Euro Chlor Risk Assessment for the Marine Environment
OSPARCOM Region - North Sea

Tetrachloroethylene

June 1997

Euro Chlor
representing the chlor-alkali industry

EXECUTIVE SUMMARY

Euro Chlor has voluntarily agreed to carry out risk assessment of 25 chemicals related to the chlorine industry, specifically for the marine environment and according to the methodology laid down in the EU risk assessment Regulation (1488/94) and the Guidance Documents of the EU Existing Substances Regulation (793/93). This was done as a parallel exercise with the on-going European Risk Assessment the scope of which being broader and covering all compartments.

The study consists of the collection and evaluation of data on effects and environmental concentrations. Basically, the effect data are derived from laboratory toxicity tests and exposure data from analytical monitoring programs. Finally the risk is indicated by comparing the "predicted environmental concentrations" (PEC) with the "predicted no effect concentrations" (PNEC), expressed as a hazard quotient for the marine aquatic environment.

To determine the PNEC value, three different trophic levels are considered: primary producers (aquatic plants), primary consumers (invertebrates) and secondary consumers (fish). In the case of tetrachloroethylene (PER) 18 data for fish, 13 data for invertebrates and 8 data for algae have been evaluated according to the quality criteria recommended by the European authorities. Both acute and chronic toxicity studies have been taken into account and the appropriate assessment factors have been used to define a final PNEC value of 51 µg/l.

All the monitoring data available indicate a progressive decrease of the tetrachloroethylene concentration in surface waters since 1983 up to now. Most of the available monitoring data apply to rivers and estuary waters and were used to calculate PECs. The most recent data (1991-1995) support a typical PEC of 0.2 µg PER/l water and a worst case PEC of 2.5 µg PER/l water. The calculated PEC/PNEC ratios give a safety margin of 20 to 250 between the predicted no effect concentration and the exposure concentration. Dilution within the sea would of course increase those safety margins.

Moreover, as the available data on persistence of tetrachloroethylene indicate a half-life in water of a few hours or days and as the bioaccumulation in marine organisms can be considered negligible, it can be concluded that the present use of tetrachloroethylene does not represent a risk to the aquatic environment.

1. INTRODUCTION : PRINCIPLES AND PURPOSES OF EURO CHLOR RISK ASSESSMENT

Within the EU a programme is being carried out to assess the environmental and human health risks for "existing chemicals", which also include chlorinated chemicals. In due course the most important chlorinated chemicals that are presently in the market will be dealt with in this formal programme. In this activity Euro Chlor members are cooperating with member state rapporteurs. These risk assessment activities include human health risks as well as a broad range of environmental scenarios.

Additionally Euro Chlor has voluntarily agreed to carry out limited risk assessments for 25 prioritised chemicals related to the chlorine industry. These compounds are on lists of concern of European Nations participating in the North Sea Conference. The purpose of this activity is to explore if chlorinated chemicals presently pose a risk to the marine environment especially for the North Sea situation. This will indicate the necessity for further refinement of the risk assessments and eventually for additional risk reduction programmes.
These risk assessments are carried out specifically for the marine environment according to principles given in *Appendix 1*. The EU methodology is followed as laid down in the EU risk assessment Regulation (1488/94) and the Guidance Documents of the EU Existing Substances Regulation (793/93).
The exercise consists in the collection and evaluation of data on effects and environmental concentrations. Basically, the effect data are derived from laboratory toxicity tests and exposure data from analytical monitoring programs.
Where necessary the exposure data are backed up with calculated concentrations based on emission models.
Finally the risk is indicated by comparing the "predicted environmental concentrations" (PEC) with the "predicted no effect concentrations" (PNEC), expressed as a hazard quotient for the marine aquatic environment.

2. DATA SOURCES

The data used in this risk assessment activity are primarily derived from the data given in the HEDSET (updated version of 11/95) for this compound. Where necessary additional sources have been used. For interested parties the HEDSET is available at Euro Chlor. The references of the HEDSET and additional sources are given in chapter 10.

3. COMPOUND IDENTIFICATION

3.1 Description

CAS number	:	127-18-4
EINECS number	:	204-825-9
EEC number	:	602-028-00-4
IUPAC name	:	tetrachloroethylene

Tetrachloroethylene is also known as perchloroethylene and is commonly abbreviated to PER. Other synonyms which are used include:

- 1,1,2,2-tetrachloroethylene
- tetrachloroethene
- ethylene tetrachloride
- ethene, 1,1,2,2-tetrachloro

Tetrachloroethylene has the following formula:

