Biodegradation Default Half-Life Values in the Light of Environmentally Relevant Biodegradation Studies

Analysis of the ECETOC Biodegradation Data Base

Technical Report No. 129

EUROPEAN CENTRE FOR ECOTOXICOLOGY AND TOXICOLOGY OF CHEMICALS

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Guidance for Effective Use of Human Exposure Data in Risk Assessment of Chemicals

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SUMMARY

The ECETOC biodegradation database contains a useful compilation of biodegradation data, generated under environmentally realistic conditions and published in peer review journals in the years between 1976 and 2006. A total of 853 entries cover 143 different chemicals. With 29 chemicals and 243 data points, the data for the freshwater compartment reflect a dense set of information on biodegradation behaviour and corresponding half-life data of chemicals. For the 12 substances categorised as 'readily biodegradable', an overall median half-life of 1.95 days can be calculated. Substance specific half-life median values span from 0.9 to 11.4 days, whereas individual chemical half-lives range from 0.3 days up to 150 days for these readily biodegradable substances, reflecting the variability in test designs, *inoculum* characterisation and temperature regimes.

In summary, the analysis of the data generated within the freshwater compartment shows that the 15-day half-life default value is a conservative value for modelling the fate and exposure of readily biodegradable chemicals in the aquatic environment. Closer inspection of the data reveals that longer half-lives resulted from inoculants taken from pristine environments with reduced degrader communities and lower nutrient levels. This finding indicates the need for a discussion of the use of one single default half-life for all substances and all freshwater environments.

1. INTRODUCTION

Modelling the environmental fate of chemicals for risk assessment ideally requires chemical-specific input data, which normally are generated during laboratory experiments. As such, forecasts about the chemical's fate and behaviour are possible, and used in estimating environmental exposure, a key step in chemical risk assessment. Parameters like the half-life of a chemical can be derogated/predicted from (lab) biodegradation studies.

Some biodegradation studies, and especially the tests for 'ready biodegradability'[1] , however, have not been designed to predict generic half-lives in the environment. The principal ideas of these tests originate from testing surfactants in respect to their (primary) biodegradability, and the basic intention to develop a pass level indicative of rapid biodegradation (loss of foaming properties) in the environment.

Under the umbrella of the OECD, a series of laboratory-based biodegradation tests have been developed and established, which cover a test regime from very stringent screening conditions to more environmentally realistic behaviour.

The test systems with stringent test conditions are summarised as tests for 'Ready biodegradability' and are grouped in the OECD 301 A-F, 306, 309 and 310 guidelines[2]. Again, the intention was to develop pass/fail criteria (for definition see Annex I) for biodegradability in order to allow for legal classification and labelling[3], and as such the tests are as much standardised as reasonable and practical.

It is widely accepted that a chemical passing the stringent conditions of an OECD Ready biodegradability test system is assumed to be non-persistent in the environment, as it will biodegrade under a broad variety of different environmental conditions. For modelling purposes, a default half-life of 15 days in fresh water had been set for chemicals categorised as 'readily biodegradable'.

The following report analyses a biodegradation database[4] generated by ECETOC from published literature. The ECETOC database comprises biodegradation studies (and derived half-lives) for the aquatic environment, from freshwater to marine conditions. This analysis compares critically biodegradation half-lives generated under a variety of environmentally more realistic conditions, e.g. *in situ* testing and laboratory tests with *inocula* taken from characterised locations and tested under non-standard ready-test conditions, with the recent default settings. The focus is on chemicals, which are categorised as 'readily biodegradable' in fresh water.

All biodegradation data originate from the ECETOC Data Base, which also includes the literature citations. Only in a few cases, specific literature citations are added directly (Annex III, IV, and V).

[1] For definition refer to Appendix I.

[2] OECD 301 A-F Ready Biodegradability; OECD 306; OECD 309; OECD 310.

[3] http://echa.europa.eu/web/guest/regulations/clp/legislation

[4] ECETOC Biodegradation Data Base, Excel file (ECETOC, 2009).

1.1 Terms of Reference

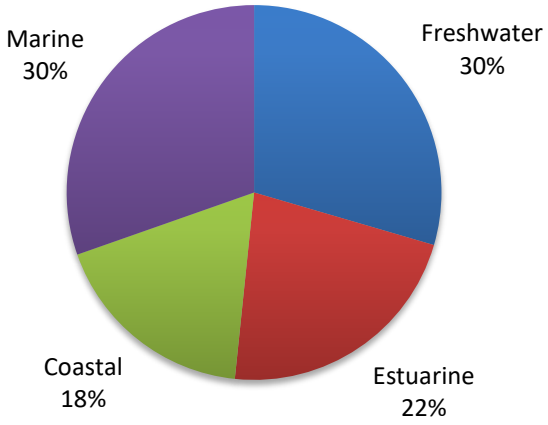
The work is based on the following Terms of Reference (ToR):

- Analyse the ECETOC biodegradation data base;
- Analyse the data generated for the freshwater compartment;
- Extract half-life data for chemicals categorised as ‘readily biodegradable’;
- Compare half-life data with default settings;
- Develop a recommendation for revisiting default values;
- Outlook.

2. THE ECETOC BIODEGRADATION DATABASE: GENERAL ASPECTS

The ECETOC biodegradation database is a compilation of data published in peer-reviewed journals between 1976 and 2005, complimented with a few industry internal GLP data sets. The data cover all aquatic compartments from freshwater to the marine environment. Around one third of the data are for the marine and freshwater compartment, respectively. Estuarine and coastal data account for 22% and 18% of the entries, respectively (Figure 1).

Figure 1: ECETOC biodegradation data base; Compartment allocation



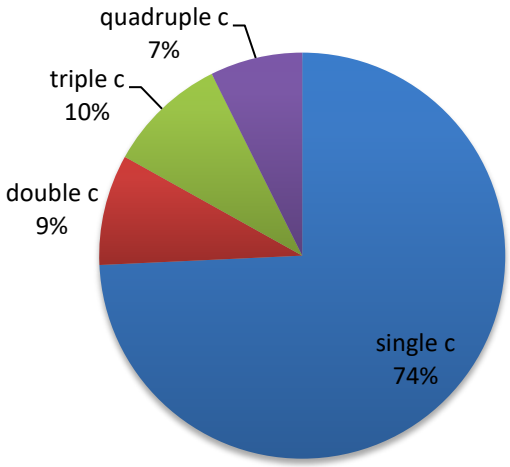
While the freshwater compartment has the largest data set (i.e. 243 measurements), it has the lowest total number of chemicals tested (Table 1) with an average of 9 data points per chemical. Entries for the marine environment have a comparable number of data, but double the number of chemicals. For the estuarine and coastal environment, the number of chemicals with biodegradation data is comparable to the marine data pool; however, the number of records is much lower, resulting in an even lower information density per chemical. It should be noted that these numbers are averages, the spread spans from a single data point per chemical up to 23 different data points per chemical (more details are given for the freshwater data in the following chapter and Annex II).

