river, recovery was expected to take many years.

*Lessons learned*: The following lessons can be learned from the accident:

a. *Type of substance*. Even if most of the substances involved in the accident were classified as *R50* (i.e. very toxic, but not persistent), the effects were devastating. Without doubt, if the acute effects are extremely severe, the damage to the ecosystem is high and the recovery long, even if the substance is not persistent. Other accidents involving R50 substances are 17 and 22 in Appendix 1.

b. *Route of contamination*. The cause of the accident was the collapse of the waste retaining wall in the fertiliser plant. Although different from the causes of other accidents involving discharge of waste into the aquatic environment, bad design of the system and reduced defence against overfilling were the underling causes.

c. *Extent of consequences*. The accident was indeed an ecological disaster: 2000 tonnes of dead fish and there was a complete eradication of the ecosystem. Without doubt, the size of the damage was due to the vast amounts of potassium salts solution released in the river.

### ***Typical Accident 5: Release of a Toxic for the environment substance***

*Date / Place*: September 2, 1997 – Meurthe, France.

*Substance(s) involved*: Nonylphenol Ethoxylate. The substance, when in contact with water and under certain conditions, produces Nonylphenol, which is a substance toxic for the aquatic environment and persistent, i.e. N; R51/53.

*Quantities released / Quantities stored or transported*: 21 tonnes released.

*Description*: In a paper manufacturing plant, a tank for washing water was erroneously filled with nonylphenol ethoxylate. The accident was a result of a mistake of the tanker driver who took the wrong trailer (human error). The sub-contractor firm, called to take away the substance, which had been wrongly supplied, poured the washing water into the rain drain[5].

*Consequences*: The river Meurthe was polluted for 15 km from the point of discharge. 1 tonne of fish were killed.

*Lessons learned*: The following lessons can be learned from the accident:

a. *Type of substance*. The substances involved in the accident are classified as R51/53.

b. *Route of contamination*. The substance was discharged in the river through the rain drainage system after a series of human errors. Attention in the design and construction of the draining system, as well as in the design and management of operations, should be taken into account, in order to avoid such accidents.

c. *Extent of consequences*. The gravity of the accident was characterised as 4 in the gravity scale. The relatively small consequences – in relation to some other accidents involving R50 and R50/53 substances – is thought to be due to the moderate toxicity of the substance (R51/53), or to the small quantity released.

***Typical Accident 6: Release of Pesticides – Agriculture***

*Date / Place*: May 4, 1995 – Erre, France.

*Substance(s) involved*: Pesticides. Most of them are classified as R50 or R50/53.

*Quantities released / Quantities stored or transported*: Not specified.

*Description*: In an agricultural warehouse, due to human error in handling of the materials, pesticides were released into the river Erre[5].

*Consequences*: The river Erre was polluted for 12 km from the point of discharge. There were significant numbers of fish killed in the river, as well as in a nearby fish-farm.

*Lessons learned*: The following lessons can be learned from the accident:

a. *Type of substance*. Pesticides were involved in the accident.

b. *Type of establishment*. It is worth noting that the establishment was actually an agricultural warehouse, where pesticides had been stored. The processes were simple physical processes, such as mixing, melting, diluting, etc. It appears that even such a simple establishment has the potential to cause a major accident with regard to the environmental effects. Moreover, the presence of a fish-farm in the vicinity of the source of pollution illustrates a different dimension to the land-use planning issue.

***Typical Accident 7: Release of Petroleum Substances***

*Date / Place*: January 2, 1988 – Floreffe, Pennsylvania, U.S.A.

*Substance(s) involved*: No. 2 Diesel fuel. This substance is proposed to be classified as R51/53 (see Section 4). Specific gravity 0.85.

*Quantities released / Quantities stored or transported*: 3.8 million gallons of diesel fuel were released (approx. 12,500 tonnes). The same amount that was stored. However, only 750,000 gallons (approx. 2,400 tonnes) were discharged into the Monongahela river and carried further to the Ohio river.

*Description*: The accident was caused by the collapse of an oil storage tank due to a failure of a ground level plate in the tank. The collapse of the storage tank containing 3 million gallons of diesel and draining of a gasoline tank next to it led to the release of 3.8 million gallons of diesel and gasoline. From the released amount, a wave-like surge of oil was created that passed over the banks of the facility's containment booms and into a nearby storm drain. 750,000 gallons (approx. 2,400 tonnes) were discharged into the Monongahela river [15].

An oil slick spread 100 miles downstream of release site. Up to 80 communities lost their water supply (up to 1 million residents) and numerous businesses were forced to close temporarily as water intakes were closed. National guard members assisted with the cleanup operation which lasted more than 4 months and cost up to $11.4 million.

*Consequences*: The river Monongahela was polluted up to 100 miles from the point of discharge. About 2,000-4,000 birds died, including ducks, looms, cormorants, Canada geese. Wildlife officials were reportedly trying to clean oil from birds contaminated by the oil and indeed many birds were cleaned and saved. Fish were killed, too. Impact on the population of an endangered species of mussel (pink mucket) was monitored.

_Lessons learned_: The following conclusions can be drawn from the accident:

a. *Type of substances*. The substances involved in the accident were petroleum distillates, mainly No. 2 diesel fuel and smaller amount of gasoline. The substances have been proposed by CONCAWE to be classified as R51/53 (discussions for the classification of petroleum distillates in the EC Working Group in the context of the Classification, Packaging and Labelling Directive are still under way). Medium and heavy petroleum distillates (mineral oils) have been involved in many accidents (see the relevant Table in Appendix 1).

b. *Route of contamination*. The cause of the accident was the collapse (structural failure and overfilling) of the oil tank. The large contamination of the river was due to the fact that oil passed over the facility's containment booms and discharged into a nearby storm drain. Although it is not easy to foresee a defence barrier for that particular case, drainage is involved in many accidents and for that reason this route has to be taken into consideration in the design of the plant and for emergency response.

c. *Extent of consequences*. The consequences are typical of this category of accidents, resulting in large numbers of oiled and dead birds, long slicks, interruption of public water supply, and intoxication of certain aquatic organisms. Concerning especially the toxic effects to aquatic organisms, it has to be acknowledged that these effects are not as severe as the effects caused by other R50/53 or R51/53 substances. The cleanup cost is also an important parameter.

d. *Ecological consequences in relation to the quantities released*. From an analysis of the accident one can conclude that relatively small quantities can still cause severe environmental damage. The quantity of diesel discharged in the river was approximately 2,400 tonnes, which is slightly higher than the proposed threshold for application of Art.6/7 for petroleum distillates.

### _**Typical Accident 8: Release of Kerosene – Airport**_

_Date / Place_: February 22, 1991 – Stansted airport, UK.

_Substance(s) involved_: Aviation fuel (kerosene). This substance is proposed to be classified as R51/53 (see Section 4).

_Quantities released / Quantities stored or transported_: Not specified.

_Description_: Aviation fuel leaked from a pipeline at Stansted airport. The oil seeped into the ground and entered a tributary of the river Stort[7].

_Consequences_: A 6 mile stretch of river Stort was contaminated by the oil. More than 100 birds including kingfishers, swans, ducks, grebes and moorhens died as a result of the contamination and a search for more oiled birds followed. Skimmers were used to draw off the oil from the water.