C_2Cl_4

```
Cl     Cl
  \   /
  C = C
  /   \
Cl     Cl
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3.2 EU labelling

According to Annex I of Directive 93/72/EEC (1.9.93 - 19th TPA), tetrachloroethylene is classified as carcinogenic, category 3:Xn, R40: (possible risks of irreversible effects). This classification is applicable for both the pure compound and products containing 1 % of tetrachloroethylene.

Environmental labelling was discussed at the EU Working Group and recently classified in Annex 1 of Directive 96/54/EC (30.10.96 - 22th - TPA) according to the EU criteria as “dangerous for the environment” with the symbol N and risk phrases R51/53 (toxic to aquatic organisms and may cause long-term adverse effects in the aquatic environment).

4. PHYSICO-CHEMICAL PROPERTIES

Table 1 gives the major chemical and physical properties of the compound which were adopted for the purpose of this risk assessment.

Table 1 : Physical and chemical properties of tetrachloroethylene

Property	**Value**
Molecular weight	165.8
Aspect	Colourless liquid
Melting point	- 22.7 °C
Boiling point	120 °C at 1000 hPa
Decomposition temperature	□ 150 °C
Density	1.62
Vapour pressure	19 hPa
log octanol-water partition Coefficient log Kow	2.53-2.88
log Koc (5 % OC)	2.3-2.4
Water solubility	0.15 g/l
Henry's Law constant	1200-2000 Pa.m^3/mol

5. COMPARTMENT OF CONCERN BY MACKAY LEVEL I MODEL

The risk assessment presented here focuses on the aquatic marine environment, with special attention for the North Sea conditions where appropriate. Although this risk assessment only focuses on one compartment, it should be borne in mind that all environmental compartments are inter-related.

An indication of the primary compartment of concern can be defined using Mackay level I calculations obtained through the ENVCLASS software distributed by the "Nordic Council of Ministers". This model describes the ultimate distribution of the compound in the environment
(Mackay et al., 1990; Pederson et al., 1994).

It should be recognized, however, that this model takes no account of transfer rates between compartments, the compartment into which the chemical is discharged, or any removal processes within compartments. Hence it is not designed to predict environmental concentrations for the purpose of risk assessment.

The results of such a calculation for tetrachloroethylene are given in Table 2.

Table 2 : Results of a Mackay level I calculation for tetrachloroethylene

Compartment	**%**
Air	99.85 - 99.86
Water	0.14
Soil	≤ 0.01
Biota	≤ 0.01

(See *Appendix 2* for details of calculations)

6. USE, APPLICATIONS

6.1 Production and Consumption

Tetrachloroethylene (PER) is obtained by chlorination or oxychlorination of several raw materials e.g. propylene, dichloroethane, chloropropenes and chloropropanes. Usually PER is jointly produced with carbon tetrachloride (CTC) or with trichloroethylene (TRI).

The "TRI-PER process" is presently the main source of PER. It uses as raw materialthe light fraction of the residues from the vinyl chloride monomer manufacture. The "CTC-PER process", which uses the same type of raw material, has been modified to drastically reduce the production of carbon tetrachloride.

According to the European Chlorinated Solvent Association (ECSA), tetrachloroethylene (PER) is produced by six companies within the European Union. For 1994, the actual production level is reported as 164,000 tonnes, the sales as 78,000 tonnes and exports as 20,000 tonnes, the remainder being used by the chemical industry as an intermediate. Tetrachloroethylene is also imported in the European Union at a level of 10,000 tonnes per year. The main uses of tetrachloroethylene are dry cleaning, metal cleaning and chemical synthesis.

6.2 Main Uses

6.2.1 Dry Cleaning

Tetrachloroethylene is today the main substitute of the solvents previously used as dry cleaning agent and which are controlled by the Montreal Protocol i.e. 1,1,1-trichloroethane and R113.

The use of modern and more efficient dry cleaning machines as well as an intensive recycling via collecting organisations set up by the producers are the primary causes of the decrease in PER consumption. For dry cleaning, about 60,000 tonnes of PER are used per year in the European Union, by about 60,000 dry cleaning shops, as estimated by a report to the EU Commission published in 1991.

6.2.2 Metal degreasing

Cleaning and degreasing of metals is another use of PER. Due to the prohibition of the 1,1,1-trichloroethane (T111) as a solvent by the Montreal Protocol some increase in PER consumption for this application have been observed, even if the main substitute of T111 is trichloroethylene.

6.2.3 Chemical intermediate

PER was used as a feedstock in the production of the solvents and refrigerants like R113, R114 and R115. Following the decision by the Montreal Protocol to progressively phase out these products, the PER consumption decreased and, even if PER continues to be used as a raw material for the production of CFCs substitutes (HFCs and HCFCs), its consumption still continues to decline.

Aside from this use as a raw material for CFC substitutes, PER is used in small quantities for the manufacture of paint removers, printing inks, formulation of adhesives, special cleaning fluids, dye carriers, silicone lubricants, …

Globally, the annual PER production and use in the European Union dropped from 340,800 tonnes to 164,000 tonnes between 1986 and 1994, due to the various changes described above.

6.3 Applicable regulations

In the European Union, the tetrachloroethylene emissions in water are governed by the EC Directive 90/415 of July 27, 1990 which gives the following values:

- For the simultaneous production of trichloroethylene and tetrachloroethylene (TRI-PER process) a monthly limit for emissions in water of 2.5 grams per tonne of combined TRI-PER capacity is applicable as per 1.1.1995.
  The maximum concentration of PER in the water effluent is 1 mg/l, applicable as per 1.1.1995.