Table 1: ECETOC Biodegradation Data Base; compartment specific entries and number of chemicals

Compartment	No. of records	No. of chemicals	Information density
Freshwater	243	29	≈ 9
Estuarine	182	57	≈ 3
Coastal	148	54	≈ 3
Marine	250	64	≈ 4

The majority of the chemicals have been tested in a single compartment only (Figure 2), and only for 10 chemicals biodegradation data cover all four aquatic environments.

Figure 2: ECETOC Biodegradation Data Base; frequency of chemicals in the compartments



3. THE ECETOC BIODEGRADATION DATA BASE: FRESHWATER DATABASE

Biodegradation behaviour had been tested under a variety of freshwater conditions. The bacterial *inoculum* employed in the various test systems originates from a variety of environments, from remote lakes or upper stretches of rivers with little or no assumed human impact to *inoculum* sources, from middle reaches of rivers or even sewage treatment plants. The latter are representative of an environment with more or less anthropogenic influence. In addition, *inoculum* sampling at various seasons, i.e. temperature regimes, had been taken into consideration.

There are 29 chemicals for which there are data in the ECETOC biodegradation database. From these 29 chemicals, 12 can be categorised as 'readily biodegradable'. Table 2 summarises this list, differentiating between 'readily' and 'not readily biodegradable' categories.

Table 2: ECETOC Biodegradation Data Base – freshwater compartment; categorisation of chemicals in respect to their biodegradation behaviour

Readily biodegradable	Not readily biodegradable
2–chlorophenol	1,2,4–trichlorobenzene
AEO C12EO9	2–methyl naphthalene
AEO C16EO3	2,4–dichlorophenol
Amino Acids	4–chloroaniline
Aniline	4–nitro phenol
Benzoic Acid	Benzene
Chlorobenzene	Benzo (a) pyrene
LAS	Di–bromomethane
m–cresol	Hexadecane
Naphthalene*	Methyl bromide
NTA	Methyl parathion
Phenol	Nonylphenol
	Octylphenol
	Phenantrene
	Pyrene
	Toluene

* CoRAP 2016, no conclusive position in ECHA registration dossier.

The frequency of data points for each of the chemicals ranges from one record per chemical up to 23 input data. Figure 3 summarised these aspects. Phenol, aniline and naphthalene are the chemicals with the highest number of data points (entries), followed by a group of surfactants, i.e. LAS and two different alkyl ethoxylates (AEO). The remaining entries range between 1 and 6 data points per chemical.

Figure 3: ECETOC Biodegradation Data Base – Freshwater; data frequency for chemicals categorised as 'readily biodegradable'

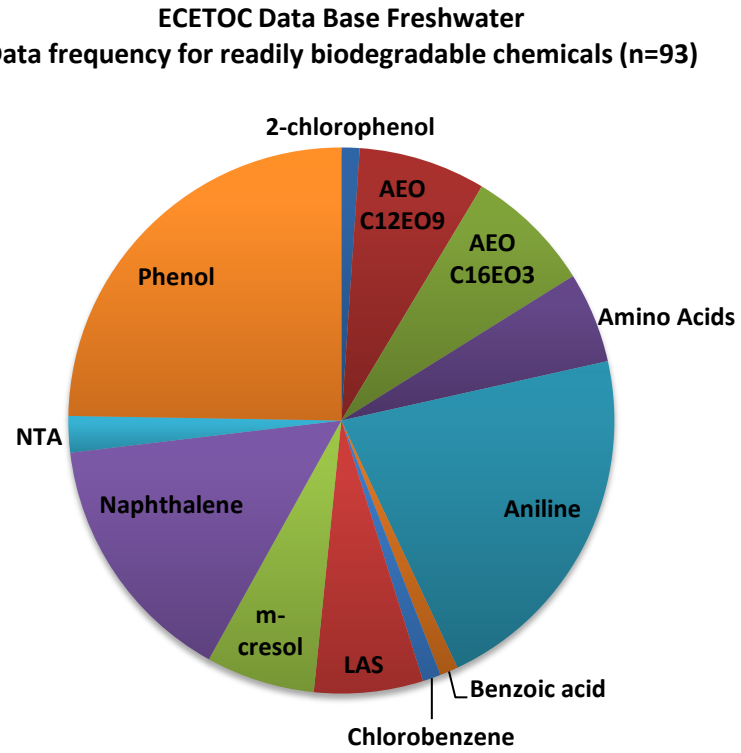


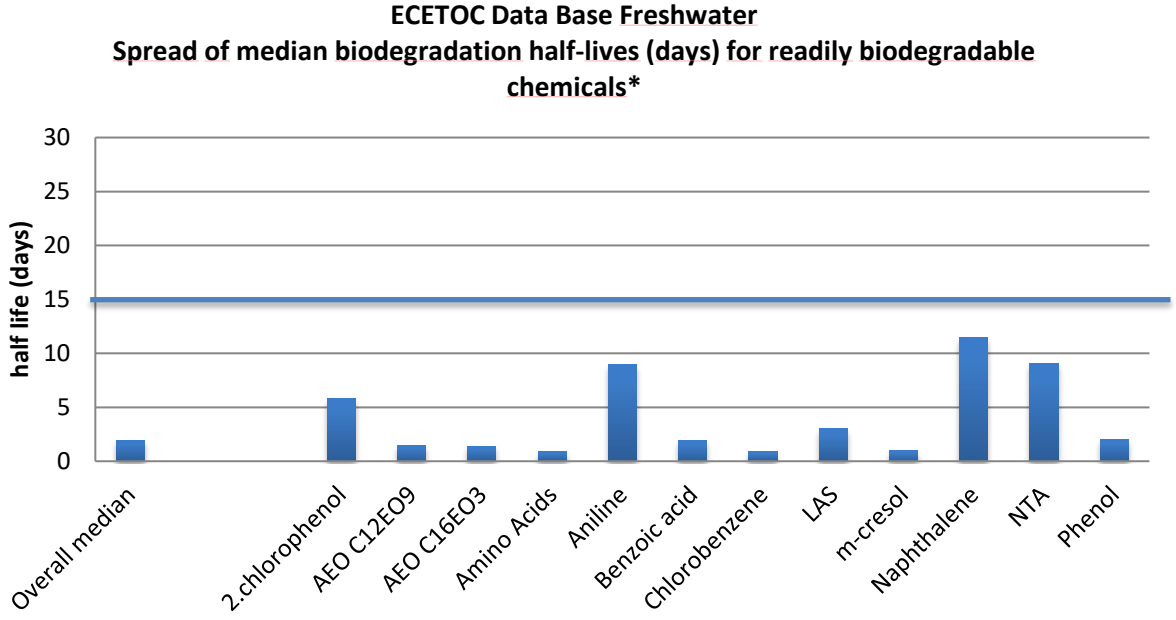
Table 3 summarises the number of data points, the range of the individual half-lives and the resulting median value. All individual values for each of the chemicals can be found in Annex II. Based on the individual half-life data, the median values were calculated for further analysis. Median values were chosen because they are most robust against outliers and extreme values.