_Lessons learned_: The following conclusions can be drawn from the accident:

a. *Type of substances*. Kerosene was involved in the accident and CONCAWE has also been proposed that it be classified as R51/53.

b. *Type of establishment*. The establishment in this case was an airport. One can therefore conclude that airports can also be a potential source of environmental accidents, given that storage of certain substances takes place there.

c. *Route of contamination*. The route of contamination was through the ground: The oil seeped into the ground and entered a tributary of the river. This underlines how difficult a task it is to predict the behaviour of certain substances and how much attention is required in the design of a plant. It also highlights the hazard of contamination of another component of the environment, namely the *groundwater*.

d. *Extent of consequences*. A 6 mile stretch of the river was contaminated, while more than 100 birds died as a result of the contamination. Without doubt the consequences of the accident were high, however, according to the criteria for notification of accidents to the Commission, as described in Annex VI of the Seveso II Directive, this accident would not be notified to the Commission for its environmental consequences, since the stretch of the river polluted was below the 10 km limit. Indeed, the criteria for notification of environmental accidents are not directly related to the damage to aquatic habitats, but rather to the size of the affected area of the environment. In this perspective, it might be appropriate to re-examine the notification criteria, supplementing them with criteria directly related to the extent of damage to the aquatic habitats (such as for atmospheric releases where it is the number of fatalities and injuries that counts and not the area covered by the toxic cloud).

### ***Typical Accident 9: Release of a "Non-Toxic for the Environment" substance***

Date / Place: January 21, 1995 – Quebec, Canada.

Substance(s) involved: Sulphuric acid (concentrated). This substance is classified as corrosive (C; R35), but no indication of toxicity to the aquatic environment is given.

Quantities released / Quantities stored or transported: 234 $m^3$ released.

Description: Following a train derailment, concentrated sulphuric acid was released, polluting the nearby river and lake[16].

Consequences: The aquatic life in the lake was killed. Spawning of indigenous species may be affected on the long term. The lake was closed for recreational purposes for 8 years, whereas the river was closed for 5 years.

Lessons learned: The following lessons can be learned from the accident:

a. *Type of substance*. The substance involved in the accident was *sulphuric acid*, classified as corrosive but not classified as dangerous for the aquatic environment substance. Similarly, other accidents have been collected involving substances which are not – at present – classified as environmentally dangerous (see for example accidents 7, 11, 24, 27 of Appendix 1).

b. *Type of activity*. The accident occurred during *transportation* of the substance. Indeed transportation is one of the activities in which contamination accidents occur, perhaps even more frequently than accidents in fixed installations. The particular characteristics of transportation make the proper design and availability of adequate emergency response measures and procedures rather difficult.

c. *Extent of consequences*. The damage to the ecosystem and the long recovery period make the accident severe, even if the substance involved is not classified as dangerous for the environment. Moreover, a somewhat trivial conclusion is that the lake's environment is more susceptible than the river's because of it being a closed system.

### *Typical Accident 10: Release of waste from a mine – Doñana*

Date / Place: April 25, 1998 – Aznalcóllar, Spain.

Substance(s) involved: Waste from a zinc mine containing acid water and metal-rich sludge (Zn, Cd, Pb, As).

Quantities released / Quantities stored or transported: About 5 million $m^3$ of waste released.

Description: After the partial collapse of the tailings pond dike of the Aznalcóllar Zn mine north of the Guadalquivir marshes (Doñana) in Southern Spain, an estimated 5 million $m^3$ of acidic metal-rich waste were released into the Guadiamar river [17, 18]. This material contaminated farmland and wetland up to 40 km downstream, including the 900-ha 'Entremuros', an important area for birds within the Doñana world heritage site.

Consequences: The pH in the Entremuros dropped from 8.4 to 4, and Zn levels of up to 270,000 μg/l, Cd levels of up to 900 μg/l, and Pb levels of up to 2500 μg/l were recorded. These concentrations are toxic to a wide range of marine, estuarine and freshwater organisms, and indeed considerable fish and invertebrate died as a result. Moreover, metals released in the accident are moving into several bird species' food-chain and present a considerable risk to the species feeding on the flora of the area.

Lessons learned: The following lessons can be learned from the accident:

a. *Type of substance*. The substance involved in the accident was waste from a zinc mine, containing acid water and various metals (As, Pb, Zn, Cd).

b. *Type of establishment*. The accident occurred in a zinc *mine* and it should be noted that the *extracting industry* has been excluded from the requirements of the Seveso II Directive. However there are striking similarities with the recent (January 31, 2000) accident in Romania (see Appendix 1), which occurred at the Aurul gold smelter in Baia Mare. This accident resulted in the pollution with cyanide of the rivers Tisza and Danube and had devastating effects on the aquatic environment. It may be opportune to revisit the Directive and consider these types of accidents involving the tailing of mine works as being equivalent to those from storage of large volumes of toxic materials in fixed installations.

c. *Extent of consequences*. The damage to the ecosystem and the importance of the Doñana Natural Park make the accident severe. Indeed, the Doñana and Baia Mare accidents, together with the one of Sandoz and a couple of marine oil spills are characterised as the worst ecological disasters in Europe in the last 20 years. The importance of avoiding contaminants entering in the food-chain has also to be highlighted. Moreover, the ecological dimension of land-use planning should be acknowledged.

### 4.3. Discussion

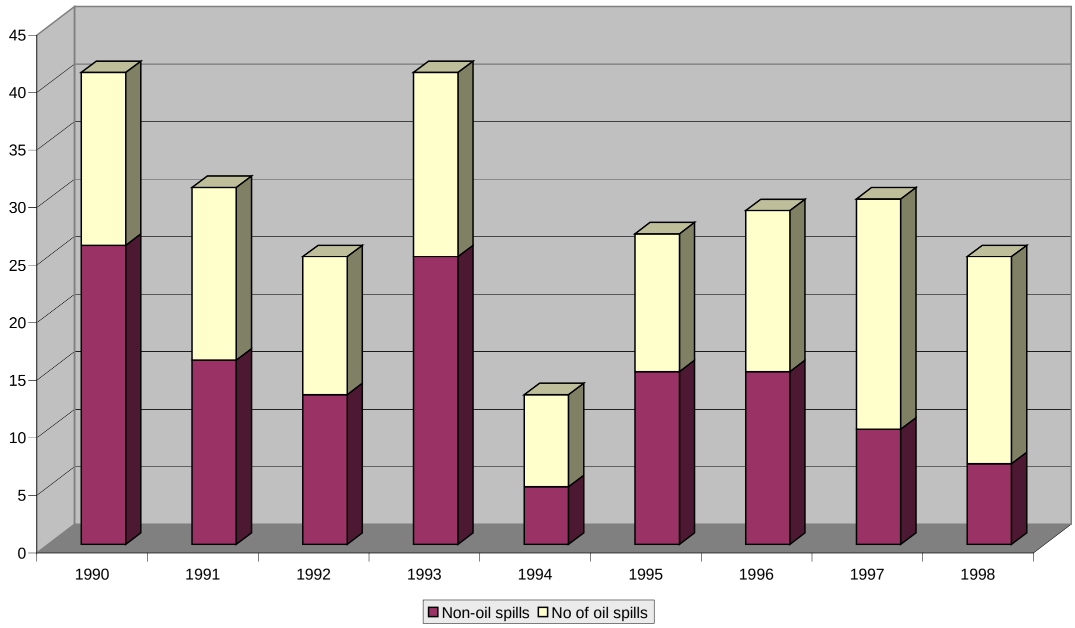
In the previous section an analysis was carried out of past accidents with environmental consequences, focusing on the lessons to be learned from these accidents. Only a limited number of accidents were analysed, considered as being typical. These accidents were selected not only because of the severity of their consequences, but also because one or more lessons can be learned from each of them. These lessons refer to the substances involved, to the type of establishment, the routes of contamination, the released quantities and the extent of the consequences. It should be noted that, although the following conclusions were drawn from the analysis of the ten accidents presented in the previous section, they are generally supported by many other accidents, either included in Appendix 1 or available in the open literature and the publicly available databases.