- For combined production of PER and carbon tetrachloride the monthly limit of PER emission is 2.5 g/t of combined capacity and the maximum concentration of PER in the water effluent is 1.25 mg/l applicable as per 1.1.1995.
- For the use of PER in metal degreasing, a monthly average limit of 0.1 mg/l in the water effluent is required as per 1.1.1993.

7. EFFECT ASSESSMENT

As a first approach, this chapter only considers the following three trophic levels: primary producers (aquatic plants), primary consumers (invertebrates) and secondary consumers (fish).
The effects on other organisms are only discussed when indicated.

The evaluation of the data was conducted according to the quality criteria recommended by the European authorities (Commission Regulation 1488/94/EEC). The evaluation criteria are given in *Appendix 1*.

Documented data from all available sources, including company data and data from the open literature, were collected and incorporated into the HEDSET for tetrachloroethylene, including their references (updated version of 11/95).
A summary of all data is given in *Appendix 3*. In total 18 data for fish, 13 data for invertebrates and 8 data for algae have been evaluated. Respectively 7, 4 and 1 data were considered valid for risk assessment purposes. For the respective taxonomic

groups, 6, 4 and 1 should be considered with care, and 5, 5 and 6 data respectively were judged as not valid for risk assessment.

It is necessary to distinguish the acute studies (LC50/EC50) from chronic studies (NOEC/LOEC). In the tables presented in *Appendix 3*, the data are ranked based on class (fish, invertebrates, algae), criterion (LC50/EC50, NOEC/LOEC), environment (freshwater, saltwater) and validity (1, 2, 3, 4).

The different trophic levels are reviewed hereafter. The reference numbers are those listed is the Table of *Appendix 3* and given in *Appendix 6*.

7.1 Marine fish

Two acute toxicity studies are reported for marine fish (Pearson, C.R. et al. 1975 and Heitmuller, P.T. et al.1981).

Both studies were conducted with adult or juvenile fish and are considered valid but should be used with care: one study was poorly described (Pearson, C.R. et al.1975)and the result of the other one was based on nominal concentration (Heitmuller, P.T. et al. 1981). There is no long-term toxicity study available.

The lowest toxicity value for marine fish is observed for *Limanda limanda* with a 96h LC50 of 5 mg/l (Pearson, C.R. et al.1975).

All remaining data are for freshwater organisms.

7.2 Freshwater fish

Ten acute toxicity studies are reported for freshwater fish; four were conducted in a flow-through system on *Jordanella floridae, Pimephales promelas* and *Salmo gairdneri* (Smith, A.D. et al.1991 - Alexander, H.C. et al.1978 - Broderius, S. et al.1985 - Shubat, P.J. et al.1982) and the results were based on measured concentrations; they are all four considered valid. The lowest acute 96h LC50 is observed for *Salmo gairdneri* with a value of 5 mg/l (Shubat, P.J. et al.1982).

In a semistatic study with *Pimephales promelas* (Alexander, H.C. et al. 1978), the test concentration was controlled with an adequate analytical method so that this study is also considered valid.

The remaining studies are considered valid but should be used with care (Smith, A.D. et al.1991 Buccafusco, R.J. et al. 1981 - Knie, J. et al.1983); they were performed under static conditions, the procedure is well described but the results were expressed as nominal concentrations.

One study conducted on *Oryzias latipes* is considered non-valid as the description of the test is lacking and the results are based on nominal concentrations.

Five long-term studies are reported, including three with early lifestage species. Two studies are valid as they were performed in a flow-through system with analysis of test solutions (Smith, A.D. et al. 1991) and capped vessels were used to avoid loss of volatiles.

Reliability is not assignable for two other chronic studies with *Carassius auratus* and *Pimephales promelas* as no information at all is available on the test procedure (Walbridge, C.T. et al1983 - EPA 1980 - Loekle, D. 1987).

The study with *Poecilia sphenops* was very poorly described; it was conducted under semistatic conditions. The results, expressed as nominal concentration are presented in a non-standardized way with an effect concentration of 1.6 mg/l corresponding to 17 % survival. This study is considered non-valid.

The lowest NOEC value for freshwater fish is observed for *Jordanella floridae* (larvae and fry) with a 10d and 28d NOEC of 1.99 and 2.34 mg/l, respectively (Smith, A.D. et al. 1991).

7.3 Marine invertebrates

Two acute toxicity studies are reported for marine invertebrates with the lowest 48h EC50 of 3.5 mg/l for larvae of *Elminius modestus*; both studies are considered non-valid as the available information on the test procedure is insufficient (Parson, C.R. et al.1975 - EPA 1980).

One long-term toxicity study is reported for marine invertebrates giving an effect concentration of 0.45 mg/l for *Mysidopsis bahia* (EPA 1980) but this study is considered not valid as there was no precision on the exposure period, the test conditions and the endpoint.

No data are relevant for marine invertebrates.

7.4 Freshwater invertebrates

Five acute EC50 values are reported for *Daphnia magna* in the range from 3.2 to 147 mg/l; most of the results were obtained from studies conducted under static conditions. The upper value of 147 mg/l was obtained after 24h exposure period and is based on the nominal concentration. This study is valid but should be used with care (Bringmann, G.et al. 1982).

One other static study was conducted with analysis of the test concentration giving a 48h EC50 of 8.5 mg/l. This study is considered as valid without restriction (Richter, J.E.1983 - Walbridge, C.T., et al. 1983).

The lowest 24h EC50 of 3.2 mg/l (Bazin, C. et al. 1987) is a nominal concentration and there was no control of volatile losses in the test system so that this study is considered valid but should be used with care.

The EC50 value obtained in two other species show that those species were less sensitive than Daphnia (Yoshioka, Y.T.et al. 1986 - Call, D.J. et al. 1983).