Table 3: ECETOC Biodegradation Database – Freshwater; Half-life median values for readily biodegradable chemicals

Substance	t ½ (days) median	Number of entries	Range of t ½ data
2-chlorophenol	5.8	1	-
AEO C12EO9	1.5	7	1 – 2.8
AEO C16EO3	1.4	7	1.2 – 1.8
Amino Acids	0.9	5	0.03 – 9.6
Aniline	9	20	0.3 – 150
Benzoic acid	1.9	1	-
Chlorobenzene	0.9	1	-
LAS	3	6	0.75 - 14
m–cresol	1	6	0.7 – 3.7
Naphthalene	11.4	14	0.21 - 44
NTA	9.1	2	0.6 – 17.5
Phenol	2	23	0.125 – 11.55
Overall	1.95		

The overall median half-life value derived from all substances categorised as readily biodegradable is 1.95 days, and well below the 15 days default setting. The values range from 0.9 days (for chlorobenzene and amino acids) up to 11.4 days (for naphthalene). None of the substance-specific median values exceed the 15-day half-life default value for readily biodegradable substances (Figure 4). A potential new 10-day half-life default value is only exceeded by a single substance, i.e. naphthalene.

Figure 4: ECETOC Biodegradation Database – Freshwater; Half-life median values for readily biodegradable substances



From the data in Table 3 as well as from the individual data given in Annex II it can be seen, that even for substances undoubtedly considered as 'readily biodegradable', like aniline, individual half-life values can be much higher than the 15-day default value given in the REACH guidance documents.

A more in-depth analysis of the data for aniline, phenol, and LAS reveals that the longer half-life values (exceeding the default value) are predominately associated with the source of the bacterial *inoculum*.

Experiments with *inoculum* from more 'pristine' sources, though spreading over the whole range of measured data, tend to lead to results at the upper range of the data spread. Such type of *inoculum* is representative of conditions characteristic of the upper more oligotrophic stretches of rivers. It covers a variety of different aspects such as the absence of (grand) human impact, lower levels of mineral nutrients, and a low numbers of bacterial counts. In essence, it can be assumed that the overall lower abundance in connection with potentially reduced diversity and variability, leads to prolonged 'adaptation' processes. Degrading pathways can be rather complex and often require more than a single strain of degraders. In addition, different biodegradation pathways may exist in different species, likewise leading to longer half-lives, due to insufficient species present or because the abundance of competent species is low.

Overall, the resulting lower abundance of competent degraders can be regarded as the most rational explanation for prolonged half-lives experienced under such 'pristine' conditions.

Under these pristine conditions, time-consuming adaptation processes can be stimulated, resulting in a prolonged lag phase before the biodegradation actually begins. Additionally, in some cases low water solubility can result in lower bioavailability, likewise potentially resulting in prolonged half-lives.

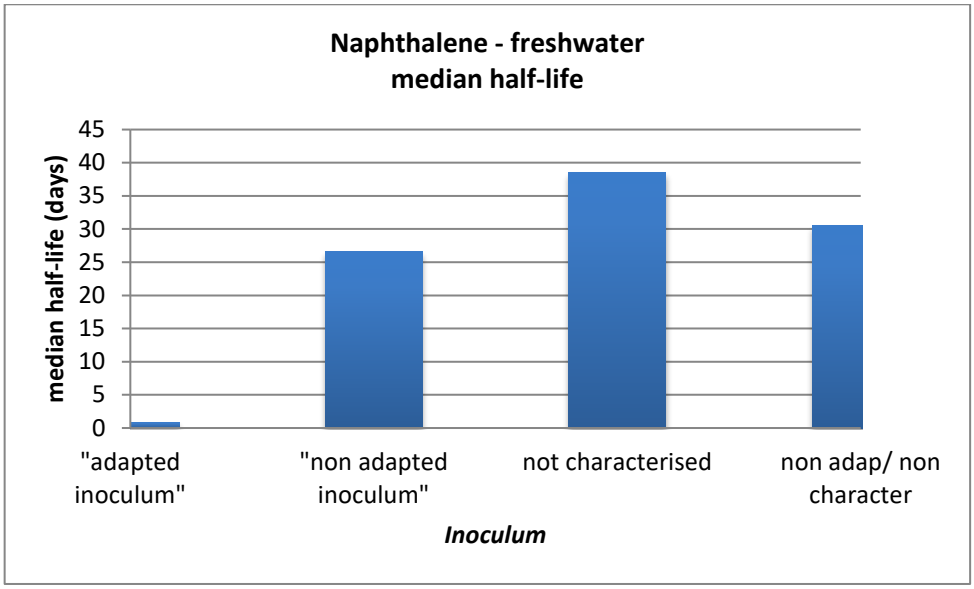
In essence, a reduced diversity including a reduced probability of competent organisms in the *inoculum* seems to be at the core of prolonged half-lives for readily biodegradable substances. Detailed data are given in Annex III for aniline, in Annex IV for LAS, and in Annex V for phenol.

The shorter half-lives are generated with *inoculum* sources, which are more representative of environmental conditions characteristic for the middle reaches of rivers. Higher nutrient levels, a broader diversity of the degrader community, often in association with higher bacterial numbers, are normal features of such environments. Additionally, anthropogenic influences can interfere with these features.

Regarding naphthalene according to the publicly accessible ECHA REACH registration dossier, there is no doubt that naphthalene is biodegradable. Whether or not it falls under the definition of a 'readily biodegradable' substance remains open[5]. Test results on biodegradation are conflicting. An in-depth examination of the literature for naphthalene in the ECETOC biodegradation database reveal that the half-life data are dependent on the source of *inoculum* being employed, with considerably shorter half-lives in studies using an adapted *inoculum* (Figure 5).

[5] ECHA Naphthalene (http://www.echa.europa.eu/web/guest/brief-profile/-/briefprofile/100.001.863)

Figure 5: ECETOC Biodegradation Data Base – Freshwater; correlation between* inoculum *source and median half-life data for naphthalene



Naphthalene falls under the CoRAP 2016 [6]listing, and will be dealt with by the UK Competent Authorities.

[6] http://www.echa.europa.eu/web/guest/information-on-chemicals/evaluation/community-rolling-action-plan/corap-table/-/dislist/details/0b0236e1807eabad

4. CONCLUSIONS

In environmental fate modelling, biodegradation half-life values for substances categorised as readily biodegradable are set to 15 days as an overall default value. Based on 'real world' half-life data for readily biodegradable substances, an overall half-life as low as 1.95 days can be calculated. This is nearly an order of magnitude lower than the set default value laid down in the ECHA guidance documents. Based on chemical specific half-life data, the corresponding median values never exceed the currently employed 15 days default value. At the same time, looking at the distribution of half-lives in individual data sets, less than 20% of these data demonstrate longer half-life values. This interpretation also holds true for a potential 10-day default value, with the exception of naphthalene (see discussion on naphthalene).