#### *4.3.1. Substances involved*

The following categories of substances were involved in the accidents examined:

- Substances very toxic to aquatic organisms, which are persistent to the aquatic environment (R50/53). Both inorganic (e.g. cyanides) and organic (e.g. pentachlorophenol) substances are included.
- Substances very toxic to aquatic organisms, which are not persistent to the aquatic environment (R50), e.g. potassium sulphide.
- Substances toxic to aquatic organisms, which are persistent to the aquatic environment (R51/53), e.g. cryolite, cumene.
- Pesticides, herbicides and insecticides (e.g. endosulfan, disulfoton, parathion, lindane). The classification of most of them with regard to their environmental effects is R50 and R50/53. They are referred to as a separate category due to their frequent involvement in accidents and the severity of effects (including any synergistic effects deriving from the release of more than one substances).
- Petroleum substances (e.g. gasoline, kerosene, diesel oil). It has been proposed that most of these substances be classified as R51/53. Again, they are mentioned separately due to the different physicochemical characteristics and behaviour regarding aquatic toxicity and environmental fate. Petroleum substances are very frequently involved in environmental accidents and spills. Figure 1 presents the number of oil spills and the total number of spills occurred in the Rhine during the last decade. The contribution of oil spills to the total number of spills ranges from 40% to 70% (though it has to be mentioned that many of these incidents occurred during transportation).
- Fire-fighting foams and pyrolysis products. These substances are associated with contamination of the aquatic environment with fire-fighting water, after large fires especially in chemical warehouses (including pesticides/fertilisers). The difficulties in predicting the formulation and pyrolysis products has to be underlined.

**Figure 1. Spills in the Rhine (Source: IRC)**




- Waste from mining activities and treatment plants. The substances present in waste-water consist another interesting category of contaminants, since, again, it is difficult to predict the exact composition of the waste. The recent accidents in Spain and Romania involving mining tailings emphasise the importance of this category.
- Substances not classified as dangerous for the environment. It is worth noting that substances presently not classified as dangerous for the environment are involved in accidents with environmental consequences. This is due to the fact that the classification of substances according to Directive 67/548/EEC is a 'dynamic' process, which progresses continuously. Some 400 substances, not classified for environmental effects up until the 23$^{rd}$ ATP, were evaluated in the 24$^{th}$ and 25$^{th}$ ATPs and classified as R50, R50/53 and R51/53. There are many more substances, which have not yet been evaluated for environmental effects and which – potentially – may be in the future classified as dangerous for the environment and characterised by one of the above risk phrases. In addition, other categories of substances, like corrosive (e.g. sulphuric acid or nitric acid), can be involved in accidents with severe environmental consequences.

### *4.3.2. Types of establishments*

The analysis of past accidents was focused on fixed installations, since this is the scope of the Seveso II Directive. However, accidents occurred during transportation of dangerous substances, or in establishments currently not covered by the Directive, have also been collected, since they can provide useful insights on the fate of the pollutants in the aquatic environment and the extent of their consequences. Therefore, the following establishments or activities were identified as potential locations of environmental accidents:

- Fixed installations

- Chemical and agrochemical warehouses
- Storage facilities of power plants
- Waste treatment plants
- Transportation activities (road, rail, marine and inland navigation). Especially for oil spills, transportation is a main source of accidental pollution, since petroleum substances are used as fuel for trucks, barges and open-sea vessels.
- Port areas and airports
- Pipelines
- Waste and tailings ponds from the extractive industries (mines, smelters, etc.).

### *4.3.3. Routes of contamination*

Investigation of the potential routes of contamination is very important, especially in the design phase of the various facilities and systems in the plant (fire-fighting system, sewage system, etc.) and for emergency preparedness and response. In the analysis of past accidents various routes of contamination were identified, more specifically:

- Discharge of fire-fighting water into the aquatic environment
- Discharge through the sewage system
- Discharge through the rain drainage system
- Discharge together with waste-water in waste treatment plants
- Direct release (e.g. from a ruptured pipeline, or a failed valve)
- Overfilling of a storage vessel
- Release during loading/unloading operations (e.g. from a ship or barge)
- Release from ship/barge
- Discharge through the cooling water system
- Release to the atmosphere and then contamination of the aquatic environment through deposition (particles or rain)
- Discharge through the ground (i.e. the dangerous substance seeps into the ground and enters the aquatic environment or the groundwater aquifer).

### *4.3.4. Consequences: Damage to the ecosystem*

One of the main parameters determining the consequences of accidents is the damage to the ecosystem. We have focused on the aquatic ecosystem (consisting of surface waters – rivers, lakes, estuaries – and marine waters) which includes not only aquatic habitats but also other species (e.g. insects, birds) which feed on these habitats. In more detail, the ecosystem under consideration includes:

- Benthic organisms
- Aquatic flora
- Daphnia / algae

- Fish (e.g. trouts, graylings, eels, salmons, marine fish)
- Invertebrates
- Insects
- Birds
- Coastal species
- Species fed by the affected habitats
- Terrestrial habitats watered from the contaminated river or lake
- Seasonal population of the aquatic environment affected (passage of birds or other animals during their immigration to different places)
- Fish-farms and aqua-culture populations

The effects of accidental spills to these species may be devastating. Various degrees of damage have been reported:

- complete eradication of the whole population of a species
- death of a significant proportion of the population, without however affecting its functioning as a community
- death of a significant proportion of the population, also affecting its functioning as a community
- population affected, but not killed (e.g. reduction of the reproduction)
- species contaminated but still alive (risk that the contaminant enters the food chain)
- simple pollution of a part of the river or the lake.

In terms of the *time horizon*, the effects can be short-term or long-term, and the recovery period short or long. The *population dynamics* are also very important: It is possible that a species is not very sensitive to a certain pollutant and it survives an accidental spill. If however, other species upon which it is fed do not survive, then its population will be affected too. *Synergistic effects* from the simultaneous action of many contaminants on the ecosystem can also increase the severity of the consequences. The *dispersal rate* for the waste is very important for the determination of the level of damage: Small lakes, as closed systems, are more susceptible than rivers, not only because the concentration of the pollutants and the duration of exposure is likely to be higher, but also because of the absence of unaffected habitats that will supply reinvading organisms.

Consequences other than ecological should also be underlined. These include interruption of the use of drinking water both to humans and animals, interruption of waterworks, and fishing and tourism losses. The cleanup cost for bringing the river or lake back to the conditions before the accident is usually very high. Another part of the environment that can be affected by accidental spills is the *groundwater*. Although the work of TWG 7 was oriented towards surface waters, the threat to groundwater aquifers should also – indirectly – be taken into consideration.

Last but not least, a different dimension of land-use planning appeared, related to the proximity or geographical closeness of potentially hazardous installations with aqua-culture activities (“population centres”) or with sites of particular ecological interest (see Art.12 of the Directive).