Two 28d studies with freshwater *Daphnia magna* are reported (Richter, J.E. et al. 1983 - Call, D.J. et al. 1983); both are conducted under flow-through conditions with analysis of test concentration. The 28d NOEC for reproduction of 0.51 mg/l is the lowest NOEC value observed for freshwater invertebrates (Richter, J.E. et al. 1983). This result is considered valid.

7.5 Marine algae

Four studies are reported for three marine algae species; three of them are considered non-valid for lack of information on the test procedure. The fourth study was performed on estuarine phytoplankton under flow-through conditions giving a 48h NOEC of 1 mg/l. This result is expressed as the nominal concentration so that this study is considered valid but should be used with care.

This 48h NOEC of 1 mg/l is the lowest toxicity value for marine algae. (Erickson, SJ. et al. 1980).

7.6 Freshwater algae

Only one study conducted on *Chlamydomonas reinhardtii* is considered valid (Brack, W. and Rottler, H. 1994). The algae were tested for 72 hour in a closed system (CO_2 was provided by a buffer K_2CO_3/$KHCO_3$). The measured 72h EC50 for growth was 3.6 mg/l and the corresponding EC10 (LOEC) of 1.8 mg/l which is the lowest available value for freshwater algae. The two other available studies are considered non-valid for lack of information on the test procedure.

7.7 PNEC for marine environment

From an evaluation of the available toxicity data for aquatic organisms, it is reasonable to conclude that the sensitivity of both marine and freshwater organisms to tetrachloroethylene is quite similar.

Valid long term studies are available for three different trophic levels.

From the lowest NOEC of the reproduction study in daphnia an assessment factor of 10 is thought adequate to derive a PNEC of 0.051 mg/l.

A summary of the valid data selected for the derivation of PNEC values at different levels is given in Table 3. This table summarises the PNEC values derived from acute, chronic and ecosystem studies. It is generally acknowledged that the latter are closer to real world than the former. Therefore the more reliable value should be in the lower end of the table. As far as the North Sea is concerned, acute effect studies are not relevant because of the absence of local sources.

<u>The final PNEC which is calculated for this risk assessment of tetrachloroethylene is 51 µg/l.</u>

7.8 Bioaccumulation

Bioaccumulation of tetrachloroethylene in aquatic species is unlikely in view of its physical and chemical properties. Barrows et al. (1978-1980) examined the bioconcentration of water-borne tetrachloroethylene by *Bluegill sunfish* in a 21 days test. A whole body concentration factor (BCF) of 49 was reported and the half life for elimination was estimated to be lower than 1 day. A BCF of 61,5 was also reported on *Fathead minnows* by Ahmad et al., (1984). The log Pow is in a range of 2.53 to 2.88.

7.9 Persistence

As indicated by the Henry's law constant tetrachloroethylene entering aquatic systems would be transferred to the atmosphere through volatilization. A half life of 4.2 hours can be deduced from this constant in average running water conditions.

The tropospheric half life of tetrachloroethylene is about 3 months and its halogenated degradation products are short-lived. This relatively short half life implies that no effect of tetrachloroethylene can be expected in stratospheric ozone depletion and in global warming. Tetrachloroethylene has a negligible tropospheric ozone creation potential in the atmosphere.

7.10 Conclusion

It can be concluded that the above information that tetrachloroethylene is not a "persistent, toxic and liable to bioaccumulate" substance as mentioned by the Oslo and Paris Convention for the Prevention of Marine Pollution (OSPARCOM) according to the criteria currently under discussion and especially those defined by UN-ECE, Euro Chlor and CEFIC.

Table 3 : Summary of ecotoxicity data selected for the PNEC derivation, with the appropriate assessment factors for tetrachloroethylene

Available valid data	Assessment factor applied to the lowest LC50/EC50 or NOEC/LOEC	Comments
At least 1 short-term LC50 from each trophic level (fish, daphnia, algae)	1000 **PNEC = 3.2 µg/l**	– *Salmo gairdneri*, LC50, 96h = 5 mg/l; Shubat et al, 1982 – *Limanda limanda*, LC50, 96h = 5 mg/l; Pearson et al, 1975 – *Daphnia magna*, EC50, 24h = 3.2 mg/l (nominal concentration); Bazin et al, 1987 – *Chlamydomonas reinhardtii*, EC50, 72h = 3.6 mg/l; Brack, et al, 1994
Long-term NOEC from at least 3 species representing three trophic levels (fish, daphnia, algae)	10 **PNEC = 51 µg/l**	– *Jordanella floridae*, NOEC (survival), 28d = 2.0 mg/l; Smith et al, 1991 – *Daphnia magna*, NOEC (reproduction), 28d = 0.51 mg/l; Richter et al, 1983 – *Chlamydomonas reinhardtii*, NOEC, 72h = 1.8 mg/l; Brack et al, 1994 – 1 study with estuarine phytoplankton; NOEC, 48h = 1 mg/l; Erickson et al, 1980

8. EXPOSURE ASSESSMENT

The exposure assessment is essentially based on exposure data from analytical monitoring. Tetrachloroethylene has been measured in a number of water systems. These levels in surface waters (river water and marine waters) are detailed in *Appendix 4*.

References of the available monitoring data can be found in HEDSET Data Sheet for tetrachloroethylene (updated version of 11/95). Additional sources have been also used. All the references are given in *Appendix 7*.

As it is generally not specified if the location of sampling is close to a source of emission (production or processing), it is assumed that the lower levels correspond to the background "regional" concentrations and the higher to contaminated areas, or "local" concentrations, considered as worst cases.

8.1 Marine waters

In coastal waters and estuaries, observed concentrations are in a range from 0.0009 µg/l up to 0.87 µg/l. Typical recent monitoring data for PER in coastal waters and estuaries which are part of the OSPARCOM region are given hereafter and illustrated on the North Sea map in *Appendix 5*.