Table 4: ECETOC Biodegradation Data Base – Freshwater; Comparison between half-life default settings and measured half-life data

Default half –life (days)	Margin*	Exceedance of default (%) Median Values	Exceedance of default (%) Ind. Values	Comments
15	5	≈ 0 %	≈ 17 %	Protective
10	3	≈ 10 %**	≈ 19 %	Protective
5	2	≈ 30 %	≈ 30 %	Not protective

* Assuming a ln –normal relationship within the 10-day window (→ t ½ = 3.2 days)

** Naphthalene (t ½ = 11.64 days)

Assuming naphthalene does not fall under the definition of 'readily biodegradable' and based on the substances assessed in the ECETOC biodegradation database, a potential new 10-day default half-life value for fate modelling of readily biodegradable substances can be regarded as protective and reasonably conservative. Further reduction to lower values, however, does not seem to be justifiable.

In summary, the ECETOC Biodegradation Data Base encompasses environmentally realistic biodegradation data for the aquatic environment. Analysis of the data generated within the freshwater compartment shows that for chemicals unequivocally categorised as 'readily biodegradable' lowering the currently employed default half-life value from 15 days to 10 days would not be unreasonable. A 10-day default value can be considered as realistic, and at the same time guaranteeing the same level of protection.

5. OUTLOOK

The 15-day half-life default value is a conservative value for modelling the fate and final levels of readily biodegradable chemicals in the aquatic environment. The data from the ECETOC database suggest that the currently employed default value could be replaced by a 10-day default value without compromising on the reliability of the resulting final level in the modelling process. This is especially true if the target compartment meets the environmental conditions as represented in the middle stretch of rivers.

Though unequivocal, however, this conclusion is backed by a limited number of 'real world' biodegradation data, and more evidence might be needed as follow up.

Longer half-lives in the environment are limited to pristine environments with its reduced degrader communities and lower nutrient levels. Whether or not a generic default value setting must necessarily also satisfy the needs of these remote environments can be argued. Though there seems to be some benefit in employing a single default value to cover for all possibilities, the disadvantage of such a generic approach is evident, too: overly conservative in some cases, and still not covering all extreme environmental conditions. A more sophisticated and more specific approach could overcome this discrepancy, allowing as much safety, reliability and certainty as needed under environmentally distinct specific circumstances.

One option is to calculate substance specific half-life data based on controlled and high quality lab biodegradation studies. These in turn then serve as the base value for modelling exposure concentrations in the environment. Compartment-specific assessment factors can be employed to safely cover specific environmental conditions, without being unreasonably conservative for other situations. A compartment-specific numerical value for such individualised assessment factors, however, is still vague and needs to be generated on a sound and reliable basis.

APPENDIX I (DEFINITIONS)

Test for the determination of 'ready biodegradability'

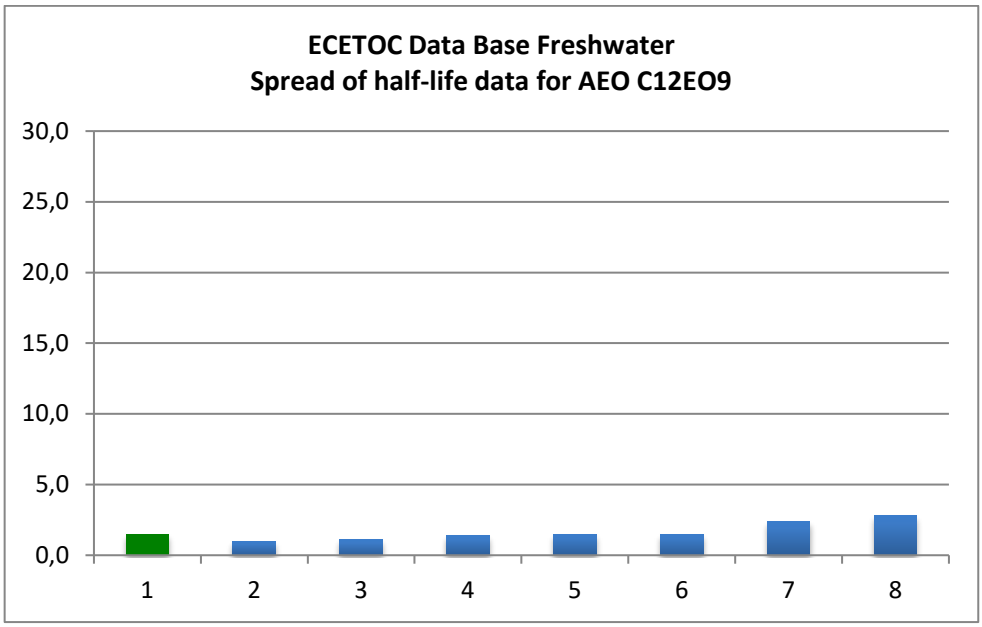
Stringent screening tests are conducted under aerobic conditions, in which a high concentration of the test substance (in the range of 2 to 100 mg/L) is used and biodegradation is measured by non-specific parameters like Dissolved Organic Carbon (DOC), Biochemical Oxygen Demand (BOD) and CO_2 production. Domestic sewage, activated sludge or secondary effluent is the typical source of microorganisms (*inoculum*) in tests for ready biodegradability. The *inoculum* should not have been pre-adapted to degradation of the test substance by previous exposure to the test substance or structurally-related chemicals. A positive result in a test for ready biodegradability can be considered as indicative of rapid and ultimate degradation in most environments including biological STPs.

The pass levels for ready biodegradability are 70% removal of DOC and 60% of ThOD or $ThCO_2$ production for respirometric methods. These pass values have to be reached in a 10-day window within the 28-day period of the test, except where mentioned below. The 10-day window begins when the degree of biodegradation has reached 10% DOC, ThOD or $ThCO_2$ and must end before day 28 of the test. Chemicals, which reach the pass levels after the 28-day period, are not deemed to be readily biodegradable.