### *4.3.5. Extent of consequences in relation to the substances involved and to the quantities released.*

The extent of consequences is directly related to the substances involved and to the quantities released. The more toxic a substance is to the aquatic environment, the more severe the effects could be. In this context substances characterised with the risk phrase R50/53 are likely to cause more severe accidents than the R51/53 ones. The persistence of the substance is also an important parameter, the more persistent a substance is, the longer it takes for the ecosystem to recover. However, long recovery periods can result from accidents involving R50 substances (i.e. very toxic but not persistent), due to the extensive consequences and the fact that no unaffected habitats are present after the accident. From this point of view, R50 substances are correctly covered by the Directive.

*Pesticides* are often involved in particularly severe accidents, due to their toxicity for the aquatic environment and the fact that many substances are simultaneously discharged and then act on the ecosystem synergistically.

*Petroleum substances* have a particular behaviour as pollutants. On the one hand there is the devastating impact that oil spills have on birds and on coastal or riverbank environments. On the other hand, their toxicity to aquatic organisms is not so high (especially compared with R50 substances), and their solubility to water is relatively low. Oil slicks have the capability of covering large areas of the water surface, forming a thin film, which restricts the exchange of oxygen with the air. Many petroleum substances are not readily biodegradable, and for that reason they are characterised by risk phrase R53. Last, it has to be underlined that spills of refined products are significantly more damaging to the aquatic environment than those of crude oils (classified as R52/53)[19].

In this context and based on the accidents examined it can be argued that the consequences of petroleum substances are in general less severe than those of other substances dangerous for the aquatic environment. The emergency response is usually more well-defined and the emergency teams more prepared to deal with cases of oil spills than with spills of other substances.

Last but not least, a wide category of substances not yet classified as dangerous for the environment has been involved in accidents with severe environmental consequences.

In terms of quantities, an important conclusion derived from the accident analysis was that *extremely small quantities – much lower than the quantities under discussion in TWG 7 – can cause severe environmental damage*. The quantity of pesticides discharged in the Rhine at the Sandoz accident was less than 20 tonnes, while at another accident only 40 kg of the pesticide Lindane (R50/53) caused the death of 15 tonnes of fish. Also, it is important whether the substance is already diluted (for example, in fire-fighting water, or in waste-water) or not. Small releases not causing devastating effects should not be neglected: they still reduce the quality of the aquatic environment and affect the well-being of the ecosystem.

### *4.3.6. Released quantities in relation to the quantities present in the establishment*

The amount released in an accident can represent only a small percentage of the inventory (in the case of the Sandoz accident this was only 1-3%). In other accidents however the total inventory was released. In general, the percentage of the inventory discharged in the aquatic environment in the case of an accident depends very much on the accident scenario and the route of contamination. Leakages from pipelines, where an intervention is possible by closing a valve upstream of the release point, usually lead to discharge of a small percentage of the inventory, while releases after explosion or collapse of large tanks or dykes can include the complete inventory. This percentage depends also on the topography of the establishment: For example, if the inventory is divided in a number of vessels, it is highly unlikely that all vessels fail simultaneously and release the total amount into the river or lake.

An attempt to statistically define this percentage actually leads to the trivial conclusion that the released quantity can be either equal to the total inventory or to a small percentage of it, depending on the accident scenario. In order to further investigate this relation and define the most likely value of this percentage *for each route of contamination* we would need a significant sample for each route, which was not available. Indeed, this information is usually missing and the number of accidents for which both the released quantity and the quantity present in the establishment together with layout details of the establishment are known is rather limited.

## 4.4. Conclusions

The following concluding remarks can be made from the analysis of past accidents and other scientific considerations:

- The substances under consideration by the group, i.e. classified as R50, R50/53, and R51/53, have been involved in many accidents with severe environmental consequences.
- Relatively small quantities – much lower than the quantities under discussion – have often caused severe environmental damage.
- Agrochemical warehouses are often involved in environmental accidents and they represent a significant hazard for the aquatic environment.
- Petroleum substances, although more frequently involved in accidents with environmental consequences than other substances, cause less damage for the same quantities involved.

## 5. THE CLASSIFICATION OF PETROLEUM SUBSTANCES

Petroleum substances are complex mixtures consisting predominantly of hydrocarbons not very soluble in water. Since, after release to the aquatic environment, each component behaves slightly differently, the classification status of the whole mixture is not easily defined.

In order to be classified with regard to particular hazards, substances have to be reviewed by the Commission's Technical Working Group in the context of Directive 67/548/EEC. They then appear in Annex I of Directive 67/548/EEC, representing the mandatory classification of dangerous substances. Until now only few petroleum substances are included in Annex I, and for them only carcinogenic and/or aspiration hazards have been addressed.

For those substances which have not been reviewed by the Commission's Working Group, it is the supplier's obligation to "self-classify" them, according to criteria laid down in the $18^{th}$ and $22^{nd}$ ATPs of Directive 67/548/EEC. It is noteworthy that this "*self-classification*" is also valid for the purposes of the Seveso II Directive.

In order to provide guidance on the classification and labelling of petroleum substances, and to satisfy the requirements for "self-classification" CONCAWE issued in 1998 report no. 98/54[20]. In this report the petroleum substances are grouped according to their refinery processing history and their properties (mainly the boiling point range). Then, for each group the environmental and other criteria are reviewed and a classification for the group is proposed. In general, it is proposed that gasolines, kerosenes, diesel fuels, gasoils and heating oils be classified as R51/53, crude oil as R52/53, and certain heavy distillates (lubricants, solvents, paraffins, used oils, etc) be classified on a case-by-case basis. Table 2 gives an overview of the proposed classification for the main petroleum groups.

It should be noted that for the purposes of the Seveso II Directive, low boiling point naphthas are covered by the Annex I, Part 1 named substance "automotive petrol and other petroleum spirits", with qualifying quantities 5,000 and 50,000 tonnes for application of Article 6/7 and Article 9, respectively. Medium and heavy petroleum distillates (kerosenes, diesel, gasoils, etc), however, are not covered by that definition, and for them the thresholds for environmentally dangerous substances have to apply. If, therefore, CONCAWE's self-classification proposal is applied, we will have the abnormal situation of unequal treatment of establishments handling gasolines on one hand and kerosenes, gasoils, diesel and heating oil on the other: although the two groups have the same environmental classification and despite the much higher flammability hazard of gasoline, the medium and heavy oil distillates will have much lower qualifying quantities.

Concerning the status of CONCAWE's report, it must be underlined that there is an ongoing debate on the data used for the tests performed by CONCAWE. Many members suggest that different data be used, which would lead to classification of most of these substances as R52/53 rather than R51/53. In addition, the Commission's Technical Working Group in the context of Directive 67/548/EEC dealing with environmental effects has started discussing the issue and has scheduled to review the petroleum substances (with a view to include them in Annex I of Directive 67/548/EEC). However, until April 2000 no significant progress had been made (the latest meeting was held in February 2000 and the next one is scheduled for autumn 2000).

| Table 2. Proposed classification of petroleum substances by CONCAWE | | | |
|---|---|---|---|
| *Group* | *Environm.* | *Flammab.* | *Other* |
| Crude oil | R52/53 | Case-case | R45 |
| Petroleum gases, refinery gases | --- | R12 | R45 |
| Low boiling point naphthas (gasolines) | R51/53 | R12 | R38,R45,R65 |
| Kerosenes | R51/53 | R10 | R38, R65 |
| Diesel Fuel, Gas Oils, Heating Oils | R51/53 | --- | R65 |
| Heavy fuel oil | R52/53 | --- | R45 |
| Grease, bitumen, etc. | --- | | case-by-case |
| Other distillates (lubricants, solvents, used oil, paraffins, petroleum resins, etc.) | *Case-by-case* | | |

TWG 7 felt that, since there is uncertainty about the correct classification of petroleum products, an appropriate way to resolve the problem, leaving no doubt about the scope of the Seveso Directive to industry and the authorities would be to move them to Annex I Part 1 (named substances). This was included in the final proposal (see section 6).