Elbe estuary (D)	0.010-0.240 µg/l	1993
Weser estuary (D)	0.0009-0.020 µg/l	1993
Rhine estuary (NL)	0.0013-0.047 µg/l	<1993
Rhine (D/NL Border)	0.020-0.070 µg/l	1993
Rhine (D/NL Border)	< 0.2 µg/l	1986-1990
Maas (B/NL Border)	< 0.4 µg/l	1986-1990
Meuse (B/NL Border)	0.4 µg/l	1992
Maas (NL)	0.42 µg/l	1992
Schelde estuary	0.870 µg/l	1993
UK Rivers estuaries	< 0.010-0.587 µg/l	1993
Seine river and estuary (F)	< 1 µg/l	1995
Coastal water (D)	0.010-0.430 µg/l	1983

The symbol < indicates that the value is under the detection limit of the analytical method.

8.2 River waters

Background levels of tetrachloroethylene in typical rivers in non-industrialized area are in general lower than 0.5 µg/l.

In the Rhine river water and other adjacent industrialized rivers, up to 2.5 µg/l is measured (worst case).

8.3 Other monitoring data

Only few data on tetrachloroethylene levels measured in aquatic organisms are available.

Many years ago, in the Thames estuary, tetrachloroethylene levels were measured in algae, invertebrates and fishes from 0.3 up to 41 µg/kg (Pearson et al., 1975), while in five species of fishes of the Irish Sea, levels up to 43 µg/kg were observed (Dickson et al., 1980).More recent data from Finland (in 1987) revealed a tetrachloroethylene concentration of 0.3 µg/kg in fish for consumption
(Kroneld, 1989a; 1989b).

Tetrachloroethylene was detected in German sediments from 18 up to 50 µg/kg (Alberti, 1989), as well as in sediments of the Solent estuary from 0.085 up to 20 µg/kg (Bianchi et al., 1991). In 1989-90, tetrachloroethylene was not detected in Scandinavian sediments; at a detection limit of 10 µg/kg (TemaNord, 1994).

9. RISK ASSESSMENT CONCLUSION

In the risk characterization of tetrachlororethylene for the aquatic organisms, the PNEC is compared to the PEC.

A PNEC of 51 µg/l was obtained for the aquatic species exposed to tetrachloroethylene.

In coastal waters and estuaries, tetrachloroethylene is observed up to 0.87 µg/l (worst case) but the concentrations of the waters support a typical value of less than 0.2 µg/l.

In non-industrialized area, a typical river water concentration below 0.5 µg/l was derived from the measured levels; a worst case was also identified in industrialized zone with measured levels up to
2.5 µg/l.

These monitoring values allow to calculate the ratios PEC/PNEC which are summarized in Table 4.

Table 4 : Calculation of PEC/PNEC ratios for tetrachloroethylene

Type of water	PEC level	PEC/PNEC
Coastal waters/Estuaries		
• typical water	0.2 µg/l	0.004
• worst case	0.87 µg/l	0.017
River waters :		
• typical water	0.5 µg/l	0.009
• worst case	2.5 µg/l	0.049

These calculated ratios which do not take into account any dilution factor within the sea correspond to a safety margin of 20 to 250 between the aquatic effect and the exposure concentration so that the present use of tetrachloroethylene should not represent a risk to the aquatic environment.
In addition, as stated in section 7.8, concentrations in biosphere and hydrosphere do not provide any sign of bioaccumulation.

10. REFERENCES

10.1 General References

Ahmad et al. Aquatic toxicity tests to characterize the hazard of volatile organic chemicals in water: A toxicity data summary - parts I and II. NTIS/PB 84-141506 US Department of Commerce, Springfield, VA (1984)

Barrows M.E., Petrocelli, S.R., Macek, K.J., Carroll, J.J. (1978): Bioconcentration and elimiation of selected water pollutants by bluegill sunfish (Lepomis macrochirus) in dynamics, exposure and hazard assessment of toxic chemicals; R. Hague Ed.; Ann Arbor, Science 379-392, Ann Aarbor Michigan

BUA Stoffbericht 139 - Stand August 1993 - S. Hirzel Ed. (1994)

Mackay, D., Patterson, S. (1990); Fugacity models; in: Karcher, W., Devillers, J. (Eds); Practical applications of quantitative structure-activity relations in environmental chemistry and toxicology: 433-460

Pedersen, F., Tyle, H., Niemelä, J.R., Guttmann, B., Lander, L., Wedebrand, A. (1994); Environmental Hazard Classification-Data collection and interpretation guide; TemaNord 1994:589

Umweltbundesamt (1994); Daten zur Umwelt, 1992/93 – Erich Schmidt Verlag GmbH - Berlin

10.2 **References for ecotoxicity data:** see *Appendix 6.*

Those references are used in *Appendix 3*.

10.3 **References for monitoring data**: see *Appendix 7.*

Those references are used in *Appendix 4*.

Environmental quality criteria for assessment of ecotoxicity data

The principal quality criteria for acceptance of data are that the test procedure should be well described (with reference to an official guideline) and that the toxicant concentrations must be measured with an adequate analytical method.

Four cases can be distinguished and are summarized in the following table (according to criteria defined in IUCLID system).

Table : Quality criteria for acceptance of ecotoxicity data

Case	Detailed description of the test	Accordance with scientific guidelines	Measured concentration	Conclusion: reliability level
I	+	+	+	**[1]** : valid without restriction
II	±	±	±	**[2]** : valid with restrictions; to be considered with care
III	insufficient or -	-	-	**[3]** : invalid
IV	the information to give an adequate opinion is not available			**[4]** : not assignable

The selected validated data LC50, EC50 or NOEC are divided by an assessment factor to determine a PNEC (Predicted No Effect Concentration) for the aquatic environment.

This assessment factor takes into account the confidence with which a PNEC can be derived from the available data: interspecies- and interlaboratory variabilities, extrapolation from acute to chronic effects, etc.

Assessment factors will decrease as the available data are more relevant and refer to various trophic levels.

APPENDIX 2a

Ultimate distribution in the environment according to Mackay level I model
(details of calculation)

Fugacity Level I calculation

Chemical: Perchlorethylene

Temperature (C)	20
Molecular weight (g/mol)	165.80
Vapor pressure (Pa)	1900
Solubility (g/m3)	150
Solubility (mol/m3)	0.90
Henry's law constant (PA.m3/mol)	2100.13
Log octanol water part. coefficient	2.53