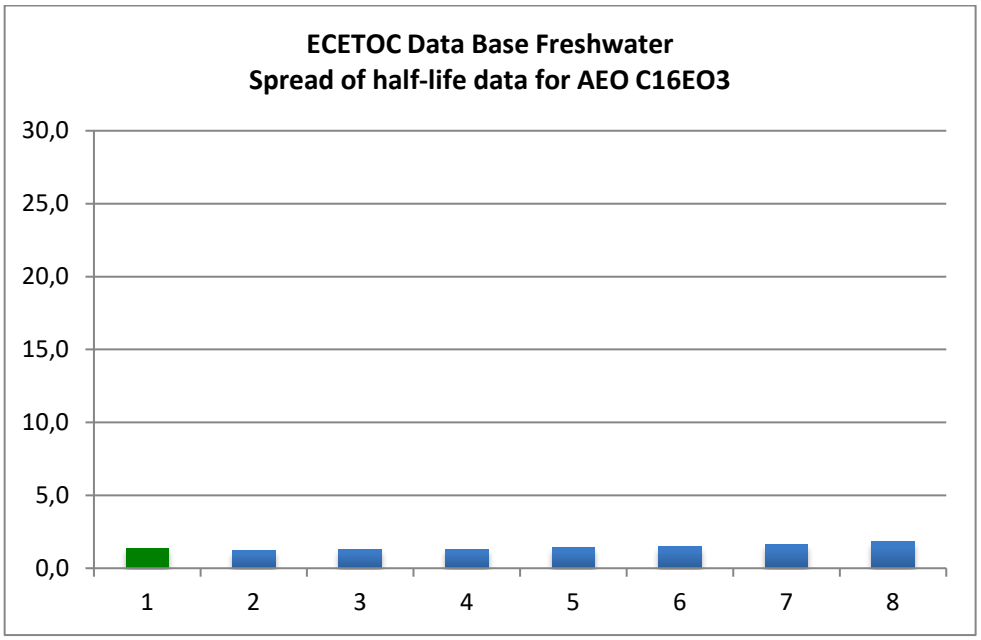
APPENDIX II (ECETOC BIODEGRADATION DATA BASE – FRESHWATER)

ECETOC Biodegradation Data Base – Freshwater; Individual half-life data for substances with more than one data point; the first entry (green bar) in each single graph represents the median half-life value.