The consequences of non-action were also examined. In that case there would be establishments using the CONCAWE's recommendations, applying low qualifying quantities for kerosene, gasoils, etc., and high values for gasolines, while other establishments in their own "self-classification" would classify medium and heavy oil distillates as R52/53, thus excluding them (or some of them) from the scope of the Directive. Apart from the chaotic situation for the authorities and industry, it is obvious that the level of control upon this important group of substances would not be adequate. For that reason the group strongly supported a consistent treatment of the petroleum substances as a whole.

## 6. INVESTIGATIONS ON ADMINISTRATIVE FEASIBILITY

As mentioned in the beginning of the report, an important task of the methodology applied by TWG 7 was the performance of a study in the Member States and industrial federations in order to estimate the number of establishments likely to be affected by various qualifying quantity levels. In this way it was possible to collect valuable information for taking pragmatic considerations into account and to balance the scientific considerations against administrative feasibility in the Member States.

Based on the results – both quantitative and qualitative – of the study, the group formed a proposal on the appropriate qualifying quantities, which was presented at the first meeting of the CCA established under Seveso II that was held in Munich in 1999 for consideration. Taking into account the comments from the CCA and some additional information from industry on establishments handling petroleum substances, the group revised its proposal with regard to petroleum substances and formed the (final) proposal presented herein.

### 6.1. Scope of Study

The substances of interest (R50, R50/53 and R51/53) frequently possess properties that would classify them also under different categories and risk phases such as "very toxic (to humans)", "toxic", "extremely flammable" etc which have lower threshold values than those for the substances "dangerous to the environment". It was important therefore to identify those substances that would qualify for inclusion under the Directive solely because of the risk they posed to the environment, and to then perform a sensitivity analysis on the number of establishments affected by different qualifying quantity values.

In more detail, the objectives of the study performed are:

(i) to gather sufficient information in order to estimate the number of establishments in the European Union likely to be affected by the qualifying quantity levels,

(ii) to investigate the effect of setting various qualifying quantity levels on the number of establishments (sensitivity analysis), and

(iii) to gather - if possible - qualitative information on the nature of the establishments likely to be affected (e.g. whether gas stations, hospitals, small labs etc. are included).

The study was based on a list of the toxic and very toxic to the environment substances (excluding petroleum products) provided by the European Chemicals Bureau (ECB) of the European Commission. For petroleum substances, CONCAWE provided the relevant list, based on their proposal for self-classification according to the requirements of Directive 67/548/EEC.

### 6.2. Results

Although the study was addressed to a wide audience covering the members of TWG 7, representatives from the Competent Authorities of all the Member States and industrial federations, the response was rather limited. Meaningful replies have been received by Austria, Finland, Italy, Norway, the Netherlands, the United Kingdom and the Basque country of Spain. Sweden gave the results of a preliminary study and a qualitative discussion on the issue. CEFIC, CONCAWE and FETSA (Federation of European Tank Storage Associations) also provided qualitative and quantitative information.

The amount of information provided by these countries was not uniform: The Netherlands and UK excluded from their study the petroleum products; Austria provided only qualitative information.

The main conclusions from the study can be summarised as follows:

- For the same qualifying quantity values, the number of establishments handling petroleum substances is very much higher than that of establishments handling other substances dangerous to the aquatic environment. This is particularly true for lower qualifying quantities (Art. 6/7).

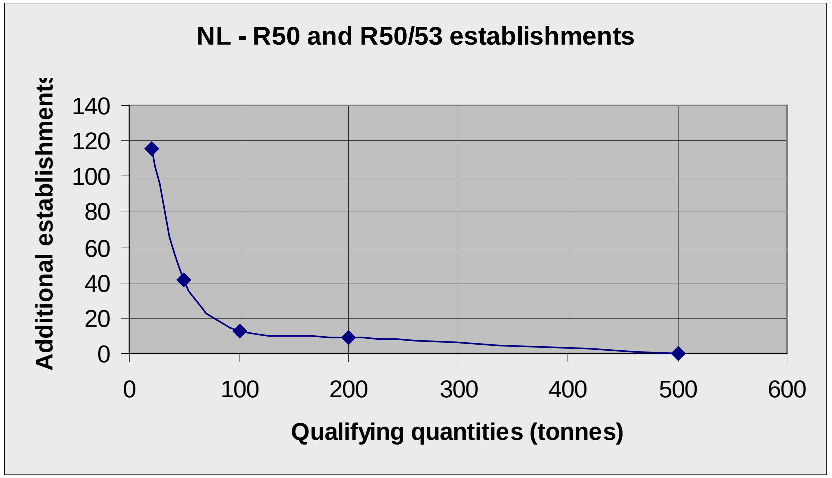
- When petroleum products are excluded, the number of establishments covered by the current qualifying quantities is very small (in some countries even 0). For lower qualifying quantities, the number of establishments increases steadily, this increase being very rapid (exponential) for very low qualifying quantities. Figure 2 presents a typical pattern of this relationship (for the Netherlands and the UK). For the very low qualifying quantities this increase in the number of establishments covered by the Directive can represent up to 50% of the **total** number of establishments currently covered by the Directive.

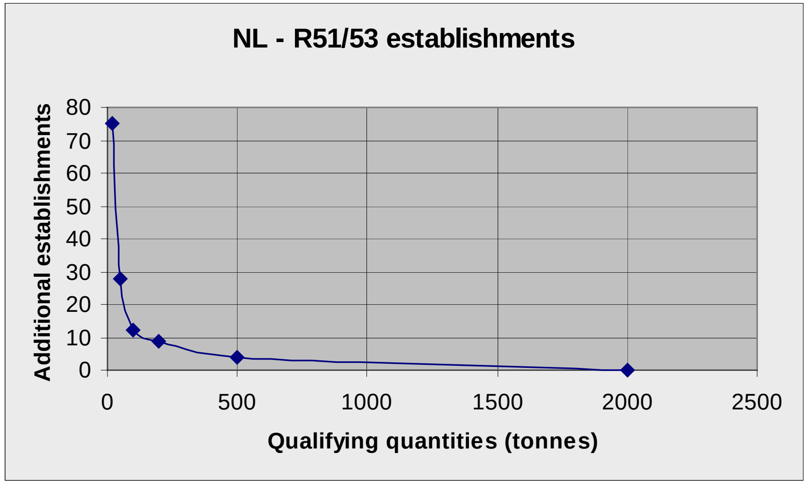
- When the qualifying quantities become too low – lower than the relevant qualifying quantities for other categories such as toxic, oxidising and highly flammables – a significant number of establishments not covered by the Directive under the present qualifying quantities now fall into the Directive due to environmental concern.