Octanol water part. coefficient	338.84
Organic C-water part. coefficient	138.93
Air-water partition coefficient	0.86
Soil-water partition coefficient	4.17
Sediment-water partition coefficient	8.34
Amount of chemical (moles)	1
Fugacity (Pa)	.40563053E-6
Total VZ products	2465297.64

Phase properties and compositions:

Phase	: Air	Water	Soil	Sediment
Volume (m3)	.6000E+10	.70000E+7	.45000E+5	.21000E+5
Density(kgm3)	.12056317E+2	.10000E+4	.15000E+4	.15000E+4
Frn org carb.	.00000E+0	.00000E+0	.20000000E-1	.40000000E-1
Z mol/m3.Pa	.41029864E-3	.47616024E-3	.19845326E-2	.39690652E-2
VZ mol/Pa	.24617918E+7	.33331217E+4	.89303968E+2	.83350370E+2
Fugacity	.40563053E-6	.40563053E-6	.40563053E-6	.40563053E-6
Conc mol/m3	.16642965E-9	.19314513E-9	.80498703E-9	.16099740E-8
Conc g/m3	.27594037E-7	.32023463E-7	.13346684E-6	.26693369E-6
Conc ug/g	.22887615E-5	.32023463E-7	.88977899E-7	.17795579E-6
Amount mol	.99857795E+0	.13520159E-2	.36224416E-4	.33809455E-4
Amount %	99.86	0.14	.36224416E-2	.33809455E-2

APPENDIX 2b

Ultimate distribution in the environment according to Mackay level I model
(details of calculation)

Fugacity Level I calculation

Chemical: Perchloroethylene

Temperature (C)	20
Molecular weight (g/mol)	165.80
Vapor pressure (Pa)	1900
Solubility (g/m3)	150
Solubility (mol/m3)	0.90
Henry's law constant (PA.m3/mol)	2100.13
Log octanol water part. coefficient	2.88
Octanol water part. coefficient	758.58
Organic C-water part. coefficient	311.02
Air-water partition coefficient	0.86
Soil-water partition coefficient	9.33
Sediment-water partition coefficient	18.66
Amount of chemical (moles)	1
Fugacity (Pa)	.40559534E-6
Total VZ products	2465511.51

Phase properties and compositions:

Phase	Air	Water	Soil	Sediment
Volume (m3)	.6000E+10	.70000E+7	.45000E+5	.21000E+5
Density(kgm3)	.12056317E+2	.10000E+4	.15000E+4	.15000E+4
Frn org carb.	.00000E+0	.00000E+0	.20000000E-1	.40000000E-1
Z mol/m3.Pa	.41029864E-3	.47616024E-3	.44428151E-2	.88856302E-2
VZ mol/Pa	.24617918E+7	.33331217E+4	.19992668E+3	.18659823E+3
Fugacity	.40559534E-6	.40559534E-6	.40559534E-6	.40559534E-6
Conc mol/m3	.16641522E-9	.19312838E-9	.18019851E-8	.36039703E-8
Conc g/m3	.27591643E-7	.32020685E-7	.29876913E-6	.59753827E-6
Conc ug/g	.22885630E-5	.32020685E-7	.19917942E-6	.39835885E-6
Amount mol	.99849132E+0	.13518986E-2	.81089332E-4	.75683376E-4
Amount %	99.85	0.14	0.01	0.01

SUMMARY TABLE OF ECOTOXICITY DATA ON TETRACHLOROETHYLENE

1a. FISH

Species	Duration d (days) -h (hours)	Type of study	Criterium (LC50/EC50, NOEC/LOEC)	Concentration (mg/l)	Validity	Comments and remarks	Reference
LC50/EC50 STUDIES							
1. FRESHWATER							
Jordanella floridae	96 h	F-T A	LC50	8.4	1		Smith et al,1991
Pimephales promelas	96 h	F-T A	LC50	18.4	1		Alexander et al,1978
Pimephales promelas	96 h	SS A	LC50	21.4	1		Alexander et al,1978
Pimephales promelas	96 h	F-T A	LC50	23.8	1	juvenile	Broderius et al, 1985
Salmo gairdneri	96 h	F-T A	LC50	5	1		Shubat et al,1982
Jordanella floridae	96 h	S N	LC50	24	2		Smith et al,1991
Lepomis macrochirus	96 h	S N	LC50	13	2		Buccafusco et al,1981
Leuciscus idus	96 h	A	LC50	130	2		Knie et al,1983

SUMMARY TABLE OF ECOTOXICITY DATA ON TETRACHLOROETHYLENE

1b. FISH

Species	Duration d (days) -h (hours)	Type of study	Criterium (LC50/EC50, NOEC/LOEC)	Concentration (mg/l)	Validity	Comments and remarks	Reference
LC50/EC50 STUDIES							
1. FRESHWATER							
Poecilia reticulata	7 d	SS	LC50	17.8	2		Koeneman, 1981
Oryzias latipes	48 h	S N	LC50	39.8	3		Yoshioka et al,1986
Pimephales promelas	96 h	F-T A	LC50	17	4	report not available	Brooke et al,1985
2. SALTWATER							
Limanda limanda	96 h	F-T A C	LC50	5	2		Pearson et al,1975
Cyprinodon variegatus	96 h	S N	LC50	52	2	juvenile; NOEC = 29 mg/l	Heitmuller et al,1981

SUMMARY TABLE OF ECOTOXICITY DATA ON TETRACHLOROETHYLENE

1c. FISH

Species	Duration d (days) - h hours)	Type of study	Criterium (LC50/EC50 NOEC/LOEC)	Concentration (mg/l)	Validity	Comments and remarks	Reference
NOEC/LOEC STUDIES							
1. FRESHWATER							
Jordanella floridae	10 d	F-T A C	NOEC LOEC	1.99 4.85	1	larvae	Smith et al,1991
Jordanella floridae	28 d	F-T A C	NOEC LOEC	2.34 5.82	1	fry	Smith et al,1991
Poecilia sphenops	60 d	SS N	EC	1.6	3		Loekle et al,1983
Carassius auratus	180 d	S	LOEC	0.1	4	endpoint = growth	Loekle, 1987
Pimephales promelas	32 d		NOEC LOEC NOEC	1.4 2.8 0.5	4	larvae endpoint : survival endpoint:loss of weight	Walbridge et al,1983 EPA,1980
SALWATER (NO DATA AVAILABLE)							

All endpoints of the tests are based on survival/mortality. Other effects are explicitly mentioned in the table.

SUMMARY TABLE OF ECOTOXICITY DATA ON TETRACHLOROETHYLENE

2a. INVERTEBRATES

Species	Duration d (days) - h (hours)	Type of study	Criterium (LC50/EC50 NOEC/LOEC)	Concentration (mg/l)	Validity	Comments and remarks	Reference
LC50/EC50 STUDIES							
1. FRESHWATER							
Daphnia magna	48 h	S A	EC50	8.5	1	juvenile, fed and unfed organisms LC50 = 9-18 mg/l	Richter et al,1983 Walbridge et al,1983
Tanytarsus dissimilis	48 h	S A	EC50	28.7-33	1	larvae	Call et al,1983
Daphnia magna	24 h	S N	EC50	3.2	2		Bazin et al,1987
Daphnia magna	48 h	A	EC50	22	2	LOEC = 1.2 mg/l	Knie et al,1983
Daphnia magna	24 h	S N	EC50	147	2		Bringmann et al,1982
Daphnia magna	48 h	S N	EC50	18	2	juvenile; NOEC = 10 mg/l	LeBlanc, 1980
Moina macropoda	3 h	S N	EC50	63	3		Yoshioka et al,1986
2. SALTWATER							
Mysidopsis bahia	96 h	S N	EC50	10.2	3		EPA,1980
Elminius modestus	48 h	S C	EC50	3.5	3	larvae	Pearson et al,1975

SUMMARY TABLE OF ECOTOXICITY DATA ON TETRACHLOROETHYLENE

2b. INVERTEBRATES

Species	Duration d (days) - h (hours)	Type of study	Criterium (LC50/C50 NOEC/LOEC)	Concentration (mg/l)	Validity	Comments and remarks	Reference
NOEC/LOEC STUDIES							
1. FRESHWATER							
Daphnia magna	28 d	F-T A	NOEC LOEC	0.51 1.1	1	endpoint = reproduction	Richter et al,1983
Daphnia magna	28 d	F-T A C	LOEC	1.1	1	endpoint = reproduction	Call et al,1983
Daphnia magna	42 d	S A	LC100-96 h	0.44	3	field study/microcosm	Lay et al,1984
2. SALTWATER							
Mysidopsis bahia	life cycle		EC	0.45	3		EPA,1980

All endpoints of the tests are based on survival/mortality. Other effects are explicitly mentioned in the table.