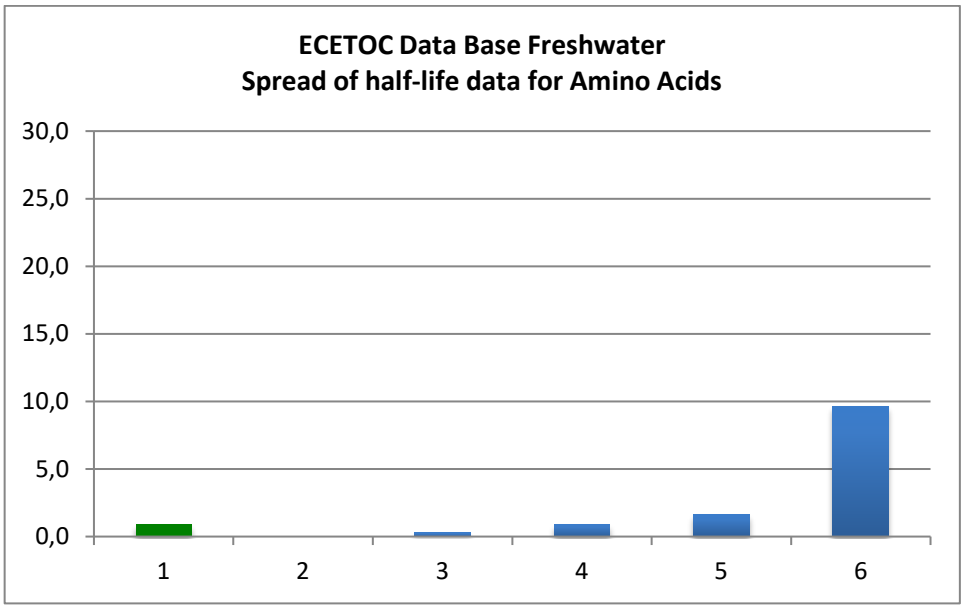
AEO C12EO9



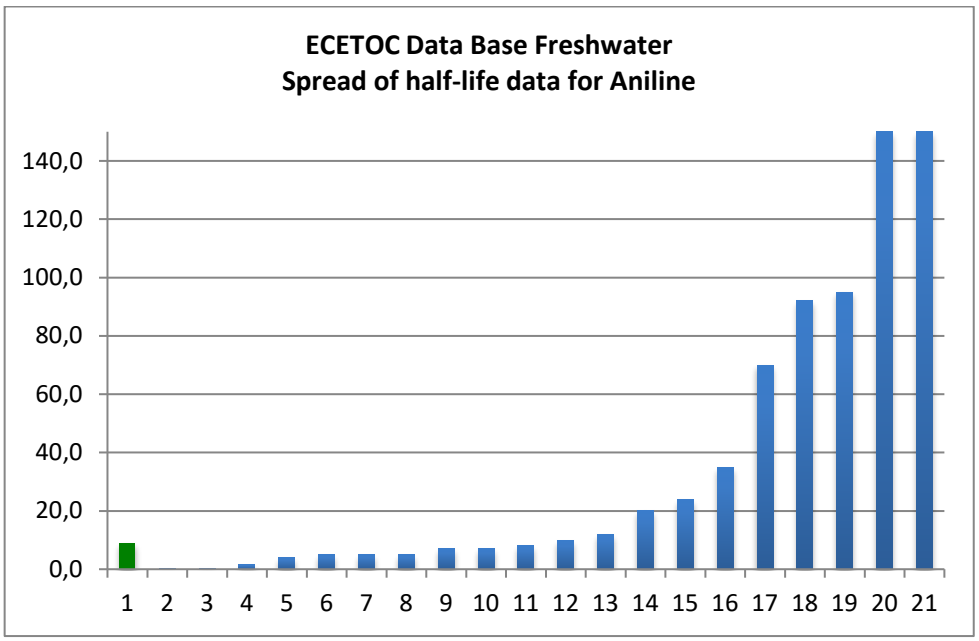
AEO C16EO03



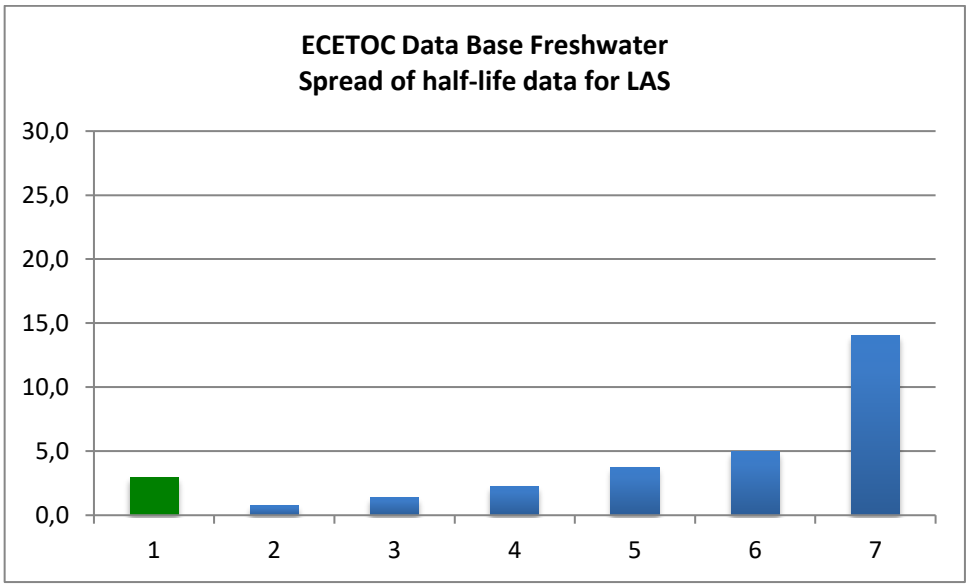
Amino Acids



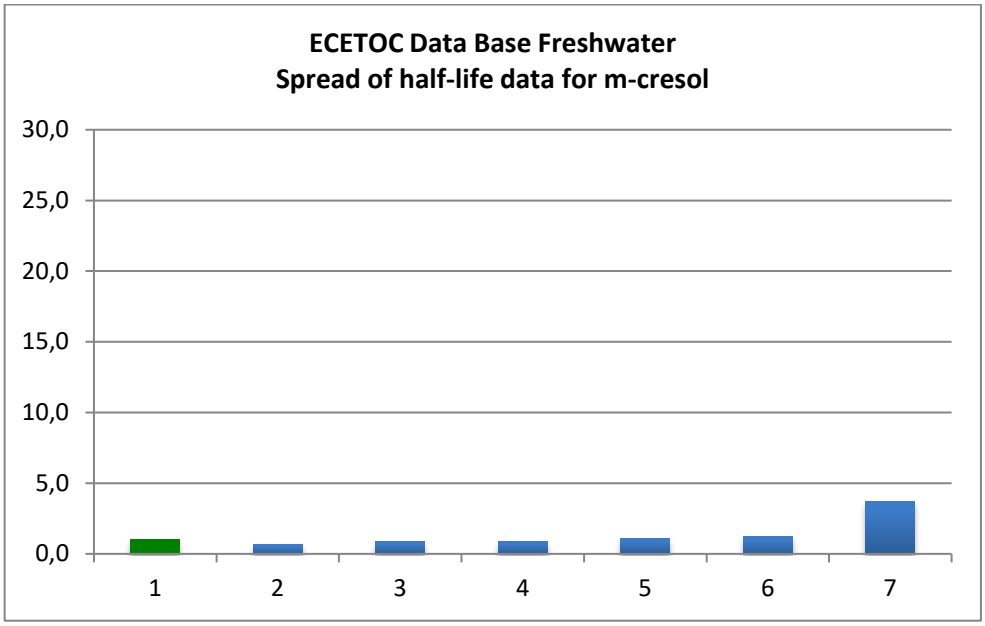
Aniline (more data in Appendix III)



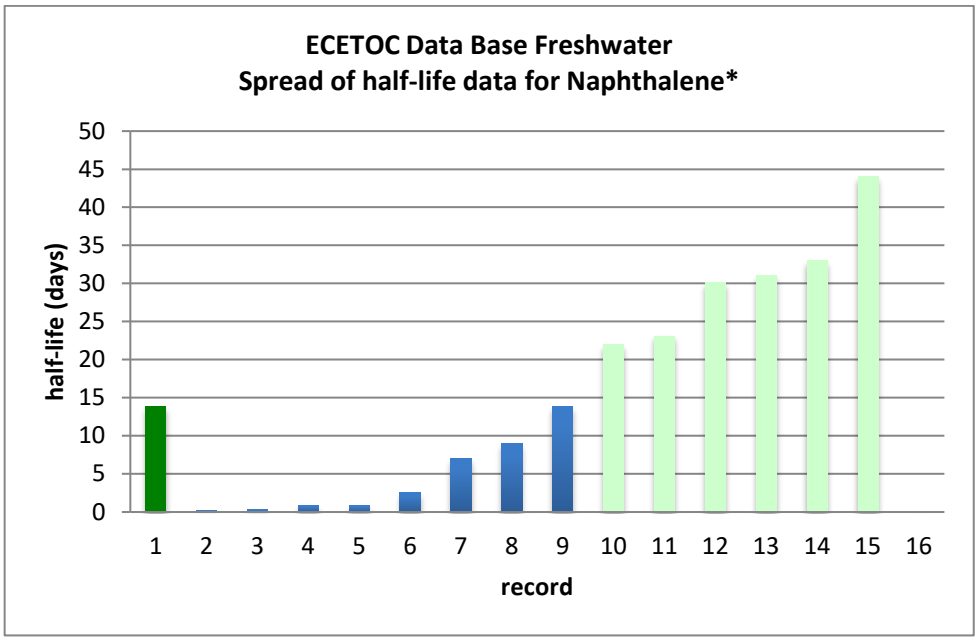
LAS (more data in Annex IV)