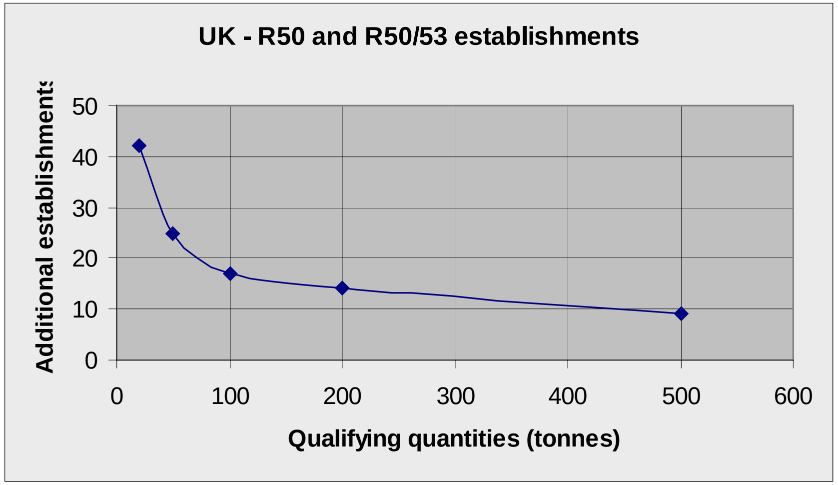
- Qualitative information indicates that storage quantities of light petroleum products in petrol stations and retail outlets are lower than 200 tonnes (typical values for petrol stations are 10-60 tonnes). Similarly, kerosene storage exceeds 500 tonnes only in large airports.

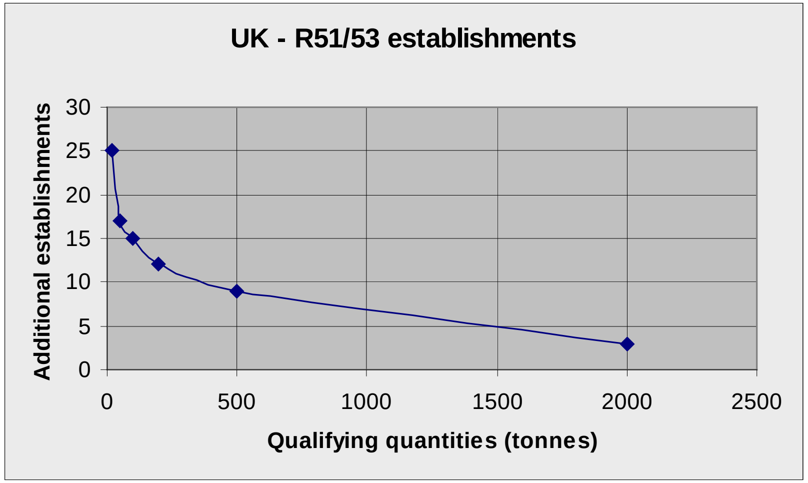
- Special focus was given to the potential effect of various qualifying quantities on Small and Medium Enterprises (SMEs). Based on the results from a limited survey carried out by CEFIC, and using the proposed qualifying quantities for non-petroleum substances as given in the interim report, a 30% increase in Art.6/7 establishments (mostly SMEs) was estimated for the whole of Europe, and a 10% increase in Art.9 establishments. Most of the affected SMEs would be in the distribution chain, in warehousing and in the agricultural chemicals business.

**Figure 2. Effect of various qualifying quantities in the number of establishments entering the scope of the Directive.**



### 6.3. Points of Concern or Discussion

The following points were identified as being of special concern and discussed extensively during the meetings of the group:

1. Concern regarding *petroleum substances*. Petroleum substances (excluding petrol and spirits) are being classified according to the self-classification scheme as toxic for the environment with long-term adverse effects (R51/53). As there is no intention to cover petrol stations, retail outlets, hospitals and small airports under the Directive this would lead to the adoption of higher qualifying quantity values. Based on indications provided by Austria and CONCAWE on the size of petrol stations, airports, hospitals, etc., it was agreed that only exceptionally large petrol stations would be covered by a 200 tonnes qualifying quantity and that airports would be covered with a qualifying quantity below 400 tonnes. However if the threshold levels for all R51/53 substances were set too high based on petroleum products considerations, pesticide storage and other activities would not be covered, as is the present situation. This led to the proposal to consider setting separate qualifying quantities for the petroleum products.
2. Concerning the establishment of *appropriate qualifying quantities* for environmentally dangerous substances *excluding petroleum substances*, a proposal was made to set the thresholds for R50 and R50/53 substances at 100 and 200 tonnes for Art.6/7 and Art.9, respectively, and the qualifying quantities for R51/53 substances at 200 and 500 tonnes for Art.6/7 and Art.9, respectively. These values permit a substantial control on the establishments handling substances dangerous for the environment, without increasing their number to unacceptable levels. In addition these thresholds are consistent with the UN/ECE Convention thresholds.
3. Concern was expressed over the *summation rule*, as the effect of this rule was not assessed in the study, but it is expected to be significant.
4. Concern was expressed over the fact that *more and more substances will be classified* as R50, R50/53 and R51/53, leading to an increase of the number of establishments covered.
5. In setting *appropriate qualifying quantities for petroleum substances*, similar considerations applied, with the difference that the qualifying quantities should be set at a level so as to avoid covering those establishments that the Directive was not intended to cover such as petrol stations, retail outlets etc.). The quantity of 5000 tonnes as an upper qualifying quantity would ensure that such establishments are not covered, whereas a 200 tonnes lower qualifying quantity would guarantee consistency between the R51/53 substances and the petroleum products.
6. In order *to implement this proposal*, it seemed as the most feasible and efficient solution to propose the modification of the named substance "automotive petrol and other petroleum spirits" to cover also kerosene, diesel oil and gasoil. In fact, petrol is likely to be also classified for its environmental hazard as R51/53 and it seems reasonable to be covered by the same thresholds as far as the environment is concerned.

The above proposal and outstanding points were presented to the first CCA meeting under the Seveso II Directive seeking its guidance.

### 6.4. Guidance from the CCA and revision of the proposal

In general, *consensus* had been achieved at the CCA concerning the overall strategy, the proposed qualifying quantities for non-petroleum substances and the proposal to include kerosene, diesel and heating oil in the named substance "automotive petrol and other petroleum spirits". *Concern* had been expressed about both lower and upper tier qualifying quantities for the Part 1 substance covering petroleum substances. In particular, the proposed lower tier qualifying quantity of 200 tonnes was considered as too low by many Authorities, while only Norway and to some extent Finland had expressed hesitation about the upper tier qualifying quantity of 5000 tonnes.

In the meantime *additional information* had become available to the group concerning the number of establishments handling petroleum substances. A CONCAWE survey on the number of sites storing petroleum distillates carried out among the National Oil Industry Associations described the overall situation in 11 of the 15 Member States (plus Norway) as follows:

- Qualifying quantities of 200 and 5000 tn: 6746 Art.6/7 sites (all additional);
  1223 Art.9 sites (at least 801 additional)
- Qualifying quantities of 500 and 2000 tn: 2010 Art.6/7 sites (all additional);
  2098 Art.9 sites (at least 1676 additional)
- Qualifying quantities of 5000 and 50000 tn: 801 Art.6/7 sites (unknown additional)
  1223 Art.9 sites (unknown additional).