SUMMARY TABLE OF ECOTOXICITY DATA ON TETRACHLOROETHYLENE

3. AQUATIC PLANTS

Species	Duration d (days) - h (hours)	Type of study	Criterium (LC50/EC50 NOEC/LOC)	Concentration (mg/l)	Validity	Comments and remarks	Reference
1. FRESHWATER							
Chlamydomonas reinhardii	72 h	A C	EC50 LOEC	3.64 1.77	1		Brack et al, 1994
Haematococcus pluvialis	4 h		LOEC	> 36	3	endpoint = carbon uptake	Knie et al,1983
Selenastrum capricornutum	96 h		NOEC	816	3		EPA,1980
2. SALTWATER							
Estuarine phytoplankton	48 h	F-T N	NOEC LOEC	1 2	2		Erickson et al,1980
Phaeodactylum tricornutum			EC50	10.5	3	endpoint = carbon uptake	Pearson et al,1975
Skeletonema costatum	7 d	S	EC50	> 16	3		Erickson et al, 1978
Skeletonema costatum	96 h		EC50	500	3		EPA,1980
Scenedesmus subspicatus	8 d		EC3	250	4		Trénel, 1982

All endpoints of the tests are based on growth.

LIST OF ABREVIATIONS USED IN TABLES

A	=	analysis
C	=	closed system or controlled evaporation
h	=	hour(s)
d	=	day(s)
MATC	=	maximum acceptable toxicant concentration
N	=	nominal concentration
S	=	static
SS	=	semistatic
F-T	=	flow-through

Validity column :
- 1 = valid without restriction
- 2 = valid with restrictions : to be considered with care
- 3 = invalid
- 4 = not assignable

BACKGROUND LEVELS OF TETRACHLOROETHYLENE IN NATURAL SURFACE WATERS

Area	Year of measurement	Average or medium concentration (µg/l)	Reference
1. Oceans			
North Atlantic	unknown	0.00012-0.00050	Pearson and McConnell, 1975, Murray and Riley, 1975
Sweden : •. Arctic sea	1980	0.0069	Fogelqvist, 1985
2. Coastal waters and Estuaries			
Germany : • Ostsee	1983	< 0.010-0.16	Hellmann, 1984
• Nordsee	1983	> 0.010-0.43	Hellmann, 1984
• Unterweser, lowerpart (flow : 330 m^3/s)	1985-1987	0.050	Bohlen *et al*, 1989
• Elbe	1990 1993	0.820 < 0.010-0.240	De Rooij, 1994 Elbe Gütebericht, 1994
• Weser	1993	0.0009-0.020	Weser Güterbericht, 1993
The Netherlands : • Rhine-Meuse estuary	1983-1984	0.009 0.090	Van de Meent *et al*, 1986
• Meuse estuary	1992	0.42	RIZA, 1994
• Rhine estuary	< 1993	0.0013-0.47	Krysemm et al., 1993
• Schelde estuary	1993	0.870	De Rooij, 1994

BACKGROUND LEVELS OF TETRACHLOROETHYLENE IN NATURAL SURFACE WATERS

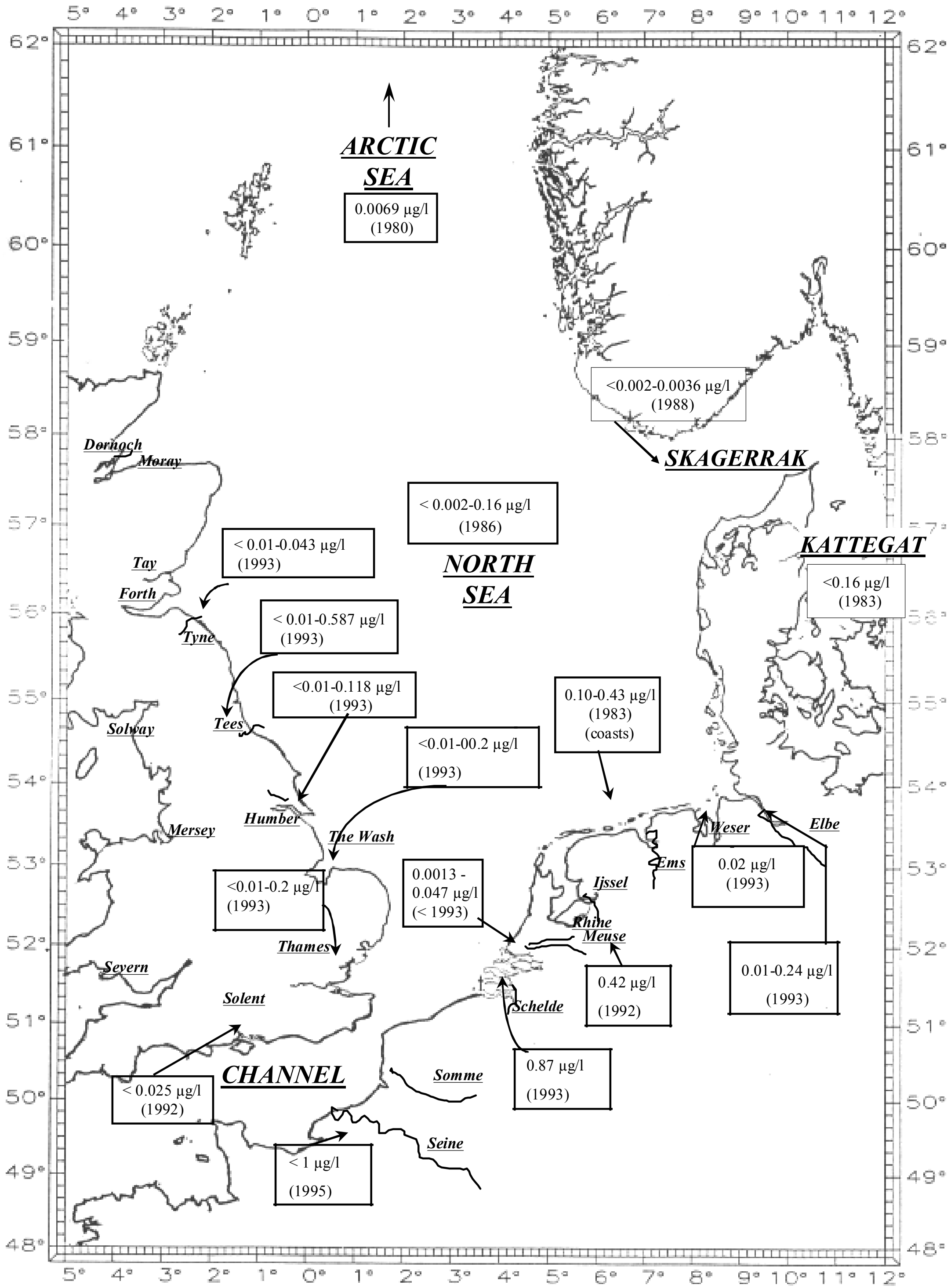
Area	Year of measurement	Average or medium concentration (µg/l)	Reference
2. Coastal waters and Estuaries			
Great-Britain : • Northsea	1986	< 0.002-0.16	Hurford et al., 1989
• Humber estuary	1993	< 0.01-0.118	MAFF, 1995
• Humber estuary	< 1993	0.00087-0.017	Krysell et al., 1993
• Humber estuary	1992	0.051-0.274	Dawes et al., 1994
• Tees estuary	1993	< 0.010-0.587	MAFF, 1995
• Tees estuary	1992	< 0.010-0.175	Dawes et al., 1994
• Tyne estuary	1993	< 0.010-0.0430	MAFF, 1995
• Tyne estuary	1992	< 0.025-0.0425	Dawes et al., 1994
• Poole, Southampton coasts	1992	< 0.025	Dawes et al., 1994
• Thames estuary	1993	< 0.01-0.2	MAFF, 1995
• Wash estuary	1993	< 0.01-0.02	MAFF, 1995
France : • Seine estuary	1995	< 1	Agence de Bassin, 1995

BACKGROUND LEVELS OF TETRACHLOROETHYLENE IN NATURAL SURFACE WATERS

Area	Year of measurement	Average or medium concentration (µg/l)	Reference
3. River waters			
Germany : • Rhine D/NL Border	1993	0.02-0.07	Rheinsbericht, 1995
• Rhine D/NL Border	1990	0.05-0.13	Rapport sur le Rhin, 1993
• Rhine D/NL Border	1986-1990	<0.2	Janus, 1994
• Rhine	1982-1984	0.1-0.5	Rippen, 1989
• Emscher, Main	1982-1984	1.3-2.5	Rippen, 1989
• Elbe	19988	0.17-0.87	Malle, 1990
• Rhine affluents, Main, Lippe, Ruhr, Wupper (mean flow : 730 m^3/s)	1989-1990	0.2-2.5	Wittsiepe, 1990
The Netherlands : • Rhine, Lobith	1991	0.05	RIVM, 1993
• Meuse, Eijsden (flow : 249 m^3/s)	1993	0.3	RIWA, 1995
• Meuse, Eijsden	1986-1990	< 0.4	Janus, 1994
• Meuse, Keizersveer (flow : 288 m^3/s)	1993	0.05	RIWA, 1995
France : • Loire	1983-1984	0.004-0.02	Marchand et al., 1986
Belgium : • Meuse	1992	0.4	De Rooij, 1994
• Meuse, Tailfer (flow: 159 m^3/s)	1993	0.1	RIWA, 1995

APPENDIX 5

NORTH SEA MONITORING DATA ON PERCHLOROETHYLENE



APPENDIX 6

REFERENCES FOR ECOTOXICITY DATA

Alexander, H.C., McCarty, W.M. Barlett, E.A. (1978); Toxicity of perchloroethylene, trichloroethylene, 1,1,1-trichloroethane and methylene chloride to Fathead minnows; Bull. Environ. Contam. Toxicology; 20:344-352

Bazin, C., Chambon, P., Bonnefille, M., Larbaigt, G. (1987); Compared sensitivity of luminescent marine bacteria (Photobacterium phosphoreum) and daphnia bioassays; Sciences de l'eau; 6:403-413

Brack, W., Rottler, H. (1994); Toxicity testing of highly volatile chemicals with green Algae; Env. Sci. Pollut. Res., 1 (4): 223-228

Broderius, S., Kahl, M. (1985); Acute toxicity of organic chemical mixtures to the Fathead minnow; Aquatic Toxicology; 6:307-322

Brooke, L.T. et al. (eds) (1985). Acute toxicities of organic chemicals to fathead minnows (Pimephales promelas), vol I, II and III. Center of Lake Superior Environmental Studies, University of Wisconsin-Superior. Quoted in RIVM 1993, report no. 679101.008.

Bringmann, G., Kuehn, R. (1982); Ergebnisse der Schadwirkung wassergefaehrdender Stoffe gegen Daphnia magna in einem weiterentwickelten standardisierten Testverfahren; Z. Wass. Abwass. Forsch.; 15: 1-6

Buccafusco, R.J., Ells, S.J., LeBlanc, G.A. (1981); Acute toxicity of priority of pollutants to Bluegill (Lepomis macrochirus); Bull. Environnm. Contam. Toxicol.; 26:446-452

Call, D.J., Brooke, L.T., Ahmad, N., Richter, J.E. (1983); Toxicity and metabolism studies with EPA priority pollutants and related chemicals in freshwater organisms; EPA 600/3-83-095, NTIS PB83-263665

EPA (1980); Ambient water quality criteria for tetrachloroethylene; EPA 440/5-80-073, NTIS PB81-117830

Erickson, S.J., Freeman, A.E.: Toxicity screening of fifteen chlorinated and brominated compounds using four species of marine phytoplankton; in: Jolley, R.L., Gorchev, H., Hamilton, D.H. Jr., Editors; Water Chlorination Environmental impact and health effects; Proc. of the second Conf. Gatlinberg, Tennessee, October 31 - November 4, 1977; Volume 2: 307-310; Ann. Arbour Science Publishers (1978)

APPENDIX 6