m-cresol

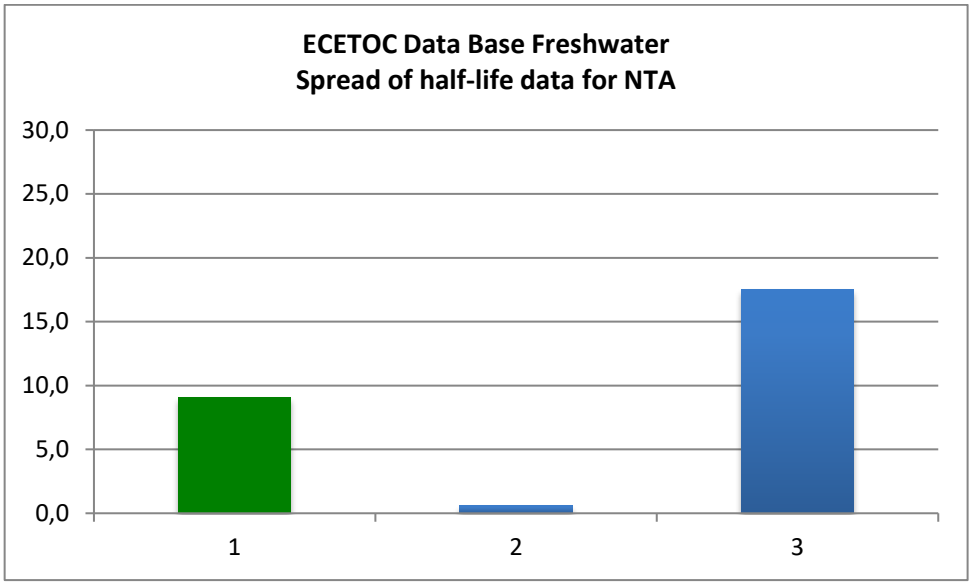


Naphthalene

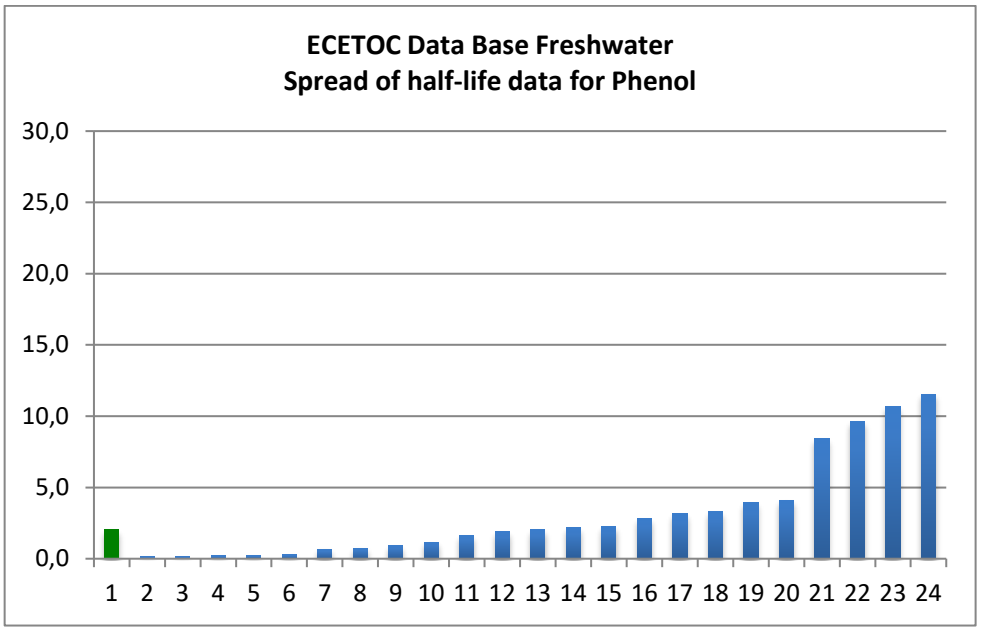


***** Green bars: data obtained with non-adapted / not characterised *inoculum*.

NTA



Phenol (more data in Annex V)



APPENDIX III (ANILINE BIODEGRADATION)

Generic remarks

Brackish water data had been summarised under the 'freshwater' compartment in the ECETOC Biodegradation database. This might be justified as the salinity in these specific areas is not much higher than 4-5 ‰, and unlike in estuaries, rather stable. This allows for the development of a rather autochthonous bacterial community, with mainly freshwater-based influences. Overall, excluding the brackish data does not make much of a difference in respect to the median value (increase from 9 → 10 days). In addition, the generic conclusions in respect to influencing factors do not change. For that reason, the brackish data are left in this freshwater data set!

Trends

- *Inocula* from pristine origin result in prolonged half-lives, irrespective of biomass and test item concentrations.

Half-life (days)	Biomass	Test Item Concentration	Temperature Gap	Remarks	Reference	*Inoculum* characterisation	Anthropogenic influence
150	Low	Low	No	Pristine, humus lake water	Ahtiainen et al, 2003	F	No
150	Low	Medium	No	Pristine river water	Ahtiainen et al, 2003	F	No
95	Low	High	NC	Pristine Baltic seawater	Ahtiainen et al, 2003	B	No
92	Medium	Low	Test >> sampling	Pristine river water	Ingerslev and Nyholm, 2000	F	No
70	Low	Low	Test > sampling	Pristine river water	Ahtiainen et al, 2003	F	No
35	Low	Medium	Test > sampling	Pristine river water	Ahtiainen et al, 2003	F	No
20	Low	Low		Pristine Baltic seawater	Ahtiainen et al, 2003	B	No
10	Low	Medium		Pristine Baltic seawater	Ahtiainen et al, 2003	B	No

- *Inocula* from sources with anthropogenic influence result in reduced half-lives, irrespective of biomass density and test item concentrations. Especially medium and high biomass densities are associated with an anthropogenic influence of the *inoculum* source. Under such conditions, a temperature difference between testing and sampling leads towards longer half-lives, i.e. the degrader population might be less versatile, given the additional temperature stress.

Half-life (days)	Biomass	Test Item Concentration	Temperature Gap	Remarks	Reference	*Inoculum* characterisation	Anthropogenic influence
24	Low	Low	Test >> sampling	January sampling	Ingerslev and Nyholm, 2000	F	Yes
12	Low	Low - medium	Test < sampling	August sampling	Ingerslev and Nyholm, 2000	F	Yes
10	Low	Low	Test >> sampling	April sampling	Ingerslev and Nyholm, 2000	F	Yes
8	Medium	High	No	Helsinki harbour	Ahtiainen et al, 2003	B	Yes
7	Medium	Medium	No	Helsinki harbour	Ahtiainen et al, 2003	B	Yes
7	Medium	Low	No	Helsinki harbour	Ahtiainen et al, 2003	B	Yes
5	High	Low	No	Inoculum STP	Ahtiainen et al, 2003	F	Yes
5	High	Medium	No	Inoculum STP	Ahtiainen et al, 2003	F	Yes
5	High	High	No	Inoculum STP	Ahtiainen et al, 2003	F	Yes
4	NC	Low	No	July sampling	Ingerslev and Nyholm, 2000	F	Yes
1.7	NC	NC	NC	Abstract only	Delépée et al, 2004	F	Yes
0.4	NC	Low - medium	No	River Rhine *inoculum*	Torang et al, 2002	F	Yes
0.3	NC	Low - medium	No	River Rhine *inoculum*	Torang et al, 2002	F	Yes

A high biomass as *inoculum* results in low half-lives, though this certainly is more associated with the anthropogenic influence of the source:

Half-life (days)	Biomass	Test Item Concentration	Temperature Gap	Remarks	Reference	*Inoculum* characterisation	Anthropogenic influence
5	High	Low	No	*Inoculum* STP	Ahtiainen et al, 2003	F	Yes
5	High	Medium	No	*Inoculum* STP	Ahtiainen et al, 2003	F	Yes
5	High	High	No	*Inoculum* STP	Ahtiainen et al, 2003	F	Yes

A low biomass as *inoculum* results in prolonged half-lives, though it seems obvious, that it is the anthropogenic influence, or better its absence, which leads to this trend:

Half-life (days)	Biomass	Test Item Concentration	Temperature Gap	Remarks	Reference	Inoculum characterisation	Anthropogenic influence
150	Low	Low	No	Pristine, humus lakewater	Ahtiainen et al, 2003	F	No
150	Low	Medium	No	Pristine river water	Ahtiainen et al, 2003	F	No
95	Low	High	NC	Pristine Baltic seawater	Ahtiainen et al, 2003	B	No
70	Low	Low	Test > sampling	Pristine river water	Ahtiainen et al, 2003	F	No
35	Low	Medium	Test > sampling	Pristine river water	Ahtiainen et al, 2003	F	No
20	Low	Low		Pristine Baltic seawater	Ahtiainen et al, 2003	B	No
10	Low	Medium		Pristine Baltic seawater	Ahtiainen et al, 2003	B	No

The influence of the test item concentration becomes evident only in combination with non-anthropogenic influence of the *inoculum*.

Half-life (days)	Biomass	Test Item Concentration	Temperature Gap	Remarks	Reference	*Inoculum* characterisation	Anthropogenic influence
95	Low	High	NC	Pristine Baltic seawater	Ahtiainen et al, 2003	B	No
8	Medium	High	No	Helsinki harbour	Ahtiainen et al, 2003	B	Yes
5	High	High	No	*Inoculum* STP	Ahtiainen et al, 2003	F	Yes

Overall conclusion

- *Inocula* from pristine environments result in prolonged half-lives. This may be explained by a reduced diversity of the (bacterial) degraders.
- Shorter half-lives are positively associated with the “anthropogenic” influence of the *inoculum*.
- Differences between (environmental) sampling temperature and testing temperature tend to prolong half-lives, resulting in a reduced diversity and/or versatility of the (bacterial) degrader community due to the temperature stress.
- Toxicity of the test item becomes evident with *inocula* from pristine environments, reduced diversity and variability being the explanation.