Another survey carried out by FETSA on terminals for petroleum products, excluding refineries and pipeline terminals, pointed out that

- Lowering the thresholds to 2000 / 5000 tonnes would result in 200% / 600% increase of the sites affected (for Art.6/7 and Art.9 sites, respectively).
- Keeping the current thresholds of 5000 / 50000 tonnes (but including gasoils) would result in increase of the sites affected ranging from 25% to 270%.

Moreover, it was pointed out that establishments with less than 2000 tonnes of petroleum distillates are not oil companies but customers and distributors.

### 6.5. Proposal

The group, in view of the guidance provided by the CCA and the additional information on the number of petroleum sites, and taking into account the conclusions from the past accidents analysis and other scientific considerations, proposed that:

- Qualifying quantities for Annex I, Part 2, item 9(i) generic category (R50 and R50/53 substances) be 100 tonnes for Art.6/7 and 200 tonnes for Art.9;
- Qualifying quantities for Annex I, Part 2, item 9(ii) generic category R51/53 substances be 200 tonnes for Art.6/7 and 500 tonnes for Art.9;
- The named substance in Annex 1, Part 1 "automotive petrol and other petroleum spirits" be amended to include medium and heavy oil distillates (including kerosene and diesel fuel) with qualifying quantities of 2000 tonnes for Art.6/7 and 5000 tonnes for Art 9.

CONCAWE proposed the following name for the Annex I, Part 1 named substance: *"Gasolines, kerosenes, gasoils and petroleum products with similar boiling ranges"*.

[It should be noted that Finland and Norway supported a figure of 10000 tonnes as the Article 9 qualifying quantity for the new named substance "Gasolines, kerosenes, gasoils and petroleum products with similar boiling ranges"]

## 7. CONCLUSIONS

**The Group propose the following amendment to Directive 96/82/EC (Seveso II):**

- **Qualifying quantities for Annex I, Part 2, item 9(i) generic category (R50 and R50/53 substances) be 100 tonnes for Art.6/7 and 200 tonnes for Art.9;**
- **Qualifying quantities for Annex I, Part 2, item 9(ii) generic category R51/53 substances be 200 tonnes for Art.6/7 and 500 tonnes for Art.9;**
- **The named substance in Annex 1, Part 1 "automotive petrol and other petroleum spirits" be amended as "Gasolines, kerosenes, gasoils and petroleum products with similar boiling ranges" in order to include medium and heavy oil distillates (including kerosene and diesel fuel) with qualifying quantities of 2000 tonnes for Art.6/7 and 5000 tonnes for Art 9.**

Thus the table in Annex I, Part 2, item 9 should be modified to read:

PART 2

**Categories of substances and preparations not specifically named in Part 1**

| | Column 1<br>Categories of dangerous substances | Column 2 | Column 3 |
|---|---|---|---|
| | | Qualifying quantity (tonnes of dangerous substances as delivered in Article 3 (4), for the application of | |
| | | Articles 6 and 7 | Article 9 |
| ... | ... ... ... | ... | ... |
| 9. | DANGEROUS FOR THE ENVIRONMENT in combination with risk phrases: | | |
| | (i) R50: 'Very toxic to aquatic organisms' **(including R50/53)** | **100** | **200** |
| | (ii) R51:'Toxic to aquatic organisms'; and R53: 'May cause long term adverse effects in the aquatic environment' | **200** | **500** |
| ... | ... ... ... | ... | ... |

and the named substance in Annex 1, Part 1 "automotive petrol and other petroleum spirits" be amended as

> **"Gasolines, kerosenes, gasoils and petroleum products with similar boiling ranges"**

with qualifying quantities in Column 2 and Column 3 of **2000** tonnes and **5000** tonnes, respectively.

# APPENDIX 1

## TABLE A.1. SELECTED ACCIDENTS WITH SEVERE CONSEQUENCES TO THE ENVIRONMENT

| No | Year, Place | Accident cause | Substance involved | Amount released | Amount stored/ transp | Eco-system affected | Short term effects | Long term effects | Time of recovery | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 15/12/74 Hattiesburg, Mississippi, USA | Overflow of waste-water pond | Pentachlorophenol | Unknown | Unknown | Lake and river | Intensive fish kills | Fish contaminated for at least 6 months | PCP found 18 months after contamination | Waste. PCP |
| 2 | 21/7/75 Strongstown, Pennsylvania, USA | Leaking of pesticides used in a private residence | Chlordane, Hystachlor, Dieldrin, Aldrin | 9.5 l of the pesticide mixture in 900 l of water | Not applicable | River and soil | All life immediately down-stream in the river was killed | None, owing to treatment | 3 months, owing to treatment | Pesticide |
| 3 | 23/7/80 Northern Sweden | Rupture of fungicide container | Pentachloro-phenol, 2,3,4,6-Tetra-chloro-phenol, 2,4,6-Trichlorophenol | 3 $m^3$ of aqueous solution containing 0.8% of fungicide mixture | Unknown | Rivers and lakes in system to 15 km down-stream | Contamination of fish (no death) | Unknown After 6 months PCP detected in water and organisms | Probably a few months | R50/53. PCP |
| 4 | 15/9/85 Drogobych, Ukraine, USSR | Collapse of waste container wall due to overloading | Potassium salt (powder) | Tons | Not stated | River and farmland | 2000 t of fish killed, 360 miles of river polluted, 500 acres of farmland flooded | | Short | Waste. Potassium chloride and other salts are R50 |
| 5 | 1/11/86 Schweizerhalle, Switzerland | Fire in a pesticide store-house, firefight-ing water entering river | Pesticides: Organophosphorus, mercury-based, zinc-based pesticides | 6-22 tonnes | 680 tn | Atmosphere soil and river | Massive kill of life in the Rhine. Benthic organisms eradicated 400 km down-stream | Decrease of eel popula-tion for years | After one year, most of the fish species and benthic organisms had recovered | R50/53. Pesticide. Fire-extinguishing water; |
| 6 | 4/12/86 Terminal Savannah River, Georgia, USA | Discharge of oil, causes unknown | No 6 fuel oil | 500000 gallons (ca. 1700 tn) | Unknown | Vegetation along river banks | Coating of vegetation with oil, a few oiled birds | Not stated | 1/2 - 1 year | Oil to river |
| 7 | 1986 | Release at industry | Toluene | Few ten tons | | Tidal river | Fauna in 5 km stretch of tidal river damaged | | 6-12 months | Non N;R |
| 8 | 8/10/87 Isla Desola-cion, Magellan Strait | Ship grounding | Light crude oil, Fuel oil | 6000 $m^3$ , 533 $m^3$ | 70348.8 $m^3$ crude oil | Marine and shore line | Seaweed contamin-ated, Impact to seabird minimal | Very limited | 6 months, except for minor areas | Oil to Sea |
| 9 | 2/1/88 Floreffe, Pennsylva-nia, USA | Collapse of oil storage tank | No 2 diesel fuel oil | 3 881841 gallons (ca. 12500 tn) 750000 gallons (ca. 2400 tn) | 3.8 million gallons | Rivers and thereby public fresh-water supply | 2000-4000 birds died, fish killed, impact on mussels | No data | No data | Oil to River |