Erickson, S.J., Hawkins, C.E. (1980); Effects of halogenated organic compounds on photosynthesis in estuarine phytoplankton; Bull. Environ. Contam. Toxicol.; 24: 910-915

Heitmuller, P.T., Hollister, T.A., Parrish; P.R. (1981); Acute toxicity of 54 industrial chemicals to Sheepshead minnows (Cyprinodon variegatus); Bull. Environm. Contam. Toxicol.; 27: 596-604

Knie, J., Haelke, A., Juhnke, I., Schiller, W. (1983); Ergebnisse der Untersuchungen von chemischen Stoffen mit vier Biotests; Deutsches gewässerkundliche Mitteilungen; 3: 77-79

Koenemann, H. (1981); Quantitative structure-activity relationships in fish toxicity studies. Part 1: relationships for 50 industrial pollutants; Toxicology; 19: 209-221

Lay, J.P., Schauerte, W., Klein, W., Korte, F. (1984); Influence of tetrachloroethylene on the biota of aquatic systems: toxicity to phyto-and zooplankton species in compartments of a natural pond; Arch. Environm. Contam. Toxicol; 13: 135-142

LeBlanc, G.A. (1980);Acute toxicity of priority polluants to water flea (Daphnia magna);Bull. Environ. Contam. Toxicol.;24(5):684-691

Loekle, D.M., Schecter, A.J., Christian, J.J. (1983); Effects of chloroform, Tetrachloroethylene and trichloroethylene on survival, growth and liver of Poecilia Sphenops; Bull. Environ. Contam. Toxicol.; 30: 199-205

Pearson, C.R., McConnell, G., (1975);Chlorinated C1 and C2 hydrocarbons in the marine environment;Proc.Roy.Soc.London;B89:305-322

Richter,J.E.., Peterson,S.F., Kleiner, C.F. (1983);Acute and chronic toxicity of some chlorinated benzenes, chlorinated ethanes and tetrachloroethylene to Daphnia magna; Arch. Environ. Contam. Toxicol.;12:679-684

Smith, A.D., Bharath,A., Massard,C., Orr,D., Smith,K., Sutton,J.A., Vukmanish,J., McCarty,L.S., Ozburn, G.W. (1991)The acute and chronic toxicity of ten chlorinated organic compounds to the American flagfish (Jordanella floridea); Arch. Environ. Contam. Toxicol., 20:94-10

Shubat, P.J., Poirier, S.H., Knuth,M.L., Brooke,L.T. (1982);Acute toxicity of tetrachloroethylene and tetrachloroethylene with dimethylformamide to Rainbow trout (Salmo gairdneri); Bull.Environ.Contam. Toxicol.28:7-10

Trénel, J. (1982), UFO-Plan 102 04 059, Forschungsbericht FB 80-175, Umweltbundesamt

APPENDIX 6

Walbridge;C.T., Fiandt,J.T., Phipps,G.L., Holcombe,G.W. (1983);Acute of ten chlorinated aliphatic hydrocarbons to the Fathead minnow (Pimephales promelas);Arch.Environ. Contam. Toxicol.; 12:661-666

Yoshioka, Y., Ose, Y., Sato, T. (1986); Correlation of the five test methods to assess chemical toxicity and relation to physical properties; Ecotoxicolo. Environm. Saf; 12(1): 15-21

APPENDIX 7

REFERENCES FOR MONITORING DATA

Aandachtstoffen in het Nederlandse Milieubeleid-Overzicht 1994 - J.A. Janus, J.M. Hesse, MGJ Rikken Ets Nov 1994 - Report N°601014006 van Rijksinstituut voor Volksgezondheid en milieuhygiene - Bilthoven

Agence de Bassin Seine-Normandie (1995)

Arbeitsgemeinschaft zur Reinhaltung der Weser Güteberict 1993 - Published 1994

Bohlen, H., Hicke, K., Stoebel, A.O., Zierott, M., Thiemann, W. (1989); Die Belastung der Unterweser in bremischen Raum mit Halogenorganika und Phosphorsäureestern 1.; Vom Wasser, 72 : 185-197

C. de Rooij - The impact of waste water from the chemical industry on the quality of the marine environment - Changes with time - Paper presented at "10 years Belgica" Symposium Ostend, 17-19 Oct. 1994

Dawes, V.J., Waldock, M.J. (1994); Measurement of Volatile Organic Compounds at UK National Monitoring Plan stations; Marine Pollution Bulletin, 28 (5): 291- 298

Deutsche Kommission zur Reinhaltung des Rheins Zahlentafeln der physikalish-chemischen Untersuchungen 1993 - Bericht Oct 1995 ISSN0173-1653

Fogelqvist , E.(1985): Carbon tetrachloride, tetrachloroethylene, 1,1,1-trichloroethane and bromoform in Arctic sea water; Journal of Geophysical Research, C: Oceans, 90 (C5): 9181-9193

Gewässergütebericht Elbe 1993 mit Zahlentafeln Ed. Internationale Kommission zum Schutz der Elbe, Magdeburg Nov 1994, Author: Dr. H. Reincke

Hellmann, H. (1984); Leichtfluechtige Chlorkohlenwasserstoffe den Gewaessern der Bundesrepublik Deutschland-Auftreten und Bilanz. Haustechnik-Bauphysik-Umwelttechnik-Gesundheits-Ingenieur, 105:269

Hurford, N., Law, R.J., Payne, A.P., Fileman, T.W. (1989); Concentrations of chemicals in the North Sea arising from discharges from chemical tankers; Oil Chem. Pollut., 5: 391-410

Krysell, M., Nightingale, P.D. (1993); Low molecular weight halocarbons in the Humber and Rhine estuaries determined using a new purge and trap gas chromatographic method; Continental Shell Research

Malle, K.G. (1990); Vergleich von Elbe und Rhein, Gegenueberstellung der Guetedaten, UWSF-Z. Umweltchem. Oekotox., 2: 92-96

Marchand, M., Caprais, J.C., Tronczynski, J., Marty, J.C., Scribe, P., Saliot, A. (1986): Processus de transport et flux des hydrocarbures et hydrocarbures halogénés dans

APPENDIX 7

l'estuaire de la Loire; Rapp. P.V. Réun. Cons. int. Explor. Mer., 186: 361-374

Murray, A.J., and Riley, J.P. (1973); The determination of chlorinated aliphatic hydrocarbons in air, natural waters, marine organisms and sediments; Nature; 242: 37-38

Pearson, C.R., McConnell, G. (1975); Chlorinated C1 and C2 hydrocarbons in the marine environment; Proc. Roy. Soc London, B. 189: 305-332

Rapport sur l'Etat du Rhin - Analyses physico-chimiques et biologiques jusqu'en 1991 - CIPR Sept 1993

Rippen (1989), Handbuch Umweltchemikalien: ECOMED (1992)

RIVM (1993); Monitoring of radioactivity and xenobiotic substances in the environment; The Netherlands, 1991

RIWA (1995); Association des Services d'Eau du Rhin et de la Meuse; Tome B: Meuse 1993; Amsterdam, 1995

RIZA - (1994/Nota N94.005). Resultaten van het waterkwlaliteitsonderzoek in de Maas in Nederland - 1978 - 1992. Directoraat Generaal Rijckswaterstaat

Van de Meent, D., Den Hollander, H.A., Pool, W.G., Vredenbregt, M.J., Van Oers, H.A.M., De Greef, E., Luyten, J.A. (1986); Organic micropollutants in Dutch coastal waters; Water Sci. Technol., 18: 73-81

Wittsiepe, J. (1990); Poster presented at DIOXIN 90, Bayreuth: Occurrence of vinyl chloride and other halogenated C1- and C2 hydrocarbons in German surface water