APPENDIX IV (LAS BIODEGRADATION)

General remarks

LAS data show short half-lives, irrespective of (assumed) biomass concentrations and test item levels. The only data point with a prolonged half-life is from pristine river water, a place which is located a couple of kilometres upstream of a sewage treatment plant at the Rapid Creek River. The corresponding value below the STP outlet shows a very short half-life of 1.4 days.

Half-life (days)	Biomass	*Inoculum*	Reference	Anthropological influence
14	Low	Pristine river water	Larson and Payne, 1981	No
4.94	Medium	River water	Henkel, 1998	Yes
3.7	Medium	River water	Henkel, 1998	Yes
2.25	NR*	NR	Van de Plassche and Feijtel, 1996	?
1.4	High	River water	Larson and Payne, 1981	Yes
0.75	NR	River water	Itrich and Federle, 1995	Yes

* Not reported.

APPENDIX V (PHENOL BIODEGRADATION)

General remarks and conclusions

The overall spread of half-life data for phenol spans from 11.55 days to 0.125 days. The *inoculum* sources have some influence on the distribution of data, though overlaps in half-life data are very obvious.

The published data do not allow a more in-depth analysis, and mostly keep vague on some of the aspects. Biomass data are normally not reported, but it can be assumed that the biomass is correlated to the source of the *inoculum*, i.e. low biomasses for pristine environments, and higher ones for more polluted sources. In addition, this might go hand in hand with the potential diversity of the degrader population. Though not in the database, a bacterial *inoculum* source from groundwater results in a phenol biodegradation half-life of 20 days (Vaishnav and Babeu, 1987), underpinning this assumption.

Overall conclusion

Prolonged half-lives for phenols are associated with *inoculum* sources with no or little assumed anthropogenic influences, resulting in a reduced variability of the degrader community. Biomasses of the inoculate have not been reported, but as for the variability of the degrader community, it can reasonably be assumed to be lower for pristine sources. Effects of test item concentration are not obvious.

Table 1: Phenol biodegradation data freshwater; all data from ECETOC Biodegradation database

Half-life (days)	Biomass*	Test Item Concentration	Source of *inoculum*	Reference	Anthropogenic influence**
11.55		Medium	Pristine pond	Paris and Rogers, 1986	No
10.66		Low/Medium	River water	Vaishnav and Babeu, 1987	No
9.625		Medium	Pristine pond	Paris and Rogers, 1986	No
8.45		Medium	Pristine pond	Paris and Rogers, 1986	No
4.08		High	Polluted river	Borighem and Vereecken, 1978	Yes
3.96		Medium	NC	Paris and Rogers, 1986	
3.3		High	Polluted river	Borighem and Vereecken, 1978	Yes
3.15		High	Polluted river	Borighem and Vereecken, 1978	Yes
2.81		Low/Medium	Lake water	Vaishnav and Babeu, 1986	Yes
2.23		High	NC	Portier, 1985	
2.16		High	Polluted river	Borighem and Vereecken, 1978	Yes
2.04		High	Polluted river	Borighem and Vereecken, 1978	Yes
1.9		High		Portier, 1985	
1.65		High	Polluted river	Borighem and Vereecken, 1978	Yes
1.17		High	Polluted river	Borighem and Vereecken, 1978	Yes
0.91		High	Polluted river	Borighem and Vereecken, 1978	Yes
0.75		High	Polluted river	Borighem and Vereecken, 1978	Yes
0.67		Low/Medium	Lake water	Vaishnav and Babeu, 1986	Yes
0.289		Medium	Pristine pond	Paris et al, 1983	No
0.239		Medium	Pristine pond	Paris et al, 1983	No
0.1925		Medium	Pristine pond	Paris et al, 1983	No
0.137		Medium	Pristine river	Paris et al, 1983	No
0.125		Medium	Pristine pond	Paris et al, 1983	No

* Not quantified in references; can be assumed to be low for pristine and medium for polluted environments – ** Estimated from *inoculum* source data

Table 2: Phenol biodegradation half-life data freshwater; Spread of half-life data generated with* inoculum *with no assumed anthropogenic influence

Half-life (days)	Biomass	Test Item Concentration	*Inoculum* Characterisation	Reference	Anthropogenic Influence
11.55		Medium	Pristine pond	Paris and Rogers, 1986	No
10.66		Low/Medium	River water	Vaishnav and Babeu, 1987	No
9.625		Medium	Pristine pond	Paris and Rogers, 1986	No
8.45		Medium	Pristine pond	Paris and Rogers, 1986	No
0.289		Medium	Pristine pond	Paris et al, 1983	No
0.239		Medium	Pristine pond	Paris et al, 1983	No
0.1925		Medium	Pristine pond	Paris et al, 1983	No
0.137		Medium	Pristine river	Paris et al, 1983	No
0.125		Medium	Pristine pond	Paris et al, 1983	No

Table 3: Phenol biodegradation half-life data freshwater; Spread of half-life data generated with* inoculum *with assumed anthropogenic influence

Half-life (days)	Biomass	Test Item Concentration	*Inoculum* Characterisation	Reference	Anthropogenic Influence
4.08		High	Polluted river	Borighem and Vereecken, 1978	Yes
3.3		High	Polluted river	Borighem and Vereecken, 1978	Yes
3.15		High	Polluted river	Borighem and Vereecken, 1978	Yes
2.81		Low/Medium	Lake water	Vaishnav and Babeu, 1986	Yes
2.16		High	Polluted river	Borighem and Vereecken, 1978	Yes
2.04		High	Polluted river	Borighem and Vereecken, 1978	Yes
1.65		High	Polluted river	Borighem and Vereecken, 1978	Yes
1.17		High	Polluted river	Borighem and Vereecken, 1978	Yes
0.91		High	Polluted river	Borighem and Vereecken, 1978	Yes
0.75		High	Polluted river	Borighem and Vereecken, 1978	Yes
0.67		Low/Medium	Lake water	Vaishnav and Babeu, 1986	Yes

ABBREVIATIONS

AEO	Alkyl ethoxylate
BOD	Biochemical oxygen demand
CoRAP	Community Rolling Action Plan
DOC	Dissolved organic carbon
ECHA	European Chemicals Agency, Helsinki, Finland
GLP	Good Laboratory Practice
LAS	Linear alkylbenzene sulphonate
OECD	Organisation for Economic Co-operation and Development
NTA	Nitilotriacetic acid
REACH	Registration, evaluation, authorisation and restriction of chemicals
STP	Standard temperature and pressure
$ThCO_2$	Theoretical carbon dioxide
ThOD	Theoretical oxygen demand

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