| No | Year, Place | Accident cause | Substance involved | Amount released | Amount stored/ transp | Eco-system affected | Short term effects | Long term effects | Time of recovery | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 8/6/88 Auzouer En Touraine, France | Explosion and fire. Release of firefighting water into river | Phenol derivatives, Toluene, Heavy metals etc. | | | Rivers Ground-water | 15-20 t of fish killed. Other species (birds, invertebrates) also killed | | | R50/53. Fire-extinguishing water |
| 11 | 22/8/88 Gueugnon, France | Accidental spill during decanting | Nitric acid | 500 l | | River | 500 kg fish killed | | | Non N;R |
| 12 | 10/10/88 Dampniat France | Accidental spill due to human or technical failure | Lindane and Sodium pentachlorophenate | 40 kg | | River, 14 km | 15 tons of fish died | | | R50/53 |
| 13 | 22/12/88 Grays Harbour, Washington USA | Puncture of cargo tank | Bunker C oil | 5500 bbl (ca. 730 t) | 70000 bbl | Marine and shoreline | 8000 dead birds | | 6 months | Oil to Sea |
| 14 | 20/3/89 Saint Andre de Majen-coules, France | Road transport, human failure | Oil fuel | 20000 l (ca 17 t) | 20000 l | River | Dead fish | | Short | Oil to River |
| 15 | 28/3/89 Vierzon, France | Road transport Accidental spill by loading | Fuel oil | 8000 l (ca 7 t) | | River | Fish killed | | | Oil to River |
| 16 | 2/1/90 Arthur Kill Waterway, USA | Leaking from an under-water pipeline | No 2 heating oil | 13500 bbl (ca. 1800 t) | | Island wetlands and shore | 600 dead birds and 100 oiled birds | None | 1 year | Oil |
| 17 | 8/4/90 Martelange,Esch, Luxemburg | Release, Road transport | Monochloroacetic acid | 7 t | 22 t | River and wells | Drinking water polluted, 12 t of dead fish | | | R50 |
| 18 | 3/12/90 Chavanay France | Fire Train derailment | Hydrocarbon fuel | Approx. 720 $m^3$ | Approx. 1760 $m^3$ | Soil and ground water | Soil and ground water polluted | | | Oil to groundwater |
| 19 | 21/1/95 Quebec, Canada | Train derailment | Sulphuric acid (concentrated) | 234 $m^3$ | | River and lake | Aquatic life in lake killed | Perhaps spawning of indigenous species will be affected | Lake closed for recreational purposes for 8 years, river closed for 5 years | Non N;R Only Corrosive |

| No | Year, Place | Accident cause | Substance involved | Amount released | Amount stored/ transp | Eco-system affected | Short term effects | Long term effects | Time of recovery | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| 20 | 19/8/94, Rho, Italy | Release from a petrochemical industry storage. The leak occurred through the little loosing well containing the ejector of the fire fighting system joined to the ACH tanks. | Acetone cyanohydrin (2-Methyllactonitrile, 2-Hydroxy-2methyl-propionitrile, alfa-hydroxyisobutyronitrile, (CH3)2COHCN CAS-No: 75-86-5 | 298 tonnes | | Groundwater | Pollution of groundwater, and particularly of the superficial water-bearing stratum (5-8 m) but not the first water-bearing stratum (30 m) due to the presence of an impermeable clay stratum. The water-bearing stratum from which the drinking water is withdrawn is at 60 m then is still more protected. | Monitoring of pollution. Daily tests over 25 wells. | | Groundwater |
| 21 | 4/5/95, River Erre, France | Release of pesticides from an agricultural warehouse due to a handling error during process. | Pesticides | Unknown | | River | Pollution of a river along 12 km. Significant fish dying in the river and in an aqua-culture | | | Pesticides. Agricultural |
| 22 | 28/2/96, Rotterdam, the Netherlands | Major fire in a storage facility in harbour area. Water contamination from fire extinguishing water containing chemicals. Matter put forward to the European parliament. | Calcium hypochlorite CAS 7778-54-3 Trichloreisocyanicacid CAS 87-90-1 | Unknown | | River and sea | Significant water pollution by fire extinguishing water containing chemicals, disturbance of normal everyday life in surrounding populated areas. | | | R50, R50/53 Fire-extinguishing water |

| No | Year, Place | Accident cause | Substance involved | Amount released | Amount stored/ transp | Eco-system affected | Short term effects | Long term effects | Time of recovery | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| 23 | 6/8/96, River Meurthe, France | Fire with some explosions in a storage facility (warehouse). The fire started at the sodium chlorate storage sector. Contamination of natural waters through the extinguishing water and rain water. | herbicides and pesticides | 200 m3 fire-fighting water contaminated with pesticides were released in the river | | River | 1.6 tons of dead fish was collected from the river. Swimming in the river, pumping of water from the river and fishing in the river were forbidden (prohibited). Increase of river water flow from a dam located upstream was used to dilute the pollution. | | | herbicides and pesticides |
| 24 | 5/4/97, Courant de Mimizan river, France | Release of 21 cubic meters of Javel water because of a failure of pipe. | Solution of 50° chlorimetric sodium hypochlorite | 21 m3 of solution | | River | All fauna and flora along the 4 km long of the river called Courant de Mimizan were destroyed. | | | Non N;R |
| 25 | 2/9/97 River Meurthe, France | A tank for washing water wrongly filled with ethoxylated alkylphenol. The sub-contractor firm, called to eliminate the substance wrongly supplied, poured the washing water into the rain drain. | Ethoxylated Alkylphenol and its products when in contact with water | | | River | The river MEURTHE was polluted for 15 km. 1 tn fish killed | | | R51/53 |
| 26 | 16/7/98 France | Failure of the waste process water treatment plant and release in a river. Failure of control apparatus and mistake of the operator. | Cyanide, copper compounds and oxidable substances. | | | River | Pollution of the river and lots of fish killed. | About 100 kg of killed fish have been recovered. The costs of the restoration of the water quality of the river is unknown. | | Waste |

| No | Year, Place | Accident cause | Substance involved | Amount released | Amount stored/ transp | Eco-system affected | Short term effects | Long term effects | Time of recovery | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| 27 | 28/7/98 France | Overfilling of a vessel and overflow of the containment pond (dyke) due to human error. Discharge to the river through the rain drain. | Javel water (sodium chlorite) | Unknown | | River | A river was polluted 1.5 km long and another river on 0.4 km long; fish were killed. | | | Non N;R |
| 28 | 24/3/89 Prince William, Alaska, USA (Exxon Valdez) | Release of crude oil following grounding of tanker EXXON VALDEZ. Human negligence suspected. | Crude oil | 11 million gallons (ca. 37,400 tonnes) | | Sea and coast | Pollution over 1090 miles of coastline killed large numbers of wildlife. Almost 1000 otters and approx. 33,000 seabirds died. Very large no. of fish killed in the height of breeding season. Most of area's plankton destroyed. Cleanup cost $1.2bn. | | Expected to be long. In 1999, 10 years after the accident, half of the species had recovered. | Crude oil in sea. |
| 29 | 31/5/98 Enns river, Steyr, Austria | Release of heating oil from a 1000 m3 storage tank used for the heating system. Release occurred during test. | Heating oil | 70 m3 | 700 m3 | River | Pollution up to 35 km. 9 weeks after the accident the drinking water wells showed significant level of hydrocarbon pollution | | | Heating oil in river |
| 30 | 31/1/2000 Baia Mare, Romania | Massive snowfalls damaged a waste dam at the Aurul gold smelter. Waste containing cyanide discharged to Tisza and through it to the Danube. | Waste containing cyanide | | | River | Pollution with cyanide of the rivers Tisza and Danube and devastating effects on the aquatic environment | | | Waste Extracting industry |

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